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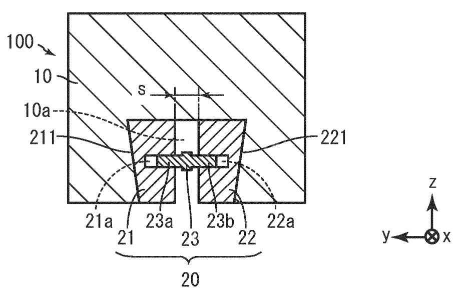
(54) **CATHODE ASSEMBLY**

(57) A cathode assembly is provided that enables simplifying the work of connecting a cathode block with a collector bar. A cathode assembly (100) is a cathode assembly used in an electrolytic furnace for aluminum smelting, including: a cathode block (10) made of carbon and having a groove (10a); and a collector bar unit (20) inserted into the groove (10a), wherein the collector bar unit (20) includes: two collector bars (21) and (22) made of a metal and shaped to extend in the same direction as the groove (10a) and arranged in the width direction of the groove (10a); and a spacing adjustment member (23) that adjusts the spacing between the two collector bars (21) and (22), the spacing adjustment member (23) including a mechanism that adjusts the spacing between the two collector bars (21) and (22) using threads.

Fig.3



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Description

TECHNICAL FIELD

[0001] The present invention relates to a cathode assembly.

BACKGROUND ART

[0002] An electrolytic furnace for aluminum smelting has a negative electrode (i.e., cathode) constituted by cathode blocks made of carbon. The cathode blocks are installed in a steel box called a "shell" and contains the furnace bottom of the electrolytic furnace. Another role played by the cathode blocks is to supply the electrolytic bath with electrons.

[0003] A cathode block is supplied with electrons via a metallic collector bar. An assembly with a cathode block and a collector bar connected thereto will be hereinafter referred to as "cathode assembly".

[0004] Connection between a cathode block and a collector bar is established by casting cast iron in between the two components. Specifically, it is achieved by forming a groove in the bottom surface of the cathode block and fitting the collector bar therein, and pouring molten cast iron heated to about 1250 °C into the gap.

[0005] WO 2018/134754 A1 discloses a cathode assembly including a cathode body made of a carbonaceous material and at least one cathode collector bar made of a metallic material. This cathode collector bar includes two bar elements. Each of the two bar elements has a main side surface to contact a side of a slot in the cathode body and a tapered surface. The two tapered surfaces form the contact line between the two bar elements.

[0006] JP 2017-534770 A discloses a cathode current-collector assembly assembled in a carbon cathode. This cathode current-collector assembly includes a current collector bar made of a high-conductivity metal positioned below the carbon cathode. This current collector bar includes an electrically conductive, flexible foil or sheet at the interface between the bar and the carbon cathode.

[0007] U.S. Patent No. 7776190 discloses a cathode used in an aluminum electrolysis cell. This cathode includes: a cathode block selected from: a carbon cathode block and a graphite cathode block, the cathode block having a collector bar slot formed therein; a collector bar made of steel and positioned in the collector bar slot; and an expanded graphite that lines the collector bar slot. FIG. 10 of this publication shows that contact resistance can be reduced by providing a foil of expanded graphite in the cathode slot (i.e., groove).

PRIOR ART DOCUMENTS

PATENT DOCUMENTS

[0008]

Patent Document 1: WO 2018/134754 A1
Patent Document 2: JP 2017-534770 A
Patent Document 3: U.S. Patent No. 7776190

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0009] Such methods involving casting cast iron require a large workload and, in addition, energy costs associated with the heating for melting cast iron and the preheating of the cathode block and collector bars. Further, if the preheating temperature is too high, the cathode block oxidizes; in view of this, the preheating temperature can only be raised to 400 to 500 °C, which poses a risk of the cathode block breaking due to a thermal shock during the pouring of molten cast iron.

[0010] The start-up of an electrolytic furnace is typically performed by raising the furnace temperature using resistive heat, a method known as resistor baking. In resistor baking, a DC current is passed through the electrolytic furnace to produce resistive heat, which is used to raise the temperature in the furnace. During start-up, for example, if the contact pressures between some cathode blocks and their collector bars are different from the others, electric current concentrates in those cathode assemblies which are experiencing high contact pressure, causing an abnormal temperature increase in these cathode assemblies. The cathode assemblies with abnormal temperature rise experience larger thermal expansion of the collector bars, making the contact between the cathode blocks and collector bars even stronger. This means an even lower contact resistance in those cathode assemblies, causing further concentration of current. There is a risk that a thermal shock by this mechanism may cause a cathode block to break.

[0011] An object of the present invention is to provide a cathode assembly that enables simplifying the work of connecting a cathode block with a collector bar. Another object of the present invention is to provide a cathode assembly that enables reducing variations in the contact resistance during temperature increase in the electrolytic furnace.

MEANS FOR SOLVING THE PROBLEMS

[0012] A cathode assembly according to one embodiment of the present invention is a cathode assembly used in an electrolytic furnace for aluminum smelting, including: a cathode block made of carbon and having a groove; and a collector bar unit inserted into the groove, the collector bar unit including: two collector bars made of a metal and shaped to extend in the same direction as the groove and arranged in a width direction of the groove; and a spacing adjustment member configured to adjust a spacing between the two collector bars, the spacing adjustment member including a mechanism adapted to adjust the spacing between the two collector bars using a thread.

EFFECTS OF THE INVENTION

[0013] The present invention simplifies the work of connecting a cathode block with a collector bar. The present invention also reduces variations in the contact resistance between the cathode block and collector bar during temperature increase in the electrolytic furnace.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

[FIG. 1] FIG. 1 is a cross-sectional view of an exemplary electrolytic furnace for aluminum smelting, schematically showing its entire construction.
[FIG. 2] FIG. 2 is a schematic perspective view of the construction of a cathode assembly according to a first embodiment of the present invention.
[FIG. 3] FIG. 3 is a cross-sectional view taken along line III-III of FIG. 2.
[FIG. 4] FIG. 4 is an exploded schematic perspective view of the construction of the collector bar unit included in the cathode assembly of FIG. 2.
[FIG. 5] FIG. 5 is an exploded schematic perspective view of the construction of a collector bar unit included in a cathode assembly according to a second embodiment of the present invention.
[FIG. 6] FIG. 6 is an exploded schematic perspective view of the construction of a collector bar unit included in a cathode assembly according to a third embodiment of the present invention.
[FIG. 7] FIG. 7 is a schematic cross-sectional view of the construction of a spacing adjustment member included in the collector bar unit of FIG. 6.
[FIG. 8] FIG. 8 is a schematic cross-sectional view of an exemplary arrangement of a conductive member.
[FIG. 9] FIG. 9 is a schematic cross-sectional view of an exemplary arrangement of conductive members.
[FIG. 10] FIG. 10 is a schematic cross-sectional view of an exemplary arrangement of conductive members.
[FIG. 11] FIG. 11 is a schematic perspective view of the construction of an exemplary collector bar.
[FIG. 12] FIG. 12 is a schematic perspective view of the construction of another exemplary collector bar.
[FIG. 13] FIG. 13 is a schematic cross-sectional view of the construction of a cathode assembly according to a sixth embodiment of the present invention.
[FIG. 14] FIG. 14 is a schematic cross-sectional view of the construction of an exemplary cathode assembly including a double-slot-type cathode block.
[FIG. 15] FIG. 15 is a schematic cross-sectional view of the construction of a cathode assembly according to a seventh embodiment of the present invention.
[FIG. 16] FIG. 16 is a schematic cross-sectional view of the construction of a test instrument used to measure changes in contact pressure caused by thermal expansion.
[FIG. 17] FIG. 17 is a photograph of the test instrument.
[FIG. 18] FIG. 18 is a graph showing the relationship between temperature and load.

EMBODIMENTS FOR CARRYING OUT THE INVENTION

[0015] Now, embodiments of the present invention will be described in detail with reference to the drawings. In the drawings, the same or corresponding elements are labeled with the same reference numerals, and their description will not be repeated. The size ratios of the components shown in the drawings do not necessarily indicate the actual size ratios.

[First Embodiment]

[Entire Construction]

[0016] FIG. 1 is a cross-sectional view of an exemplary electrolytic furnace for smelting aluminum, i.e., electrolytic furnace 1, schematically showing its entire construction.

[0017] The electrolytic furnace 1 includes a cathode assembly 100 according to a first embodiment of the present invention. A plurality of cathode assemblies 100 are arranged in the depth direction (i.e., y-direction) in FIG. 1. Each of the cathode assemblies 100 includes a cathode block 10 made of carbon and two collector bar units 20. The cathode blocks 10 constitute the furnace bottom of the electrolytic furnace 1. Each collector bar unit 20 includes metallic collector bars (details of their construction will be given further below) and is electrically connected to the cathode block 10 at these collector bars. For each collector bar unit 20, one end extends outside the electrolytic furnace 1.

[0018] In addition to the cathode assemblies 100, the electrolytic furnace 1 includes an anode 91, a shell 92, and a lining 93, among other components. Inside the electrolytic furnace 1 is contained melt 94 that contains aluminum oxide. The collector bar units 20 as well as the anode 91 are electrically connected to a power source, not shown. The power source applies a voltage between the cathode blocks 10 and the anode 91. This reduces the aluminum oxide in the melt 94 to aluminum 95.

[Construction of Cathode Assembly 100]

[0019] The construction of a cathode assembly 100 will be described in detail with reference to FIG. 2 and 3. FIG. 2 is a schematic perspective view of the construction of the cathode assembly 100. FIG. 3 is a cross-sectional view taken along line III-III of FIG. 2.

[0020] As discussed above, the cathode assembly 100 includes a cathode block 10 and two collector bar units 20.

[0021] The cathode block 10 is made of carbon. "Cathode block made of carbon" encompasses a cathode block made of a composite material of TiB_2, TiC or the like with carbon. The cathode block 10 is preferably made of graphite. The cathode block 10 has the shape of a rectangular parallelepiped, and includes a groove 10a in its bottom surface. In addition to the bottom surface of the cathode block 10, the groove 10a is open in side surfaces of the cathode block 10 (i.e., surfaces perpendicular to the x-direction in FIG. 2). Two collector bar units 20 are inserted into the groove 10a.

[0022] Each of the collector bar units 20 includes two collector bars (i.e., a collector bar 21 and a collector bar 22), and a plurality of spacing adjustment members 23 (FIG. 3).

[0023] Each of the collector bars 21 and 22 is made of a metal, preferably steel. Each of the collector bars 21 and 22 is shaped to extend in the same direction as the groove 10a (i.e., x-direction in FIG. 2). The collector bars 21 and 22 are located within the groove 10a and arranged in the width direction of the groove 10a. More specifically, the width direction of the groove 10a means the direction perpendicular to both the direction in which the groove 10a extends (i.e., x-direction in FIG. 2) and the vertical direction (i.e., z-direction in FIG. 2), i.e., the width direction of the groove 10a means the y-direction in FIG. 2.

[0024] The spacing adjustment members 23 (FIG. 3) are disposed between the collector bars 21 and 22 to adjust the spacing *s* between the collector bars 21 and 22. Details of the construction of the spacing adjustment members 23 and the method of adjusting the spacing *s* will be given further below.

[0025] The collector bars 21 and 22 include surfaces 211 and 221 (FIG. 3) that contact the respective side surfaces of the groove 10a. It is preferable that the surfaces 211 and 221 fit snugly in the respective side surfaces of the groove 10a.

[0026] FIG. 2 and 3 show an implementation where, as seen in a cross section perpendicular to the direction in which the groove 10a of the cathode block 10 extends (i.e., yz-cross section in FIG. 3), the groove 10a has a trapezoidal cross-sectional shape of an opening with a width decreasing toward the bottom surface. This cross-sectional shape is preferable because it is capable of preventing the collector bar unit 20 from dropping through the bottom surface. Nevertheless, the groove 10a may have any cross-sectional shape. The groove 10a may have a rectangular cross-sectional shape, for example.

[0027] The collector bars 21 and 22, too, may have any cross-sectional shape. Nevertheless, as discussed above, it is preferable that the surfaces 211 and 221 that contact the respective side surfaces of the groove 10a fit snugly in the respective side surfaces of the groove 10.

[0028] Although not shown, the gap between the collector bars 21 and 22 is preferably filled with a filler. The filler may be cement, for example.

[0029] Although not shown, it is preferable that a spacer of a thermoplastic resin or a metal or alloy with a melting point not higher than 700 °C is positioned between the collector bars 21 and 22, for example. Specifically, it is preferable that a spacer of a thermoplastic resin or a metal or alloy with a melting point not higher than 700 °C is positioned at least one of between the collector bars 21 and 22 (if the above-mentioned filler fills this space, at least one between the collector bar 21 and the filler and between the collector bar 22 and the filler), between the collector bar 21 and the associated side surface of the groove 10a, and between the collector bar 22 and the associated side surface of the groove 10a. The metal with a melting point not higher than 700 °C may be aluminum, for example. It is preferable that the spacer is sheet-shaped.

[0030] Next, details of the construction of the spacing adjustment members 23 and the method of adjusting the spacing *s* (FIG. 3) between the collector bars 21 and 22 will be described with reference to FIG. 4. FIG. 4 is an exploded schematic perspective view of the construction of the collector bar unit 20. As discussed above, the collector bar unit 20 includes collector bars 21 and 22 and a plurality of spacing adjustment members 23.

[0031] The spacing adjustment members 23 are located between the collector bars 21 and 22 and arranged in the longitudinal direction of the collector bars 21 and 22, spaced apart from one another by generally the same distance. The spacing adjustment members 23 are disposed such that they will be present only inside the cathode block 10, and not outside the cathode block 10, when the collector bar unit 20 has been inserted into the groove 10a (FIG. 2) of the cathode block 10.

[0032] The spacing adjustment members 23 may have high or low electrical conductivity. The spacing adjustment members 23 may be made of metal, for example.

[0033] Each of the spacing adjustment members 23 includes a threaded portion 23a at one end and a threaded portion 23b at the other. The collector bar 21 includes threaded holes 21a that allow the threaded portions 23a to be screwed therein. The collector bar 22 includes threaded holes 22a that allow the threaded portions 23b to be screwed therein. In this construction, the spacing *s* (FIG. 3) between the collector bars 21 and 22 may be adjusted by changing the amount of screwing between the threaded portions 23a and the threaded holes 21a and the amount of screwing between the threaded portions 23b and the threaded holes 22a.

[0034] According to the present embodiment, a threaded portion 23a and a threaded portion 23b have threads in opposite directions. Specifically, if a threaded portion 23a has a right-handed thread, a threaded portion 23b has a left-handed thread. If a threaded portion 23a has a left-handed thread, a threaded portion 23b has a right-handed thread. In this construction, rotating a spacing adjustment member 23 in one direction moves both the threaded portions 23a and 23b to be tightened simultaneously (or loosed simultaneously). Thus, the collector bars 21 and 22 can be moved in a uniform manner.

[Effects of Cathode Assembly 100]

[0035] In the construction of the cathode assembly 100 according to the present embodiment, each collector bar unit 20 includes collector bars 21 and 22 arranged in the width direction of the groove 10a. The collector bar unit 20 further includes spacing adjustment members 23 that adjust the spacing *s* (FIG. 3) between the collector bars 21 and 22.

[0036] With the surfaces 211 and 221 in contact with the respective side surfaces of the grooves 10a, rotating the spacing adjustment members 23 in a direction that increases the spacing *s* increases the contact pressure between the collector bars 21, 22 and the cathode block 10. On the contrary, rotating the spacing adjustment members 23 in a direction that reduces the spacing *s* reduces the contact pressure between the collector bars 21, 22 and the cathode block 10.

[0037] In other words, the present embodiment enables adjustment of the contact pressure between the collector bars 21, 22 and the cathode block 10. This enables adjustment of the contact resistance between the collector bars 21, 22 and the cathode block 10.

[0038] In an arrangement where collector bars are simply placed in a groove 10a, variations in processing may cause variations in the gaps between the collector bars and groove 10a. This may cause variations in contact resistance, particularly in a low-temperature range (e.g., the temperature range from room temperature up to approximately 500 °C). In an electrolytic furnace 1 (FIG. 1), a plurality of cathode assemblies 100 may be used. Typically, the temperature in an electrolytic furnace 1 is raised by electrical resistance heating (i.e., resistor baking) from room temperature to near an operational temperature (e.g., approximately 960 °C). If there are variations in contact resistance among a plurality of cathode assemblies 100, during temperature rise, electric current concentrates in cathode assemblies 100 with low contact resistance, which may cause a local temperature increase. During operation, too, electric current concentrating in cathode assemblies 100 with low contact resistance may cause local wear of the cathode electrolysis surfaces, or lead to biased thermal balance that may destabilize operations.

[0039] Conventionally, the gaps between the collector bars and groove 10a may be filled by pouring molten cast iron therein. Such methods involving casting cast iron require a large workload. The present embodiment will simplify the work of connecting the cathode block with the collector bars compared with methods involving casting cast iron. Further, it will reduce the energy costs associated with the heating for melting cast iron and the preheating of the cathode block and collector bars. Furthermore, since there is no risk of breaking due to a thermal shock, the manufacturing cost will be reduced.

[0040] The present embodiment further produces the effect of reducing variations in the contact resistance between the cathode block 10 and the collector bars 21, 22 during temperature rise in the electrolytic furnace 1, as will be discussed below.

[0041] During temperature rise in the electrolytic furnace 1, the cathode blocks 10 and collector bars 21 and 22 thermally expand such that the contact pressures between the collector bars 21 and 22 and the cathode blocks 10 vary. During temperature rise, a temperature gradient may be generated in the electrolytic furnace, which may cause non-uniform thermal expansion within the electrolytic furnace.

[0042] FIG. 10 of U.S. Patent No. 7776190 shows that a foil of expanded graphite may be provided in a cathode slot (i.e., groove) to reduce contact resistance. Meanwhile, the same graph shows that, in the range of contact pressure up to $2 N/mm^2$, an increase in contact pressure causes a rapid change in contact resistance from a value not lower than $100\ m\Omega\cdot cm^2$ to a value near $25\ m\Omega\cdot cm^2$.

[0043] Non-uniform thermal expansion may result in non-uniform contact pressure, which in turn may result in non-uniform contact resistance, causing non-uniform current. A large amount of non-uniform current may cause rapid local temperature increase, which may cause local oxidation or breaking of the affected cathode block 10.

[0044] According to the present embodiment, the spacing adjustment members 23 may be used to adjust contact pressure to a predetermined level (e.g., $2 N/mm^2$) or higher in advance when the assembly is still at room temperature. This enables preventing contact resistance from significantly varying due to thermal expansion during temperature rise. Particularly, according to the present embodiment, the spacing adjustment members 23 include a mechanism that adjusts the spacing *s* using threads, which enables fine adjustment of contact pressure. Furthermore, since a plurality of spacing adjustment members 23 are arranged in the longitudinal direction of the collector bars 21 and 22, contact pressure can be adjusted across the entire length of the collector bars 21 and 22.

[0045] After contact pressure has been adjusted using the spacing adjustment members 23, it is preferable to fill the gap between the collector bars 21 and 22 with a filler. During operation, the cathode assembly 100 is heated to a high temperature (e.g., 960 °C). Thermal expansion of the collector bars 21 and 22 may cause deformation of the spacing adjustment members 23. Filling the gap between the collector bars 21 and 22 with a filler to increase strength enables maintaining contact pressure when the assembly is at high temperature.

[0046] Further, it is preferable that a spacer of a thermoplastic resin or a metal or alloy with a melting point not higher than 700 °C is provided between the collector bars 21 and 22, for example. Providing a spacer of a thermoplastic resin or a metal or alloy with a melting point not higher than 700 °C will mitigate stress caused by thermal expansion of the collector bars 21 and 22, thereby preventing the cathode block 10 from breaking.

[0047] Although FIG. 4 shows an implementation where the collector bar unit 20 includes six spacing adjustment members 23, any number of spacing adjustment members 23 may be provided. Only one spacing adjustment member 23 may be provided. Nevertheless, providing a plurality of spacing adjustment members 23 arranged in the longitudinal direction of the collector bars 21 and 22 is preferable because this enables adjusting the contact pressure between the collector bars 21, 22 and the cathode block 10 across the length of the collector bars. If a plurality of spacing adjustment members 23 are to be provided, the spacing between the spacing adjustment members 23 need not be equal. Further, in addition to inside of the cathode block 10, spacing adjustment members 23 may also be provided that are disposed such that they will be present outside of the cathode block 10.

[0048] If a plurality of spacing adjustment members 23 are to be provided arranged in the longitudinal direction of the collector bars 21 and 22, adjustment may be made such that the contact pressure between the collector bars 21 and 22 and the cathode block 10 varies depending on the position along the longitudinal direction of the collector bars 21 and 22.

[0049] For example, adjustment may be made such that the contact pressure between the collector bars 21, 22 and the cathode block 10 at the middle of the cathode block 10 as determined along the longitudinal direction of the collector bars 21 and 22 is higher than at the ends of the cathode block 10. In such implementations, as determined along the longitudinal direction of the collector bars 21 and 22, the contact resistance of the cathode block 10 at the ends thereof is higher than that at the middle of the cathode block 10.

[0050] In a typical cathode assembly, electric current tends to concentrate near the ends of the cathode block. A higher contact resistance at the ends of the cathode block 10 as determined along the longitudinal direction of the collector bars 21 and 22, as discussed above, enables achieving a uniform distribution of current flowing through the cathode block 10. This will reduce decrease of overall efficiency and/or local wear.

[0051] The cathode assembly 100 according to the first embodiment of the present invention has been described. The present embodiment will simplify the work of connecting the cathode block with the collector bars.

[0052] The above embodiment describes an implementation where the cathode assembly 100 includes two collector bar units 20. In other words, it describes an implementation where two collector bar units 20 are connected to one cathode block 10. Alternatively, only one collector bar unit 20 may be connected to the cathode block 10, or three or more units may be connected. Further, although the above embodiment describes an implementation where the collector bar units 20 are inserted through two opposite sides of the cathode block 10, a collector bar unit 20 may be passed from one side to the opposite side of the cathode block 10.

[Second Embodiment]

[0053] Cathode assemblies according to second and third embodiments described below are only different from the cathode assembly 100 (FIG. 2) in the construction of the collector bar units. Specifically, in the cathode assembly according to the second or third embodiment, each collector bar unit 20 (FIG. 4) is replaced by a collector bar unit 30 (FIG. 5) or a collector bar unit 50 (FIG. 6), respectively.

[0054] FIG. 5 is an exploded schematic perspective view of the construction of a collector bar unit 30 included in a cathode assembly according to a second embodiment of the present invention. The collector bar unit 30 includes a collector bar 31 and a collector bar 32, and a plurality of spacing adjustment members 33.

[0055] Each spacing adjustment member 33 includes a threaded portion 33a. The collector bar 31 includes threaded holes 31a that allow such threaded portions 33a to be screwed therein. Similarly, the collector bar 32 includes threaded holes 32a that allow such threaded portions 33a to be screwed therein. Otherwise, the construction of the collector bars 31 and 32 is the same as that of the collector bars 21 and 22 (FIG. 4).

[0056] While a spacing adjustment member 23 of the collector bar unit 20 (FIG. 4) includes threaded portions at both ends thereof, a spacing adjustment member 33 includes a threaded portion 33a at one end only. According to the present embodiment, the spacing between the collector bars 31 and 32 is adjusted by screwing the threaded portion 33a of each spacing adjustment member into a threaded hole of one of the collector bars 31 and 32 (i.e., threaded hole 31a or 32a) and bringing the end of the member that includes no threaded portion 33a into abutment with the other collector bar.

[0057] Similar to the first embodiment, the present embodiment enables adjusting the contact resistance between the collector bars and the cathode block. This will simplify the work of connecting the cathode block with the collector bars.

[0058] While FIG. 5 shows an implementation where the threaded holes 31a and threaded holes 32a are alternately arranged along the longitudinal direction of the collector bars 31 and 32, the threaded holes 31a and threaded holes 32a may be arranged in any manner. For example, no thread holes 31a, and only threaded holes 32a, may be provided.

[Third Embodiment]

[0059] FIG. 6 is an exploded schematic perspective view of the construction of a collector bar unit 50 included in a cathode assembly according to a third embodiment of the present invention. Unlike FIG. 4 and 5, FIG. 6 shows the collector bar unit 50 as seen looking at the bottom of the cathode block.

[0060] The collector bar unit 50 includes a collector bar 51 and a collector bar 52, and a plurality of spacing adjustment members 53.

[0061] The collector bars 51 and 52 include semi-columnar grooves 51a and 52a that will form columnar recesses when the collector bars 51 and 52 are positioned side-by-side. Each spacing adjustment member 53 is positioned in a recess formed by grooves 51a and 52a. Otherwise, the construction of the collector bars 51 and 52 is the same as that of the collector bars 21 and 22 (FIG. 4).

[0062] FIG. 7 is a schematic cross-sectional view of the construction of a spacing adjustment member 53. The spacing adjustment member 53 includes a bolt 531, a sleeve 532, and a base 533.

[0063] The base 533 includes a threaded hole 533a that allows the bolt 531 to be screwed therein. The base 533 is tapered in shape where the outer diameter increases as it goes away from the end surface in which the threaded hole 533a is open.

[0064] The sleeve 532 is cylindrical in shape and is positioned between the head of the bolt 531 and the base 533 to surround the shaft of the bolt 531. The sleeve 532 includes a slit 532a (FIG. 6) that is open in its end portion adjacent to the base 533.

[0065] When the bolt 531 is screwed into the threaded hole 533a in the base 533, the sleeve 532 is pushed by the head of the bolt 531 and moves toward the base 533. At this time, since the base 533 is tapered in shape, the sleeve 532 receives stress in directions that expand it outwardly. This stress enlarges the slit 532a such that the lower end portion of the sleeve 532 expands outwardly.

[0066] As shown in FIG. 6, each spacing adjustment member 53 is positioned in a recess formed by grooves 51a and 52a. When the lower end portion of the sleeve 532 expands outwardly, it pushes the collector bars 51 and 52 to increase the spacing therebetween.

[0067] In other words, the spacing between collector bars 51 and 52 can be increased by screwing in the bolts 531. At this time, the spacing between the collector bars 51 and 52 can be adjusted by changing the amount of screw-in of the bolts 531.

[0068] Similar to the first embodiment, the present embodiment enables adjusting the contact resistance between the collector bars and the cathode block. This will simplify the work of connecting the cathode block with the collector bars.

[0069] The spacing adjustment members 53 are only required to be constructed such that their outer diameter increases in response to some operation. For example, in lieu of screwing in a bolt, a spacing adjustment member may be constructed such that its outer diameter is increased by tightening a nut.

[0070] The cathode assemblies according to the first to third embodiments of the present invention have been described. As can be understood from these embodiments, the spacing adjustment members are only required to be able to adjust the spacing between two collector bars by means of a thread mechanism, and may have various specific constructions.

[0071] A spacing adjustment member includes a mechanism that adjusts the spacing between two collector bars using threads. The thread mechanism enables even finer adjustment of the contact pressure between the two collector bars and the cathode block.

[Fourth Embodiment]

[0072] A cathode assembly according to a fourth embodiment of the present invention is only different from the cathode assembly 100 (FIG. 2) in the construction of the collector bar units. In addition to the components included in a collector bar unit 20 (FIG. 3), each collector bar unit of the cathode assembly according to the present embodiment further includes a conductive member / conductive members made of a metal with a higher electrical conductivity than that for the collector bars 21 and 22. The conductive member(s) may be made of copper, for example.

[0073] FIG. 8 to 10 show exemplary arrangements of a conductive member / conductive members.

[0074] In FIG. 8, in addition to the components included in the collector bar unit 20 (FIG. 3), the collector bar unit 20A further includes a conductive member 24. FIG. 8 does not show the spacing adjustment members 23. The same applies to FIG. 9 and 10. The conductive member 24 is positioned between the upper surfaces of the collector bars 21 and 22 and the bottom surface of the groove 10a. The conductive member 24 may be present across the entire extension of the groove 10a, or may be present intermittently.

[0075] In FIG. 9, in addition to the components included in the collector bar unit 20 (FIG. 3), the collector bar unit 20B further includes conductive members 25. The conductive members 25 are positioned on those surfaces of the respective collector bars 21 and 22 which are opposite to each other.

[0076] In FIG. 10, in addition to the components included in the collector bar unit 20 (FIG. 3), the collector bar unit 20C further includes conductive members 26. The conductive members 26 are embedded within the collector bars 21 and 22.

[0077] As the collector bar unit further includes a conductive member / conductive members made of a metal with a higher electrical conductivity than that for the collector bars 21 and 22, cathode voltage drop (CVD) will be reduced.

[0078] The arrangements of the conductive member(s) shown in FIG. 8 to 10 are merely illustrative, and the conductive members are not limited to these arrangements. Further, although the above embodiment describes constructions starting from the collector bar unit 20 described in connection with the first embodiment where the collector bar unit 20 further includes conductive members, the collector bar units described in connection with the second and third embodiments may be combined with such conductive members.

[Fifth Embodiment]

[0079] A cathode assembly according to a fifth embodiment of the present invention is different from the cathode assemblies according to the first to fourth embodiments in the shape of the collector bars included in the collector bar units. Specifically, each of the collector bars of the cathode assembly according to the present embodiment includes projections on a surface.

[0080] FIG. 11 is a schematic perspective view of the construction of a collector bar 21A, which is an exemplary collector bar included in the cathode assembly according to the present embodiment. The upper surface of the collector bar 21A is provided with a plurality of dot-shaped projections 21Aa. The projections 21Aa may be created by machining the collector bar, or may be created by welding separate metallic components to the collector bar. Although not limiting, it is preferable that the projections 21Aa are disposed such that they will only be present inside the cathode block when the collector bar unit has been inserted into the groove of the cathode block.

[0081] The collector bar 21A receives the load of the cathode block 10 (FIG. 1) and the loads of the melt 94 and aluminum 95 applied thereto. Providing the projections 21Aa reduces the contact area between the collector bar 21A and the cathode block 10. This increases the contact pressure, thereby reducing the contact resistance between the collector bar 21A and cathode block 10. In implementations where a conductive member 24 is positioned between the upper surface of collector bars 21A and the bottom surface of the groove 10a (FIG. 9), providing the projections reduces the contact resistance between the collector bars 21A and conductive member 24.

[0082] FIG. 12 is a schematic perspective view of the construction of a collector bar 21B, which is another exemplary collector bar included in the cathode assembly according to the present embodiment. The upper surface of the collector bar 21B is provided with a plurality of line-shaped of projections 21Ba. As is the case with the collector bar 21A, the construction of the collector bar 21B also reduces the contact resistance between the collector bar 21B and cathode block 10 (FIG. 1) or the contact resistance between the collector bar 21B and conductive member 24 (FIG. 8).

[0083] The shapes and arrangements of the projections 21Aa and projections 21Ba shown in FIG. 11 and 12 are merely illustrative, and the projections are not limited to these shapes and arrangements.

[Sixth Embodiment]

[0084] FIG. 13 is a schematic cross-sectional view of the construction of a cathode assembly 101 according to a sixth embodiment of the present invention. The cathode assembly 101 is different from the cathode assembly 100 (FIG. 3) in the size of the cathode block. The cathode assembly 101 includes a cathode block 11 that replaces the cathode block 10 (FIG. 3) of the cathode assembly 100.

[0085] The cathode assembly 101 may be suitably used to replace a cathode assembly including a cathode block known as a double-slot-type cathode block. FIG. 14 is a schematic cross-sectional view of the construction of a cathode assembly 900, which is an exemplary cathode assembly including a double-slot-type cathode block. The cathode assembly 900 includes a cathode block 910 and two collector bars 920. The cathode block 910 includes two grooves 910a, where each of the grooves 910a receives a collector bar 920 inserted therein.

[0086] The cathode block 11 of the cathode assembly 101 (FIG. 13) includes a single wide groove 11a that replaces the two grooves 910a of the cathode block 910 (FIG. 14). In the cathode assembly 101, the collector bar unit 20 is inserted into this groove 11a.

[0087] In the collector bar unit 20, a clearance is formed between the collector bar 21 and the collector bar 22. Thus, with the groove of the cathode block having the same cross-sectional area, the total cross-sectional area of the collector bars is smaller, although slightly, than that for implementations with a single collector bar. On the other hand, if a cathode assembly including a double-slot-type cathode block is replaced by the cathode assembly 101, the cross-sectional area of the groove of the cathode block is increased, as shown in FIG. 13 and 14; thus, even if a clearance is provided between the collector bars 21 and 22, the total cross-sectional area of the collector bars does not decrease. It is even possible to increase the total cross-sectional area of the collector bars over that before replacement. This will reduce CVD.

[Seventh Embodiment]

[0088] FIG. 15 is a schematic cross-sectional view of the construction of a cathode assembly 102 according to a seventh embodiment of the present invention. In addition to the components of the cathode assembly 100 (FIG. 3), the cathode assembly 102 includes a filler 61 located between the collector bars 21 and 22 and two spacers 62 located between the two collector bars 21 and 22 and the filler 61.

[0089] The filler 61 may or may not be conductive. The filler 61 may be, for example, cement such as aluminum cement, ramming paste, ceramics, steel shot, or coke particles.

[0090] The spacers 62 are made of a thermoplastic resin or a metal or alloy with a melting point not higher than 700 °C. The metal with a melting point not higher than 700 °C may be aluminum, for example. Preferably, the spacers are sheet-shaped. The spacers 62 may or may not be conductive. The spacers 62 are preferably made of a thermoplastic resin.

[0091] It is preferable that spacers 62 are positioned between the collector bars 21 and 22 and the filler 61; alternatively, a spacer may only be provided between one of the collector bars 21 and 22 and the filler 61. In other words, it is sufficient if a spacer 62 is provided between at least one of the collector bars 21 and 22 and the filler 61.

[0092] During operation, the cathode assembly 102 is heated to a high temperature (e.g., 960 °C). Thermal expansion of the collector bars 21 and 22 may deform the spacing adjustment members 23. According to the present embodiment, the filler 61 fills the gap between the collector bars 21 and 22 to increase strength, thereby maintaining the contact pressure when the assembly is at high temperature.

[0093] Furthermore, providing the spacers 62 mitigates stress due to thermal expansion of the collector bars 21 and 22, thus preventing the cathode block 10 from breaking. Further, when the spacers 62 soften, this reduces changes in contact pressure during temperature rise will be reduced.

EXAMPLES

[0094] Now, the present invention will be described more specifically with reference to examples. The present invention is not limited to these examples.

[0095] A test instrument imitating the construction of the cathode assembly of the seventh embodiment described above was used to measure changes in contact pressure caused by thermal expansion. FIG. 16 is a schematic cross-sectional view of the construction of the test instrument 70 used for this measurement. FIG. 17 shows a photograph of the test instrument 70.

[0096] The components 71 and 72 in FIG. 16 were circular columns made of steel corresponding to the collector bars 21 and 22 in FIG. 15. The component 73 was a component corresponding to the spacing adjustment member 23 and, similar to the spacing adjustment member 23, included threaded portions at both ends. The component 74 was made of alumina cement corresponding to the filler 61, while the components 75 were sheets of a thermoplastic resin corresponding to the spacers 62.

[0097] The components 71 and 72 were fixed in such a manner that the distance D between the upper end 71a of the component 71 and the lower end 72a of the component 72 was kept constant. The component 73 was operated to apply an initial load of about 20 kN to the components 71 and 72 and, with this state kept, the gap between the two components 75 was filled with alumina cement to form the component 74. The components 71 and 72 were heated by heating equipment, not shown, and the changes in load caused by thermal expansion of the components 71 and 72, among other components, were measured.

[0098] FIG. 18 is a graph showing the relationship between temperature and load obtained by this test. The load increased from the initial value of 20 kN to about 30 kN in the temperature range from room temperature to about 100 °C before staying near 30 kN in the temperature range up to about 400 °C. The load decreased temporarily in the temperature range near 100 °C presumably because the components 75 of thermoplastic resin softened in this range. The load decreased temporarily in the temperature range near 250 °C presumably because the steel components 71 and 72 softened in this range. As a result, the load was stable near 30 kN in the temperature range from about 100 °C to about 400 °C, with little variation.

[0099] Although the distance D (FIG. 16) was stable in this test, it is assumed that, in an actual cathode assembly, thermal expansion of the cathode block will cause the width of the groove (corresponding to the distance D) to increase as the temperature rises. This suggests that temperature changes in the load in an actual cathode assembly will be smaller than those in FIG. 18, allowing an estimation that the variation in load in the temperature range up to about 500 °C will be reduced.

[0100] In the arrangement of the cathode assembly according to the present embodiment, contact pressure is adjusted to a predetermined level (e.g., 2 N/mm^2) or higher in advance when the assembly is at room temperature to prevent contact resistance from significantly varying due to thermal expansion during temperature rise. In addition, variations in contact pressure will be reduced in the temperature range from room temperature to 500 °C, in which otherwise variations could easily occur in the temperature distribution in the furnace.

[0101] Although embodiments of the present invention have been described, the present invention is not limited to the above-described embodiments, and various modifications are possible within the scope of the invention.

REFERENCE SIGNS LIST

[0102]

1: electrolytic furnace
100, 101, 102, 900: cathode assembly
10, 11, 910: cathode block
10a, 11a, 910a: groove
20, 20A, 20B, 20C, 30, 50: collector bar units
21, 22, 31, 32, 51, 52, 21A, 22A, 920: collector bars
23, 33, 43, 53: spacing adjustment members
61: filler
62: spacers
24, 25, 26: conductive members

91: anode
92: shell
93: lining
94: melt
95: aluminum

Claims

1. A cathode assembly used in an electrolytic furnace for aluminum smelting, comprising:

a cathode block made of carbon and having a groove; and
a collector bar unit inserted into the groove, the collector bar unit including:

two collector bars made of a metal and shaped to extend in the same direction as the groove and arranged in a width direction of the groove; and
a spacing adjustment member configured to adjust a spacing between the two collector bars,
the spacing adjustment member including a mechanism adapted to adjust the spacing between the two collector bars using a thread.

2. The cathode assembly according to claim 1, wherein:

the collector bar unit includes a plurality of spacing adjustment members; and
the plurality of spacing adjustment members are arranged in a longitudinal direction of the two collector bars.

3. The cathode assembly according to claim 1 or 2, wherein the collector bar unit further includes:
a conductive member made of a metal with a higher electrical conductivity than for the two collector bars.

4. The cathode assembly according to claim 1 or 2, further comprising:

a filler positioned between the two collector bars; and
a spacer of a thermoplastic resin or a metal or alloy with a melting point not higher than 700 °C, the spacer positioned between at least one of the two collector bars and the filler.

Fig.1

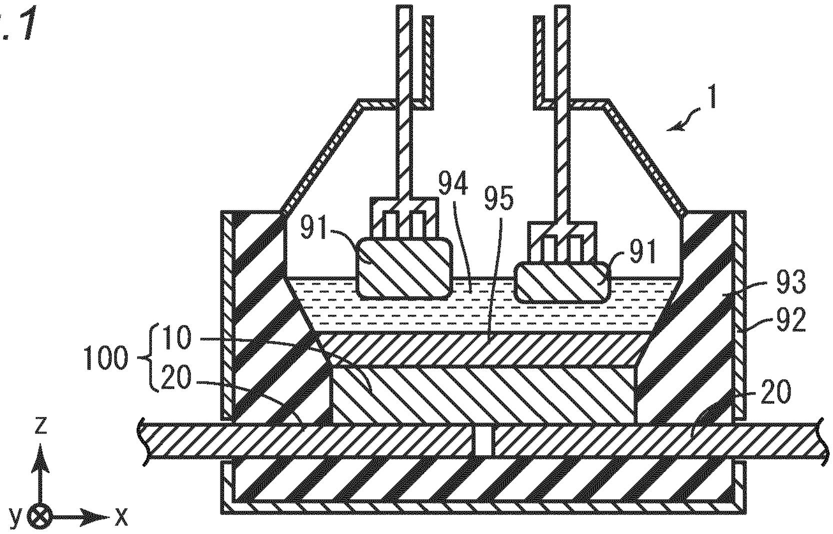


Fig.2

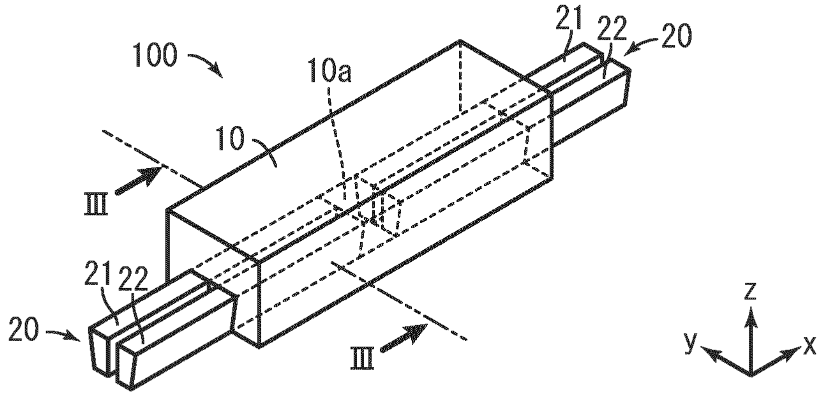


Fig.3

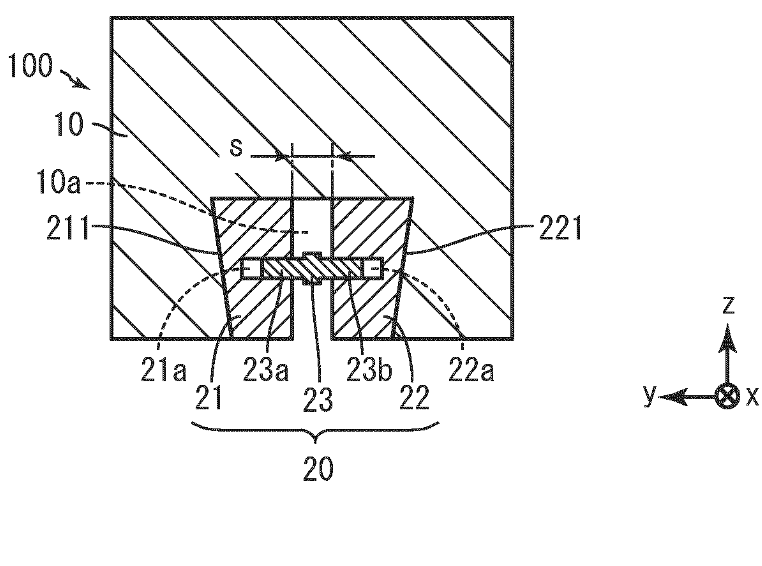
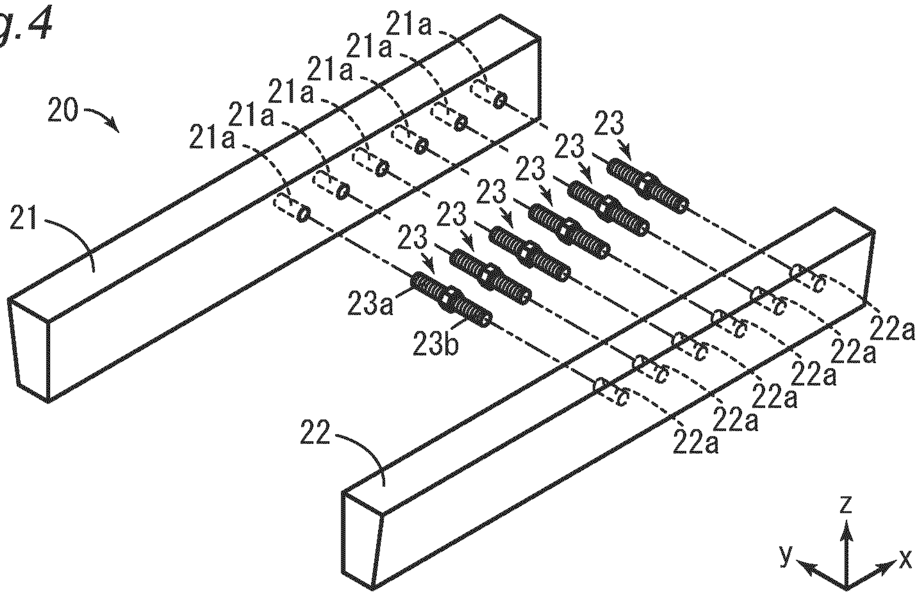


Fig.4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22
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y
x

Fig.5

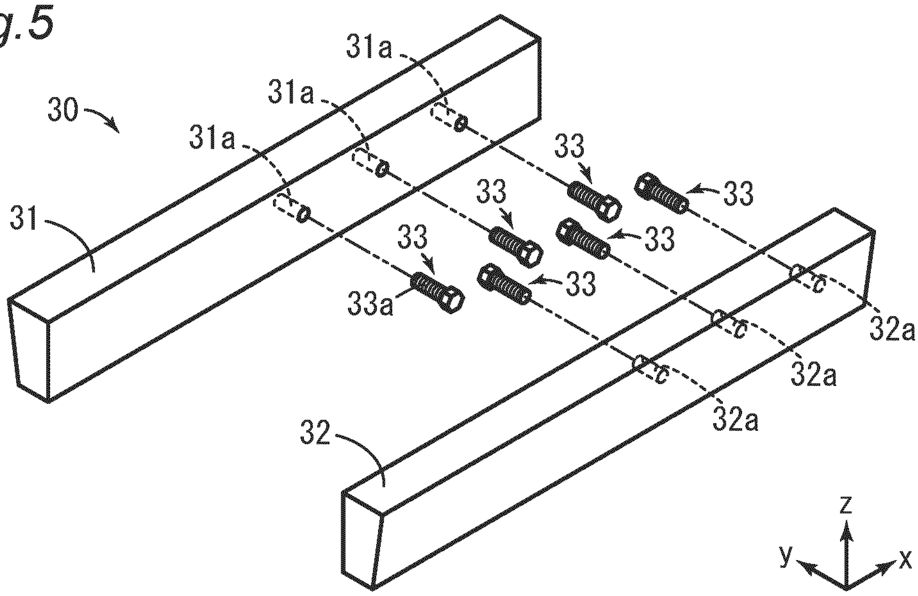
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Fig.6

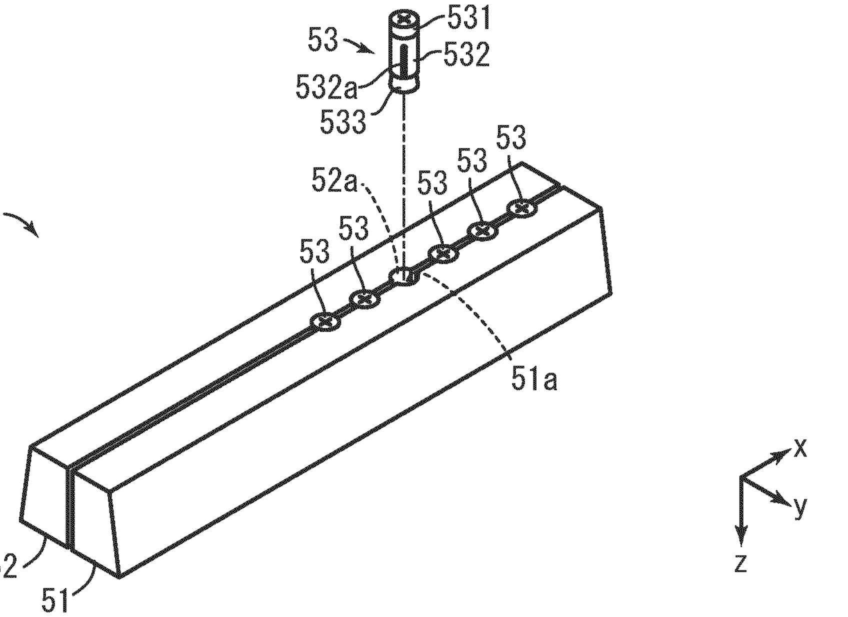
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Fig.7

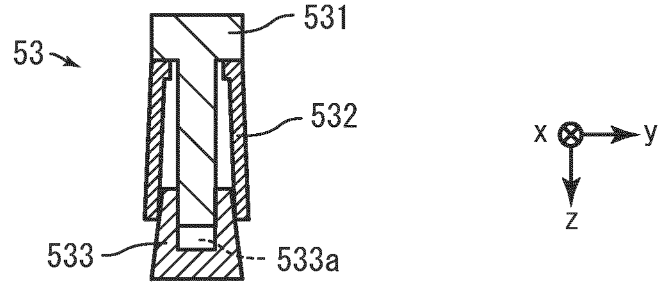
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Fig.8

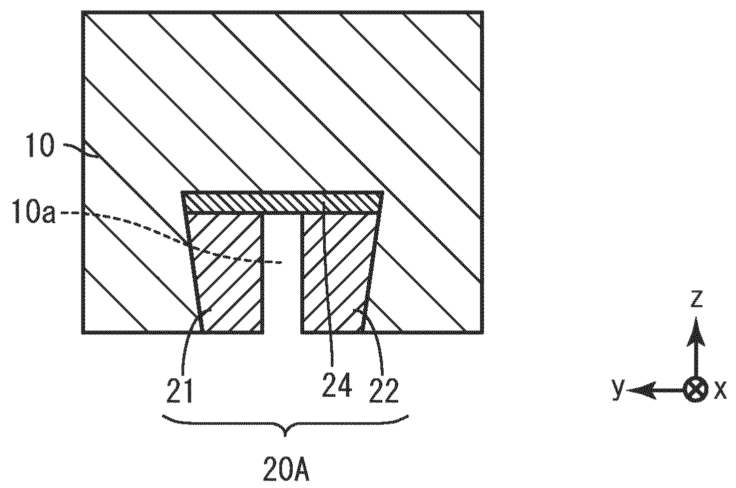


Fig.9

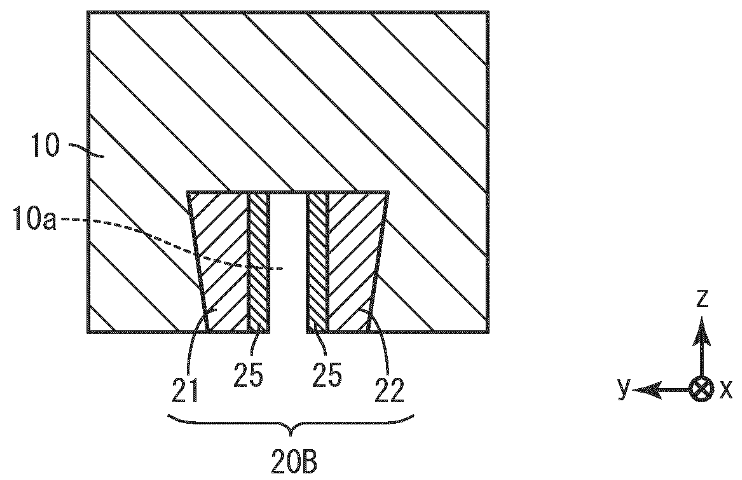


Fig.10

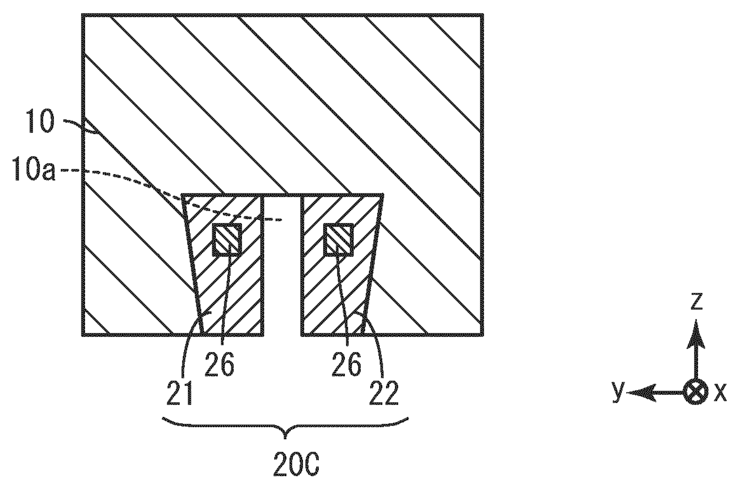


Fig.11

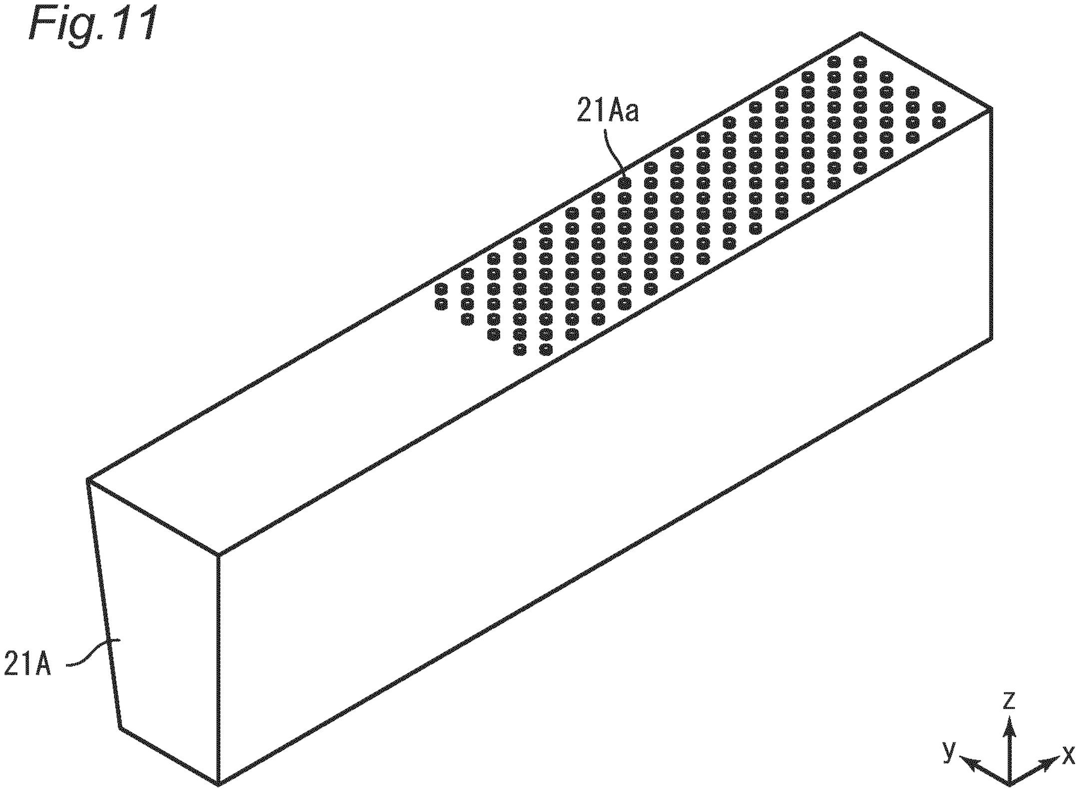


Fig.12

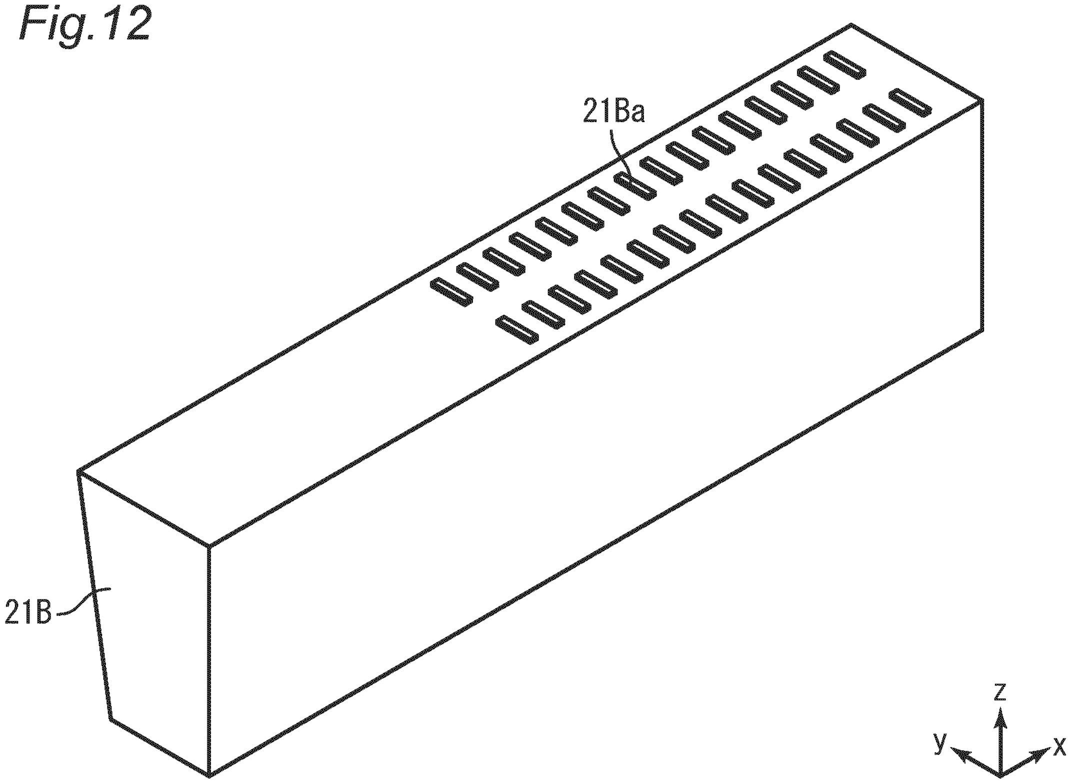
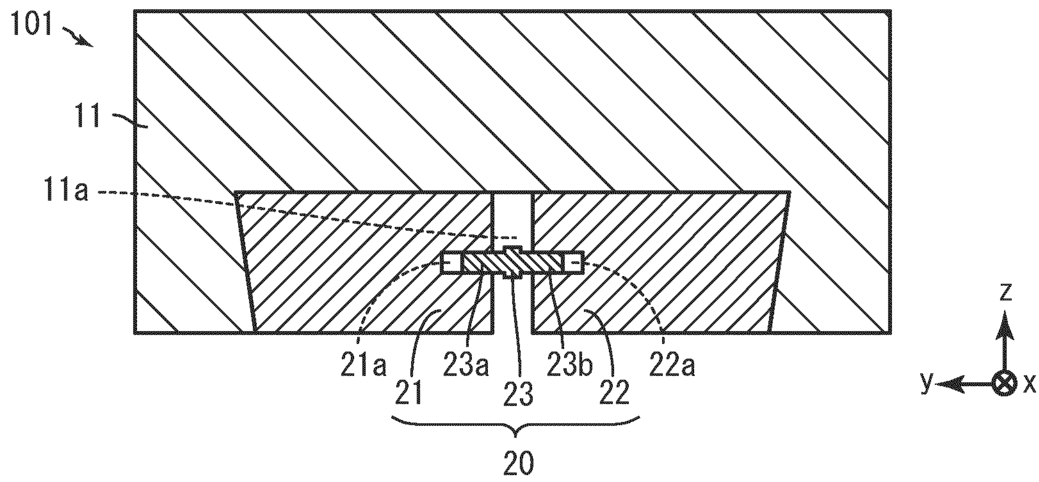


Fig.13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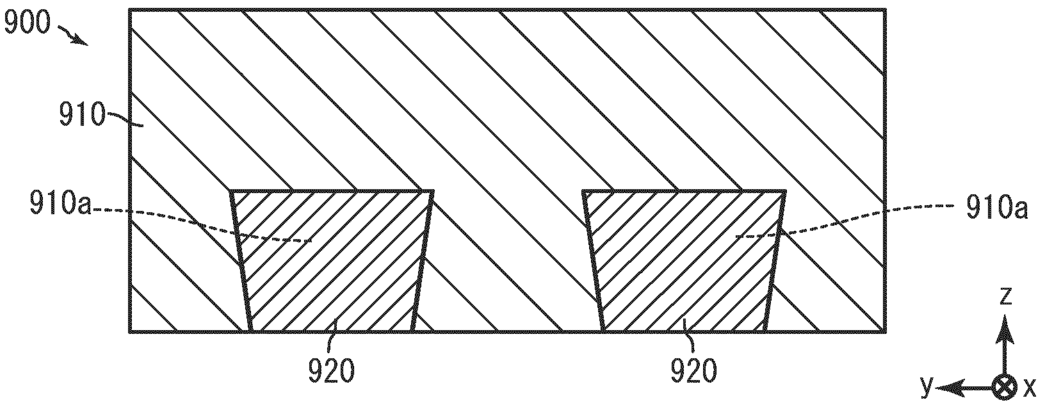
x

Fig.14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z
y
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Fig.15

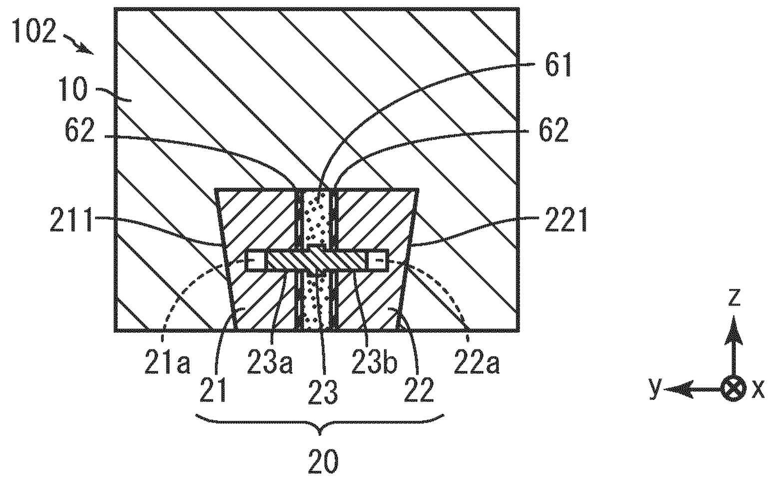
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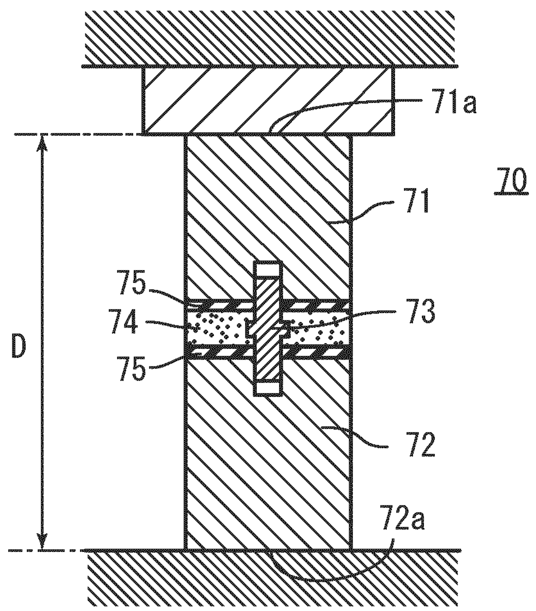
Fig.16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72a

Fig.17

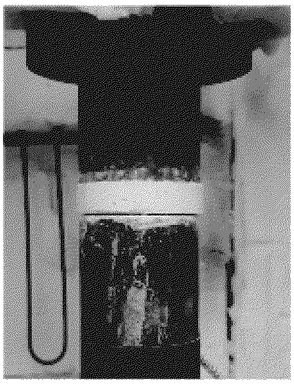
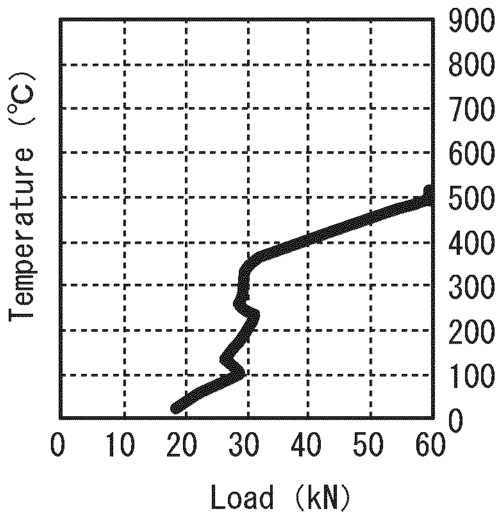


Fig.18


Temperature (°C)
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700
600
500
400
300
200
100
0
0
10
20
30
40
50
60
Load (kN)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2022/038136

A. CLASSIFICATION OF SUBJECT MATTER

C25C 3/08(2006.01)i; ***C22B 21/00***(2006.01)i; ***C25C 7/02***(2006.01)i; ***F27B 3/08***(2006.01)i
FI: C25C3/08; C22B21/00; C25C7/02; F27B3/08

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)

C25C3/08; C22B21/00; C25C7/02; F27B3/08

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

Published examined utility model applications of Japan 1922-1996
Published unexamined utility model applications of Japan 1971-2022
Registered utility model specifications of Japan 1996-2022
Published registered utility model applications of Japan 1994-2022

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2016/0208399 A1 (HATCH LTD.) 21 July 2016 (2016-07-21) entire text	1–4
A	US 2013/0319853 A1 (SGL CARBON SE) 05 December 2013 (2013-12-05) entire text	1-4
A	JP 2017-222914 A (SEC CARBON LTD) 21 December 2017 (2017-12-21) entire text	1–4

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
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"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
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"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
30 November 2022	**13 December 2022**

Name and mailing address of the ISA/JP	Authorized officer
Japan Patent Office (ISA/JP) **3-4-3 Kasumigaseki, Chiyoda-ku, Tokyo 100-8915** **Japan**	 Telephone No.

Form PCT/ISA/210 (second sheet) (January 2015)

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/JP2022/038136

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
US 2016/0208399 A1	21 July 2016	EP 3017090 A1 CN 104831320 A	
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JP 2017-222914 A	21 December 2017	CA 3027826 A1 entire text	

Form PCT/ISA/210 (patent family annex) (January 2015)

REFERENCES CITED IN THE DESCRIPTION

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- JP 2017534770 A **[0006] [0008]**
- US 7776190 B **[0007] [0008] [0042]**