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Paton et al.

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[45] **Dec. 4, 1973**

[54] **METHOD OF ELECTROSLAG REMELTING**

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[21] Appl. No.: **125,744**

[52] **U.S. Cl.** ..... **164/52,** 75/10 C, 164/56

[51] **Int. Cl.** **B22d 27/02,** C22d 7/00

[58] **Field of Search** ..... 75/10, 11, 12, 13, 75/93 E; 164/52, 252; 13/9

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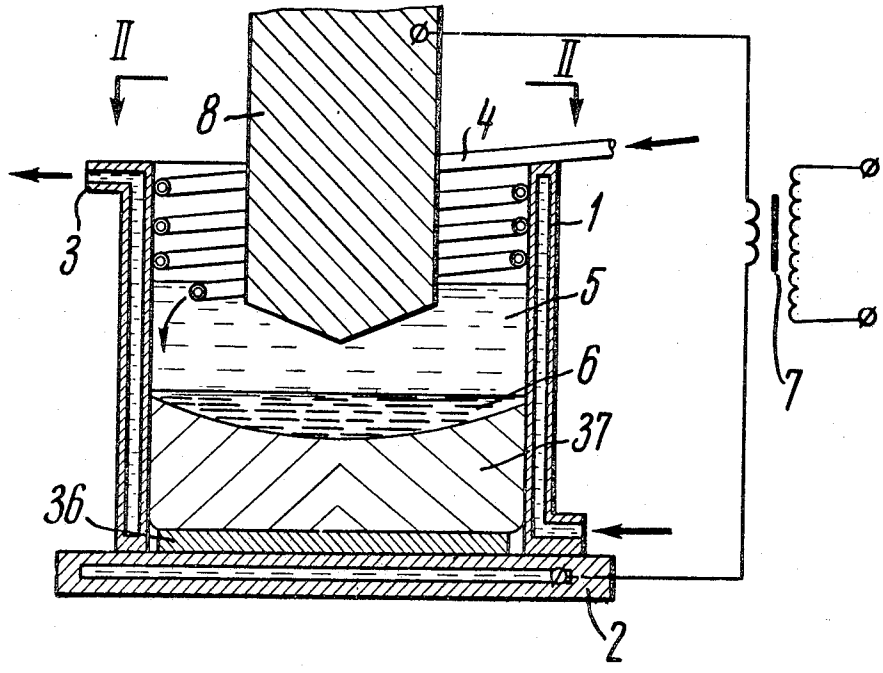
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Assistant Examiner—M. J. Andrews
Attorney—Holman & Stern

[57] **ABSTRACT**

A method of electroslag remelting of consumable electrodes according to the invention, characterized in that the agents improving the quality of the ingot are blown into the melt so that the injected flow of these agents cause rotation of this melt.

5 Claims, 12 Drawing Figures



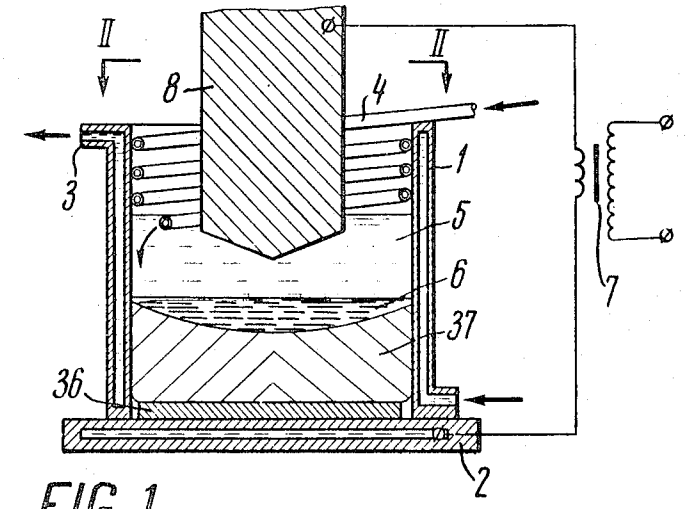


FIG. 1

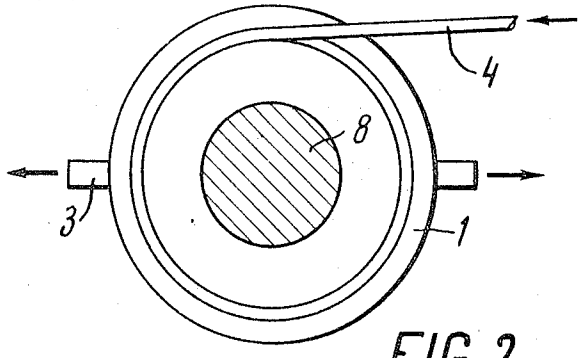


FIG. 2

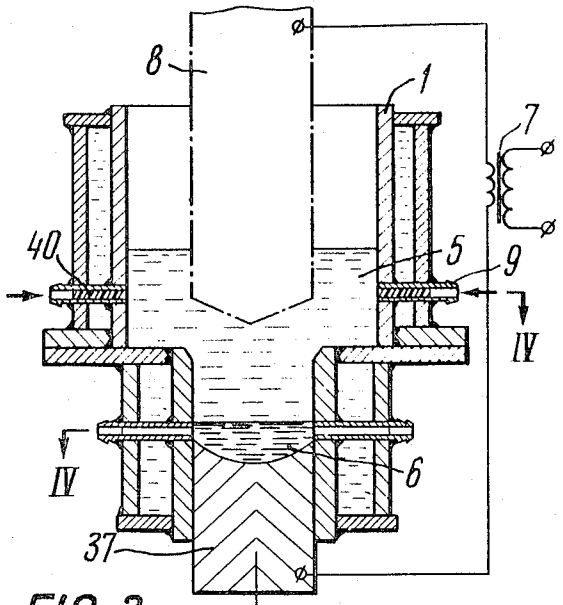


FIG. 3

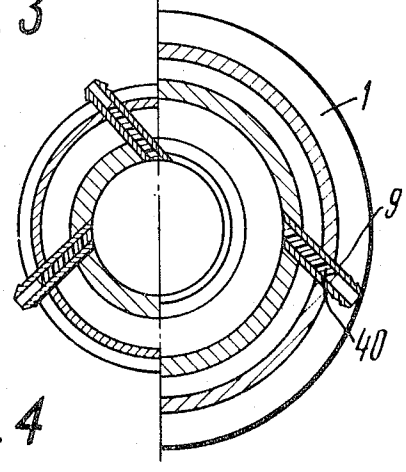


FIG. 4

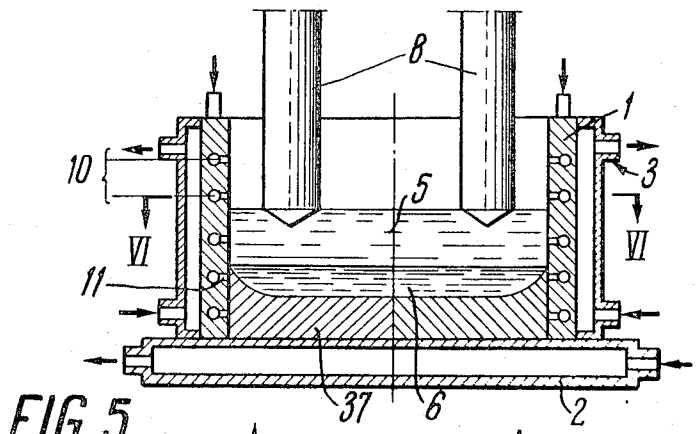


FIG. 5

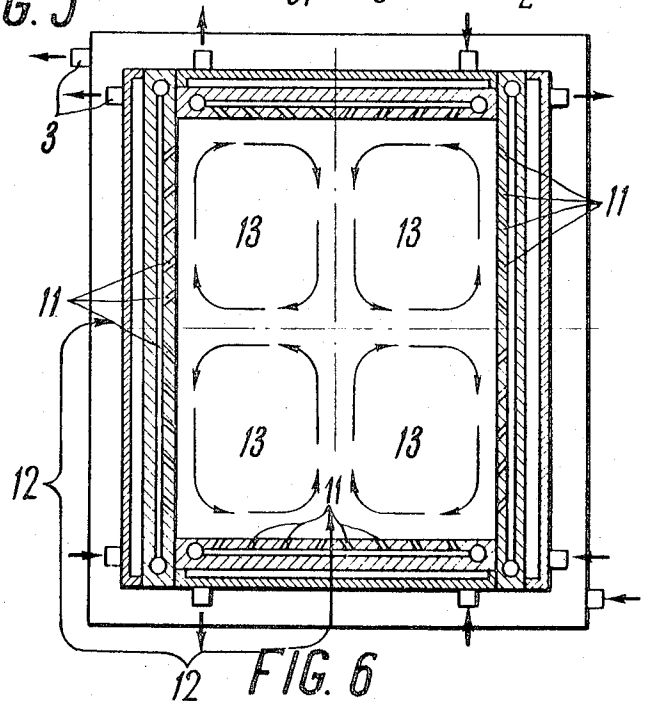


FIG. 6

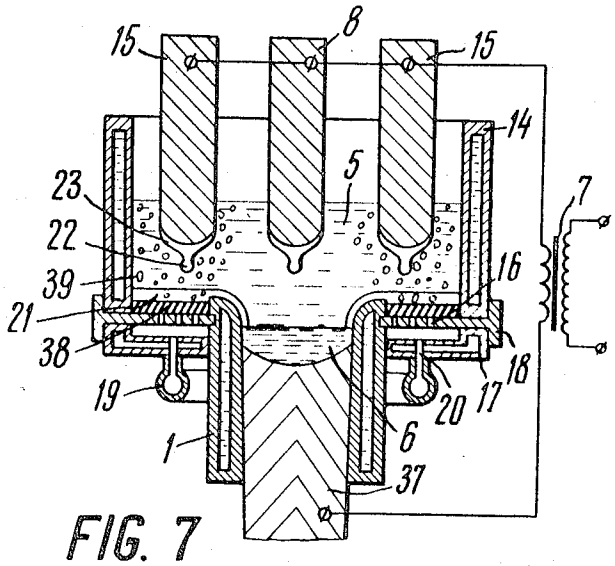


FIG. 7

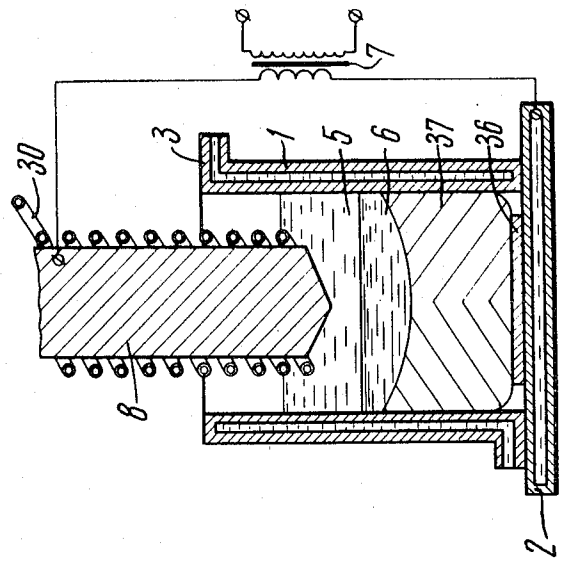


FIG. 10

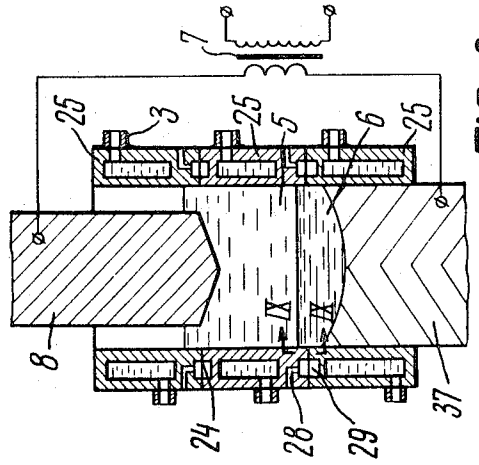


FIG. 8

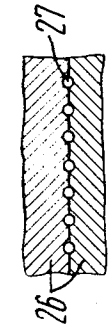


FIG. 9

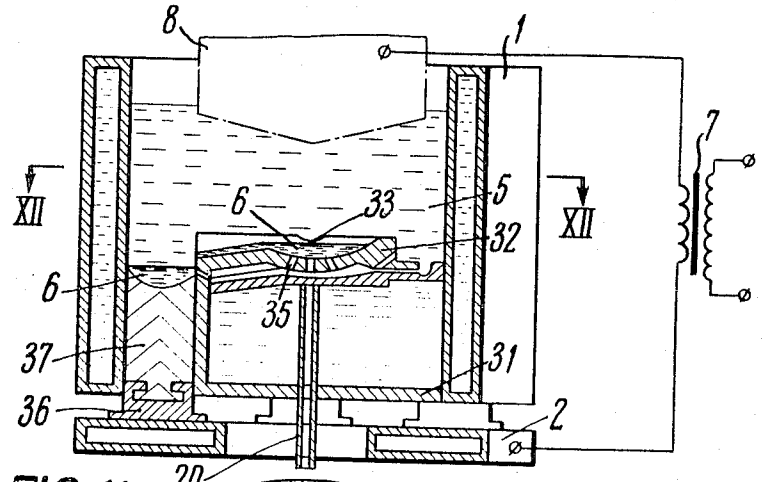


FIG. 11

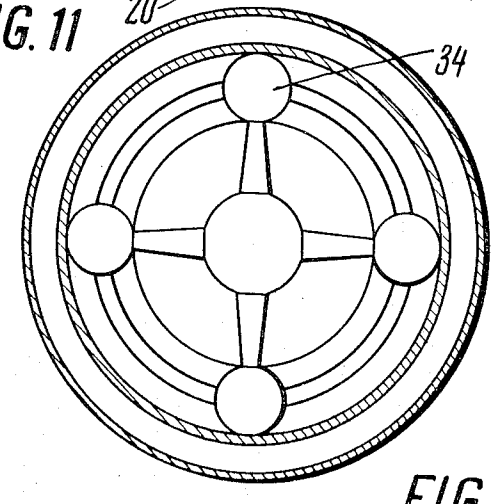


FIG. 12

METHOD OF ELECTROSLAG REMELTING

BACKGROUND OF THE INVENTION

The present invention relates to electrometallurgy and, more particularly, it relates to a method of electroslag remelting of consumable electrodes and to devices for effecting this method. More particularly, the invention relates to production of ingots of high-quality electroslag metal.

Well known in the art is a method of electroslag remelting of consumable electrodes in moulds, in which a controllable gas atmosphere is created above the electroslag bath.

In this case saturation of the remelted metal with deleterious gases from the surrounding atmosphere is eliminated but required degasification of the metal is not achieved.

In addition, when large ingots are produced by the method of electroslag remelting of high-dimension consumable electrodes with a higher content of gases (O_2, H_2, N_2) and deleterious impurities (S, P, etc.), it is necessary not only to prevent the saturation of the remelted metal with gases from the surrounding atmosphere, but also to intensify the process of degasification, to increase the purity of the metal by excluding deleterious impurities and non-metallic inclusions, as well as to improve the formation of the ingots of the electroslag remelting which can not be provided by means of the known method.

In present-day metallurgy there is also well known a method of gas treatment of molten metal consisting in blowing (bubbling) of the metal by gases and powders in a gas flow, thus somewhat improving the melt quality. During the bubbling the mixing of the melt takes place only near the injected flow, while "dead zones" are formed in separate portions of the melt. In these "dead zones," the process of degasification and cleaning of the melt from the deleterious and non-metallic inclusions (Pb, Sn, etc.) is not adequately intensive, and this deteriorates the quality of the obtained ingots.

SUMMARY OF THE INVENTION

The principal object of the invention is to provide an improved method of electroslag remelting of consumable electrodes wherein there is ensured intensive stirring (rotation) of the melt within the mould throughout the whole volume of this melt in the process of remelting.

These and other objects are attained due to the fact that in the proposed method of electroslag remelting of consumable electrodes the agents contributing to improvement of the quality of the ingot are injected into the melt in such a manner that they cause rotation of this melt.

It is expedient that the agents injected into the slag and metal portions of the melt are blown in opposite directions.

To equalize the speeds of rotation of the slag and metal portions of the melt, the agents are preferably blown into the slag portion of the melt under a pressure which is lower than the pressure of the agents injected into the metal portion of the melt by a factor equal to the difference between the specific gravity of the metal portion of the melt and the specific gravity of the slag portion of the melt.

In a mould having large dimensions it is expedient to create several zones of rotation in a horizontal plane in the melt bath by blowing the agents into a corresponding number of the portions separately and in opposite directions in the adjacent portions.

The agents are preferably blown into the slag portion of the melt directly under the consumable electrodes.

The above objects are also attained due to the fact that the mould for carrying out the method is provided with a nozzle for injecting the agents into the melt made in the form of a coil of a metal being remelted which is wound inside the mould along the walls thereof.

The mould is preferably provided with at least one additional nozzle made in the form of a coil of a melted material, the melting point of which differs from the melting point of the material of the main coil, the additional nozzle being located adjacent to the main coil and having a winding directed in opposition to the winding of the main coil.

In the mould at least at one level within the slag portion of the melt there can be located at least one nozzle for injection of the agents into the melt made in the form of a branch pipe mounted into the lateral wall of the mould, the longitudinal axis of the branch pipe being directed tangentially to the mould wall.

It is expedient to mount several groups of pipe branches in the mould walls for injection of the agents into the melt with various angles of inclination of their axes to the walls of the mould to provide for several zones of rotation of the melt within the mould with different directions of rotation in the adjacent zones, the number of the zones corresponding to that of the groups of pipe branches.

In the mould having a widened upper portion the nozzles for blowing the agents into the slag portion are preferably arranged in the bottom of the upper widened portion of the mould directly under the consumable electrodes.

The bottom of the upper widened portion of the mould is preferably provided with removable inserts into which there are mounted said pipe branches for blowing the agents into the slag portion of the melt.

The nozzles for blowing the agents into the melt are preferably provided with porous inserts of refractory metals.

The mould can be made sectional along a vertical line with at least two sections, in which case the mould walls in the place of joining of the sections should be provided with a hermetically sealed chamber communicating through a slot with the bath of melt and through a channel with the source of agent improving the quality of the ingot.

It is expedient to provide knurling at least on one plane forming the slot.

The above objects are also attained due to the fact that the consumable electrode provided with a nozzle for blowing the agents into the melt has a nozzle in the form of a coil wound around the electrode and made of the metal being melted.

The consumable electrode is preferably provided with at least one additional nozzle shaped as a coil wound around the electrode, the winding being directed opposite to the winding of the main coil and made of the material being melted, the melting point of the additional coil differing from the melting point of the main coil.

DESCRIPTION OF THE DRAWINGS

The invention will be apparent from the following detailed description of one embodiment thereof, reference being made to the accompanying drawings, in which:

FIG. 1 shows a device for electroslag remelting having a mould provided with a nozzle in the form of a coil, according to the invention;

FIG. 2 is a sectional view taken along the line II—II in FIG. 1;

FIG. 3 shows a device for electroslag remelting with a mould according to the invention provided with nozzles in the form of pipe branches mounted into the wall of the mould;

FIG. 4 is a sectional view along th line IV—IV in FIG. 3;

FIG. 5 shows a device for electroslag remelting with a mould provided with nozzles in the form of pipe branches mounted by groups into the wall of the mould according to the invention;

FIG. 6 is a sectional view taken along the line VI—VI in FIG. 5;

FIG. 7 is a device for electroslag remelting with a mould having a widened upper portion according to the invention;

FIG. 8 shows a device for electroslag remelting with a sectional mould, according to the invention;

FIG. 9 is a sectional view taken along the line IX—IX in FIG. 8;

FIG. 10 shows a device for electroslag remelting with a consumable electrode, according to the invention, the consumable electrode being provided with a nozzle in the form of a coil;

FIG. 11 shows a device for electroslag remelting with a mould intended for simultaneously melting several separate ingots;

FIG. 12 is a sectional view taken along the line XII-XII in FIG. 11.

The device for electroslag remelting (FIG. 1) includes a water-cooled mould 1 and a pan 2, pipe branches 3 for supply and removal of the cooling agents and a nozzle made in the form of a coil 4 wound within the mould 1 along the walls thereof. The coil 4 is made of a material to be melted and is designed for blowing into the slag portion 5 and into the metal portion 6 of the melt agents which assist in improving the quality of the ingots, for example gases (Ar, He, N_2, CO_2, etc.), a mixture a various gases (Ar + O_2, etc.), gas-powder mixtures (Ar + CaF_2, etc.), aerosoles and so on. In addition, the device is provided with a current supply source 7 one terminal of which is connected to a consumable electrode 8 and the other terminal being connected to the pan 2.

In the embodiment of the invention shown in FIG. 1*a* single coil 4 is used. Other modifications of the device may be equipped with a plurality of coils. In this case the winding of the additional coils should be directed opposite to the winding of the main coil. The additional coils are also made of the material to be melted but their melting point should differ from the melting point of the main coil.

Shown in FIG. 2 is a section through the line I—I of the device for electroslag remelting shown in FIG. 1, in which there is illustrated the position of the coil 4 and consumable electrode 8 relative to the walls of the mould 1 and also the disposition and shape of the cross section of the consumable electrode 8.

FIG. 3 shows a device for electroslag remelting which differs from the modification shown in FIGS. 1 and 2 in that it is provided with nozzles for injection of the agent in the form of pipe branches 9 mounted into the side walls of the mould 1. Depending on the cross section of the mould 1, the number of pipe branches 9 may be varied. The pipe branches 9 are disposed both within the zone of the slag portion 5 and the zone of the metal portion 6 of the melt. In the device shown in FIGS. 3 and 4 four pipe branches 9 are located along the diameter of the mould 1 at one level within the zone of the slag portion 5 and four pipe branches 9 are located at one level within the zone of the metal portion 6 of the melt.

In addition, in FIG. 4 it is illustrated that the pipe branches 9 are mounted tangentially to the walls of the mould 1 and are located in such a manner that the flows of agents blown through these pipe branches cause rotation of the slag portion 5 and the metal portion 6 of the melt in opposite directions.

FIG. 5 illustrates a modification of the device of electroslag remelting used for producing ingots of a large cross section. In this case, unlike the above-described modifications of the remelting device, the mould 1 is provided with nozzles for injection of the agent which are made in the form of pipe branches 11 mounted into the walls of the mould 1 at several levels 10 along the height of the mould 1. The distance between the levels 10 is selected so that during the whole process of melting both the slag portion 5 and the metal portion 6 of the melt are blown with the agents.

The pipe branches 11, depending on the cross section of the mould, are combined into several groups 12 (FIG. 6) in each of which the longitudinal axes of the pipe branches 11 are inclined at such angles to the wall of the mould 1 that in the process of injection of the agents into the melt through these pipe branches, there are formed within the melt several zones 13 of rotation corresponding to the number of groups 12 with opposite direction of rotation within the adjacent zones 13. FIG. 6 shows four such zones 13.

FIG. 7 shows a version of the device for electroslag remelting with a mould having a widened upper portion 14 and a group of consumable electrodes 15 located along the periphery of the upper portion 14. In this case the nozzles for feeding the agent into the melt made in the form of a pipe branches 16 are preferably located in the bottom 17 of the widened upper portion 14 of the mould directly under the consumable electrodes 15. The pipe branches 16 are mounted in replaceable inserts 18 which are mounted in the bottom 17. The supply of the agent to the pipe branches from the source (not shown in FIG. 7) of agent is effected by means of a distributing unit 19 through channels 20.

The disposition of the pipe branches 16 for blowing the agents into the slag portion 5 of the melt directly under the consumable electrode 15 allows the agents to be used not only for treatment of the molten metal 21 but also for treatment of the drops 22 and the thin film 23 of molten metal formed on the meltable ends of the consumable electrodes 15.

To use the agent for treatment of the metal portion 6 of the melt, the lower portion of the mould 1 is preferably made in the form of a collector (not shown in FIG. 7) into the walls of which there are mounted noz-

zles for feeding the agents through the gap between the ingot and the internal wall of the collector into the melt, the above-said nozzles being made in the form of pipe branches.

Shown in FIG. 8 is a version of the device for electroslag remelting provided with a sectional mould. In this case the nozzles for supplying the agent into the slag portion 5 and metal portion 6 of the melt include slots 24 formed in the places of connection of the sections 25 with the planes 26 thereof. The planes 26 have a knurling 27 (FIG. 9). In this construction the agent is supplied to the slots 24 from the source (not shown) in FIGS. 8 and 9, through the channels 28 and through the hermetically sealed chambers 29 in the walls of the mould 1.

Shown in FIG. 10 is a version of the device for electroslag remelting by means of a consumable electrode 8 provided with a nozzle for blowing an agent into the slag portion 5 of the melt made of the material being melted and shaped as a coil 30 which, unlike the version of the device shown in FIGS. 1 and 2 is wound around the consumable electrode 8.

Shown in FIGS. 11 and 12 is a modification of the device for electroslag remelting provided with a mould 1 designed for melting several ingots simultaneously.

In this case, unlike the above-described devices, the mould 1 is provided with a bottom 31 having a central portion 32 protruding into the mould 1, said central portion 32 having a cup 33 serving as a collector of the metal portion 6 of the melt and openings 34 (FIG. 12) used for shaping the ingot being melted and located along the periphery of the bottom 31. The nozzles for blowing the agent into the melt are made in the form of pipe branches 35 and are mounted into the walls of the protruding portion 32 of the bottom 31 at levels corresponding to the position of the slag portion 5 and metal portion 6 of the melt.

The device for electroslag remelting shown in FIGS. 1 and 2 operates, according to the invention, in the following manner:

Prior to the process of electroslag remelting the mould 1 provided with a nozzle made of the material being melted in the form of a coil 4 is placed onto the pan 2. A starting rod 36 is also placed on the pan 2, thereafter and the consumable electrode 8 is inserted into the mould 1. After that an electric current from the current source 7 is applied to the consumable electrode 8 and the pan 2. From the source of agent (not shown in FIGS. 1 and 2) the agent is fed into the coil 4, while the cooling medium is fed into the jacket of the mould 1 and the pan 2. Then molten slag is poured into the mould 1 to form a slag portion of the melt (bath) until a current appears in the circuit: the consumable electrode 8 — the pan 2, which current causes melting of the electrode 8.

During the whole process of melting the consumable electrode 8 is fed into the mould 1 at a rate equal to the rate of melting thereof. As fast as the consumable electrode melts off, molten metal is collected in the mould 1 forming a metal portion 6 of the melt, said metal gradually solidifying into an ingot 37. In the process of melting, the ingot 37 is built-up, the metal portion 6 and the slag portion 5 ascend within the mould 1. In this case, simultaneously with the melting of the consumable electrode 8, there is effected the melting of the coil 4, wound inside the mould 1 along the walls thereof, at a rate equal to the speed of lifting of the slag and metal portions 5 and 6 of the melt. The agent forced from the end of the coil 4, which is within the slag portion 5 of the melt during the whole process of melting, bubbles the slag portion 5 and partially the metal portion 6 of the melt and simultaneously rotates them about the vertical axis of the mould 1. This makes it possible to considerably intensify the process of degasification and refining of the metal of the ingot 37.

The device for electroslag remelting shown in FIGS. 3 and 4 operates similarly to the device shown in FIGS. 1 and 2 with a single distinction that the ingot 37 in the process of melting is withdrawn from the mould 1 at a speed which enables the slag and metal portions 5 and 6 of the melt during the whole process of melting to be in the mould 1 at the same level as the agent-injecting nozzles shaped as pipe branches 9.

In addition, as the longitudinal axes of the pipe branches 9 located within the zone of slag portion 5 of the melt are directed opposite to the longitudinal axes of the pipe branches 9 located within the zone of the metal portion 6 of the melt and are tangentially mounted into the walls of the mould 1, the agent blown through these pipe branches causes rotation of the slag and metal portions 5 and 6, respectively, in opposite directions.

The electroslag remelting device shown in FIGS. 5 and 6 operates similarly to the device shown in FIGS. 1 and 2, the difference being that the agent is blown through the nozzles shaped as pipe branches 11, mounted into the walls of the mould 1 and combined into four independent groups 12.

The agent blown through the pipe branches 11 simultaneously bubbles and rotates the slag and metal portions 5 and 6 of the melt, in which case each group 12 of pipe branches 11 builds up an independent zone 13 of rotation of the melt. To mix the melt portions more intensively, the pipe branches 11 of the adjacent groups 12 are located so that the agent blown therethrough causes opposite rotation of the melt in the adjacent zones 13.

The device for electroslag remelting shown in FIG. 7 and designed for remelting of a group of consumable electrodes 15 operates similarly to the device shown in FIGS. 3 and 4; however, in this case during the whole process of melting the agent is blown through the pipe branches 16 located in the bottom 17 of the widened portion 14 of the mould into the slag portion 5 of the melt directly under the consumable electrodes 15. In this case the flows of the agent injected into the melt and encountering the drops 22 and the thin film 23 of molten metal on the melted ends of the consumable electrodes 15 acts to erode the drops 22 and treat the metal (degasification and refining).

Furthermore, due to the fact that the bottom 17 of the widened upper portion 14 of the mould is cooled, a porous slag skin 38 is formed on the bottom 17 in the places of disposition of the pipe branches 16 after pouring the slag into the mould. The agent blown through the pipe branches 16 into the slag portion 5 of the melt, while passing through the slag skin 38, is pulverized into fine fractions and bubbles the slag and metal portions 5 and 6 of the melt, as well as the drops 22 and the film 23 of molten metal, by small blisters 39. This provides for a better treatment of the melt by the agent, thereby improving the quality of the ingot 37.

The electroslag remelting device shown in FIGS. 8 and 9 operates similarly to the device shown in FIGS.

3 and 4, the only difference being that the agent injected into the slag and metal portions 5 and 6 of the melt is blown by small blisters along the entire perimeter of the mould through the nozzles made in the form of slots 24 communicating with a source of agent (not shown in FIGS. 8 and 9) through a hermetically sealed chamber 29 and channels 28.

The electroslag remelting device shown in FIG. 10 operates similarly to the device shown in FIGS. 1 and 2, but in this case the agent is injected into the slag portion 5 of the melt through a nozzle made of material being melted and shaped as a coil 30 wound on the consumable electrode 8. In this case, during the melting the consumable electrode 8 and the coil 30 are continuously fed into the mould 1 in which they are melted together.

The electroslag remelting device shown in FIGS. 11 and 12 operates similarly to the device shown in FIGS. 3 and 4, the only difference being that the agent is blown into the slag portion 5 and the metal portion 6 of the melt through nozzles made in the form of pipe branches 35 mounted into the walls of the protruding portions 32 of the bottom 31.

The agent blown through the pipe branches 35 simultaneously bubbles and rotates the metal portion 6 of the melt not only in the openings 34 shaping the ingot 37 but also in the cup 33 of the central portion 32 of the bottom 31. This provides for more complete treatment of the whole metal portion 6 of the melt, thus improving the quality of the ingot 37 being melted.

In the above-described modifications of the device the pipe branches for blowing the agent into the melt are provided with porous inserts 40 (shown in the modification of the device in FIGS. 3 and 4) made of refractory materials (for example porous W, Mo, etc.).

This makes it possible to inject the agent into the melt by fine streams or mist and this increases the quality of treatment of the melt by the agent.

The advantages of the present invention include the fact that during the electroslag remelting of consumable electrodes according to the proposed method, the bubbling of the melt by an agent improving the quality of the ingot is associated with the rotation of the melt throughout the whole volume of the mould, thus making it possible to considerably intensify the process of degasification of the melt and cleaning of the same from deleterious impurities, non-metal inclusions and fusible impurities as well as to improve the surface of the ingot which eventually improves the quality of the ingot being melted.

The rotation of the slag and metal portion of the melt in opposite directions increases the path of the agent through the metal portion of the melt and assists in improvement of the quality of the ingot being melted.

The proposed method can be effected by means of devices built around known electroslag remelting apparatus having a simple construction and featured by a low cost of manufacture, and this is still another advantage of the proposed invention.

We claim:

1. A method of degasification and removal of deleterious inclusions and impurities during electroslag remelting of consumable electrodes wherein at least one consumable electrode is melted by means of an electric current between said electrode and liquid slag and metal contained in a vessel, the improvement comprising blowing agents which improve the quality of the resultant ingot into the liquid slag and metal during the remelting process, the flow of said agents being so directed as to cause a rotation throughout the complete volume of the liquid slag and metal.

2. The method as claimed in claim 1, in which said agents are blown into the liquid metal and slag in opposite directions.

3. The method as claimed in claim 2, in which said agents are blown into the liquid slag under a pressure which is lower than the pressure of said agents blown into the liquid metal by a factor equal to the difference between the specific gravity of the liquid metal and the specific gravity of the liquid slag.

4. The method as claimed in claim 1, in which there are created in the bath of said liquid slag and metal several zones of rotation in a horizontal plane by blowing said agents into adjacent portions of said bath in opposite directions.

5. A method as claimed in claim 1, in which said agents are blown into the liquid slag directly under said consumable electrode.

* * * * *