United States Patent [19]

Paton et al.

[11] **3,709,283**

[45] **Jan. 9, 1973**

[54] **MULTIPLE ELECTRODE ELECTROSLAG CASTING APPARATUS HAVING CURRENT EQUALIZER**

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[22] Filed: **Sept. 28, 1970**

[21] Appl. No.: **76,205**

Related U.S. Application Data

[63] Continuation of Ser. No. 676,873, Oct. 20, 1967, abandoned.

[52] **U.S. Cl.** ..... **164/252,** 75/10 C, 164/50

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

[58] **Field of Search** ..... 164/50, 52, 250, 252; 13/24; 75/10 C, 11, 12

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[57] **ABSTRACT**

In an electroslag remelting installation, a pair of consumable electrodes are immersed into molten slag bath in a mold for forming an ingot. AC power is applied between the electrodes to cause AC current to flow through the molten slag bath, thus causing the electrodes to melt. As the electrodes melt, they feed simultaneously together into the slag bath. A conductor is connected between the bottom plate of the mold and either a center tap on the secondary winding of the transformer supplying AC power to the electrodes or to a center tap on a choke coil connected in parallel with the secondary winding.

31 Claims, 3 Drawing Figures

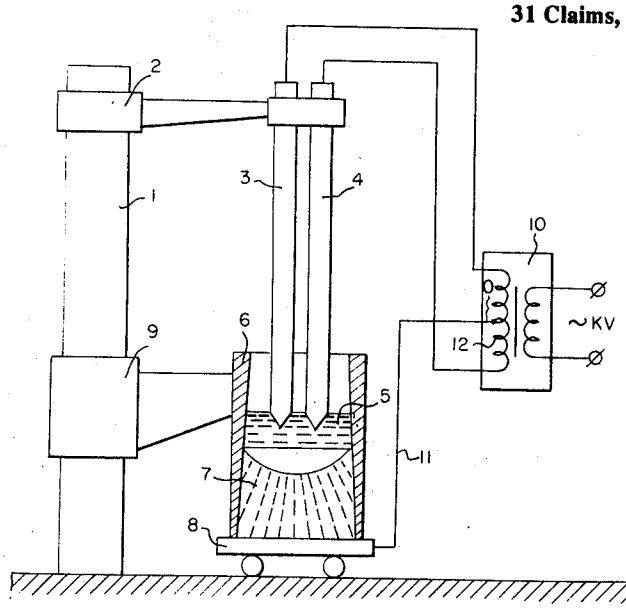


FIG. 1.

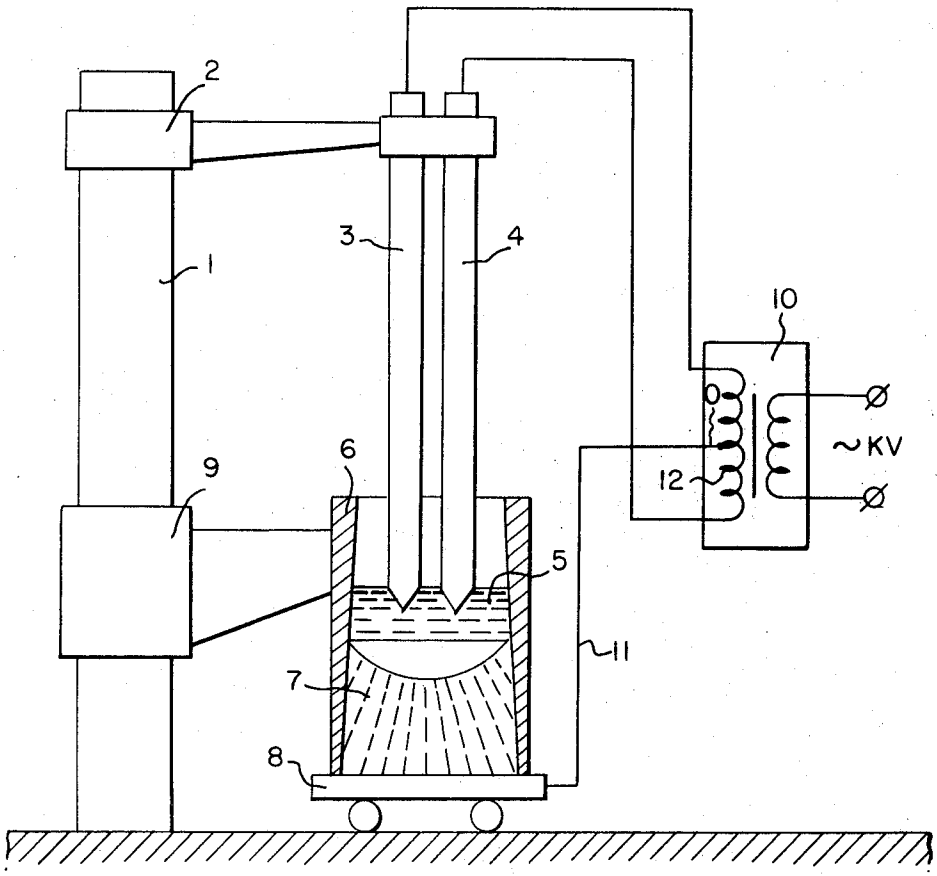


FIG. 3.

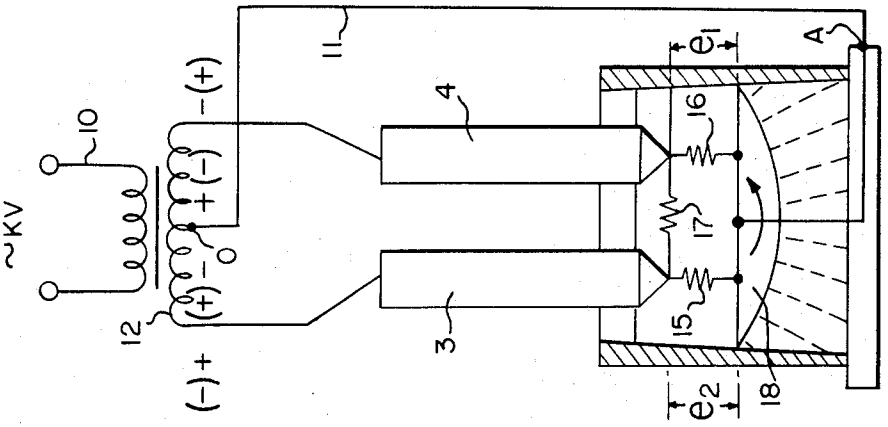
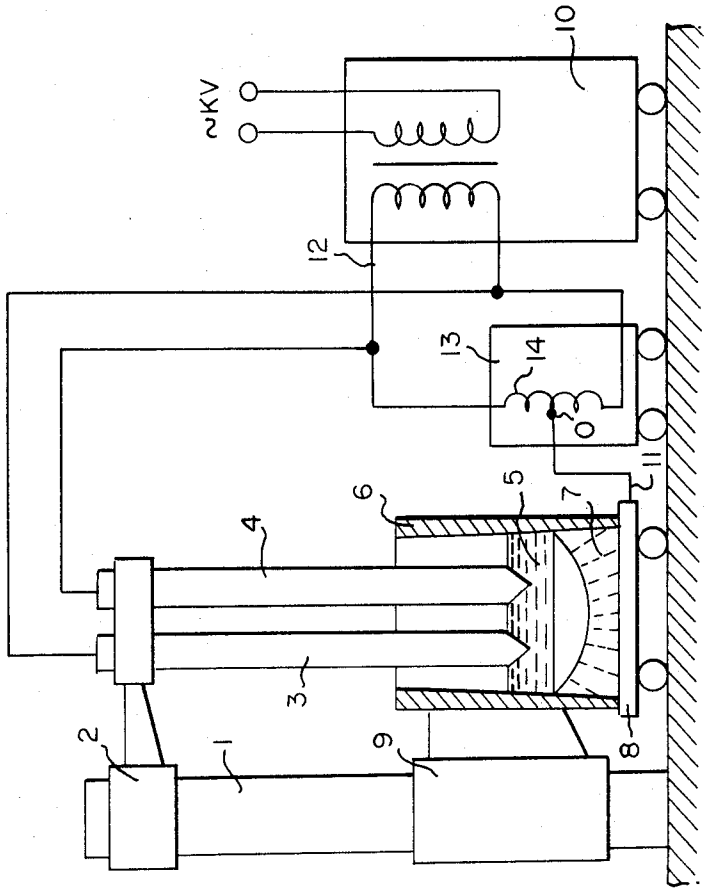


FIG. 2.



MULTIPLE ELECTRODE ELECTROSLAG CASTING APPARATUS HAVING CURRENT EQUALIZER

CROSS-REFERENCE TO RELATED APPLICATION

The present application is a continuation of copending application Ser. No. 676,873, filed Oct. 20, 1967 and now abandoned.

The present invention relates to the electroslag remelting of metals and alloys in a cooled mold two consumable electrodes or two groups of such electrodes.

In particular, disclosed in Patent No. 670,299 of Belgium is a similar installation, capable of producing ingots of a fairly high quality.

The installation disclosed in the above-mentioned patent is provided with a mold placed on a bottom plate, in which a slag bath is prepared by any conventional method. Two consumable electrodes or two groups of consumable electrodes are immersed into this bath, said electrodes being connected in series to the secondary winding of a single-phase power transformer, employed as a power supply source for the installation, the electrodes being moved together during the operation by a feeding mechanism while being melted in the slag bath.

The specified remelting conditions are maintained by controlling the magnitude of current and voltage by transferring the electrodes and switching over the voltage stages of the transformer, respectively.

In some cases, however, in the process of electroslag remelting, as carried out in the existing installations, the equality of linear speeds of melting of each electrode or electrodes of each two groups may be disturbed. These disturbances may be caused, for example, by a local difference in the cross-sections of the electrodes by the presence of porosity therein, and a misalignment of electrodes with respect to the mold.

In case of a protracted disturbance of the equality in the linear speeds of melting the electrodes, a gradually increasing misalignment of the electrodes will occur such that one of the electrodes may become immersed into the liquid metal bath, i.e. an emergency mode of operation of the installation is possible.

To eliminate said disadvantages, it was required to provide an installation for the electroslag remelting of consumable electrodes, in which the electrodes would be connected in the electric circuit of the power transformer in such a manner that their melting during the operation is uniform.

SUMMARY OF THE INVENTION

The present invention features an installation for the electroslag remelting of two consumable electrodes or two groups of consumable electrodes, which are connected in series into the circuit of the power supply source, and are immersed into a slag bath prepared in a mold being placed on a cooled bottom plate. These electrodes are moved together by a common feeding mechanism while being melted in the slag bath. In conformity with the invention, a conductor of equalizing current connects the supply source to the slag bath being prepared in the mold.

It is advisable to connect one end of the conductor of equalizing current to the center tap of the secondary winding of the transformer of said power supply source, while the other end thereof is connected to the bottom plate or the mold.

If for some reasons it is impossible to tap off the center tap of the secondary winding of the transformer, one end of the conductor of equalizing current may be connected to the center tap of the winding of a choke, which is connected in parallel with the secondary winding of the transformer. The other end of the conductor of equalizing current is also connected either to the bottom plate or the mold.

When remelting in the installation, designed according to the present invention, entirely identical electrodes, disposed strictly symmetrically relative to the mold, the current of the same magnitude is flowing through each of the electrodes; the same amount of power is evolved at each electrode immersed in the liquid slag; the depth of immersion of the electrodes into the slag bath is the same, and the conductor of equalizing current is deenergized.

In case of misalignment of the electrodes due to a short-term influence of any of the above-said factors, the intensity of current, flowing in the electrode immersed deeper into the slag bath, becomes higher than that of the current flowing through the electrode immersed to a smaller extent, the difference being equal to the magnitude of equalizing current, which will then flow through the conductor of equalizing current. On account of such a variation in the currents flowing through the electrodes, the power evolved at the electrode immersed deeper into the slag bath will be greater than that at the electrode immersed to a smaller extent. This will result in eliminating the misalignment and reducing the equalizing current to zero.

In the case of permanently acting factors, causing the misalignment of the electrodes, a ratio of currents is established in the electrodes, so that the electrodes melt down at equal linear speeds, with equal or close to equal depths of immersion of the electrodes into the liquid slag.

The installation of the invention makes it possible to effect the electroslag remelting of two consumable electrodes or two groups of consumable electrodes, fed simultaneously into one mold without any misalignment of the electrodes under the action of any of the above-mentioned causes which bring about the inequality in the linear speeds of melting of the electrodes, and also to completely eliminate the possibility of emergency operation.

Specific embodiments of the invention will now be described by way of example with reference to the accompanying drawings, wherein:

FIG. 1 represents an installation for the electroslag remelting according to the invention, wherein the bottom plate is connected by means of a conductor of equalizing current to the center tap of the secondary winding of a single-phase power transformer.

FIG. 2 represents the same installation, wherein the bottom plate is connected by means of a conductor of equalizing current to the center tap of the winding of an equalizing choke connected in parallel to the secondary winding of the single-phase transformer.

FIG. 3 represents an equivalent electrical circuit diagram of the installation of FIG. 1, according to the invention.

In the embodiments of the invention, represented in FIGS. 1 and 2, the installation is provided with a supporting column 1 mounting a mechanism 2 for feeding electrodes 3 and 4, to be introduced together into a slag

bath 5, as prepared in a mold 6 intended for shaping an ingot 7, built up from electrodes 3 and 4.

The mold 6 is placed on a bottom plate 8 and connected with a lifting mechanism 9 mounted on the column 1.

The electrodes 3 and 4 are connected in series to a single-phase power transformer 10, being the supply source of the installation, said electrodes being moved simultaneously by the mechanism 2 while melting down in the slag slag bath 5. One end of a conductor 11 of equalizing current is connected to the bottom plate 8, while the other end thereof is connected to the center tap "0" of the secondary winding 12 of the single-phase power transformer 10, as shown in FIG. 1.

In case the conductor 11 of equalizing current cannot, for some reasons, be connected to the center tap "0" of the secondary winding of the single-phase power transformer 10, an equalizing choke 13 can be employed, to be connected in parallel with said secondary winding 12 of the transformer 10.

The conductor 11 of equalizing current is then connected to the center tap "0" of a winding 14 of the equalizing choke 13, as it is shown in FIG. 2, and to the bottom plate 8.

The equalizing choke operates as an auto-transformer having the transformation ratio equal to two.

The principle of operation of the installation of the invention, as represented by the embodiment of FIG. 1, may be explained by means of the equivalent electrical circuit diagram shown in FIG. 3.

In the diagram of FIG. 3, numerals 15 and 16 correspondingly designate the resistances of slag in the circuit, constituted by the electrode 3 - slag - metal bath and mold - slag - electrode 4, while the resistance of slag between the electrodes is indicated by numeral 17.

As it is obvious from the diagram, current flows in the slag bath 5 through two circuits via the resistance 17 and the resistances 15 and 16.

When the electrodes are immersed into the liquid slag at an equal depth, the resistances 15 and 16 are of equal value, the equalizing current in the conductor 11 is absent, since the drop of voltage across the resistance 15 and resistance 16 (the resistances of the short circuit to each electrode and the resistances of the electrodes being not shown in the equivalent diagram) are equal to each other and to the half-voltage of the secondary winding 12 of the transformer, i.e., the points A and O are points of the same potential.

In this case the installation operates according to a purely bifilar circuit diagram, the same current flowing through each electrode.

In case of a short-term action of one or a plurality of factors causing the inequality in the linear speeds of melting of the electrodes, one of the electrodes will become immersed into the slag to a greater depth than the second one. For example, the electrode 4 will become immersed to a greater depth. Then the value of resistance 16 will be decreased as compared with the resistance 15, because the distance l_1 between the end of the electrode 4 and metal bath 18 will be smaller than the distance l_2 between this bath and the end of the electrode 3. Owing to the fact that the resistance 16 is smaller than the resistance 15, a portion of the current of the electrode 4 will flow, by-passing the electrode 3, along the conductor 11 to the point of half-voltage of the secondary winding 12 of the transformer 10. Thus a greater amount of power will be dissipated in the slag at the electrode 4 than that at the electrode 3, which will result in an increase in the speed of melting of the electrode 4 and in a decrease in the speed of melting of the electrode 3, i.e. in the elimination of the misalignment.

When constant factors are acting, causing the misalignment an equalizing current will constantly flow through the conductor of equalizing current, said current being sufficient for equalizing the linear speeds of melting of the electrodes, the depths of immersion of the electrodes being nearly equal.

The installation for the electroslag remelting, according to the present invention, allows the elimination of the misalignment of the electrodes irrespective of factors causing it; the installation also permits remelting of electrodes made of metals featuring different melting points, completely eliminating the possibility of emergency operation.

The installation of the invention permitted a stable process at equal linear speeds of melting of electrodes with a small misalignment of the electrodes, when the difference between the cross-sectional areas of the electrodes was equal to 20 percent. The magnitude of the equalizing current amounted to 18 percent of the intensity of current flowing through the electrode of a smaller cross-sectional area.

Yet the remelting of electrodes, having such a difference between the cross-sectional areas, proves to be impracticable in the conventional installation, provided with the mechanism for simultaneous feeding of the electrodes, because in the course of the melt the depth of immersion of the electrode with a greater cross-sectional area gradually increases, and the electrode end is thus immersed into the metal bath.

What is claimed and desired to be secured by Letters Patent is:

1. An installation for electroslag remelting of metals and alloys, comprising a cooled mold for the formation of at least one ingot in which a slag bath is prepared; a bottom plate, mounting said mold; consumable electrodes, two or two groups thereof forming a pair to be immersed into said slag bath; a power supply source connected in series with said pair of electrodes and said slag bath for providing current flow between each electrode or group of electrodes and the other electrode or group of electrodes of said pair, and said current flow between said electrodes consisting of single phase current flow; a mechanism for effecting simultaneous feeding of said electrodes while they are melted in said slag bath; a conductor of equalizing current connected to said slag bath from said power supply source in a manner to compensate for a difference of linear speeds of melting of said consumable electrodes.

2. An installation for the electroslag remelting of metals and alloys, comprising a cooled mold for the formation of an ingot, in which a slag bath is prepared; a bottom plate, mounting said mold; a power supply source having a single phase power transformer; consumable electrodes, two or two groups thereof to be immersed into said slag bath and connected in series into the circuit of said supply source; a mechanism for effecting simultaneous feeding of said electrodes while they are melting in said slag bath; a conductor of

equalizing current connected between said bottom plate and the center tap of the secondary winding of said single phase power transformer of said power supply source for compensating for any difference in the linear speed of melting of said electrodes.

3. An installation for the electroslag remelting of metals and alloys, comprising a cooled mold for the formation of an ingot, in which a slag bath is prepared; a bottom plate, mounting said mold; a power supply source having a single phase power transformer; consumable electrodes, two or two groups thereof to be immersed into said slag bath and connected in series into the circuit of said supply source; a mechanism for effecting simultaneous feeding of said electrodes while they are melting in said slag bath; a conductor of equalizing current connected between said bottom plate and the center tap of the winding of a choke connected in parallel with the secondary winding of said single phase power transformer of said power supply source for compensating for any difference in the linear speed of melting of said electrodes.

4. An electroslag remelting system comprising a mold means for forming at least one ingot in which a bath of molten slag is prepared; means for supporting a pair of consumable electrodes immersed in the molten slag bath in said mold means and for feeding said electrodes together into said molten slag bath as they melt while maintaining said electrodes fixed relative to each other; power supply means connected in series with said pair of consumable electrodes and with said molten slag bath for providing current flow from one electrode to the other electrode through said molten slag bath, and said current flow from one electrode to the other consisting of single phase AC current flow; and equalizing means electrically connected to said mold means for increasing the single phase AC current flow through one of said electrodes relative to the other of said electrodes responsive to said one of said electrodes becoming more deeply immersed in said molten slag bath than the other of said electrodes.

5. A system as recited in claim 4 wherein said equalizing means comprises a conductor connected between said mold means and a voltage in circuit with said power supply means between the voltages applied by said power supply means to said electrodes.

6. An electroslag remelting system as recited in claim 5 wherein said conductor is connected between the bottom of said mold means and said voltage in circuit with said power supply means.

7. An electroslag remelting system as recited in claim 5 wherein said voltage in circuit with said power supply means is midway between the voltages applied by said power supply means to said electrodes.

8. An electroslag melting system comprising: mold means for the formation of at least one ingot in which a slag bath is prepared; said mold means including a bottom plate; a pair of consumable electrode means, each means of said pair including at least one consumable electrode to be immersed into said slag bath; a power supply source connected in series with said pair of consumable electrode means and said slag bath for providing interelectrode means current flow between one of said consumable electrode means and the other consumable electrode means of said pair of consumable electrode means, and said interelectrode means current flow consisting of single phase current flow; a mechanism to hold and adapted to effect simultaneous feeding of said pair of consumable electrode means while said pair is melted in said slag bath; a conductor connected between said slag bath and said power supply source, for supplying equalizing current flow to said consumable electrode means in such a manner as to compensate for a difference of linear speeds of melting of said consumable electrode means.

9. A system as defined in claim 8 wherein said pair of consumable electrode means consists of one pair of electrodes.

10. A system as defined in claim 8 wherein said pair of consumable electrode means comprises separate groups, each group including at least two electrodes each.

11. An installation for the electroslag remelting of metals and alloys, comprising: mold means for the formation of at least one ingot in which a slag bath is prepared, said mold means including a bottom plate; a power supply source comprising a transformer with a center tap secondary winding; consumable electrode means forming a pair, each means of said pair including at least one consumable electrode to be immersed into said slag bath; said power supply source connected in series with said pair of consumable electrode means and said slag bath for providing interelectrode means current flow between one of said consumable electrode means and the other consumable electrode means for said pair of consumable electrode means, and said interelectrode means current flow consisting of single phase current flow; a mechanism to hold and adapted to effect simultaneous feeding of said consumable electrode means as they are melting in said slag bath; and an equalizing means electrically connected between said mold means and the center tap of said secondary winding for distributing said single phase current flow between said consumable electrode means with respect to changes in resistance to equalize the melting rates of said pair of consumable electrode means.

12. An installation for the electroslag remelting of metals and alloys comprising: mold means for the formation of an ingot in which a slag bath is prepared, said mold means including a bottom plate; a power supply source including a transformer with a secondary winding and a center tap choke connected in parallel with said secondary winding; consumable electrode means forming a pair, each means of said pair including at least one consumable electrode to be immersed into said slag bath and with said slag bath connected in a series circuit to said power supply source with each means of said pair connected to respective opposite terminals of said choke; said power supply source connected in series with each means of said pair for providing interelectrode means current flow between one of said consumable electrode means and the other consumable electrode means of said pair of consumable electrode means, and said interelectrode means current flow consisting of single phase current flow; a mechanism to hold and adapted to effect simultaneous feeding of said electrode means while they are melting in said slag bath; an equalizing means electrically connected between said mold means and the center tap of said choke to provide equalizing current flow to said consumable electrode means depending upon changes

in resistivity thereof to equalize the melting rate of said pair of consumable electrode means.

13. An installation as defined in claim 11, wherein said pair of consumable electrode means consists of one pair of electrodes and wherein said power supply source provides AC current.

14. A system as defined in claim 4, wherein said equalizing means comprises: a conductor connected between said mold means and a voltage point in said power supply means providing a voltage with a value between that of the voltages applied by said power supply means to said pair of electrodes.

15. An electroslag remelting system as defined in claim 14, wherein said conductor is connected between the bottom of said mold means and said voltage point.

16. An electroslag remelting system as defined in claim 14, wherein said voltage point provides a voltage with a value midway between that of the voltages applied to said pair of consumable electrodes.

17. An installation according to claim 1, wherein said power supply source includes a single phase power transformer, one end of said conductor of equalizing current is connected to the point of half-voltage of the secondary winding of said single-phase power transformer and the other end thereof is connected to said bottom plate.

18. An installation according to claim 1, wherein said power supply source includes a single phase power transformer and a choke connected in parallel with the secondary winding of said single-phase power transformer, and one end of said conductor of equalizing current is connected to the point of half-voltage of the winding of said choke while its other end is connected to said bottom plate.

19. An electroslag melting system as defined in claim 8, wherein said power supply means includes a power transformer; one of the pair of said electrode means is connected to one terminal of the secondary winding of said transformer and the other of the pair of said electrode means is connected to the other terminal thereof.

20. An electroslag melting system as defined in claim 8, wherein each consumable electrode means of said pair includes at least two consumable electrodes depended into said mold means, in contact with said molten slag bath and connected to said power supply means.

21. An electroslag melting system as defined in claim 8, wherein a common electrode holder mounts said electrodes and means in said common holder insulates each pair of consumable electrode means from one another, within the holder.

22. A system as defined in claim 8, wherein said power supply means includes a single phase transformer and the transformer secondary winding and said pair of consumable electrode means are connected in series.

23. A system as defined in claim 8 wherein said pair of consumable electrode means are disposed symmetrically relative to said mold means.

24. A system as defined in claim 8, wherein of said pair of consumable electrodes, one has a greater cross sectional area than the other.

25. A system as defined in claim 24, wherein the difference in cross sectional areas is approximately 20 percent and said equalizing current means enables the magnitude of the equalizing current flowing in said equalizing current conductor to be approximately 18 percent of the current flow through the electrode having the smaller cross sectional area.

26. A system as defined in claim 8, wherein said mold means is cooled.

27. A system as defined in claim 8 wherein said electrical power supply means is an AC power supply.

28. A system as defined in claim 8, wherein a plurality of consumable electrodes are included in each of said electrode means and are depended into said mold means into contact with said molten slag bath and all electrodes are connected to said power supply means; one of said pair of electrode means is connected to a high voltage point of said power supply means, the other of said pair of electrode means is a relatively lower voltage point of said power supply means.

29. A system as defined in claim 28, wherein said equalizing current conductor is connected to said power supply means at a point supplying voltage at a value intermediate said high and lower voltage points.

30. A system as defined in claim 28, wherein said equalizing current conductor is connected to said power supply means at point supplying voltage at a value midway between said high and lower voltage points.

31. An installation as defined in claim 11, wherein said pair of consumable electrode means comprises separate groups, each group including at least two electrodes each, and wherein said power supply source provides AC current.

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