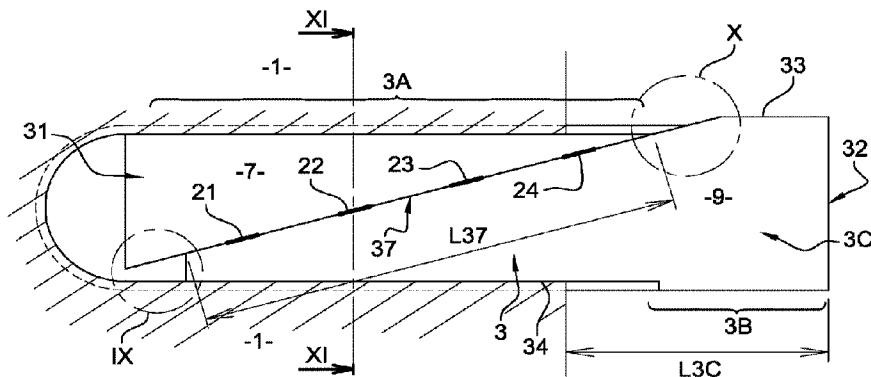




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(57) **Abrégé/Abstract:**

This cathode assembly(C) comprises: -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. According to the invention, 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.

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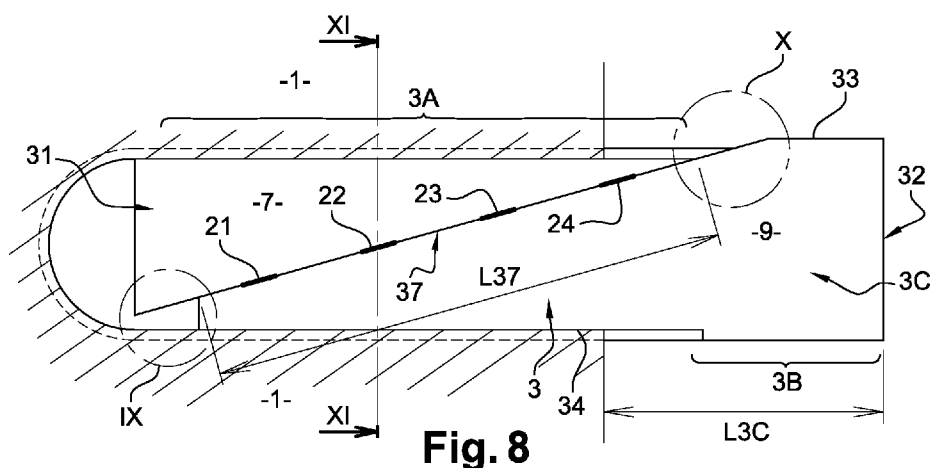
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(57) **Abstract:** This cathode assembly(C) comprises: -a cathode body(1) made of a carbonaceous material, said cathode body being provided with at least one slot (17, 17'), said slot being provided with side walls (171, 172, 171', 172') parallel to 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. According to the invention, 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.



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Cathode assembly with metallic collector bar for electrolytic cell suitable for the Hall-Héroult process

Technical field of the invention

5 The invention relates to the field of fused salt electrolysis using the Hall-Héroult 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

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 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.

30

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 several hundreds) of pots (such a series being also called a "potline"); within each series DC currents flow from one cell to the

35

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
5 500 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.

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
10 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
15 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
20 bar and the carbon body, as described in GB 663 763 (assigned to Compagnie de Produits Chimiques et Electrométallurgiques Alais, Froges & Camargue).

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
25 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.

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
30 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
35 expansion. As a consequence, a well-defined allowance for thermal expansion must be provided when machining the groove; otherwise strains and stresses caused by the expanding copper bar may lead to cracks in the carbon material of the cathode block. If no glue is used for accommodating dimensional tolerances, a very precise machining of the

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.

Usually, large carbon products such as cathodes for use in Hall-Héroult cells are machined with a tolerance of ± 2 mm; a tolerance of ± 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.

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

A first object of the invention is a cathode assembly suitable for a Hall-Héroult 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.

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.

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.

5

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.

10

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.

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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.

20

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.

25

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

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.

30

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.

35

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

Another object of the present invention is a process for making a cathode assembly as
5 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
10 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
15 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.

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

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
25 said slot.

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.

30 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.

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

Another object of the present invention is an electrolytic cell suitable for the Hall-Héroult 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
5 and the liquid metal resulting from the Hall-Héroult 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,
10 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
15 assembly as described above.

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

20

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

25 **Figures**

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.

- 30 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
35 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.

10

The following reference signs are used on the figures:

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'
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
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	α s	Angle of slotted bar
α 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
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
3C	Protrusion of 3	77',97'	Linking portion of 77,97
D17,D17'	Depth of 17, 17'	H1	Height of 1
LX	Length of element X : L1, L17, L17', L5, L7, L93, L94, L37, L3C'		
WX	Width of element X : W1, W5, W17, W17', W7, W91, W92		

Detailed description

15 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.

20

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**.
5 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.

10 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.

15

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 assemblies **C**, each of which bears at least one cathode bar **3, 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. 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
20 "cathode bar".
25

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

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**
35 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.

5 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.

10 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
 15 (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.

By way of example, width $W17$ or $W17'$ (see figure 2) of each slot **17**, **17'**, i.e. the distance
 20 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 α 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
 25 the inner volume of the slot, when turning over the cathode assemblies. For sake of clarity, the value of α is exaggerated on this figure 11.

By way of example, depth $D17$ or $D17'$ of each slot **17**, **17'** (see figure 3), i.e. the distance
 30 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'.

35

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.

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.

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**.

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 αS 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.

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.

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.

5 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 α_c , with the main longitudinal axis A5 of rough bar **5**. By way of example, this angle α_c is between 1° and 4° , typically of about 2° . The cutting operation can be carried out by water jet cutting
 10 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.

15

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**.

20

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
 25 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**.

As also shown on figure 5, second bar element **9** has a shape which is different from a
 30 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**.

This second bar element can therefore be divided into two parts, namely a handling part
 35 **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:

- W_{92} (width of **92**) = W_5 ;
- L_{93} (length of **93**) = L_5 ;
- 5 - L_{94} (length of **94**) = $L_5 - L_7$;
- H_9 (height of **9**) = H_5 .

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 W_7 is inferior to W_{17} 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**.

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.

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 L_{37} of contact line is slightly inferior to both L_{77} and L_{97} , 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
5 welding machines, known as such.

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 L_{21} to L_{24} the length of each of these lines, as well as L_w the
10 so called welding length, which corresponds to the sum ($L_{21} + L_{22} + L_{23} + L_{24}$) of the lengths of these lines. Each of L_{21} to L_{24} is typically between 50 and 100 mm, whereas the welding ratio, i.e (L_w / L_{37}) is between 10 and 40 %.

After above described welding step, bar elements 7 and 9 are mutually attached and form
15 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.

20 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
25 side wall 73.

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
30 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.

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
35 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.

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.

10 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
15 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 PAPYEX® by MERSEN. The density of the foil is typically
20 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

25 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
30 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
35 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.

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
5 (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).

10

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
15 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.

The cell was then autopsied; the copper bars could be easily cut out, and it was found that
20 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
25 graphite foil. The copper could be fully recovered for recycling.

CLAIMS

1. A cathode assembly suitable for a Hall-Héroult 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;wherein 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 respective tapered wall, the respective tapered walls of said two bar elements forming a contact line between the two bar elements.
2. A cathode assembly according to claim 1, further comprising fixation means between said respective tapered walls of said two bar elements.
3. A cathode assembly according to claim 2, wherein said fixation means comprise welding means.
4. A cathode assembly according to claim 3, wherein said welding means comprise at least one welding line, extending over at least part of said contact line.
5. A cathode assembly according to any one of claims 1 to 4, wherein with the at least one slot comprises at least one first and one second slots, each one of the first and second slots being provided with a blind wall defining a longitudinal end of said slot, each one of the first and second slots receiving a respective cathode bar.
6. A cathode assembly according to claim 5, wherein said cathode bar is jammed against said longitudinal end of a respective one of the first and second slots.
7. A cathode assembly according to any one of claims 1 to 6, wherein a first one of the two bar elements has a triangular shape and comprises a first front wall, said main side wall and said tapered wall.
8. A cathode assembly according to any one of claims 1 to 7, wherein a second one of the two bar elements comprises a further side wall, opposite to the main side wall, said further side wall protruding with respect to the main side wall of the first one of the two bar elements, along a transversal direction of said slot.

9. A cathode assembly according to claim 7, wherein said first front wall of the first one of the two bar elements is positioned against longitudinal end of said slot, and said second bar element comprises a second front wall, a length of which is far inferior to that of the first front wall of the first one of the two bar elements, the second front wall of the second one of the two bar elements being remote from the longitudinal end of said slot.

10. A cathode assembly according to any one of claims 1 to 9, wherein said cathode bar has two portions, a first portion a width of which is equal to that of slot, as well as a second portion a width of which is superior to that of slot.

11. A cathode assembly according to claim 10, wherein said cathode bar has a protrusion which extends outside said slot.

12. A cathode assembly according to claim 10 or 11, wherein said protrusion is formed by said second portion and by a fraction of said first portion.

13. A cathode assembly according to any one of claims 1 to 12, wherein said main side wall of each bar element protrudes outside said slot.

14. A cathode assembly according to any one of claims 1 to 13, wherein said main side wall of each bar element directly contacts a respective side wall of said slot.

15. A cathode assembly according to any one of claims 1 to 13, wherein said main side wall of each bar element indirectly contacts a respective side wall of said slot, an intercalary material being interposed between said main side wall and said respective side wall of said slot.

16. A cathode assembly according to claim 15, wherein a further intercalary material is interposed between upper wall of said slot and facing walls of bar elements.

17. A cathode assembly according to any one of claims 1 to 16, wherein said side walls of said slot and said side walls of said bar elements show a slope, so as to retain said bar elements in an inner volume of said slot.

18. A cathode assembly according to any one of claims 1 to 17, wherein said cathode bar is made of copper.

19. A cathode assembly according to any one of claims 1 to 17, wherein said cathode bar is made of steel.

20. A process for making a cathode assembly according to any one of claims 1 to 19, 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 one of the at least two bar elements being provided with a main side wall and a tapered wall,
- d) placing a first one of the at least two bar elements into the slot, with the main side wall adjacent to facing a first one of the side walls of the slot;
- e) urging forward, substantially along said longitudinal direction of said slot, a second one of the at least two bar elements, so as to urge the main side wall of said first one of the at least two bar elements against facing the first one of the side walls of the slot, so as to urge the main side wall of said second one of the at least two bar elements against facing opposite the second one of the side walls of the slot, and so as to set into contact the two tapered walls of said at least two bar elements, along a contact line.

21. A process according to claim 20, wherein said urging forward said second one of the of the at least two bar elements also provokes jamming of said first one of the at least two bar elements against one longitudinal end of said slot.

22. A process according to claim 20 or 21, further comprising providing said side walls of said slot and said side walls of said at least two bar elements with a slope, so as to retain said at least two bar elements in an inner volume of said slot.

23. A process according to any one of claims 20 to 22, wherein said second one of said at least two bar elements is provided with a handling portion, and wherein said second one of the at least two bar elements is urged forward manually, by handling said handling portion.

24. A process according to any one of claims 20 to 23, wherein said at least two 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.

25. A process according to any one of claims 20 to 24, further comprising providing fixation means between said tapered walls of said at least two bar elements, once said tapered walls of said at least two bar elements are in mutual contact.

26. An electrolytic cell suitable for a Hall-Héroult electrolysis process, comprising:
a cathode forming a bottom of said electrolytic cell and comprising a plurality of parallel cathode assemblies, each one of said plurality of parallel cathode assemblies comprising at least one metallic cathode collector bar protruding out of each of two ends of the cathode,
a lateral lining defining together with the cathode a volume containing a liquid electrolyte and a liquid metal resulting from the Hall-Héroult electrolysis process,
an outer metallic potshell containing said cathode and lateral lining,
a plurality of anode assemblies suspended above the cathode, each one of the plurality anode assemblies 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 cathodic bus bar being connected to at least part of said plurality of parallel cathode assemblies,
said electrolytic cell being characterized in that
at least one of said plurality of parallel cathode assemblies is a cathode assembly according to any of claims 1 to 19.

27. An electrolytic cell for a production of aluminium by a Hall-Héroult process, comprising at least one cathode assembly according to any of claims 1 to 19.

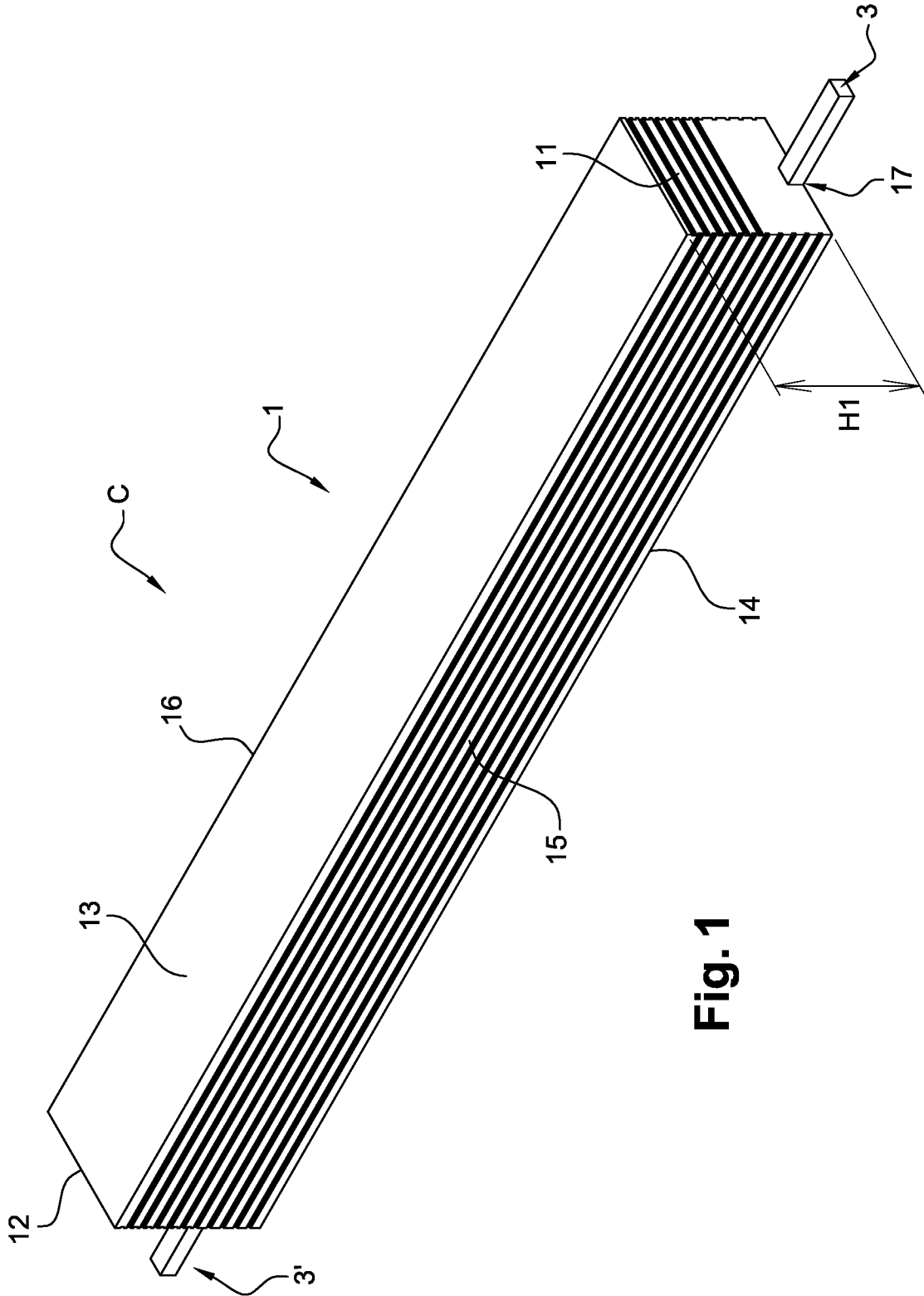


Fig. 1

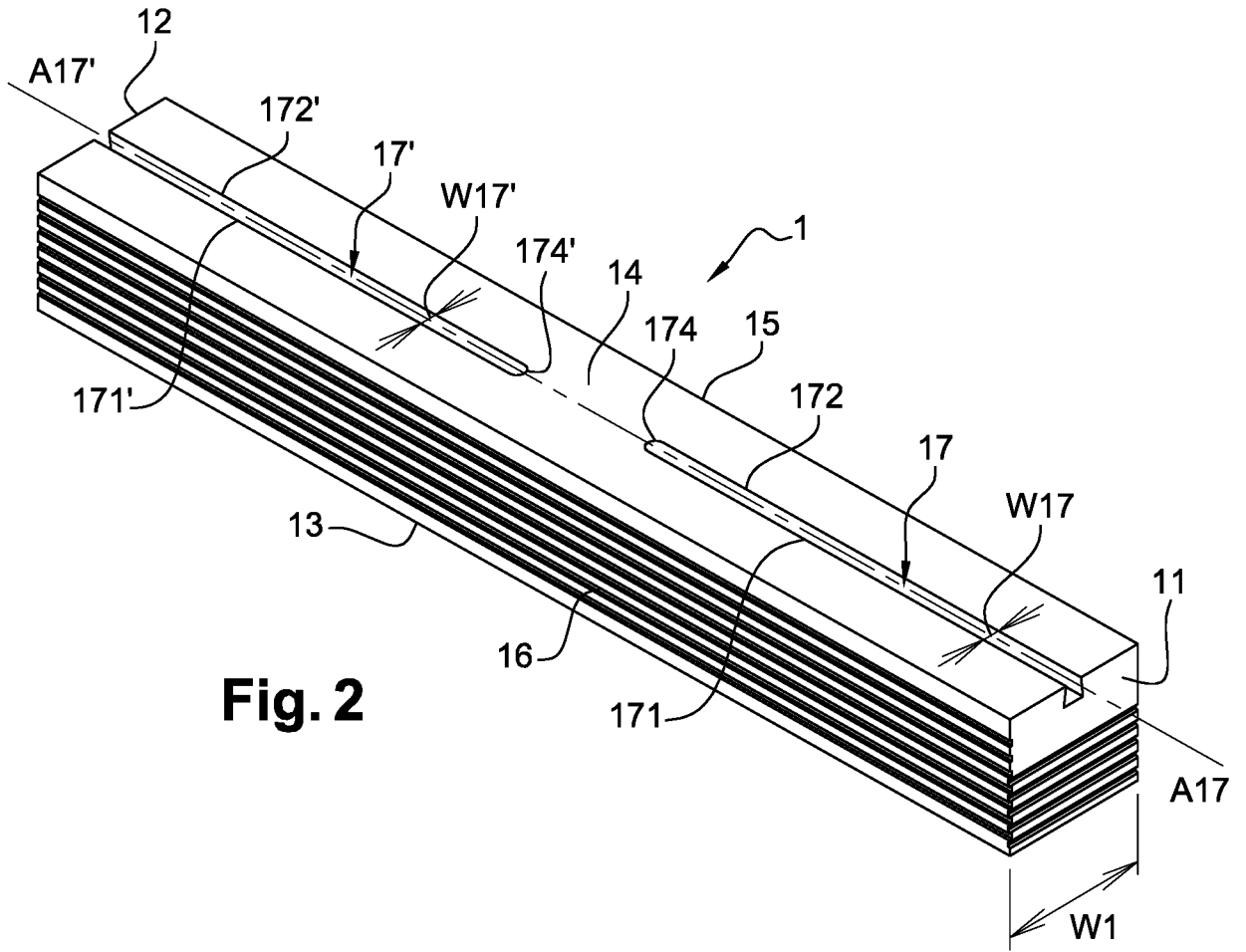


Fig. 2

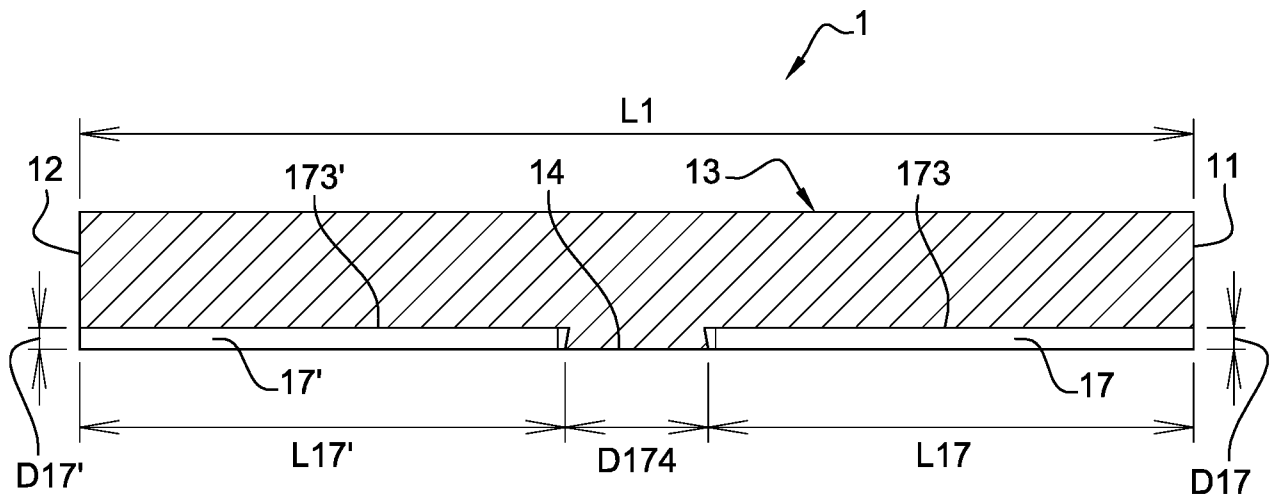


Fig. 3

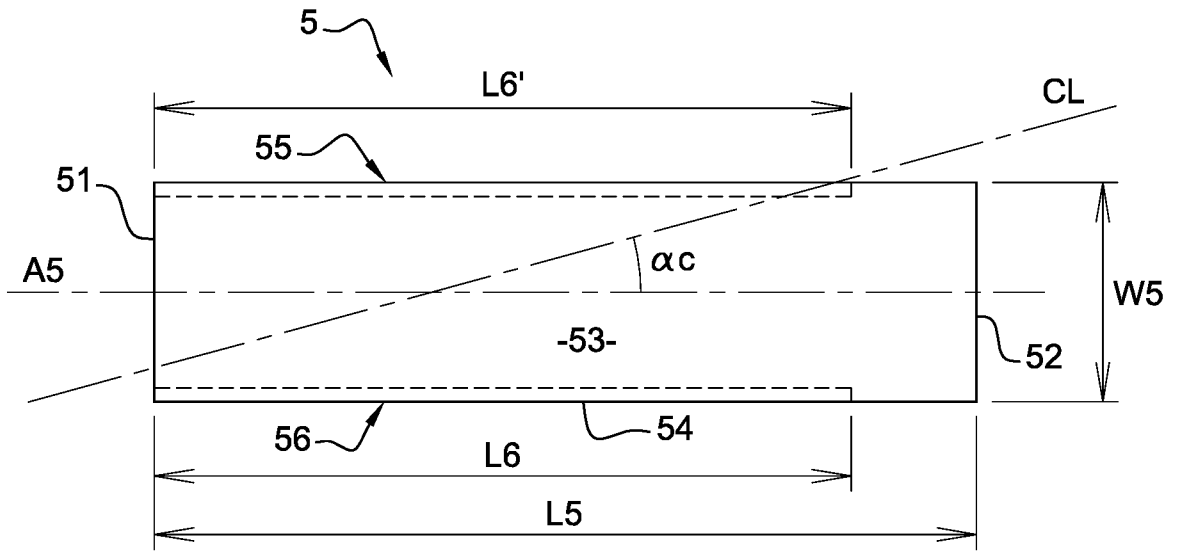


Fig. 4

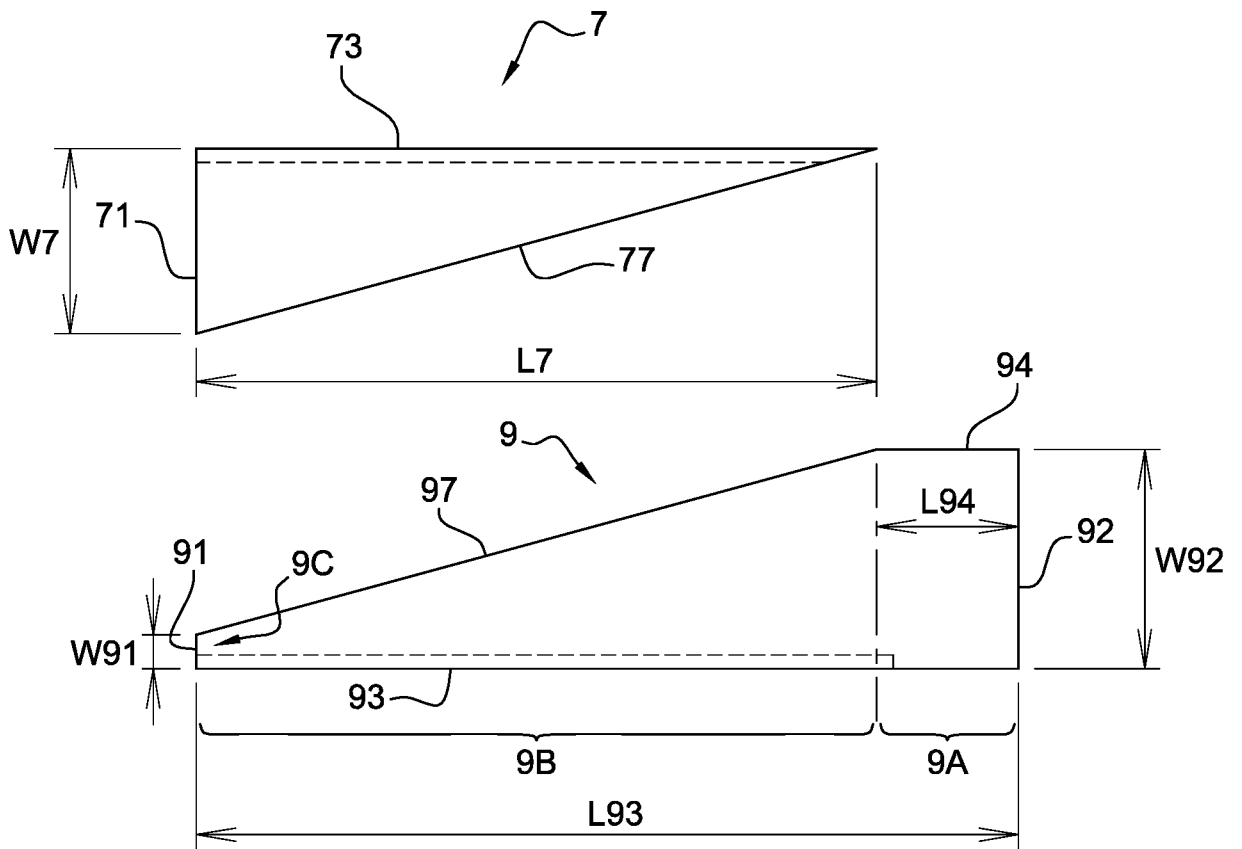


Fig. 5

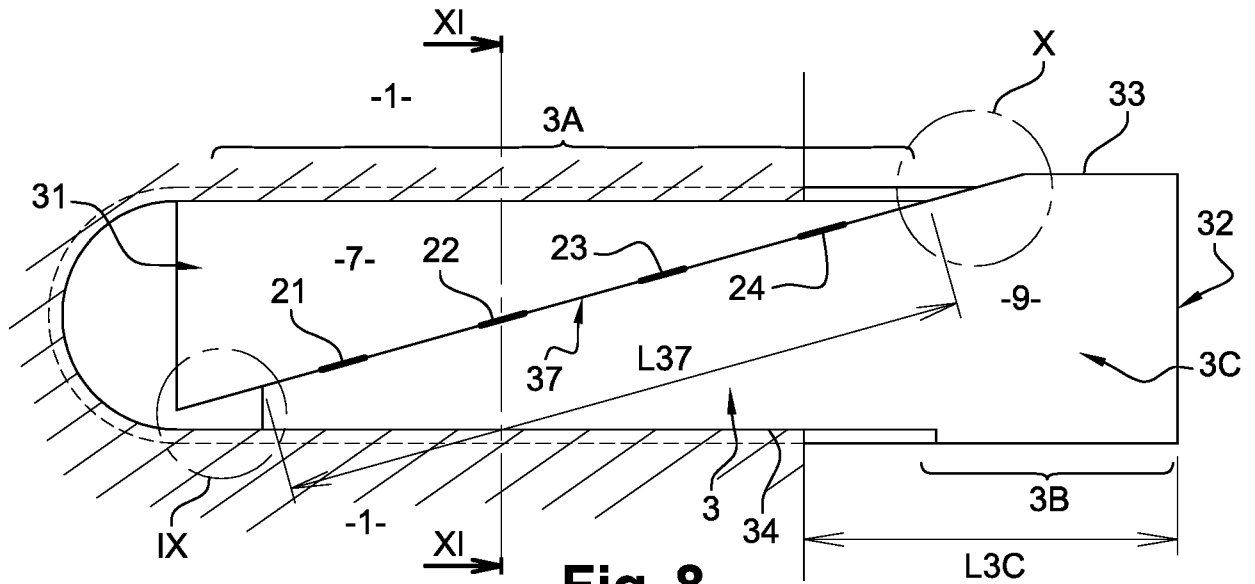


Fig. 8

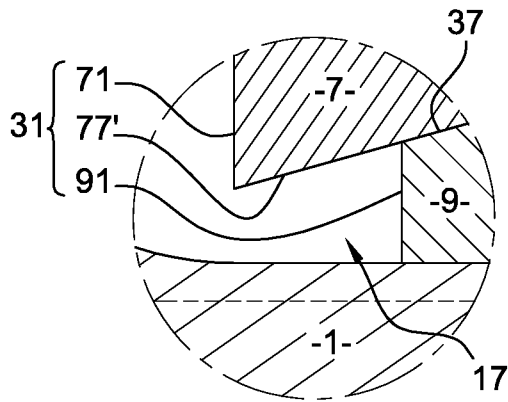


Fig. 9

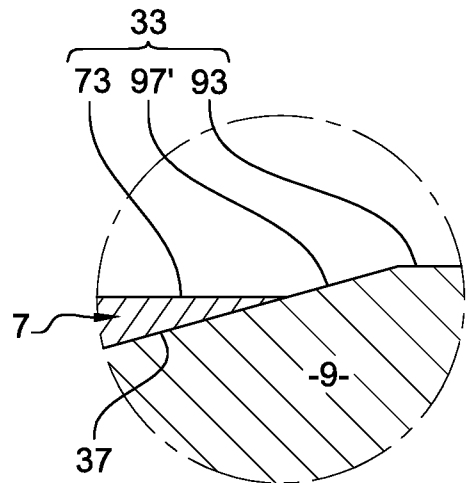


Fig. 10

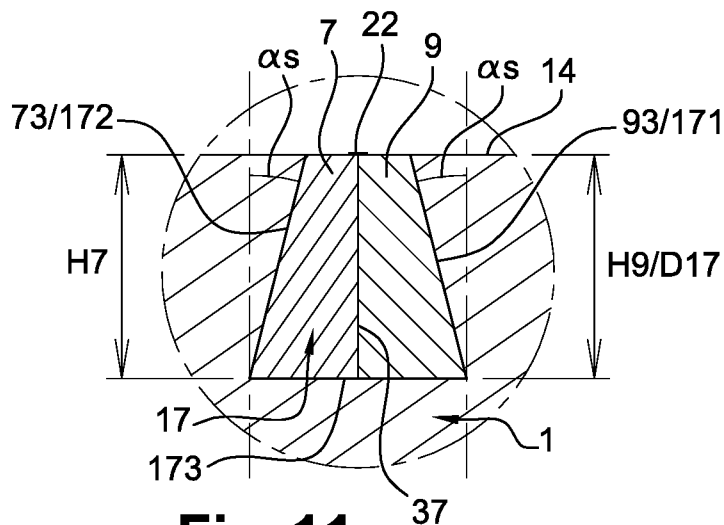


Fig. 11

