United States Patent [19]

Paton et al.

[11] **3,867,130**

[45] **Feb. 18, 1975**

[54] **METHOD FOR ELECTROSLAG REMELTING OF CONSUMABLE ELECTRODES**

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[22] Filed: **Feb. 17, 1972**

[21] Appl. No.: **227,638**

Related U.S. Application Data

[60] Division of Ser. No. 56,141, July 6, 1970, Pat. No. 3,693,700, which is a continuation of Ser. No. 641,605, May 26, 1967, abandoned.

[52] **U.S. Cl.** ..... **75/10 R,** 13/9

[51] **Int. Cl.** **C22d 7/00,** H05b 7/18

[58] **Field of Search** 75/10–12; 13/9, 12, 13, 24; 164/50, 52, 250, 252; 219/412

[56] **References Cited**

UNITED STATES PATENTS

3,767,831	10/1973	Plockinger	75/10
3,379,238	4/1968	Sieckman	164/52
3,193,758	7/1965	Friedlander	13/12
3,186,043	6/1965	Murtland	164/52
3,055,959	9/1962	Vaughn	13/24
3,036,188	5/1962	Ditto	219/492

Primary Examiner—C. Lovell
Assistant Examiner—Peter D. Rosenberg
Attorney, Agent, or Firm—Strauch, Nolan, Neale, Nies & Kurz

[57] **ABSTRACT**

The method of electroslag remelting of consumable electrodes in cooled moulds, the amplitude of the alternating current of low frequency of the installation being modulated by means of various modulators series-connected in the primary or secondary circuit of a transformer feeding the electroslag remelting installation. The modulation of the amplitude of the alternating current of a frequency equal or close to the frequency of the oscillations of the liquid metal bath causes resonance oscillations of the metal bath, which cause refining of the structure of the crystallizing ingot, elimination of dendritic non-uniformity and a higher quality of the metal.

8 Claims, 6 Drawing Figures

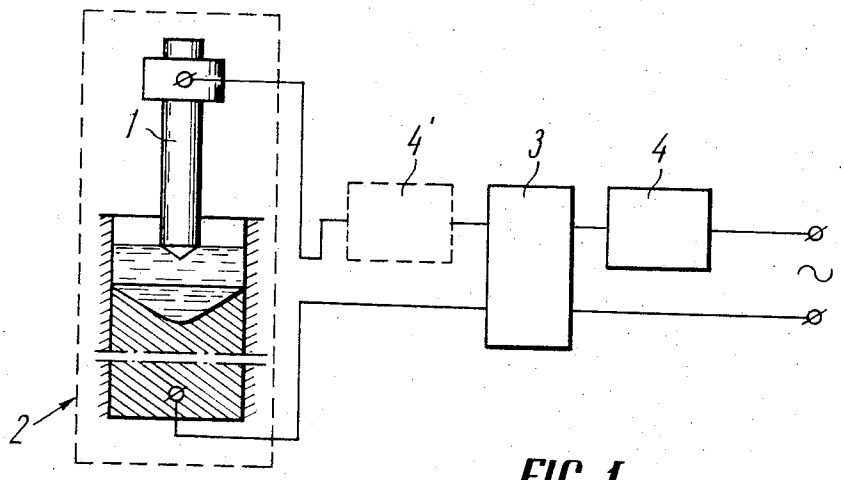


FIG. 1

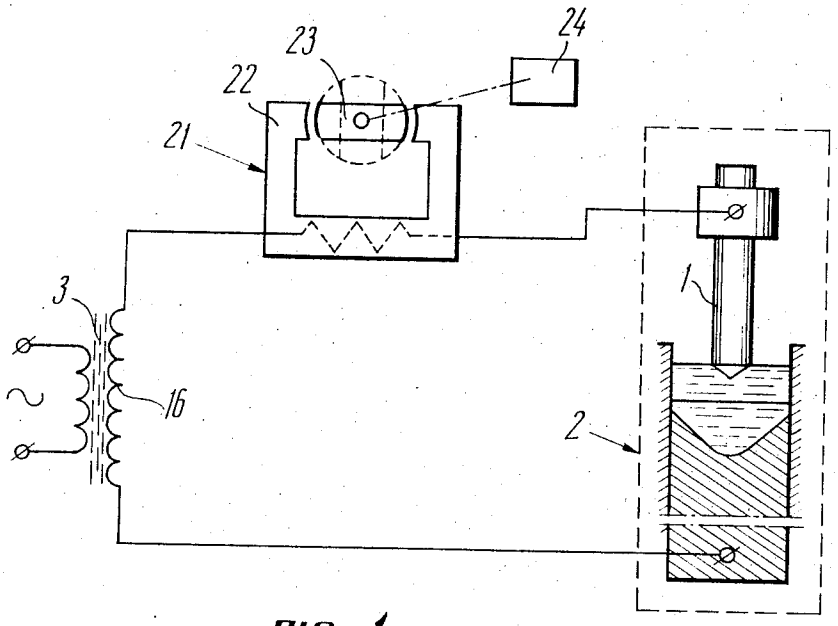


FIG. 4

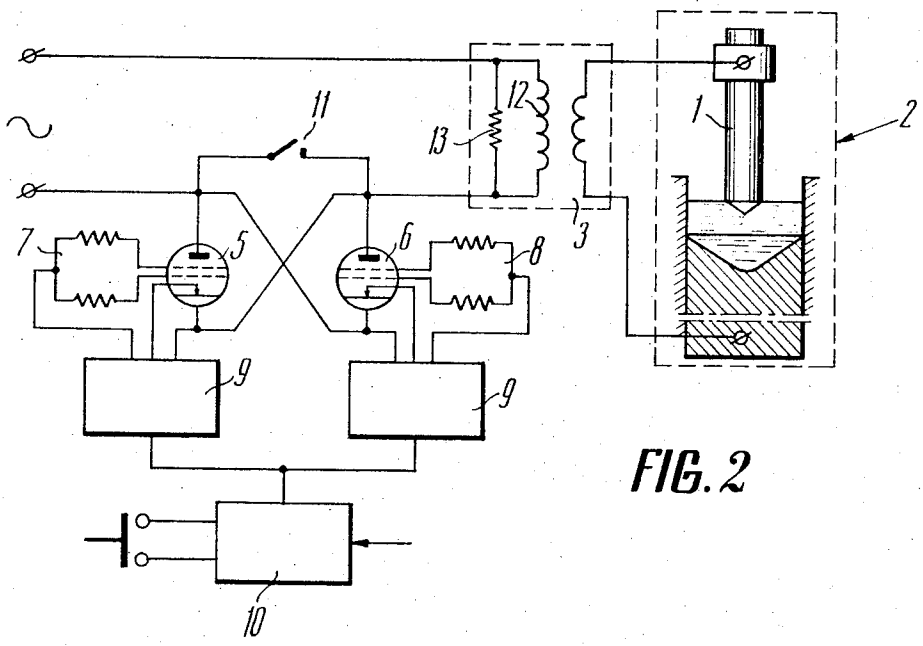


FIG. 2

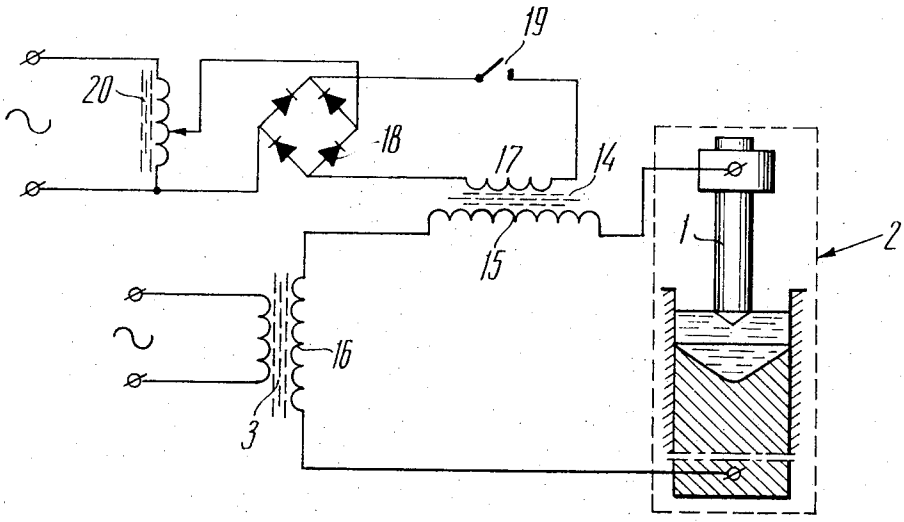


FIG. 3

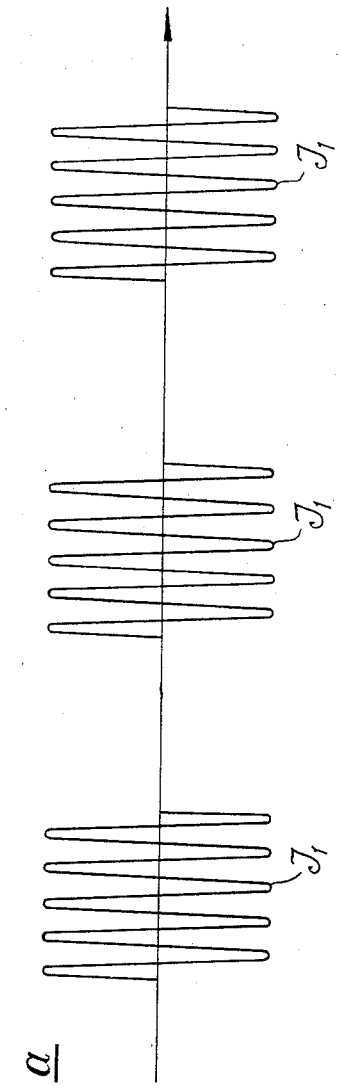


FIG. 5 a

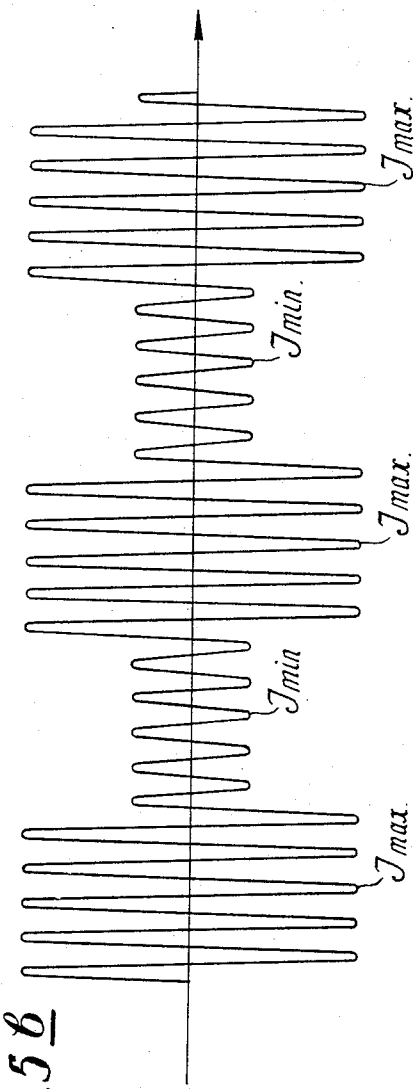


FIG. 5 b

METHOD FOR ELECTROSLAG REMELTING OF CONSUMABLE ELECTRODES

This application is a division of application Ser. No. 56,141, filed July 6, 1970, now U.S. Pat. No. 3,693,700, which is in turn a continuation of application Ser. No. 641,605 filed May 26, 1967, now abandoned.

The present invention relates to installations for the electroslag remelting of consumable electrodes.

It is intended to be utilized in electrometallurgy, and more particularly in the production of high-quality steels and alloys by using a method of electroslag remelting.

Known in the prior art are installations for the electroslag remelting of consumable electrodes with the use of an alternating current in a cooled mould (see the book, written by Medovar B. I. and others, entitled "Electroslag remelting", 1965, pages 20–26).

Ingots, however, obtained in the existing plants, for example, ingots of austenitic steels and nickel-based alloys, have a coarse-grained structure with a fairly considerable development of the dendritic segregation. In particular, bearing and high-speed tool steels in large sections obtained from ingots to be melted in the existing installations, are of a low quality as to the structure and carbide string formation.

The existing methods of eliminating an increased non-uniformity, for example, a long heat treatment, homogenizing annealing of ingots, applicable to a steel produced by the electroslag remelting, have proved to be of a low efficiency. For this reason, when carrying into effect the electroslag remelting of a number of steel grades and alloys, it is required to provide such conditions of the ingot solidification which would prevent the formation of the dendritic segregation, especially carbide segregation during the electroslag remelting of steel of the carbide class.

An object of the present invention is to provide an installation for the electroslag remelting of consumable electrodes, which would enable obtaining ingots of the metal with a minimum formation of strings and dendritic non-uniformity in the metal structure, clean as to the gaseous and non-metallic inclusions, and having a fine-grained crystalline structure.

The essence of the invention consists in the fact that in the installation for the electroslag remelting of consumable electrodes with the use of an alternating current in a cooled mould, a means for modluating the amplitude of an alternating current of low frequency is connected in series with the alternating-current source.

It is expedient that the source of alternating current should be made in the form of a transformer, while the means for modulating the amplitude of an alternating current of low frequency must be connected into the circuits of primary or secondary winding of the transformer.

The means for modulating the amplitude of the alternating current of low frequency may be made in the form of an ignitron interrupter.

The means for modulating the amplitude of the alternating current of low frequency can be made in the form of a saturation choke complete with an interrupter of its control current for varying the inductance of the working choke winding.

It is expedient that the means for modulating the amplitude of the alternating current of low frequency should be made in the form of a choke provided with a movable yoke for varying the inductance of the secondary winding of the transformer.

Other objects and advantages of the present invention will become more fully apparent from a consideration of the following description of exemplary embodiments thereof, taken in conjunction with the appended drawings, in which:

FIG. **1** is an elementary diagram of the installation, realized according to the present invention;

FIG. **2** is an electrical diagram of the installation complete with an ignitron interrupter, realized according to the present invention;

FIG. **3** is an electrical diagram of the installation complete with a saturation choke employed as a means for modulating the amplitude of the alternating current, realized according to the present invention;

FIG. **4** is an electrical diagram of the installation complete with an electromagnetic modulator, realized according to the present invention;

FIG. **5***a* represents a graph characteristic of the variation of the feeding current with time;

FIG. **5***b* is another embodiment showing the relation between the feeding current and time.

The installation for the electroslag remelting of consumable electrodes **1** (FIG. **1**) in a cooled mould **2** comprises a source of alternating current in the form of a transformer **3** and a means **4**(**4**′) for modulating the amplitude of the alternating current of low frequency, connected into the primary or secondary winding of the feeding transformer **3**.

The means **4** for modulating the amplitude of the alternating current of low frequency is essentially an ignitron interrupter, consisting of ignitrons **5, 6** (FIG. **2**) connected in parallel in direction towards each other, elements **7, 8** of the grid shift and ignition, phase shifters **9** and a time relay **10**. The ignitron interrupter is connected into the circuit of the primary winding **12** of the feeding transformer **3**, which is shunted by a ballast resistor **13**.

The installation operates as follows.

The process of electrosalg remelting is affected according to one of the existing methods; the ignitron interrupter is thereby shunted by the contacts **11** of an oil switch. After the preparation of the slag bath in the mould **2**, the contacts **11** are opened, and a signal is supplied onto the elements **7, 8** for igniting the ignitrons **5, 6** complete with a time relay **10**, operating according to an automatic duty "impulse-pause."

Depending upon the duties of electroslag remelting adopted, there are practicable two orders of operation of the ignitron interrupter. According to the first duty, the modulation of the alternating current of low frequency is effected by switching in and off the ignitrons **5, 6**, while the second duty involves abrupt variations of the phase of ignition of ignitrons, providing for the alternation of impulses of current and pauses (FIG. **5***a*) or alternations of impulses of current with maximxum and minimum values of the amplitude (**5***b*). In order to exclude an additional magnetizing of the feeding transformer, the ignitrons are synchronously actuated with the network, while each impulse is composed of an even number of half periods.

FIG. **3** illustrates another embodiment of the installation, in which a device for modulating the amplitude of the alternating current of low frequency is a saturation choke **14**, whose working winding **15** is connected into

the circuit of secondary winding **16** of the transformer **3.** The winding **17** for controlling the saturation choke **14** is connected through a rectifier **18** and contacts **19** of the time relay to an autotransformer **20.**

When the contacts **19** are opened, the inductance of the working winding **15** is great, and almost the whole voltage, induced in the secondary winding **16** of the transformer **3,** drops in the saturation choke **14.** The current of the melting process is of an insignificant value.

After closing the contacts **19,** the inductance of the saturation choke drastically drops, and a current, sufficient for heating the slag bath up to the temperature of melting of the electrode **1,** begins to flow along the circuit "choke mould."

The required depth of modulation of the main current is achieved by adjusting the current flowing in the control winding **17** to be actuated by the aid of the autotransformer **20.**

The frequency of modulation is specified by the time of switching in and switching off of the contacts **19** of the time relay.

The modulation of the alternating current of a frequency equal or near the frequency of own oscillations of the liquid metal bath, on account of the presence of electrocapillar vibrations on the boundary "slag-metal" and electrodynamic forces, is likely to cause the resonance oscillations of the liquid metal, bath, which contributes to the refining of the structure of the ingot being produced, a decrease in the non-uniformity of the structure of metal and a reduction in the extent of development therein of the dendritic segregation.

FIG. **4** illustrate another embodiment of a means for modulating the amplitude of the alternating current of low frequency. A choke **21** is connected into the circuit of secondary winding **16** of the transformer **3.** The magnetic circuit of said choke is provided with a rotating yoke **23,** connected to an electric motor **24.** The value of the gap and resistance of the magnetic circuit **22** vary depending upon the position of the yoke **23.**

This results in a variation of the inductive resistance of the choke **21,** and is likely to modulate the alternating current feeding the mould **2.**

The installation, represented in FIGS. **3** and **4,** operates similarly to that shown in FIG. **2.**

Though the present invention is described in connection with its preferred embodiment, it is evident that there may be allowed variations and modifications thereof that do not depart from the idea and scope of the invention, which will be readily understood by those skilled in the art.

These variants and modifications are considered to be within the essence and scope of the invention, as defined by the appended claims.

What is claimed is:

1. A method of electroslag remelting of a consumable electrode comprising preparing a bath of molten slag in a mold, immersing said consumable electrode in said bath of molten slag, passing alternating current through said electrode to melt and form a liquid metal bath in said mold, and modulating the amplitude of said alternating current at a predetermined frequency substantially below the frequency of said alternating current.

2. A method of electroslag remelting of a consumable electrode as recited in claim **1** wherein said predetermined frequency of modulation of said alternating current is near the natural frequency of oscillation of said liquid metal bath.

3. A method of electroslag remelting of a consumable electrode comprising preparing a bath of molten slag in a mold, immersing said consumable electrode in said bath of molten slag, passing electrical current through said electrode into said bath of molten slag, thereby causing said electrode to melt and form a liquid metal bath in said mold, and varying the amplitude of said electrical current at a frequency near the natural frequency of oscillation of said liquid metal bath.

4. A method of electroslag remelting as defined by claim **1,** wherein said passing step is carried out with a transformer having primary and secondary circuits, and said modulating step carried out in the secondary circuit.

5. A method of electroslag remelting as defined by claim **1,** wherein said passing step is conducted with a transformer having primary and secondary circuits, and wherein said modulating step is carried out in the primary circuit.

6. The method of electroslag remelting as defined by claim **1,** wherein the depth of modulation occurring in said modulating step is one hundred percent whereby the alternating current is applied to the molten slag in the form of on-off alternating current impulses.

7. A method of electroslag remelting as defined by claim **1,** wherein said modulating step varies the amplitude of the alternating current between predetermined high and low values greater than zero.

8. The method of electroslag remelting as defined by claim **1,** wherein said modulating step is conducted in a manner to minimize formation of stringers and dendritic non-uniformity in the metal ingot formed.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,867,130

DATED : February 18, 1975

INVENTOR(S) : BORIS EVGENIEVICH PATON et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, between lines 45 and 46 insert the following paragraphs

--This is accomplished by modulating the amplitude of an alternating current of low frequency feeding the electroslag remelting furnace.

It is known that when an alternating current passes through the boundary between the liquid slag and the liquid metal, there arises, in conventional installations for electroslag remelting, an electrocapillary vibration of the surface of the network. Besides, the liquid metal bath is subjected to electrodynamic forces which, as compared to the frequency of the feeding network, act with double frequency.

In the proposed installation for electroslag remelting, the modulation of the amplitude of the alternating current at a frequency, equal or close to the natural frequency of oscillation of the liquid metal bath, causes the electrodynamic

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,867,130 (continued) - 2 -

DATED : February 18, 1975

INVENTOR(S) : BORIS EVGENIEVICH PATON et al

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

forces and electrocapillary vibration in the liquid bath to change with the same frequency, thus causing resonant oscillation of the liquid metal bath, which reduces dendritic segregation in the crystallizing metal, refining of the structure of the ingot and elimination of horizontal and dendritic non-uniformity.--

Column 1, line 49, change "modluating" to --modulating--.

Column 2, line 42, change "electrosalg" to --electroslag--

Column 2, line 54, change "in" after "switching" to --on--

Column 3, line 33 change "illustrate" to--illustrates--.

Column 4, claim 4, line 30, insert --is-- after "step"

Signed and Sealed this

sixteenth Day of *December 1975*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks