May 29, 1973 H. BOHNER ET AL 3,736,244

ELECTROLYTIC CELLS FOR THE PRODUCTION OF ALUMINUM

Filed April 30, 1971

FIG. 1

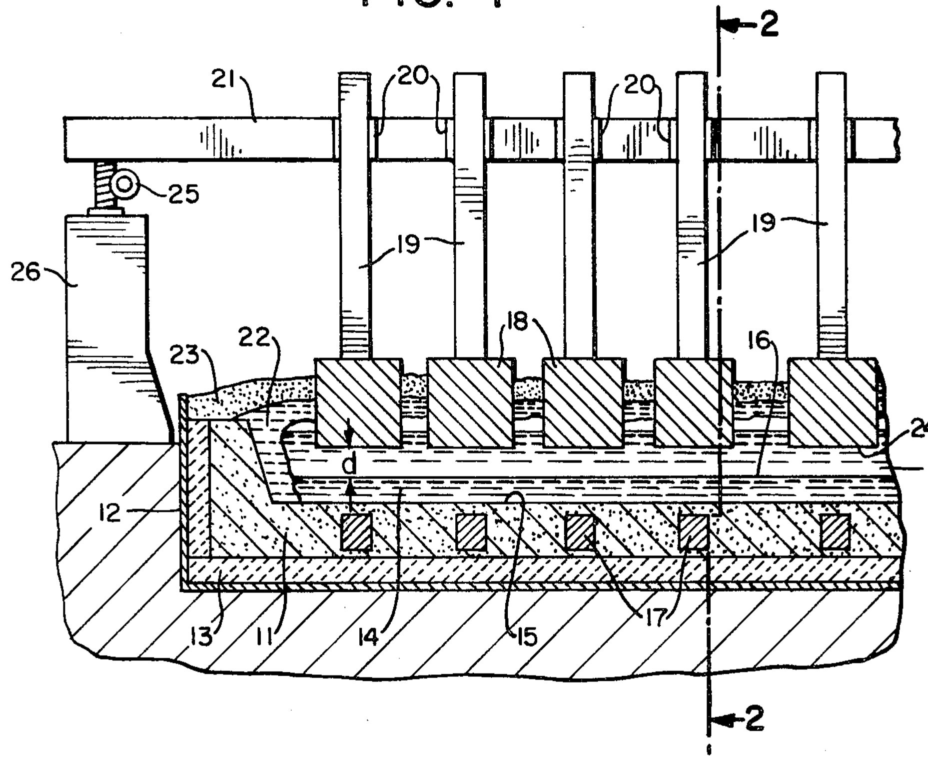
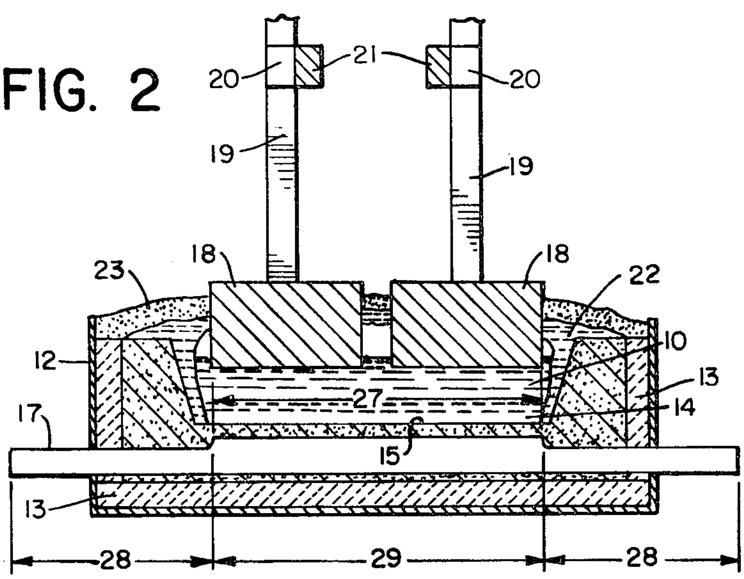


FIG. 2



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ELECTROLYTIC CELLS FOR THE PRODUCTION OF ALUMINUM

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U.S. Cl. 204—243 R 2 Claims

ABSTRACT OF THE DISCLOSURE

An electrolytic cell for the recovery of aluminum comprising a pot for the fluoride electrolyte with a carbon bottom and iron cathode bars extending through the carbon bottom to emerge from each side of the cell in which the cross section of the bars on each side of the central length which lies beneath the anodes is less than that of the central length of the bars.

This invention relates to electrolytic cells for the recovery of aluminum from an alumina-containing fluoride melt.

A typical cell is shown diagrammatically in FIG. 1 of the accompanying drawings, and comprises a steel pot **12** lined by an insulating layer **13** of heat-resistant material. Within this lining there is a lining **11** of carbon in which iron cathode bars **17** are embedded. The cathodically separated aluminum collects as shown at **14** below the fluoride melt shown at **10** and on the surface **15** of the carbon lining **11**. A crust **22** forms on the fluoride melt as a result of solidification, and is covered by a layer **23** of aluminum oxide.

Anodes **18** of amorphous carbon dip into the melt from above, and normally are carried by rods **19** which, as shown at **20**, are fixed to current conducting beams **21**. These beams can be raised or lowered through hoisting units **25** mounted on columns **26**.

The distance *d* from the underside of an anode to the surface **16** of the aluminum, which is known as the interpolar distance, can be varied by vertical movement of the beam **21**.

In the operation of such a typical cell the temperature of the melt is kept constant as far as possible between 940 and 975° C. Oxygen is released at the anodes and combines with the carbon of the anodes to form carbon monoxide and carbon dioxide. Because of this, the lower ends of the anodes are consumed to an extent of about 1.5 to 2 cm. of their length each day in accordance with the particular construction of the cell.

The cathode bars **17** are good heat conductors, and accordingly carry away heat outwards from within the cell. The heat thus lost must be made up by the supply of electrical energy. In addition, heat (I^2R) is generated in the bars, but by decreasing the thermal gradient reduces the amount of heat which would otherwise flow outwards by conduction.

FIG. 2 of the accompanying drawings is a diagrammatic cross-section through the cell. It shows that the cathode bars **17** extend completely through the carbon lining **11** to emerge from each side of the cell, and lie beneath the anodes. In the cell shown there are two rows of anodes **18**, each carried by its own beam **21**.

Now the cathode bars **17** have two functions. One is to collect current from that part of the carbon lining which lies beneath the anodes, and which may be called the active part of the lining, and which is shown at **27**. The other function is to carry the current outwards from the cell, so that the lengths **28** of the bars outside the

active part act simply as current conductors. In the central length **29** between the two lengths **28**, the current density in each cathode bar increases outwards from the centre. This central length **29** within the active part of the carbon lining must be of large cross-section so as to present a considerable area of contact resistance.

In practice, the bars are of uniform cross-section throughout their whole length, but in view of the conduction of heat outwards from the cell this is not satisfactory.

According to the invention the cross-section of the bars outside the active part of the carbon lining, that is to say on each side of the central length **29** which lies beneath the anodes, is less than that of this central length. This difference in cross-section is clearly shown in FIG. 2.

It is undesirable to reduce the cross-section of the lengths **28** too much, because reduction leads to increase in the I^2R heat because of the higher current density in each length. More of this heat could be produced than would be saved by reduction in the amount of heat lost by conduction. The point at which there is no saving in heat loss, and therefore of electrical energy, can best be determined by practical tests on a given cell. In deciding where the economic limit lies, account must also be taken of the saving in the material of the cathode bars.

Ignoring the saving in material, which is of a minor nature in comparison with the saving of energy, it is possible to determine the optimum reduction in cross-section of the cathode bars outside the active part of the carbon lining to the cross-section inside the active part) is given by the following equation:

$$R=\sqrt{\frac{I^2\cdot\delta\cdot 0.8\cdot L^2(1-\alpha)}{\lambda(T_1-T_2)\cdot A_o^2}}\cdot 10^2 \text{ (percent)}$$

R. Ratio of the cathode bar cross-section outside the active part of the carbon lining to the cathode bar cross-section inside the active part (percent).
I. Current density in the cathode bars (A).
δ. Specific electric resistance of the cathode bars at a temperature which corresponds to $\frac{1}{2}(T_1+T)$ (Ωm).
L. Length of the cathode bars outside the active part of the carbon lining (m).
α. Proportion of the I^2R heat of the cathode bars which does not flow outwards.
λ. Specific thermal conductivity of the cathode bars at a temperature which corresponds to

$$\tfrac{1}{2}(T_1+T_2)\left(\frac{\text{kcal.}}{\text{mh. °C.}}\right).$$

T_1. Temperature of the cathode bars at the outlet point of the rods from the active part of the bottom lining (° C.).
T_2. Temperature of the cathode bars at their outer ends (° C.).
A_o. Cross-section of the cathode bars inside the active part of the carbon lining ($m.^2$).

In the invention the ratio R is preferably in accordance with this equation ±10%.

As an example, in a 100 ka. cell with 19 iron cathode bars, that is to say with 38 bar ends projecting outwards, the various factors in the equation may be as follows:

I	2630 a.
δ	$0.4.10^{-6}$ Ωm.
L	0.6 m.
α	0.2.
λ	45 kcal./mh. ° C.
T_1	700° C.
T_2	200° C.
A_o	$11.0.10^{-3}$ m.^{2}.

Calculation shows that the ratio would be 50%, and accordingly preferably should not be less than 45% or more than 55%.

In an electrolytic cell of the size in question witz bars of uniform cross-section throughout their length, the heat loss through the 19 bars is from 400.000 to 500.000 kcal. in 24 hours. If the cross-section of the lengths 28 is so reduced as to give a ratio R of 50%, 250,000 to 300,000 kcal. can be saved in 24 hours, which corresponds to a reduction in the specific consumption of electrical energy up to 0.5 kwh./kg. of Al. Additionally, by the reduction of the removal of heat by the cathode bars the thermal gradient in the bottom of the cell is reduced, and this has a satisfactory effect on the maintenance of the carbon lining of the pot. Moreover, the savings in the amount of iron required for the cathode bars can amount to one ton or more per cell.

What we claim is:

1. An electrolytic cell for the recovery of aluminum from an alumina-containing fluoride melt comprising a pot for the electrolyte with a carbon lining on the bottom and iron cathode bars extending through the carbon lining to emerge from each side of the cell, in which the cross-section of the bars on each side of the central length which lies beneath the anodes in the active part of the lining is less than that of the central length of the bars.

2. A process for operating an electrolytic cell according to claim **1** in which the ratio R of the cross-section of the lengths of the cathode bars outside the central

lengths relative to the cross-section beneath the anodes has the value $R+10\%\ R$ where

$$R=\frac{I^2\cdot\delta\cdot 0.86\cdot L^2(1-\alpha)}{\lambda(T_1-T_2)\cdot A_o^2}\cdot 10^2 \text{ (percent)}$$

I being the current density in the cathode bars in Amperes, δ the specific electric resistance of the cathode bars in Ωm. at a temperature which corresponds to $\frac{1}{2}(T_1+T_2)$, L the length of the cathode bars outside the active part of the lining in meters, α the proportion of the Joule's law effect of the cathode bars which does not flow outwards, λ the specific thermal conductivity in kcal./mh. ° C. of the cathode bars at a temperature which corresponds to $\frac{1}{2}(T_1+T_2)$, T_1 the temperature in ° C. of the cathode bars at the outlet point of the bars from the active part of the bottom lining. T_2 the temperature in ° C. of the cathode bars at their outer ends and A_o the cross-section in m.² of the cathode bars inside the active part of the lining.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3 736 244 Dated May 29, 1973

Inventor(s) Hans Bohner et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

In column 2 line 40 "$T_1 + T$" should read --$T_1 + T_2$--.

Signed and sealed this 29th day of January 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

RENE D. TEGTMEYER
Acting Commissioner of Patents

34