

[54] **ELECTROSLAG REFINING**

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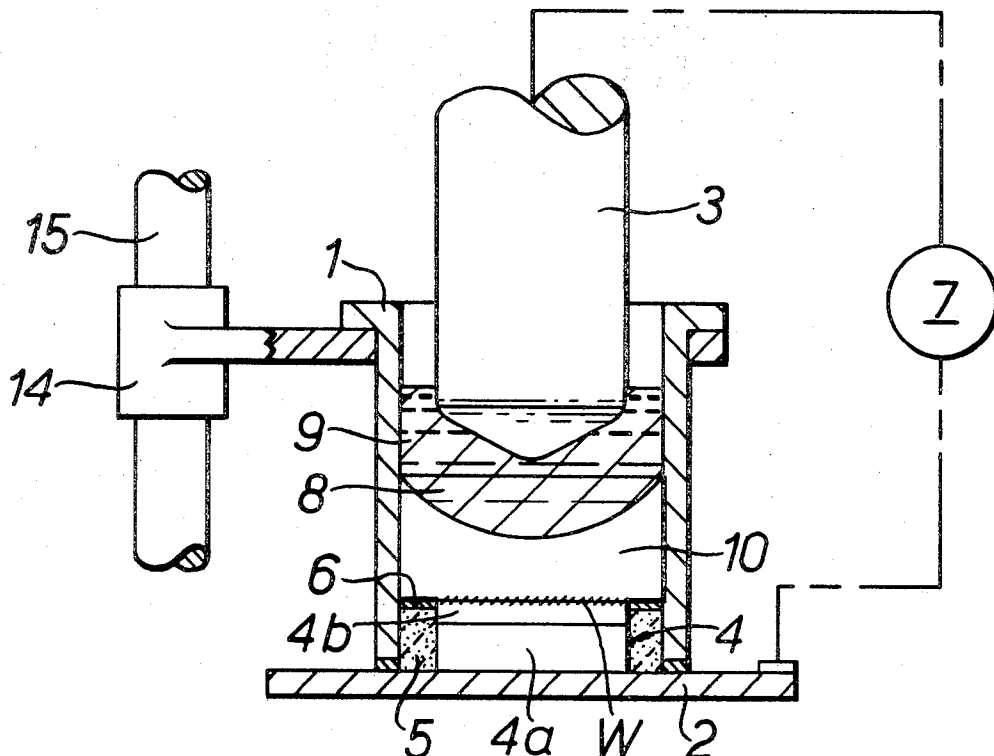
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[57] **ABSTRACT**

A method of forming an ingot of refined metal by the electroslag refining process comprises the steps of introducing into the lower open end of a cooled mould a solid un-cooled electrically-conductive member of a material weldably compatible with the metal to be refined, the member having a surface area sufficient to conduct the full working current employed in the process and being spaced from the internal walls of the mould, introducing a compactable material into the annular spacing formed between the solid member and the internal mould walls, forming a bath of molten slag within the mould, passing an electric current through the slag bath to maintain the temperature of the bath at or above the melting point of the metal to be refined and causing droplets of unrefined metal to travel through the molten slag bath and to collect above the member and compactable material, which droplets form a pool of refined liquid metal which progressively solidifies to form an ingot of refined metal which is supported by and is welded to the upper surface of the member.

8 Claims, 2 Drawing Figures



ELECTROSLAG REFINING

This invention relates to the electroslag refining process and to apparatus for use therewith.

In the electroslag refining process, an electrically-conductive slag within a mould is maintained in a molten state and at a temperature above the melting point of the metal to be refined. Unrefined metal is introduced into the mould and is refined as it passes in droplet form through a bath of the molten slag, refined droplets collecting to form a pool beneath the slag bath. The mould walls are cooled by the circulation of a coolant, normally water, and a solidified ingot is built up beneath the molten metal pool. The metal to be refined may be introduced to the mould in the form of one or more consumable electrodes which extend into the upper open-end of the mould, and the slag may be maintained molten by passage of an electric current from the electrode(s) to the baseplate on which the mould stands; alternatively, the metal may be introduced in molten form or as particulate matter, for example in the form of scrap or pellets, electrical energy being supplied to the slag bath by means of one or more non-consumable electrodes or plasma torches. In each case, electrical current flows from the electrode or plasma torch, through the slag bath and solidified ingot to the mould baseplate from which it is returned to the electricity supply.

Previously it has been found that upon solidification, the bottom of the ingot may shrink away from the mould baseplate, this leading to arcing and subsequent damage to the baseplate. Also, when electroslag refining apparatus is employed in which the mould is raised relative to the ingot during melting to produce an ingot of greater height than that of the mould, the ingot may move upwardly with the mould so that a gap is formed between the bottom of the ingot and the baseplate, this again leading to bad electrical conduction and arcing.

Furthermore, electroslag refining plant have hitherto incorporated baseplates having internal passages for the flow of a coolant (normally water). Such baseplates are expensive to construct and suffer from the disadvantage that starting stubs cannot satisfactorily be welded to their upper surfaces.

According to the present invention in one aspect, there is provided a method of forming an ingot of refined metal by the electroslag refining process which comprises the steps of introducing into the lower open-end of a cooled mould a solid un-cooled electrically-conductive member of a material weldably compatible with the metal to be refined, the member having a surface area sufficient to conduct the full working current employed in the process and being spaced from the internal walls of the mould, introducing a compactable material into the annular spacing formed between the solid member and the internal mould walls, forming a bath of molten slag within the mould, passing an electric current through the slag bath to maintain the temperature of the bath at or above the melting point of the metal to be refined and causing droplets of unrefined metal to travel through the molten slag bath and to collect above the member and compactable material, which droplets form a pool of refined liquid metal which progressively solidifies to form an ingot of refined metal which is supported by and is welded to the upper surface of the member.

According to the invention in another aspect, electroslag refining apparatus includes a cooled mould into the open lower end of which extends a member constructed of an electrically-conductive material weldably compatible with the metal of the ingot to be formed, the member being spaced from the internal walls of the mould and having a surface area sufficient to convey substantially the full melting current which is conveyed to the electroslag refining apparatus during operation of the same. The space defined between the upstanding member and the opposed wall of the mould may be filled with a compactable material, e.g. crushed used slag, which will not react with the molten slag employed during operation of the process and will permit movement of the mould relative to the formed ingot. A ring of heat-resisting material, e.g. asbestos, may be positioned above the crushed slag to prevent, or reduce, flow of molten slag into the space formed between the upstanding member and the mould.

The mould may, during operation of the process, move vertically relative to the formed ingot; in such an arrangement the space between the member and the opposed surface of the mould is sufficient to permit thermal expansion of the member without preventing movement of the mould relative to the ingot formed.

In the accompanying diagrammatic drawing,

FIG. 1 is a sectional elevational view of electroslag refining apparatus embodying the invention, and

FIG. 2 is a similar view of alternative electroslag refining apparatus embodying the invention.

The apparatus illustrated in FIG. 1 includes an open-ended cooled mould 1 mounted on and insulated from an uncooled baseplate 2 constructed of mild steel plate. A consumable electrode 3 extends into the upper open-end of the mould 1. Welded to the upper surface of the baseplate 2 is a member 4 which extends upwardly into the lower open-end of the mould 1 and which comprises a mild steel lower portion 4a and an upper portion 4b cut from one end of the electrode 3 and welded to the lower portion. Alternatively, the member 4 may consist entirely of a material weldably compatible with the material to be refined. The annular space defined between the internal wall of the mould 1 and the member 4 is filled with a compactable material 5 which is substantially inert with respect to the molten slag to be employed in the process. For example, crushed used slag may be employed. A ring 6 of heat-resistant material, e.g. asbestos, is placed above the material 5. The area of the upper surface of the member 4 is sufficiently large to support the ingot to be formed and to carry the full working current which will, during operation, flow from the electrode 3. The permissible surface area of member 4 is limited only by the fact that the volume of crushed slag between the member and the mould must be large enough to ensure that thermal expansion of the member does not exert a force on the mould wall sufficient to prevent movement of the mould relative to the baseplate. Preferably, the diameter of the member 4 is between two-fifths and nine-tenths of the internal diameter of the mould 1. For example, in the melting of an electrode within a mould of internal diameter 12 inches, a member of 9 inches diameter is employed and the current conveyed to the molten slag from the electrode 3 is of the order of 320 KW.

The electrode 3 and baseplate 2 are electrically connected to a current source 7.

In operation, droplets of unrefined metal pass from the electrode 3 and collect in a pool 8 below an electrically-conductive refining slag 9. Heat from the molten metal pool 8 melts the upper surface of the portion 4b of the member 4 so that the ingot 10 which is formed is welded at "W" to the member 4 across the complete upper surface of the portion 4b, thus ensuring good electrical conduction from the member 4 to the baseplate 2. As the consumable electrode 3 melts and an ingot is built up below the metal pool 8 the mould 1 is raised at a controlled rate by means of a carriage 14 moveable vertically relative to a mast 15 to maintain a pre-determined gap between the electrode tip and the surface of the metal pool. The large surface area over which the ingot 10 is welded to the member 4 ensures that the ingot 10 does not lift away from the member 4 as the mould 1 is raised.

The crushed slag 5 and the asbestos ring 6 prevent molten slag from penetrating the space between the member 4 and the wall of the mould 1. It has been found that if molten slag is allowed to enter this space, subsequent solidification of the slag and thermal expansion of the member 4 causes the mould to be gripped so tightly as to prevent its upward movement. Also, melting of the baseplate 2 may occur if it should come into contact with molten slag.

On conclusion of a melt, the member 4 can readily be removed from the ingot bottom by breaking the weld W and can be re-used with a minimum of preparation.

In the apparatus illustrated in FIG. 2, in which like integers to those illustrated in FIG. 1 bear the same reference numerals, the mould comprises an ingot forming section 1 and a lower extension piece 11 which seats upon the baseplate 2, and the crushed slag 5 is positioned between the member 4 and the internal wall of the mould extension piece 11. In this embodiment, the mould 1 remains stationary during a melt, a duct 12 being provided for admitting molten slag to the base of the mould for starting purposes and means being provided for lowering the electrode 3 as melting proceeds to maintain a pre-determined gap between the electrode tip and the surface of the molten metal pool. As in the previous embodiment, the upper surface area of the member 4 is sufficiently large to support the ingot formed and to carry the full melting current which will, during operation, flow from the electrode 3.

In addition to ensuring good electrical conduction throughout a melt, the present invention is advantageous in that cooling of the baseplate on which the mould rests is unnecessary. Previously, baseplates have been cooled (usually water-cooled) in order to prevent melting of the baseplate by the molten slag. Also, the presence of the member 4 has the effect of concentrating the working current within the central portion of the mould.

I claim:

1. A method of forming an ingot of refined metal by the electroslag refining process comprising the steps of introducing into the lower open end of a cooled mould

a solid un-cooled electrically-conductive member of a material weldably compatible with the metal to be refined, the member having a surface area sufficient to conduct the full working current employed in the process but small enough to leave an annular space beneath the top of said member between its periphery and the internal walls of the mould, filling said annular space with a compactible electrically insulating material which accommodates reductions in the annular spacing caused by differential thermal expansion between the member and the lower end of the mould into which the member extends and which is readily removed from the surfaces of the member and the ingot formed following completion of the process, forming a bath of molten slag within the mould and above the member and the electrically insulating material, passing an electric current through the slag bath to maintain the temperature of the bath at or above the melting point of the metal to be refined and causing droplets of unrefined metal to travel through the molten slag bath and to collect above the member and compactible electrically insulating material, which droplets form a pool of refined liquid metal which progressively solidifies to form an ingot of refined metal which is supported by the aforesaid member and electrically insulating material and is welded to the upper surface of the member.

2. A method according to claim 1 wherein, during operation of the process, the mould is moved vertically relative to the ingot formed and wherein the annular spacing between the solid member and the internal mould walls is sufficient to accommodate thermal expansion of the member relative to the mould walls and to permit vertical movement of the mould relative to the member.

3. A method according to claim 1 wherein the droplets of unrefined metal originate from a consumable electrode which depends into the molten slag bath and comprising the step of first cutting the solid member from one end of the consumable electrode.

4. A method according to claim 1 wherein the solid member and the mould interior are of circular cross-section and wherein the diameter of the solid member is between 0.4 and 0.9 times the internal mould diameter.

5. A method according to claim 1 wherein the electrically insulating material comprises crushed used slag covered by a ring of heat-resistant material.

6. A method according to claim 1 wherein the mould is mounted on an uncooled steel baseplate and wherein the solid member is welded to the upper surface of the steel baseplate.

7. A method according to claim 6 wherein the mould includes a lower extension piece mounted on the steel baseplate and wherein the solid member extends upwardly into the said extension piece of the mould.

8. A method according to claim 1 in which said compactible material is inert with respect to the molten slag.

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