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(54) **CATHODE ASSEMBLY WITH METALLIC COLLECTOR BAR FOR ELECTROLYTIC CELL SUITABLE FOR THE HALL-HÉROULT PROCESS**

KATHODENANORDNUNG MIT METALLISCHER SAMMELSCHIENE FÜR EINE ELEKTROLYSEZELLE, DIE FÜR DEN HALL-HÉROULT-PROZESS GEEIGNET IST

ENSEMBLE CATHODE AVEC BARRE COLLECTRICE MÉTALLIQUE POUR CELLULE D'ÉLECTROLYSE SE PRÉTANT AU PROCÉDÉ HALL-HÉROULT

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(56) References cited:  
**EP-A1- 1 845 174 CN-A- 105 671 592**  
**CN-Y- 2 892 888 GB-A- 1 065 080**  
**US-A- 4 795 540 US-A- 5 976 333**  
**US-A1- 2004 011 661 US-B1- 6 294 067**

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**Description****Technical field of the invention**

5 **[0001]** The invention relates to the field of fused salt electrolysis using the Hall-Heroult process for making aluminium. More specifically it relates to the improvement of the cathode blocks of such an electrolysis cell, the improvement being related to the cathode drop and the current distribution along the cathode blocks. In particular, the invention relates to an improvement for cathode block provided with a cathode collector bar.

10 **Prior art**

**[0002]** The Hall-Héroult process is the only continuous industrial process for producing metallic aluminium from aluminium oxide. Aluminium oxide ( $\text{Al}_2\text{O}_3$ ) is dissolved in molten cryolite ( $\text{Na}_3\text{AlF}_6$ ), 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-Heroult process typically comprises a steel shell (so-called pot shell), a lining (comprising refractory bricks protecting said steel shell against heat, 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 and oxygen ions, then into aluminium at the cathode and oxygen at the anode; said oxygen reacting with the carbon of the anode to form carbon dioxide. 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.

25 **[0003]** Industrial electrolytic cells used for the Hall-Heroult 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 several hundreds) 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, 450 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.

35 **[0004]** Cathode assemblies for use in electrolytic cells suitable for the Hall-Heroult 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. Sørli and H. Øye, 3rd edition (Düsseldorf 2010). They comprise a cathode body made from a carbon material and one or more metallic cathode bars that are fitted into slots or grooves machined into the lower surface of said carbon body. Said metallic cathode bar protrudes out of each end of the cathode block, thereby allowing to connect the cathode assembly to the cathode busbar system. The metallic cathode bar is usually made from steel; copper inserts within the steel bar can be used in order to increase the electrical conductivity of the cathode bar. 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 body, as described in GB 663 763 (assigned to Compagnie de Produits Chimiques et Electrométallurgiques Alais, Froges & Camargue).

**[0005]** Other prior art designs of cathode assemblies are described in US 6 294 067, EP 1 845 174, US 4 795 540, US 2004 0011661, CN 105 671 592, SU 1 260 412, GB 1 065 080, CN 2 892 888, and US 5 976 333.

50 **[0006]** During the past decades, much effort has been devoted to the decrease of ohmic losses in cathode bars. Most inventions reported in prior art patents focus on the intrinsic conductivity of the steel cathode bar, or on the contact resistance between the cathode bar and the cathode block or between the cathode bar and the aluminium busbar.

**[0007]** A cathode with a full copper cathode bar inlaid into a groove machined in the lower surface of the carbon body is known from WO 2016/079605 (Kan Nak s.a.), in particular figures 7 and 9 of said document. The contact between the carbon body and the copper bar is critical for the electrical performance of the electrolysis cell. Copper has a much higher thermal expansion coefficient than the carbon material of the cathode block body, and the copper bar in direct contact with the carbon body will operate at a temperature that is probably less than 100°C lower than its melting point, leading to significant thermal expansion. As a consequence, a well-defined allowance for thermal expansion must be groove is required in order to ensure a good and reliable electrical contact between the copper bar and the carbon body

over the whole length. Reliability of this contact is of paramount importance, because once installed into a cell and the cell started, a cathode block cannot be repaired, and cannot be replaced without relining of the whole cell. The normal lifetime of a cathode lining is comprised between five and seven years.

[0008] Usually, large carbon products such as cathodes for use in Hall-Heroult cells are machined with a tolerance of  $\pm 2$  mm; a tolerance of  $\pm 1$  mm can be reached, but at a high cost. The applicant has found that it is very difficult to get reliable contacts by inserting metallic bar, in particular copper bar, directly into grooves machined into the carbon bodies without using glue.

[0009] The problem addressed by the present invention is therefore to improve the quality and reliability of the electrical contact of metallic bars, in particular copper bars, inserted into grooves machined into the carbon body of a cathode block.

### Objects of the invention

[0010] A first object of the invention is a cathode assembly suitable for a Hall-Heroult electrolysis cell, comprising

- a cathode body made of a carbonaceous material, said cathode body being provided with at least one slot, said slot being provided with side walls parallel to a longitudinal direction of said slot;
- at least one cathode collector bar made of a metallic material, said cathode bar being provided with side walls, which are in contact with said side walls of said slot;

characterized in that said cathode bar comprises two bar elements, each bar element being provided with a main side wall which is in contact with a respective side wall of said slot, as well as a tapered wall, the two tapered walls of said bar elements forming a contact line between these two bar elements.

[0011] Advantageously, said cathode assembly is provided with fixation means, in particular permanent fixation means, between said tapered walls of said bar elements. Said fixation means are advantageously welding means. In one embodiment, said welding means comprise at least one welding line, in particular several welding lines, extending over at least part of said contact line.

[0012] In an advantageous embodiment, said cathode body is provided with at least one first and one second slots, each slot being provided with a blind wall defining a longitudinal end of said slot, each slot receiving a respective cathode bar. Advantageously, said cathode bar is jammed against said longitudinal end of a respective slot.

[0013] In one embodiment, one first bar element has a triangular shape and comprises a front wall, said main side wall and said tapered wall. Advantageously, one second bar element comprises a further side wall, opposite to main side wall, said further side wall protruding with respect to main side wall of first bar element, along a transversal direction of said slot.

[0014] In an advantageous embodiment said front wall of first bar element is positioned against longitudinal end of said slot, and said second bar element comprises a front wall, the length of which is far inferior to that of front wall of first bar element, front wall of second bar element being remote from end of said slot.

[0015] In one embodiment said cathode bar has two portions, i.e. a first portion the width of which is equal to that of slot, as well as a second portion the width of which is superior to that of slot.

[0016] In an advantageous embodiment said cathode bar has a protrusion which extends outside said slot. Said protrusion is in particular formed by said second portion and by a fraction of said first portion. In one embodiment main side wall of each bar element protrudes outside said slot.

[0017] In one embodiment main side wall of each bar element directly contacts a respective side wall of said slot.

[0018] In an alternative embodiment main side wall of each bar element indirectly contacts a respective side wall of said slot, an intercalary material, in particular at least one graphite foil, being interposed between said main side wall and said respective side wall of said slot. A further intercalary material, in particular at least one further graphite foil, may be interposed between upper wall of said slot and facing walls of bar elements.

[0019] In an advantageous embodiment said side walls of said slot and said side walls of said bar elements show a slope, the value of which is in particular of about 10 degrees, so as to retain said bar elements in the inner volume of said slot.

[0020] Said cathode bar is advantageously made of copper. In an alternative embodiment said cathode bar is made of steel.

[0021] Another object of the present invention is a process for making a cathode assembly as described above, comprising the steps of

- a) providing a cathode body made of a carbonaceous material;
- b) providing at least one slot in said cathode body, said slot being provided with side walls parallel to a longitudinal direction of said slot;
- c) providing at least two bar elements made of a metallic material, each bar element being provided with a main

side wall and a tapered wall,

d) placing a first bar element into the slot, with its main side wall adjacent to facing first side wall of the slot;

e) urging forward, substantially along said longitudinal direction of said slot, second bar element, so as to urge main side wall of said first bar element against facing first side wall of the slot, so as to urge main side wall of said second bar element against facing opposite second side wall of the slot, and so as to set into contact the two tapered walls of said bar elements, along a contact line.

**[0022]** In an advantageous embodiment urging forward said second bar element also provokes the jamming of said first bar element against one longitudinal end of said slot.

**[0023]** In an advantageous embodiment said process further comprises providing said side walls of said slot and said side walls of said bar elements with a slope, the value of which is in particular of about 10 degrees, so as to retain said bar elements in the inner volume of said slot.

**[0024]** In an advantageous embodiment second bar element is provided with a handling portion and said second bar is urged forward manually, by handling said handling portion.

**[0025]** In an advantageous embodiment bar elements are provided by cutting a rough bar along a cutting line, said cutting line being tapered with respect to main axis of said rough bar.

**[0026]** In an advantageous embodiment said process further comprises providing fixation means, in particular permanent fixation means, between said tapered walls of said bar elements, once said tapered walls of said bar elements are in mutual contact.

**[0027]** Another object of the present invention is an electrolytic cell suitable for the Hall-Heroult electrolysis process, comprising

a cathode forming the bottom of said electrolytic cell and comprising a plurality of parallel cathode assembly, each cathode assembly comprising at least one metallic cathode collector bar protruding out of each of the two ends of the cathode,

a lateral lining defining together with the cathode a volume containing the liquid electrolyte and the liquid metal resulting from the Hall-Heroult electrolysis process,

an outer metallic potshell containing said cathode and lateral lining,

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, said bus bar being connected to at least part of said cathode assemblies said electrolytic cell being characterized in that

at least one of said cathode assembly, and preferably more than 60% of said cathode assemblies and, more preferably, each of said cathode assemblies, is a cathode assembly as described above.

**[0028]** Another object of the present invention is an electrolytic cell for the production of aluminium by the Hall-Heroult process, comprising at least one cathode assembly as described above.

**[0029]** Another object of the present invention is a process for making aluminium by the Hall-Heroult process, using an electrolytic cell provided with cathode assemblies as described above.

#### Figures

#### **[0030]**

Figures 1 to 11 represent one embodiment of the present invention.

Figure 1 is a perspective view, showing one embodiment of a cathode assembly according to the invention.

Figure 2 is a perspective view, showing upside down a cathode body which belongs to said cathode assembly according to the invention, said figure 2 showing in particular slots provided in said cathode body.

Figure 3 is a longitudinal section showing the cathode body of figure 2.

Figure 4 is a top view, showing at a greater scale a rough bar from which a cathode bar is formed, said cathode assembly of figure 1 being equipped with said cathode bar.

Figure 5 is a top view, analogous to figure 4, showing a cutting operation of said rough bar of figure 4, in order to form two bar elements.

Figures 6 and 7 are top views, analogous to figure 5, showing two steps of the insertion of said bar elements into a slot of said cathode body.

Figure 8 is a top view, analogous to figures 6 and 7, showing the final cathode bar of the cathode assembly according to the invention, said cathode bar being formed from said bar elements once inserted in said slot and mutually attached.

Figures 9 and 10 are top views, showing at still a greater scale the details IX and X of figure 8.

Figure 11 is a cross section showing the cathode bar of figure 8, along line XI-XI of figure 8.

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**[0031]** The following reference signs are used on the figures:

5	C	Cathode assembly	1	Cathode body
	11,12	Front/rear wall of cathode body 1	171, 172	Side walls of slot 17
	13,14	Upper/lower wall of cathode body 1	173	Top wall of slot 17,17'
	15,16	Side walls of cathode body 1	174,174'	Blind wall of slot 17,17'
10	17, 17'	Slots in cathode body 1	D174	Distance between 174 174'
	3,3'	Cathode bar	31,32	Front/rear wall of cathode bar 3
	33,34	Side walls of cathode bar 3	37	Contact line of 3
	5	Rough bar	51,52	Front / rear wall of rough bar 5
15	53,54	Upper / lower wall of rough bar 5	55,56	Side walls of rough bar 5
	A5	Axis of rough bar 5	CL	Cutting line
	L6	Length of slotted bar	$\alpha s$	Angle of slotted bar
20	$\alpha c$	Angle between A5 and CL	A17,A17'	Axis of slots 17, 17'
	7, 9	Bar elements	9A	Handling part of 9
	9B	Tip of 9	9C	Shoulder of 9
	71	Front wall of bar element 7	91,92	Front / rear wall of bar element 9
25	73	Side wall of bar element 7	93,94	Side walls of bar element 9
	77	Tapered wall of bar element 7	97	Tapered wall of bar element 9
	F9, S9	Motion of 9	F73, F93	Motion of 73,93
	21-24	Welding lines	3A,3B	Portions of 3
30	3C	Protrusion of 3	77',97'	Linking portion of 77,97
	D17,D1 7'	Depth of 17, 17'	H1	Height of 1
	LX	Length of element X : L1, L17, L17', L5, L7, L93, L94, L37, L3C'		
35	WX	Width of element X : W1, W5, W17, W17', W7, W91, W92		

**Detailed description**

**[0032]** In the present description, the terms "upper" and "lower" refer to a cathode block in the position of its industrial use, lying on a horizontal ground surface, i.e. the upper surface being intended to be in contact with the liquid aluminium in the electrolysis cell. Moreover, unless specified otherwise, "conductive" means "electrically conductive". According to the terminology used in the art, a "cathode assembly" **C** comprises a cathode body **1** and at least one cathode bar **3**.

**[0033]** The present invention is first applicable to cathode assemblies **C** comprising a cathode body **1** and at least one cathode bar **3** and **3'**. In particular, the invention is applicable to cathode assemblies comprising two cathode bars **3,3'**, one **3** of which is protruding out of the front wall **11**, the other **3'** protruding out of the rear wall **12** of the cathode body **1**. These cathode bars, which are half bars, form two portions of a so-called "split bar" in the sense that they are not through bars, i.e. each cathode bar is not extending through the whole length of the cathode block.

**[0034]** The present invention is also applicable to cathode assemblies having one (or more) through bar(s) instead of above defined split bars. The invention applies in particular to such through bars, which have a short length. However, the use of split bars is preferred, since it allows a better jamming of these bars, as will appear at reading the following description.

**[0035]** The present invention applies to cathodes used in the Hall-Heroult process that form the bottom of an electrolysis cell, said cathodes being assembled from individual cathode assemblies **C**, each of which bears at least one cathode bar **3, 3'**. The Hall-Heroult 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. The invention will be explained in relation with embodiments comprising one split cathode bar per cathode assembly **C**, said split cathode bar comprising two portions **3, 3'** but it is understood that the present invention can be applied to cathode assemblies **C** comprising any number of split cathode

bars with portions **3**, **3'**, such as two sets of split bars arranged parallel to each other. In the following the portion of a split cathode bar will be referred to as the "cathode bar".

**[0036]** The cathode assembly of the invention is designated as a whole by alphanumeric reference **C**. It is suitable for a Hall-Heroult electrolysis cell, but could be used in other electrolytic processes.

**[0037]** The cathode assembly **C** first comprises a cathode body **1**, of known type, which is made of a carbonaceous material, typically graphitized carbon or graphite. This cathode body **1**, which has an elongated shape, has opposite end walls, i.e. 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 3), i.e. the distance between walls **11** and **12**, is between about 3100 millimetres (mm) and about 4000 mm. By way of example, its width  $W1$  (see figure 2), i.e. the distance between walls **15** and **16**, is between about 400 mm and about 700 mm. By way of example, its height  $H1$  (see figure 3), i.e. the distance between walls **13** and **14**, is between about 375 mm and about 580 mm.

**[0038]** As more clearly shown on figures 2 and 3, the lower wall **14** of cathode body **1** is provided with two housings, each being formed by a respective longitudinal slot **17** and **17'**, the longitudinal main axis of which is referenced **A17**, **A17'**. Figure 2 shows cathode body "upside down", with reference to its above defined industrial use position.

**[0039]** Each slot **17**, **17'** is provided with opposite side walls **171**, **171'** and **172**, **172'** (see figure 2), parallel to said main axis **A17**, **A17'**, whereas its top wall is referenced **173**, **173'** (see figure 3). Moreover each slot **17**, **17'** is provided with a respective rear wall, or blind wall **174**, **174'** (see figure 2), each defining a respective longitudinal end of said slot. The distance  $D174$  (see figure 3) between these two walls is typically between 200 millimetres (mm) and 600 mm. Viewed from bottom, blind wall **174**, **174'** is rounded, which makes it possible to ease the slot machining. First slot **17** does lead to front wall **11** of this cathode body, whereas second slot **17'** does lead to rear wall **12** of this cathode body.

**[0040]** By way of example, width  $W17$  or  $W17'$  (see figure 2) of each slot **17**, **17'**, i.e. the distance between side walls, is between about 50 mm and about 250 mm. Advantageously, as illustrated in particular on figure 11, each side wall **171** and **172** shows a slope, the value as of which is typically of about 10 degrees. Therefore the above defined width  $W17$  or  $W17'$  decreases from top wall **173**, **173'** of this slot to lower wall **14** of cathode body. As will be described hereafter, these slopes make it possible to maintain the bar elements in the inner volume of the slot, when turning over the cathode assemblies. For sake of clarity, the value of as is exaggerated on this figure 11.

**[0041]** By way of example, depth  $D17$  or  $D17'$  of each slot **17**, **17'** (see figure 3), i.e. the distance between top wall **173**, **173'** and the surface of lower wall **14** of the body **1**, is between about 50 mm and about 150 mm. By way of example, its length  $L17$  or  $L17'$  (see figure 3), i.e. the distance between front wall or rear wall of cathode body and blind wall **174**, **174'**, is between about 1200 mm and about 1850 mm. This length is taken from the junction of rounded portion of said blind wall with rectilinear part of side walls **171**, **171'** and **172**, **172'**.

**[0042]** The cathode assembly **C** also comprises two cathode bars **3** and **3'** (schematically shown on figure 1), each of which is accommodated in a respective slot **17** and **17'**. Each cathode bar **3** or **3'** is made of a conductive material, typically able to conduct the current from the cathode to the exterior Bus Bar. Advantageously, the material of these cathode bars is copper. However, the invention encompasses cathode bars made of other materials, such as for example steel, or other materials usually installed inside the cathode assemblies. The insertion process of cathode bar **3** into its slot **17** will now be described, bearing in mind that insertion process of other cathode bar **3'** into other slot **17'** is identical.

**[0043]** The first step of said insertion process is the provision of a so called rough bar, which is shown on figure 5 and is referenced **5** as a whole. As will appear more clearly at reading the next steps of this process, the dimensions of said rough bar **5** are globally analogous to those of final cathode bar **3**, but slightly different. This bar **5**, which has an elongated shape, is not shown with its real scale on figure 4, in order to clearly illustrate the insertion process. The same remark applies to mechanical elements of figures 5 to 10: slot **17**, cathode bar **3** and bar elements **7** and **9**, formed from rough bar **5**. In particular, the width of these mechanical elements is far exaggerated with respect to their length. Moreover, top views of figures 6 to 10 have been hatched to clearly distinguish the different mechanical elements.

**[0044]** Rough bar **5** has front **51** and rear **52** walls, parallel upper and lower walls **53** and **54**, as well as parallel side walls **55** and **56**. Respective length  $L5$ , width  $W5$  and height  $H5$  of rough bar **5** are defined the same way as above length  $L1$ , width  $W1$  and height  $H1$  of cathode body **1**.

**[0045]** Length  $L5$  of rough bar is far superior to that  $L17$  of slot **17**, so that final cathode bar **3** will protrude outside slot **17**, above front wall **11**. The value of the difference  $(L5 - L17)$  implies the length of the protrusion of final cathode bar **3**. Typically, this difference  $(L5 - L17)$  is between 400 and 700 mm. Side walls **55** and **56** show slopes, the angle of which is similar to that  $\alpha S$  of the side walls of the slot. The lengths of slotted parts of these side walls are referred  $L6$  and  $L6'$  on figure 4. Both  $L6$  and  $L6'$  are superior to the length  $L17$  of the cathode slot. Typically, the difference  $(L6 - L17)$  or  $(L6' - L17)$  is between 150 and 200 mm.

**[0046]** In addition, width  $W5$  of rough bar **5** is slightly superior to that  $W17$  of slot **17**, which enables a steady jamming of final cathode bar **3** in the slot **17**. Typically, the difference  $(W5 - W17)$  is between 5 to 10 mm.

**[0047]** Finally, height  $H5$  of rough bar **5** is equal or slightly inferior to depth  $D17$  of cathode slot, so as to prevent final cathode bar from protruding outside the slot **17**, above lower wall **14**. Typically, the difference  $(D17 - H5)$  is between 0

and 4 mm.

**[0048]** The insertion process then implies cutting rough bar 5, so as to form two cathode bar elements, or so called bar elements 7 and 9. Rough bar 5 is cut along a cutting line referenced CL, shown on figure 4. This line CL forms an angle, noted  $\alpha_c$ , with the main longitudinal axis A5 of rough bar 5. By way of example, this angle  $\alpha_c$  is between 1° and 4°, typically of about 2°. The cutting operation can be carried out by water jet cutting following a machining of the two surfaces, since the cut cannot be straight and the roughness will not be good enough to get a good contact between the two parts. Another way is cutting the two parts directly by machining using a circular cutting blade, typically of 3 to 6 mm of thickness. The latest way is preferred, since the cutting surface will present a good roughness and machining the cut surfaces will therefore not be necessary.

**[0049]** As shown on figure 5, first bar element 7 has a triangular shape. It has a front wall 71, a main side wall 73, as well as a tapered wall 77. It has neither a rear wall, nor a second side wall, since wall 77 directly connects both walls 71 and 73. Side wall 73 shows a slope, which corresponds to that of side wall 55 of rough bar 5.

**[0050]** Let us note length L7 and width W7 of said bar element 7. Width W7 is inferior to that W5 of rough bar 5, and is also slightly inferior to that W17 of the slot, so as to enable an insertion without jamming of said bar element 7 into slot 17. Typically, the difference (W17 - W7) is between 10 and 40 mm. Length L7 is far inferior to that L5 of rough bar 5, but is slightly superior to that L17 of slot, so as to enable a protrusion of said bar element 7 outside slot 17. Typically, the difference (L7 - L17) is between 20 and 100 mm. Finally, height H7 of bar element 7 is equal to that H5 of rough bar 5.

**[0051]** As also shown on figure 5, second bar element 9 has a shape which is different from a triangle. It has a short front wall 91, a long rear wall 92, a main side wall 93, a short side wall 94, as well as a tapered wall 97. Side wall 93 shows a slope, which corresponds to that of side wall 56 of rough bar 5.

**[0052]** This second bar element can therefore be divided into two parts, namely a handling part 9A with constant width, as well as an insertion part or tip 9B, with a tapered shape. Tip 9B is ended by a shoulder 9C, formed adjacent front wall 91, which eases the jamming of bars 7 and 9 into the slot. The respective dimensions of above defined walls and parts of bar element 9 are as follows:

- W92 (width of 92) = W5;
- L93 (length of 93) = L5;
- L94 (length of 94) = L5 - L7;
- H9 (height of 9) = H5.

**[0053]** According to next step of the process of the invention, shown on figure 6, first bar element 7 is inserted into slot 17. It is to be noted that this step is carried out with a cathode block upside down. In other words, during said insertion, access to slot 17 is permitted from the end of the cathode block groove, whereas so called lower wall of cathode body is in an upper position. Once inserted in the slot, bar element 7 rests by gravity against wall 173 of this slot. Since W7 is inferior to W17 of slot, this insertion can be carried out easily, without jamming of said bar element 7 into slot 17. Bar element 7 is positioned in the slot, so that its front wall 71 is close to the end of the slot, and its main side wall 73 is adjacent side wall 172 of the slot. End of the slot is defined by the transition between rectilinear side walls 171, 172 and rounded wall 174.

**[0054]** Then an operator handles second bar element 9, at the handling part 9A thereof. The operator pushes bar element 9 forward, i.e. towards the end of the slot, along arrow F9. At an intermediate stage of this forward pushing motion, the facing tapered walls 77 and 97 come into mutual contact (see figure 7). Since first bar element 7 is axially jammed by the end of the slot, second bar element 9 slides with respect to bar element 7 along arrow S9, so that the global motion of bar element 9 now comprises a tapered component. Due to this sliding motion, both bar elements 7 and 9 are urged against the walls of the slot 17. More precisely, main side wall 73 of first bar element 7 is urged against facing side wall 172 of slot 17, along arrow F73, whereas main side wall 93 of second bar element 9 is urged against facing opposite side wall 171 of slot 17, along arrow F93. In the above paragraph, insertion operation has been described manually. However, an automatic operation may be considered, with any appropriate tool.

**[0055]** Once bar elements 7 and 9 are jammed in slot 17, their tapered walls 77 and 97 are in mutual contact along nearly their whole length, so as to form a tapered contact line 37 (see figure 8). The length L37 of contact line is slightly inferior to both L77 and L97, since one short end region of each wall 77 or 97 does not contact other wall 97 or 77. The required adjustment of the bar inside the slot can be achieved by moving the bar element 9 with respect to the first bar element 7 already installed. When the protrusion of the bars outside the cathode L3C is adjusted at the required value, then the two bar elements 7 and 9 are advantageously mutually attached, in particular with a permanent fixation means. In this respect, welding is preferred, such as copper to copper type using MIG welding machines, known as such.

**[0056]** Referring to figure 8, at least one and, preferably several welding lines are provided along the above defined contact line 37. In the illustrated example, four welding lines 21 to 24 are provided. Let us note L21 to L24 the length of each of these lines, as well as Lw the so called welding length, which corresponds to the sum (L21 + L22 + L23 + L24) of the lengths of these lines. Each of L21 to L24 is typically between 50 and 100 mm, whereas the welding ratio, i.e (Lw

/  $L_{37}$ ) is between 10 and 40 %.

**[0057]** After above described welding step, bar elements 7 and 9 are mutually attached and form final cathode bar 3 shown on figure 8. Said global cathode bar has front **31** and rear **32** walls, as well as side walls **33** and **34**. Said figure 8 also illustrates above described tapered line **37**, separating walls **77** and **97** of bar elements **7** and **9**. First, rear wall **32** and side wall **34** are respectively constituted by those **92** and **94** of bar element **9**.

**[0058]** Moreover, as shown by detail 9, front wall **31** is formed by front wall **71** and front wall **91**, as well as by a linking portion **77'** of tapered wall **77**. Front wall **91** is remote from end of slot, whereas front wall **71** is positioned against said end, as explained above. In addition, as shown by detail **10**, side wall **33** is formed by side wall **73** and side wall **93**, as well as by a linking portion **97'** of tapered wall **97**. Side wall **93** protrudes laterally, with respect to side wall **73**.

**[0059]** Cathode can be decomposed into two portions, i.e. a first portion **3A** the width of which  $W_{3A}$  is equal to that  $W_{17}$  of slot **17**, as well as a second portion **3B** the width of which  $W_{3B}$  is equal to that  $W_5$  of rough bar **5**. This cathode defines a protrusion **3C**, which extends outside slot **17**. This protrusion, which is formed by portion **3B** as well as by a fraction of portion **3A**, has a typical length  $L_{3C}$  between 400 and 700 mm.

**[0060]** Once cathode bars 3 and 3' are positioned and jammed in their respective slot 17 and 17', the whole cathode assembly is turned upside down, so as to be in its final position of figure 1. Due to the slopes of side walls of both the slots and the bar elements, as above described in reference to figure 11, cathode bars cannot escape from their slots due to gravity, so that they are firmly retained therein.

**[0061]** In the above described embodiment, each side wall of cathode bar **3** directly contacts facing side walls of the slot **17**, i.e. without any intercalary material. The invention also encompasses alternative embodiments, wherein side walls of cathode bar indirectly contacts facing side walls of the slot. In this respect, a thin sheet of an intercalary material is interposed between said facing walls of slot and cathode bar.

**[0062]** According to an advantageous embodiment of the invention, said intercalary material is a graphite foil, inserted between said facing side walls. This graphite foil is typically placed against the side walls of the slot, before insertion of bar elements. A further intercalary material, in particular at least one further graphite foil, may also be interposed between upper wall **173** of said slot and facing walls of the bar elements **7** and **9**. As a variant, one single intercalary graphite foil may recover both side walls and upper wall of the slot. The adjustment will be set, so that no substantial gap or space is left between bar elements, graphite foil and cathode body. Said graphite foil can be a flexible graphite foil of compressed expanded graphite. Said foil is available from various suppliers under different trademarks, such as POPYEX® by MERSEN. The density of the foil is typically 0.7 and it may have 0.5 mm of thickness. In addition, graphite material is compressible to cope with the thermal expansion of bar elements.

### Example

**[0063]** An industrial trial was carried out using an electrolysis cell of the so-called D18 technology; this cell was part of an existing D18 potline. The D18 technology has been described in several papers such as: "Update on the development of D18 cell technology at DUBAL" (D. Whitfield et al., Light Metals 2012, p. 727-731); "D18+: potline modernization at DUBAL" (S. Akhmetov et al., Light Metals 2013, p. 561-656); "From D18 to D18+: Progression of DUBAL's original potlines" (D. Whitfield et al., Light Metals 2015, p. 499-504). The selected electrolysis cell was provided with new cathode blocks; seventeen cathode assemblies were used, and the assembly n° 2, 7, 11, and 16 had copper cathode bars according to the invention, whereas the other ones were provided with conventional steel cathode bars. Cathode assemblies n° 2 and 7 had a sheet of graphite foil between the cathode bar and the cathode block, whereas assemblies n° 11 and 16 had a direct contact between the copper cathode bar and the cathode material. All cathode bars were half bars. Contact tabs were made from copper.

**[0064]** The cell was started up according to conventional practice and run for about 3.5 months under production conditions (211 kA). Its overall performance was slightly better than that of the other cells with 100 % conventional cathode assemblies: as an example, compared to conventional D18 cells of the same potline, the average net voltage was slightly lower (60 mV), the aluminium purity was identical (99.873 %), aluminium production was slightly higher, specific energy consumption was lower (approximately 300 kW/h per ton), bath height and metal height as well as bath temperature (958 °C) were comparable, cell stability was comparable, base resistance set point and cathode voltage drop were slightly lower (approximately 20 mV).

**[0065]** It was found that the cathode assemblies with copper bars according to the invention were pulling about 40 % more current than cathode assemblies with steel bars in the same cell. This demonstrates that a significant gain can be obtained by constructing a pot equipped with all cathodes having full copper bars. At the beginning of the operations, a small difference was observed between copper cathode bars in direct contact with the cathode block and copper cathodes bars with an intercalary graphite foil, giving the benefit to the latest.

**[0066]** The cell was then autopsied; the copper bars could be easily cut out, and it was found that for each half bar the two bar elements were firmly welded together at their tapered interface and did not separate upon removal. This shows that the electrical contact at the tapered interface between the two bar elements was excellent. No melting of the

copper bar was observed, no significant visual change was observed. Slight remains of graphite foil were visible on the collector bar side for the two bars that had been in contact with graphite foil. The copper could be fully recovered for recycling.

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## Claims

1. A cathode assembly (C) suitable for a Hall-Heroult electrolysis cell, comprising
  - a cathode body (1) made of a carbonaceous material, said cathode body being provided with at least one slot (17, 17'), said slot being provided with side walls (171, 172, 171', 172') parallel to a longitudinal direction (A17, A17') of said slot;
  - at least one cathode collector bar (3, 3') made of a metallic material, said cathode bar being provided with side walls (33, 34), which are in contact with said side walls of said slot;

**characterized in that** said cathode bar comprises two bar elements (7, 9), each bar element being provided with a main side wall (73, 93) which is in contact with a respective side wall (171, 172) of said slot, as well as a tapered wall (77, 97), the two tapered walls of said bar elements forming a contact line (37) between these two bar elements.
2. A cathode assembly according to claim 1, **characterized in that** it is provided with fixation means, in particular permanent fixation means (21-24) such as welding means, between said tapered walls (77, 97) of said bar elements (7, 9).
3. A cathode assembly according to claim 2, **characterized in that** said welding means comprise at least one welding line, in particular several welding lines (21-24), extending over at least part of said contact line (37).
4. A cathode assembly according to any above claim, **characterized in that** one first bar element (7) has a triangular shape and comprises a front wall (71), said main side wall (73) and said tapered wall (77).
5. A cathode assembly according to any above claim, **characterized in that** one second bar element (9) comprises a further side wall (94), opposite to main side wall (93), said further side wall protruding with respect to main side wall (73) of first bar element (7), along a transversal direction of said slot.
6. A cathode assembly according to any above claim, **characterized in that** said cathode bar (3) has two portions, i.e. a first portion (3A) the width of which (W3A) is equal to that of slot (17), as well as a second portion (3B) the width of which (W3B) is superior to that of slot.
7. A cathode assembly according to claim 6, **characterized in that** said cathode bar has a protrusion (3C) which extends outside said slot (17).
8. A cathode assembly according to claim 7, **characterized in that** said protrusion (3C) is formed by said second portion (3C) and by a fraction of said first portion (3A).
9. A cathode assembly according to any of claims 1 to 8, **characterized in that** said main side wall of each bar element indirectly contacts a respective side wall of said slot, an intercalary material, in particular at least one graphite foil, being interposed between said main side wall and said respective side wall of said slot, and optionally a further intercalary material, in particular at least one further graphite foil, is interposed between upper wall (173) of said slot and facing walls of bar elements (7, 9).
10. A cathode assembly according to any above claim, **characterized in that** said side walls (171, 171', 172, 172') of said slot and said side walls (73, 93) of said bar elements (7, 9) show a slope, the value ( $\alpha$ s) of which is in particular of 10 degrees, so as to retain said bar elements in the inner volume of said slot.
11. A process for making a cathode assembly (C) according to any of above claims, comprising the steps of
  - a) providing a cathode body (1) made of a carbonaceous material;
  - b) providing at least one slot (17, 17') in said cathode body, said slot being provided with side walls (171, 171', 172, 172') parallel to a longitudinal direction of said slot;

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- c) providing at least two bar elements (7, 9) made of a metallic material, each bar element being provided with a main side wall (73, 93) and a tapered wall (77, 97),
- d) placing a first bar element (7) into the slot, with its main side wall (73) adjacent to facing first side wall (172) of the slot;
- 5 e) urging forward, along said longitudinal direction of said slot, second bar element (9), so as to urge main side wall (73) of said first bar element against facing first side wall (172) of the slot, so as to urge main side wall (93) of said second bar element (9) against facing opposite second side wall (171) of the slot, and so as to set into contact the two tapered walls (77, 97) of said bar elements, along a contact line (37).
- 10 **12.** A process according to claim 11, further comprising providing said side walls (171, 171', 172, 172') of said slot and said side walls (73, 93) of said bar elements (7, 9) with a slope, the value ( $\alpha$ s) of which is in particular of 10 degrees, so as to retain said bar elements in the inner volume of said slot.
- 15 **13.** A process according to any of claims 11 to 12, wherein said second bar element (9) is provided with a handling portion (9A), and wherein said second bar element is urged forward manually, by handling said handling portion.
- 14.** A process according to any of claims 11 to 13, wherein said bar elements are provided by cutting a rough bar (5) along a cutting line (CL), said cutting line being tapered with respect to main axis (A5) of said rough bar.
- 20 **15.** A process for making aluminium by the Hall-Heroult process, using an electrolytic cell provided with cathode assemblies according to any of claims 1 to 10.

#### Patentansprüche

- 25 **1.** Kathodenanordnung (C), die für eine Hall-Heroult-Elektrolysezelle geeignet ist, umfassend
- einen Kathodenkörper (1), der aus einem kohlenstoffhaltigen Material besteht, wobei der Kathodenkörper mit mindestens einem Schlitz (17, 17') versehen ist, wobei der Schlitz mit Seitenwänden (171, 172, 171', 172') versehen ist, die zu einer Längsrichtung (A17, A17') des Schlitzes parallel verlaufen;
  - 30 - mindestens eine Kathodenkollektorstange (3, 3'), die aus einem metallischen Material besteht, wobei die Kathodenstange mit Seitenwänden (33, 34) versehen ist, die sich mit den Seitenwänden des Schlitzes in Berührung befinden;
- 35 **dadurch gekennzeichnet, dass** die Kathodenstange zwei Stangenelemente (7, 9) umfasst, wobei jedes Stangenelement mit einer Hauptseitenwand (73, 93), die sich mit einer jeweiligen Seitenwand (171, 172) des Schlitzes in Berührung befindet, sowie einer schrägen Wand (77, 97) versehen ist, wobei die zwei schrägen Wände der Stangenelemente eine Berührungslinie (37) zwischen diesen zwei Stangenelementen bilden.
- 40 **2.** Kathodenanordnung nach Anspruch 1, **dadurch gekennzeichnet, dass** sie mit Befestigungsmitteln, insbesondere dauerhaften Befestigungsmitteln (21-24), wie etwa Verschweißungsmitteln, zwischen den schrägen Wänden (77, 97) der Stangenelemente (7, 9) versehen ist.
- 45 **3.** Kathodenanordnung nach Anspruch 2, **dadurch gekennzeichnet, dass** die Verschweißungsmittel mindestens eine Schweißnaht, insbesondere mehrere Schweißnähte (21-24) umfassen, die sich über mindestens einen Teil der Berührungslinie (37) erstrecken.
- 4.** Kathodenanordnung nach einem obigen Anspruch, **dadurch gekennzeichnet, dass** ein erstes Stangenelement (7) eine dreieckige Form aufweist und eine Vorderwand (71), die Hauptseitenwand (73) und die schräge Wand (77) umfasst.
- 50 **5.** Kathodenanordnung nach einem obigen Anspruch, **dadurch gekennzeichnet, dass** ein zweites Stangenelement (9) Hauptseitenwand (93) gegenüberliegend eine weitere Seitenwand (94) umfasst, wobei die weitere Seitenwand in Bezug auf Hauptseitenwand (73) des ersten Stangenelements (7) entlang einer Querrichtung des Schlitzes übersteht.
- 55 **6.** Kathodenanordnung nach einem obigen Anspruch, **dadurch gekennzeichnet, dass** die Kathodenstange (3) zwei Abschnitte aufweist, d. h. einen ersten Abschnitt (3A), dessen Breite (W3A) gleich der von Schlitz (17) ist, sowie

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einen zweiten Abschnitt (3B), dessen Breite (W3B) größer als die des Schlitzes ist.

7. Kathodenanordnung nach Anspruch 6, **dadurch gekennzeichnet, dass** die Kathodenstange einen Überstand (3C) aufweist, der sich außerhalb des Schlitzes (17) erstreckt.

8. Kathodenanordnung nach Anspruch 7, **dadurch gekennzeichnet, dass** der Überstand (3C) vom zweiten Abschnitt (3C) und von einem Bruchteil des ersten Abschnitts (3A) gebildet wird.

9. Kathodenanordnung nach einem der Ansprüche 1 bis 8, **dadurch gekennzeichnet, dass** die Hauptseitenwand jedes Stangenelements eine jeweilige Seitenwand des Schlitzes indirekt berührt, wobei ein Zwischenlagematerial, insbesondere mindestens eine Graphitfolie, zwischen der Hauptseitenwand und der jeweiligen Seitenwand des Schlitzes eingefügt ist, und gegebenenfalls ein weiteres Zwischenlagematerial, insbesondere mindestens eine weitere Graphitfolie, zwischen der oberen Wand (173) des Schlitzes und zugewandten Wänden der Stangenelemente (7, 9) eingefügt ist.

10. Kathodenanordnung nach einem obigen Anspruch, **dadurch gekennzeichnet, dass** die Seitenwände (171, 171', 172, 172') des Schlitzes und die Seitenwände (73, 93) der Stangenelemente (7, 9) eine Steigung aufweisen, deren Wert ( $\alpha$ s) insbesondere 10 Grad beträgt, um die Stangenelemente im Innenvolumen des Schlitzes zu halten.

11. Verfahren zur Herstellung einer Kathodenanordnung (C) nach einem der obigen Ansprüche, das die Schritte umfasst des

a) Bereitstellens eines Kathodenkörpers (1), der aus einem kohlenstoffhaltigen Material besteht;

b) Bereitstellens mindestens eines Schlitzes (17, 17') in dem Kathodenkörper, wobei der Schlitz mit Seitenwänden (171, 171', 172, 172') versehen ist, die zu einer Längsrichtung des Schlitzes parallel verlaufen;

c) Bereitstellens von mindestens zwei Stangenelementen (7, 9), die aus einem metallischen Material bestehen, wobei jedes Stangenelement mit einer Hauptseitenwand (73, 93) und einer schrägen Wand (77, 97) versehen ist, d) Anbringens eines ersten Stangenelements (7) im Schlitz, mit seiner Hauptseitenwand (73) an die zugewandte erste Seitenwand (172) des Schlitzes angrenzend;

e) Vordrücken des zweiten Stangenelements (9) entlang der Längsrichtung des Schlitzes, um Hauptseitenwand (73) des ersten Stangenelements an die zugewandte erste Seitenwand (172) des Schlitzes zu drücken, um Hauptseitenwand (93) des zweiten Stangenelements (9) an die zugewandte, gegenüberliegende zweite Seitenwand (171) des Schlitzes zu drücken, und um die zwei schrägen Wände (77, 97) der Stangenelemente entlang einer Berührungslinie (37) in Berührung zu bringen.

12. Verfahren nach Anspruch 11, das weiter das Versehen der Seitenwände (171, 171', 172, 172') des Schlitzes und der Seitenwände (73, 93) der Stangenelemente (7, 9) mit einer Steigung umfasst, deren Wert ( $\alpha$ s) insbesondere 10 Grad beträgt, um die Stangenelemente im Innenvolumen des Schlitzes zu halten.

13. Verfahren nach einem der Ansprüche 11 bis 12, wobei das zweite Stangenelement (9) mit einem Handhabungsabschnitt (9A) versehen ist, und wobei das zweite Stangenelement manuell, durch Handhaben des Handhabungsabschnitts, vorgedrückt wird.

14. Verfahren nach einem der Ansprüche 11 bis 13, wobei die Stangenelemente durch Schneiden einer Rohstange (5) entlang einer Schnittlinie (CL) bereitgestellt werden, wobei die Schnittlinie in Bezug auf Hauptachse (A5) der Rohstange schräg verläuft.

15. Verfahren zur Herstellung von Aluminium nach dem Hall-Héroult-Prozess unter Verwendung einer elektrolytischen Zelle, die mit Kathodenanordnungen nach einem der Ansprüche 1 bis 10 versehen ist.

### Revendications

1. Ensemble cathode (C) approprié pour une cellule d'électrolyse de Hall-Héroult, comprenant :

- un corps de cathode (1) fait d'un matériau carboné, ledit corps de cathode étant pourvu d'au moins une fente (17, 17'), ladite fente étant pourvue de parois latérales (171, 172, 171', 172') parallèles à une direction longitudinale (A17, A17') de ladite fente ;

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- au moins une barre collectrice de cathode (3, 3') faite d'un matériau métallique, ladite barre de cathode étant pourvue de parois latérales (33, 34), qui sont en contact avec lesdites parois latérales de ladite fente ;

5 **caractérisé en ce que** ladite barre de cathode comprend deux éléments de barre (7, 9), chaque élément de barre étant pourvu d'une paroi latérale principale (73, 93) qui est en contact avec une paroi latérale respective (171, 172) de ladite fente, ainsi que d'une paroi en biseau (77, 97), les deux parois en biseau desdits éléments de barre formant une ligne de contact (37) entre ces deux éléments de barre.

10 2. Ensemble cathode selon la revendication 1, **caractérisé en ce qu'**il est pourvu de moyens de fixation, en particulier de moyens de fixation permanents (21 à 24) tels que des moyens de soudure, entre lesdites parois en biseau (77, 97) desdits éléments de barre (7, 9).

15 3. Ensemble cathode selon la revendication 2, **caractérisé en ce que** lesdits moyens de soudure comprennent au moins une ligne de soudure, en particulier plusieurs lignes de soudure (21 à 24), s'étendant sur au moins une partie de ladite ligne de contact (37).

20 4. Ensemble cathode selon une quelconque revendication précédente, **caractérisé en ce qu'**un premier élément de barre (7) présente une forme triangulaire et comprend une paroi avant (71), ladite paroi latérale principale (73) et ladite paroi en biseau (77).

25 5. Ensemble cathode selon une quelconque revendication précédente, **caractérisé en ce qu'**un second élément de barre (9) comprend une paroi latérale (94) supplémentaire, opposée à la paroi latérale principale (93), ladite paroi latérale supplémentaire faisant saillie par rapport à la paroi latérale principale (73) du premier élément de barre (7), le long d'une direction transversale de ladite fente.

30 6. Ensemble cathode selon une quelconque revendication précédente, **caractérisé en ce que** ladite barre de cathode (3) présente deux parties, c'est-à-dire une première partie (3A) dont la largeur (W3A) est égale à celle de la fente (17), ainsi qu'une seconde partie (3B) dont la largeur (W3B) est supérieure à celle de la fente.

35 7. Ensemble cathode selon la revendication 6, **caractérisé en ce que** ladite barre de cathode présente une saillie (3C) qui s'étend à l'extérieur de ladite fente (17).

40 8. Ensemble cathode selon les revendications 7, **caractérisé en ce que** ladite saillie (3C) est formée par ladite seconde partie (3C) et par une fraction de ladite première partie (3A).

45 9. Ensemble cathode selon l'une quelconque des revendications 1 à 8, **caractérisé en ce que** ladite paroi latérale principale de chaque élément de barre est indirectement en contact avec une paroi latérale respective de ladite fente, un matériau intercalaire, en particulier au moins une feuille de graphite, étant intercalé entre ladite paroi latérale principale et ladite paroi latérale respective de ladite fente, et facultativement un matériau intercalaire supplémentaire, en particulier au moins une feuille de graphite supplémentaire, est intercalé entre une paroi supérieure (173) de ladite fente et des parois en regard d'éléments de barre (7, 9).

50 10. Ensemble cathode selon une quelconque revendication précédente, **caractérisé en ce que** lesdites parois latérales (171, 171', 172, 172') de ladite fente et lesdites parois latérales (73, 93) desdits éléments de barre (7, 9) présentent une pente, dont la valeur ( $\alpha$ s) est en particulier de 10 degrés, de manière à retenir lesdits éléments de barre dans le volume interne de ladite fente.

55 11. Procédé de fabrication d'un ensemble cathode (C) selon l'une quelconque des revendications précédentes, comprenant les étapes consistant à

- a) fournir un corps de cathode (1) fait d'un matériau carboné ;
- b) fournir au moins une fente (17, 17') dans ledit corps de cathode, ladite fente étant pourvue de parois latérales (171, 171', 172, 172') parallèles à une direction longitudinale de ladite fente ;
- c) fournir au moins deux éléments de barre (7, 9) faits d'un matériau métallique, chaque élément de barre étant pourvu d'une paroi latérale principale (73, 93) et d'une paroi en biseau (77, 97),
- d) placer un premier élément de barre (7) dans la fente, avec sa paroi latérale principale (73) adjacente à la première paroi latérale (172) en regard de la fente ;
- e) pousser vers l'avant, le long de ladite direction longitudinale de ladite fente, le second élément de barre (9),

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de manière à pousser la paroi latérale principale (73) dudit premier élément de barre contre la première paroi latérale (172) en regard de la fente, de manière à pousser la paroi latérale principale (93) dudit second élément de barre (9) contre la seconde paroi latérale (171) en regard opposée de la fente, et de manière à mettre en contact les deux parois en biseau (77, 97) desdits éléments de barre, le long d'une ligne de contact (37).

- 5
- 12.** Procédé selon la revendication 11, comprenant en outre la fourniture auxdites parois latérales (171, 171', 172, 172') de ladite fente et auxdites parois latérales (73, 93) desdits éléments de barre (7, 9) d'une pente, dont la valeur ( $\alpha$ s) est en particulier de 10 degrés, de manière à retenir lesdits éléments de barre dans le volume interne de ladite fente.
- 10
- 13.** Procédé selon l'une quelconque des revendications 11 à 12, dans lequel le second élément de barre (9) est pourvu d'une partie de manipulation (9A), et dans lequel ledit second élément de barre est poussé vers l'avant manuellement, en manipulant ladite partie de manipulation.
- 15
- 14.** Procédé selon l'une quelconque des revendications 11 à 13, dans lequel lesdits éléments de barre sont fournis en coupant une barre brute (5) le long d'une ligne de coupe (CL), ladite ligne de coupe étant effilée par rapport à un axe principal (A5) de ladite barre brute.
- 20
- 15.** Procédé de fabrication d'aluminium par le procédé Hall-Héroult, utilisant une cellule électrolytique pourvue d'ensembles cathode selon l'une quelconque des revendications 1 à 10.

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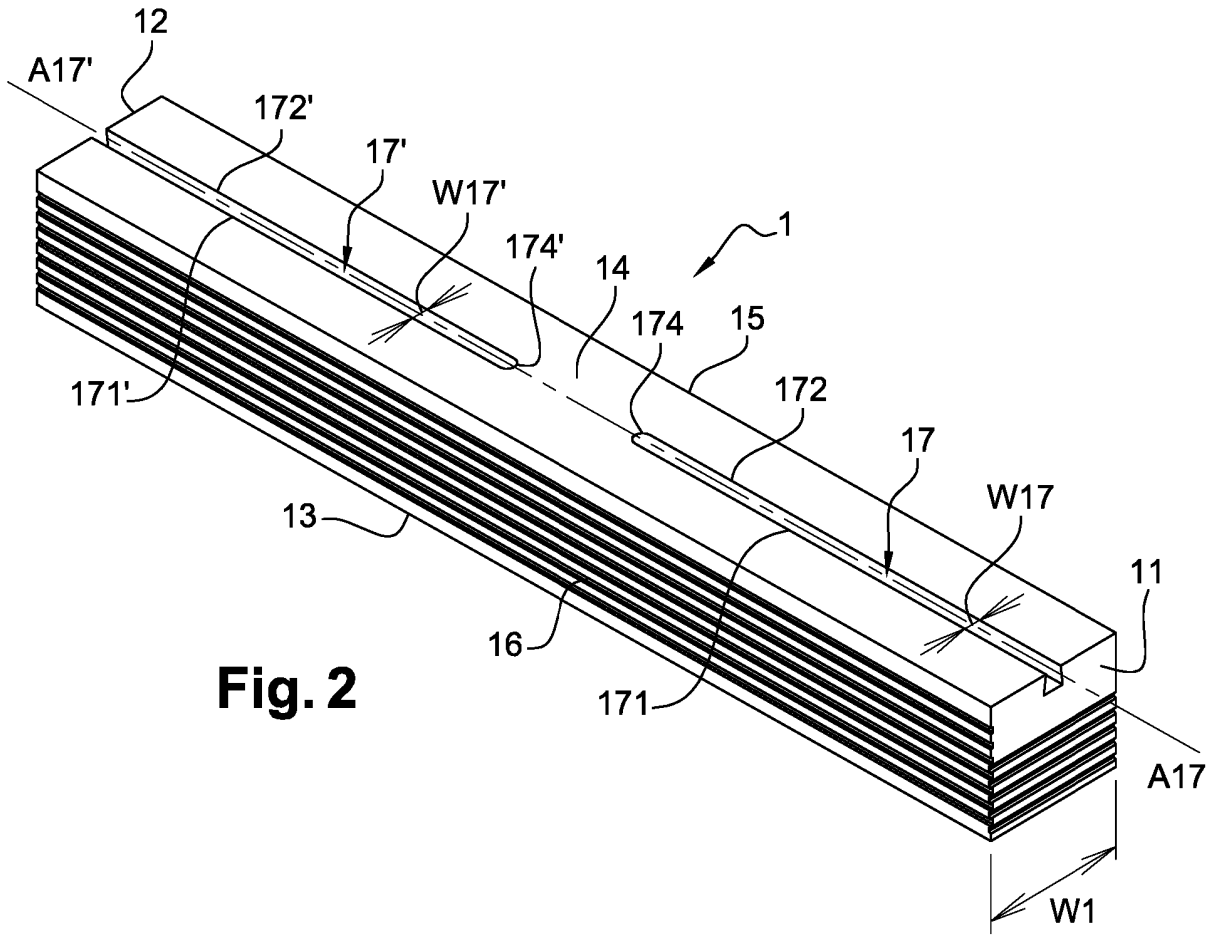
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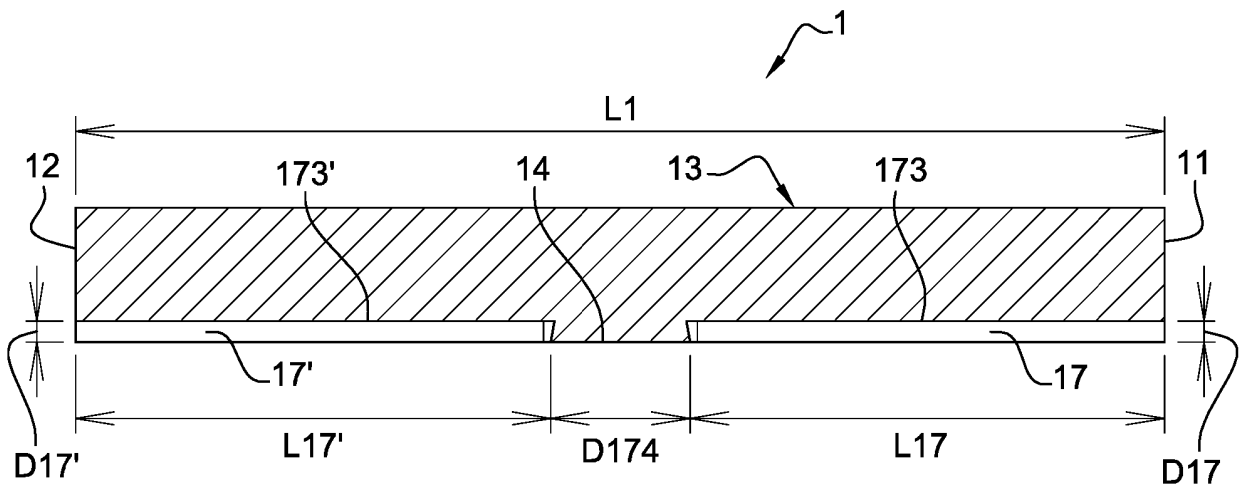
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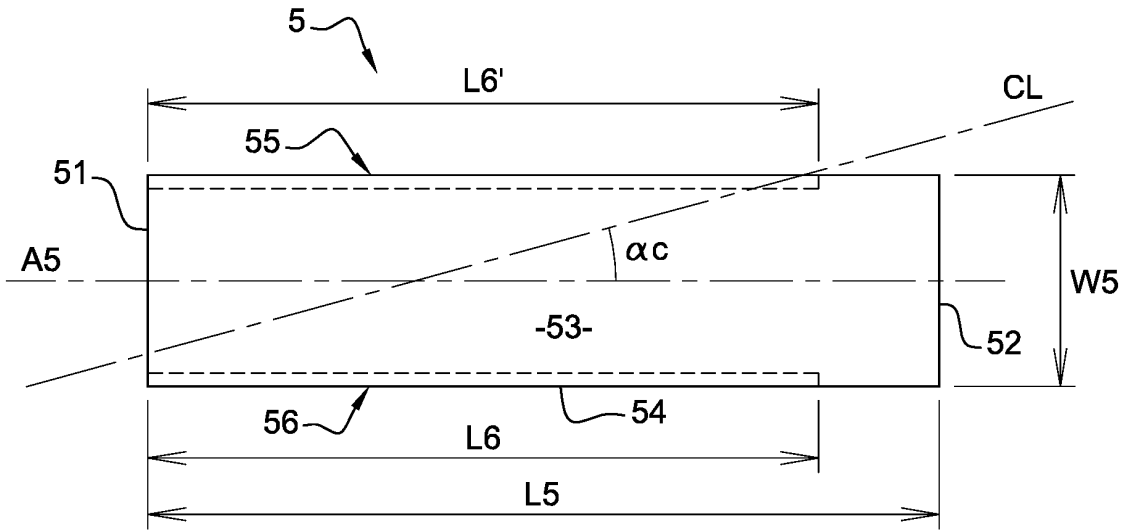




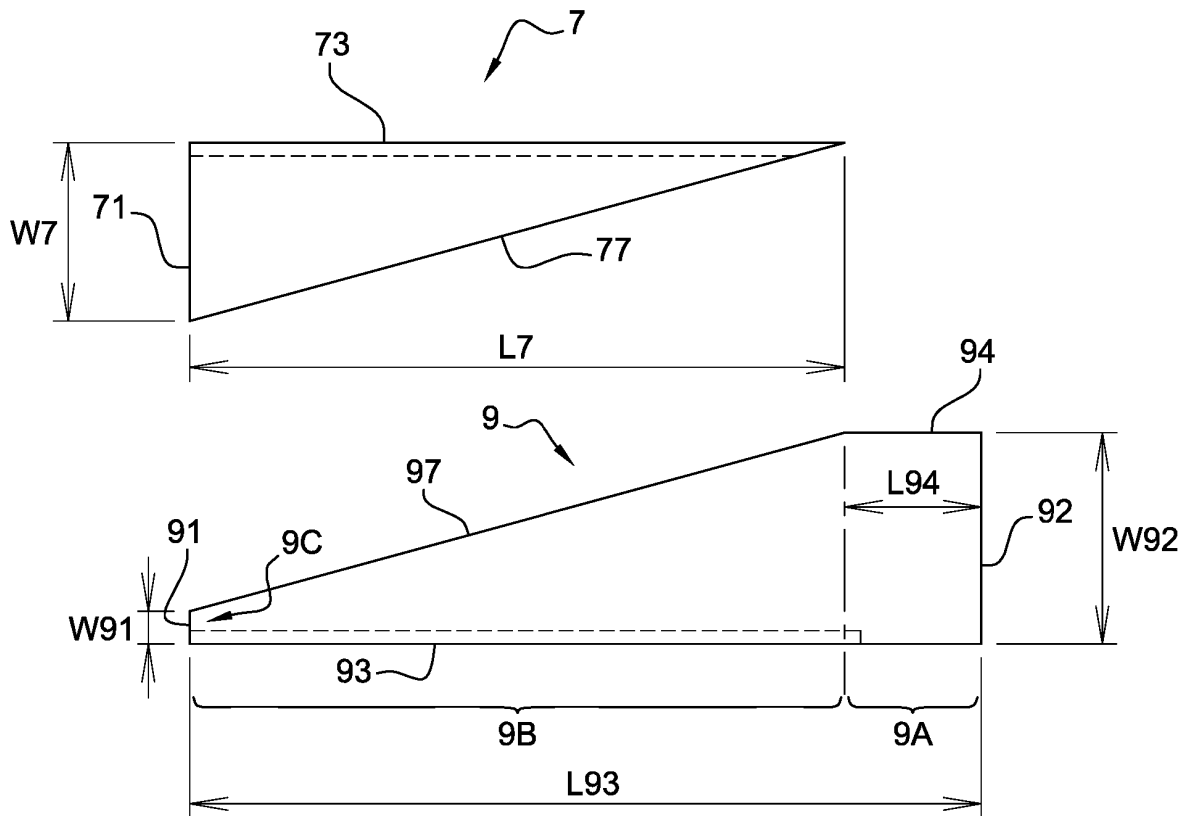
**Fig. 2**



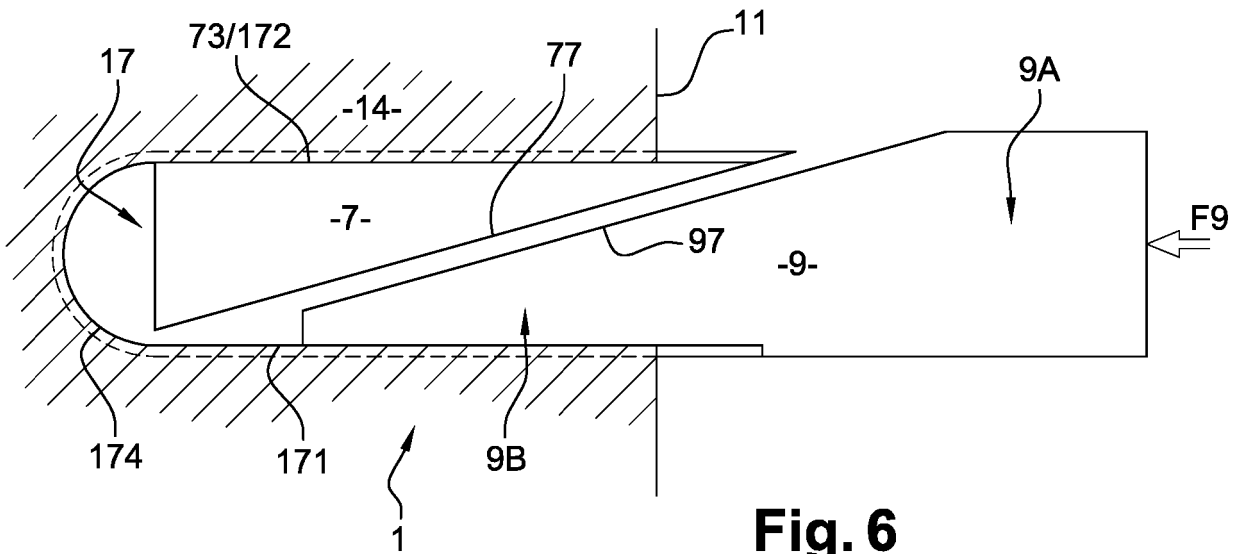
**Fig. 3**



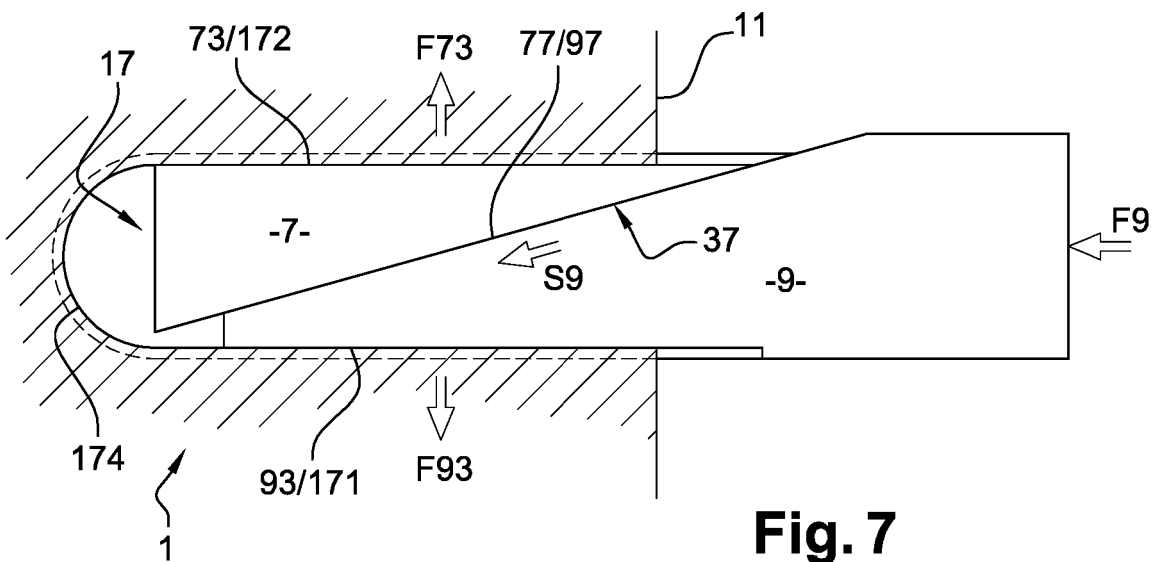
**Fig. 4**



**Fig. 5**



**Fig. 6**



**Fig. 7**



**REFERENCES CITED IN THE DESCRIPTION**

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**Patent documents cited in the description**

- GB 663763 A [0004]
- US 6294067 B [0005]
- EP 1845174 A [0005]
- US 4795540 A [0005]
- US 20040011661 A [0005]
- CN 105671592 [0005]
- SU 1260412 [0005]
- GB 1065080 A [0005]
- CN 2892888 [0005]
- US 5976333 A [0005]
- WO 2016079605 A [0007]

**Non-patent literature cited in the description**

- **M. SØRLIE ; H. ØYE.** Cathodes in Aluminium Electrolysis. 2010 [0004]
- **D. WHITFIELD et al.** Update on the development of D18 cell technology at DUBAL. *Light Metals*, 2012, 727-731 [0063]
- **S. AKHMETOV et al.** D18+: potline modernization at DUBAL. *Light Metals*, 2013, 561-656 [0063]
- **D. WHITFIELD et al.** From D18 to D18+: Progression of DUBAL's original potlines. *Light Metals*, 2015, 499-504 [0063]