Feb. 5, 1952 L. FERRAND 2,584,565

FUSED BATH ELECTROLYTIC CELL FOR THE PRODUCTION AND REFINING OF METALS

Filed Aug. 12, 1946 3 Sheets-Sheet 1

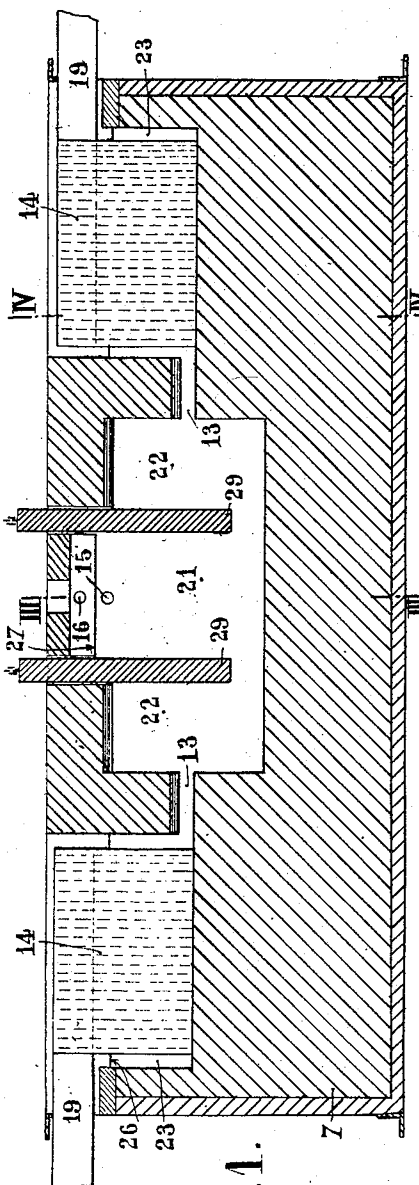

Fig.1.

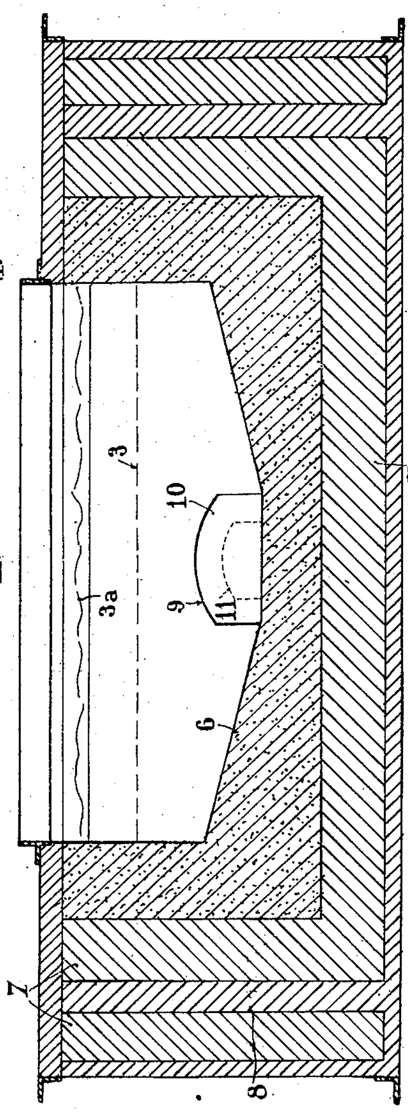

Fig.2.

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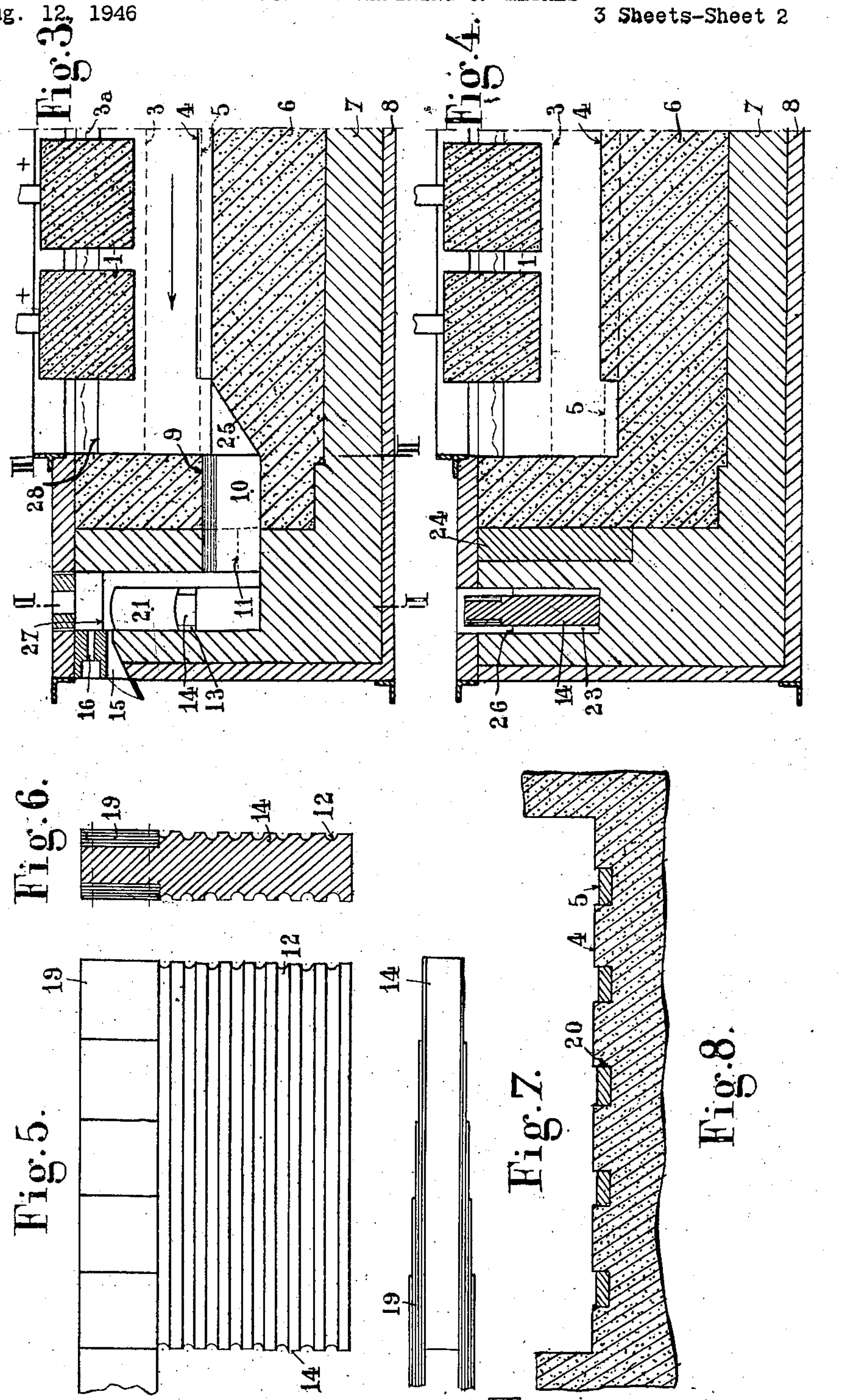

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Fig. 10.

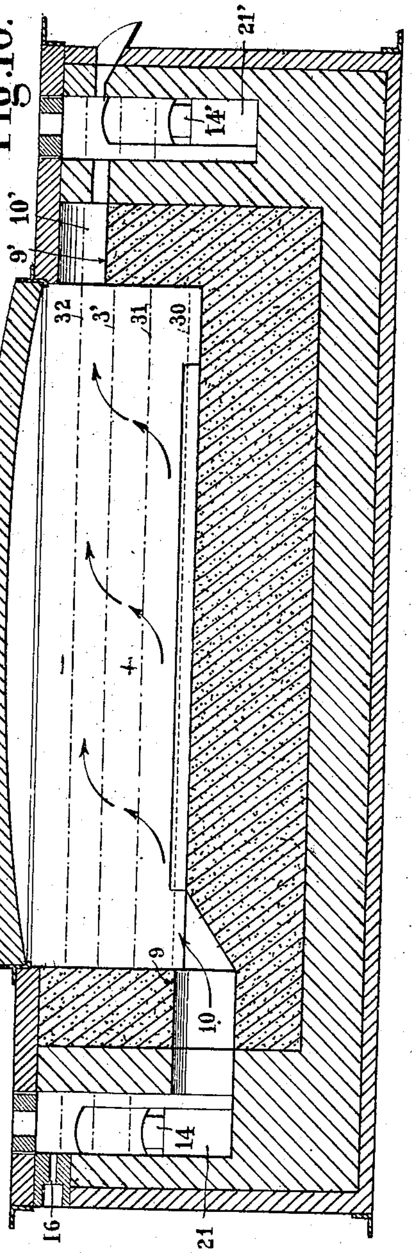
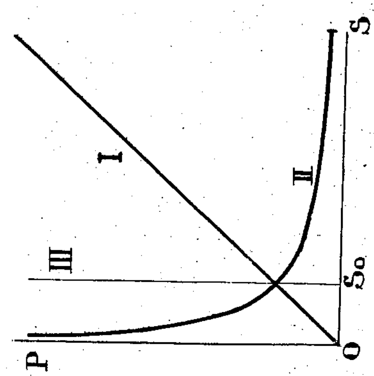


Fig. 9.



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Patented Feb. 5, 1952

2,584,565

UNITED STATES PATENT OFFICE

2,584,565

FUSED BATH ELECTROLYTIC CELL FOR THE PRODUCTION AND REFINING OF METALS

Louis Ferrand, Paris, France

Application August 12, 1946, Serial No. 689,921
In France August 11, 1943

Section 1, Public Law 690, August 8, 1946.
Patent expires August 11, 1963

3 Claims. (Cl. 204—243)

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Usually, in fused bath electrolytic cells or furnaces designed for the performance of electrolytic processes in the melt and particularly in those which are used for the production of aluminum or light metals, the sole which provides the negative pole of the cell is made up of assembled carbon blocks in the inside of which metal parts are secured in various ways that serve to lead in the electric current.

Successive improvements have been made in the construction of the said soles, aiming at decreasing the ohmic resistance thereof, but in spite of the utmost care it has proved difficult to cut down the voltage drop in such soles to less than 0.5 v.

The cell providing the subject-matter of this invention, which is designed for the electrical production or refining of metals, is arranged with the particular view of minimizing the voltage drop in the sole while decreasing as much as possible the power losses occurring between the melted mass present in the cell or oven and the external current-intake members.

This cell belongs to the class wherein the pan or crucible is lagged with carbon on the inside thereof and wherein at least one of the electrodes or pole-pieces is located at the periphery of the cell.

The electrolytic cell according to this invention, designed for the production or the electrolytic refining of metals and comprizing a carbon-lagged pan and at least one fixed electrode located at the periphery thereof, is characterised in that the current is led between the metal processed in the cell and the said electrode in such manner that the voltage drop shall be extremely small, in order that the heat-power loss by conduction may be substantially equal to the electric-power loss attending the passage of the current.

Two embodiments of a cell designed in accordance with the foregoing will now be described, reference being had to the appended drawing in which:

Figures 1 to 4 relate to a first embodiment of a cell designed for the electrolytic production of aluminum, Figs. 1 and 2 being fractional vertical sections taken on lines I—I and II—II in Fig. 3; Figs. 3 and 4 are vertical sectional views taken on lines III—III and IV—IV in Fig. 1. The materials processed in the said cell are indicated merely by the levels reached thereby in the various parts of the cell.

Figures 5, 6 and 7 illustrate an electrode in elevational cross-sectional and top plan view respectively.

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Figure 8 is a fractional cross sectional view of the cell pan.

Figure 9 is a chart relating to the heat and electric losses.

Figure 10 is a vertical section of an electrolytic refining cell with two metal layers.

Referring to Figs. 1 to 4, the cell pan walls comprize layers of refractory materials 7 and layers of heat-insulating materials 8, 24; they are lagged at the inside thereof with a carbon layer 6 providing the sole of the cell. Cut in the top face of the sole are channels 20 (Figs. 3 and 7) which lead at one end thereof into a cavity 25 provided in the sole.

Provided in the oven brickwork and leading from said recess 25 is a channel 10, 21 which is divided at 21 in two branch channels 22, 13 that lead into two cavities 23 that contain the negative electrodes 14. The various portions of said channel, whose dimensions are chosen with particular care, are filled with metal to serve as a passage for the electric current which is fed into the cell pan or crucible through positive electrodes 1 which generally are made of carbon.

Provided in the upper part of portion 21 of said channel, which has a comparatively large section, is a tap hole 15.

3 indicates the level of the liquid metal within the cell in operation, 28 the level of melted cryolite. 3a (Figs. 2 and 3) the surface of the supernatant solidified alumina, 27 the level of liquid metal in compartment 21, and 26 the level of solidified metal in cavities 23. The electrodes 1 are immersed in the bath and extend downwards to a few centimeters short of level 3, whilst the electrodes 14 are almost entirely immersed in the metal present in cavities 23.

As far as the heat and electric losses are concerned, the branched channel 10, 21, 22, 13, 23 may be likened to one single channel having a length L and a constant section S, the length L being reckoned from cavity 25 to either electrode 14, the distances to the branch point being the same for both, whilst section S is twice the mean section of portions 22, 13.

The heat losses by conduction in such a hypothetical channel are proportional to the quotient

$$\frac{S}{L}$$

and to the difference in the temperature of the melted metal in the cell and that of the electrodes, the latter temperature being slightly higher than the surrounding temperature. On the other hand, the electric losses by Joule's effect are proportional to the quotient

$$\frac{L}{S}$$

and to the voltage drop, which is to be decreased as much as possible.

Fig. 9 shows how the said losses would vary in such a channel having a constant section throughout by varying the said section from zero upwards, the length L remaining constant. In the chart the sections are plotted as abscissae and the losses calculated in calories are plotted as ordinates. Curve I represents the losses by heat conduction; it is a straight line that starts from the origin; curve II, an equilateral hyperbola, represents the electric losses. The latter find their minimum at the intersection of curves I and II, i. e. at that point where the losses in calorific energy are equal to the losses in electric energy in the channel considered.

The straight line III, parallel to the axis of ordinates, through the point of intersection of curves I and II, divides the plane in two regions.

In the region at the right side of line III Joules' effect is insufficient to cover the whole of the losses by heat conduction that occur in the enlarged-section channel, with the result that same will "borrow" the missing amount from the cell itself. The conditions then are those of unsatisfactory operation from the thermal point of view.

In the region at the left side of line III Joule's effect is excessive (channel undersized in section) and the requirement stated above ("the latter temperature being slightly higher than the surrounding temperature") is no longer complied with. The temperature of the pole pieces 14 and of the free surface of the metal 26 surrounding the same will rise until balance is reached between the thermal energy liberated by Joule's effect in the channel itself and the thermal energy dissipated by convection and radiation from the end surfaces into the air. However, no thermal energy is borrowed from the cell itself. Joule's effect is self-supporting. The conditions then are those of unsatisfactory operation from the electrical point of view.

The abscissa of line III is that optimum section S_0 with which Joule's effect is barely sufficient to cover the heat losses occurring in the channel without any borrowing from the cell itself, whilst the pole pieces 14 and the surface 26 of the surrounding metal are kept at normal temperature. Said optimum section determines the minimum electric losses acceptable without the risk of excessive heat losses, part of which would then have to be covered by the cell itself.

According to the invention, one is thus led to adopt the value S_0 of the abscissa corresponding to the said point of intersection as the optimum value to be taken as the section of the single channel (or of the sum of the sections of the branches of said channel where same is branched as in the example shown).

However, such a constant-section channel will not give satisfactory technical results, since not only are the losses to be minimized but in addition the temperature should be suitably distributed all along the said channel in such manner that the metal present in chamber 21 shall be kept sufficiently fluid to allow its being poured through hole 15; it is also necessary that the metal present in recesses 23 shall be sufficiently cooled that it will solidify and will not dissolve the electrodes 14, which preferably are made of a material with high electrical and low thermal conductivities.

With a view to securing a satisfactory temperature distribution while complying with the requirement expressed by the optimum value S_0 the following means can be resorted to:

1. Using channels 13 whose section is decidedly lower than

$$\frac{S_0}{2}$$

and whose length is comparatively small, so that they will allow but little heat to flow from channels 22 to recesses 23 whilst only small electrical losses will be set up thereby; upon the whole, the length and section of channels 13 can easily be determined in such manner that the corresponding thermal and electrical losses shall be equivalent.

2. Taking a value, as that of the mean section of channel 10 and the whole of channels 22, which is equal or substantially equal to S_0, which is considered as being the optimum mean value.

3. In order that a temperature may be maintained in chamber 21 which is at least equal to the melting point of the metal processed, vertically adjustable partitions 29 in the form of refractory flagstones may be provided between said chamber and channels 22; owing to the heat-screening properties of said partitions, same will enable the alteration of the thermal conductivity of the whole structure without substantially modifying the electric resistance, and consequently connecting the temperature distribution.

4. A gas burner (not shown) may be arranged at 16 above tap-hole 15 to heat the upper layers of the metal present in chamber 21; this will allow keeping the metal at its melting point without any heat transmission from the oven pan; the effective heat developed by said auxiliary burner should barely be equal to the complement of thermal energy to be supplied to the channel where Joule's effect (on account of the voltage drop being too small due to the fact that a mean section S_1 has been taken which is higher than the optimum section S_0) is insufficient to cover the loss by heat conduction through the channel. For that portion of the electric power which is consumed in the cell to cover that surplus demand upon thermal energy there is thus substituted an equivalent amount of thermal energy which can be provided at lower cost. In that case it is possible to provide for a channel 10 of larger sectional area in order to decrease the voltage drop therealong, since thenceforth the heat losses will only depend on the length and sectional area of the channel between chamber 21 and pole pieces 14.

The metal converts gradually to the solid state in the narrow and comparatively deep channels 22.

Where no auxiliary heating means are provided in chamber 21 it is advisable to decrease the section of channel 10 over a small fraction of the length of the same as indicated in broken lines at 11 in Figs. 2 and 3; whereby it becomes possible to throttle the heat flow from the pan to the central chamber 21 down to the point at which the metal therein is still in the liquid state, at the cost of little increase in the total electric resistance.

Care should also be taken that even if the pan should be drained of all the metal therein (through a tap-hole which is not shown in the drawing), the bath of melted cryolite would have no possibility of getting into the channel 10, which would make same partly or completely unable to conduct the current. For that purpose, the crown 9 of channel 10 is located slightly below the surface of sole 4.

In the operation of the cell the level 3 of the liquid metal in the pan should be kept sufficiently high to provide that under the pressure of the metal and the cryolite bath the metal present in chamber 21 shall reach a level which is slightly higher than orifice 15. The metal can thus be run off continuously or at close intervals instead of being run at several day's intervals as it used to be with some cells of the prior art. The advantage with such a continuous running is that the metal level will remain practically constant, so that the layer of solidified bath and alumina that covers the liquid bath will always remain in the same position, which dispenses with breaking it to pieces to re-form it at a lower level. Moreover, the carbon walls of the pan will no longer be successively covered and uncovered throughout the area corresponding to fluctuations in the level of the bath, which makes them less liable to early deterioration.

The advantage with the use of electrodes 14 made of manganese-steel is that it contributes to lessening the thermal and electrical losses, since not only has such a steel a thermal conductivity which is from 5 up to 16 times less than that of aluminum and from 3 to 10 times less than that of graphite (depending on the qualities employed), but it also possesses an electric conductivity which is about 35 times higher than that of graphite.

It is moreover to be remarked that in a cell according to the invention the current is led from the positive to the negative electrodes exclusively through the materials in the liquid state in the pan and the channels 10, 21, 22 or in the solid state in sections 13 and 23 without having to flow through the sole 6, and this is true, even at the start of the operation, since prior to such starting molten metal is poured into channels 20 as well as into cavity 25 and channels 10, 21, 22, 13, 23. The procedure for that purpose may be as follows: In the construction of the cell metal is poured into the channels 20 and cavity 25 up to level 5 which is located about one centimeter below the surface of the sole; said metal enters channel 10 and closes the same by solidifying therein; metal is also poured into compartment 21 and channels 22 and 13, then into cavities 23 up to level 26. The cell can then be set into operation as usual by having its anodes 1 applied against the surface of the sole 4.

Figures 5 to 7 show that the electrodes 14 are formed with horizontal grooves 12 intended to improve the contact with the solidified aluminum; secured to the upper part of the electrodes, whose side faces are faced and copper-plated, are copper bars 19 of decreasing lengths to be connected with the current leads.

In this embodiment the compartment 21 is provided in the middle of one single face of the cell, but it should be understood that one or several compartments similarly arranged could be provided at one or several other points in the perimeter of the cell, either in the middle of the sides or at the corners, etc. Moreover, it is not necessary that each channel leading from the pan should be branched.

Besides, the invention is not limited to the use of a cell for the electric melting of aluminum or like metals from cryolite or other materials; for instance, it extends to the use of the cell for the electrolytic refining of metals.

Figure 10 illustrates a cell according to the invention designed for electrolytic refining processes in two metal layers; the lower anodic layer 31 consisting of raw metal is connected here with the plus pole in the same way as in the preceding embodiment, the metal in the pan being connected with the minus pole while the cathodic upper layer 32 made up of refined metal is connected with the minus pole through a system of channels similar to the channels 10, 21, 22, 13, 23 already described, except that the connecting channel 10′ here is located at the upper portion of the pan, on a level with layer 32, its bottom 9′ thus being located slightly above the plane 3′ that separates the cathodic layer from the electrolyte layer 3′—31 comprized between the two metal layers. 14 here designates the positive electrodes and 14′ the negative electrodes; the current flows in the direction shown by the arrows. In such conditions it is no longer necessary to resort to graphite cathodes for supplying current to the supernatant cathodic layer 32, so that there is no objection to having the refining oven completely closed; the compartment 21 connected with the anodic layer 30 serves for introducing the raw metal whilst the opposite compartment 21′ connected with the cathodic layer 32 serves for the running off of the refined metal. Such an arrangement is accompanied by considerable savings in power consumption.

What I claim as my invention and desire to secure by Leters Patent is:

1. In a fused bath electrolytic cell for the production and refining of metals, said cell being of the type comprising a pan adapted to contain in its bottom a body of metal constituting one pole of the cell, a wall structure surrounding said pan, and an electrode fixedly secured within a cavity in said wall structure beyond the outer periphery of said pan, the improved means for conducting an electric current from the body of metal in said pan to said electrode, comprising a first channel in said wall structure extending from a level lower than the bottom of said pan to the top of said wall structure, a lower channel connecting the bottom of said pan to the bottom of said first channel, a substantially horizontal upper channel connecting an intermediate point of the first channel with the bottom of said cavity, and a vertically adjustable refractory partition of heat-insulating material disposed in said first channel between the lower channel and the upper channel for adjustably controlling the effective cross-section and thereby the thermal conductivity of the current path between said metal and said electrode.

2. In a fused bath electrolytic cell for the production and refining of metals, said cell being of the type comprising a pan adapted to contain in its bottom a body of metal constituting one pole of the cell, a wall structure surrounding said pan, and electrodes fixedly secured within respective cavities in said wall structure beyond the outer periphery of said pan, the improved means for conducting electric current from the body of metal in said pan to said electrodes, comprising a first channel in said wall structure extending from a level lower than the bottom of said pan to the top of said wall structure, a lower channel connecting the bottom of said pan to the bottom of said first channel, a pair of substantially horizontal upper channels connecting intermediate

points of the first channel with the respective bottoms of said cavities, the cross-sectional area of said lower channel being substantially less than the cross-sectional area of said pan and substantially less than the cross-sectional area of each of said cavities and the total cross-sectional area of said upper channels being equal to the cross-sectional area of said first channel, and vertically adjustable refractory partitions of heat-insulating material disposed in said first channel between the lower channel and the respective upper channels for adjustably controlling the effective cross-sections and thereby the thermal conductivities of the current paths between said metal and said electrodes.

3. In a fused bath electrolytic cell for the production and refining of metals, said cell being of the type comprising a pan adapted to contain in its bottom a body of metal constituting the positive pole, a wall structure surrounding said pan, and positive and negative electrodes fixedly secured within respective cavities in opposite sides of said wall structure beyond the outer periphery of said pan, the improved means for conducting electric current from the body of metal in said pan to said electrodes, comprising a first channel in said wall structure extending from a level lower than the bottom of said pan to a level at the top of said wall structure, a lower channel connecting the bottom of said pan to the bottom of the first channel, a substantially horizontal upper channel connecting an intermediate point of the first channel with the bottom of the cavity containing the positive electrode, a second channel disposed in said wall structure on the opposite side of said pan and having the same vertical extent as said first channel, an upper channel connecting an upper level of said pan with said second channel, a third channel connecting said second channel with the cavity containing said negative electrode, and a vertically adjustable refractory partition of heat-insulating material disposed in each of said first and second channels between the respective channels communicating therewith, for adjustably controlling the effective cross-sections and thereby the thermal conductivities of the respective current paths between said metal and said electrodes.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
795,886	Betts	Aug. 1, 1905
1,815,977	Hitner	July 28, 1931
1,833,806	Weber et al.	Nov. 24, 1931
2,407,691	Suchy et al.	Sept. 17, 1946

FOREIGN PATENTS

Number	Country	Date
38,159	Norway	Oct. 29, 1923

OTHER REFERENCES

Ser. No. 369,610, Hilling et al. (A. P. C.), published May 18, 1943.