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INDUCTION ELECTRIC FURNACE

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My invention relates to induction electric furnaces, and especially to the coreless type.

A purpose of my invention is to increase the secondary resistance of an induction furnace in order to improve the efficiency of the furnace.

A further purpose is to avoid excessive stirring of the molten bath, especially that noticed in coreless induction furnaces operating upon normal or low frequencies, by a special construction of the secondary coil surrounding the bath and by proper shaping of the crucible.

A further purpose is to incline the inductor coil turns to the horizontal wholly or in part throughout their circumference.

A further purpose is to slope the crucible bottom at an angle to the horizontal over all or part of its extent.

A further purpose is to use the same slope for the furnace bottom as that used for the turns of the inductor coil.

A further purpose is to use an induction furnace bath of variant depth around the circumference of the inductor coil.

A further purpose is to use an inductor coil so formed that the vertical distance from any point on the coil to the surface of the bath will be variant.

A further purpose is to heat an induction furnace bath with only moderate stirring, so that the slag cover will remain continuous over the surface of the bath, and slag may be removed from above the metal.

A further purpose is to avoid excessive exposure due to boiling up of the bath in contact with the gases of the atmosphere by maintaining the bath more quiescent throughout operation of the furnace.

A further purpose is to force the molten metal toward the pouring spout and thereby withdraw slag to that part of the surface of the pool farthest from the pouring spout.

Further purposes will appear in the specification and in the claims.

In the familiar coreless induction furnace as at present known, boiling up near the center of the bath is due to the mutual attraction of currents at the circumference of the bath (pinch effect) and the repulsion be-

tween the primary and secondary current. With coil constructions as at present known, the boiling up of the surface near the center of the bath is so excessive that it is practically impossible to skim off slag. Therefore it is very difficult to use the furnace.

Several suggestions have previously been made with a view to improving the efficiency of the furnace by increasing the secondary resistance. For example, an attempt has been made to increase the length transversely by the secondary current by increasing the diameter of the bath, or to decrease the cross section of the metal through which the current passes by placing a fireproof refractory structure concentric with the wall of the bath.

The increase of the diameter has the disadvantage of decreasing the heat efficiency of the furnace, as the most desirable shape of the bath, that in which the height and diameter are equal, can no longer be utilized. The insertion of a fireproof refractory body within the furnace makes it necessary to heat this additional mass of inert material up to the furnace temperature.

My invention is directed particularly to a coreless induction furnace in which the inductor coil is wound in a plane inclined to the axis to the coil, rather than perpendicular or nearly perpendicular to it. In the form of my invention, the angle of inclination will be much greater than the well-known angle of winding necessitated by the thickness of the individual turn and the thickness of the insulation between adjacent turns. By analogy to a thread I may refer to that angle as the pitch angle of the inductor coil.

Since the secondary current flows in the same plane as the primary current, but in opposite phase, the current flow in a bath heated by my novel coil will be in an ellipse whose small diameter is the same as the bath diameter. This arrangement therefore increases the secondary resistance compared with that in baths encircled by inductor coils of the current type.

The decrease of the secondary current by increasing the secondary resistance is not alone sufficient to prevent excessive boiling in the center of the bath, especially in coreless

furnaces operated with normal or low frequency. According to my invention, therefore, the boiling up at the center of the surface of the bath is further decreased by inclining the bottom of the crucible to the same angle as the angle of the inclination of the winding.

The weight of the vertical column of liquid metal is therefore not uniform throughout the bath, and this effect operates to oppose the pinch effect.

Similarly, the distance from the top of the bath to the top of the inductor coil differs at different points along the bath circumference. With this construction, the pinch effect will be greatest where the vertical distance between the surface and the top of the inductor coil is greatest, but since at that point the vertical column of metal counteracting the pinch effect is also greatest, the bath will remain comparatively quiescent.

On the opposite side of the bath, the metal, instead of being pushed upwardly by the motor effect and the force of gravity, will be repelled toward a point opposite the bottom of the inductor coil.

As the vertical metal column is of greatest height and weight along that side of the furnace where the inductor turns are low (i. e., the "down" of the slope), the movement of the bath will be reduced to such an extent that the bath surface will be inclined very slightly and will slope upwards from the side at which the inductor coil is highest to the side at which the inductor coil is lowest. However, the metal at the surface will be in constant motion. This motion at the surface of the bath is of great advantage for skimming the slag, while, on the other hand, the undesirable boiling up or eruption of the metal at the surface is eliminated.

In the figures I illustrate a few of the many forms in which my invention might be embodied, choosing those which are practical and convenient in operation, and which well illustrate the principle of my invention. The forms which I show are made diagrammatic for convenience in pointing out the important features.

Figure 1 shows a structure according to my invention, with the supports for the crucible sectioned so that the inductor coil and crucible may be seen in side elevation.

Figure 2 corresponds to Figure 1 except as to the shape of the inductor coil and crucible bottom.

Figure 3 also corresponds generally to Figure 1, but shows a somewhat different inductor coil and crucible bottom.

In the drawing like numerals refer to like parts throughout.

The crucible 1 is shown as supported upon frame structure 2 and is covered with a lid 3 which may desirably be of refractory material.

The crucible may be of any suitable material or of any structure provided the bottom is made to conform to the structure herein disclosed.

About the crucible is placed an inductor coil 4 having the plane of the winding inclined rather than perpendicular to the coil axis. Thus, in the form shown the lowest point of the inductor coil is on the side provided with the pouring spout 5. While this is desirable, it is not of course necessary in the use of my invention.

In order to avoid stray field losses at the ends of the inductor coils, the furnace is provided with annular segments 6 and 7 of magnetic material.

The bottom 8 of the crucible is inclined, preferably at the same angle as that of the inductor coil winding. With the use of a furnace bottom as shown at 8, the combined action of motor effect and gravity will cause the surface of the liquid bath to assume a shape as shown at 9. The metal is in constant motion from point 10 to point 11, so as to have a constantly changing surface allowing for exposure of the draft to the air without excessive movement of the bath. Reduction of the metal can occur also without the occurrence of excessive bath movement.

At the point 11 in the crucible it is practical to provide a cavity to allow yielding by the metal at the point of high pressure. Instead of this cavity, the spout may be used for this purpose, provided the lowest point of the inductor coil be placed below the spout.

The secondary current runs parallel to the windings of the inductor coil 4 and forms ellipses whose small diameters are the same as the internal diameter of the crucible.

As far as the construction of the supports for the crucible are concerned, Figure 2 is the same as Figure 1. The inductor coil in Figure 2 has a part of each turn inclined with respect to the coil axis and the remainder of each turn perpendicular to the axis or at a small pitch angle from the perpendicular with respect to the coil axis. Thus we see that the portion 12 is substantially perpendicular with respect to the coil axis while the portion 13 is inclined. The bottom 8 of the crucible is similarly constructed, so that a portion 14 is perpendicular to the coil axis and a portion 15 is inclined thereto.

This arrangement has the advantage of forcing the liquid metal from the center of the bath toward the circumference by virtue of the repelling action of the secondary current of opposite direction, thus obtaining a still greater decrease in the violence of boiling up at the bath center.

Another structure embodying my invention is seen in Figure 3. In this form the inductor coil turns are inclined to the axis in one direction on one side and in the other direction on the other side of a mid point.

The furnace bottom 8 is somewhat similarly V-shaped in this form.

Thus, considering one inductor coil turn, a segment 16 slopes to one side with respect to the axis of the coil, while the segment 17 slopes oppositely. A considerable angle is made between the segments 16 and 17.

The repulsion of the secondary current and the tendency of the metal to be forced against the walls of the crucible are still more pronounced in this form.

It will be evident that an advantage of my invention could be gained without using the specific forms shown. For example the individual turns could be curved instead of straight, and could be inclined according to any law desired, providing that their electric effect upon the bath was to produce secondary currents generally inclined to the vertical axis of the bath rather than perpendicular to the axis.

It will be evident that the molten metal may be given diagonal movement toward the pouring spout, lifting it higher at the spout than at the other parts of the surface of the metal and freeing the molten metal from slag for the double reason that this metal will be higher than that at the opposite side and that the molten metal stream breaking at the surface near the pouring spout will carry slag with it down along the surface toward the far (low) side of the surface of the pool.

In view of my invention and disclosure variations and modifications to meet individual whim or particular need will doubtless become evident to others skilled in the art, to obtain part or all of the benefits of my invention without copying the structure shown, and I, therefore, claim all such in so far as they fall within the reasonable spirit and scope of my invention.

Having thus described my invention, what I claim as new and desire to secure by Letters Patents is:

1. In an electric induction furnace, a crucible containing a metal bath, an inductor coil surrounding the crucible and diagonally inclined to the vertical axis of the crucible to an extent greater than the pitch of the winding, and a source of current for the inductor coil.

2. In an electric induction furnace, a crucible having a sloping bottom, an inductor coil about the crucible wound in a plane making an angle with the perpendicular to the inductor coil axis substantially greater than the pitch angle of the coil and in the general direction of the bottom slope, and a source of current for the inductor coil.

3. In an electric induction furnace, a crucible, an inductor coil about the crucible in which an individual turn is inclined to the axis of the coil over part of its length and perpendicular to the axis of the coil over

another part of its length, and a source of current for the coil.

4. In an electric induction furnace, a crucible, an inductor coil around the crucible in which the planes parallel to the winding of an individual turn slope more than the pitch of the turns, a source of current for the coil and a pouring spout for the crucible above the lower, as distinguished from the higher part of the turns.

5. In an electric induction furnace, a crucible, an inductor coil surrounding the crucible in which the winding of each individual turn is sloped, a bottom for the crucible similarly sloped and a pouring spout at the side of the crucible above the lowest part of the bottom.

6. In an electric induction furnace, a crucible, an inductor coil surrounding the crucible in which an individual turn has one portion in a plane inclined in generally parallel planes extending in one direction and another portion in a plane inclined in generally parallel planes intersecting the first planes with respect to the coil axis, and a source of current for the coil.

7. In an electric induction furnace, a crucible having its bottom inclined to the horizontal in two directions, an inductor coil surrounding the crucible having its individual turns similarly inclined to the horizontal, and a source of current for the coil.

8. In an electric induction furnace, an inductor coil having two portions of its individual turns oppositely inclined to the horizontal, a crucible within the inductor coil having its bottom similarly inclined from a mid point, and a source of current for the coil.

9. In an electric induction furnace, a crucible adapted to contain a molten charge, a inductor coil about the crucible whose individual turns vary in vertical distances from the horizontal to an extent different from that due to their pitches throughout their lengths, and a source of current for the coil.

10. In an electric induction furnace, a crucible adapted to contain a molten charge, a pouring spout for said crucible and an inductor coil surrounding the crucible and having its turns at a distance from the pouring spout higher than the corresponding portions of the turns beneath the pouring spout by an extent exceeding the pitch so as to direct its induced flow of molten metal toward the pouring spout side of the crucible.

11. In an electric induction furnace, a crucible, an inductor coil having its individual turns inclined with respect to the coil axis, and a stray-field-eliminating strip along the top of the coil.

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