

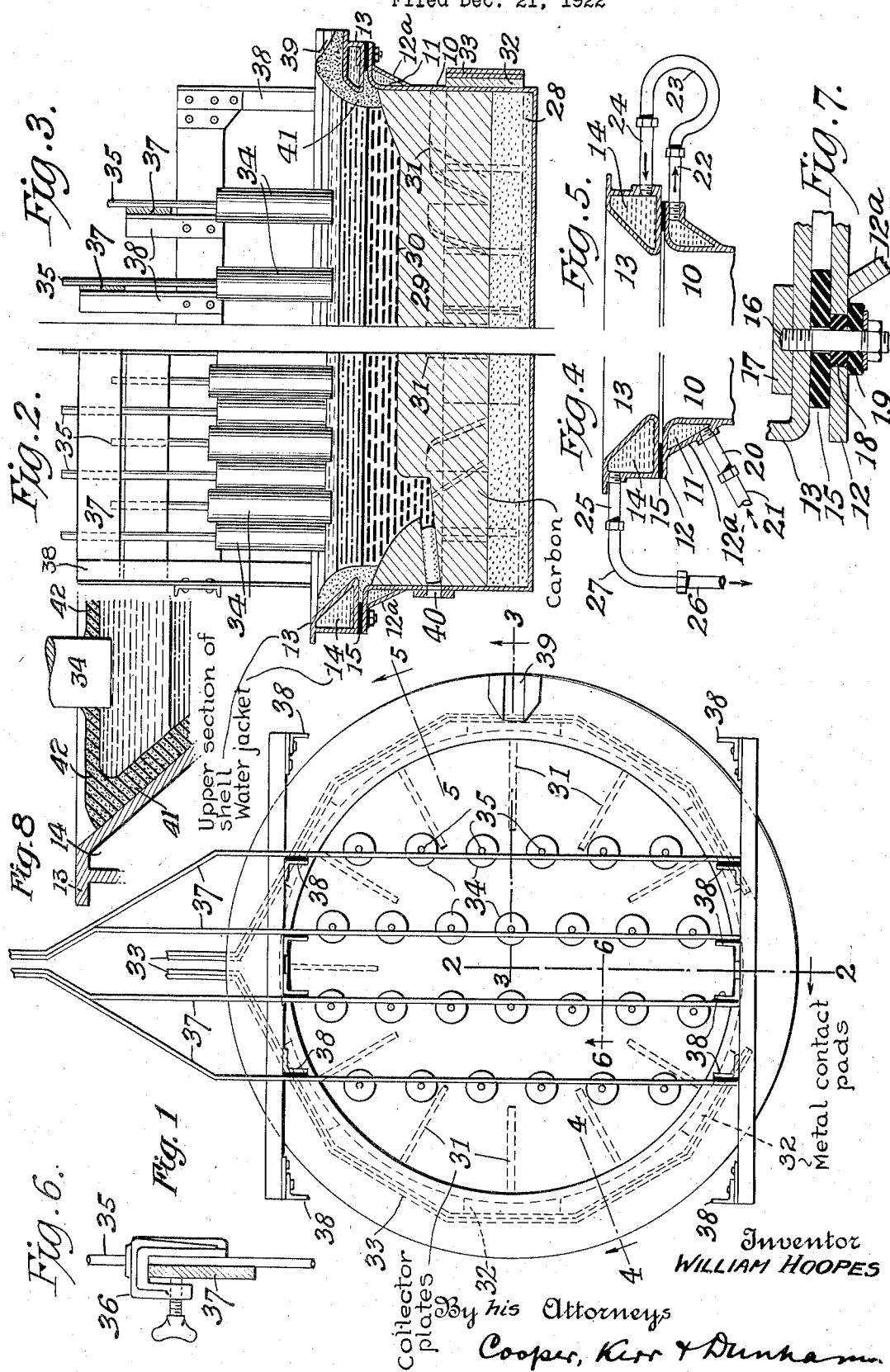
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CELL FOR ELECTROLYTIC REFINING OR SEPARATING PROCESS

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UNITED STATES PATENT OFFICE.

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CELL FOR ELECTROLYTIC REFINING OR SEPARATING PROCESS.

Application filed December 21, 1922. Serial No. 608,287.

To all whom it may concern:

Be it known that I, WILLIAM HOOPES, a citizen of the United States of America, residing at Pittsburgh, in the county of Allegheny and State of Pennsylvania, have invented certain new and useful Improvements in Cells for Electrolytic Refining or Separating Processes, of which the following is a full, clear, and exact description.

This invention relates to the refining of metals by electrolytic separation or removal thereof from alloys or mixtures containing other metals or substances, and pertains more particularly to the cell or pot in which the refining is effected. Its chief object is to provide improved apparatus of high efficiency which can be constructed and maintained at reasonable cost and which can be used advantageously in processes or operations involving the high temperatures incident to the refining of aluminum with fused or molten electrolytes, as for example electrolytes containing cryolite in substantial amounts. To this and other ends the invention comprises the novel features and combinations hereinafter described.

Of the various forms in which the invention can be embodied I have selected for illustration and specific description herein the one which at the present time is considered most convenient and effective for use in refining aluminum alloy or impure aluminum to obtain metallic aluminum of substantial purity or substantially devoid of metals or other substances which, although present in the alloy or impure metal, are not desired in the refined product. The embodiment referred to comprises a metal shell of cylindrical form with a closed bottom, preferably made of steel, to furnish the necessary mechanical strength. In some cases it may be advantageous to cover part or all of the shell outside with heat-insulating material. The shell is divided horizontally near its top into two sections electrically insulated from each other, providing a relatively deep lower section and a correspondingly shallow upper section. Inside of the lower section is a bottom-lining of refractory and electrically conductive material, preferably carbon, and beneath the latter there may be a layer of refractory heat-insulating material, as powdered bauxite, alumina, mag-

nesia, or fire-clay bricks, etc., to diminish or minimize loss of heat through the bottom of the cell. Above the carbon bottom lining, at the sides thereof, the shell is provided with a refractory side-lining joined to the said bottom lining and extending over the joint between the two shell sections to a plane well up toward the top of the upper section. This side lining has marked thermal and electrical insulating properties, and serves the important purpose of keeping the contents of the cell (when in use) from contact with either shell section and of lessening or minimizing the escape of heat through the sides of the cell above the carbon bottom. Being electrically non-conductive, or having very high specific resistance, the side lining does not impair the electrical separation of the shell sections although covering and closing the joint or space between the two. Around its upper portion the shell may be provided with cooling means, preferably a water jacket made in two parts, one above and one below the joint between the shell sections. This may serve either or both of two purposes: to form the aforesaid side lining by freezing in close adherence to the inner surface a fused material (or mixture of materials), and to prevent undue heating of the outer portion of the side lining at the high temperatures that may be encountered when the cell is in use.

The embodiment outlined above is illustrated in the accompanying drawings, in which

Fig. 1 is a plan view of the cell.

Figs. 2 and 3 are cross sections on lines 2—2 and 3—3, respectively, of Fig. 1.

Figs. 4 and 5 are detail cross sections on lines 4—4 and 5—5, respectively, of Fig. 1, illustrating the water connections to and from and between the water jackets.

Fig. 6 is a detail cross section on line 6—6 of Fig. 1, showing the method of connecting the upper electrodes to the negative busbars.

Fig. 7 is a detail cross section on the same plane as Fig. 2, illustrating the method of securing the upper and lower shell sections together to give adequate mechanical strength without connecting the two electrically.

Fig. 8 is a detail section on the same plane

as Fig. 2, showing the heat-insulating top crust above the cathode metal.

The lower shell or shell section 10 is preferably made of steel in the form of a cylindrical vessel of considerably greater diameter than height, and at or near its top it is provided with a water jacket 11 which is most conveniently formed by providing at the upper edge of the shell section an outwardly extending flange 12 of suitable width, and a flaring or conical ring 12^a welded or otherwise hermetically joined to the underside of the flange and to the body of the shell below.

Above the lower shell section 10 is an upper shell section 13 which may also be of steel and formed with hollow walls to provide an upper water jacket 14. The inner surface of the upper shell section is preferably flaring, as indicated. To keep the sections electrically insulated or separated from each other a flat ring or gasket 15, of asbestos or other suitable material, may be used between the two.

In order to give the shell structure sufficient mechanical strength the sections may be secured together by means of machine studs 16 passing upwardly through the flange 12 and threaded into pads 17 welded on the bottom of the upper shell inside the water jacket. To prevent electrical connection the holes in the flange 12, through which the studs pass, may have insulating bushings 18, and insulating washers 19 may be used. If the water jackets are used, as in most cases they will be, the bushings and washers will not be subjected to a high temperature and hence they can be made of practically any insulating material which will not soften at temperatures below 100° C. and which can withstand the crushing stress exerted by the studs. Mica has been found satisfactory for the purpose.

Suitable water connections for the water jackets are provided, and for the sake of simplicity and convenience these connections may be so constructed and arranged that the water flows through the two jackets in succession, preferably through the lower jacket first. For this purpose the jacket 11 may be provided at the bottom with an inlet nipple 20 connected by a pipe 21 to any convenient source of water, not shown, and at the top (to prevent pocketing of air) with an outlet nipple 22 connected by a pipe 23 to the inlet nipple 24 by which water from the lower jacket is led into the bottom of the upper. The latter is equipped with an outlet nipple 25 (at the top to prevent air pocketing) which may be connected to a waste pipe 26 by means of a pipe 27. To avoid electrical grounding the pipes 21 and 27 may consist of rubber hose, as may also the pipe 23 to keep the two shell sections electrically separate. The water used when

the jackets are connected should be of sufficient purity to prevent material flow of current from one shell section to the other at the voltage employed in operation.

In the bottom of the lower shell section a layer 28 of heat-insulating material may be provided, as powdered bauxite, alumina, magnesia, or refractory bricks, to decrease or minimize loss of heat through the bottom of the cell, and above this layer is a bottom lining 29 of refractory electrically conducting material, preferably carbon, and preferably having its upper portion shaped to form a bowl-like receptacle for the alloy or other material to be refined, as shown. The bottom lining can be conveniently and satisfactorily made by tamping into the shell a mixture of tar, pitch and granular or powdered coke, at a temperature high enough to make the mass plastic, and placing the shell and contents in an oven in which the temperature is gradually raised, say to about 600° C., for the purpose of baking and solidifying the carbonaceous mass.

Good electrical connection may be provided between the shell and its bottom lining by means of metal collector plates 31, welded to the inner surface of the shell so as to be electrically and mechanically continuous therewith. These plates extend inwardly into the bottom lining, which is molded around them. At the plane of the collector plates the shell may be provided on the outside with metal contact pads 32, preferably welded to the shell so as to be mechanically and electrically continuous therewith, to which pads busses or busbars of copper, aluminum or other suitable metal may be bolted tightly in place. The busbars may be in the form of long flat plates 33 embracing the lower shell section, with their ends brought out at one side of the cell for convenient connection to one terminal of a suitable source (not shown) of continuous or unidirectional current. In the refining operation these busses are connected to the positive terminal or pole of the source, so that the current enters the cell at the bottom. The carbon bottom or bottom-lining, 29, constitutes what may for convenience be termed the lower electrode of the cell.

The upper electrode may be multiple, composed of a suitable number of short thick rods 34 of refractory conducting material, as for example carbon but preferably graphite, arranged vertically and having copper or other metal rods 35 threaded or otherwise suitably secured in the tops of the electrodes. These metal rods serve to support the graphite cylinders or upper electrodes and convey current to or from the same, and for this purpose they may be releasably and adjustably secured, as by means of clamps 36, to metal busbars 37 extending horizontally across the cell. For conven-

ience of access to the electrodes, for adjustment, replacement, etc., the busbars may be arranged at two or more different levels, as indicated, and may be supported on and secured to a plurality of legs 38 to form a rigid framework. The latter may rest on the upper shell section, in which case it is preferable to have them insulated from the shell section, as by any convenient and suitable means, not shown.

It is recognized that, strictly speaking, the aluminum layer floating on the bath and the layer of alloy underlying the bath, are the upper and lower electrodes, respectively, but these layers are termed herein the cathode and the anode, and hence it is deemed permissible as well as convenient to refer to the graphite cylinders and the carbon bottom-lining, or their equivalents, as the upper and lower electrodes.

Metal or other molten material may be withdrawn from the upper portion of the cell through a tapping notch 39, which may be closed by means of any suitable refractory material (as for example bath material) which will not contaminate the cell contents with which it comes in contact. Molten metal or other material may be withdrawn from the lower part of the cell through a port or tapping hole 40, normally closed by means of a plug of dense charcoal or other suitable material.

On the inside of the cell is a side-lining 41, extending upwardly from the carbon bottom 29, over the joint between the shell sections and well up toward or even over the top of the upper shell section. This side-lining should be both thermally and electrically insulating, to decrease or minimize the conduction of heat to the water jackets as well as to prevent by-passing of current around any part of the cell contents undergoing electrolytic treatment in the refining operation. The lining should also be chemically unobjectionable and refractory enough to remain solid at the temperatures to which it is subjected in the electrolytic refining operation. Under these conditions a lining composed of or formed from mixtures containing metal fluorids as hereinafter more fully described, has been found highly satisfactory in practice.

A side-lining having the desired properties can be made as follows, using mixtures of the kind referred to above.

The upper electrodes (which for this purpose may be composed of amorphous carbon) are lowered into contact with the carbon bottom and current is sent through the cell from the upper electrodes to the lower, resulting in generation of heat at the points of contact. Powdered or granular fluorid mixture is deposited in the cell, and after a sufficient quantity has been melted the upper electrodes are raised so that the current

is compelled to pass through the fused bath, and more bath material is supplied until the cell is filled to the desired height, the upper electrodes being raised accordingly. In the meantime water is being circulated through the water-jackets. Under such conditions there is formed on the cooled portions of the shell sections by freezing of the bath thereon a closely adherent crust which has good thermal and electrical insulating properties. Nor is the crust attacked in any substantial degree by fused fluorids subsequently used as electrolyte in the apparatus. In forming the crust it is sometimes difficult to prevent the admixture with it of more or less finely divided carbon, which would tend to render it conductive even when cold, and it is therefore important, in forming the crust, to exercise care to maintain the bath, from which the crust is formed, free from carbon and finely divided metal which would have the effect of rendering the crust initially conductive. Covering the carbon bottom of the cell with a layer of metal as soon as possible in order to minimize the amount of carbon exposed, aids in maintaining the bath in a carbon-free condition.

After the crust has been built up, the molten bath remaining may be dipped out, or drained out through the tap hole 40, and the current cut off. Any residue of the bath material which freezes on the carbon bottom will ordinarily do no harm, so long as the entire bottom is not covered and insulated thereby, since it will be fused when the refining process is started and hence will be displaced by the heavier metal which in such processes underlies the electrolyte; but such frozen material may be chipped off the carbon bottom if desired, care being taken to avoid injury to the union between the carbon bottom and the side crust or lining.

If the bath or crust-forming mixture employed is of such character as to make it usable in the subsequent operation of the cell, as for example a mixture containing aluminum, sodium and barium fluorids, the side-lining is preferably formed in the following manner.

Bath material is melted in the carbon bottom, as above described, until the joint between the two cell-sections is covered, and molten alloy of the kind which is to be used as the anode in the aluminum-refining process is poured into the cell in amount sufficient to form a layer of the desired depth. Being heavier than the bath, the alloy raises the latter to a higher level. More bath material is then supplied and the melting continued, until the shell is filled to the desired height. When the crust has been built up, by freezing on the cooled sides of the shell, the current is cut off and a portion of the molten bath dipped out to make room for a layer of molten aluminum, preferably the

purest available, which is then poured on top of the remaining electrolyte or bath to serve as the cathode, it being understood, of course, that the bath is of greater density than the aluminum, so that the latter will float on the bath. There is thus established in the cell (which has been provided with a side-lining of high electrical and thermal resistance) a lower layer of alloy containing aluminum, a layer of electrolyte floating on the alloy, and an upper layer of aluminum floating on the electrolyte.

The refining process can now be begun, with the alloy as anode and the top metal as cathode, the current being led from the latter by the above described graphite cylinders dipping into it. When the desired amount of aluminum has been removed from the anode and added to the cathode, a portion of the top metal is removed through the opening 39. The impoverished anode alloy is then withdrawn through the tap hole 40, fresh anode alloy in the molten state being supplied in any convenient way, such that the refined metal floating on the bath will not be contaminated. This operation may be conveniently performed by means of a carbon funnel, which, after being preheated, is let down until it nearly reaches the bottom of the cell, which has preferably been cut out of the circuit. The refined metal entrapped in the funnel may be dipped out with a hand ladle, after which fresh anode alloy is poured in. The funnel is then lifted out and the refining process resumed. The fresh anode alloy introduced is preferably sufficient in amount to raise the bath and top metal until the surface of the latter is at the same level as before the withdrawal.

The provision of a tapping opening, as the notch 39, is an advantageous feature, as it permits top metal to be removed without dipping it out, which is a laborious method and is apt to contaminate the metal. Moreover, the upper tapping opening permits removal of the top metal automatically as fresh anode alloy is supplied to the cell, the top metal rising and flowing out at the same rate as the inflow of the anode alloy. The cell is thus left in condition for immediate resumption of the refining operation when the proper amount of fresh alloy has been supplied.

The side-lining or crust may be composed of or formed from any suitable material or materials which will not seriously contaminate the electrolyte or bath subsequently employed in refining and which will produce a crust having the desired insulating properties, preferably thermal as well as electrical. It has been found that cryolite (aluminum and sodium fluorids) with the addition of a relatively large amount of fluorid of higher freezing point, as for example calcium fluorid, gives a crust which stands up

well. In that mixture the proportions of cryolite and fluorspar may be about one to one. Or the lining may be formed by the method described and claimed broadly in the copending application of William Hoopes, Junius D. Edwards and Basil T. Horsfield, Serial No. 608,289, filed December 21, 1922. A side-lining produced by that method contains a substantial proportion of alumina as corundum or in corundum-like form.

The voltage and amperage needed to fuse the mixture in the crust formation depend largely upon the composition of the mixture and the quantity to be melted, the size of the cell and the effectiveness of its heat-insulation, etc., and hence it is impossible to give definite figures which would be universally applicable. In practice the power input is regulated to produce fusion of the materials used and maintain them at the desired temperature.

The anode alloy should be supplied in such amount that it will remain in an electrically continuous layer on the bottom of the cell throughout the refining operation. A bath layer of such depth should be used that the top metal (the pure aluminum) will in no case come into contact with any portion of the side crust which has previously been covered by the anode alloy. It is to be noted in this connection that the changes in composition of the anode alloy, incident to the refining operation, cause corresponding changes in its volume and in the position of the upper and lower surfaces of the bath layer.

In using the cell for electrolytic refining in the manner described, it is highly desirable to have the upper shell section electrically insulated from all portions of the apparatus. That is, the upper shell section should be electrically neutral. This is advantageous for the following reasons.

If the upper shell section should become electrically positive, current would leak from it through any conducting regions that might exist in the side lining and would flow directly to the top metal, thus by-passing more or less of the current around the bath or electrolyte with consequent impairment of the efficiency of the cell. Moreover, although every precaution be taken to make the side-lining non-conductive when it is formed, it is in most cases difficult to prevent it from being slightly conductive in one portion or another. Even though such portions are very poorly conductive, some current will pass from the metal composing the upper shell section if that section is made positive, and the passage of this current will be accompanied by more or less attack on the steel of the shell. This attack injures the shell and may eventually cause complete penetration of the water jacket. On the

other hand, gradual breaking down of the resistance of the crust also takes place if the upper portion of the shell is connected with the negative terminal or otherwise becomes negative, probably because of deposition of metal along leakage paths due (apparently) to initial penetration of sodium vapor into the crust and subsequent substitution of aluminum for the sodium.

Accordingly it is preferred to have the upper section electrically neutral, but nevertheless advantage may be taken of a lining, made conducting in this or any other manner, as a means for carrying current to the upper section as the negative terminal of the cell.

Cooling of the shell by means of water has been found to be preferable, but air cooling may in some cases be permissible; the latter method, however, is less certain, because although a properly formed crust is non-conductive or nearly so when cold, it becomes conductive when hot. When air cooling is used, it may happen that heat penetrates the crust at certain portions, for various reasons, until the shell becomes heated in spots to a temperature at which the entire thickness of the crust at such points becomes conductive. This forms a comparatively low resistance path for current, after which the heating becomes cumulative, due to the passage of current accompanied by gradual increasing of the temperature of the section of crust through which the current flows. The more effective cooling obtained by the use of water prevents these hot spots in the crust from penetrating through to the shell, and it is therefore easier to maintain proper insulation by water-cooling than by air cooling.

A heat-insulating crust, as indicated, for example, at 42, Fig. 8, may be formed on the cathode metal, to reduce the loss of heat therefrom by radiation, may be produced by dusting over the upper surface of the aluminum layer, soon after it is put in place, a layer of finely divided alumina, carbon, magnesia, or suitable powdered material, which rapidly becomes cemented together in solid form. The heat insulating property of the top crust may be increased by dusting any suitable powdered material over it after it has been formed, so that it is covered by a layer of such material, which is an excellent insulator by reason of its porous condition. Being supplied to the surface of the top crust after the latter has solidified, the additional heat-insulating material is not cemented together and therefore retains its porosity. In general, the best material for the purpose is bath which has been allowed to solidify since if any of it accidentally or incidentally finds its way below the top metal it does not contaminate the electrolyte. With this top crust a cell cover or lid is in general unnecessary and hence can be omitted, thus

eliminating the difficulties and disadvantages incident to the use of a cover.

An arrangement of conducting members for leading current to the anode and from the cathode, whereby a magnetic field is produced in the cell, is considered to be an advantageous feature. Thus in the apparatus illustrated the currents in the upper transverse horizontal busbars 37 and vertical electrodes 34, and in the lower encircling horizontal busses 33 and tapering horizontal distributor or collector plates 31, produce in the cell a powerful and non-uniform magnetic field having both vertical and horizontal components. On account of the relatively high specific resistance of the electrolyte, as compared with that of either the anode alloy or the top metal layer, the current density throughout the horizontal cross section of the electrolyte and hence at its upper and lower surfaces, is substantially uniform. Likewise, the current density at the surface of contact between the conducting bottom lining and the anode alloy (which latter has much better conductivity than the former) is substantially uniform, although the conducting plates or ribs in the bottom lining tend somewhat to concentrate the current. But in the anode alloy the current flow may have horizontal as well as vertical components, due in part to the concentrating effect of the aforesaid plates in the bottom lining, and, probably more especially, to the bowl-like receptacle in the bottom lining, whereby some of the current can flow between the anode alloy and the conducting side walls of the receptacle. These horizontal components of current-flow in the alloy are largely radial in direction. The interaction of the current flowing in the anode alloy and the non-uniform magnetic field produced as explained above, causes the anode alloy (which, being molten, is in effect composed of movable conductors) to flow in various directions, and produces a powerful circulation and mixing of the alloy. The stirring thus produced is believed to be an important factor in replenishing the active surface of the anode alloy with aluminum fast enough to satisfy the anions set free thereat, making possible more extensive removal of aluminum from the alloy, or the use of a higher current density, or both, without the deposition of impurities at the cathode in such amount as to seriously affect its quality. Moreover, the interaction of currents and magnetic field in the bath and in the cathode produces a like stirring effect in these layers, which is advantageous in promoting homogeneity of composition and temperature and especially in preventing the bath from being impoverished of aluminum at the surface in contact with the cathode.

As indicated in the drawing, the upper

section of the cell is preferably made flaring. This shape has been found to be particularly advantageous for a number of reasons. In the actual operation of the refining cell, the fused metal cathode floats within the portion of the side lining which is included within the upper part of the upper shell section. It is very desirable, in order to maintain the upper shell section in an electrically neutral state, that an electrically insulating side lining be maintained between the floating metal cathode and the metal shell. In the refining process there is a decided tendency for electrolyte, on account of capillary action, to creep up along the surface which bounds the floating metal cathode. If this surface is cooled there is a decided tendency for the creeping bath to solidify and thus build up the side lining, particularly when the bath is nearly or completely saturated with alumina, as more fully discussed in the before mentioned copending application of Junius D. Edwards, Basil T. Horsfield, and myself, Serial No. 608,289, filed December 21, 1922. If the surface of contact is vertical there is more tendency for metal to be included in the solidifying bath and hence to produce a conducting side lining, than there is when the surface is outwardly flaring. Moreover, in the refining operation it often happens that the side lining gradually builds up on the inside by deposits which are more conducting than the lining should be. To get rid of this conducting portion the side lining is broken out and removed from time to time. Also, it is sometimes desirable to remove more or less of the side lining for the purpose of removing alumina from the cell. In breaking out the side lining for either purpose the flaring shape facilitates the operation and enables the workmen to get the lining out with minimum escape of fragments into the cell contents. When the side lining is removed and the cathode metal comes in contact with the steel of the upper shell section (which is then no longer electrically neutral) it is comparatively easy, if the shell section is flaring, to separate the cathode metal from the shell by sprinkling upon the edge of the former some powdered or granulated bath material, which promptly sinks through the molten metal and comes to rest on the inclined surface of the shell, where it superficially frites together and quickly forms an insulating crust. Such a renewal of the insulating lining would be very difficult if the upper shell section were not flaring.

The use of graphite as material for the upper electrode or electrodes is not claimed herein but forms the subject of the copending application of Francis C. Frary, Serial No. 672,867, filed November 5, 1923.

It is to be understood that the invention is

not limited to the construction herein specifically illustrated or described but can be embodied in other forms without departure from its spirit.

I claim—

1. An electrolytic refining cell having a metal shell divided horizontally into electrically neutral and electrically live upper and lower sections, and having a refractory insulating lining extending over the joint between the shell sections and into the upper section to insulate molten metal in the upper section from electrical connection therewith.

2. An electrolytic refining cell having a metal shell divided horizontally into electrically neutral and electrically live upper and lower sections, and having a thermally and electrically insulating lining extending over the joint between the shell sections.

3. An electrolytic refining cell having a metal shell divided horizontally into electrically neutral and electrically live upper and lower sections, a thermally and electrically insulating lining extending over the joint between the sections, and means for cooling the shell and lining in the neighborhood of said joint.

4. An electrolytic refining cell having a metal shell divided horizontally into electrically neutral and electrically live upper and lower sections, a thermally and electrically insulating lining extending over the joint between the shell sections, and water-jacket means for cooling the shell and lining in the neighborhood of the joint between the shell sections.

5. An electrolytic refining cell having a metal shell divided horizontally into electrically neutral and electrically live upper and lower sections, a carbon bottom-lining in the lower shell section, a thermally and electrically insulating side-lining extending upwardly from said carbon bottom-lining and over the joint between the shell sections, and water-jacket means for cooling the shell and side-lining in the neighborhood of the joint between the shell sections.

6. An electrolytic refining cell having a metal shell divided horizontally into electrically neutral and electrically live upper and lower sections, a carbon bottom-lining in the lower shell section, a thermally and electrically insulating side-lining extending upwardly from said carbon bottom-lining and over the joint between the shell sections, and means for cooling the shell and lining in the neighborhood of the joint between the shell sections.

7. An electrolytic refining cell having a metal shell divided horizontally into electrically neutral and electrically live upper and lower sections, a thermally and electrically insulating side-lining extending over the joint between the shell sections, and a carbon bottom-lining in the lower shell section.

8. An electrolytic refining cell having a metal shell composed of electrically neutral and electrically live upper and lower sections, and water-jackets around the shell sections adjacent to the joint between the same.

9. An electrolytic refining cell having a metal shell composed of electrically separated upper and lower sections, a water-jacket around the upper shell section above the joint between the same and the lower section, a water-jacket around the upper portion of the lower shell section adjacent to the said joint, and means for passing cooling water through the water jackets in succession without connecting the shell sections electrically.

10. An electrolytic refining cell comprising a lower shell section of metal, an upper shell section having hollow walls composed of metal and electrically separated from the lower section, and means for passing cooling water through said hollow walls.

11. An electrolytic refining cell having a metal shell divided horizontally into electrically neutral and electrically live upper and lower sections, and a thermally and electrically insulating refractory lining composed of material having a high freezing point.

12. An electrolytic refining cell having a metal shell divided horizontally into upper and lower electrically separated sections, and a thermally and electrically insulating lining extending over the joint between the shell sections and composed of a mixture containing aluminum and sodium fluorids.

13. An electrolytic refining cell having a metal shell divided horizontally into upper and lower electrically separated sections, a thermally and electrically insulating lining extending over the joint between the sections and composed of material having a high freezing point, and means for cooling the shell and lining in the neighborhood of the joint between the shell sections.

14. An electrolytic refining cell having a metal shell divided horizontally into electrically separated upper and lower sections, a carbon bottom-lining in the lower shell section; a thermally and electrically insulating side-lining extending upwardly from the carbon bottom-lining and over the joint between the said shell sections, said side-lining being composed of a mixture containing aluminum and sodium fluorids.

15. An electrolytic refining cell having a metal shell divided horizontally into electrically separated upper and lower sections, a carbon bottom-lining in the lower shell section; a thermally and electrically insulating side-lining extending upwardly from the said bottom-lining and over the joint between the said shell sections, said lining being composed of material having a high

freezing point and containing aluminum and sodium fluorids; and means for cooling the shell and lining in the neighborhood of the joint between said shell sections.

16. An electrolytic refining cell comprising a concave conducting refractory bottom portion and substantially non-conducting refractory side walls, means exterior to said walls for supporting said walls, means for cooling said walls, and electrical conductors embedded in said bottom portion and provided with exterior connecting means.

17. An electrolytic refining cell comprising a concave conducting refractory bottom portion and substantially non-conducting refractory side walls, means exterior to said walls for supporting said walls, means for cooling said walls, and an exterior conductor surrounding said bottom and conductors electrically connected therewith embedded in said bottom portion.

18. An electrolytic cell having a metal shell divided horizontally into sections, electrically separated from one another, one of said shell sections being arranged to be kept electrically neutral and another arranged for electrical connection to serve as a conductor.

19. An electrolytic refining cell having metallic reinforcing means divided horizontally into sections electrically insulated from one another, refractory linings for said cell, the lining of one section being electrically conductive and arranged for electrical connection to a source of current, and the lining of another section being relatively non-conducting.

20. An electrolytic refining cell having a metal shell horizontally divided into upper and lower sections electrically separated from each other, electrical connections on the exterior of said lower section, at circumferentially spaced intervals, a refractory conducting bottom lining in said lower section, and a refractory substantially insulating side lining extending upward from said bottom lining and covering the joint between said sections.

21. An electrolytic refining cell having a metal shell horizontally divided into upper and lower sections electrically separated from one another, a conductor surrounding said lower section and electrically connected thereto at a plurality of points, a refractory conducting bottom lining in said lower section and a refractory substantially insulating side lining extending upwardly from said bottom lining and covering the joint between said sections.

22. An electrolytic refining cell having a metal shell horizontally divided into upper and lower sections electrically separated from one another, a refractory conducting bottom lining in said lower section, a conductor surrounding said lower section and electrically connected thereto at a plurality

of points, conductors connected to said lower section on the interior thereof and embedded in said bottom lining, and a refractory substantially insulating side lining extending
 5 upward from said bottom lining and covering the joint between said sections.

23. An electrolytic refining cell having a metal shell horizontally divided into upper and lower sections, electrically separated
 10 from one another, a refractory conducting bottom lining in said lower section, a refractory substantially insulating side lining extending upward from said bottom lining and covering the joint between sections, heat insulating means between the bottom of said
 15 shell and said conducting bottom lining, and heat dissipating means associated with said shell above said bottom lining to cool portions of the shell in contact with said side
 20 lining.

24. An electrolytic refining cell having a concave conducting bottom portion, conductors connected with said conducting bottom, and arranged to produce in the cell
 25 when traversed by refining current, a powerful magnetic field having vertical and horizontal components, an electrically neutral portion above said bottom portion, and refractory electrodes arranged to dip into said
 30 cell, but otherwise insulated therefrom.

25. An electrolytic refining cell comprising a metal shell horizontally divided into upper and lower sections electrically insulated from one another, a concave refractory conducting bottom lining in said lower
 35 section, a conductor system associated therewith for connection to a source of current including conductors embedded in said conducting bottom, said conductor system being
 40 arranged to produce when traversed by refining current, a powerful magnetic field having horizontal and vertical components, a refractory substantially insulating side lining extending from said bottom lining
 45 upward and covering the joint between sections, cooling means associated with said shell above the bottom lining for maintaining said side lining in its substantially non-conducting state, and current carrying, refractory electrodes arranged to dip into the
 50 contents of said upper shell portion but insulated therefrom.

26. In an electrolytic cell, a refractory conducting bottom portion, a metal shell surrounding said bottom portion, conductors welded to the interior of said shell and embedded in said bottom, and exterior electrical connections for said shell circumferentially spaced at a plurality of points
 60 around said conducting bottom.

27. In an electrolytic cell, a refractory conducting bottom portion, a metal shell surrounding said bottom portion, conductors welded to the interior of said shell and embedded in said bottom, and exterior electrical

connections for said shell circumferentially spaced at a plurality of points around said conducting bottom, refractory substantially insulating side walls above said bottom, a current carrying electrode arranged
 70 to dip into the contents of said cell, but otherwise insulated therefrom, and electrical connections for said electrode.

28. In an electrolytic refining cell designed to operate with a lower molten metallic anode, an upper molten metallic cathode and a molten electrolyte therebetween, a metallic shell for said cell, divided horizontally into upper and lower sections electrically insulated from one another, a
 80 concave refractory conducting bottom lining in the lower section and extending close to the top thereof, and refractory side lining extending from said bottom lining upward across the joint between said sections, and formed by solidification of material from the electrolyte, and means associated with said shell sections for maintaining said last named lining in a substantially non-conducting state.
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29. In an electrolytic cell for electrolysis of fused salts, electrically neutral and electrically live metal shell portions, conducting electrodes for said cell, arranged to be connected to opposite poles of a source of current and insulated from said neutral shell portion, an adherent refractory substantially non-conducting lining for said neutral shell portion making a joint with one of said electrodes and impenetrable by said
 95 fused salts, and cooling means for maintaining the impenetrability of said lining.

30. An electrolytic cell for the electrolysis of fused salts, having a conducting portion and an electrically neutral portion, an electrode in said conducting portion, an impenetrable non-conducting lining for said neutral portion extending to and joining said electrode, cooling means for maintaining said lining in the presence of said fused salts, and an electrode in said electrically neutral portion but insulated therefrom.
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31. In an electrolytic cell for electrolysis of fused salts, an electrically neutral shell portion, a bottom electrode, electrically live means for supporting the same electrically insulated from said shell portion, an adherent refractory substantially non-conducting side lining for said neutral shell portion making a joint with said electrode and impenetrable by said fused salts, and cooling means for maintaining said lining in the presence of said fused salts.
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32. In an electrolytic cell for electrolysis of fused salts, an electrically neutral shell portion of upwardly flaring form, a bottom electrode, means for supporting the same electrically insulated from said flaring shell portion, an adherent refractory substantially non-conducting side lining for said neu-
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tral shell portion making a joint with said electrode and impenetrable by said fused salts, and cooling means for maintaining said lining in the presence of said fused salts.

33. In an electrolytic cell for electrolysis of fused salts, an electrically neutral shell portion of upwardly flaring form, a lower shell portion, a bottom electrode in the latter, an adherent refractory substantially non-conducting side lining for said neutral shell portion and making a joint with said electrode, and cooling means for maintaining said lining solid in the presence of said fused salts.

34. In an electrolytic cell for electrolysis of fused salts, a metal shell portion of upwardly flaring form, a lower shell portion, a bottom electrode in the latter, and an adherent refractory substantially non-conducting side lining for said flaring shell portion making a joint with said electrode.

35. In an electrolytic cell, a metal upper shell portion of upwardly flaring form, a lower shell portion, and an adherent refractory substantially non-conducting side lining for said flaring shell portion and covering the joint between the said shell portions.

36. In an electrolytic refining cell, a shell having an upwardly flaring upper portion, and a refractory insulating side lining in said flaring portion.

37. In an electrolytic refining cell for use with fused materials, an electrically neutral upper shell portion having inwardly and downwardly sloping walls, an insulating side lining in the upper shell portion to keep the same electrically neutral when containing a current-carrying body of metal, and means for cooling the upper shell portion.

38. In an electrolytic refining cell for use with fused materials, a shell having inwardly and downwardly sloping walls, means for cooling said walls, and a thermally insulating lining on said walls.

39. In an electrolytic refining cell for use with fused materials, a shell having an electrically live lower section and an electrically neutral upper section provided with inwardly and downwardly sloping walls and having at its top a tapping notch, means for cooling said walls, and a thermally and electrically insulating lining on said walls and notch.

40. In an electrolytic refining cell for use with fused materials, a shell having an electrically live lower section and an electrically neutral upper section and having at its top a tapping notch, means for cooling said sections, and a thermally and electrically insulating lining on said walls and notch.

41. In an electrolytic refining cell for use with fused materials, a shell having inwardly and downwardly sloping walls provided at its top with a tapping notch, and a

thermally and electrically insulating lining on said walls and notch.

42. In an electrolytic refining cell for use with fused materials, a shell provided at its top with a tapping outlet in the form of a groove open upwardly throughout its length, and a thermally and electrically insulating lining on said shell and groove.

43. In the electrolytic refining of aluminum, the steps comprising establishing in a cell having metallic reinforcing means divided into electrically separated sections provided with an electrically and thermally insulating refractory lining, a body of molten aluminum alloy as anode, a body of fused salts as electrolyte, and a body of molten aluminum as cathode, the latter lying wholly within one of said sections, and leading electrolyzing current into and out of the metallic bodies while maintaining in electrically neutral condition the section containing the said cathode.

44. In the electrolytic refining of aluminum, the steps comprising establishing in a cell having metallic reinforcing means divided into electrically separated sections provided with an electrically and thermally insulating lining, a body of molten aluminum alloy as anode, a body of fused salts as electrolyte, and a body of molten aluminum as cathode, the latter lying wholly within one of said sections, leading electrolyzing current into and out of the metallic bodies while maintaining in electrically neutral condition the section containing the said cathode, and cooling the lining of the electrically neutral section to preserve its insulating properties.

45. In the electrolytic refining of metals, the steps comprising establishing in a cell having a metal shell divided into an electrically neutral section provided with an electrically insulating refractory lining and an electrically live section provided with a conducting refractory bottom a body of molten alloy to be refined, as anode on the conducting bottom, a body of molten refined metal, as cathode, wholly within the electrically neutral section, and a body of fused salts as electrolyte, passing electrolyzing current through said bodies, and by flow of electrolyzing current through said conducting bottom producing a non-uniform magnetic field for interaction with electrolyzing current in the mobile contents of the cell to cause circulation of said contents.

46. In the electrolytic refining of aluminum, the steps comprising establishing in a cell having a metal shell divided into electrically live and neutral sections and provided with a thermally and electrically insulating refractory lining a body of molten alloy to be refined, as anode, a body of molten refined metal, as cathode, and a body of fused salts as electrolyte, passing electrolyzing current through said bodies while

confining the refined metal cathode wholly within one of said sections and maintaining the same electrically neutral, and producing in the cell a magnetic field adapted to interact with electrolyzing current in the mobile contents of the cell to cause active circulation of the same.

47. In the electrolytic refining of metals, the steps comprising establishing in a cell having a metal shell divided into electrically insulated sections and provided with a thermally and electrically insulating refractory lining a body of molten alloy to be refined, as anode, a body of molten refined metal, as cathode wholly within one of said sections, and a body of fused salts as electrolyte, passing electrolyzing current through said bodies while maintaining electrically neutral the shell section containing the cathode, and by withdrawal from and replenishment of the metallic contents of the cell confining the cathode wholly within the electrically neutral section.

48. In the electrolytic refining of metals, the steps comprising establishing in a cell having a metal shell divided into electrically insulated sections and provided with a thermally and electrically insulating refractory

lining a body of molten alloy to be refined, as anode, a body of molten refined metal, as cathode, and a body of fused salts as electrolyte, and passing electrolyzing current through said bodies while confining the refined metal cathode wholly within one of said sections and maintaining the same electrically neutral.

49. In the electrolytic refining of aluminum, the steps comprising establishing in a cell having metallic reinforcing means divided into an electrically live section having a refractory conducting bottom and an electrically neutral section provided with an electrically insulating refractory lining, a body of molten aluminum alloy as anode, a body of fused salts as electrolyte, and a body of molten aluminum as cathode, the latter lying within said neutral section, and leading electrolyzing current into and out of the metallic bodies through said conducting bottom and through one or more refractory electrodes dipping into the molten cathode but electrically insulated from said neutral section.

In testimony whereof I hereto affix my signature.

WILLIAM HOOPES.