United States Patent [19]

Holzgruber et al.

[11] **3,835,915**

[45] **Sept. 17, 1974**

[54] **ARRANGEMENT FOR USE IN MAKING SLAB INGOTS BY ELECTRIC SLAG-REFINING**

[75] Inventors: **Wolfgang W. Holzgruber,** Kapfenberg; **Peter J. V. Machner,** Leoben; **Ludwig Schwarz,** Kapfenberg, all of Austria

[73] Assignee: **Gebr. Bohler & Co. AG., Vienna,** Kapfenberg, Austria

[22] Filed: **Apr. 26, 1972**

[21] Appl. No.: **247,576**

[30] **Foreign Application Priority Data**

Aug. 30, 1971 Germany 2143302

[52] **U.S. Cl.** **164/252,** 13/18

[51] **Int. Cl.** **B22d 27/02**

[58] **Field of Search** 164/52, 252; 13/18

[56] **References Cited**

UNITED STATES PATENTS

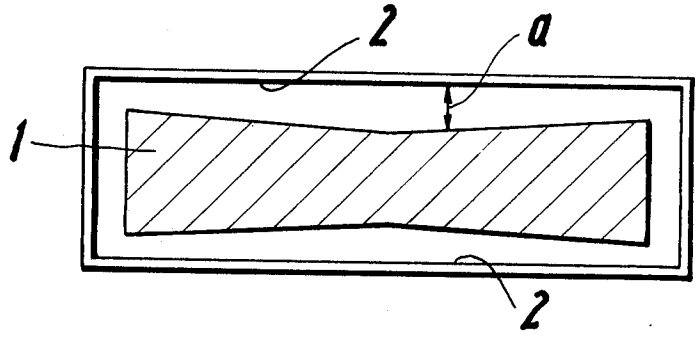
3,620,287 11/1971 Medovar 164/52

Primary Examiner—J. Spencer Overholser
Assistant Examiner—John E. Roethel
Attorney, Agent, or Firm—Arthur O. Klein

[57] **ABSTRACT**

The arrangement comprises an ingot mold having inside surfaces which define an elongated horizontal cross-section. The horizontal cross-section has a pair of long sides each of which has a central portion and outer portions. Fusible electrode means extend in said ingot mold and are horizontally spaced from said inside surfaces at said central portions by a larger distance than at said outer portions.

11 Claims, 11 Drawing Figures



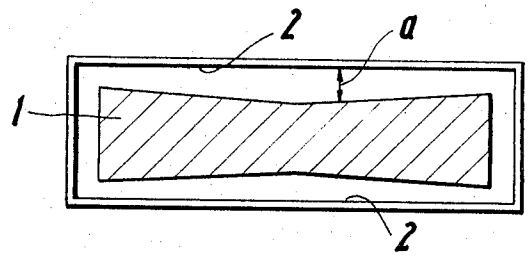


Fig. 1

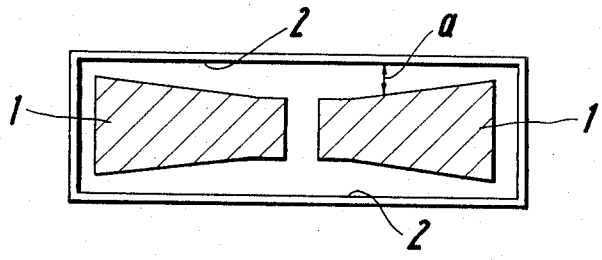


Fig. 2

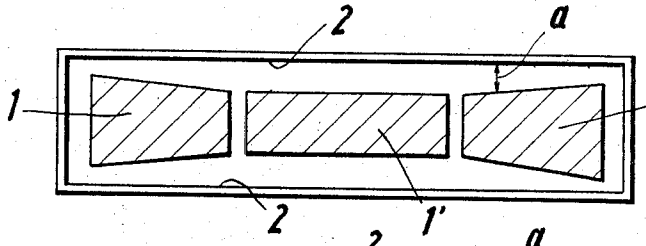


Fig. 3

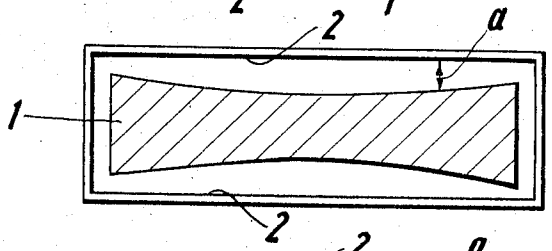


Fig. 4

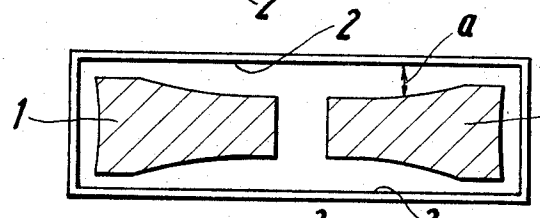


Fig. 5

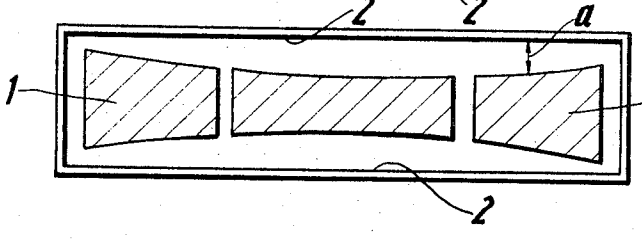


Fig. 6

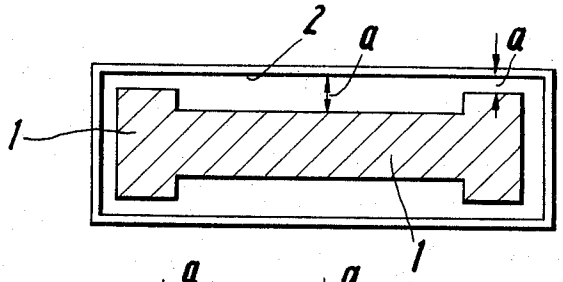


Fig. 7

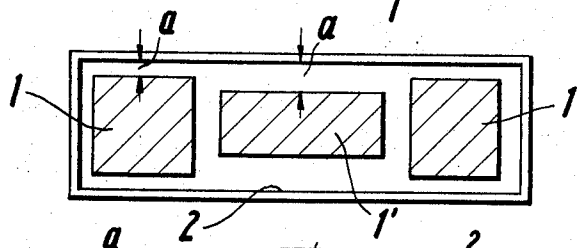


Fig. 8

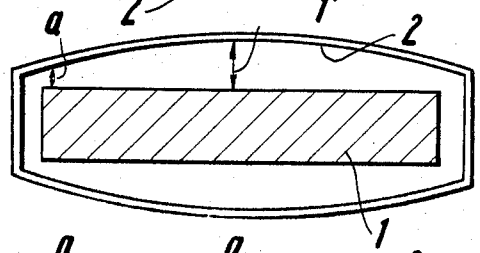


Fig. 9

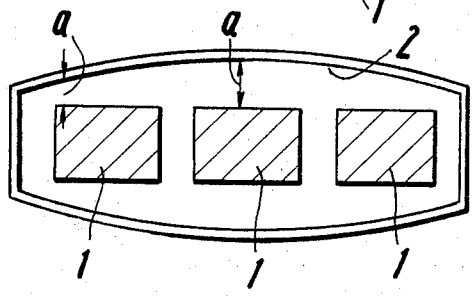


Fig. 10

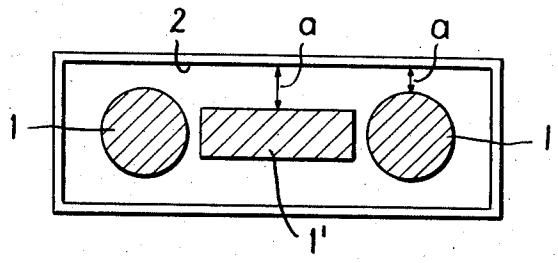


FIG. 11

ARRANGEMENT FOR USE IN MAKING SLAB INGOTS BY ELECTRIC SLAG-REFINING

This invention relates to a fusible electrode arrangement for use in the production of ingots by electric slag-refining in slab ingot molds. The flat or slab ingots made in such ingot molds are often required for the manufacture of flat products.

In the manufacture of such ingots, it is conventional to melt an electrode having a rectangular cross-section in a rectangular ingot mold. The cross-sectional dimensions are selected so that there is a uniform distance between the outside surfaces of the fusible electrodes and the inside surfaces of the ingot mold. Investigations which have resulted in the present invention have shown that this electrode arrangement has the disadvantage that the temperature distribution is highly non-uniform because the slag bath and particularly the molten metal as well as the solidified portion of the ingot are cooled more intensely adjacent to the narrow sides of the cross-section of the mold whereas less heat is dissipated from the central portions of the long sides of the cross-section of the mold. Due to the differential supply of heat to the walls of the ingot mold, the primary crystallization varies greatly in various parts of its cross-section.

This disadvantage caused by a non-uniform temperature distribution is also inherent in other known fusible electrode arrangements. For instance, where three circular section electrodes are disposed one beside the other in the ingot mold, the above-mentioned disadvantage is even more pronounced. This is also the case where three electrodes are used which are rectangular in cross-section and have the same thickness. Only with electrodes which are horizontally reciprocated along the axis of symmetry which extends parallel to the long sides of the rectangular cross-section of the ingot mold can the above-mentioned disadvantage be avoided if a relatively long residence time is provided for at the turning points, but this would involve a high structural expenditure.

It is an object of the invention to avoid said disadvantage. This object is accomplished according to the invention by the use of one or more electrodes, which are horizontally spaced from the ingot mold walls which form the long sides of the horizontal cross-section by a larger distance at the central portion of these ingot mold walls than at the edge portions of said walls to promote a uniform temperature distribution in the ingot as it solidifies. Because the electrode spacing increases as stated and its thickness decreases correspondingly relative to the thickness of the ingot, the slag layer area flown through by the electric current is decreased too. Hence, less heat is generated in the central portion of the cross-section of the ingot and the heat is generated there at a larger distance from the ingot mold walls.

The electrode arrangement according to the invention has also the advantage that it can be adapted to all known circuit and electrode arrangements. Preferred embodiments are shown by way of example on the accompanying drawing in top plan views.

FIG. **1** shows an arrangement comprising a single electrode disposed in a rectangular ingot mold.

FIG. **2** shows an arrangement which comprises two electrodes in a rectangular ingot mold.

FIG. **3** shows an arrangement comprising three electrodes in a rectangular ingot mold.

FIGS. **4, 5** and **6** show arrangements comprising one, two, and three electrodes, respectively, which have curved surfaces spaced from the long sides of the inside surfaces of the ingot mold;

FIG. **7** shows an arrangement which comprises one I-shaped electrode in a rectangular ingot mold;

FIG. **8** shows an arrangement comprising three rectangular electrodes in a rectangular ingot mold;

FIG. **9** shows an arrangement comprising one rectangular electrode in a curved ingot mold;

FIG. **10** shows an arrangement comprising three rectangular electrodes in a curved ingot mold; and

FIG. **11** shows an arrangement comprising two round electrodes and one rectangular electrode in a rectangular ingot mold.

The simplest embodiment comprises a single electrode, which is disposed in a rectangular ingot mold and has such a double-trapezoidal cross-section that the electrode has the smallest thickness at the center of its cross-section. This embodiment is shown in a top plan view in FIG. **1** of the drawing. The spacing *a* of this electrode **1** from the ingot mold walls **2** forming the long sides of the cross-section of the ingot mold is not uniform but increases toward the center. The increase of the spacing *a* is selected so that the average angle between the ingot mold wall and the surface of the electrode is about 2° to 8°. Such a remelting plant may be supplied in known manner with single-phase alternating current if the bottom plate and the electrode are connected to respective output terminals of the transformer.

Another embodiment of the invention is shown in FIG. **2** and comprises two electrodes **1,** which may be connected in parallel and supplied with single-phase alternating current. In this arrangement, any known power supply system may be employed, e.g., a supply from two separate transformers or a supply from one transformer with the electrodes **1** connected in series. In this embodiment, the distance *a* between the ingot mold walls **2** and the electrodes **1** varies in the same manner as in FIG. **1.**

If the remelting plant is arranged to be supplied with three-phase a.c., an electrode arrangement as shown in FIG. **3** is recommendable, in which the distance *a* of the electrodes **1** differs only for the outer electrodes **1,** whereas the central electrode **1'** is rectangular in cross-section. The electrodes are connected in known manner to the transformer for three-phase alternating current.

It will be obvious to a person skilled in the art that the distance between the electrode and the ingot mold wall need not vary along a straight line or in a linear manner if the object of the invention is to be accomplished. For instance, changes according to a curve are possible, provided that the distance in the central portion is larger than in the edge portions, as is shown in FIGS. **4, 5** and **6.** FIG. **4** shows an arrangement according to the invention with a single electrode **1,** FIG. **5** an arrangement with two electrodes and FIG. **6** one with three electrodes. All these embodiments exhibit a non-uniform change of the distance *a* between the electrode and the ingot mold wall in that the electrode cross-section is defined by a curve.

FIGS. **2** and **5** show examples in which the change spacing is changed only in part. Step changes of the

spacing are also possible within the scope of the invention. Such embodiments are illustrated by way of example in FIGS. **7** and **8** showing electrode arrangements comprising one and three electrodes, respectively.

It is also within the scope of the invention to change the horizontal distance between the electrodes and the ingot mold walls which form the long sides of the cross-section of the ingot mold by the use of ingot mold walls which are outwardly cambered on their inside surface. In this case, electrodes may be used which have a constant thickness at their edge portions and in their central portion. Embodiments comprising a cambered ingot mold are shown in FIGS. **9** and **10** with a single rectangular electrode and three rectangular electrodes respectively. In FIG. **11** the outer electrodes are circular in cross-section and have a larger diameter than the thickness of the inner rectangular electrode. It will be understood that electrodes having a non-uniform thickness may be combined with cambered ingot molds. Where ingot molds and/or electrodes are used which have undulated surfaces, the mean spacing is critical, i.e., the lines passing through the waves at one-half of the height thereof are considered as the boundaries of the cross-sections of the ingot mold and electrode or electrodes.

We claim:

1. An arrangement for use in making slab ingots by an electric slag-refining process, which comprises

an ingot mold having inside surfaces which define an elongated horizontal cross-section having long sides, each of said long sides having a central portion and outer portions, and

fusible electrode means extending in said ingot mold and horizontally spaced from said inside surfaces at said central portions by a larger distance than at said outer portions, all of said electrode means being movable with respect to said mold.

2. An arrangement as set forth in claim **1,** in which said fusible electrode means comprise a single electrode.

3. An arrangement as set forth in claim **1,** in which said fusible electrode means comprise a plurality of electrodes.

4. An arrangement as set forth in claim **1,** in which

said inside surfaces define a rectangular horizontal cross-section and

said fusible electrode means consist of a single electrode which is trapezoidal and tapers inwardly in horizontal cross-section.

5. An arrangement as set forth in claim **1,** in which

said inside surfaces define a rectangular horizontal cross-section and

said electrode means comprise an inner electrode which is rectangular in horizontal cross-section and disposed between said central portions and two outer electrodes which are trapezoidal and taper inwardly in horizontal cross-section and disposed on opposite sides of said inner electrode.

6. An arrangement as set forth in claim **1,** in which

said inside surfaces define a rectangular horizontal cross-section and

said electrode means comprise an inner electrode which is rectangular in cross-section and disposed adjacent to said central portions and two outer electrodes which have a larger horizontal thickness than and are disposed on opposite sides of said inner electrode.

7. An arrangement as set forth in claim **6,** in which said outer electrodes are rectangular in horizontal cross-section.

8. An arrangement as set forth in claim **7,** in which said outer electrodes are square in horizontal cross-section.

9. An arrangement as set forth in claim **7,** in which said outer electrodes are circular in horizontal cross-section.

10. An arrangement as set forth in claim **1,** in which

said inside surfaces define a horizontal cross-section in which said long sides are outwardly cambered and

said electrode means are of uniform horizontal thickness.

11. An arrangement as set forth in claim **1,** in which said fusible electrode means comprises a pair of electrodes which are trapezoidally shaped and inwardly tapered in horizontal cross-section.

* * * * *