

Sept. 15, 1953

O. W. SIMMONS
ELECTRIC ARC MELTING FURNACE

2,652,440

Filed July 18, 1950

2 Sheets-Sheet 1

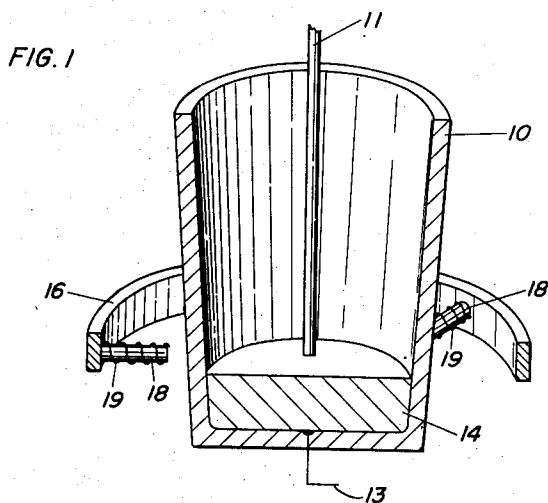
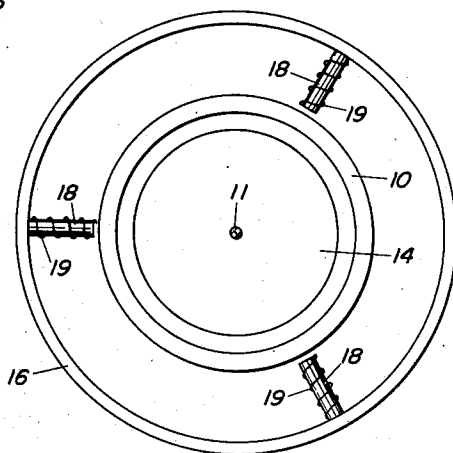


FIG. 2



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FIG. 4

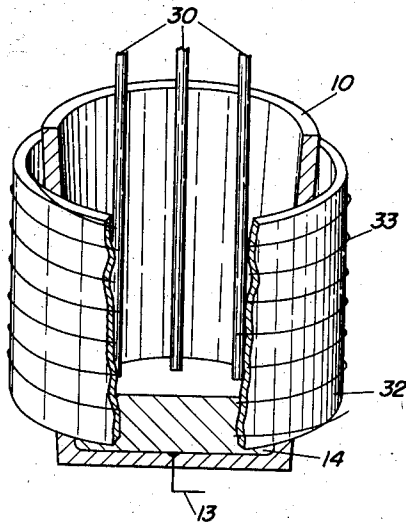
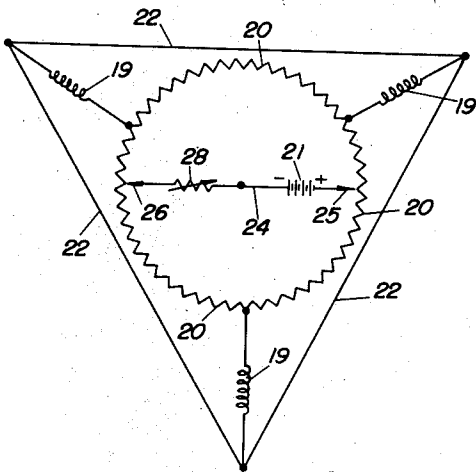


FIG. 3

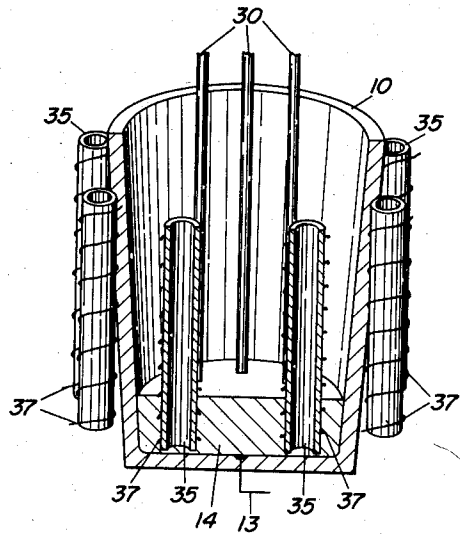


FIG. 5

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ELECTRIC ARC MELTING FURNACE

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6 Claims. (Cl. 13—11)

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This invention relates to electric arc furnaces, and more particularly to means for insuring production of a homogeneous ingot in such a furnace.

Electric arc furnaces have been used for many years to obtain high temperatures in the melting of metals in the forming of ingots. It is desirable to be able to direct the application of heat in an arc melting furnace or crucible to any desired zone on the surface of the melt. This, of course, could be accomplished by using a large number of electrodes, but would result in an uneconomical and inefficient melting operation. Moreover, the number of electrodes which may be used is frequently limited by the composition of the crucible or the geometry of the particular crucible. Compositional limitations arise because the electrodes have to be placed a minimum distance from the walls of crucibles formed from certain materials. The geometry of a particular crucible also limits the number and/or the position of the electrodes within the melting chamber. The size of the electrodes themselves often place a limitation on the total number of electrodes which may be placed within a particular crucible. Consequently, while it is theoretically possible to direct heat to any desired zone on the surface of the melt merely by increasing the number of electrodes, quite often this is a practical impossibility.

Additional limitations on the number of electrodes which may be used are imposed by the necessity, in handling readily reactible materials, of using an inert atmosphere, the space needed for the appurtenances for which consequently reduce the maximum number of electrodes which may be used. Moreover, when readily reactible metals are being melted the types of materials from which the crucible may be constructed are few in number and thus an additional limitation is placed upon the maximum number of electrodes which may be used. This is true because certain materials, although suitable for readily reactible melts, cannot be subjected to close contact with electrodes, such as would be the situation if a large number of electrodes were placed in the crucible.

It is, therefore, one object of this invention to provide an electric arc melting furnace which comprises means for varying the location of the electric arc or arcs within the crucible or furnace without moving the electrode or electrodes projecting into the crucible.

It is another object of this invention to provide an electric arc furnace which comprises

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means for uniformly varying the position of a single arc or a plurality of arcs within said furnace.

It is a further object of this invention to provide an electric arc furnace and means for agitating the molten metal in said furnace.

Various additional objects and advantageous features of this invention will become apparent to those skilled in the art from the following description when read in conjunction with the accompanying drawings, in which:

Fig. 1 is a front elevation perspective view, partly in section, showing this invention applied to an arc furnace having a single, centrally disposed electrode;

Fig. 2 is a plan view of the device shown in Fig. 1;

Fig. 3 is a wiring diagram of a device used to control the positioning of the arc generated in the device shown in Figs. 1 and 2;

Fig. 4 is a front elevation perspective view, partly in section, with portions broken away, of a modification of this invention applied to an electric arc furnace having three electrodes therein; and

Fig. 5 is a view similar to Fig. 4 showing a modification of the device shown therein.

Referring to the drawings, and more particularly to Figs. 1 and 2, 10 is an arc melting furnace crucible or container, which may be made of a refractory material, or a non-refractory material, such as copper, supplied with a cooling system. Any other material commonly used for such purposes and which will withstand heat, may be used. Where the furnace is to be used to melt readily reactive materials, 10 may be made of a material which will not readily combine with the active material being melted. 11 is an electrode which may be made of any of the various common electrode materials, and if desired, may be a water-cooled tungsten-tipped electrode, such as is known to those skilled in the art. 13 is an electrical lead, contacting the mass of metallic material 14 being formed into an ingot. The electrode 11 is generally the cathode and the mass of metallic material is generally the anode in the electric arc furnace, when direct current is used. However, alternating current may also be used effectively. Completely enclosing container 10, but spaced therefrom, is a ring 16 of a magnetic material such as soft iron. Attached to this ring and equally spaced therearound are inwardly projecting pole pieces 18—18. These pole pieces are provided with windings 19—19, which are connected

as shown in Fig. 3. It is important that ring 16 and pole pieces 18—18 associated therewith be positioned in the horizontal plane which would intersect the arc formed between electrode 11 and the molten metal 14, in order to obtain the desired results described hereinafter.

Referring to Fig. 3, the windings 19—19 on pole pieces 18—18 are connected at corresponding ends by resistances 20—20 and wires 22—22. A rotatable, two contact switch 24, having contacts 25 and 26, is so positioned that during its rotation it will continuously contact resistances 20—20. Connected to this switch is a source of current 21 in series with a variable resistance 28.

The operation of the device shown in Figs. 1, 2 and 3 is as follows: Assuming that an arc is established between electrode 11 and the surface of the metal 14 which is being formed into an ingot, the pole pieces 18—18 are energized by a suitable source of current, such as 21 shown in Fig. 3. In the position of contacts 25 and 26 shown in Fig. 3 the pole piece having its windings 19 in contact with contact 26 will, let us assume, present a north pole adjacent the container 10. If that is true, then the remaining two poles will each be one-half south. Consequently, the lines of flux will flow from the north pole and through the zone inside the container 10 and be split equally between the south poles and thence back through ring 16 to the other end of the pole piece having a north pole adjacent container 10. Since the arc column may be considered a conductor, it will have circular lines of flux therearound, one portion of which will be cancelled out by the lines of flux flowing from the north pole to one of the one-half south poles, while the other portion of such lines of flux will be added to the magnetic forces flowing from the north pole to the other one-half south pole. Such an unstable group of forces on the arc column will cause it to be deflected upwardly away from the anode 14 and in a particular direction depending upon which pole is north and which poles are south. The bearing angle, or the direction in which the arc column is deflected may be controlled by alternately exciting the pole piece windings. If the pole pieces are regularly alternately excited the electric arc column will be caused to rotate around the electrode 11, while maintaining one end at the electrode. By varying the intensity of the voltage supplied to the windings on the pole pieces, the current in turn is varied, which in turn varies the force of the magnetic field, thereby varying the deflection angle or the degree to which the arc column is raised from a vertical path between the cathode and the anode.

It is necessary in the three electrode arc furnace to use a device other than merely the device shown in Figs. 1 and 2 to control the deflection of the arc, because if the device shown in Figs. 1 and 2 is applied to a three electrode arc furnace the net result is to cause a brush type discharge which is extremely ineffective as a heating means.

Referring now more particularly to Fig. 4, crucible 10 is shown with electrical lead 13 and the mass of metallic material 14 therein which is to be formed into an ingot. However, instead of a single electrode, a plurality of electrodes 30—30 are positioned within the container, equi-spaced from the center thereof and from each other. Surrounding the container 10 is a tubular member 32, preferably made of a non-magnetic material such as brass. Wound on this tubular mem-

ber 32, is a coil 33, attached to a suitable source of electrical energy (not shown).

The operation of this device is as follows:

Arc columns are established between the lower ends of electrodes 30—30 and the surface of the metal 14 which is being formed into an ingot. The lower ends of such arc columns are mutually attracted, and tend to converge at a point which is on the surface of the metal 14 equi-spaced from the electrodes. Electrical energy is then caused to flow through coil 33. The resulting vertically extending magnetic field causes the arc column at the lower end of each electrode to be deflected outwardly from the central mutual impinging location and slant upwardly away from the anode 14. The bearing angle, which is the angle which indicates the direction in which the arc column is deflected will vary depending upon the polarity of the coil 33 and the intensity of the magnetic field created thereby. Therefore, the bearing angle may be controlled by changing the polarity of the coil and by varying the intensity of the magnetic field created thereby. The intensity of that field will also affect the initial angular deflection of the arc columns. The deflection angle, and to a certain extent the bearing angle, may also be varied by tilting the coil 33 and member 32. If member 32 and the electrodes are not coaxial, the arc columns will be deflected depending upon the direction in which the coil is tilted. Their bearing angle will also vary, but not as noticeably.

Referring now more particularly to Fig. 5, there is shown a crucible 10, electrical lead 13 and the mass of metallic material 14 which is to be formed into an ingot. Electrodes 30—30 are positioned as in Fig. 4. Surrounding crucible 10 is a plurality of vertically extending hollow cylindrical solenoid members 35—35, preferably made of a non-magnetic material, and each of which has wound therearound a coil of wire 37—37, each of said coils being connected to a suitable source of electrical energy. The results obtained with the device shown in Fig. 5 are very similar to those obtained with the device shown in Fig. 4, but differ in that by using the device shown in Fig. 5 it is possible to have certain sections of the ring of members 35—35 create a stronger magnetic field than other sections merely by varying the flux density in individual members 35—35.

The operation of the device shown in Fig. 5 is as follows:

With an arc column established between the lower end of each of the electrodes 30—30 and the mass of material 14, each of the coils 37—37 are connected to sources of electrical energy so that all of the vertically extending members 35—35 have the same polarity at corresponding ends. By varying the flux density in a certain portion of the interior of crucible 10, the bearing angle may be more readily controlled than merely by changing the entire polarity of the coil and the entire density of the magnetic field within the container 10. Moreover, while both the deflection and bearing angles may be controlled by tilting the plurality of solenoid members 35—35, these angles may also be controlled by adjusting the polarity of various members 35—35, and the flux density for those members.

It will be obvious that with all of the devices disclosed herein, the arc heat may be directed and concentrated in various parts of the upper surface of the mass of material being formed into an ingot, and consequently an ingot which is homogeneous in character may be formed.

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There is an additional and totally unexpected result obtained by the use of the device constituting this invention. If the arc column in a single electrode furnace is rotated in a uniform manner, or if the deflection angles of the arc columns in a multiple electrode furnace are suitably adjusted and the bearing angles for each arc column are established so that the arc columns are placed in the same relative direction around a circle inscribed through the electrodes, the upper surface of the melt will be caused to rotate. The reason for this rotation is not known but it is believed to be due to the jet reaction of metallic vapors created at the point of contact of the arc column with the surface of the melt. Such unexpected rotation of the molten metal insures the formation of an extremely uniform, homogeneous ingot.

While this invention has been described with respect to one electrode and to three electrode arc furnaces merely for purposes of simplification, it is to be understood that this invention should not be limited thereto. The arc columns of any number of electrodes may be controlled and directed with the apparatus disclosed herein.

Furthermore, the magnetic equipment shown in Fig. 1 and Figs. 4 and 5 may be combined so that their functions are superimposed, if desired.

While this invention has been described in its preferred embodiment it is to be understood that the words used are words of description rather than of limitation and that changes within the purview of the appended claims may be made without departing from the true scope and spirit of the invention.

What is claimed is:

1. An electric arc melting furnace comprising a container means, means for producing a vertically-extending electric arc within said container means, and means, exterior of said container means, for producing two, divergent, horizontally-extending, magnetic fields which would be adjacent said electric arc, on either side thereof, and within said container means.

2. An electric arc melting furnace comprising a container means, means for producing a vertically-extending electric arc within said container means, and means, exterior of said container means, for producing two, divergent, horizontally-extending, magnetic fields of variable intensity which would be adjacent said electric arc, on either side thereof, and within said container means.

3. An electric arc melting furnace comprising a container means, means for producing a vertically-extending electric arc within said container means, and means, exterior of said container means, for producing two, divergent, horizontally-extending, movable, magnetic fields which would be adjacent said electric arc, on either side thereof, and within said container means.

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4. An electric arc melting furnace comprising a container means, means for producing a vertically-extending electric arc within said container means, and three, equi-spaced, radially extending, horizontally positioned, solenoid members, exterior of said container means, and lying in a plane extending through the zone which would be occupied by an electric arc produced by said means for producing said electric arc for producing two, divergent, horizontally extending, magnetic fields which would be adjacent said electric arc, on either side thereof, and within said container means.

5. An electric arc melting furnace comprising a container means, means for producing a vertically-extending electric arc within said container means, an annular magnetic material containing member, exterior of said container means and equi-spaced therefrom, but lying in a plane extending through the zone which would be occupied by an electric arc produced by said means for producing an electric arc, and three equi-spaced, radially-extending, horizontally positioned, solenoid members inwardly-extending from said annular member for producing two, divergent, horizontally extending, magnetic fields which would be adjacent said electric arc, on either side thereof, and within said container means.

6. An electric arc melting furnace comprising a container means, a single vertical electrode adapted to produce an electric arc within said container means, an annular magnetic material containing member, exterior of said container means and equi-spaced therefrom, but lying in a plane adjacent the lower end of said electrode, and three, equi-spaced, horizontally positioned, radially-extending solenoid members, inwardly-extending from said annular members for producing two, divergent, horizontally extending, magnetic fields which would be adjacent said electric arc, on either side thereof, and within said container means.

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