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Camacho

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[45] **July 31, 1973**

[54] **TROUGH HEARTH CONSTRUCTION AND METHOD FOR PLASMA ARC FURNACE**

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[73] Assignee: **Technology Application Services Corporation,** Raleigh, N.C.

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[21] Appl. No.: **283,552**

[52] **U.S. Cl.** **13/9,** 13/1, 13/35

[51] **Int. Cl.** **H05b 7/18**

[58] **Field of Search** ..... 13/1, 2, 9, 31, 34, 13/35; 219/121 P

[56] **References Cited**

UNITED STATES PATENTS

3,406,241	10/1968	Robinson	13/9 X
3,422,206	1/1969	Baker et al.	13/34
3,459,867	8/1969	Estes	13/9
3,578,943	5/1971	Schoumaker	219/121 P

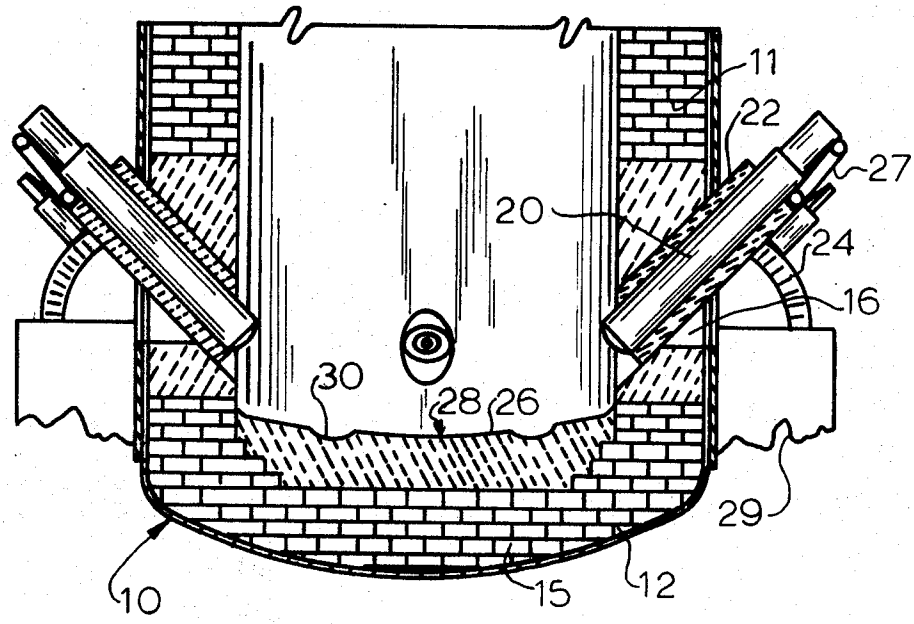
Primary Examiner—Roy N. Envall, Jr.

Attorney—B. B. Olive

[57] **ABSTRACT**

An improved hearth construction and method are disclosed for plasma arc furnaces adapted for melting metallic raw or scrap materials and are based on using a shaped receptacle, e.g., an annular-shaped trough, integrally molded into the furnace hearth which enables molten metallic materials to rapidly accumulate and the molten accumulated materials to be contacted by long arc plasma columns very early in the melting procedure, thereby substantially reducing the damage to torch parts due to arc flashing and improving the operating efficiency.

13 Claims, 8 Drawing Figures



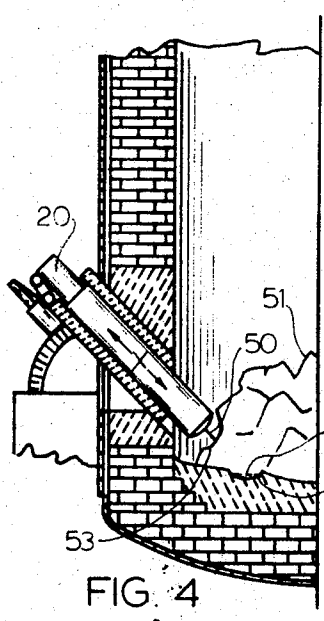


FIG. 4

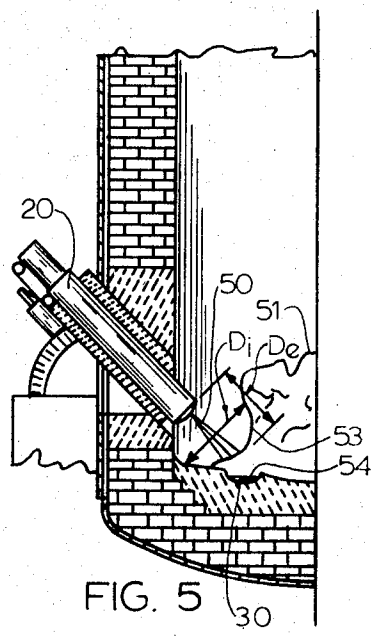


FIG. 5

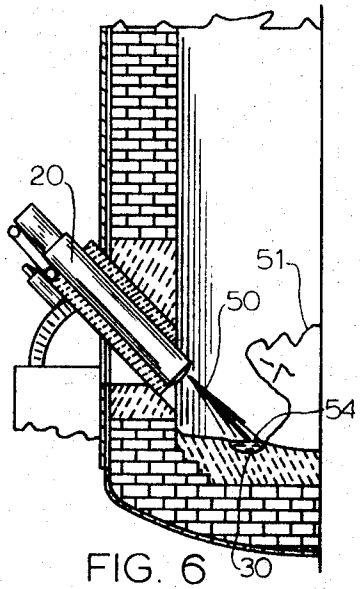


FIG. 6

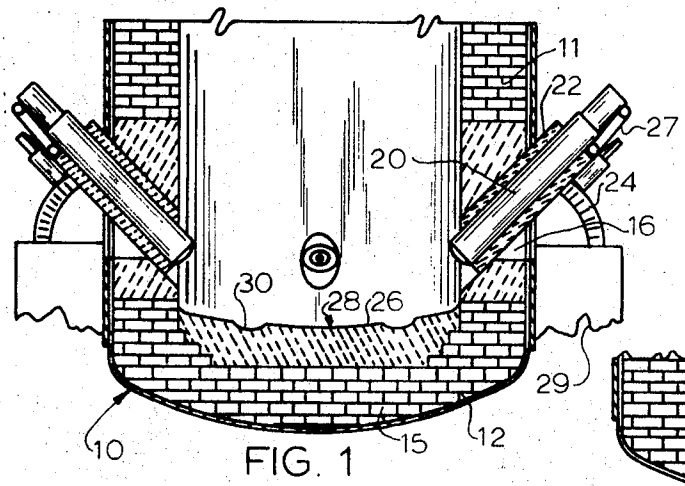


FIG. 1

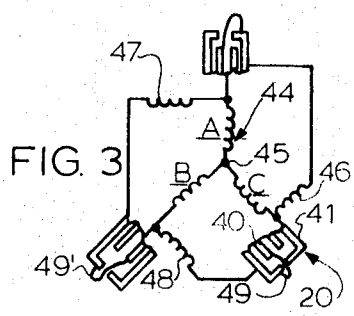


FIG. 3

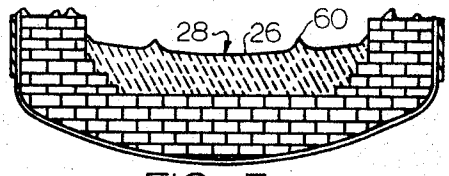


FIG. 7

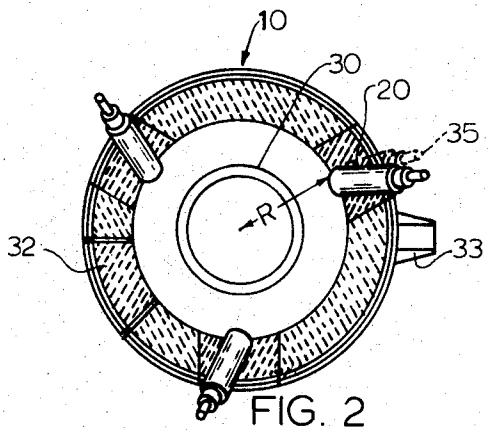


FIG. 2

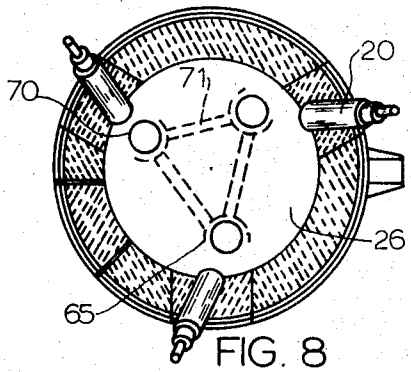


FIG. 8

TROUGH HEARTH CONSTRUCTION AND METHOD FOR PLASMA ARC FURNACE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to electric arc furnaces adapted for melting raw or scrap metallic materials and especially to those furnaces employing long arc column forming plasma torches.

2. Description of the Prior Art

Plasma column torches, per se, are taught, for example, in U. S. Pats. Nos. 3,194,941 and 3,673,375. Electric arc furnace prior art includes U. S. Pat. No. 1,479,662 which broadly teaches the utilization of an annular trough in a carbon arc type electric furnace. The trough, as taught in this reference, is adapted to reside proximate the furnace interior vertical wall concentric to a bottom and centrally located carbon electrode. Although admittedly quite old in the art, such a trough configuration has never, so far as is known, been heretofore used with a long arc column forming plasma torch. More specifically, such an annular trough has never been used in a configuration which allows the molten material in the trough to form part of the arc circuit.

Other notable prior art includes Baker et al. U. S. Pat. No. 3,422,206, which teaches the use of sidewall mounted plasma torches in a furnace, as opposed to conventionally top mounted arc forming electrodes, as a means to promote greater furnace efficiency. Such furnaces employing side mounted plasma torches, while constituting a significant improvement in furnace efficiency by minimizing heat losses, have still been characterized by certain degrees of inefficiency by what may be characterized as "arc flashing" before flat bath, i.e., a total molten state of the charge, has been achieved. "Arc flashing" may be defined as random electrical contact of a plasma arc column with metallic scrap not in alignment with the axis of the arc forming plasma torch. Melting of scrap material normally proceeds as a plasma arc column is established between a metallic scrap in axial alignment with the plasma torch. The two critical factors contributing to "arc flashing" now come into play. These are depth of melting into the scrap (D_e), and the diameter of the path formed through the scrap (D_i). It has been experimentally recognized by this inventor and by others skilled in the art that when the ratio D_e/D_i becomes greater than 1, the arc column becomes unstable and transfers or "flashes" to the closest point of electrical contact which affords the least electrical resistance. This point is typically an outer edge of the hole which has been melted in the scrap. This action results in bending of the arc column from its normal axis, contacting of cooler surfaces by the arc and consumption of more power than would otherwise be required. In addition, "arc flashing" often leads to "double arcing", a phenomenon in which substantial bending of the arc causes the torch nozzle to become part of the arc. Two arcs are thus formed: one inside the torch and one outside, extending from the nozzle to the metal scrap. Extensive damage to the nozzle often results because the "double arc" is now formed across portions of the nozzle which have not been adequately water cooled. Only when a flat or nearly flat bath has been reached is the inefficient arc flashing eliminated.

The above cited Baker et al. patent does not suggest a means for reducing the characteristic "arc flashing" of the plasma arc columns randomly arcing between various bits of metal until a flat bath or totally molten fluid state has been reached. While side mounting of plasma torches has been taught, side mounting of long arc column forming plasma torches in combination with a furnace hearth having an annular or equivalent shaped trough has not been suggested. Nor has such a combination been suggested as a means for electrically connecting the various torches being utilized to the same electrical circuit in order to speed melting, eliminate arc flashing, and thereby obtain even greater operating efficiencies.

SUMMARY OF THE INVENTION

The present invention is directed to a furnace chamber utilizing sidewall mounted plasma arc torches in the same general sense as the previously cited U. S. Pat. No. 3,422,206. Various embodiments are described. In the preferred embodiment of the present invention, however, there is employed a furnace hearth having an annular-shaped trough integrally molded therein. The furnace hearth is further adapted by sloping interior floor portions lying concentrically adjacent the annular trough to cause molten metallic materials to flow into the trough.

In the present invention it has been discovered that an exceptionally long transferred plasma arc can best be established and maintained in a furnace of the class described, when melting metallic scrap or raw material, by collecting molten metal in the annular trough early into the melting procedure and electrically connecting each transferred plasma arc with the molten metal. In so doing, the previously mentioned depth/diameter D_e/D_i relation has been found to no longer hold true. The least resistive electrical path, and thus the one which the plasma transferred arc column will seek to follow, has been found to be the path between each respective torch and the trough of molten metal.

Operation of a plasma arc furnace according to the invention proceeds more rapidly and smoothly to flat bath and in the near absence of destructive arc flashing, while at the same time consuming substantially less power than conventional plasma arc furnaces which employ flat or concave hearth floors.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical cross-sectional view of an electric furnace utilizing long arc column forming plasma torches showing a trough hearth construction according to the invention.

FIG. 2 is a top plan view of an electric furnace according to the invention showing the relation of side mounted plasma torches to the trough hearth configuration.

FIG. 3 is a somewhat schematic diagram showing a power circuit adapted for use by the invention.

FIGS. 4, 5, and 6 are partial front views in cross-section of the furnace showing a long arc column forming plasma torch in various positions indicating subsequent stages of melting raw metallic materials in accordance with the invention.

FIG. 7 is a front view in cross-section of a first alternate trough embodiment of the invention.

FIG. 8 is a top plan view of an electric furnace according to the invention showing a second alternate trough embodiment.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the description which follows, reference will be made to a plasma generator which has been defined in U. S. Pat. No. 3,673,375, entitled "Long Arc Column Plasma Generator and Method", issued to same inventor, as an apparatus adapted to generate a long high-temperature plasma arc between the apparatus and an electrical conductor in the arc circuit. Such an arc device comprises a cylindrical shaped electrode; a gas-directing nozzle axially aligned with, forwardly spaced and insulated from said electrode; and appropriate gas, water and electrical supply means. The plasma generator or torch disclosed in U. S. Pat. No. 3,673,375 is highly suited to the needs of the present invention due to its ability to provide an exceptionally long transferred arc. Other plasma torches having a somewhat shorter arc capability may be adapted for use by the invention. See, for example, Baird, U. S. Pat. No. 3,194,941. Reference will also be made to the term "raw metallic materials" which, for purposes of the disclosure, is defined as any material capable of conducting electric current at least in the fused state and includes metals, metal alloys, fused salts, slags, etc.

Referring now to FIG. 1 of the drawings, a portion of an electric furnace generally designated **10** constructed according to known furnace techniques includes side **11** and bottom **12** wall portions, and a hearth **15** formed of molded refractory material. In the preferred invention embodiment, the furnace sidewalls **11** are provided with a plurality of suitable apertures **16** each being adapted to receive a long arc column forming plasma torch **20.** A cylindrical collar **22** is adapted to line each aperture **16** and receive each torch in sealingly movable engagement. Angular adjustment of each torch with respect to the sidewalls **11** is provided by appropriate remotely controllable jack means **24,** while depth of torch insertion is controlled by suitable motorized carriage means **27.** Lateral angular movement of each torch is provided by a movable support member **29** which supports jack **24** and carriage **27.**

A hearth in such a furnace has a conventionally comprised a somewhat concave interior floor **26** having a lowermost point at the hearth center **28.** In what is considered the heart of the present invention, an annular trough **30** is formed integral with such a concave hearth floor **26.** Such trough is utilized in the instant invention, as will later be described in greater detail, for collecting a ring of molten metal early into the melting of raw metallic materials. In conventional furnaces having concave interior hearth floors, the metal drippings which occur early in the melting sequence are adapted to flow toward the center of the hearth. In the present invention, however, trough **30** is adapted to be approximately medially located between the hearth center and the furnace sidewall thereby collecting metal drippings before they reach the hearth center **28.** The distance of trough **30** from the sidewall should not be so great so as to prevent electrical contact between long arc (10–40 inches) plasma columns, not shown, being formed by said torches **20** and molten metal, not shown, collected in the trough.

Referring now to FIG. 2 which shows a somewhat simplified top plan view of the same furnace **10** shown in FIG. **1,** an inspection door **32** and tapping spout **33** are also provided in such a furnace. In a preferred form of the invention, torches **20** are angled slightly away from the radius R in order to achieve slight stirring of molten metal collected in trough **30.** In plasma arc furnaces of the prior art stirring was recognized to occur at or near the time "flat bath" was reached by slightly angling the torches utilized away from the furnace radius. It is a recognized advantage of this invention to achieve stirring from very early in the melting sequence up until "flat bath" thereby creating a more uniform and homogeneous molten charge. As represented by dashed lines **35,** each torch **20** may be laterally angled, by previously mentioned means, toward the radius R during the first few minutes of furnace operation to utilize the most direct arc pathway to the molten metal being collected in trough **30,** then swung slightly away from the radius to begin stirring.

Referring now to FIG. **3,** each long arc column forming plasma torch **20** utilized in the present invention (shown in cross section) includes a cylindrical shaped internal electrode **40** and a gas directing nozzle **41** axially aligned with, forwardly spaced and insulated from electrode **40,** and appropriate gas, water and electrical supply means. While the last mentioned gas and water supply means are considered well-established in the art requiring no further elaboration herein, a better understanding may be gained of the invention by a discussion of its use of power in starting and maintaining the various long arc plasma columns. A three phase A. C. wye connected source **44** having a floating neutral **45** supplies power to three long arc column forming plasma torches **20.** Each torch internal electrode **40** is connected across an individual phase or leg A, B or C of the wye source **44.** It is apparent that if more than three torches are employed a greater number of phases may be utilized. Each torch nozzle **41** is connected to an adjacent leg or phase via an appropriate choke such as indicated at **46, 47** and **48.** In this manner a "pilot arc" **49** may be struck between the nozzle **41** and internal electrode of each torch without introducing a consumable electrical conductor by applying the phase to adjacent phase voltage differential, caused by the respective choke, across internal electrode **40** and nozzle **41** and by simultaneously introducing a gas vortical flow through nozzle **41.** The current in the "pilot arc" is substantially smaller than that of the "main arc" which is subsequently adapted to be transferred to the metal scrap to be melted. Simultaneous transferral of at least two "pilot arcs" **49, 49'** to the raw metallic materials establishes at least two main transferred arcs (not shown) and completes a phase B to adjacent phase C loop whereby the full available current is now utilized. Other pairs of arcs act similarly.

Referring next to FIGS. **4, 5** and **6** which illustrate subsequent stages during the melting of raw metallic materials **51** charged into the furnace **10,** and which also illustrates an important new relationship serving as a basis for this invention, each long arc column-forming plasma torch **20** is slightly extended as necessary into the furnace during the main arc striking procedure. When a pilot arc comes within 4–7± inches of a metal scrap **51** in the electrical circuit, transfer is made to a main arc **50.** This operation normally occurs simultaneously with all three torches being electrically con-

nected. Simultaneous electrical connection of at least two torches is necessary for proper furnace operation according to this invention. Once the main transferred long arc column **50** has been established, as shown in FIG. **4**, a pathway **53** in axial alignment with the longitudinal axis X of torch **20** is begun to be melted in the raw metallic materials **51** and molten drippings **54** now begin to accumulate in trough **30**. Referring to FIG. **5**, as melting proceeds, within the first few minutes of furnace operation torch **20** is slightly withdrawn to form a longer transferred arc column **50**, thereby radiating more heat, while melting a wider and deeper path **53**. At this time, two dimensions come into play, the ratio of which has been experimentally determined to be critical. These are depth of path D_e and diameter of path D_i. Up to a point, D_e will increase at roughly the same rate as D_i with D_i being greater, then D_e will increase more rapidly than D_i. As the ratio of D_e/D_i begins to reach **1** "arc flashing" or bending of the arc column to contact metal surfaces not in the axial arc pathway will occur. At this stage "arc flashing" is not damaging because very significant bending does not occur. When D_e/D_i greatly exceeds **1**, however, very significant bending of the arc column will occur resulting in "arc flashing", and often leading to the previously mentioned "double arcing" in which the torch nozzle may be damaged. As a recognized object, the instant invention substantially reduces the harmful arc flashing occurring as D_e/D_i becomes significantly greater than 1, by providing a molten pool of metal at that stage and in axial alignment with the torch, to which the long transferred plasma arc may become connected. Although further from the torch **20** the molten pool of metal **54** collected in trough **30** offers much less resistance than surrounding cooler scrap surfaces nearer to torch **20** but not in axial alignment, and therefore attracts and holds the arc column **50** (best shown in FIG. **6**). By collecting and forming a continuous trough of molten metal early in the melting procedure, all torches being utilized may now function at maximum efficiency. The result is a higher quality, more homogeneous bath due to the constant stirring from early in the melting sequence to flat bath, at a substantial savings in power consumed and torches damaged, due to the virtual elimination of harmful "arc flashing". It is recognized that the ratio D_e/D_i will vary between raw metallic materials, and any trough according to the invention will be located with respect to the torches, with this consideration in mind. On the average the trough should be at a distance where D_e/D_i has been found to approximately **1** for the materials normally being melted.

Referring now to FIG. **7**, an alternate embodiment according to the invention utilizes the previously described conventional concave hearth floor **26** but provides a medially circular ridge **60** located between the sidewall **11** and hearth floor center **28** thereby effectively forming a trough **30'** outwardly and concentrically adjacent ridge **60**, accomplishing the same invention objectives. Such a ridge type construction may find particular application in existing furnaces being refitted for long arc column forming torches, but wherein the hearth has become substantially hardened through prolonged use, to preclude the easy formation of a trough **30** as shown in FIG. **1**.

Referring to FIG. **8**, a second alternate embodiment of the invention includes pockets or depressions **70** formed in the hearth in axial alignment with the respective torches utilized and being adapted to collect molten raw metallic material to accomplish the aforementioned invention objects. To complete electrical connection between the adjacent depressions **70**, small troughs indicated by dashed lines **71** may be provided. As is apparent from the foregoing invention embodiments, the depressions **70** may be formed in any suitable configuration down into the hearth floor **26** and may be at least partially surrounded by semicircular ridges indicted by dashed lines **65** in FIG. **8**. Of course, with a concave floor such semicircular ridges **65** could, by themselves, be used as the melt collecting receptacles.

In accordance with the invention it is contemplated that such a method and apparatus as are disclosed herein will find wide application in either batch or continuous type melting operations. The art is sufficiently established as to the parameters of either operation so as to not warrant further discussion herein.

Summarizing what has been stated above, a generalized statement of the method of the invention includes:

a. charging a furnace of the class described with raw metallic materials;

b. initiating and sustaining from a multi-phase power source at least two long plasma arc columns in axial alignment with and produced by at least two long arc column forming plasma torches;

c. melting the materials by use of the columns and providing a trough configuration for collecting metal drippings in axial alignment with said torches and at a distance from said torch whereby the ratio of depth of path melted to diameter of path melted is kept approximately **1** for the material being melted;

d. contacting the molten metal pool formed in said trough configuration with at least two of the said long arc plasma columns, whereby phase-to-phase electrical connection is formed between said torches via said molten metal pool with the torches angled to cause the columns to strike the pool in a minimum distance; and

e. then horizontally angling the torch after melting has been initiated to facilitate stirring.

On the basis of the above, it is apparent that the instant invention provides an effective method and apparatus for melting and stirring raw metallic materials in an electric furnace of the class described through the utilization of an annular trough or equivalent configuration together with long arc column forming plasma torches so as to consume substantially less power than conventional furnaces and produce a higher quality, more homogeneous molten bath. The elongated pool of melt initially formed may take any of various forms so long as it is positioned so as to be contactable by the main arc columns of at least two of the torches during the initial melting. Once a relatively deep pool has been formed, all of the torches may, of course, maintain contact through the pool independent of the initial configuration of the melt. Axial, vertical and lateral positioning of all the torches may take place simultaneously or independently according to the nature of the material and melting conditions encountered. In some furnace applications the torches may be found to operate successfully in fixed positions directed at the particular hearth depression. In other applications not all of the three forms of motion, i.e., axial, vertical and lateral,

may be required for torch positioning. However, it can be seen that in the initial starting of the melting procedure the invention both in an apparatus as well as a method sense offers advantages not heretofore recognized or achieved in the art. Of special significance is the use of a long arc plasma column torch or generator by which is meant a plasma column generally in the 10 to 40 inches range but possibly longer and drawing relatively high current in the range, for example, of 1,000 amperes or more. It is this type plasma generator when combined with the described hearth that brings about the mentioned advantages.

What is claimed is:

1. A method of melting raw metallic materials in an electric furnace having at least two wall mounted peripherally spaced long arc column forming plasma torches energized through interconnected phases of a multi-phase electric source and having a hearth said hearth including a depression adapted to collect an elongated pool of molten metal, comprising:

a. charging the furnace with raw metallic material;

b. energizing said torches from said electric source and establishing for each torch a main arc plasma column in circuit with said material;

c. as melting proceeds positioning the torches such that the columns are directed to contact the said depression at selected points spaced from the respective torch nozzles whereby the ratio of depth of path melted to diameter of path melted approximates 1 for the material being melted;

d. collecting the molten in said depression to provide said pool of molten metal and transferring said main arcs to contact said pool of metal whereby to establish respective long arc columns which include at least a portion of said pool of metal in circuit therewith; and

e. thereafter continuing to melt said material while maintaining said long arc columns in contact with and in circuit with the melt.

2. The method as claimed in claim **1** wherein each said torch is angled downwardly towards the hearth during initial operation whereby each respective column thereof contacts said depression in a minimum distance, rapidly melts a path in said material and upon sufficient melt collecting in said depression each said column contacts and includes said melt in electrical circuit therewith, and then angling each said torch while its respective column maintains contact with said melt in the depression in a manner to cause stirring of the melt in said depression during the early stages of melting said material.

3. The method of claim **1** including the step of positioning said torches through means remote to the furnace.

4. The method of claim **2** including the step of positioning said torches through means remote to the furnace.

5. The method of claim **1** wherein at least three said torches are employed.

6. The method of claim **1** wherein said depression takes the form of an annular depression in the hearth floor spaced inwardly from the furnace sidewall and said torches and columns are respectively directed towards and contact the melt in said annular depression.

7. The method of claim **1** wherein said positioning is effected axially, laterally and vertically by means remote from said furnace.

8. The method of claim **1** wherein said elongated pool collected in said depression is of sufficient length and positioned on the hearth floor so as to be contactable by the said main arc columns of at least two of said torches during initial melting of said material.

9. An electric furnace adapted for melting raw metallic materials and having side and bottom walls and a plural number of apertures extending through portions of said sidewalls comprising, in combination:

a. a plurality of long arc column forming plasma torches individually mounted in said apertures and adapted for adjustable positioning therein;

b. positioning means adapted to adjustably position each said torch with respect to the said hearth;

c. a hearth forming the said furnace bottom wall and including a depression therein for collecting an elongated pool of molten metal disposed such that upon appropriate torch positioning a distance between each respective torch nozzle and the said pool may be maintained such that the ratio of depth to diameter of melted path being formed approximate 1 for the material being melted; and

d. electrical circuit means connected to said torches and adapted to initiate a pilot arc in each said torch enabling the creation from each pilot arc of a main arc column for each torch, with each respective column including said material in electrical circuit therewith, subsequently enabling the transfer of each main arc column to the melt in said pool to form respective long arc columns passing through respective open melted paths free of said material and of substantially less resistance than provided by paths through the said material.

10. A furnace as claimed in claim **9** including control means adapted to remotely effect said positioning.

11. A furnace as claimed in claim **10** wherein said control means are adapted to effect said positioning axially, laterally and vertically.

12. A furnace as claimed in claim **9** wherein said depression is annular in form and whose collected melt is adapted to electrically connect at least two said long arc transferred columns.

13. A furnace as claimed in claim **9** wherein said electrical circuit means provides a multi-phase A.C. source and includes electrical connection of an internal electrode of each said torch being utilized with a separate phase of said source and electrical connection of a nozzle portion of each said torch with an adjacent phase of the source via an electrical choke whereby a potential may be established between said internal electrode and said nozzle of each said torch to initiate said pilot arc, and whereby said pilot arc may be transferred to a proximate raw metallic material to establish a direct phase-to-phase potential between at least two torches having main arc plasma columns in electrical contact with the said raw metallic material.

* * * * *

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,749,803 Dated July 31, 1973

Inventor(s) Salvador L. Camacho

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 7, line 31, the word -metal- should appear after the work "molten".

Signed and sealed this 1st day of January 1974.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

RENE D. TEGTMEYER
Acting Commissioner of Patents

FORM PO-1050 (10-69)

USCOMM-DC 60376-P69
* U.S. GOVERNMENT PRINTING OFFICE : 1969 O—366-334.

UNITED STATES PATENT OFFICE
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