June 13, 1961 R. E. LYMAN 2,987,788

CRUCIBLE ASSEMBLY FOR ELECTRIC ARC FURNACE

Filed March 6, 1958 2 Sheets-Sheet 1

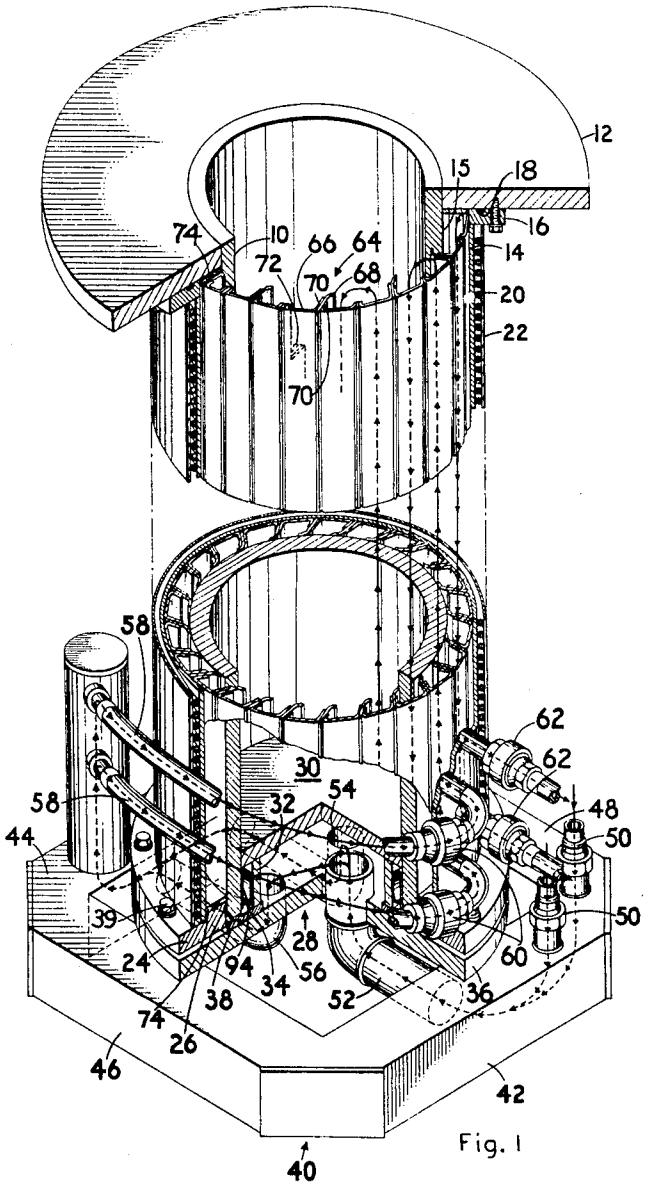

Fig. 1

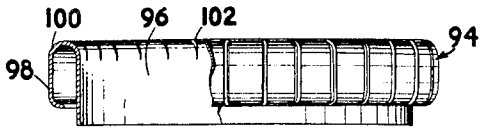

Fig. 2

Inventor:
Richard E. Lyman
by M. W. Goodwin
His Attorney

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CRUCIBLE ASSEMBLY FOR ELECTRIC ARC FURNACE

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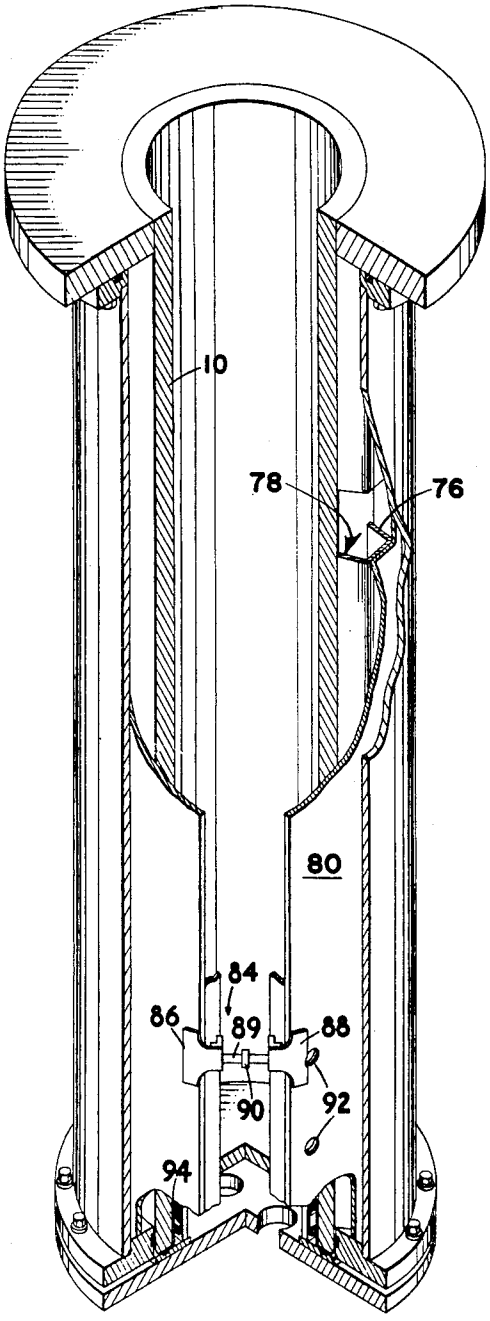

Fig. 3

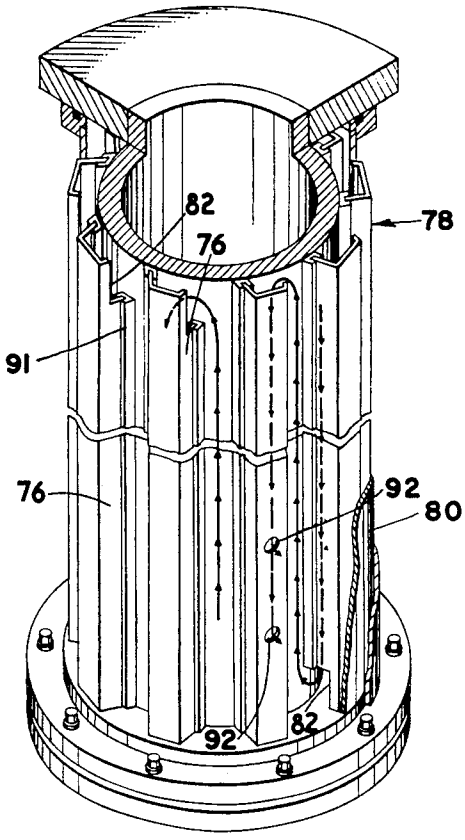

Fig. 4

Inventor :
Richard E. Lyman
by M. W. Goodwin
His Attorney

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CRUCIBLE ASSEMBLY FOR ELECTRIC ARC FURNACE

Richard E. Lyman, Homewood, Ill., assignor to General Electric Company, a corporation of New York

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4 Claims. (Cl. 22—177)

This invention relates generally to electric arc furnaces and more specifically to a novel and improved crucible adapted for use with an electric arc furnace of the consumable electrode type wherein the heat source for the furnace is provided by an electric arc between a molten pool of metal in the crucible and an electrode fabricated of the metal to be melted and which is consumed by the arc it produces.

In order to prevent melting of the walls of the molten metal containing portion of the crucible during furnace operation, it is known practice to provide water cooling of this portion of the crucible. Even with this cooling, the side walls of the portion containing the molten metal have a relatively short service life compared with the remainder of the crucible. Accordingly, it is desirable and known practice to provide the crucible with a removable or separable mold or liner which may be readily replaced. Further, in order to facilitate removal of an ingot from the mold, it is desirable and known practice to provide the mold with a removable separately cooled bottom.

It is the primary object of this invention to provide in a crucible having a removable mold or liner, novel and improved means for fluid cooling the side walls of the mold which will provide improved heat transfer, which is easily separable from the mold to permit re-use and which is relatively simple and economical to fabricate while providing an extended service life.

It is another object of this invention to provide in a crucible including a replaceable mold having a removable bottom, novel and improved means for electrically connecting the mold bottom to the mold whereby improved current transfer will be achieved and which will permit relatively large tolerances in the manufacture of the mold without adversely affecting the electrical connection between the mold and removable bottom.

In carrying out my invention, I provide a crucible including an elongated mold or liner open at both ends and surrounded by an elongated tubular jacket spaced outwardly of the mold with the respective ends of the mold and jacket being in sealed relation. In the annular space between the mold and jacket are disposed a plurality of baffle elements extending longitudinally of the mold and forming a plurality of side-by-side passages for the circulation of cooling fluid in intimate contact with the mold. Each passage is connected in fluid flow communication with a next adjacent passage, only, thus providing a continuous sinuous passage around the mold which may be connected to a source of cooling fluid such as water. The reduced cross section of the sinuous passage, as compared to the over-all cross section of the annular space between the mold and jacket, provides a relatively high velocity flow of cooling fluid at reasonable line pressures, normally available. The multiple vertical flow of cooling fluid at a relatively high velocity provides improved heat transfer and more effective removal of steam pockets which may result from local boiling of the cooling fluid and which can form an undesirable insulation on the mold wall. In one embodiment of my invention the baffle elements are formed by a plurality of side-by-side channel shaped members inserted longitudinally within the annular space between the mold and jacket; in an alternative embodiment of my invention the baffle elements are provided by a plurality of spaced apart channel

members carried by a flexible metal banding sheet the ends of which are connected by turnbuckles or the like to clamp the channel members to the mold wall.

The mold is provided with a removable bottom which telescopes into one end of the mold and in accordance with one object of my invention, I provide an annular resiliently compressible electrical connector between the removable bottom and the mold. The connector is dimensioned to provide a current path of relatively large area between the mold and bottom, and the resilient compressibility of the connector permits a fairly wide range of tolerances in the construction of the mold without affecting current transfer performance.

For a more complete understanding of my invention, reference should be made to the accompanying drawing in which:

FIGURE 1 is a fragmentary perspective view, partly cut away and in section, of a crucible assembly embodying my invention;

FIGURE 2 is an enlarged side elevational view partly in section of the electrical connector between the mold and removable bottom of the crucible of FIGURE 1;

FIGURE 3 is a perspective view, partly cut away and in section, of a mold and jacket member of a crucible, such as shown in FIGURE 1; incorporating a modified embodiment of my invention; and

FIGURE 4 is a fragmentary perspective view, partly cut away and in section, of the mold and jacket assembly of FIGURE 3.

With reference to FIGURE 1 of the drawings, a crucible assembly of a type with which my invention is concerned comprises an inner mold or liner **10** in the form of an open ended metal tube having a radially outwardly extending flange **12** welded thereto at its upper end. A jacket member **14** in the form of a metal tube surrounds the outer side walls **15** of the mold in concentric outwardly spaced relation. The upper end of the jacket has a radially outwardly extending flange **16** bolted to the underside of the flange **12** with a seal **18** being carried by the flange **16** and engaging the underside of the flange **12**. To provide for movement of the molten metal in the crucible during furnace operation, a stirring coil **20** is provided about the jacket **14** and is enclosed by an outer casing **22**.

The lower end of the jacket **14** carries an annular plate or ring **24** welded thereto and forming a radially outwardly and inwardly extending flange. The radially innermost portion of the flange **24** carries a seal **26** engaged with the outer side wall of the mold to seal the lower end of the annular space between the mold and jacket. The lower end of the mold is closed by a removable bottom **28** which telescopes into the mold and comprises a raised bottom plate **30** spaced inwardly of the lower end of the mold and supported by cylindrical web member **32**. The web **32** is supported on an annular plate or ring **34** welded to and forming a boss on a baseplate **36**. The boss **34** supports the lower end of the mold **10** and carries a seal **38** engageable therewith. The removable bottom **28** is maintained in assembly with the crucible by means of bolts **39** between the lower flange of the jacket and the baseplate **36**. As will be apparent from FIGURE 1 the lower ends of the jacket and mold are in registry whereby when the mold's lower end is supported on the boss **34**, the flange **24** of the jacket is spaced axially of the baseplate **36**.

The baseplate of the removable bottom **28** is supported on a cooling fluid manifold **40** comprising an inlet manifold **42** and an outlet manifold **44** formed by lengths of square tubing. The inlet and outlet manifolds are jointed structurally, although not of course in flow communication, by additional lengths of square tubing **46, 48**. As will be obvious, the interior of the inlet manifold **42**

may be separated from the interior of the outlet manifold 44 by any suitable means, for example, walls or baffles in the tubes 46 and 48 or at the junctures of these tubes with manifolds 42 and 44. The inlet manifold has a pair of closed couplings 50 for connection to a source of cooling fluid and an inlet pipe 52 leads from the inlet manifold to an aperture in the baseplate 36 to provide fluid flow into the space beneath the bottom plate 30 and within the web 32. A pair of outlet pipes 54, 56 are connected from the baseplate 36 to the outlet manifold to provide a fluid outlet for the space within the web 32. A header is mounted on the outlet manifold 44 in flow communication therewith, and a pair of hoses, such as 58, are connected from the header to the jacket 14 by means of quick disconnect couplings 60. The couplings 60 communicate with apertures in the jacket which are aligned longitudinally thereof. A pair of quick disconnect hose couplings 62 aligned longitudinally of the jacket are carried thereby for connection of the annular space between the mold and jacket to drain.

In accordance with my invention a plurality of elongated baffle elements 64 are disposed between the jacket and mold and extend longitudinally thereof to provide a plurality of linear fluid flow passages. The baffles in the embodiment of FIGURE 1 are formed by a plurality of elongated flexible channel shaped members 66 circularly arranged between the mold and jacket with a pliable resilient seal 68 of silicon rubber or other suitable material supported in engagement between the sides 70 of next adjacent channel members. The seals engage the outer side wall of the mold to prevent lateral short circuiting of cooling fluid between next adjacent channels. The channel members are provided with cutouts as at 72 in the sides 70 thereof adjacent both the tops and bottoms of the channels but with the cutouts in each channel being on opposite sides thereof. In this manner fluid may flow up one channel and down the next completely around the mold. One of the channel members is provided with a pair of apertures registering with the inlet couplings 60, and the next adjacent channel is provided with a pair of apertures registering with the outlet couplings 62. The next adjacent sides of the inlet and outlet channels are of course not provided with cutouts in order to prevent short circuiting of fluid flow therebetween. A quantity of packing 74 is provided between the ends of the channels and the flanges 12 and 24 of the mold and jacket to prevent fluid flow across the tops and bottoms of the channels other than that provided by the cutouts in the channel sides. While the channels 66 are shown in Fig. 1 with a square configuration, it will be understood that any channels having a substantially U-shaped configuration may be used.

To assemble the channel members in the crucible they are merely inserted longitudinally between the mold and jacket in side-by-side engagement whereby the channel members will support each other in the desired arrangement. The relatively small cross section of the channels, as compared to the overall cross section of the space between the mold and jacket, not only provides a high fluid flow rate but also provides a smaller volume of water for contact with molten metal in the crucible should a burn-through inadvertently occur, thus providing added safety of operation. The cross sectional dimensions of the channel members may be varied as desired to obtain optimum heat transfer with a reasonable quantity of fluid while obtaining an effective flow velocity through the channels at available inlet pressures. The pliable resilient seals 68 are preferably of a width which will permit a fairly wide range of tolerances in the mold outer diameter, as well as conformity to service irregularities in the mold, thus simplifying mold manufacture. The channel members are easily separated from the mold and do not require the use of special tools or procedures for assembly with or disassembly from the crucible thus providing conveniently reusable multiple pass cooling means for a replaceable mold.

In the modified embodiment of my invention shown in FIGURES 3 and 4, the multiple vertical pass fluid cooling of the mold 10 is provided by a plurality of baffle elements 76 formed by the sides of a plurality of substantially U-shaped channel members 78 which are welded to a flexible banding sheet 80 in parallel laterally spaced apart relation. The channel members are preferably laterally spaced by an amount equal to their width to provide a plurality of linear fluid flow passages of substantially equal cross sectional area within and between the channel members. The channel members are provided with a pair of notches or cutouts 82 in the sides thereof with one cutout in the upper end of one side and with the other cutout in the lower end of the other side. The banding sheet terminates at both ends, as shown in FIGURE 3 in alignment with a channel member. A plurality of turnbuckle like fixtures 84, only one of which is shown, are provided between the ends of the banding sheet to clamp the baffle elements to the outer wall of the mold. The fixtures 84 each comprise a pair of draw blocks 86, 88 carried by the ends of the sheet and connected by a threaded rod 89 having a wrench engageable nut 90 or the like fixed thereon intermediate its ends. An elongated pliable resilient seal 91 or boot of silicon rubber or other suitable material is carried by each channel side for sealing engagement with the mold.

With the channel members clamped to the mold as shown in FIGURE 3, there will be a space between the clamping fixtures 84 which is aligned with the inlet couplings in the crucible such as shown at 60 in FIGURE 1. A pair of apertures 92 are provided in the banding sheet and next adjacent channel member for registry with outlet couplings such as 62 in FIGURE 1. The fluid flow through the baffling of FIGURES 3 and 4 will be, as is indicated by arrows in FIGURE 4, a multiple vertical pass flow as in the embodiment of FIGURE 1. The advantages and operational features of the embodiment of FIGURES 3 and 4 are the same as those of the embodiment of FIGURE 1 and thus will not be repeated.

In the operation of an electric arc furnace of the consumable electrode type, it is usual to connect one side of the power source for sustaining the arc to the mold. This connection is most conveniently accomplished by a connection to the upper flange 12 of the mold. Inasmuch as the arc is usually initially struck between the electrode and a quantity of scrap metal in the bottom of the mold, it is necessary to provide an electrical connection between the mold and removable bottom. To provide such a connection, I utilize an annular resiliently compressible member 94 which as shown in FIGURE 1 is engaged between the web 32 of the removable bottom and the inner wall of the mold. The connector 94 comprises a pair of cylindrical members 96, 98 concentrically arranged one within the other and connected at one end by an integral bight portion 100. The bight portion and outer member are slotted as at 102 so that there is provided, in effect, a plurality of resiliently compressible contacts for engagement with the mold inner wall. This construction of the connector 94 permits a relatively wide range of tolerances in the inner diameter of the mold, provides a large surface area for current transfer, and allows for thermal expansion of the mold. Further, the provision of a current path directly to the inner wall of the mold rather than through the baseplate 36 to the end of the mold materially reduces the possibility of burning the seal 38 at the lower end of the mold.

One added advantage of the crucible construction shown in FIGURE 1, not heretofore mentioned, is that the remote spacing of the seals 38 and 26 and the spacing of the baseplate 36 and lower jacket flange 24 assures that the failure of either or both of these seals will not result in the flow of cooling fluid into the mold where it could react with molten metal therein.

While I have illustrated and described my invention in terms of the preferred embodiments thereof, it is not intended to limit my invention to these specific embodiments, but rather to include within the scope thereof all modifications falling within the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination with a crucible including a removable hollow mold having side walls and an open end, a plurality of baffle elements extending longitudinally of the mold in parallel spaced apart relation and resiliently and separably and sealingly engaging the outer side wall of the mold, a flexible sheet extending about the baffle elements and mounting the same, and adjustable means connecting the ends of the sheet which extend longitudinally of the baffle elements to draw said ends of the sheet toward each other and engage the baffle elements and mold, the baffle elements and sheet forming a plurality of linear passages longitudinally of the mold for the sinuous circulation of cooling fluid in intimate contact with the mold.

2. In combination with a crucible including a removable hollow mold having side walls and an open end, a flexible metal sheet extending about the side walls of the mold in outwardly spaced relation, a plurality of channel-shaped members disposed between the sheet and mold having bases fixed to the sheet and having sides extending longitudinally of the mold, the sides of the channel-shaped members carrying pliable resilient seals separably engaged with the outer side wall of the mold, and adjustable means for drawing the ends of the sheet which extend longitudinally of the channel-shaped members toward each other to engage said seals with the mold, the channel-shaped members and sheet forming a plurality of end connected linear passages extending longitudinally of the mold for the sinuous circulation of cooling fluid in intimate contact with the mold.

3. In a crucible constructed for use with an electric arc furnace including a removable hollow mold having a side wall and an open end, cooling means for the side wall of the mold comprising a hollow jacket member surrounding the mold and spaced outwardly therefrom, a baffle means comprising a plurality of substantially U-shaped channel members each disposed in the space between the mold and the jacket member with the open side of the channel facing the mold, resilient sealing means on the edges of the channel facing the mold, and means biasing the sealing means into resilient engagement with the mold so as to seal the edges of the channel against the mold while permitting relative movement between the channel and the mold, the channels forming a plurality of side-by-side sealed linear passages extending longitudinally of and substantially the full length of the mold for the circulation of cooling fluid solely in a sinuous path and intimate contact with the removable mold's outer wall.

4. In a device as recited in claim 3, a removable bottom for the mold telescoped into the open end of the mold, a resilient current connecting means for the passage of current between the side wall of the mold and the removable bottom comprising a resiliently compressed connector extending around said bottom and resiliently engaged between said bottom and the inner side wall of the mold for positive and immediate electrical contact of said bottom and wall.

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