VACUUM ARC MELTING FURNACE WITH CRUCIBLE CHANGING APPARATUS

Helmut Graebner and Helmut Scheldig, Hanau am Main, Germany, assignors to W. C. Heraeus G.m.b.H., Hanau am Main, Germany, a firm of Germany

Inventor

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The present invention relates to an apparatus for exchanging melting crucibles in a vacuum arc furnace. In vacuum arc furnaces with consumable electrodes it has so far been possible to utilize only approximately 40% of the entire period of operation for melting the metal, while the remainder of the period, that is, approximately 60%, has been required for charging the furnace, for evacuating it, for removing the crucible with the ingot therein, and especially for allowing the molten metal to cool. This poor ratio between the melting period and the time required for the entire operation of the furnace may be considerably improved if the molten ingot in the crucible is not cooled within the furnace, but if it is removed from the furnace immediately after the melting process has been completed. It has therefore already been proposed to use a carriage or other conveyor to move the filled crucible together with its surrounding cooling jacket immediately after the completion of the melting process to a cooling position and replace it by moving a new crucible with a new consumable electrode by a second carriage or on the conveyor to the proper position underneath the furnace.

These known crucible changing mechanisms in which the change requires a reciprocating translatory movement in one general direction have the serious disadvantage that, if the costs of operation are to be kept within reasonable limits, only two crucibles which are enclosed by cooling jackets can be used, and that at each change it is necessary to disconnect the inlet and outlet lines for the cooling agent from the cooling jacket. This requires, for example, that the cooling period of the molten ingot must always be shorter or at least amount to no more than the period which is required for filling the next crucible with molten metal by melting the consumable electrode. If the cooling period is longer than the melting period, such crucible changing mechanisms require the melting process to be interrupted until the first molten ingot has cooled off and can be removed from the crucible. Until such time, this crucible can therefore not be used again for the further melting operation.

A further disadvantage of these known crucible changing mechanisms consists in the fact that they require two positions at opposite sides of the furnace for removing the cooled ingot from the crucible and for inserting a new consumable electrode into this crucible. Apart from the great expense for the apparatus required for this purpose, these two necessary removal and insertion positions involve considerable difficulties in tightly sealing the furnace if such a crucible changing mechanism is, for example, to be built into a chamber which is to be kept under reduced pressure.

It is an object of the present invention to provide a crucible changing mechanism which overcomes the above-mentioned disadvantages by effecting the change of the crucibles by a rotary movement thereof in a horizontal direction, even though the crucibles are attached to or removed from the furnace by a rectilinear movement in a manner known as such. According to the invention, the crucibles are, for example, mounted on a suitable support which may be raised or lowered hydraulically and be rotated by conventional means. Depending upon the number of crucibles provided, which may amount, for example, to two, three, or four, crucibles or even more than four crucibles, especially if they are of a smaller size, the supporting means of the crucibles are turned horizontally about an angle of 180°, 120°, 90°, or a smaller angle, whereby a crucible which is filled with molten metal will be exchanged for another crucible which may either be empty or may contain a new consumable electrode. The advantages of the crucible changing mechanism according to the invention consist primarily in the fact that it permits the use of more than two crucibles which are enclosed by cooling jackets and that it only requires a single position in which the cooled ingot may be removed from the furnace and in which a new consumable electrode may also be inserted into the furnace. The inventive feature that more than two, for example, four crucibles may be used results in the further advantage that the cooling period of the molten ingot may be increased to twice or even to nearly three times the length of the melting period which is required for filling one crucible with molten metal. If, for example, four crucibles are provided, the crucible which has been filled with molten metal is then at first moved by a horizontal rotation of the crucible support about an angle of 90° from the position underneath the furnace to a cooling position from which, at the following exchange of crucibles, it passes to a second cooling position where it will remain before passing to the removal position until the next exchange of crucibles is taking place. Even though the ingot has during this time been cooled considerably, it may, if necessary, cool in this removal position for a certain additional length of time before it will be removed from the jacket-enclosed crucible. A new consumable electrode may then be inserted into this empty crucible and will at the next changing movement be placed into the position underneath the furnace.

These as well as additional objects, features, and advantages of the present invention will become more apparent from the following detailed description thereof, particularly when read with reference to the accompanying drawings, in which:

FIGURE 1 shows a diagrammatic over-all side view, partly in section, of a vacuum arc furnace according to the invention;

FIGURE 2 shows a diagrammatic side view of the driving mechanism, as seen from one side of FIGURE 1;

FIGURE 3 shows a cross section taken along line A—A of FIGURE 1; while

FIGURE 4 shows a cross section similar to FIGURE 2, but of a modification in which the crucible changing mechanism is provided with four crucibles.

FIGURE 1 of the drawings shows an over-all view of a vacuum arc furnace according to the invention, in which the entire furnace is built into and supported by a frame 1. An electrode supporting rod 2 is inserted through a cover 4 into the furnace chamber 5, and the part of supporting rod 2 within chamber 5 is sealed therein vacuum-tight by suitable sealing means 3, for example, by one or more pressure-reducing stages, while the lower end of rod 2 is secured to a consumable electrode 6 which consists of the metal to be melted. The vertical movement of the electrode 6 together with supporting rod 2 is effected, for example, through a chain 7 by means of a gear 8. Furnace chamber 5 is connected by a pipe 9 to a vacuum pump unit 10. The respective crucible to be used for receiving the molten metal which is melted off the consumable electrode 6 is changed to the lower end of furnace chamber 5. Each crucible 12 is encased by a cooling jacket 11 through which a coolant is circulated which is passed into and out of jacket through flexible
hoses \( i \). The cables \( i \) for supplying the melting current extend from a control room \( i \) to the electrode supporting rod \( i \). The melting process in furnace chamber \( i \) may be controlled from control room \( i \) in accordance with the observations which are made through a telescopic system \( i \).

The present invention primarily concerns the mechanism for exchanging one crucible after it has been filled with molten metal for an empty crucible, for cooling the metal in the first crucible while the melting operation is carried out to fill the next crucible, and for inserting a new consumable electrode into the furnace chamber and securing it to the electrode supporting rod \( i \) after the previous electrode has been consumed. This mechanism which may be of different designs may consist, for example, of a stationary supporting or guide rod \( i \) on which a cylinder \( i \) may be raised and lowered hydraulically in a conventional manner by the operation of suitable control means in control room \( i \). Cylinder \( i \) serves as a support of two or more crucibles \( i \) and \( i \), each of which is enclosed in a cooling jacket \( i \) which is secured to cylinder \( i \) by a suitable bracket \( i \), as shown in the drawings. Insertion of the crucibles in the cooling jacket \( i \) to cylinder \( i \) by means of such brackets \( i \), they may also be mounted on a common supporting plate which, in turn, is secured to cylinder \( i \) and may be raised and lowered thereby.

For exchanging a filled crucible \( i \) for an empty one, and also for mounting a new electrode \( i \) on the supporting rod \( i \) after the previous electrode has been consumed, an electric motor \( i \) is secured to the outside of cylinder \( i \). The shaft of motor \( i \) carries a pinion \( i \) which is in mesh with a gear \( i \) which is splined along guide rod \( i \) and prevent from rotating therein by a key which is spladable within a groove \( i \) in rod \( i \). Gear \( i \) is supported on the lower end of cylinder \( i \) by brackets \( i \) which engage into an annular recess \( i \) in cylinder \( i \) and rest on the lower shoulder \( i \) formed by this recess by means of rollers or balls \( i \). Thus, when motor \( i \) is started, pinion \( i \) rolls around the nonrotatable gear \( i \) and thereby turns cylinder \( i \) together with crucibles \( i \) in their cooling jackets \( i \) about guide rod \( i \), whereas when cylinder \( i \) is raised or lowered hydraulically, it takes along gear \( i \) which thus remains in constant engagement with the driving pinion \( i \) of motor \( i \). Motor \( i \) is controlled by suitable means known in the art so that, whenever it is started, it will carry out a predetermined number of revolutions which depends upon the number of crucibles to be used in the operation of the furnace and thus upon the angle about which the crucibles have to be turned so as to be moved from one position to the other.

Assuming that the furnace is to be taken into operation for the first time when all of the crucibles \( i \) are empty, a new consumable electrode \( i \) is inserted from above into a crucible \( i \) which is disposed at one side of the furnace, as shown in FIGURE \( i \). Cylinder \( i \) is then lowered together with all the crucibles \( i \) in their cooling jackets \( i \), and motor \( i \) is switched on to turn cylinder \( i \) until the electrode contained in electrode \( i \) in an upright centered position is moved to a position exactly vertically underneath furnace chamber \( i \). Cylinder \( i \) together with all of the crucibles is then hydraulically lifted along guide rod \( i \) until the crucible containing the electrode is pressed against the bottom end of furnace chamber \( i \) to which this crucible is then clamped. The electrode supported on rod \( i \) is then lowered so as to engage with the upper end of electrode \( i \) which is then secured to rod \( i \) either by suitable automatic clamping means or by being fused thereto electrically by passing a current impulse through cable \( i \) and rod \( i \). Thereupon the electrode is sufficiently raised from the bottom of crucible \( i \) to start the melting process.

After crucible \( i \) has been filled and disconnected from furnace chamber \( i \), the entire charge unit is again lowered and then turned by means of motor \( i \) so as to move the next crucible directly underneath furnace chamber \( i \), while \( i \) filled crucible is raised until it reaches a cooling position. If electrode \( i \) is of a size so as to last for filling several crucibles, the charge unit only needs to be lowered sufficiently to permit the filled and empty crucibles to be moved past the lower end of the remainder of the electrode. After electrode \( i \) has been consumed completely, the new electrode is inserted in the manner as previously described.

Instead of providing a hydraulic elevating mechanism, as shown in FIGURE \( i \), in which cylinder \( i \) is moved, it is, of course, also possible to utilize one in which the cylinder is stationary, while a pistonlike rod to which the brackets \( i \) or a supporting plate carrying the crucibles are secured is hydraulically raised or lowered. For changing the crucibles, such a pistonlike rod, which, of course, requires special guiding means, is then likewise turned about its axis by a suitable gear mechanism which is driven by a motor so as to move the crucibles horizontally from one position to the other whenever one crucible becomes empty.

The number of crucibles to be used in a change mechanism according to the invention depends primarily upon the length of time which is required for cooling the ingots until they can be removed from their respective crucibles. Thus, while in FIGURES \( i \) and \( i \) the change mechanism is only provided with two crucibles \( i \) and \( i \), FIGURE \( i \) shows a similar mechanism which is provided with four crucibles. Assuming that crucible \( i \) in position \( i \) at the right side of FIGURE \( i \) has just been filled with molten metal and been lowered from the furnace, it is then turned to the first cooling position \( i \), while a new crucible containing a new electrode \( i \) is required as shown at the same time from the previous position \( i \) to position \( i \) directly underneath the furnace, in which position it is then raised hydraulically until it can be clamped to the bottom of the furnace. At the end of the next melting operation, the crucibles are again lowered and turned, whereby the first-mentioned crucible is moved from the first cooling position \( i \) to the second cooling position \( i \) and, after the next melting operation, to the third cooling position \( i \). During the period in which the respective crucible remains in this position \( i \) for the length of time required for the next melting operation, the ingot contained in this crucible may further cool and may then be removed from the crucible, whereupon a new consumable electrode, if required, may then be inserted therein. If the ingot has cooled sufficiently already in a position earlier than position \( i \), that is, either in position \( i \) or \( i \), it may, of course, be removed in such earlier position. The new electrode may then be inserted into the empty crucible either in such earlier position or in the following position preceding the filling or melting position.

If three or more crucibles are provided, the elevating mechanism may also be modified so that the crucibles which are located in the actual cooling stages, for example, in stages \( i \) and \( i \), do not need to be raised or lowered, but only the empty or filled crucible directly underneath the furnace and possibly also the crucible from which the cooled ingot is to be removed and into which a new electrode is to be inserted. The crucibles may then be intermittently rotated on a turntable and the crucible filled and possibly also the crucible to be emptied may be raised and subsequently lowered hydraulically, for example, by a plunger passing from below through an aperture in the turntable underneath the respective crucible, or by designing bracket \( i \) so as to clamp and release each individual crucible, for example, by magnetic means, so that only one or two crucibles are raised and lowered, while the other brackets are released so as to slide loosely along the cooling crucibles in the lowered position.

If four or more crucibles are to be used, the change mechanism according to the invention may also be used
so as to operate two adjacent furnaces simultaneously. This is indicated diagrammatically in FIGURE 1, in which the second furnace is shown in dotted lines at the left side above electrode 28 which, of course, is in this case inserted in a rotary position of the change mechanism inter
dmediate the two furnaces. The change mechanism may then be mounted between the two furnaces which are disposed, for example, diametrically opposite to each other from the axis of rotation of the change mechanism. The stages I and II according to FIGURE 4 may then, for example, by those stages in each of which a crucible is disposed underneath one of the furnaces, while stages II and IV and possible additional stages would serve as cooling, ingot-removal, and electrode-inserting stages.

Although our invention has been illustrated and de
scribed with reference to the preferred embodiments thereof, we wish to have it understood that it is in no way limited to the details of such embodiments, but is capable of numerous modifications within the scope of the appended claims.

Having thus fully disclosed our invention, what we claim is:

1. A vacuum arc melting furnace comprising at least two furnace chambers laterally spaced from each other, at
least four crucibles, support means for supporting said crucibles and arranged below said chambers, said crucibles being arranged in radially uniform positions about and at equal distances from a vertical axis which in turn is spaced at equal distances from the axes of said chambers, means for intermittently rotating said support means in a direction about said vertical axis, control means for controlling rotation of said support means about said vertical axis for successively moving each of said crucibles from a position underneath and laterally of one of said furnace chambers to a filling position vertically under
neath said one chamber, then to at least one position intermediate said chambers and laterally of said filling position, in which intermediate position the metal in the crucible thence is cooled and adapted for removal, then to the next filling position vertically underneath the other of said two furnace chambers, and then to the next inter
mediate position, a cooling jacket for said crucibles arranged below said chambers, and means for raising each of said crucibles while in said filling position into engagement with and communication with the lower end of the respective furnace chamber for filling said crucible and for thereafter lowering said filled crucible from said re
spective chamber.

2. In a vacuum arc furnace plant as defined in claim 1, in which said rotating means comprise driving means for intermittently rotating said crucibles in one direction from one position to the other, said means for raising and lowering said crucibles comprising hydraulic means.

3. In a vacuum arc furnace plant as defined in claim 1, in which said raising and lowering means comprise hy-
draulic means, means for securing said crucibles at equal distances from each other to said hydraulic means, and means for connecting said rotating means to said hydraulic means for intermittently rotating said hydraulic means and said crucibles.

4. In a vacuum arc furnace plant as defined in claim 1, in which said raising and lowering means comprise hydraulic means, means for supporting all of said crucibles in uniform radial positions relative to and at equal dis
tances from each other, means for securing said supporting means to said hydraulic means, means for connecting said rotating means to said hydraulic means for inter
mittently rotating said hydraulic means and all of said crucibles on said supporting means, and means for rigidly

securing at least the crucible in said filling position to said supporting means so that, when said hydraulic means are operated, they will elevate at least said crucible in said filling position.

5. In a vacuum arc furnace plant as defined in claim 1, in which said furnace further comprises an electrode supporting rod extending into said furnace chamber, and means for raising and lowering said rod, each of said crucibles when empty being also adapted when in one of said lateral positions to permit a consumable electrode to be inserted from above into said crucible, so that when said crucible containing said electrode is then turned to said filling position and is then elevated, said electrode will be inserted into said furnace chamber to permit it to be secured to said supporting rod.

6. A vacuum arc melting furnace comprising a furnace chamber, a consumable electrode movable within said chamber, means within said chamber for supporting and moving said electrode vertically within said chamber dur-
ing melting thereof, means for reducing the pressure within said chamber during arc melting of said electrode, a plurality of crucibles each of which is adapted to be clamped to the lower end of the chamber when used to receive the molten metal from the consumable electrode, a cooling jacket for said crucibles arranged below said chamber, support means for supporting said crucibles and arranged below said chamber, means for rotating said support means about a vertical axis for successively positioning each of said crucibles below and in alignment with said chamber and another of said crucibles in a position lateral of said chamber, means for raising and lower-
ing said support means for moving each of said crucibles into and out of communication with said chamber, re
spectively, and means for securing each of said crucibles relative to said chamber after said support means has been raised to position one of said crucibles below and in engagement with said chamber, said raising and lower-
ing means comprising a stationary vertical shaft, a cyl
inder slidable as well as rotatable on said shaft, means for supplying a pressure medium to said cylinder to slide said cylinder upwardly and downwardly along said shaft, means for securing said crucibles to said cylinder in uni
form radial positions relative to and at equal distances from each other, said rotating means comprising a gear slidable vertically along but being nonrotatable relative to said shaft, means for supporting said gear on said cy
ylinder so as to permit said cylinder to rotate freely rela
tive to said gear, a motor secured to said cylinder and
having a drive shaft, a second gear mounted on said drive
shaft and in mesh with said first gear, and means for operating said motor intermittently to rotate for a pre
determined number of revolutions, whereby said second
geared rides around said first gear and thereby turns said
cylinder and said crucibles thereon about said stationary
shaft.

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RICHARD M. WOOD, Primary Examiner.

ROBERT K. WINDHAM, Examiner.