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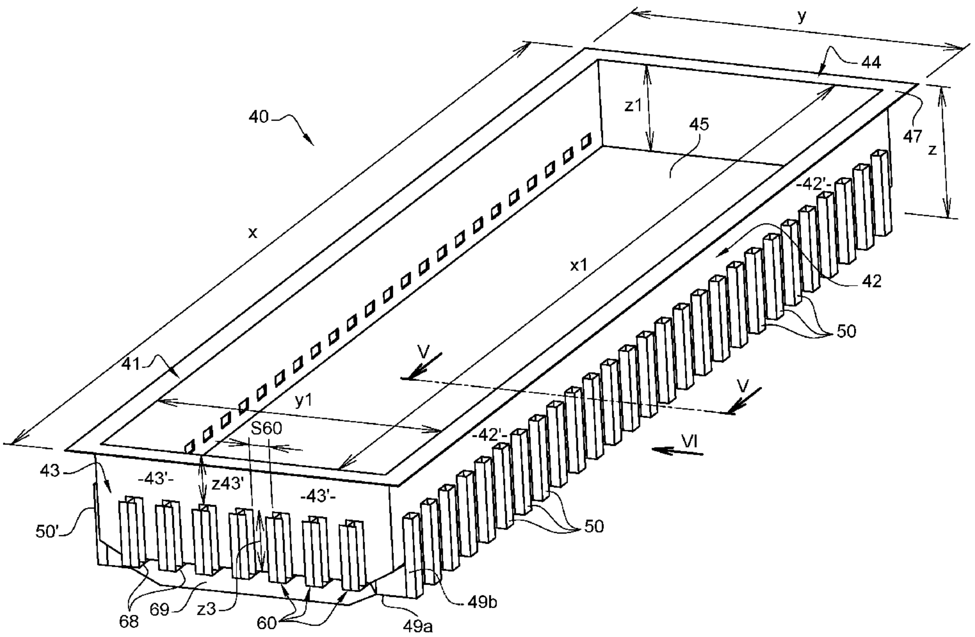

Fig. 4

(57) Abstract: A potshell (40) for an electrolytic cell (1) suitable for the Hall-Heroult electrolysis process, said potshell being intended to receive - a plurality of parallel cathode blocks (8), each cathode block comprising a metallic cathode collector bar (9) protruding out of each of the two ends of the cathode block (8), - a lateral lining (5) defining together with the cathode a volume containing the liquid electrolyte (11) and the liquid metal (12) resulting from the Hall-Heroult electrolysis process, said potshell (40) comprising : - a bottom wall (45) and peripheral walls (41-44) extending upwards from said bottom wall (45), said peripheral walls comprising side walls (41, 42) and end walls (43, 44), - a plurality of reinforcement members or stiffeners (50, 60), said potshell being characterized in that at least part of said stiffeners comprise an attachment wall (51), for attachment with facing wall (42) of potshell, said attachment wall comprising an attachment region (51), said attachment region and said facing wall (42) of said potshell being attached by fixation means.

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Potshell for electrolytic cell to be used with the Hall-Héroult process

Technical field of the invention

The invention relates to the technical field of electrolysis in molten salts for making aluminium using the Hall-Héroult process. More precisely, the invention relates to an improved potshell design that maximizes the usable cathode surface area for a given total outside dimension. This is achieved in particular by redesigning the cradles of the potshell.

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), a superstructure and a plurality of anodes (usually made from carbon) wherein part of anodes is submerged into the liquid electrolyte. Anodes and cathodes are connected to external aluminium busbars. An electrical current is passed through the cell (typically at a voltage between 3.7 V and 5 V) which electrochemically reduces the aluminium oxide, split in the electrolyte into aluminium and oxygen ions, 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 from where it needs to be tapped from time to time, usually by suction into a crucible.

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

Industrial electrolytic cells used for the Hall-Héroult process are generally rectangular in shape and connected electrically in series, the ends of the series being connected to the positive and negative poles of an electrical rectification and control substation. The general outline of these cells is known to a person skilled in the art and will not be repeated here in detail. They have a length usually comprised between 8 and 25 meters and a width usually comprised between 3 and 5 meters. The cells (also called “pots”) are always operated in series of several tens (up to more than four hundred) of pots (such a series being also called a “potline”); within each series DC currents flow from one cell to the neighbouring cell. For protection the cells are arranged in a building, with the cells arranged in rows either side-by-side, that is to say that the long side of each cell is perpendicular to the axis of the series, or end-to-end, that is to say that the long side of each cell is parallel to the axis of the series. It is customary to designate the sides for side-by-side cells (or ends for end-to end cells) of the cells by the terms “upstream” and “downstream” with reference to the current orientation in the series. The current enters the upstream and exits downstream of the cell.

The production of aluminium in an electrolytic cell is proportional to the current supplied to the 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. It is generally accepted that modern electrolysis cells using the Hall-Héroult process are limited to an electrode current density of the order of 1 A / cm^2, and that the productivity of the cell is proportional to the area of the electrodes, which can be represented as the area of the cathodes or anodes in a horizontal plane.

The present invention is more particularly related to the potshell of such electrolysis cells. Potshells are made of low carbon structural steel. Their interior cavity is defined by sheet steel and has a cuboid shape, the potshell bottom being horizontal and the potshell sidewalls being arranged so as to lie approximately vertically. The sheeting is stiffened by means of an external carrying structure. The external carrying structure includes an upper rim (also called “deckplate”) that forms the circumference of the rectangular structures, and lateral structural elements (so-called “cradles”) arranged at a right angle with respect to the direction of the sidewall, at a regular spacing.

As mentioned above, the interior cavity contains the lining, i.e., refractory bricks to protect the sheeting, and the cathodes and the side lining intended to be in contact with the liquid electrolyte and liquid metal (in operation, the side lining is protected from the liquid electrolyte by a layer of frozen electrolyte). An array of regularly spaced windows, arranged on a straight line parallel to the upper rim, is provided in both long sidewalls, to allow the cathode bars to cross the sidewall; these windows are then tightly closed with carbonaceous or refractory material. Pots need to be relined regularly; the typical lifetime of a lining is five to eight years. During relining the old lining is removed, the potshell is cleaned and then a new lining is installed. The lifetime of a potshell can be of the order of two decades, or even longer.

Potshells represent a significant cost. Their lifetime is limited by deformation: as they support a permanent load at elevated temperature, potshells are subject to creep. Also, transient abnormally high temperatures of the potshell (for example during start-up and during so-called prolonged anode effects or when the pot is “sick”) may lead to transient deformation of the steel potshell due to thermal expansion and softening; overheating can also lead to permanent deformation of the potshell. Over the years of use, the potshell tends to “open”, that is to say permanently deformed; the deformation is quite significant in the longitudinal, in the transverse as well as in the vertical directions. As the length of the newly designed pots tends to increase, the forces acting on the end walls of the potshell tend to increase, too due to accumulation of the expansion of the individual cathode blocks towards the end walls. These forces need to be taken into account when designing very long electrolytic cells.

Furthermore, in order to bring down the capital cost per unit of aluminium produced in the plant, it is desirable to maximise the surface area of the inner cavity for a given footprint (i.e. outside area of the potshell), without compromising on mechanical integrity, strength and lifetime. As an example, it would be desirable to replace an end-of-life potshell in a potline by a new potshell that fits into the available space (i.e. having the same footprint) but offers a greater cathode surface area; this will lead to a direct increase of both the production and the productivity of the pot (provided that the additional electrical power is actually available along with the availability of the longer anodes). Providing a potshell design that is easy to fabricate and has lesser weight will also contribute to minimize the capital cost, as well as subsequent maintenance cost. The present invention provides improvements of the potshell design that meets these targets.

It should be noted that most modern high amperage cells use graphitized or graphitic cathodes that absorb much less sodium from the bath than anthracitic cathodes. Sodium absorption by anthracite leads to swelling, which needs to be counteracted by very large confining forces. As a consequence, potshells used in modern high amperage cells do not need to withstand swelling forces that are as high as in older cells; this may be counterbalanced at least in part by their larger size which increases deformation.

US 2,861,036 (Pechiney), US 4 322 282 (Swiss Aluminium Ltd), and US 4,421,625 (Swiss Aluminium Ltd) are representative for a potshell design that needs to withstand enormous swelling forces; the first patent uses springs to exert a counterforce against opening forces, in second and third the potshell is stiffened by a set of horizontal expansion rails, with additional springs in the third one. US 3,702,815 uses horizontal rails only for the short sides of the potshell.

WO 2011/028132 (Norsk Hydro) discloses a potshell with vertical stiffeners and horizontal webs on its outside, said web having openings for efficient air cooling.

WO 2016/077932 (Hatch Ltd) presents a potshell design wherein the sidewalls are stiffened using vertical structural elements with free upper ends acting as cantilever springs that can be loaded and adjusted using wedges. These wedges need to be adjusted manually throughout the life of the potshell, using a hammer, a portable hydraulic jack or a wrench. While this design seems indeed to be able to provide a larger cathode surface for a given footprint compared to prior art cells, the perspective of manual fine-tuning of several dozens of wedges per cell during the lifetime of the pot, carried out in the hot working environment of a potroom and at a location of the pot that is particularly hot and not readily accessible is not especially appealing for the workers involved in this operation, and for their supervisors.

Moreover, all these potshell designs are complex and do not meet all of the multiple goals mentioned above: low capital cost, sufficient strength, long lifetime, small footprint. The present invention aims at providing an improved potshell design that meets at least several of these goals.

Objects of the invention

According to the invention, the problem is solved by a redesign of the potshell that uses modified cradles, thereby increasing their strength and decreasing their dimensions, and more precisely, both their height (i.e. their dimension parallel to the height of the potshell) and their width (i.e. the dimension in the direction protruding out of the sidewall to which they are attached, parallel to the upper rim of the adjacent sidewall).

Compared to the approach described in WO 2016/077932 the side stiffeners are not spring-loaded structural elements but rigid profiles. Said profiles can be welded profiles.

According to an essential feature of the invention, these stiffeners are fixedly connected to the shoebox along substantially their whole length. According to a first variant of the invention, fixation means between stiffeners and shoebox are distinct from both said stiffeners and shoebox. In other words, said fixation means are external or inserted fixation means. In an advantageous embodiment, said fixation means are welding means, so that stiffeners are welded against the shoebox; said welding connection can comprise point welding spaced over substantially the whole length of the stiffener, and/or can comprise one or more welding seams, such as one continuous welding seam extending over at least three quarter (and preferably over at least 90%) of the length of the stiffener, or two or more sections of welding seams spaced over substantially the whole length of the stiffener.

According to a second variant of the invention, said fixation means are form-fitting or interlock fixation means. In other words, this second variant does not require external fixation means, since the latter are defined by the facing shapes of stiffeners and shoebox themselves. In this respect, said stiffeners and shoebox are adapted to directly contact one another in view of said form-fitting fixation. When starting the pot (i.e. starting the electrolysis process), stiffeners and shoebox have been mutually mounted, potentially providing a slight clearance there between; this will help to release stresses. Typically, such a clearance is inferior to 5 mm, preferably inferior to 3 mm, and still more preferably inferior to 2 mm. Then, during operation of the pot, said shoebox progressively undergoes a functional deformation, in particular by creep, so that said shoebox and said stiffeners come into close contact and create said form-fitting fixation.

The stiffeners are arranged in a way such that between each two neighboring stiffeners there is a cathode collector bar protruding out of the potshell; this is known as such and applies both in the case where each cathode block has one collector bar protruding out of the cathode block on each end, and in the case where each cathode block has two cathode collector bars protruding out of the cathode block on each end. The potshell side stiffener design has been further optimized for the case where each cathode block has two steel collector bars. In this case a T shape stiffener has been introduced in the central part of each cathode block and it does not make a continuous U loop between upstream and downstream of the shell sides. The underneath part of the intermediate cradle has been removed to reduce the overall weight of the potshell. This feature also provides better access to welding of the neighboring continuous cradles. The cross sections of the intermediate cradles have been chosen in such a way that the mechanical integrity and strength of the potshell remains intact.

A first object of the present invention is a potshell for an electrolytic cell suitable for the Hall-Héroult electrolysis process, said potshell being intended to receive firstly a cathode forming the bottom of said electrolytic cell and comprising a plurality of parallel cathode blocks, each cathode block comprising at least one metallic cathode collector bar protruding out of each of the two ends of the cathode block, and secondly a lateral lining defining together with the cathode a volume containing the liquid electrolyte and the liquid metal resulting from the Hall-Héroult electrolysis process, said potshell comprising a bottom wall and peripheral walls extending upwards from said bottom wall, so as to define an inner reception volume, said peripheral walls comprising side walls and end walls, and said potshell further comprising a plurality of reinforcement members or stiffeners, provided side by side along at least part of said peripheral walls, said potshell being characterized in that at least part of said stiffeners comprise at least one attachment wall, said attachment wall being provided with an attachment region, said potshell further comprising fixation means, said fixation means allowing for attachment of said attachment region with facing wall of potshell.

In an embodiment said fixation means are permanent fixation means such a welding means. In any case they can be distinct from both said attachment region and said facing wall of potshell.

In another embodiment said fixation means are defined by both said attachment region and said facing wall of potshell, said attachment region and said facing wall being adapted to directly contact one another in view of a form-fitting fixation.

Advantageously, viewed from above, said attachment region defines an attachment line, the main dimension of attachment line being superior to 30 millimeters, preferably to 60 millimeters, more preferably to 100 millimeters.

Said stiffeners provided with said attachment wall can be located on side walls of said potshell. They can be formed by a hollow body, which is closed by peripheral walls, in cross section, said peripheral walls comprising said attachment wall. Said peripheral walls can for example be polygonal, in particular rectangular. At least the top of said hollow body can be open.

According to another advantageous feature of the invention the height of the stiffeners is reduced with respect to stiffeners used in prior art pot shells. More precisely, their height does not reach the upper rim of the potshell. Therefore, in another embodiment which can be combined with any other embodiment of the invention, at least part of said stiffeners extend only over a lower region of said side wall of said potshell, so as to define a so-called free upper region of said side wall of said potshell. In particular, the ratio between the height of the stiffener and the height of the side wall of the potshell is between 0.4 and 0.7, in particular between 0.45 and 0.55.

In an advantageous embodiment the height of the stiffeners does not exceed the level of the top of the cathode blocks by more than 15 cm, preferably not by more than 10 cm, still more preferably not by more than 5 cm, and still more preferably not by more than 2 cm. It can be at the same level. There is no advantage not to reach this level, and a loss of mechanical stiffness would result from this option.

The design according to the invention has several advantages. First of all, it uses less steel while providing an equivalent stiffness compared to prior art. Secondly, it leaves free a significant portion of the shoebox, that is to say a substantially planar portion of the potshell, for the action of heat exchanger and/or cooling devices. In particular, it leaves free the hottest portion of the potshell, that is to say the zone corresponding to the position and thickness of the liquid metal pad and the molten bath. This zone typically extends until about 30 cm to 50 cm above the bottom of the cathode blocks.

According to a particularly advantageous embodiment of the invention, said stiffeners extend only over part of said side wall, and in particular only over a lower region of side wall, so as to define a free upper region, as mentioned above. Said free upper region can be equipped with heat exchange means. Said heat exchange means can be fixed against a planar and smooth region of the potshell (shoebox). Providing said heat exchange means on the upper region of side walls can be advantageous, and in particular if mounted close to a height of the potshell that corresponds to the level of the liquid bath, as this is the hottest region of the potshell, in use.

Said heat exchange means may be of any appropriate type. In particular, they may be similar to those described in patent documents WO 2012/039642, WO 2013/055228, WO 2013/055229 and WO 2014/182176. According to the invention, said heat exchange means extend substantially horizontally, along above cited free upper region of the potshell.

Another advantage of the invention is that the total depth of the sidewall stiffeners (measured from the shell outside to the outermost wall of the stiffener) is reduced with respect to prior art; it can be less than 180 mm, preferably less than 165 mm, and still more preferably less than 155 mm, whereas in the design disclosed in WO 2016/077932 this value is given as about 200 mm.

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 blocks (each cathode block comprising at least one metallic cathode collector bar protruding out of each of the two ends of the cathode block), a lateral lining defining together with the cathode a volume containing the liquid electrolyte 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 carbon anode and at least one metallic anode rod connected to an anode beam), a cathodic bus bar surrounding said potshell, a plurality of connectors (each connecting one end of a cathode collector bar of a cathode block to said cathodic bus bar), said electrolytic cell being characterized in that said outer metallic potshell is a potshell according to the invention.

Yet another object of the present invention is an aluminium electrolysis plant comprising at least one line of electrolysis cells of substantially rectangular shape, and said plant further comprising means for electrically connecting said cells in series and for connecting the cathodic busbar of a cell to the anode beam of a downstream cell, characterized in that more than 60 % (preferably more than 80%) of the electrolysis cells in at least one of said line, and preferably each electrolysis cell of said line, is an electrolysis cell according to the invention.

Yet another object of the invention is a method for making aluminium by the Hall-Héroult electrolysis process, characterized in that said method is carried out in an aluminium electrolysis plant according to the invention.

Yet another object of the invention is a method for adding heat exchange means to a potshell, wherein said cooling fins are removed from said upper free region, and said heat exchange means are mounted in said upper free region.

A last object is a method of operating a potshell according to the invention, characterized in that it comprises mutually mounting said stiffeners and said potshell upon starting the potshell, potentially providing a slight clearance therebetween, and then operating the pot so that said potshell undergoes a functional deformation, in particular by creep, and so that said potshell and said stiffeners come into close contact and create said form-fitting fixation.

Brief description of figures

Figures 1 to 3 represent prior art, figures 4 to 13 illustrate several embodiments of the invention.

Figure 1 shows a schematic transverse cross-sectional view of a prior art electrolytic cell for aluminium production according to the Hall-Héroult process.

Figure 2 is a schematic cross section along a transversal plane across a Hall-Héroult electrolytic cell. The arrows represent the current flow across the cell.

Figure 3 is a schematic perspective view of a prior art potshell.

Figure 4 is a schematic perspective view of a potshell according to the invention.

Figure 5 is a transverse cross section along line V-V of figure 4, analogous to figure 1 but at a greater scale, showing a stiffener and the end of a cathode bar, provided on the side wall of the potshell illustrated on figure 4.

Figure 6 is a front view along arrow VI of figure 4, showing two adjacent stiffeners as well as the end of a cathode bar provided between said stiffeners.

Figure 7 is a perspective view, showing at a much greater scale the upper end of a stiffener illustrated on figures 5 and 6.

Figure 8 is a perspective view, analogous to figure 4 but at a greater scale, showing some stiffeners provided on potshell of figure 4, the walls of said potshell being not illustrated on said figure 8.

Figure 9 is a top view, showing at a much greater scale a stiffener provided on the end wall of the potshell illustrated on figure 4.

Figure 10 is a perspective view, showing at a greater scale the end wall of a potshell, which is provided with stiffeners according to a variant of the invention.

Figure 11 is a perspective view, analogous to figure 10 but along a different angle, showing some stiffeners of figure 10, the walls of the potshell being not illustrated on said figure 11.

Figure 12 is a perspective view of a potshell according to another variant of the invention.

Figure 13 is a perspective view, showing a part of the bottom of potshell illustrated on figure 12.

The following reference numbers are used in the figures:

1	Electrolytic cell (prior art)	41,42	Sidewalls of potshell 40
2,3	Sidewalls of potshell	43,44	Endwall of potshell 49
4	Bottom of potshell	45	Bottom of potshell 40
5	Lining	46	Stiffener (cradle) of potshell 40
6	Anode rod	47	Deckplate of potshell 40
7	Anode	48	Window for cathode collector bar
8	Cathode block	49	Bottom beam
9	Cathode collector bar	50	Side wall stiffener
10	Anode frame	51,52	Front walls of stiffener 50
11	Electrolytic bath	53,54	Lateral walls of stiffener 50
12	Liquid aluminium pad	55	Attachment line
13	Hood	60	End wall stiffener
20,21	Cathodic busbar	61,62	Front and rear walls of stiffener 60

22,23	Flexible connector	63	Median wall of stiffener 60
30	Potshell (prior art)	65	Attachment line
31,32	Sidewalls of potshell 30	68	Base beam
33,34	Endwalls of potshell 30	69	Base plate
35	Bottom of potshell 30	70	End wall stiffener
36	Stiffener (cradle) of potshell 30	76	Intermediate panel of potshell
37	Deckplate of potshell 30	77	Cooling fins
38	Window for cathode collector bar	78	Base beam
39	Belt-like stiffener	79	Base plate
40	Potshell (invention)	42’	Free upper region of 42
T50	Thickness of 50	x50	Inner front dimension of 50
y50	Inner lateral dimension of 50	S50	Spacing between 50 and 50’
S59	Spacing between 9 and 50	L55	Length of 55
Z50	Height of 50	Z42	Height of 42
Z42’	Height of 42’	9’	Free end of 9
P50	Distance between 9’ and 50	Z58	Distance between 8 and 58
T61-T63	Thickness of 61-63	W61-W63	Width of 61-63

Detailed description of the invention

The general structure of a Hall-Héroult electrolysis pot is known *per se* and will not be explained here in detail. It is sufficient to explain, in particular in relation with Figure 1, that a typical cell **1** includes a potshell comprising a first longitudinal sidewall **2**, a second longitudinal sidewall **3**, first and second transversal end walls (not visible on figure 1) and a bottom **4**. The potshell walls define a space lined on its bottom and sides with refractory materials **5** (protecting the potshell against heat) along with the cathode blocks **8**, thereby defining a volume containing the molten metal and electrolyte. The side lining **5** comprises a layer of carbonaceous material (not shown on the figures) protected in steady state operation by solid electrolyte in contact with molten liquid material. Said cathode blocks **8** comprise one or more cathode collector bars **9**. They protrude out of the potshell. Electrical current enters the cell through anodes **7** (suspended above the cell by anode rods **6** attached to an aluminium frame called anode beam **10**), passes through the molten electrolytic bath **11** and the molten aluminium pad **12**, and then enters the carbon cathode block **8**. The current is carried out of the cell by the cathode collector bar **9** connected to the cathode busbar **20, 21** (shown on figure 2). The cell **1** is closed by a set of hoods **13**.

Figure 2 explains in more detail the typical current flow in a Hall-Héroult electrolysis cell. The current is fed into the anode frame **10** (called anode beam, shown on figure 1), flows from the anode beam **10** to the anode rod **6** and to the anode **7** in contact with the liquid electrolyte **11** where the electrolytic reaction takes place, crosses the liquid metal pad **12** resulting from the process and eventually will be collected at the cathode block **8**. Each collector bar end **24**, **25** is connected through a flexible connector **22**, **23** to the closest cathode busbar **20**, **21** extending parallel to each of the longitudinal sidewalls of the potshell.

As shown on figure 3 representing a typical prior art embodiment, the potshell **30** of an electrolytic cell for the Hall-Héroult process can be represented as a “shoe box” of external length *x*, width *y* and depth *z*, made from steel sheet, comprising two parallel upright sidewalls **31**, **32**, two parallel upright endwalls **33**, **34**, and a bottom **35**. Said sidewalls **31**, **32** and endwalls **33**, **34** are connected to a reinforcement structure. Said reinforcement structure comprise stiffeners **36** (so-called “cradles”). They are usually regularly spaced and extend over all the length and width of the potshell. These stiffeners are often T-profiles, as on figure 3, the width of the section parallel to the potshell being larger at the bottom than at the top.

A deckplate **37** can be provided over the whole rim of the potshell. In some embodiments of prior art potshells **30** there is an additional belt-like stiffener **39** at each of the small sides of the potshell.

Figure 3 does not show the cathode blocks which are positioned on the bottom **35** of the potshell **30**, but shows the windows **38** provided in both sidewalls **31**, **32** for allowing the cathode bars to protrude out of the potshell; electrical connectors (usually flexible ones) are used to connect the collector bars to the cathode busbars (not shown on the figure) that extend parallel to both sidewalls **31**, **32**. The internal length, width and depth of the potshell are designated by x_1, y_1 and z_1, respectively.

Figure 4 shows an embodiment of a potshell **40** according to the invention. It has the same kind of shoebox structure as the prior art potshell **30**, with two parallel upright sidewalls **41**, **42**, two parallel upright endwalls **43**, **44**, a bottom **45** and a deckplate **47**. Potshell **40** differs from that **30** of prior art, in particular for what concerns the structure of stiffeners. Potshell **40** is equipped with cradles **46**, shown on figure 8, which are provided on its side walls **41**, **42**, as well as with end wall stiffeners **60**, provided on its end walls **43**, **44**.

Figure 8 shows the structure of some cradles **46**, as well as some windows **38** there between, but does not illustrate the walls of potshell for sake of clarity. Each cradle **46** comprises a central part **49**, as well as two terminal parts **50** and **50’**. Central part **49** extends parallel to the bottom wall of potshell, in particular in a horizontal way, whereas terminal parts extend perpendicular to said bottom wall, in particular in a vertical way.

Central part **49** is attached, in particular is welded on the lower face of the bottom wall of potshell. Central part **49** is called bottom beam, whereas terminal parts **50** and **50’** are called side wall stiffeners. Stiffeners **50** are provided on side wall **42**, whereas stiffeners **50'** are provided on side wall **41**. The structure of stiffeners **50** will now be described, bearing in mind that structure of stiffeners **50'** is analogous.

Figures 5 to 7 show more in detail some stiffeners **50**, provided on side wall **42**. Said stiffeners **50** are formed by a hollow body, which is defined and closed by peripheral walls, in cross section. Said walls comprise two so called opposite front walls **51** and **52**, as well as two so called opposite lateral walls **53** and **54** (see in particular figure 7). By way of example, the following typical numeric values are given, with reference to this figure 7:

- thickness *T50* (figure 7) of peripheral walls is between 1 mm and 15 mm, and preferably between 2 mm and 10 mm;

- inner front dimension *x50* (figure 7) between inner faces of front walls **51** and **52** is between 100 mm and 180 mm;

- inner lateral dimension *y50* (figure 7) between inner faces of lateral walls **53** and **54** is between 120 mm and 220 mm;

- spacing *S50* (figure 8) between 150 mm to 300 mm facing faces of adjacent stiffeners; in particular, distance (*S50*) between facing faces (53', 54) of adjacent stiffeners (50, 50') can be between 250 mm and 300 mm, and preferably between 275 mm and 300 mm.

- distance *S59* (figure 6) between one cathode bar **9** and facing face of lateral wall **54** of adjacent stiffener **50** is between 30 mm and 70 mm, in particular between 40 mm and 50 mm. This distance *S59* substantially corresponds to distance window **38** and facing face of lateral wall **54.** Front wall **51**, which is adjacent to side wall **42** of the potshell, forms an attachment wall, i.e. it is suitable for a fixation with respect to said potshell. Said attachment wall defines an attachment region, which contacts side wall **42** and is attached thereto by fixation means. Said contact may be a direct contact, or an indirect contact, i.e., said fixation means are interposed between said attachment region and said facing wall. Advantageously, said attachment or contact region extends over a substantial part of the attachment wall, in particular over the entire height of the vertical cradle, preferably tack welded at the edges. The contact between the vertical cradle and the sidewall can be left even free to allow free sliding of the potshell wall against the cradle and would help to release mechanical stresses between the said surfaces.

Viewed from above (see in particular figure 5), said attachment region defines an attachment line **55**, also called a contact line, the length of which is noted L55 (see figure 7). The tack weld achieved on the entire length *L55* is superior to any weld carried out on part of the cradle height. This allows a reliable fixation of the whole stiffener **50** on the wall

42 of the potshell. Let us note that *L55* is slightly superior to *x50*, since it takes into account twice the thickness *T50* of the walls.

In an advantageous embodiment, attachment wall **51** is welded against the wall **42**. Said welding connection can comprise point welding spaced over substantially the whole length of the line **55**, and/or can comprise one or more welding seams, such as one continuous welding seam extending over at least three quarter (and preferably over at least 90%) of the length of the line **55**, or two or more sections of welding seams spaced over substantially the whole length of the line **55**.

The hollow stiffeners **50** have a rectangular shape, in cross section. As an alternative, this shape may be different. However, providing a polygonal shape is advantageous: a side of this polygon is adapted to be in contact with the side wall of the potshell and, therefore, to create a reliable attachment wall. As shown in particular on figure 7, the top of said hollow body preferably is closed to avoid accumulation of loose alumina and other foreign material.

As shown by figures 5 and 6, stiffeners **50** extend advantageously over only part of the height of side wall **42** of potshell. Let us note *z50* and *z42* the respective heights of said stiffener **50** and said side wall **42** (see figure 6). Height *z42* is considered from the bottom of deckplate **47**. Advantageously, the ratio (*z50/z42*) is between 0.4 and 0.7, in particular between 0.45 and 0.55.

This makes it possible to define a so called free, or smooth, upper region **42'** of said side wall **42** of potshell. Advantageously, said free upper region is equipped with not shown heat exchange means. Advantageously, height *Z42'* (see figure 6) of upper region **42'** is between 500 mm to 600 mm, in particular between 530 mm to 560 mm. This allows an easy positioning and a reliable fixation of above mentioned heat exchange means.

Turning back to figure 5, let us note the so called distance of protrusion *P50*. This distance corresponds to the distance, along main longitudinal axis of cathode bar **9**, between free end **9'** of said cathode bar and outer face of front wall **52** of stiffener **50**. Said distance *P50* is between 80 mm and 150 mm, in particular between 90 mm and 110 mm. By way of convention, if this distance is positive, it means that stiffener **50** extends beyond cathode bar **9**. Figure 5 shows, in solid lines, a first possibility according to which stiffener extends beyond cathode bar and, in dotted lines, a second possibility according to which cathode bar extends beyond stiffener.

Referring again to figure 5, let us note *Z58* the distance, along vertical axis, between top of stiffener **50** and top of cathode blocks **8**. Advantageously, *Z58* is inferior to 100 millimeters, preferably inferior to 50 millimeters, and still more preferably inferior to 20 millimeters.

Figures 4 and 9 show more particularly the structure of a first embodiment of stiffeners **60**, provided on both end walls **43** and **44**. Stiffeners **60** differ from those **50**, such as described above, essentially in that they are not hollow. On the other hand, they are substantially H or I-shaped. Each stiffener is formed by three walls, i.e. two parallel opposite walls **61** and **62**, and a medium wall **63** which links said walls **61** and **62**.

Wall **61**, adjacent potshell end wall **43**, is called front wall, whereas wall **62**, opposite potshell end wall **43**, is called rear wall. Both walls **61** and **62** extend parallel to potshell end wall **43**, whereas medium wall **63** extends perpendicular to said potshell end wall. Stiffeners **60** rest each on a base beam **68**, said beams being attached to a base plate **69** which extends also under the central parts **49a** and **49b** of last and last but one cradles **46a** and **46b** (see also figures 10 and 11 for details).

By way of example, the following typical numeric values are given, with reference to figure 9:

- thickness *T61* of wall **61** and thickness *T62* of wall **62** are between 8 mm and 12 mm;

- thickness *T63* of wall **63** is between 5 mm and 7 mm;

- width *W61* of wall **61** and width *W62* of wall **62** are between 120 mm and 140 mm;

- length *L63* of wall **63** is between 160 mm and 185 mm;

- spacing *S60* (figure 4) between facing faces of adjacent stiffeners **60** is between 300 mm and 500 mm.

By analogy with above described front wall **51**, front wall **61** forms an attachment wall. The contacting face thereof defines an attachment line **65** (figure 9), the length of which is noted *L65*, which is equal to *W61*. The same way as for line **55**, the entire length *L65* is to be welded on its edges. The same way as for line **55**, attachment wall **61** is advantageously welded against the wall **43**.

In the first embodiment of figures 4 and 9, the stiffeners extend only over the lower part of potshell end wall **43**. By analogy with potshell side wall **42**, this makes it possible to define a so called free, or smooth, upper region **43'** of said end wall **43** of potshell. Advantageously, said free upper region is equipped with heat exchange means (not shown on the figures), typically similar to those described here above. Advantageously, height *z43'* (see figure 4) of upper region **43'** is between 450 mm to 600 mm, in particular between 470 mm to 520 mm. This allows an easy positioning and a reliable fixation of above mentioned heat exchange means.

Figures 10 and 11 show another embodiment of end wall stiffeners of potshell end walls **43**, which are referenced as **70**. In this first variant, said stiffeners **70** extend over the whole height of end wall **43**. The same way as above stiffeners **60** of first embodiment, each stiffener **70** rests on a base beam **78**, said beams being attached to a base plate **79** which extends also under the central parts **49a** and **49b** of last and last but one cradles **46a** and **46b**.

Let us note **76** the so called intermediate panels, between two adjacent stiffeners. Said intermediate panels **76** are part of the potshell end wall **43**. According to an advantageous embodiment, the upper region of panels **76** is equipped with cooling fins **77**. These fins are vertical plate-like elements. In a typical way, between 3 and 8 fins are provided on each panel **76**. The height *H77* of each fin is between 40 to 60 % of the whole height of said end wall 43.

The purpose of said cooling fins **77** in the upper free region (42’) is to provide sufficient cooling of the potshell when there are no heat exchangers. That is to say that the potshell according to the invention, equipped with said cooling fins **77** if required in order to ensure a convenient thermal equilibrium, can be mounted in an electrolysis cell and operated without heat exchangers; if the potshell is to undergo a retrofit with heat exchangers, said cooling fins **77** can be removed, totally or in part, in order to ensure thermal equilibrium. If required, heat exchangers can be put in place at the section of the end walls **43** that were previously covered by said cooling fins **77**.

Said cooling fins **77** can be removed for instance by simple cutting operations. This can be useful because the installation of heat exchangers in a potline will require various installations for the circulation of heat transfer fluids that will transport the heat from the heat exchanger to the point where said heat is needed; these installation may not be ready when a potshell according to the invention is mounted and the pot is put into operation. As a consequence, the pot will have to operate without heat exchangers for a certain period of time, and the potshell should therefore be designed such as to reach a convenient thermal equilibrium with natural cooling only. The use of removable cooling fins **77** meets this target. A method for adding heat exchange means to a potshell according to the invention equipped with cooling fins **77** in the upper free region **42’** comprises therefore the steps of removing said cooling fins **77** from said upper free region **42’**, and mounting said heat exchange means in said upper free region **42’**.

Likewise and for the same purpose, cooling fins **77** can be provided at the side walls of the potshell, and during a retrofit operation they can be replaced, totally or in part, by heat exchangers; this variant is not shown on the figures.

Figures 12 and 13 illustrate a further embodiment of a potshell according to the invention. On these figures, the mechanical elements analogous to those of figures 4 to 11 are given the same references added by the number 100.

Potshell **140** of figures 12 and 13 differs from that with reference number **40**, essentially by the shape and dimensions of its cradles. Indeed some first cradles **146** are identical to those **46** of first embodiment: they comprise two sidewalls stiffeners **150** and **150'** as well as a continuous beam **149** extending under the bottom wall of potshell. On the other hand, bottom part of said potshell is also provided with further cradles **166**, which are different from those **46** and **146**. In a typical way, as illustrated on figures 12 and 13, these two different types of cradles **146** and **166** are arranged in an alternate manner, along main dimension of potshell.

Cradles **166** are so called partial, in that they do not extend over the whole width of the bottom part of the potshell. A first so-called half cradle **167** comprises a sidewall stiffener **170**, which is T shaped in a similar way as end wall stiffener **70**, as well as a cutout beam **171** extending from said stiffener **170**, under only part of bottom wall of potshell. In an analogous manner a second half cradle **167'** comprises a sidewall stiffener **170'** as well as a cutout beam **171'**. Cooling fins **177**, analogous to those **77**, are provided above top end of at least some stiffeners **170** and/or **170'**.

Facing ends of said beams **171** and **171'** define an intercalary space or gap **190**. The latter provides a satisfactory access to the neighboring continuous beams **149**, in particular in view of their welding. This embodiment of figures 12 and 13 is especially adapted and advantageous, in case each cathode block has two collector bars.

The invention has many advantages. The side wall and end wall stiffeners **50, 60** are wider (i.e. their main dimension *L55* is greater) than the cradles used in prior art potshells, but their height *z50* is less than that of the cradles used in prior art potshells. It both increases the available surface of the cavity (i.e. the surface that is available for the cathodes forming the bottom of the electrolytic cell) of the potshell (at a given "footprint" (i.e. at a given total outside dimension) and decreases the height of the cradles (fins) below the deckplate.

Due to the higher surface of the cavity the potshell according to the invention allows to increase the cathode surface area by about 10 % to about 21% depending on the cell technology. It should be noted that potshells according to the invention can be used for virtually any cell technology using the Hall-Héroult process. The increase in cathode surface area allows using longer anodes, thereby reducing the voltage drop in the electrolyte region and reducing the anodic current density at any given amperage. As a consequence, end-of-life electrolytic cells can be replaced by new electrolytic cells, using pothshells according to the invention, that fit into the footprint of the old ones but having a higher production capacity.

Furthermore, the new design leads to decreased heat loss because of the smaller surface area of the cradles that unavoidably act not only as stiffeners but also as cooling fins. This is due to their smaller height and (optionally) smaller width.

Another advantage of the potshell according to the invention is that the upper part of the sidewalls and/or endwalls is fully accessible over a height designated as *z42'*. This allows providing the potshell with heat exchangers in contact with the upper part of the sidewalls and/or endwalls of the potshell.

Example

A test cell was based on so-called DX+ technology that is used and offered for sale by Emirates Global Aluminium for many years. Concerning the potshell, two major changes were made in side and end wall cradle design in accordance to the present invention: narrowing down the portion of the cradle width to bare minimum, and reducing the cradle height below the deckplate up to the top of the cathode blocks. Additionally the potshell height was reduced by about 150 mm from the top of the deckplate to the bottom of the side cradles at the location of concrete support where potshell rests.

The structural features of the new potshell design are the following: narrower side cradles, shorter side cradles, side cradles at every cathode block, increased inner cavity width, increased inner cavity length, maintaining similar mass of the potshell, reduced shell height by 165 mm.

This innovative potshell design also enables to install heat recovery system in the upper portion of the potshell facing the meal and bath, utilizing the full perimeter on the potshell. This thermal energy can be utilized further for other purposes and potentially can be helpful to reduce energy consumption of the cell.

Another aspect of the wider cavity and narrower cradle potshell design is to increase cell productivity by increasing cell current or reducing the specific energy consumption. This increase in cell current can be easily calculated by the % gain in anode panel surface area due to longer anodes. Similarly reduction in specific energy consumption can be estimated by taking into the account of reduction in bath voltage for a given anode to cathode distance and anode size.

Claims

1. A potshell (40) for an electrolytic cell (1) suitable for the Hall-Héroult electrolysis process, said potshell being intended to receive

- a cathode forming the bottom of said electrolytic cell and comprising a plurality of parallel cathode blocks (8), each cathode block comprising at least one metallic cathode collector bar (9) protruding out of each of the two ends of the cathode block (8),
- a lateral lining (5) defining together with the cathode a volume containing the liquid electrolyte (11) and the liquid metal (12) resulting from the Hall-Héroult electrolysis process,

said potshell (40) comprising :

- a bottom wall (45) and peripheral walls (41-44) extending upwards from said bottom wall (45), so as to define an inner reception volume, said peripheral walls comprising side walls (41, 42) and end walls (43, 44),
- a plurality of reinforcement members or stiffeners (50, 60), provided side by side along at least part of said peripheral walls,

said potshell being characterized in that at least part of said stiffeners comprise at least one attachment wall (51), said attachment wall being provided with an attachment region (51), said potshell further comprising fixation means, said fixation means allowing for attachment of said attachment region (51) with facing wall (42) of potshell. ,

2. Potshell according to claim 1, characterized in that said fixation means are permanent fixation means.

3. Potshell according to claim 1 or 2, characterized in that said fixation means are distinct from both said attachment region (51) and said facing wall (42) of potshell, said fixation means being in particular welding means.

4. Potshell according to claim 1 or 2, characterized in that said fixation means are defined by both said attachment region (51) and said facing wall (42) of potshell, said attachment region (51) and said facing wall (42) being adapted to directly contact one another in view of a form-fitting fixation.

5. Potshell according to any of above claims, characterized in that, viewed from above, said attachment region defines an attachment line, the main dimension (*L55*) of

attachment line being superior to 30 millimeters, preferably to 60 millimeters, more preferably to 100 millimeters.

6. Potshell according to any of above claims, characterized in that said stiffeners (50) provided with said attachment wall (51) are located on side walls (41, 42) of said potshell.

7. Potshell according to any of above claims, characterized in that said stiffeners (50) provided with said attachment wall (51) are formed by a hollow body, which is closed by peripheral walls (51-54), in cross section, said peripheral walls comprising said attachment wall (51).

8. Potshell according to claim 7, characterized in that said peripheral walls are polygonal, in particular rectangular.

9. Potshell according to any of above claims, characterized in that at least part of said stiffeners (50) extend only over a lower region of said side wall (41, 42) of said potshell, so as to define a so called free upper region (42') of said side wall (41, 42) of said potshell.

10. Potshell according to claim 9, characterized in that ratio (*z50/z42*) between height (z*50*) of stiffener (50) and height (z*42*) of side wall of potshell is between 0.4 and 0.7, in particular between 0.45 and 0.55.

11. Potshell according to any of above claims 9 or 10, characterized in that free upper region (42') is equipped with heat exchange means.

12. Potshell according to any of above claims, characterized in that distance (*S50*) between facing faces (53', 54) of adjacent stiffeners (50, 50') is between 275 mm and 300 mm.

13. Potshell according to any of claims 11 or 12, characterized in that distance (*S59*) between one window (38) and facing face of adjacent stiffener is between 30 mm and 70 mm, in particular between 40 mm and 50 mm

14. Potshell according to any of claims 9 to 13, characterized in that it is provided with cooling fins (77) in said upper free region (42').

15. Potshell according to any of above claims, characterized in that it comprises a first type of cradles (46; 146), each comprising two sidewall stiffeners (50; 150) provided on opposite side walls of potshell, as well as a continuous beam (149) extending under whole bottom of potshell.

16. Potshell according to any of above claims, characterized in that it comprises a second type of cradles (166), each comprising two half cradles (167, 167'), each half cradle comprising a sidewall stiffener (170, 170') provided on one side wall of potshell, as well as a cut out beam (149, 149') extending under only part of bottom of potshell.

17. Potshell according to claims 15 and 16, characterized in that said first type of cradles (46; 146) and said second type of cradles (166) are arranged in an alternate manner.18. 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 blocks (8), each cathode block (8) comprising at least one metallic cathode collector bar (9) protruding out of each of the two ends of the cathode block (8),
- a lateral lining (5) defining together with the cathode a volume containing the liquid electrolyte (11) and the liquid metal (12) resulting from the Hall-Héroult electrolysis process,
- an outer metallic potshell (40) containing said cathode and lateral lining (5),
- a plurality of anode assemblies suspended above the cathode, each anode assembly comprising at least one carbon anode (7) and at least one metallic anode rod (6) connected to an anode beam (10),
- a cathodic bus bar surrounding said potshell (40),
- a plurality of connectors, each connecting one end of a cathode collector bar (9) of a cathode block (8) to said cathodic bus bar (20, 21),

said electrolytic cell being characterized in that said outer metallic potshell is a potshell according to any of claims 1 to 17.

19. An electrolytic cell according to claim 16, characterized in that the distance of protrusion (*P50*) between said cathode collector bar (9) and said stiffener is between 80 mm and 150 mm.

20. An electrolytic cell according to claim 18 or 19, characterized in that the distance (*Z58*), along vertical axis, between top of stiffener (50) and top of cathode block (8) is inferior to 100 millimeters, preferably inferior to 50 millimeters, and still more preferably inferior to 20 millimeters.

21. An electrolytic cell according to any of claims 18 to 20, comprising a potshell according to claim 17, characterized in that at least one cathode block comprises two cathode collector bars.

22. An aluminium electrolysis plant comprising at least one line of electrolysis cells of substantially rectangular shape, and said plant further comprising means for electrically connecting said cells in series and for connecting the cathodic busbar (20, 21) of a cell to the anode beam (10) of a downstream cell,

characterized in that more than 80% of the electrolysis cells in at least one of said line, and preferably each electrolysis cell of said line, is an electrolysis cell according to any of claims 15 to 17.

23. A method for making aluminium by the Hall-Héroult electrolysis process, characterized in that said method is carried out in an aluminium electrolysis plant according to claim 22.

24. A method for adding heat exchange means to a potshell according to claim 14, wherein said cooling fins (77) are removed from said upper free region (42'), and said heat exchange means are mounted in said upper free region (42').

25. A method of operating a potshell according to any of claims 4 to 17, characterized in that it comprises mutually mounting said stiffeners and said potshell upon starting the potshell, potentially providing a slight clearance therebetween, and then operating the pot so that said potshell undergoes a functional deformation, in particular by creep, and so that said potshell and said stiffeners come into close contact and create said form-fitting fixation.

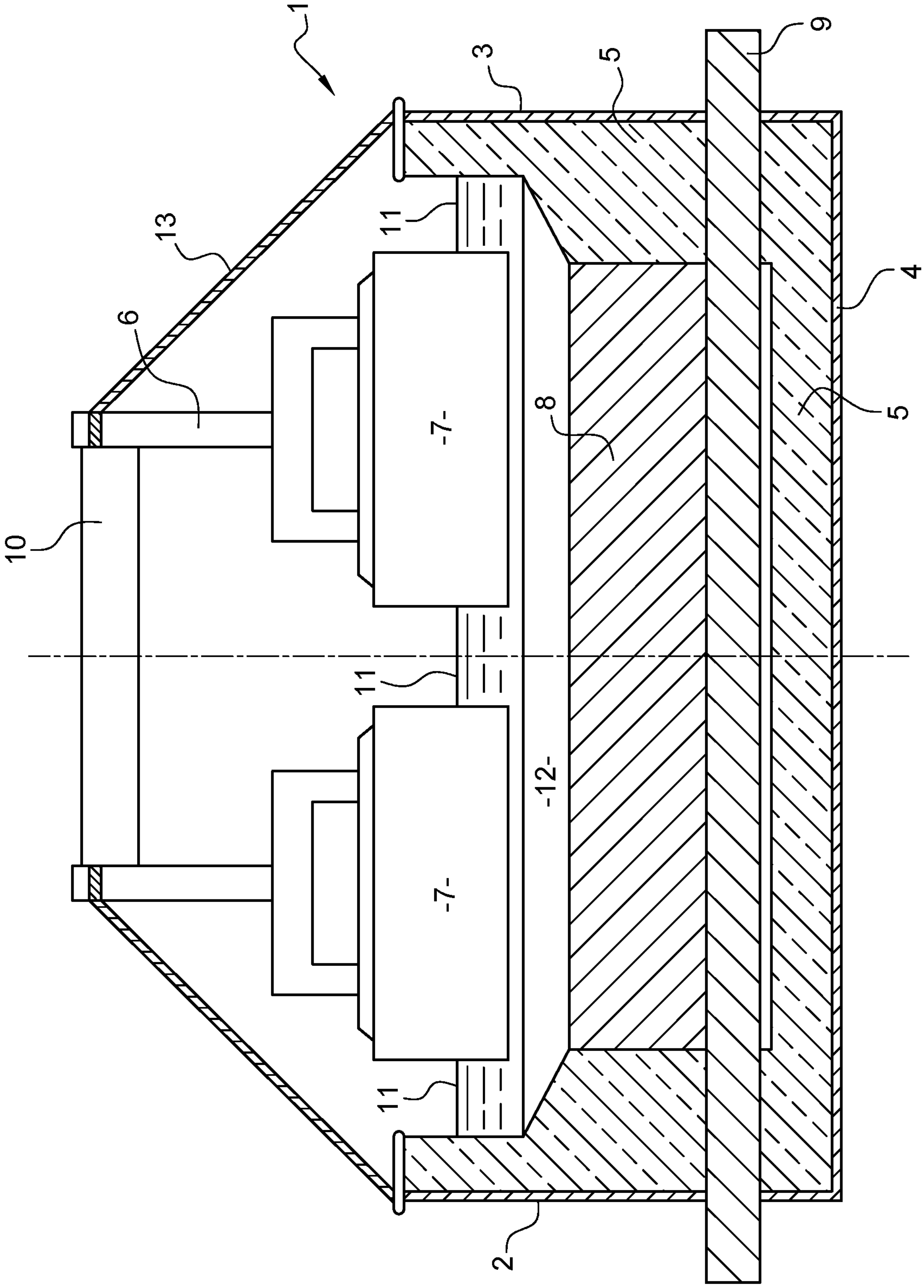

Fig. 1

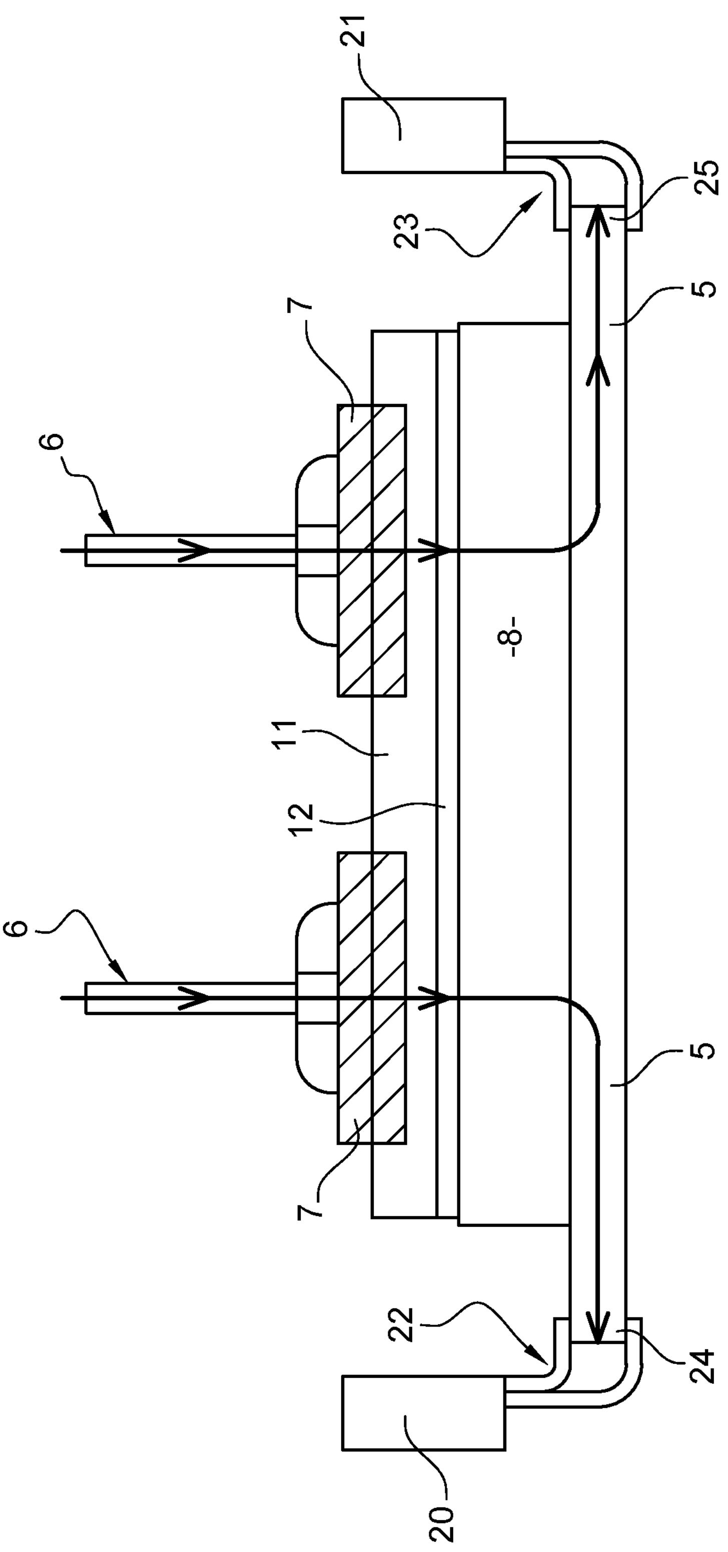

Fig. 2

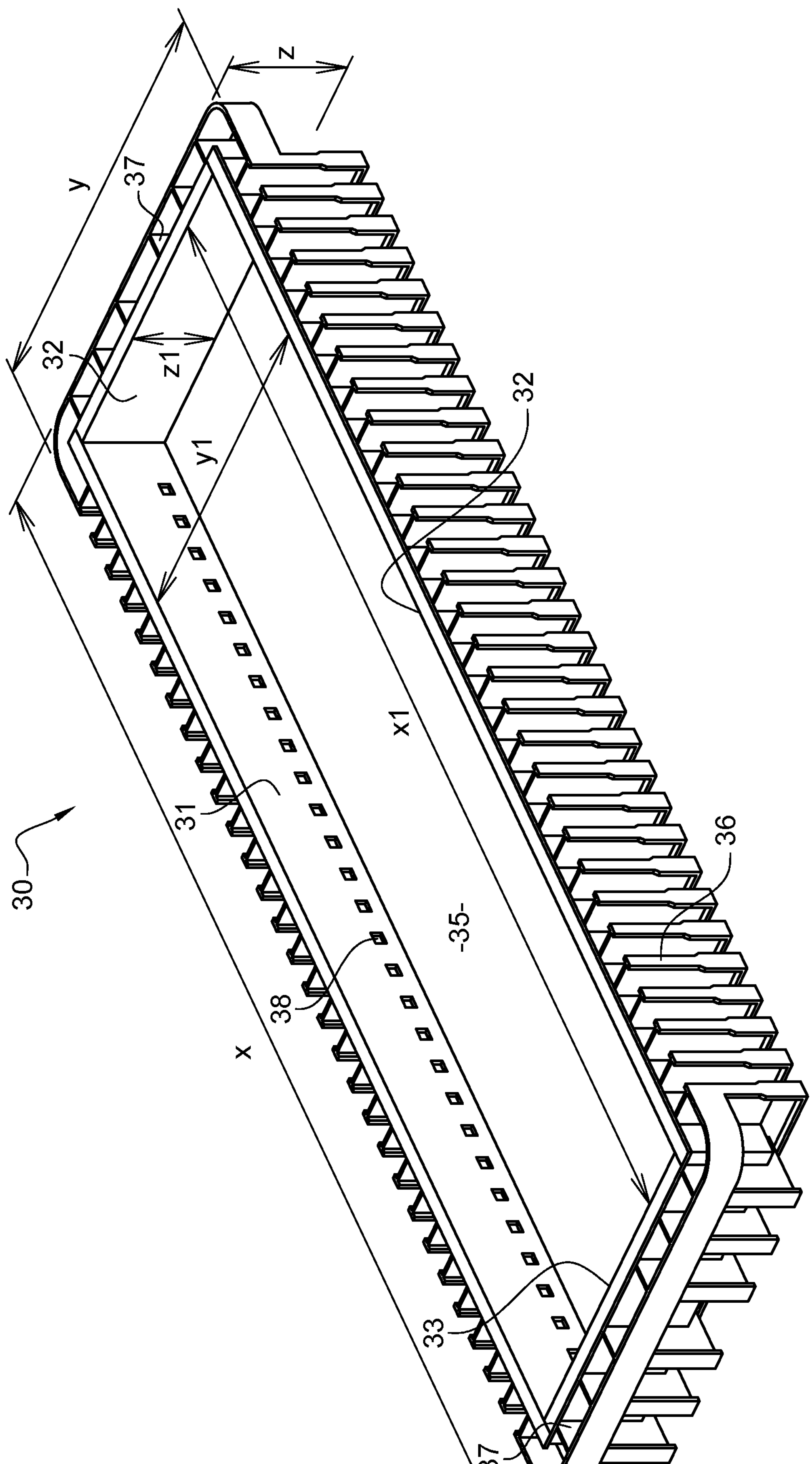

Fig. 3

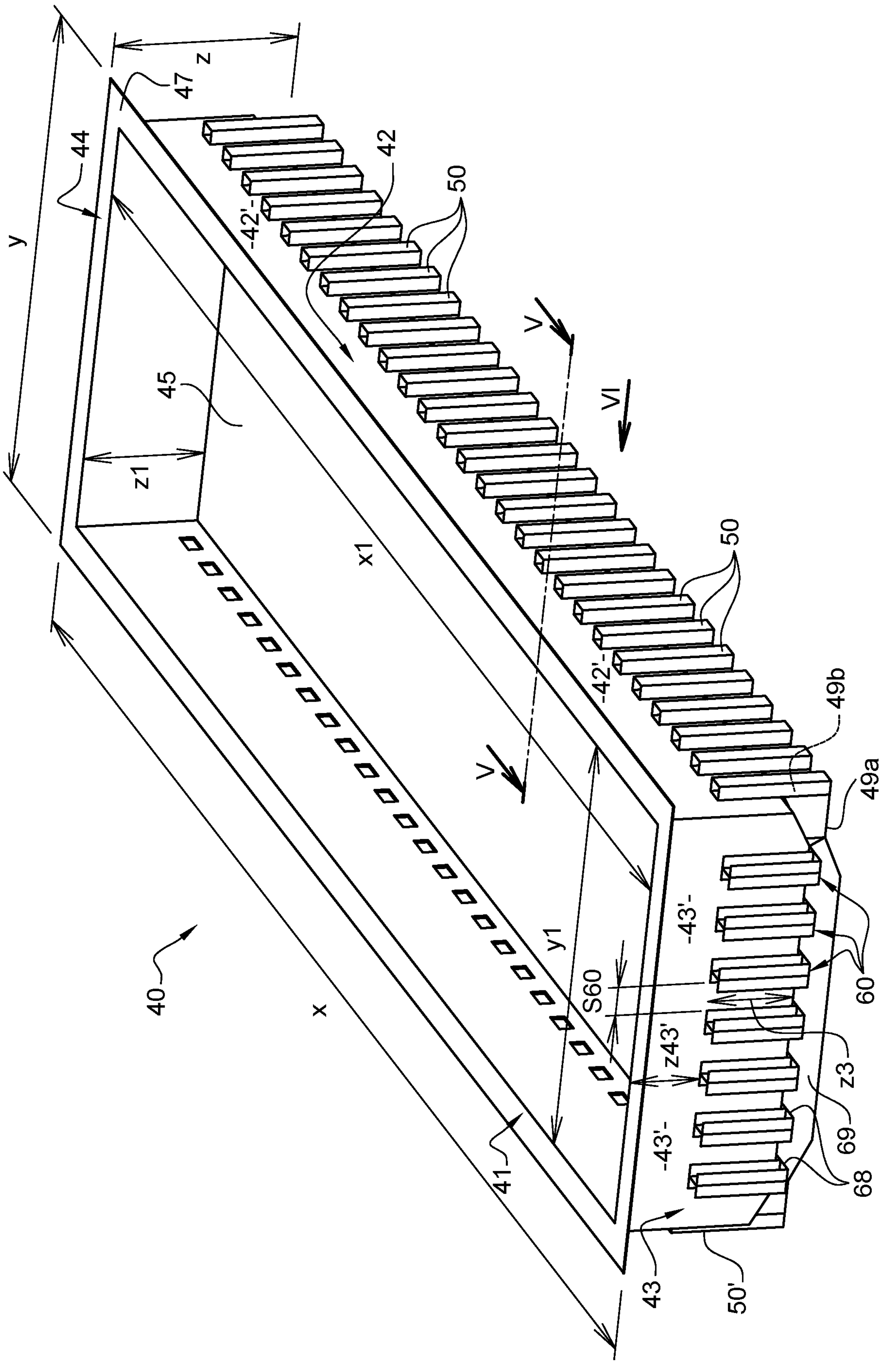
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Fig. 4

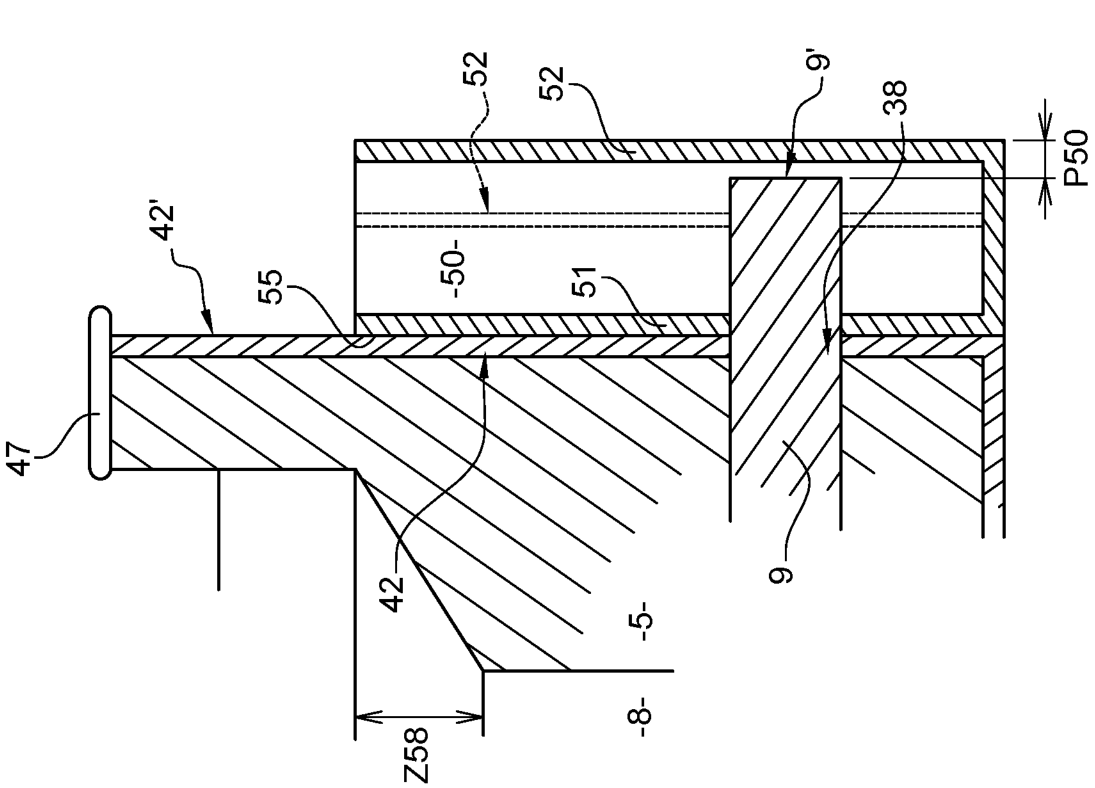

Fig. 5

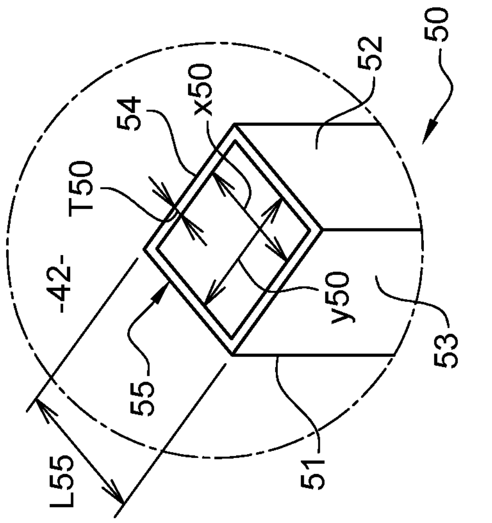

Fig. 7

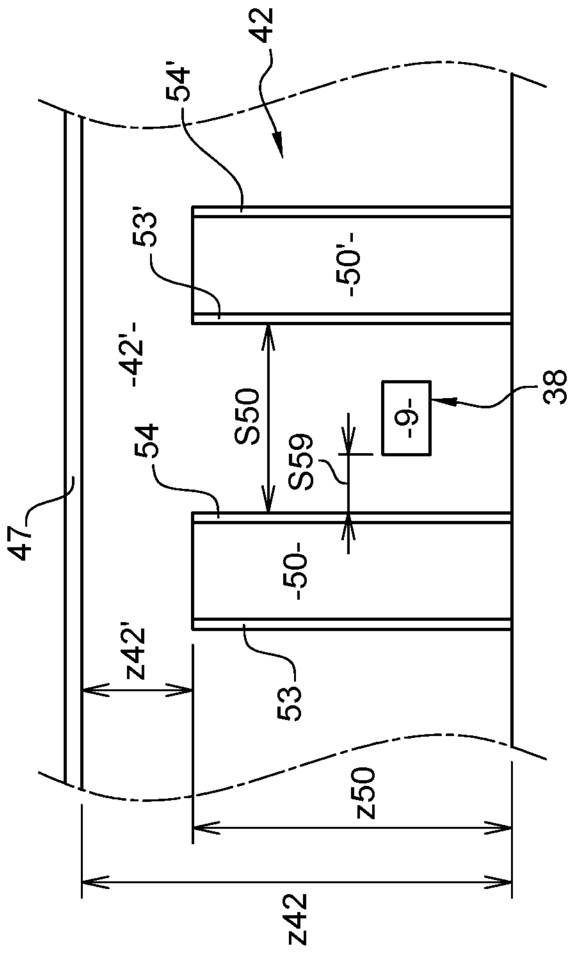

Fig. 6

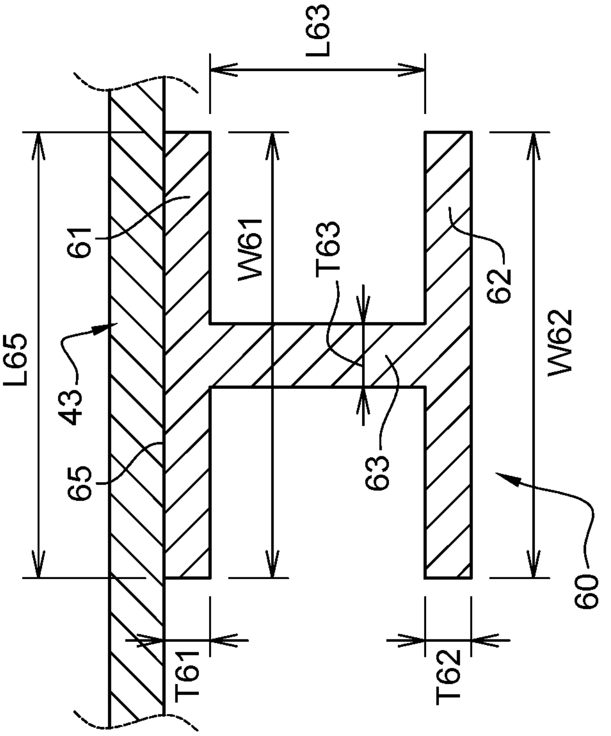

Fig. 9

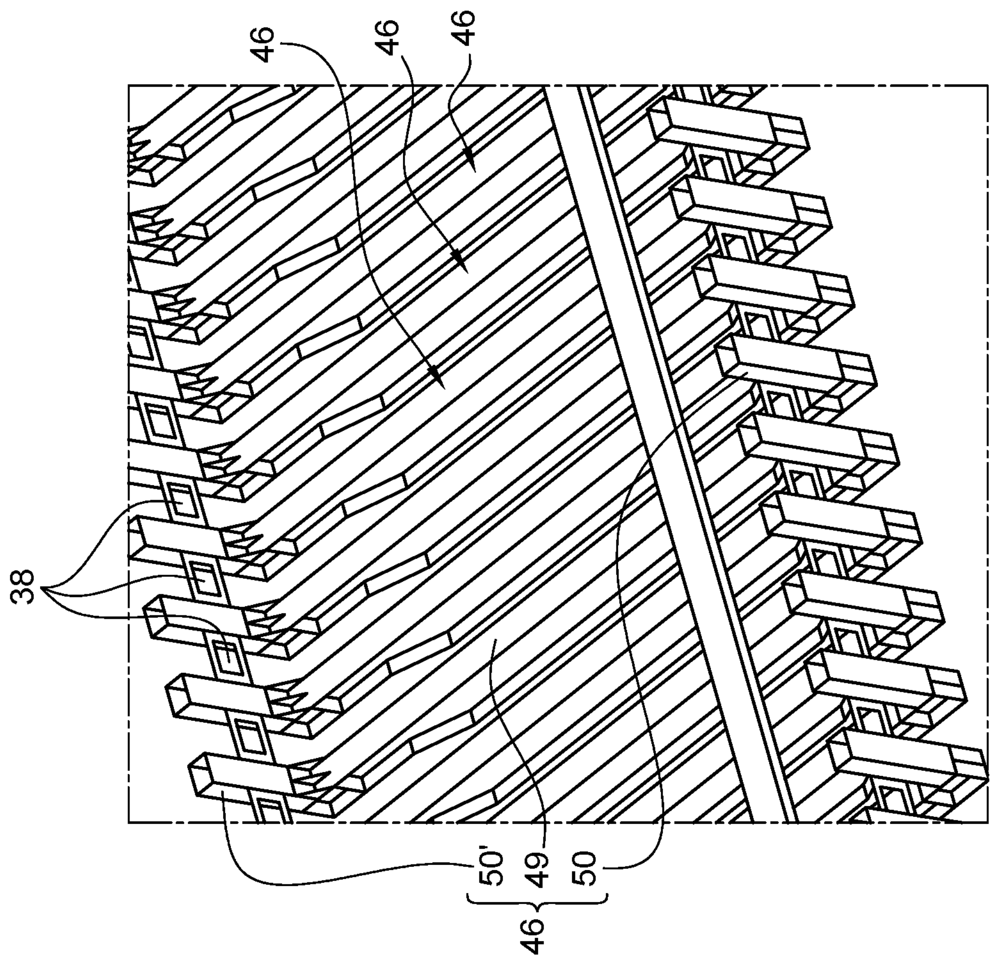

Fig. 8

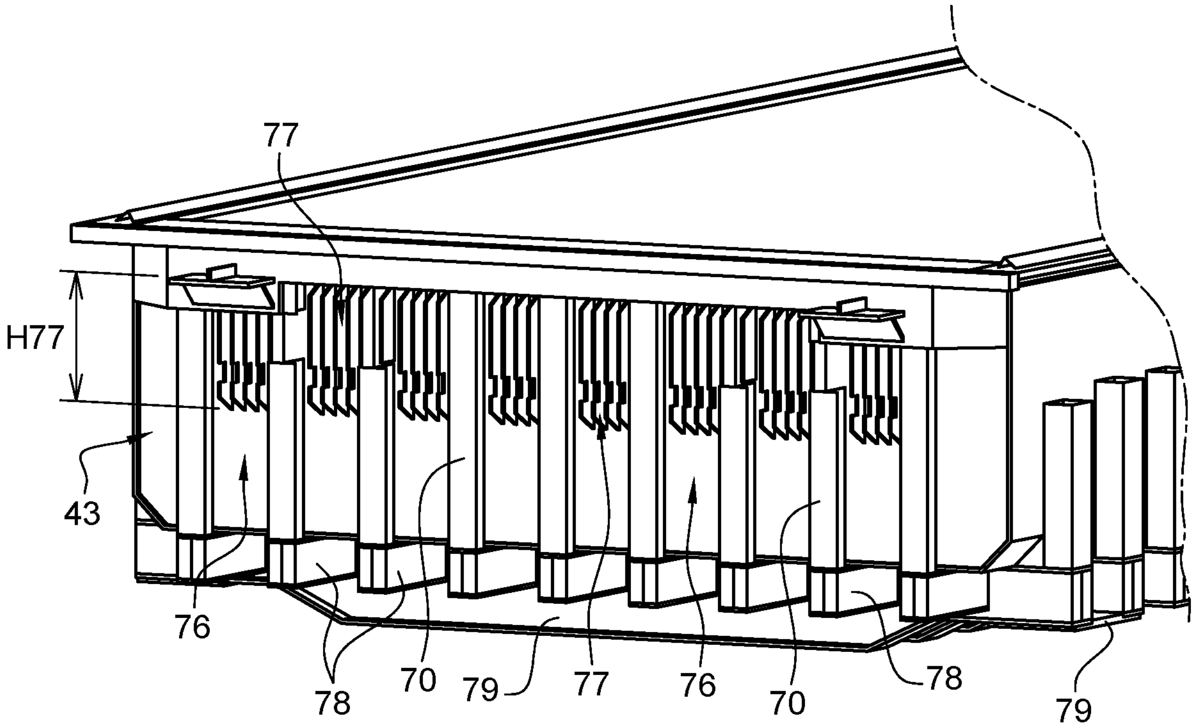
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Fig. 10

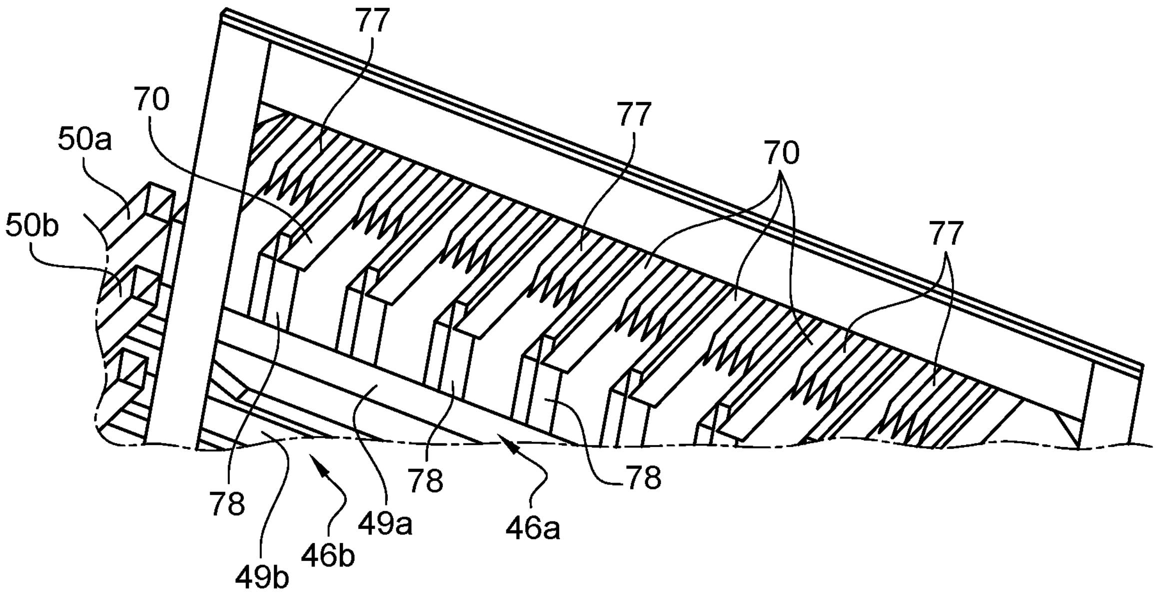
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Fig. 11

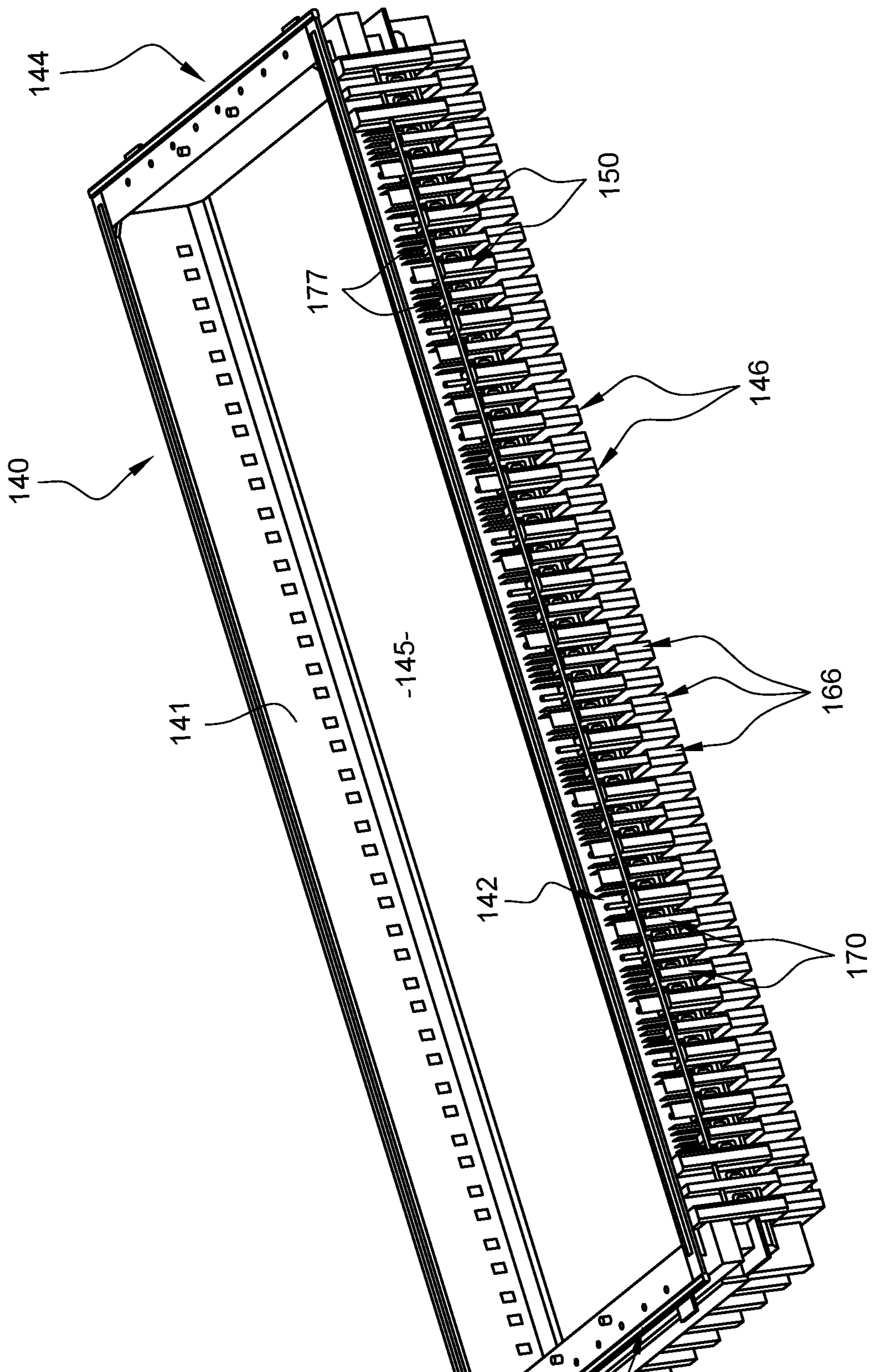

Fig. 12

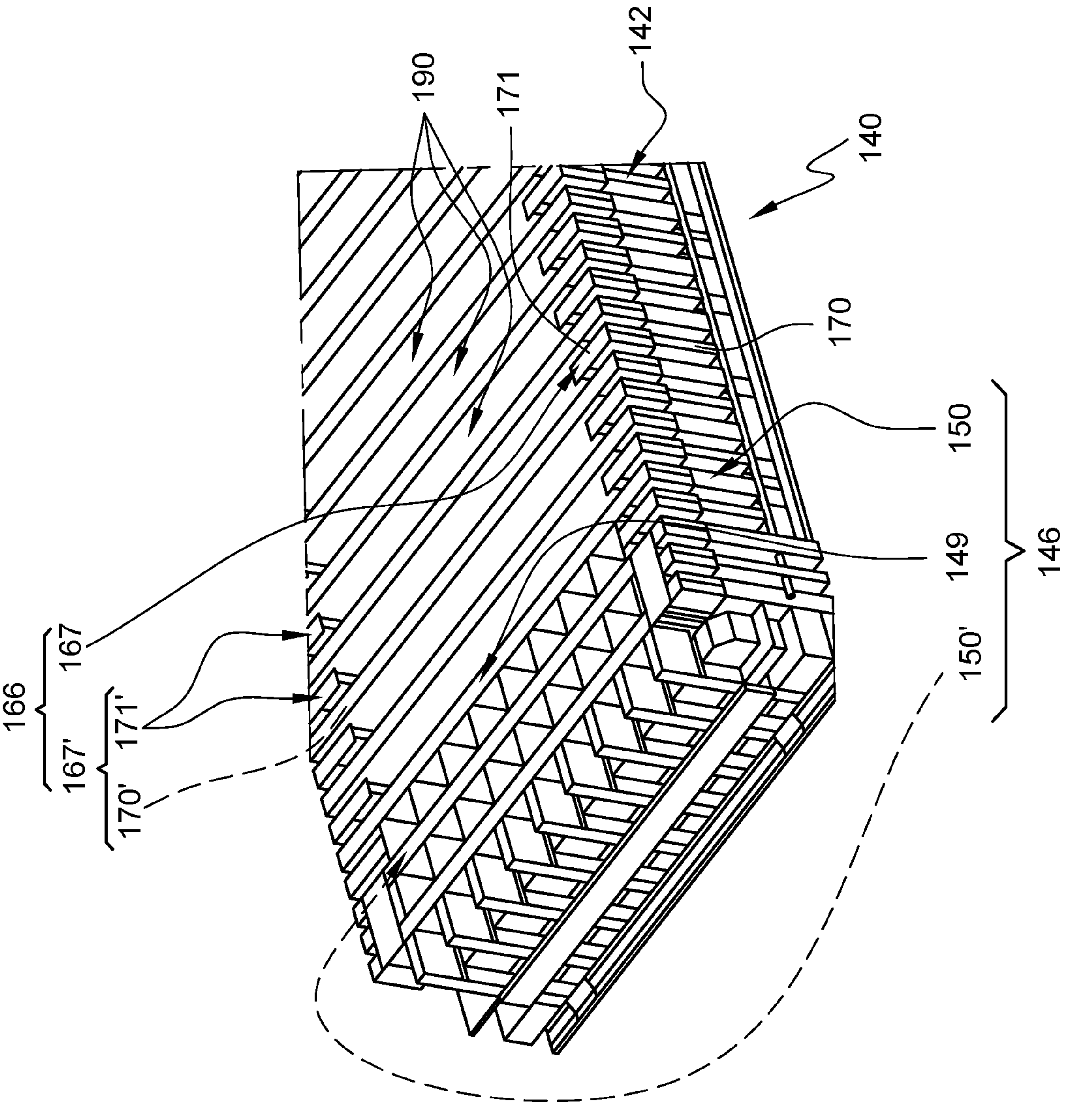

Fig. 13

INTERNATIONAL SEARCH REPORT

International application No.
PCT / IB 2019/052419

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***C25C 3/06*** (2006.01); ***C25C 3/10*** (2006.01)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C25C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPIAP, EPODOC, PAJ, PATDEW, PATENW, Espacenet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4087345 A (SANDVIK et al.) 02 May 1978 (02.05.1978) whole document	1-25
A	US 4322282 A (JEMEC, RAOUL) 30 March 1982 (30.03.1982) Claims 1 and 5, figure 2, abstract	1-25
A	US 4421625 A (FISCHER et al.) 20 December 1983 (20.12.1983) Claims 1, 8 and 17, figure 3, abstract	1-25
A	WO 2006053372 A1 (BHP BILLITON INNOVATION PTY LTD) 26 May 2006 (26.05.2006) Claims, figure 3	1-25
A	WO 2016077932 A1 (HATCH LTD) 26 May 2016 (26.05.2016) Claims, figure 2	1-25

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
15 July 2019 (15.07.2019)	16 July 2019 (16.07.2019)
Name and mailing address of the ISA/AT Austrian Patent Office Dresdner Straße 87, A-1200 Vienna Facsimile No. +43 / 1 / 534 24-535	Authorized officer STEPANOVSKY M. Telephone No. +43 / 1 / 534 24-135

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT / IB 2019/052419

Patent document cited in search report			Patent family member(s)			Publication date
US	A	4087345	US	A	4087345	1978-05-02
US	A	4322282	BR	A	8006723	1981-04-22
			DE	A1	2948104	1981-04-30
			GB	A	2060705	1981-05-07
			CH	A5	643602	1984-06-15
			AU	A	6303180	1981-04-30
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