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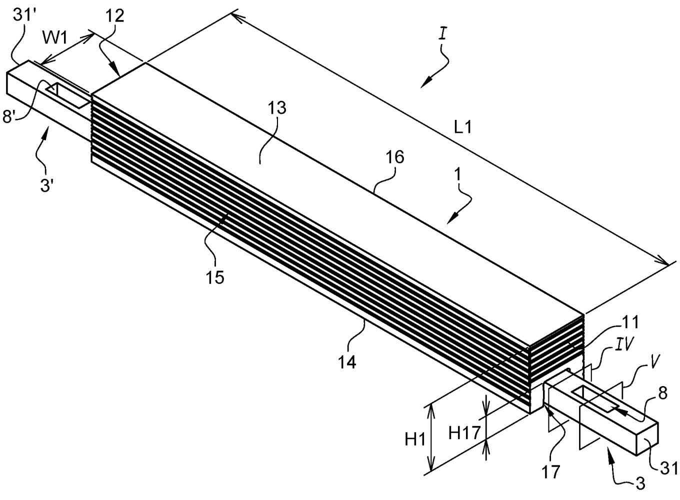
(54) CATHODE COLLECTOR BAR AND CATHODE ASSEMBLY FOR HALL-HEROULT PROCESS WITH LOW VOLTAGE DROP AND LOW THERMAL LOSS

(57) A cathode collector bar (3, 3’; 3a; 103; 103’) for a cathode assembly (I; II; III) suitable for a Hall-Héroult electrolysis cell, said cathode assembly comprising
- a cathode block (1; 101; 201) made of a carbonaceous material, a groove (17; 117) being provided in said cathode block,
- at least one said cathode bar (3, 3’; 3a; 103; 103’; 203), each of said cathode bar partly fitted in said groove,
- said cathode bar being made of at least one electrically conductive material,
- said cathode bar being intended to protrude outside a side wall (92; 192; 292) of a pot shell (9; 109; 209) which is part of said electrolysis cell,
said cathode bar being thus divided into
an inner region (40; 140) intended to be located inside the groove,
an outer region (50; 150) intended to protrude outside said side wall, and
a median region (60; 160) connecting said inner region and said outer region,

characterized in that said median region is provided with a low thermal loss zone (70; 170), the function of which is to locally reduce thermal losses, said low thermal loss zone having a reduced conductive surface (Sr; S’r) caracterized by a value inferior to the total conductive surface (St; S’t) of said cathode collector bar.

Fig. 1



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Description

Technical field of the invention

[0001] The invention relates to the technical field of electrolysis in molten salts for making aluminium using the Hall-Héroult process. More specifically the invention relates to the improvement of cathode assemblies used in Hall-Héroult electrolysis cells, the improvement being related to the design of the cathode collector bar in order to decrease the thermal loss occurring by heat conduction through the cathode bars which are protruding out of the electrolysis cell. In particular, the invention relates to an improvement for cathode blocks provided with a cathode collector bar made from steel with a copper insert, or with a cathode collector bar made from copper.

Prior art

[0002] The Hall-Héroult process is the only continuous industrial process for producing metallic aluminium from aluminium oxide. Aluminium oxide (Al_2O_3) is dissolved in molten cryolite (Na_3AlF_6), and the resulting mixture (typically at a temperature comprised between 940 °C and 970 °C) acts as a liquid electrolyte in an electrolytic cell. An electrolytic cell (also called "pot") used for the Hall-Héroult process typically comprises a steel shell (so-called pot shell), a lining (comprising refractory bricks protecting said steel shell, and cathode blocks usually made from graphite, anthracite or a mixture of both), and a plurality of anodes (usually made from carbon) that plunge into the liquid electrolyte contained in the volume defined by the cathode bottom and a side lining made from carbonaceous material. Anodes and cathodes are connected to external busbars. An electrical current is passed through the cell (typically at a voltage between 3.5 V and 5 V) which electrochemically reduces the aluminium oxide, split in the electrolyte into aluminium ions and oxygen ions, then into aluminium at the cathode and carbon dioxide after reacting with the carbon at the anode. The resulting metallic aluminium is not miscible with the liquid electrolyte, has a higher density than the liquid electrolyte and will thus accumulate as a liquid metal pad on the cathode surface below the electrolyte from where it needs to be removed from time to time, usually by suction into a crucible (so-called "tapping" operation).

[0003] The electrical energy is a major operational cost in the Hall-Héroult process. Capital cost is an important issue, too. Ever since the invention of the process at the end of the 19th century much effort has been undertaken to improve the energy efficiency (expressed in kWh per kg or ton of aluminium produced), and there has also been a trend to increase the size of the pots and the current intensity at which they are operated in order to increase the plant productivity and bring down the capital cost per unit of aluminium produced in the plant.

[0004] Industrial electrolytic cells used for the Hall-Héroult process are generally rectangular in shape and connected electrically in series, the ends of the series being connected to the positive and negative poles of an electrical rectification and control substation. The general outline of these cells is known to a person skilled in the art and will not be repeated here in detail. They have a length usually comprised between 8 and 25 meters and a width usually comprised between 3 and 5 meters. The cells (also called "pots") are always operated in series of several tens (up to more than four hundred) of pots (such a series being also called a "potline"); within each series DC currents flow from one cell to the neighbouring cell. The electrical currents in most modern electrolytic cells using the Hall-Héroult process exceed 200 kA and can reach 400 kA, 470 kA or even more; in these potlines the pots are arranged side by side. Most newly installed pots operate at a current comprised between about 350 kA and 600 kA, and more often in the order of 400 kA to 500 kA. The passage of these enormous current intensities through the electrolytic cell leads to ohmic losses at various locations of the pot and its environment.

[0005] Cathode assemblies for use in electrolytic cells suitable for the Hall-Héroult process are industrially manufactured for more than a century, and the state of the art is summarized in the reference book "Cathodes in Aluminium Electrolysis" by M. Sortie and H. Øye, 3rd edition (Düsseldorf 2010). They comprise a cathode block made from a carbon material and one or more metallic cathode bars (often called "cathode collector bars") that are fitted into slots or grooves machined into the lower surface of said carbon block. Said metallic cathode collector bar embedded in the cathode block collects the current of said cathode block and carries it to the cathode busbar system. In order to be able to achieve this, it protrudes out of each end of the cathode blocks, thereby allowing to connect the cathode assembly to the cathode busbar system.

[0006] The metallic cathode collector bar is usually made from steel. Said steel bars are inserted into grooves that are wider than the steel bars, and then fixed with electrically conductive glue (carbonaceous glue or cement, or ramming paste) or with cast iron that is poured into the interstitial space between the steel bar and the carbon block, as described in GB 663 763 (assigned to Compagnie de Produits Chimiques et Electrometallurgiques Alais, Froges & Camargue).

[0007] The cathode collector bar contributes to the voltage loss of a Hall-Héroult electrolysis cell. In order to increase the energy efficiency of the electrolytic cell, much effort has been devoted during the past decades to the decrease of ohmic losses in cathode bars. Most inventions reported in prior art patents focus on the intrinsic electrical conductivity of the cathode collector bar, or on the contact resistance between the cathode collector bar and the cathode block or between the cathode collector bar and the aluminium busbar.

[0008] As mentioned above, cathode collector bars are usually made from steel. Their electrical conductivity can be increased by inserting copper bars into grooves machined into these steel bars; this has been described in several documents. More recently, it has been suggested to replace the steel cathode collector bars by copper bars (see WO 2016/157021 assigned to DUBAL Aluminium PJSC); this can lead to a decrease in voltage drop of about 50 mV compared to a conventional steel cathode collector bar with Cu insert. However, copper has not only a higher electrical conductance than steel, but also a higher thermal conductivity; as a consequence, the use of copper inserts into steel cathode collector bars, or the use of full copper bars as cathode collector bars, will also lead to an increase of thermal loss of the electrolytic cell. Depending on the cell design and operation conditions, the extraction of heat through the cathode collector bar may be desirable or undesirable: in the former case, heat extraction through the cathode collector bars contributes to the cooling of the cell, whereas in the latter case, the thermal energy carried out of the cell by the cathode collector bars needs to be retained inside the cell. Whatever the design of the cathode collector bar, an additional condition for its proper functioning is mechanical strength: the cathode collector bar should be mechanically strong to bear the mechanical stresses and should not break during the life span of the cell to maintain the continuity of the current flow.

[0009] Concerning the cell design and operating conditions, it has been found that for a given cell design, there is often a trade-off between high metal production and low energy consumption. When the amperage of a cell is gradually increased (so-called amperage creep), for a given anode to cathode distance and anode size, generally an increase in amperage will require more heat losses from the exterior surfaces of the cell, as more heat is produced. On the other hand, cells designed for and operated at low energy consumption conditions require more heat to be preserved inside the cell: heat losses are here undesirable. This can be achieved through design changes in cathodes as well as in anodes. As an example, Hall-Héroult cells which are to be designed for a Specific Energy Consumption (abridged as SEC) below 11.5 kWh/kg of produced aluminium need to preserve a significant amount of heat within the cell, but in order to meet the SEC target, the contribution of the cathode collector bar to ohmic losses must be low.

[0010] In order to decrease the thermal conductivity of an electrical conductor, it is known to provide a portion having a reduced cross section which tends to impede thermal conduction (see WO 2018/019888 for a cathode collector bar and WO 2019/123131 for an anode yoke). This means to decrease the thermal conduction will, however, also significantly increase the voltage drop. Moreover, the solution described in WO 2018/019888 is not thermally efficient for a Hall-Héroult electrolysis cell, because it focuses on the connection of the cathode collector bar to the busbar, and does not prevent heat from being conducted out of the potshell.

[0011] The present invention focuses on cathodes. The problem to be solved by the present invention is to come up with a cathode bar design exhibiting decreased heat loss, while minimizing the increase in voltage drop.

Objects of the invention

[0012] According to the invention the problem is solved by a specific redesign of the current collector bar in which the location of the smallest cross section of the copper insert is located outside of the cathode block.

[0013] A first object of the invention is a cathode collector bar for a cathode assembly suitable for a Hall-Héroult electrolysis cell, said cathode assembly comprising a cathode block made of a carbonaceous material, a groove being provided in said cathode block, and at least one said cathode bar, each of said cathode bar partly fitted in said groove. Said cathode bar is made of at least one electrically conductive material, and is intended to protrude outside a side wall of a pot shell which is part of said electrolysis cell, said cathode bar said bar being thus divided into an inner region intended to be located inside the groove, an outer region intended to protrude outside said side wall, and a median region connecting said inner region and said outer region.

[0014] According to the invention, said cathode collector bar is characterized in that said median region is provided with a so-called low thermal loss zone, the function of which is to locally reduce thermal losses, said low thermal loss zone having a so-called reduced conductive surface, said reduced conductive surface having a value inferior to the so-called total conductive surface of said cathode collector bar.

[0015] In a first advantageous embodiments of the invention the low thermal loss zone is a thinned zone of said median region, knowing that in a variant, said thinned zone may be formed by a through hole which leads to both upper wall and lower wall of the bar. Said through hole may be provided with rounded longitudinal ends, in particular shaped as half circles, and/or the width of said hole is advantageously comprised between 40 % and 80 %, in particular between 60 % and 80 % of the width of said bar, and/or the length of said thinned zone is advantageously comprised between 10 % and 80 %, preferably between 40 % and 60 %, in particular about 50 % of the length of said median region, and/or the ratio between said reduced conductive surface of low thermal loss zone (70) and said total conductive surface of said cathode collector bar is advantageously comprised between 0.5 and 0.8.

[0016] Said bar can be made of one single material, in particular copper.

[0017] In a second advantageous embodiment of the cathode collector bar according to the invention, said cathode collector bar comprises a bar body made of a first material, in particular of steel, as well as an insert made of a second material, in particular of copper, said insert being accommodated in a housing of bar body, in particular in a channel leading on the top surface of the bar, or in a cylindrical central hole provided in the bar, and said insert extending over only a part of said bar body so as to form a so-called intercalary volume which defines said low thermal loss zone. Said intercalary volume may, at least partly, be filled with an insulating material.

[0018] In said second embodiment of the cathode collector bar according to the invention:

- the cathode collector bar may further comprise an end tip, received at the end of said channel, said insert and said tip extending on either side of said intercalary volume, and/or
- the length of said low thermal loss zone is comprised between 10 % and 80 % of the length of said median region.

[0019] A second object of the invention is a cathode assembly suitable for a Hall-Héroult electrolysis cell, comprising a cathode block made of a carbonaceous material, a groove being provided in said cathode block, and at least one cathode collector bar made of at least one electrically conductive material, said cathode collector bar being partly fitted in said groove, said cathode bar being intended to protrude outside a side wall of a pot shell which is part of said electrolysis cell, said cathode assembly being characterized in that said cathode collector bar is a cathode collector bar according to any of the preceding objects and its embodiments.

[0020] A third object of the present invention is an electrolytic cell suitable for the Hall-Héroult electrolysis process, comprising

- an outer metallic potshell,
- a cathode received in said potshell, said cathode forming the bottom of said electrolytic cell and comprising a plurality of parallel cathode assemblies, each cathode assembly comprising a cathode block and at least one cathode collector bar protruding outside a side wall of said pot shell,
- a lateral lining also received in said pot shell, said lining defining together with the cathode a volume containing the liquid electrolyte and the liquid metal resulting from the Hall-Héroult electrolysis process,
- a plurality of anode assemblies suspended above the cathode, each anode assembly comprising at least one anode and at least one metallic anode rod connected to an anode beam,
- a cathodic bus bar surrounding said potshell,
- a plurality of connectors, each connecting one end of a cathode collector bar of a cathode assembly to said cathodic bus bar,

said electrolytic cell being characterized in that at least one and preferably all the cathode collector bars are according to any of the embodiments of the present invention, and in that said low thermal loss zone of said bar is located between an end wall of said cathode block and said side wall of said pot shell.

[0021] The design according to the invention has numerous advantages and helps in particular, in a Hall-Héroult cell of the DX+Ultra™ type designed to a low specific energy consumption at lower current density operation as low as about 12.8 kWh/kg, to further decrease the heat loss through the collector bars by about 17 kW, with an overall increase of cathode voltage drop is about 6 mV calculated at 470 kA. This is equivalent to about 100 Wh/kg Al SE energy reduction at lower current density operation. It has further advantages which are related to the location of the smallest cross section of the copper insert outside of the cathode block. First, the region outside of the cathode block is much cooler when compared to the temperature within the cathode block. Second, the inventive design of the collector bar, which is the element which, in prior art, carries a significant amount of heat out of the cell (due to the much higher thermal conductivity of the collector bar compared to refractory bricks), ensures that no significant amount of heat reaches the outside potshell through the collector bar. Third, any accidental leakage of liquid aluminium from the cavity and reaching up to the collector bar and thereby chemically dissolving the collector bar is less risky due to low temperature around the smaller cross section of the copper bar.

[0022] A specific advantage of the cathode collector bar according to the second embodiment of the invention is that the copper insert all along its length is mechanically supported by the steel bar in which is it embedded. Advantageously, at the location of the smallest cross section of the copper bar, said steel bar has thinner side and bottom faces that are thick enough to provide mechanical strength as well as sufficient electrical conductivity in the case the copper insert is broken, but that are thin enough such as to limit heat losses.

Figures

[0023]

Figures 1 to 10 represent various embodiments of the present invention, but are not meant to limit in any way the scope of the invention.

Figure 1 is a perspective view, showing a first embodiment of a cathode assembly according to the invention, wherein the cathode collector bar of this assembly is fully made of copper.

Figure 2 is a perspective view, showing at greater scale the cathode assembly of figure 1, with a vertical middle cut of the cathode assembly.

Figure 3 is a top view at still a greater scale, showing in further details the different regions of the cathode bar.

Figures 4 and 5 are cross sections along cutting planes IV and V on figure 1.

Figure 6 is a top view, illustrating a preferred variant of said first embodiment.

Figure 7 is a perspective view, analogous to figure 1, showing a second embodiment of a cathode assembly according to the invention, wherein the cathode bar of this assembly is made of both steel and copper.

Figure 8 is a perspective view, analogous to figure 2, showing at greater scale the cathode assembly of figure 7, with a middle cut of the cathode assembly.

Figure 9 is a top view at still a greater scale, showing in further details the different regions of the cathode bar.

Figures 10 and 11 are cross sections along cutting planes X and XI on figure 7.

Figure 12 is a perspective view, analogous to figure 8, illustrating a variant of said second embodiment comprising a cylindrical insert.

[0024] The following reference signs are used on the figures and in the description:
For the first variant of the first embodiment:
I Cathode assembly

1 Cathode block / 11, 12 Front, rear wall of cathode block 1
13, 14 Upper, lower wall of cathode block 1 / 15, 16 Side walls of cathode block 1
17 Longitudinal groove in cathode block 1 / 171, 172 Side walls of groove 17
173 Upper wall of groove 17
3, 3' Cathode bar / *X3* main axis of 3 / 31 Front wall of cathode bar 3
33, 34 Upper, lower wall of cathode bar 3 / 35, 36 Side walls of cathode bar 3
40, 50, 60 inner, outer and median regions of bar 3
70 thinned zone of bar 3 / 8 cutout / 81 82 front and rear walls of 8
9 Potshell / 90 bottom wall of 9 / 92 side wall of 9 / 94 window in 92
d70 distance between window 94 and wall 81 of the hole 8
X70 distance between wall 82 and wall 11

[0025] For the second variant of the first embodiment:
1a Cathode block / 3a Cathode bar / 8a cutout / 81a 82a rounded walls of 8a

[0026] For the first variant of second embodiment:
II Cathode assembly

101 Cathode block / 117 Longitudinal groove in cathode block 101
103, 103' Cathode bar / *X103* main axis of 103 / 131 end wall of 103
140, 150, 160 inner, outer and median regions of bar 103
122 bar body / 142, 152, 162 inner, outer and median regions of bar body
124 insert / 144, 164 inner and median regions of insert / 125 end wall of insert
126 end tip / 127 rear wall of 126 / 156, 166 outer and median regions of tip
108 intercalary volume / 128 layer of insulating material in 108
170 zone of bar 103 provided with layer 128
109 Potshell / 190 bottom wall of 109 / 192 side wall of 109 / 194 window in 192
d170 distance between wall 127 and sidewall 192
X170 distance between wall 125 and wall 111

[0027] For the second variant of the second embodiment:
III Cathode assembly

201 Cathode block / 203 Cathode bar / 222 bar body / 224 insert / 226 end tip
208 intercalary volume / 228 layer of insulating material in 108

(continued)

270 zone of bar provided with layer 228 / 109 Potshell / 292 side wall of 109

HX Height of element X : *H1, H17*
LX Length of element X : *L1, L50, L60, L70, L160, L170, L270*
WX Width of element W : *W1, W3, W8, W17, W103, W124*

Sr/*S'r* reduced cross conductive surface of zone 70/170

St/*S't* total cross conductive surface of the bar

Description

[0028] In the present description, the terms "upper" and "lower" refer to a cathode block in use, lying on a horizontal ground surface. Moreover, unless specific indication to the contrary, "conductive" means "electrically conductive"; it should however be borne in mind that in the framework of the present invention, all materials that are labelled as "conductive" are metallic materials; in metallic materials the relationship between the electrical conductivity and the thermal conductivity is usually well described by the Wiedemann-Franz law.

[0029] According to the terminology used in the present description and in the art, a "cathode assembly" **I** comprises a cathode block **1** and a cathode collector bar, or cathode bar **3.** The present invention applies to cathodes used in the Hall-Héroult process that form the bottom of an electrolysis cell, said cathodes being assembled from individual cathode assembly ***I,*** each of which bears at least one cathode bar **3*.*** The Hall-Héroult process and the outline of an electrolysis cell (also called "pot") are known to a person skilled in the art and will not be described here in great detail.

[0030] The cathode assembly of the invention is designated as a whole by reference **I.** It is suitable for a Hall-Héroult electrolysis cell, but could be used in other electrolytic processes.

[0031] The cathode assembly **I** first comprises a cathode block **1,** of known type, which is made of a carbonaceous material, typically graphitized carbon or graphite. This cathode block **1,** which has an elongated shape, has opposite front **11** and rear **12** walls, as well as peripheral walls. The latter are formed by parallel upper and lower walls **13** and **14,** as well as parallel side walls **15** and **16.** By way of example, its length *L1* (see figure 1), i.e. the distance between walls **11** and **12,** is between about 3000 mm and about 4000 mm. By way of example, its width *W1* (see figure 1), i.e. the distance between walls **15** and **16,** is between about 400 mm and about 675 mm. By way of example, its height *H1* (see figure 1), i.e. the distance between walls **13** and **14,** is between about 300 mm and about 600 mm.

[0032] The lower wall **14** of cathode block **1** is provided with a longitudinal groove **17** extending from one cathode block end to the other (see in particular figure 2). The free end of the groove **17** leads to front wall **11** or to rear wall **12** of cathode block **1.** The structure of groove **17** will now be described. Opposite side walls of groove **17** are referenced **171** and **172** (see figure 3), whereas its upper wall is referenced **173** (see figure 2). By way of example, its width *UV17* (see figure 3), i.e. the distance between walls **171** and **172,** is between about 130 mm and about 280 mm. By way of example, its height *H17* (see figure 1), i.e. the distance between upper wall **173** and the surface of lower wall **14,** is between about 150 mm and about 240 mm.

[0033] The cathode assembly **I** also comprises two cathode bars **3** and ***3',*** each of which is accommodated in groove **17.** Each cathode bar **3** or **3'** is made of a first electrically conductive material. In this first embodiment, the material of these cathode bars is copper. The structure of bar **3** will now be described, bearing in mind that structure of the other bar **3'** is identical. This cathode bar **3,** which has an elongated shape, has a front wall **31** and a not represented rear wall, as well as peripheral walls. The latter are formed by upper and lower walls **33** and **34,** as well as side walls **35** and **36.**

[0034] In a known manner two adjacent walls may form longitudinal or rounded corners, which are not shown on the drawings for sake of clarity. In the illustrated embodiment upper and lower wall **33,34** and/or side walls **35,36** are parallel; however, in a way known as such, they might not be parallel inside the block and parallel outside the block in some designs, and not parallel along whole bar length in some other designs. In an advantageous variant of this embodiment the cathode bar is essentially rectangular in cross section.

[0035] Figure 2 shows in a very partial way a potshell **9** of an electrolytic cell for the Hall-Héroult process. Said pot shell is shaped as a "shoe box", in a way known as such. Figure 2 illustrates only a part of bottom wall **90,** as well as one upright side wall **92** of this pot shell. The latter is also provided with not represented further walls, namely one opposite upright side wall, as well as two parallel upright endwalls. Figure 2 also shows one **94** of the windows provided in both sidewalls, for allowing the cathode bars to protrude out of the potshell.

[0036] As illustrated on figure 3, said cathode bar 3 can therefore be divided into three regions, being located the one behind the other with respect to main axis *X3* of this bar 3. First, one so-called inner region **40** extends inside the groove **17** of the cathode block 1. At its opposite end, one so-called outer region **50** protrudes out of the side wall 72 of the pot shell, beyond the window **94.** Finally a so-called median region **60** extends between said inner region **40** and said outer region **50.** By way of mere example, the length *L50* of region **5**0 is between about 50 mm and 210 mm, and the length *L60* of region **60** is between about 270 mm and about 320 mm. By sake of clarity, the proportions between these regions are not necessarily respected on figure 3.

[0037] According to the invention, the median region **60** is provided with a cutout **8,** formed by a through hole which leads to both upper **33** and lower **34** walls of the bar **3.** Said cutout **8** therefore defines a thinned zone **70** of the bar, namely a lower cross section zone of the bar. Still in other words, said zone **70** includes less material than the rest of the bar.

[0038] In the embodiment illustrated on figures 1 to 5, cutout **8** is represented with a rectangular shape, which is given as modelling purpose. By way of example, let us give the following values of said rectangular cutout (as illustrated on figure 3).

[0039] Let us note first *L70* length of the thinned zone **70,** along main axis *X3:* advantageously, *L70* is superior to 20 mm, in particular to 50 mm. In theory cutout 8 may extend over the whole median region **60,** namely from inner wall **92** of pot shell to facing wall **11,** so that *L70* corresponds to *L60.* In a preferred way, said cutout does not extend beyond each of these walls 11 and 92, so that L70 is inferior or equal to *L60.* As a typical range of value, *L70* is between 10% and 80% of *L60,* advantageously between 40% and 60% of *L60,* in particular about 50% of L60.

[0040] Let us also note width *W8* of the hole **8.** In an advantageous way, said width W8 is between 40% and 80% of *UV3.* This range makes it possible to reach the required technical effect, without any risks for the proper operation of the pot. In a preferred way, said width W8 is between 60 % and 80 % of *W3.*

[0041] Let us also note *d70* closest distance along main axis *X3,* between the inner wall **92** of pot shell and facing front wall **81** of the hole **8.** Since cutout **8** may extend over the whole median region **60,** the value of d70 may be equal to 0; a typical maximum value is about 100 mm.

[0042] Let us finally note *X70* closest distance along main axis *X3,* between other front wall **82** of hole **80** and front wall **11** of cathode block **1.** Since cutout **8** may extend over the whole median region **60,** the value of *X70* may be equal to 0.

[0043] The thinned zone **70** defines a zone in which the conductive cross surface is reduced, with respect to the conductive cross surface of the other parts of the bar. In this respect, figures 4 and 5 show cross sections respectively along part of median region **60,** which is not recessed by the cutout **8,** and thinned zone **70.** Let us note *Sr* the so-called reduced cross conductive surface of the zone **70,** as well as *St* the total cross conductive surface of the not recessed bar. In a typical way the ratio *Sr*/*St* is between 0.50 and 0.8.

[0044] Figure 6 illustrates a preferred variant of the first above embodiment, including a cutout. The variant of figure 6 is preferred, since it brings about an easier fabrication. Contrary to the variant of figures 1 to 5, cutout **8a** provided in bar **3a** is not rectangular shaped, but rather oval shaped: indeed its longitudinal end walls **81a** and **82a** are rounded, preferably in the form of half circles. As another not shown variant, said cutout might be circular, namely formed only by said half circles.

[0045] The dimensions mentioned with reference to the above variant still apply, for what concerns variant of figure 6. Moreover, taking into account rounded walls **81a** and **82a,** length *L70'* of the zone **70'** of this second variant is advantageously superior to 40% of width *W3.*

[0046] Figures 7 to 11 show a first variant of a second embodiment of a cathode assembly II, according to the present invention. On these figures the mechanical elements, which are analogous to those illustrated on figures 1 to 5, are given the same references added by number 100.

[0047] Cathode assembly II differs from that I, which has been described above, first in that cathode bar **103** is made of two different materials. Indeed said bar first comprises a bar body **122,** typically made of steel, as well as an insert **124,** typically made of copper. In a way known as such, in this first variant, bar body **122** is U shaped and insert **124** is accommodated in the longitudinal housing, forming a channel, which is defined in said bar body. The ratio *UV124*/*UV103* between width *W124* of the copper insert and global width *UV103* of the bar is typically between 0.25 and 0.7. It shall be noted that the whole bar is symmetrical, viewed from the top.

[0048] Let us note **142, 152** and **162** the respective inner, outer and median regions of the steel body, as well as **144** and **164** the respective inner and median region of the copper insert. According to the invention, insert **124** does not extend over the whole length of the cathode bar **103,** so that said insert **124** is not provided with an outer region. In this respect, let us note **125** end wall of this insert, which is located in the median region **160** of the whole bar.

[0049] An auxiliary metallic tip **126,** also called end tip, is inserted in the channel of body **122.** Said tip extends from end wall **131** of cathode bar **103,** so that it has an outer region **156** as well as a median region **166.** This tip does not contact insert **124** so that, as shown on figure 8, front wall **125** of insert and rear wall **127** of tip define an intercalary volume **108.** In the illustrated example, this volume is filled with a layer **128** of insulating material. The latter can be any standard insulation material, like calcium silicate or vermiculate.

[0050] The layer **128** is flush with the upper wall of both insert **124** and end plate **126.** In a similar way as above zone **70,** let us define zone **170** which corresponds to the layer **128.** Contrary to the first embodiment, zone **170** is not thinned since it comprises the same amount of material as the rest of the bar. However, due to said insulating layer, the conductive cross surface is reduced in this zone **170,** the same way as for zone **70** of first embodiment.

[0051] In this respect, figures 10 and 11 show cross sections respectively along part of median region **160,** which is not occupied by the insulating layer, and zone **170.** Let us note (figure 11) *S'r* the so-called reduced cross conductive surface of the zone **170:** said surface corresponds only to the surface of steel body **122.** On the contrary, the total cross conductive surface *S't* (figure 10) of zone **160** corresponds to the surfaces of both steel body 122 and insert **124.**

[0052] By way of example, let us give the following values:

- let us note first *L170* the length of the zone **170,** along main axis *X103.* As a typical range of value, *L170* is between 10% and 80% of *L160,* in particular between 30% and 50% of *L160.* Contrary to above described first embodiment, it is preferred that the zone **170** does not extend over the whole median region **160.**
- let us also note *d170 the* closest distance along main axis *X103* between wall **127** of tip and sidewall **192** of the pot (ie outer region **150**). In a preferred way, this distance is : between 10 and 50 mm.
- *X170, which is the* closest distance along main axis *X103* between wall **125** of insert and front wall **111** of cathode block **101,** will depend upon the values of *L170* and *d170.* The value of *d170* is typically comprised between 0 mm and about 100 mm.

[0053] Contrary to first embodiment, where width W8 has been detained, the width of insulating layer **128** is not of importance. Indeed this width necessarily corresponds to the width *W124* of insert 124.

[0054] In this second embodiment, figure 8 illustrates in addition a connector **196.** The latter, which is known as such, is intended to connect end **131** of cathode collector bar **103** with a not shown bus bar. An analogous connector may be provided on end 31 of bar 3, which is part of the above first embodiment.

[0055] Figure 12 shows a second variant of the above described second embodiment of the cathode assembly III, according to the present invention. On these figures the mechanical elements, which are analogous to those illustrated on figures 7 to 11, are given the same references added by number 100.

[0056] In this second variant, bar body **222** is not U shaped like in the variant of figures 7 to 11. On the contrary, in a way known as such, it is provided with a central cylinder hole, which forms a longitudinal housing wherein cylindrical insert **224** is accommodated. In an advantageous embodiment of this variant, the ratio *D224*/*D203* between diameter *D224* of the copper insert **224** and the global diameter *D203* of the cathode bar **203** is comprised between about 0.2 and about 0.8, and preferably between about 0.3 and about 0.7.

[0057] Like in the first variant of figures 7 to 11, insert **224** does not extend over the whole length of the cathode bar **203.** Said insert defines, with auxiliary end tip **226,** also called end tip, an intercalary volume **208.** Like in the first variant this volume is advantageously filled with a layer **228** of an insulating material, amongst other also calcium silicate or vermiculate. Zone **270,** which corresponds to the layer **228,** has a reduced cross conductive surface like above zone **170.** By way of example, the length *L270* of this zone **270,** has the same values as above detailed length *L170.*

Claims

1. A cathode collector bar (3, 3'; 3a; 103; 103') for a cathode assembly (I; II; III) suitable for a Hall-Héroult electrolysis cell, said cathode assembly comprising

- a cathode block (1; 101; 201) made of a carbonaceous material, a groove (17; 117) being provided in said cathode block,
- at least one said cathode bar (3, 3'; 3a; 103; 103'; 203), each of said cathode bar partly fitted in said groove,
- said cathode bar being made of at least one electrically conductive material,
- said cathode bar being intended to protrude outside a side wall (92; 192; 292) of a pot shell (9; 109; 209) which is part of said electrolysis cell,

said cathode bar being thus divided into

an inner region (40; 140) intended to be located inside the groove,
an outer region (50; 150) intended to protrude outside said side wall, and
a median region (60; 160) connecting said inner region and said outer region, **characterized in that** said median region is provided with a so-called low thermal loss zone (70; 170), the function of which is to locally reduce thermal losses, said low thermal loss zone having a so-called reduced conductive surface (Sr; S'r), said reduced conductive surface having a value inferior to the so-called total conductive surface (St; S't) of said cathode collector bar.

2. A cathode collector bar according to claim 1, wherein the low thermal loss zone is a thinned zone (70) of said median region (60).

3. A cathode collector bar according to claim 2, wherein the thinned zone is formed by a through hole (8; 8a) which leads to both upper wall and lower wall of the bar.

4. A cathode collector bar according to any claim 2 or 3, wherein said bar (3) is made of one single material, in particular copper.

5. A cathode collector bar according to any claim 3 to 4, wherein the width (W8) of said hole (8) is between 40% and 80%, in particular between 60% and 80% of the width (W3) of the bar (3).

6. A cathode collector bar according to any of claims 2 to 5, wherein the length (L70) of said thinned zone (70) is between 10% and 80%, preferably between 40% and 60%, in particular about 50% of the length (L60) of median region (60).

7. A cathode collector bar according to any of claims 2 to 6, wherein the ratio (Sr/St) between said reduced conductive surface (Sr) of low thermal loss zone (70) and said total conductive surface (St) of said cathode collector bar is between 0.5 and 0.8.

8. A cathode collector bar according to any of claims 3 to 7, wherein said through hole (8a) is provided with rounded longitudinal ends (81a, 82a), in particular shaped as half circles.

9. A cathode collector bar according to claim 1, wherein said bar (103; 203) comprises a bar body (122; 222) made of a first material, in particular of steel, as well as an insert (124; 224) made of a second material, in particular of copper,

said insert being accommodated in a housing of bar body, in particular in a channel leading on the top surface of the bar (103), or in a cylindrical central hole provided in the bar (203),
said insert extending over only a part of said bar body so as to form a so-called intercalary volume (108; 208) which defines said low thermal loss zone (170; 270).

10. A cathode collector bar according to preceding claim, wherein said intercalary volume is at least partly filled with an insulating material (128; 228).

11. A cathode collector bar according to claim 9 or 10, comprising also an end tip (126; 226), received at the end of said channel, said insert (124; 224) and said tip (126; 226) extending on either side of said intercalary volume (108; 208).

12. A cathode collector bar according to any claim 9 to 12, wherein the length (L170; L270) of said low thermal loss zone (170; 270) is between 10% and 80% of the length (L160) of median region.

13. A cathode assembly (I; II; III) suitable for a Hall-Héroult electrolysis cell, comprising

- a cathode block (1; 101; 201) made of a carbonaceous material, a groove (17; 117) being provided in said cathode block,
- at least one cathode collector bar (3, 3'; 3a; 103, 103'; 203) made of at least one electrically conductive material, said cathode collector bar being partly fitted in said groove,
said cathode bar being intended to protrude outside a side wall (92 ; 192) of a pot shell (9 ; 109) which is part of said electrolysis cell,
characterized in that said cathode collector bar is a cathode collector bar according to any preceding claim.

14. An electrolytic cell suitable for the Hall-Héroult electrolysis process, comprising

- an outer metallic potshell (9; 109),
- a cathode received in said potshell, said cathode forming the bottom of said electrolytic cell and comprising a plurality of parallel cathode assemblies (I; II), each cathode assembly comprising a cathode block (1; 101) and at least one cathode collector bar (3, 3'; 3a; 103, 103') protruding outside a side wall of said pot shell,
- a lateral lining also received in said pot shell, said lining defining together with the cathode a volume containing

the liquid electrolyte and the liquid metal resulting from the Hall-Héroult electrolysis process,

- a plurality of anode assemblies suspended above the cathode, each anode assembly comprising at least one anode and at least one metallic anode rod connected to an anode beam,
- a cathodic bus bar surrounding said potshell,
- a plurality of connectors (196), each connecting one end of a cathode collector bar of a cathode assembly to said cathodic bus bar,

said electrolytic cell being **characterized in that** at least one and preferably all the cathode collector bars are according to any claims 1 to 12,

said low thermal loss zone of said bar being located between an end wall (11) of cathode block (1) and said side wall (92) of pot shell.

Fig. 1

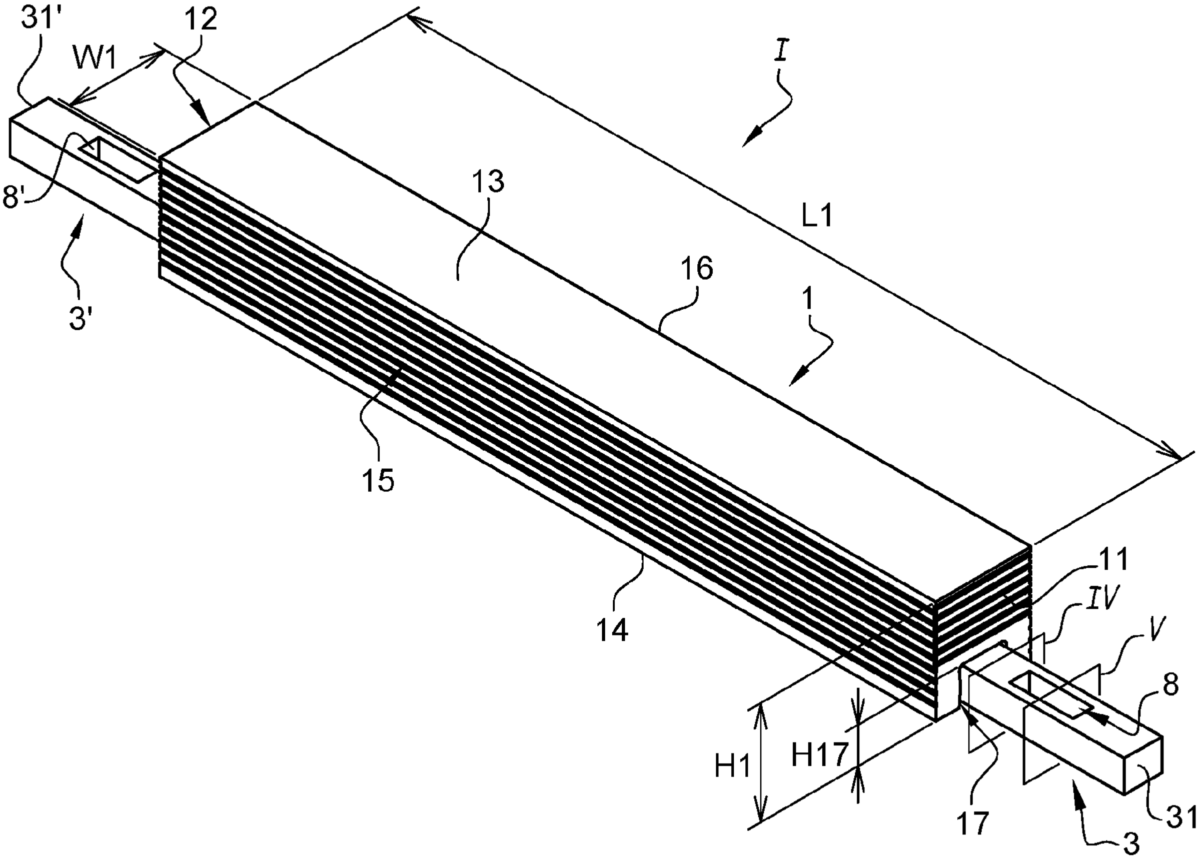
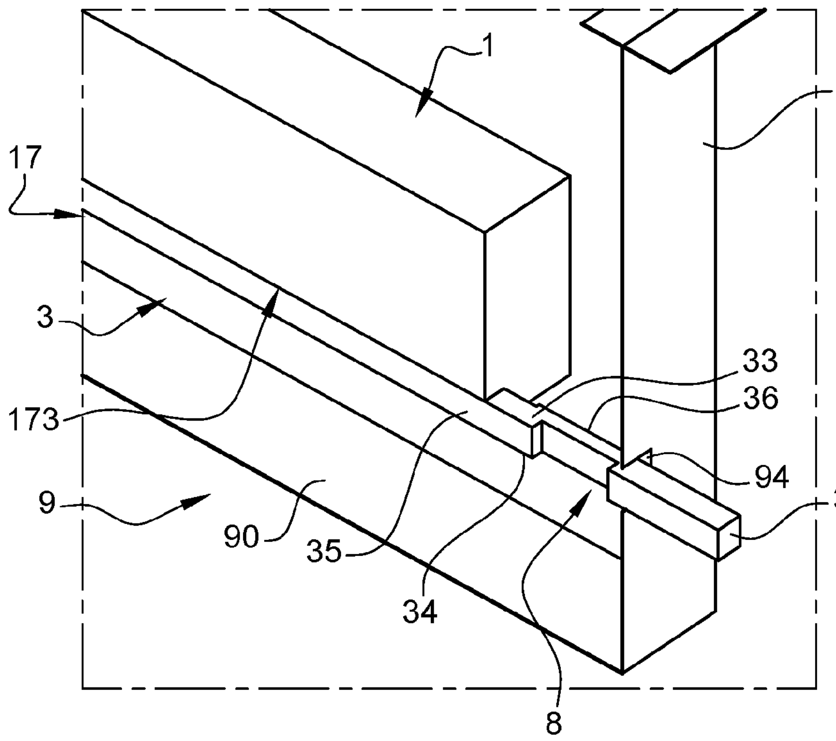

31'
12
W1
I
8'
13
L1
3'
16
1
15
11
14
IV
V
8
H1
H17
17
31
3

Fig. 2


1
92
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3
33
36
173
94
9
31
90
35
34
8

Fig. 3

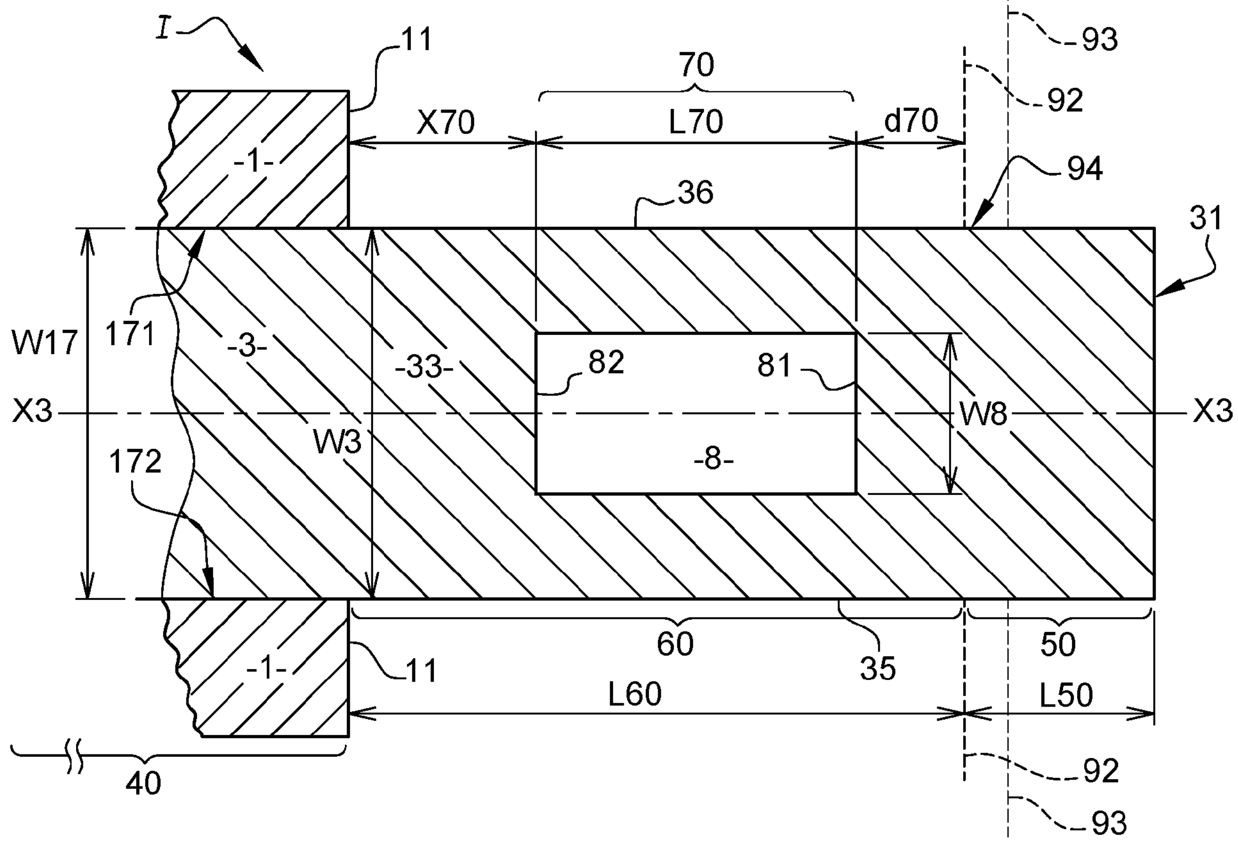


Fig. 4

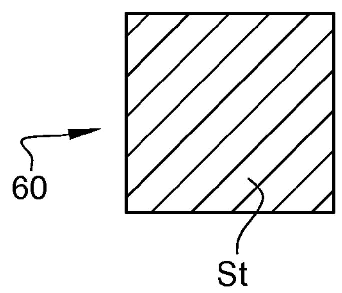


Fig. 5

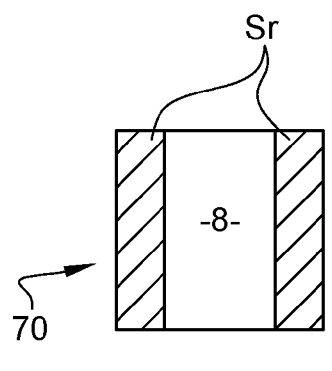


Fig. 6

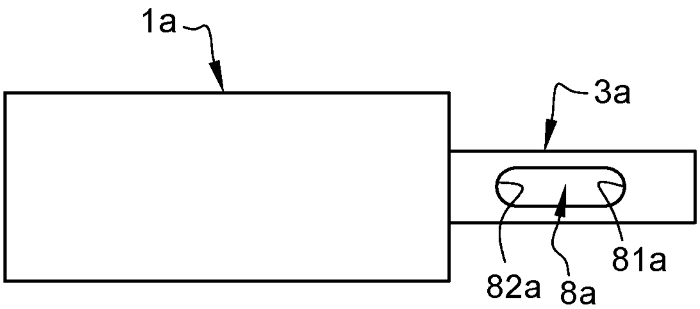

1a
3a
82a
8a
81a

Fig. 7

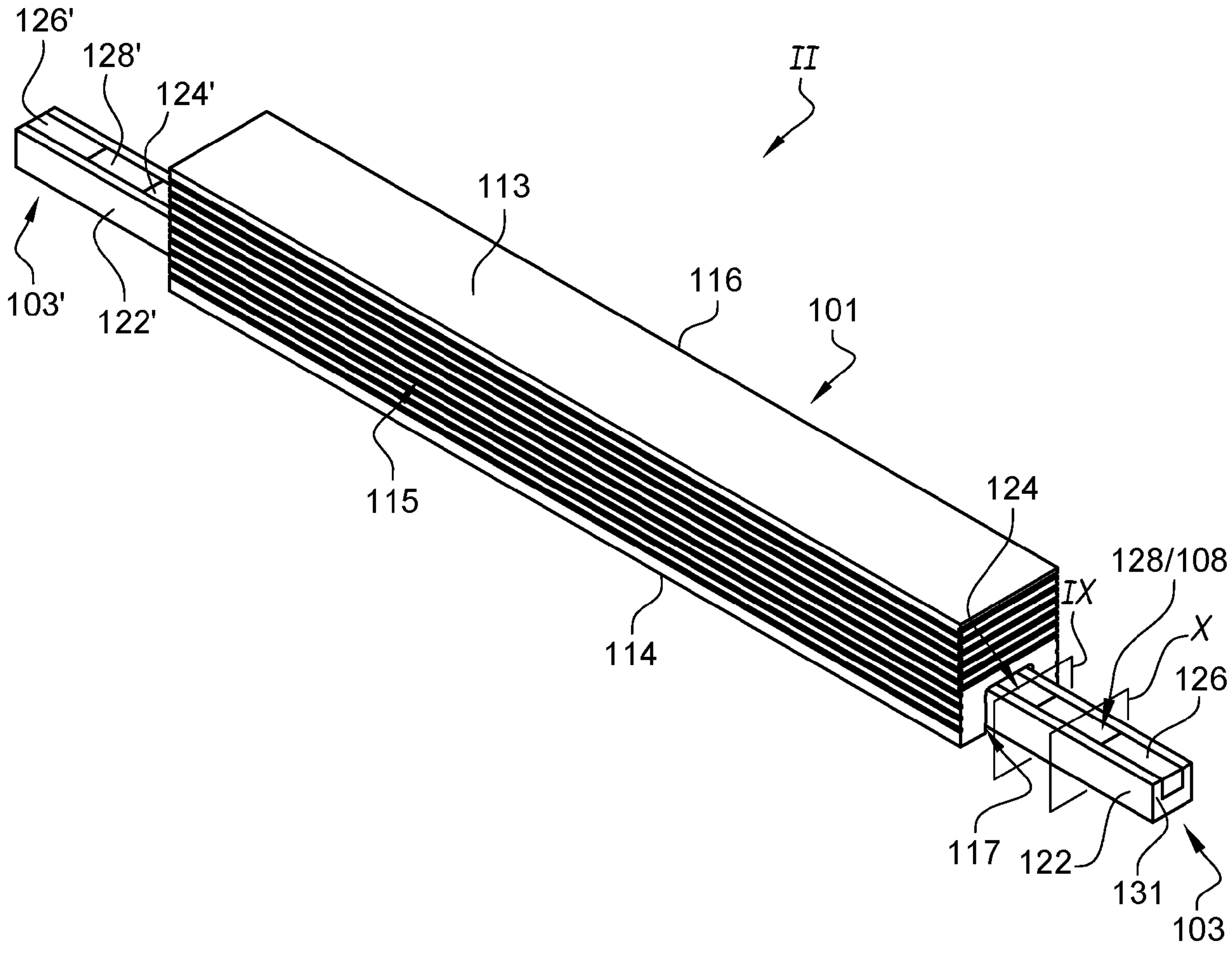
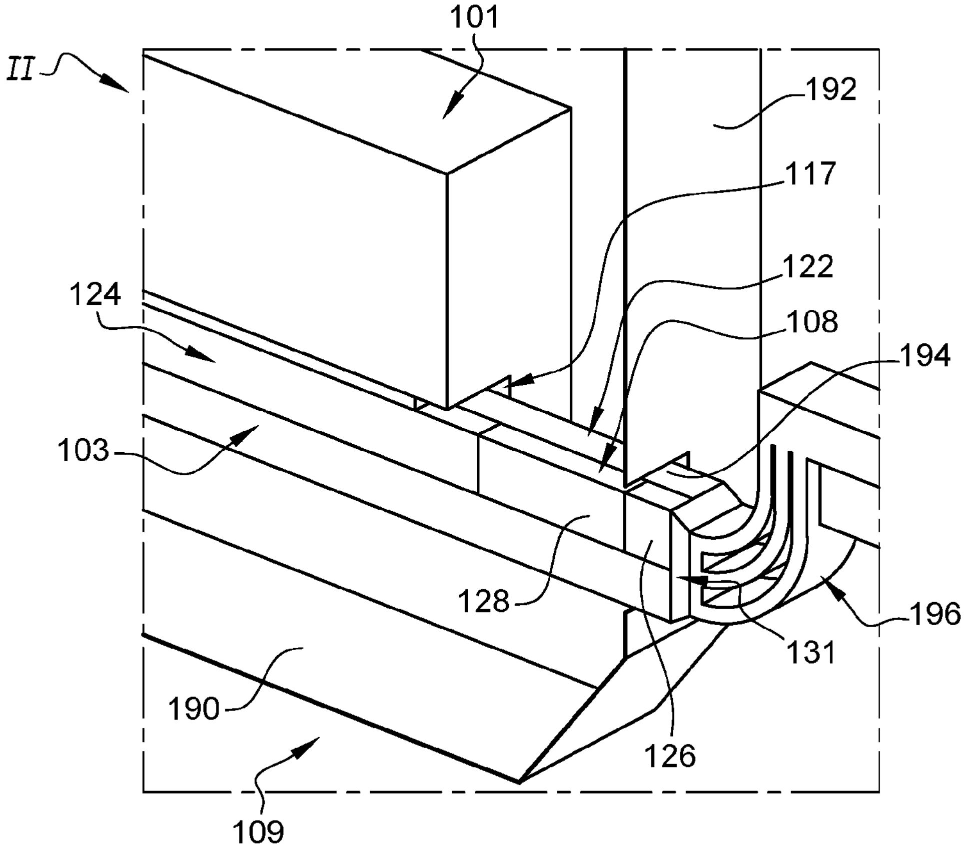

126'
128'
124'
II
113
116
101
103'
122'
115
114
124
128/108
IX
X
126
117
122
131
103

Fig. 8


II
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122
108
124
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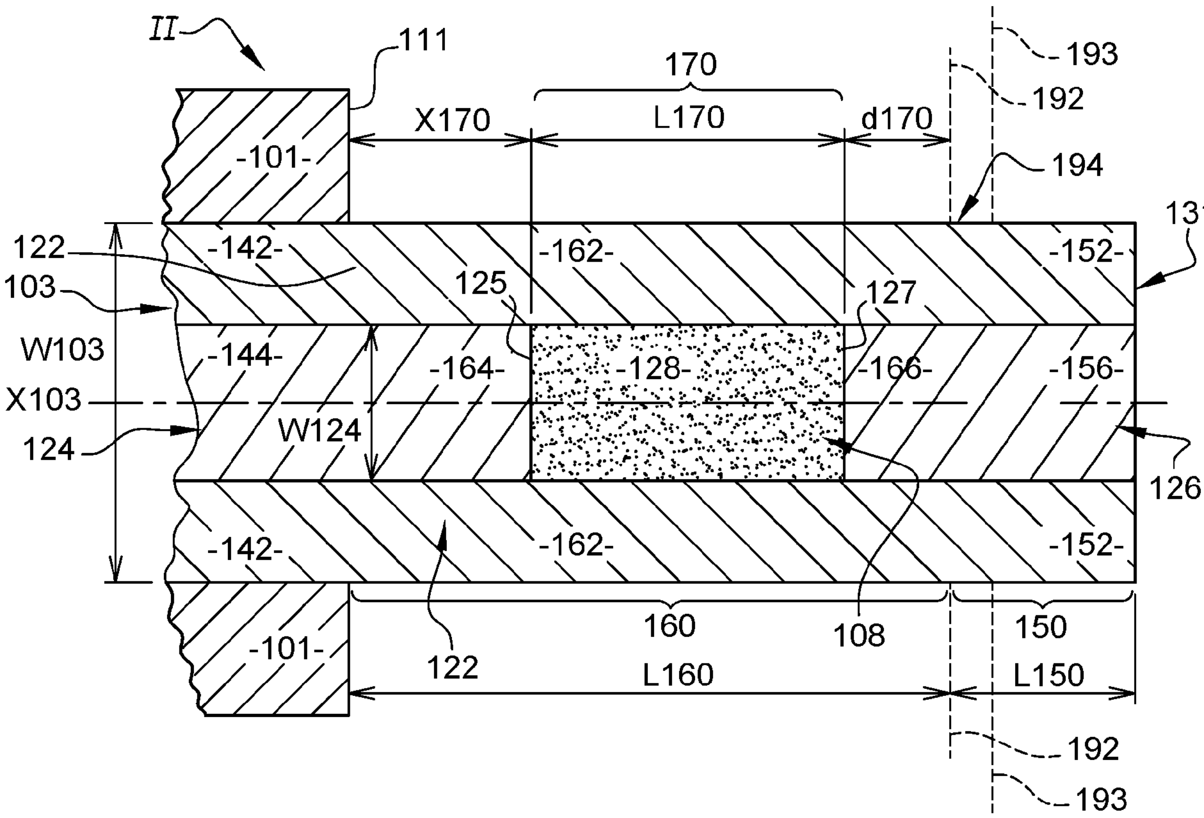
103
128
131
196
190
126
109

Fig. 9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193
X170
L170
d170
192
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194
131
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-144-
-164-
-128-
-166-
-156-
X103
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L150
192
193

Fig. 10

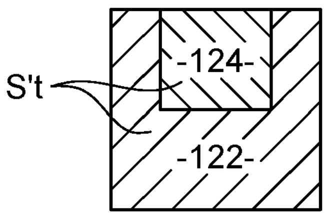


Fig. 11

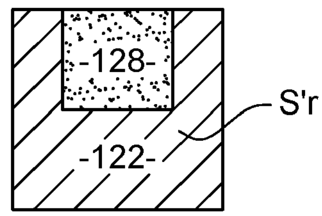
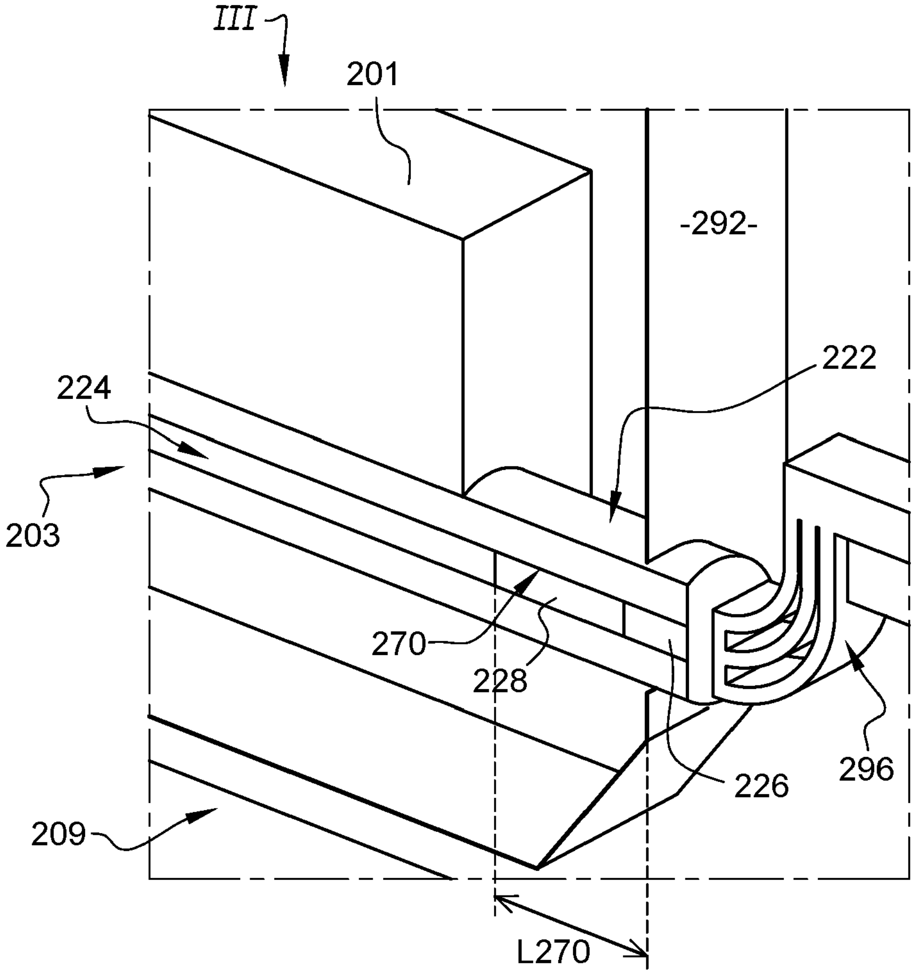


Fig. 12



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EUROPEAN SEARCH REPORT

Application Number
EP 22 21 6681

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	CH 670 658 A5 (JMC ENGINEERING) 30 June 1989 (1989-06-30) * the whole document * -----	1-14	INV. C25C3/16 C25C3/08
X	US 9 371 593 B2 (ALCOA INC [US]) 21 June 2016 (2016-06-21) * the whole document * -----	1-14	
X,D	WO 2018/019888 A1 (SGL CFL CE GMBH [DE]; NOVALUM SA [CH]) 1 February 2018 (2018-02-01) * the whole document * -----	1-14	
X	US 2 846 388 A (PAUL MOREL) 5 August 1958 (1958-08-05) * figure 2 * -----	1,2,4	

TECHNICAL FIELDS SEARCHED (IPC)
C25C

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	5 June 2023	Juhart, Matjaz

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EP 22 21 6681

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05-06-2023

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CH 670658 A5	30-06-1989	CH 670658 A5	30-06-1989
		YU 10888 A	31-12-1989
US 9371593 B2	21-06-2016	CA 2882837 A1	20-03-2014
		CN 103668338 A	26-03-2014
		CN 203569208 U	30-04-2014
		EP 2896081 A1	22-07-2015
		US 2014069820 A1	13-03-2014
		WO 2014043066 A1	20-03-2014
WO 2018019888 A1	01-02-2018	CA 3031717 A1	01-02-2018
		CN 109863258 A	07-06-2019
		EP 3491176 A1	05-06-2019
		JP 7284240 B2	30-05-2023
		JP 2019527462 A	26-09-2019
		JP 2022016478 A	21-01-2022
		RU 2723867 C1	17-06-2020
		UA 124537 C2	05-10-2021
		US 2019284711 A1	19-09-2019
		WO 2018019888 A1	01-02-2018
US 2846388 A	05-08-1958	DE 1110879 B	13-07-1961
		FR 1125949 A	12-11-1956
		US 2846388 A	05-08-1958

EPO FORM P0459

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- GB 663763 A **[0006]**
- WO 2016157021 A **[0008]**
- WO 2018019888 A **[0010]**
- WO 2019123131 A **[0010]**

Non-patent literature cited in the description

- **M. SORTIE ; H. ØYE.** Cathodes in Aluminium Electrolysis. 2010 **[0005]**