March 4, 1958 L. FERRAND 2,825,690

SELF-BAKED ANNULAR ANODE FOR MELTING FURNACES

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Fig. 1.

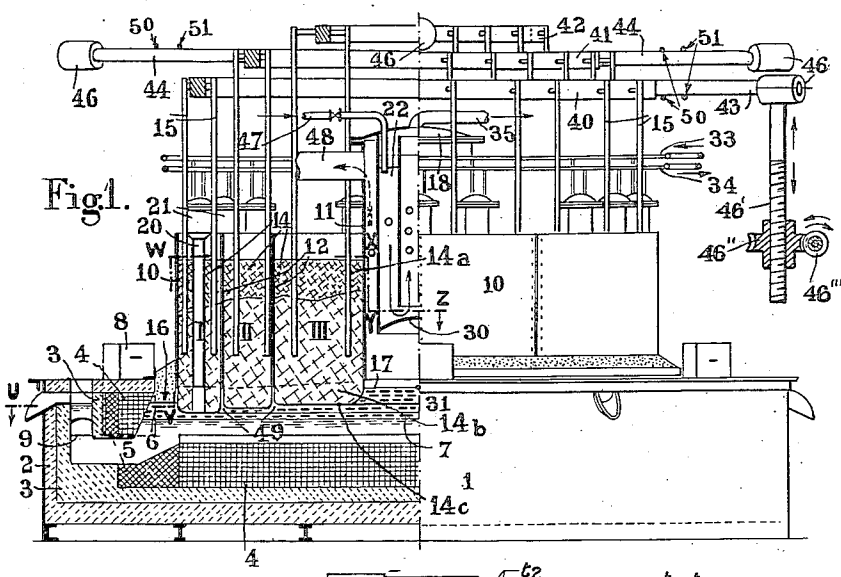


Fig. 3.

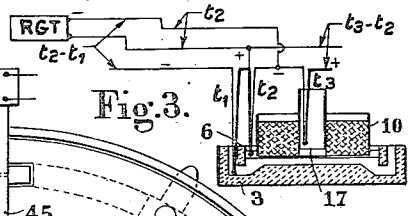
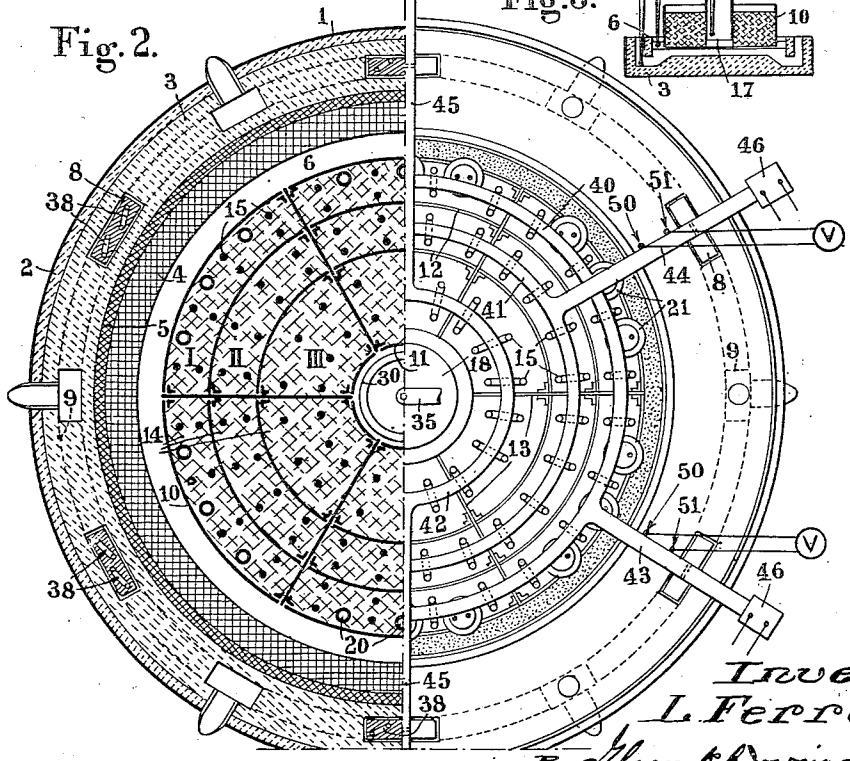


Fig. 2.



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# SELF-BAKED ANNULAR ANODE FOR MELTING FURNACES

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Claims priority, application France April 18, 1951

6 Claims. (Cl. 204—228)

My invention relates to a self-baked anode for use in the continuous and automatic operation of furnaces for the electrolytic production of metals, notably of aluminum, by the dry process and is intended to remedy the inconveniences inherent to self-baking anodes in accordance with Soderberg's process as known up to the present, and making it possible to use large-diameter annular anodes while making it also possible to design a furnace for use in aluminum production which is absolutely continuous in its operation from the double point of view of metal tapping and alumina supply.

A way of achieving such an anode will be described hereinafter.

The description is concerned principally with the anode structure itself, the way in which it is built and the carrying out of the electrolytic process, exclusive of the means by which the anode is suspended and the current distributed, which means are well known and need not be represented in any great detail.

Figure 1 illustrates an embodiment of an electrolytic furnace in half-elevational and half-sectional views.

Figure 2 illustrates the same furnace with the one half in top plan view and the other half in a horizontal sectional view taken on line U—V—W—X—Y—Z in Fig. 1.

Figure 3 diagrammatically represents the three thermoelectric couples adapted to govern the temperature, and the way in which they are connected differentially.

The smallest circles in the left half of Fig. 2 represent suspension or distribution studs which are not shown in Fig. 1 in order to make it more easily readable.

The furnace illustrated, which is intended more specifically for the electrolytic production of aluminum, is comprised primarily of a substructure rested on the ground and composed in its turn of a sheet metal shell 1, a first heat-insulating kieselguhr lining 2, a second refractory lining 3, an inner amorphous carbon lining 4 spaced from the latter, with a view to making it fluid-tight with the aid of strongly tamped carbon paste 5, and delimiting an inner elaboration chamber 6 having suitably shaped side walls adapted to contain the molten salt mixture serving in the elaboration of the metal and on the bottom of which rests the metal layer 7 which covers the non-conductive carbon sole which is integral with the carbon lining 4.

The metal layer 7 which provides the liquid cathode is conductively connected with the steel negative pole pieces 8 through channels 9 provided in a well-known manner within the refractory lining 3.

According to my invention, the furnace superstructure providing the anode unit is comprised of a fixed cylindrical shell 10 made of suitably reinforced steel, a vertical axial stainless steel chimney 11 arranged concentric with said shell, cylindrical metal partitions 12 arranged likewise concentric with said chimney and spaced at distances from one another which increase from the outside towards the centre, radial bracing webs 13 between each pair of the aforesaid partitions and agglomerated



carbon paste filling the intervals 14 between the several elements of the structure, the metal framework thus provided being rigidly connected with the furnace metal framework which however is supported independently of the substructure.

The axial chimney 11 is perforated over the second third of its height with vents through which the tar vapours resulting from the self-baking of the carbon paste filling can be sucked with electrolytic gases by the action of a vacuum created in said chimney. Depending from the cover 18 which is secured in fluid-tight manner to the axial chimney 11 is a heat recuperator 22 composed of vertical tubes and designed to recover the sensible heat in the gases from the electrolytic process, exclusive of the heat rays emanating from the free surface 17 of the melt, owing to the provision of a polished stainless steel reflector 30 with a parabolic generatrix, by which said rays are reflected back onto said surface; said parabolic reflector being secured to the tube bundle in such a manner that its focus 31 is substantially coincident with the free surface of the melt 17.

The various sector-shaped or prismatic block sets thus constituted, which are assumed to be three in number in the example illustrated, and each layer of these blocks is suspended from a separate ring with the aid of vertical studs 15 in such a manner that the various annular layers can be moved up and down individually. The vertical studs 15 in each coaxial layer or ring I, II, III are attached each to one of three rings 40, 41, 42 rigid respectively with radial arms 43, 44 and 45 at the ends of which the intensity of the current fed thereto can be ascertained by the measurement of the voltage drop between two equidistant points 50 and 51. The ends of said radial arms are acted upon by motors 46 adapted to adjust the interpolar distance for each particular coaxial layer in dependency on the intensity of the current fed thereto, and consequently to set the current density for each layer at any desired value and to ensure that the interpolar distance increases stepwise from the outermost layer to the one closest to the centre. An annular stepped anode surface can thus be obtained which approximates a conical surface leading at its apex into the axial chimney. The gases arising from the electrolysis will ascend naturally along the said conical surface and the time taken to sweep the anode bottom surface will be shortened considerably with the aid of an exhauster connected at 35 with a branch pipe leading from the emergent portion of the axial chimney 11.

It is to be remarked that owing to the sucking action exerted thereby the level of the melt will be higher at 17 in the axial chimney than at 16 in the peripheral region.

According to my invention, in order to provide for the supply of alumina where an anode of the kind described is used, supply hoppers 21 are provided at the periphery of the anode mass which communicate with discharge tubes 20 issuing at 49 under the burnt portion 14*b* of the block I. The alumina falls freely through tubes 20 only of the block I near the casing 10 as a result of the difference in the pressures prevailing in the tubes 20 and in the supply hoppers 21 thereabove and is entrained into the melt by means of the gas bubbles which are let thereinto at a rate or frequency which depends on the gas pressure. It is obvious that as the outer casing 10 is fixed, the tubes 20 rigid therewith are also fixed. These tubes have their lower ends flush with the lower edges of the casings 10, 11, 12 along a radius indicated by the moderately ascending dotted line from the outer periphery to the inner periphery of the casing assembly (Fig. 1). It is also evident that the carbon paste 14 introduced in the well-known manner through the top in raw state, i. e. in the form of a quite

plastic material (see fine-squared portion 14*a*) is progressively baked as the temperature increases towards the bath, until the carbon becomes solid (see larger squares 14*b*) and becomes an integral part of the rods 15 by adhering strongly thereto, so that when these rods are pulled or pushed it is possible to move the carbonated masses I, II, III upwards or downwards. It is evident that these carbonated masses of layer I, by sliding in most cases along the wall 10 and around the tubes 20 to compensate the anode wear will leave above these tubes a cylindrical orifice opening at 49 in the bath above the metal layer 7. The rate at which the gas, and consequently the alumina, is fed is so adjusted that the percentage of dissolved alumina in the melt shall decrease towards the centre from a maximum which corresponds to the lowest melting point of the melt, in order to prevent the same from coagulating in the peripheral region, down to a minimum which is close to zero in the central region, which together with the higher temperature prevailing in the said central region favours the obtainment of a high conductivity of the melt in the said region, as required in view of the larger interpolar distance of the central annular mass.

The alumina is led into the said hoppers 21 pneumatically through a manifold 33 while a pressure is maintained in said hoppers through a manifold 34 connected with the delivery side of the exhauster through a pressure regulator, which means that a certain yet very small amount of the gases from the electrolysis is recycled. The gases of electrolysis raise at the contact with the faces 14*c* of the anodes and are withdrawn by the action of a vacuum created in the chimney; they escape from the surface of the bath 17 and are cooled prior to being exhausted at 48 by circulating in the direction of the dotted arrows around the recuperator 22 cooled by a fluid streaming through the conduit 47 and leaving through conduit 35 in the direction of the full line arrows.

In adjusting the current densities through the various annular concentric anode masses it is necessary to account for the differences that may exist between the temperature of the interpolar layer of the melt and the temperatures on the one hand of the bottom metal layer providing the cathode and the top layer of the melt within the axial chimney.

With this end in view, according to my invention, an intermediate thermo-couple $t_2$ immersed through the protective alumina layer in the melt 6 and located just above the liquid metal surface 7 is provided which is adapted to influence the temperature regulator RGT in dependency on the temperature of the melt in the interpolar region, together with two further thermo-couples $t_1$ and $t_3$ of which the former is immersed down to the bottom of one of the cavities 9 and gives the temperature of the metal bottom layer while the latter through the central chimney reaches the surface of the melt or even remains a little clear of the same and gives the temperature of the melt in the upper layer of said central region.

The three aforementioned couples are connected differentially (see Fig. 3), that portion of each strip which is made of the one metal being represented by a thick line while that portion which is made of the other metal being represented by a thin line.

In addition to the recording temperature $t_2$ on a separate chart in order to supervise the operation of the temperature regulator depending on the value of $t_2$ assigned thereto, the differences $t_2-t_1$ and $t_3-t_2$ may be recorded by an additional apparatus of high sensitiveness by means of which the said temperature differences can be ascertained directly and controlled more easily.

Following the adjustment of $t_2-t_1$ by suitably acting upon the cooling of the pole pieces 8 which is effected in a manner known per se by varying the rate of flow of the cooling water through coils 38 embedded in the



said pole pieces 8, so that $t_1$ shall at all times be less than $t_2$ by ten odd degrees centigrade, $t_3-t_2$ is adjusted in such a manner that $t_3$ shall at all times be higher than $t_2$ by about 20 to 40 degrees depending on the value assigned to $t_2$, and this, by suitably setting the current intensities $I_1$, $I_2$, $I_3$ of each layer I, II, III so that a sufficient fluidity of the melt in the central region may be obtained together with a correct stepping of the interpolar distances $d_1$, $d_2$, $d_3$ enabling the gases from the electrolysis to escape more easily.

It should be pointed out that the temperature differences $t_2-t_1$ and $t_3-t_2$ are set with a view to obtaining the best physico-chemical conditions (density, conductivity, viscosity of the melt) adapted to contribute to the obtaining of the highest efficiency of the electrolysis.

What I claim is:

1. In a cell for the electrolytic production of metals and more particularly of aluminum, said cell comprising a carbon pan adapted to contain a salt melt and a subjacent body of metal constituting one pole of the cell, a wall structure surrounding said pan, and at least one negative cathode contact fixedly secured within a cavity filled of the same metal in said wall structure beyond the outer periphery of said pan, and in communication with said pan, the improved means comprising a self-baked annular anode arranged to dip into the salt melt contained in said cell, a fixed cylindrical metal casing surrounding said annular anode, a vertical cylindrical chimney arranged coaxially within the innermost anode, cylindrical metal partitions arranged between said casing and said chimney and coaxial with them at increasingly wider radial spacing intervals starting from the outside, radial metal partitions dividing said anode into a plurality of coaxial uniformly thick sector-shaped prismatic chambers filled with a block of sintered carbon paste successively raw then cooked from the top to the bottom, means for maintaining the prismatic blocks of each annular layer at the same level, the basic level of each layer concerned being adjusted to a progressively increasing height from the outside to the inside, according to a modified adjustment of each annular layer which decreases from the outside to the inside.

2. In a cell according to claim 1, wherein the vertical cylindrical chimney is perforated in the middle third of its height with vents through which the gases proceeding from the baking of the carbon paste can be sucked together with those proceeding from the electrolytic process by the action of a vacuum created in said chimney.

3. In a cell according to claim 1, coaxial metal rings supporting each one of said annular layers, radial arms supporting said rings, motors at the free end of each radial arm adapted to raise or lower each annular layer as a whole.

4. In a cell according to claim 1, cylindrical discharge tubes rigid with said fixed cylindrical metal casing and arranged at the periphery of the anode segments in the outer annular layer which can slide freely on said tubes, supply hoppers at the tops of said tubes and communicating therewith through calibrated orifices, a manifold for the intake of fluidified alumina, a manifold for the removal of the excess conveying gas, both of which manifolds communicate with the said supply hoppers.

5. In a cell according to claim 1, a fluid-tight cover for the chimney, a heat recuperator depending from said cover, a reflector with a parabolic generatrix secured to said recuperator having its focus coinciding with the free surface of the melt and an exhauster connected with said chimney.

6. In a cell according to claim 1, a first thermo-couple immersed in the molten metal bottom layer, a second thermo-couple immersed in the lower portion of the melt at interpolar space level, a third thermo-couple in the upper portion of the melt within the chimney, a temperature regulator actuated by said second thermo-

couple, apparatus responsive to the voltage drop between two equidistant points on the current inputs leading to each annular layer and consequently to control the current density through each annular layer.



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