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Kolisnyk

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[54] **ELECTRO-SLAG FURNACE FOR PRODUCING CONTINUOUS INGOT**

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[63] Continuation-in-part of Ser. No. 692,452, Dec. 21, 1967, abandoned.

[52] **U.S. Cl.** **164/252**

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

[58] **Field of Search** 164/50, 52, 252

[56] **References Cited**

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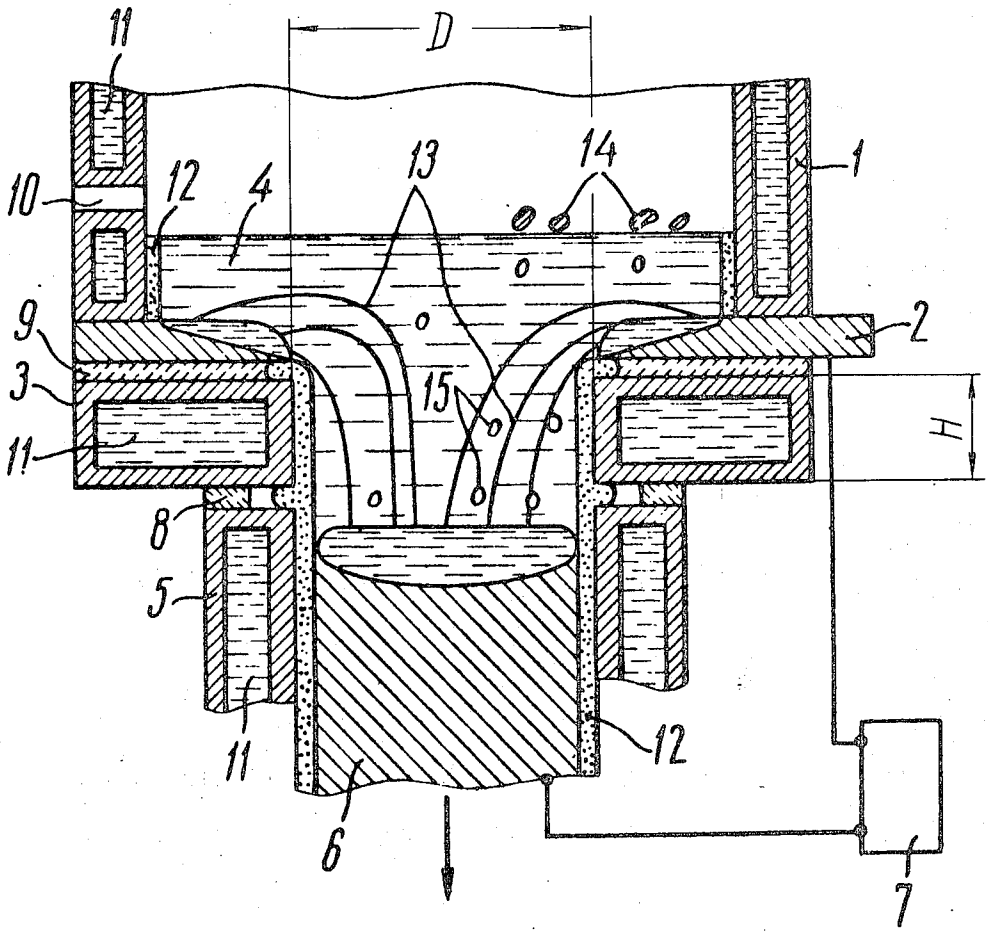
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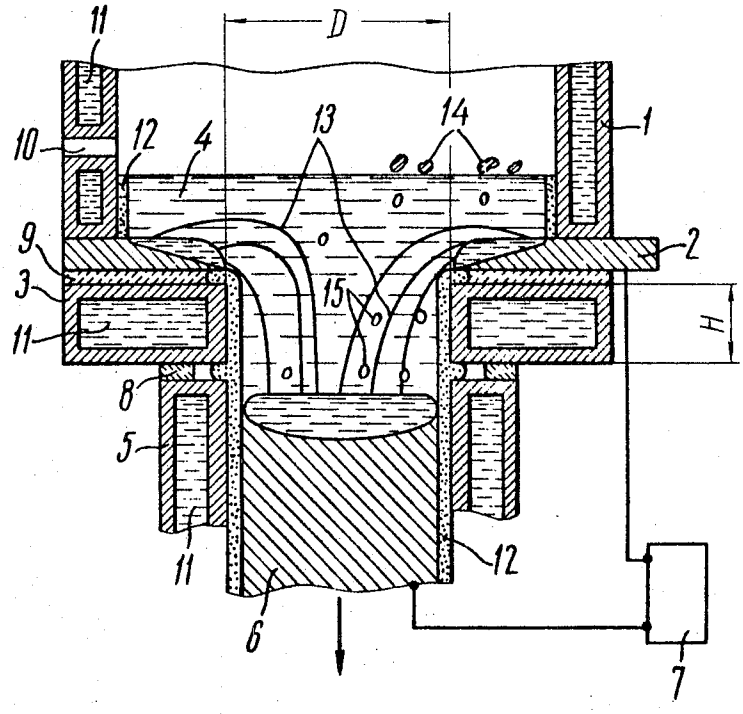
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[57] **ABSTRACT**

An electro-slag furnace for producing a continuous metallic ingot comprises a housing having a bottom portion in which an electrode constituted of the forming ingot is shiftable. A further electrode is spaced above the ingot electrode and a cooling channel is provided to cool the slag in the furnace to form a slag crust on the wall of the channel. The depth of the bottom portion between the electrodes is determined as a function of the diameter of the channel such that the thickness of the crust layer on the channel wall relative to the length thereof between the electrodes is sufficient for preventing a shunting electric discharge between the channel wall and slag.

5 Claims, 1 Drawing Figure




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ELECTRO-SLAG FURNACE FOR PRODUCING CONTINUOUS INGOT

CROSS-RELATED APPLICATIONS

This is a continuation-in-part application of my previously co-pending parent application Ser. No. 692,452 filed on Dec. 21, 1967 and now abandoned.

SUMMARY OF THE INVENTION

The present invention relates to metallurgy, and, more particularly, to electro-slag furnaces for producing a continuous metallic ingot.

Known in the art is an electro-slag furnace for producing a continuous metallic ingot, the furnace comprising a cooled hollow housing filled with molten slag and communicating with a mold through an opening provided in the bottom of the housing, the mold being electrically insulated from the latter. In the zone of said opening, the bottom of the housing is fashioned as a copper pipe line with cooled hollow walls extending downwardly with respect to said housing, said pipe line being installed in said mold. The depth of the opening exceeds its diameter by approximately six times. Metal is cast in the cooled housing with the aid of consumable melting electrodes which are essentially hollow cylinders filled with metallic particles and manufactured from a band with the aid of rolls. The metal forms a pool on the bottom of the housing, flows into the mold through said pipe line and forms a pool on the ingot. The housing of the furnace and the molds are connected to an electric current source. An electric discharge takes place between the end portion of the cooled pipe line disposed in the mold and the ingot to pass through the molten slag. This discharge heats the metal of the pool and the slag in the mold (cf. U.S. Pat. No. 2,445,670; Cl. 22–57.2, 1948).

When using the conventional furnace of the aforedescribed type there arise difficulties entailed by the necessity to provide equipment for manufacturing sufficiently intricate electrodes and to consume the metallic band. Moreover, to heat the metal and the slag, the mold can employ a d.c source whose poles are connected in a strictly definite manner. In this respect, the negative pole must be connected to the housing and the positive pole must be connected to the mold.

This manner of connection of the poles of the d.c. source, however, inevitably results in electrolysis of the molten slag, which lessens the quality of the metal of the ingot and changes the composition of the slag in the mold.

Furthermore, a portion of the current supplied by the source flows between said pools, and this portion is absolutely insufficient for forming a pool, thus necessitating employment of a plurality of electrodes. Such arrangements are shown in U.S. Pat. Nos. 3,507,968 and 3,511,303.

It is an object of the present invention to obviate the above mentioned disadvantages.

The present invention relates to the provision of an electro-slag furnace for producing a continuous metallic ingot, in which furnace the bottom portion of the housing includes means for melting the metal and heating the slag by an electric discharge passing through the slag between the metallic electrode on the bottom of the housing and the ingot in the mold.

In accordance with the present invention, the object is accomplished by providing the bottom of the furnace

housing with a thickness or depth which is sufficiently small to preclude an electric discharge between the bottom and the molten slag. The electrodes are positioned such that one is mounted on the bottom of the housing and the other, which is essentially the ingot, is connected to an electric current source whose power is sufficient for providing for the formation of a pool of molten metal on the electrodes. The spaces of the cooled housing and the mold are in communication with a pump providing for flowing of coolant at a rate sufficient for maintaining the skin of the cooled slag on the walls of the opening and the mold.

This embodiment of the furnace allows dispensing with a supply of metal in the form of a consumable electrode. The metal can be supplied in practically any form, including a compound of metal with a reducing agent. It is also possible to use alternating current.

In the preferred embodiment of the furnace, according to the present invention, it is expedient to make the thickness of the bottom portion of the housing, determining the depth of the opening through which the furnace housing communicates with the mold, equal to approximately one tenth of the lateral dimension or diameter of the opening.

With the bottom portion of the housing embodied as described above, the thickness of the skin or crust of the slag formed on the walls of the opening is sufficient to preclude an electric discharge between said bottom portion and the molten slag.

A substantial advantage of the present invention is that the metal can be deposited or charged into the furnace in the form of separate particles of any shape, that are not connected to the electric current source.

The present invention therefore contemplates to an electro-slag furnace comprising a chamber containing molten slag, means for introducing metal particles into the molten slag, a first electrode fixed in the chamber, a second displaceable electrode spaced from the first electrode and constituted by solidified metal derived from said metal particles, means for applying electrical energy to said electrodes, and cooling means for cooling the chamber between said electrodes for forming a slag crust which prevents short circuit between the second electrode and the chamber.

BRIEF DESCRIPTION OF THE DRAWING

The sole FIGURE of the drawing is a diagrammatic, vertical sectional view of the furnace according to the invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT:

The electro-slag furnace comprises a cooled hollow housing **1** having a metallic electrode **2** mounted therein. The electrode **2** is mounted on a cooled bottom portion **3** of the housing **1** filled up with molten slag **4**. The housing **1** communicates through an opening or channel provided in the bottom portion **3** thereof with a cooled mold **5** accommodating an ingot **6** serving as a second metallic electrode. The electrodes **2** and **6** are connected to electric current source **7**. The power of the source **7** must be sufficient to melt the electrodes **2** and **6** and to form on their surfaces pools of molten metal. It is desirable to use an a.c. source as the electric current source **7**. The bottom portion **3** of the housing **1** and the mold **5** are each electrically insulated from each other by a packing **8** constituted of as-

bestos. Provided between the bottom portion 3 of the housing 1 and the metallic electrode 2 is also a layer of an electro- and thermo-insulating material, i.e., asbestos packing 9. The housing 1 is provided with slag hole 10. The walls of the housing 1, bottom portion 3 and mold 5 are cooled by circulating medium 11. These walls can be made from copper. The spaces of said walls are in communication with a pump (not shown in the drawing) providing for the flow of cooling medium 11 at a rate sufficient to preserve or maintain skin 12 of the cooled slag as a crust formation on the bottom portion 3 and mold 5. As compared to the molten slag 4, the skin or crust 12 has a lower electrical conductivity.

Prior to the electro-slag furnace operation, the pump is started so as to fill the furnace with the molten slag 4, and the electric current source 7 is then switched on. Lines 13 conventionally show the paths of flow of the electric current.

In order to operate the furnace, it is necessary to make the thickness or depth of the bottom portion 3 sufficiently small to prevent a shunting electric discharge between the bottom portion 3 and the molten slag 4. A drop in voltage in the column of the molten slag 4 inside the opening in the bottom portion 3 will not result in or maintain said electric discharge which can destroy the slag crust layer on the wall of the bottom portion 3 and/or prevent the formation of a pool of molten metal on the electrode 2.

It is desirable to make the thickness or depth H of said bottom portion 3 equal to one tenth of the lateral dimension or diameter D of the channel or opening in the bottom portion 3, which is confirmed by casting a metal ingot in molten calcium fluoride.

An ingot of metal is cast by supplying a metal charge 14 onto the surface of the molten slag 4. This charge melts on the surface of the molten slag 4 upon contacting the latter, and there results the formation of metallic drops 15 which settle down in a pool of liquid metal on the ingot 6. When using a charge 14 composed of large pieces, such as granules or scrap, the latter are supplied into the zone of the molten slag 4 above the electrode 2 to settle down onto the electrode 2 to be melted thereon, and thus flow into a pool on the ingot 6. By gradually supplying the charge 14 and maintaining a continuous film, the ingot becomes larger by absorbing the solidifying molten metal of the pool.

The ingot is gradually moved down from the mold, which is usually the case during continuous casting.

The metal charge for producing ingots may be supplied in particulate form or as fusible rods or wire, bars such as conventional electro-slag remelts, or as a mixture of a chemical compound of a metal and a recovering agent, or as a liquid or as a combination of the aforementioned forms.

In sum, the solidification and cooling of the slag which is accompanied by a considerable decrease in electric conductivity is utilized to provide an electrical insulation in the form of the crust of slag solidified on the cooled metal surfaces in contact with the molten slag.

Note should be made to the effect that the electrical conductivity of the crust of solidified slag depends upon the composition of slag and temperature of crust and, consequently, upon the thickness and type of material of the wall being cooled on which said crust has solidified, as well as upon the intensity with which said wall is cooled and upon the temperature of the molten slag. Fluoride slags (such as 95% CaF_2 and 5% CaO, or 65% CaF_2, 30% Al_2O_3 and 5% CaO, and the like) feature a high electrical conductivity in the molten state, forming during solidifcation a crust having a lower electric strength as compared with oxide slags (such as 55% Al_2O_3 and 45% CaO, or 40% Al_2O_3, 25% CaO, 17% MgO and 18% CaF_2).

Therefore, by making use of cooled metal elements coated with a crust of solidified slag, there can be insulated from each other the electrodes, and the pools of liquid metal, placed in the molten slag.

In order to make the current between the liquid metal baths sufficient for melting the metal in said baths, the following conditions must be met:

a. to provide for sufficient cooling to insure the formation thereon of low-electroconductive crust of solidified slag serving to preclude an electrical discharge between the electrodes and the housing 1, the bottom 3, and mold 5, and

b. to considerably reduce the length of the bottom 3 so that, during the passage of electric current between the baths, across the molten slag column inside the bottom 3 there should occur no excessive voltage drop that could bring about an electrical breakdown of the slag crust insulation and cause a shunting discharge between the bottom 3 and the molten slag.

By reducing the ratio between the height of the molten slag column in the bottom 3 and the diameter or cross-section of said column, the voltage drop across said column can be reduced, other things being equal, while providing discharge between the liquid metal baths or pools.

The requirements placed upon the proportions of the cooled metal element of an electroslag furnace containing molten slag through which electric current passes under conditions of electroslag remelting are as follows:

$$U = HI/\alpha S \text{ and } U = 4HI/\alpha\pi D^2$$

wherein:

U is the voltage drop across the slag column;

α is the specific electric conductivity of the molten slag at a preset temperature;

H is the height of the slag column;

I is the melting current;

S is the cross-section area of the slag column; and

D is the diameter of the slag column.

In a first approximation, the current strength during the electroslag process is determined by the specific electric conductivity of the molten slag and can be proportional to the diameter of the molten slag column or to the square root of the cross-sectional area of the slag column or to the perimeter of the cross-section of said column. Based on the conditions of electro-slag remelting and on specific electric conductivity of molten slags at the temperatures of the electroslag process, and neglecting the small thickness of the slag crust as compared to the dimensions of the electroslag furnace, approximate results are presented in the appended Table.

Based on indirect data, it is concluded that the voltage of the electric breakdown of the slag crust under conditions of electroslag remelting using water-cooled copper elements is approximately equal to 15–100 volts. It follows from the data on the Table that, when using cooled elements with a molten slag column featuring an H/D ratio exceeding 1–2, electrical break-

down of even a double layer of slag crust is likely, which can bring about the appearance in the place of this breakdown of an intensive discharge between the cooled wall and the molten slag.

In order to preclude such a discharge, a readily attainable and adequately reliable solution for a cylindrical column of molten slag is an H/D ratio of about 0.1. At such H/D ratio, the voltage drop across the molten slag column is less than the voltage of the electrical breakdown of the slag crust. A further decrease of said ratio makes for an increased reliability of the furnace operation. The above method of calculation can likewise be used in the case of cross-sectional shapes of the molten slag column which are other than cylindrical.

TABLE

Voltage drop across molten slag column under conditions of electroslag remelting

Composition of Slag	Ratio of Current Strength to Slag Column Diameter amp/100 mm	Temp. of melting °C.	Voltage drop (in volts) across molten slag column at the temperature of melting at various ratios of H/D			
			0.1	0.2	1.0	2.0
95% CaF_2, 5% CaO	1,800	1,700	4.2	8.4	42	84
65% CaF_2, 30% Al_2O_3 5% CaO	1,800	1,750	5.1	10.2	51	102
55% Al_2O_3, 45% CaO	1,600	1,850	16.3	32.6	163	326
40% Al_2O_3, 25% CaO,	1,700	1,800	6.8	13.6	68	136

What is claimed is:

1. An electro-slag furnace comprising a chamber containing molten slag, means for introducing a metal charge into the molten slag, a first electrode fixed in the chamber, a second displaceable electrode spaced from the first electrode and constituted by solidified metal derived from said metal charge, means for applying electrical energy to said electrodes, cooling means for cooling the chamber between said electrodes for forming a slag crust which prevents short circuit between the second electrode and the chamber, said chamber comprising a housing provided with a bottom opening and a mold in extension of the opening, said second electrode being positioned in said mold, the electrical energy applied to the electrodes forming pools of said metal charge at the surfaces thereof, and means for maintaining the surface of the second electrode spaced from said bottom opening by a distance substantially less than the diameter of said opening.

2. A furnace as claimed in claim 1 wherein said housing has a cross-section which is greater than the size of said bottom opening.

3. A furnace as claimed in claim 1 comprising further cooling means including a plurality of axially spaced coolant channels surrounding said housing bottom and said mold respectively.

4. An electro-slag furnace comprising a chamber containing molten slag, means for introducing a metal charge into the molten slag, a first electrode fixed in the chamber, a second displaceable electrode spaced from the first electrode and constituted by solidified metal derived from said metal charge, means for applying electrical energy to said electrodes, cooling means for cooling the chamber between said electrodes for forming a slag crust which prevents short circuit between said molten slag and the chamber, said chamber comprising a housing provided with a bottom opening and a mold below the opening in extension thereof, said second electrode being positioned in said mold, the electrical energy applied to the electrodes forming pools of said metal charge at the surfaces thereof, the distance between the surface of said second electrode and said bottom opening being no more than one-tenth the diameter of said opening.

5. An electro-slag furnace comprising a chamber containing molten slag, means for introducing a metal charge into the molten slag, a first electrode fixed in the chamber, a second displaceable electrode spaced from the first electrode and constituted by solidified metal derived from said metal charge, means for applying electrical energy to said electrodes, cooling means for cooling the chamber between said electrodes for forming a slag crust which prevents short circuits between said molten slag and the chamber, said chamber comprising a housing provided with a bottom opening and a mold below the opening on extension thereof, said second electrode being positioned in said mold, the electrical energy applied to the electrodes forming pools of said metal charge at the surfaces thereof, the height of said housing disposed between the first and the second electrodes being about ten times smaller than the distance between the opposite sides of said opening.

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