March 7, 1944. F. W. BROOKE 2,343,443

ELECTRIC ARC FURNACE

Filed Aug. 19, 1941 2 Sheets-Sheet 1

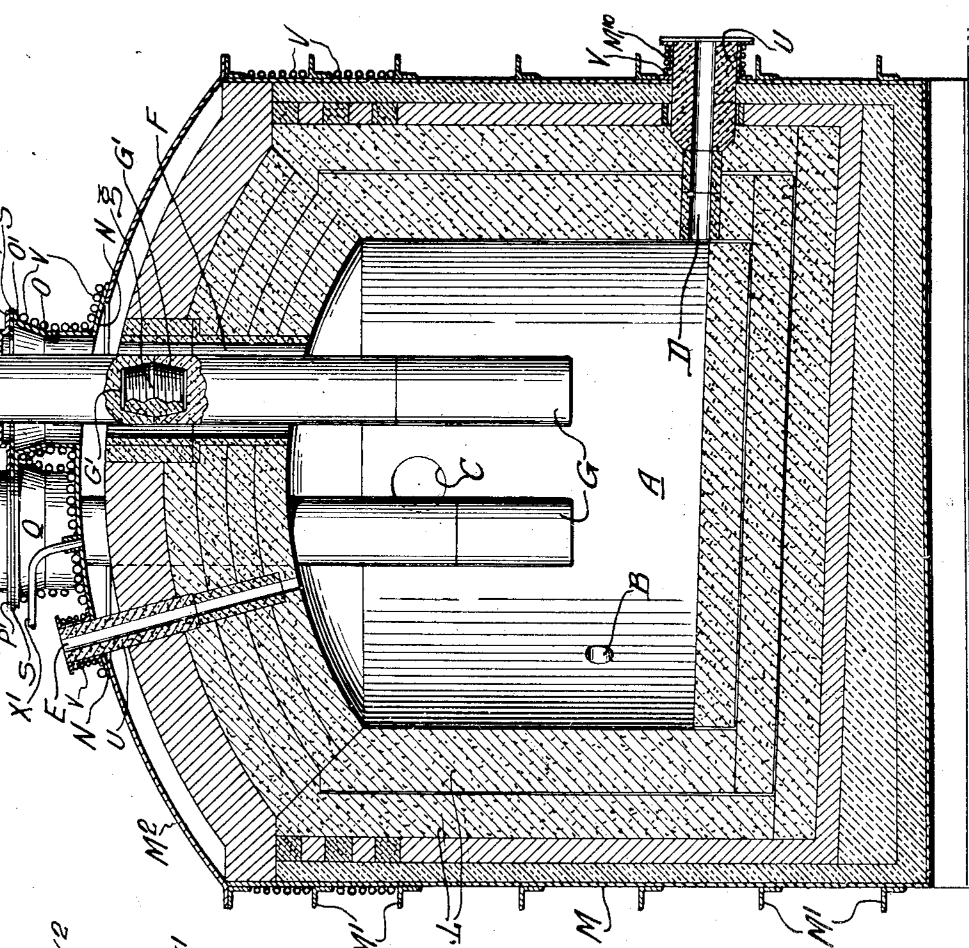

Fig. 2.

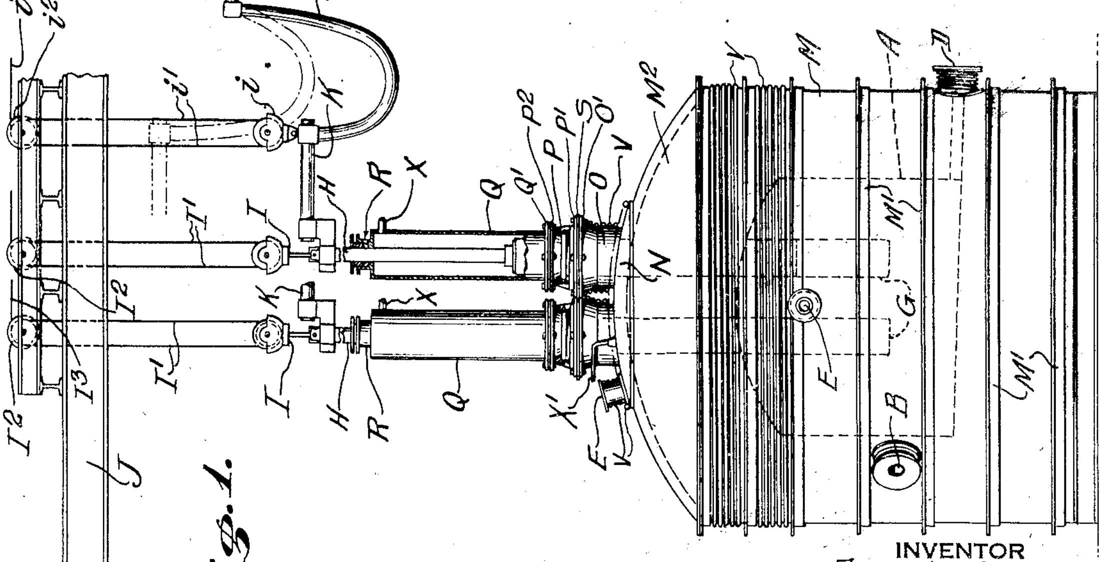

Fig. 1.

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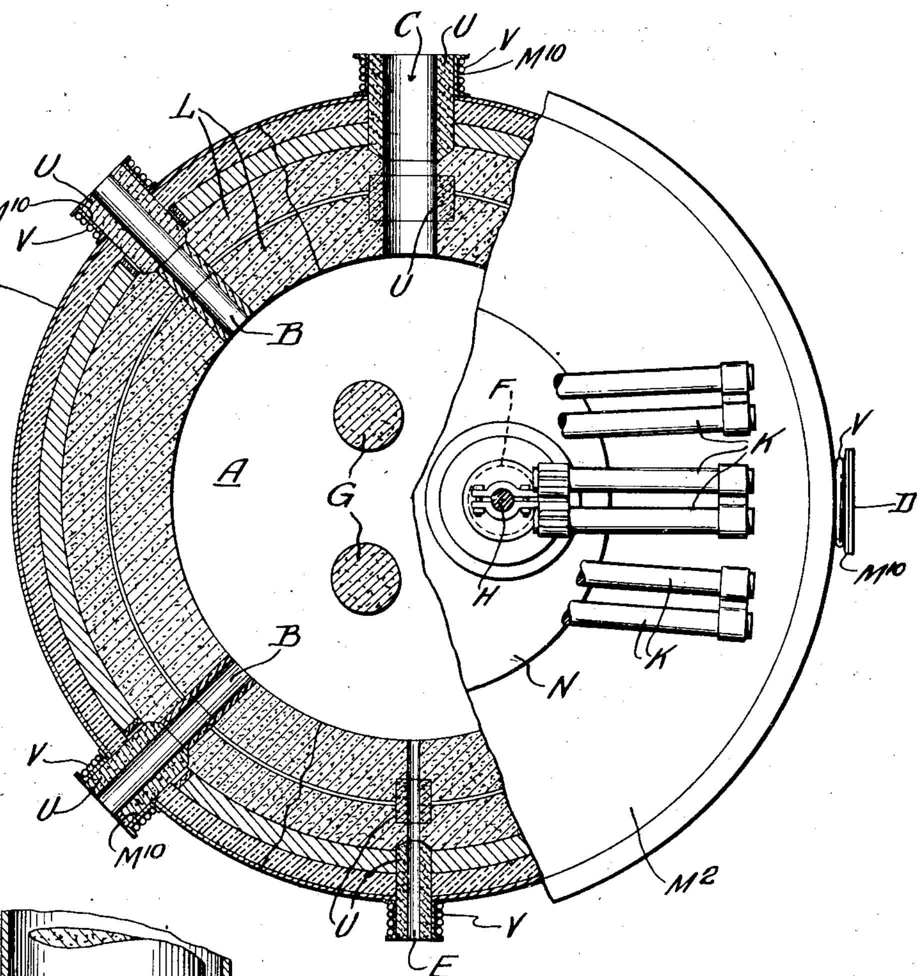
Filed Aug. 19, 1941 2 Sheets-Sheet 2

Fig. 3.



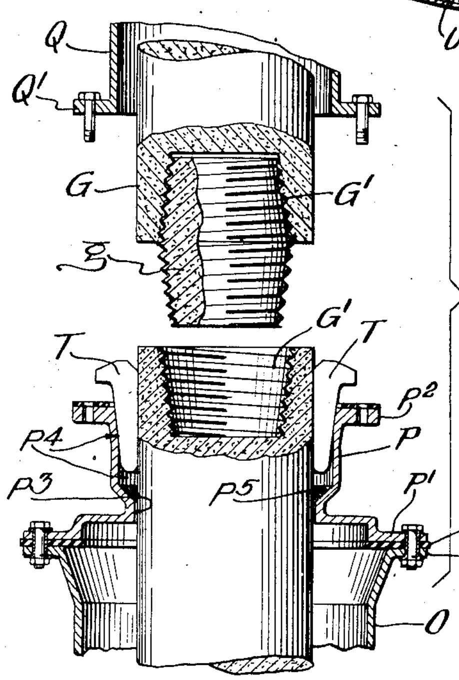


Fig. 4.

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ELECTRIC ARC FURNACE

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6 Claims. (Cl. 13—9)

The general object of the present invention is to provide an improved electric arc furnace adapted for use under conditions making it highly important to prevent all air and gas leakage through the furnace chamber wall in the normal operation of the furnace.

The present invention was primarily devised and is especially adapted for use in the production of magnesium vapor from magnesia, but is well adapted for use in and in connection with smelting furnaces used in vaporizing other metals such as phosphorus and zinc, and for other purposes. In the contemplated use of the present invention in the production of magnesium, carbon, ordinarily in the form of granular or finely divided coke, and magnesia are heated in the furnace chamber to a temperature high enough to effect the combination of the carbon with the oxygen content of the magnesia and the conversion of the magnesium content of the magnesia into magnesium vapor which can be withdrawn from the furnace along with the carbon monoxide for the ultimate segregation of the magnesium in solid form.

In producing magnesium in the manner described, to insure the desired reaction of magnesia and coke, a furnace chamber temperature of the order of 4,000° F. is required. That action is reversible and may be reversed as a result of furnace chamber temperature and pressure variations. The magnesium vapor formed is extremely inflammable, and the leakage of air even in relatively minute amount into the furnace chamber may result in a destructive explosion, or in intense and injurious combustion therein. Heated magnesium vapor leaking out of the furnace chamber through minute cracks in the furnace wall will form high temperature flame jets on contact with the atmospheric air. In normal operation a furnace chamber pressure appreciably above that of the atmosphere may be desirable, but in preparing for normal operation a high vacuum is desirably created in the furnace chamber to eliminate oxygen therefrom.

In the operation of an electric arc furnace it is essential to effect longitudinal movements of each furnace electrode to compensate for the wasting away of the furnace end of the electrodes, and, also, to avoid undesirable fluctuations in the arc voltages and in the electric current flowing through the electrodes. The electrodes used are invariably porous rods or bars of carbon in amorphous or graphitic form, and customarily each such electrode in use in a furnace consists of two or more end to end electrode sections with threaded connections between the adjacent ends of adjacent sections. Customarily a new section is added to the outer end of an electrode whenever breakage or wastage at its arcing end makes the length of a furnace electrode as short as is practically desirable, the operation of the furnace being interrupted while the section is being added.

The present invention is characterized by the effective and relatively simple provisions for preventing air and gas leakage into and out of a furnace chamber of the type mentioned notwithstanding the high furnace chamber temperatures and substantial variations in furnace chamber pressure which may be created and which permit the electrode adjustment movements and the addition of electrode sections to be effected in a simple and satisfactory manner.

The various features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, however, its advantages, and specific objects attained with its use, reference should be had to the accompanying drawings and descriptive matter in which I have illustrated and described preferred embodiments of the invention.

Of the drawings:

Fig. 1 is an elevation of an electric arc furnace and associated external electrode adjusting mechanism;

Fig. 2 is a vertical section through the furnace shown in Fig. 1;

Fig. 3 is a plan view partially broken away and in section of the furnace shown in Fig. 2; and

Fig. 4 is a view illustrating the relative positions of electrode and electrode casing parts during the operation of adding a section to the outer end of an electrode.

In the drawings, the furnace chamber A is shown as circular in horizontal cross section and as having an arched or dome-shaped roof. The wall of the furnace chamber is shown as formed with two feed openings B, a vapor outlet C, a slag or molten material drawoff opening D, and peep sight openings E. The outer ends of the feed inlets B and the vapor outlet C are normally connected to feeding means and vapor drawoff means respectively, and the openings D and E are normally closed by plugs or other closures not shown, but as the form of such connections and closures constitutes no part of the present invention they need not be illustrated or further referred to herein.

The roof of the furnace chamber is formed with three side by side vertical passages F through which the three electrodes G respectively extend downward into the furnace chamber. As shown and in accordance with regular electric furnace practise, each electrode is formed of similar end to end cylindrical carbon sections, and each of said sections is initially formed with an axial tapered and internally threaded socket G' at each end, so that the adjacent ends of adjacent sections of each electrode may be connected by a correspondingly tapered and externally threaded carbon connector g.

In accordance with the present invention, each electrode is provided at its upper end with an axial extension member or metallic outer end electrode section H formed of a suitable metal and having an enlarged, tapered and externally threaded lower end portion H' which is screwed into the upper socket G' of the upper section of the electrode. Each electrode as a whole may be suspended through its extension or section H. The various sections H form permanent portions or elements of the furnace to which they pertain. At its upper end each extension member H is adapted for detachable connection with an electrode suspension element I. The latter, as shown, is the shank of a pulley engaged by a cable I' which connects the element I to an upper supporting pulley element I^2 mounted on a superstructure J above the furnace. Customarily the movable end I^3 of each suspension cable is connected to a motor driven hoist (not shown) which is automatically controlled to raise and lower the electrode as required to maintain the desired strength of current flow through the electrode.

As shown, each electrode is connected into an electric energizing circuit by means comprising a rigid horizontal conductor bar K having one end clamped to the upper end of the electrode extension H. The rigid bar K has its other end connected by a flexible conductor K' to a stationary conductor section K^2. Because of the large current flow through each electrode, which may well be of the order of 35,000 amperes in the case of an electrode having the moderate diameter of 20 inches, the electrical conductors need to be thick and heavy. To prevent the weight of the corresponding conductor parts K and K' from subjecting each member H and associated electrode to objectionable strains, the connected ends of the two sections K and K' are connected to a pulley i which is connected by a cable i' to a pulley i^2 mounted on the superstructure J and the end of the cable i^3 extending away from the pulley i^2 may be connected to any suitable means adapted to support the weight of the conductor parts K and K' as the member H is adjusted through its range of vertical adjustment. The electrode and conductor supporting provisions I, I', etc., i, i', etc., may be, and as shown are of conventional form, except that the conductor K and the suspension element I for each electrode are each directly connected to the electrode extension H instead of to the electrode itself.

The wall of the furnace chamber is shown as comprising a thick body portion of non-metallic refractory material L and an outer gas-tight metallic shell M. When the furnace is devised for use as a magnesium producing, smelting furnace with a furnace chamber temperature of the order of 4,000° F., a major inner portion of the furnace wall body L may advantageously be formed of carbon blocks or bodies and the remainder of said body portion may well be formed of material which is a better heat insulator than the carbon bodies. However, the particular construction of the body portion of the furnace wall forms no part of the present invention, and may follow the usual practice of the prior art and hence need not be further referred to herein.

The metallic outer shell M needs to be strong enough to withstand the bursting tendency of an internal pressure appreciably above that of the atmosphere, and the collapsing tendency created under the operation condition in which a high vacuum is established in the furnace chamber as hereinafter described. In the particular furnace design shown by way of example in the drawings, the external diameter of the shell is approximately 20 feet and the cylindrical body and bottom of the shell M is formed of steel plates one inch thick, and the cylindrical portion of the cell is surrounded by a plurality of superposed reinforcing rings M' which are welded to the shell and are of angle bar cross section.

As shown, the roof portion of the metallic casing comprises an annular outer portion M^2 and a central portion N, and is dome-shaped to conform to the shape of the refractory body portion of the roof, and is spaced away from the latter to provide an intervening heat insulating space. The section M^2 may be formed of the same steel plate material as the cylindrical and bottom wall portions of the casing. The section N, however, is formed of a suitable non-inductive metal and extends over the electrode roof openings F and beyond the latter far enough to prevent significant inductive interaction between the electrodes and the casing section M^2.

The casing section N is formed with openings in register with the electrode roof openings F and supports a separate uprising tubular casing for each electrode. In the form shown, each such tubular electrode casing comprises superposed metallic sections O, P, and Q, and a stuffing box R at the upper end of the section Q in which the body portion of the corresponding electrode extension H is slidingly received. The electrode casing elements O, P and Q and the metallic portions of the stuffing box R are all formed of non-inductive metal. Each casing element O may be welded at its lower end to the roof section N at the margin of the corresponding electrode passage in said section.

Each member O has an outturned flange O' at its upper end to which the outturned bottom flange portion P' of the casing section P is bolted or otherwise secured. An annular gasket S of suitable insulating material is clamped between the flanges O' and P' and thus serve to insulate the furnace casing M including the tubular parts O, from the electrodes G which are not insulated from the upper portions of the electrode casings.

The major portion of the length of each electrode casing is formed by the corresponding tubular casing part Q which has an outturned flange Q' at its lower end bolted or otherwise detachably connected to the outturned flange P^2 at the upper end of the member P. By disconnecting the parts P and Q and raising the latter, the corresponding electrode is made accessible for the addition of a new carbon section, without disturbing the insulated connector between the electrode casing part Q and P. To permit electrode sections to be added by the procedure hereinafter described, each electrode casing section P, which can be of relatively small vertical extent, is shown as comprising a portion P^3 adjacent its lower end having a diameter only slightly larger than the electrode diameter. Above the portion P^3 the internal diameter of the member P is enlarged to provide an annular packing and wedge receiving space P^4 surrounding the electrode. As shown, the upper end portion of the member P is shaped to provide tapering seats for wedge members T extending into the space P^4 through the upper end of the latter in the condition of the apparatus shown in Fig. 4. The wedges T when in place grip the portion of the electrode passing through the member P so as to support and hold the electrode against movement during the operation incidental to the addition of an electrode section to the upper end of the corresponding furnace electrode.

With the structure described, the procedure advantageously followed in adding an electrode section to the upper end of an electrode which has become short enough to make the addition necessary or desirable comprises the following steps; namely,

(1) The loosening of the clamping bolts or other means normally connecting the casing sections P and Q.

(2) The elevation of the casing element Q relative to the subjacent section P and the corresponding electrode G.

(3) The insertion of wedges T into the open upper end of the space P^4 to lock the electrode in place in the member P, coupled with the steps, if any, needed to prevent or suitably minimize gas flow through the joint space between the portion P^3 of the member P and the electrode.

(4) The rotation of the electrode extension H to screw its threaded lower end H' out of its socket G' of the upper end of the electrode section locked in the casing part P. The threading together of the electrode section locked in the part P and an additional carbon electrode section having a metallic electrode section H threaded into its upper end socket G'.

After the new electrode section is screwed into the electrode section locked in the corresponding casing part P, the wedges T are removed and the casing section Q is lowered into engagement with casing part P and secured to the latter. The apparatus may then be put back into regular service. As shown and as is necessary to permit the operation just described, the length of the casing section Q is somewhat greater than that of the individual electrode sections which ordinarily are of a predetermined standard length. During the operation of disconnecting the sections P and Q and raising the latter preparatory to the addition of a new section to the electrode, the latter must be sustained by the supporting element I, until the wedges T are put into locking engagement with the electrode, and the parts must be restored to the condition in which the electrode is supported by the element I before the wedges T are removed and after the new section has been added to the electrode. To prevent or minimize trouble due to leakage through the joint space between a member P and the corresponding electrode when said member is disconnected from the corresponding casing element Q as shown in Fig. 4, asbestos fiber or analogous packing material P^5 may be held in the tapered space immediatley above the restricted diameter portion P^3 or may be inserted in that space as soon as the corresponding casing element Q is removed.

In the contemplated use of the furnace for the production of magnesium in the manner mentioned above, a gas pressure in the furnace chamber of a few inches of water above the pressure of the atmosphere may be maintained in regular operation, though under certain conditions of use the furnace pressure may well be several pounds per square inch above atmospheric pressure. When the operation of the furnace is interrupted for the addition of an electrode section, the pressure in the furnace chamber is lowered appreciably, but may well be kept a quarter to a half inch of water above atmospheric pressure, so that any leakage through the electrode casing then opened up will be out-leakage and not in-leakage. The last mentioned pressure may be regulated by adjustment of the gas flow through the pipe X'. To maintain the proper furnace chamber pressure and atmosphere under such conditions, the furnace chamber may well be connected to a source of carbon monoxide under a pressure suitably in excess of atmospheric pressure.

A carbon electrode is quite porous and some air will be initially held in the void space in the newly added electrode section. Ordinarily, however, I believe it will not be necessary to create a vacuum in the furnace chamber following the addition of an electrode section to one of the furnace electrodes, so as to eliminate air, as is desirable in initially starting the furnace into operation. Preparatory to resealing the joint between the casing sections P and Q which have been separated for the addition of an electrode section, the air then held in the free space within the element may well be purged of air, as by passing carbon monoxide into the upper end of said free space through the inlet X with which the casing section Q is provided for the purpose. Carbon monoxide or other similar gas may also be supplied continuously or intermittently to the space between the roof of the metallic casing and the refractory furnace wall roof portion through an inlet X'. The continuous supply of carbon monoxide to the furnace chamber through inlets X or X' opening into the electrode casings or into the space at the inner side of the metallic furnace casing adjacent the electrode casings has the advantage of preventing magnesium vapor from entering spaces in which it will condense. This is particularly important in respect to the space between the metallic casing and refractory roof of the furnace chamber which is made of carbon, an electrical conductor.

The various furnace wall openings B, C, D and E may advantageously be lined with tubular bodies U of graphite which have their outer ends surrounded by flange tubular portions M^{10} of the metallic casing M which are adapted for pipe connections. The portions M^{10} and the casing parts O and P and the upper portion of the cylindrical body portion of the casing M are shown as provided with water cooling pipes V. The latter are at the outer side of the casing so as to eliminate the risk of injury due to leakage of the cooling fluid if the cooling fluid passages were within instead of being without the furnace casing M. The coke used in the production of magnesium may well be in powdered, rather than in granular form, since, in general, the more intimate the mixture of the coke and magnesium, the better are the operating results obtainable.

My improved furnace is not restricted to the particular uses previously mentioned, but is well adapted for use in the production or processing of a wide variety of materials under pressure or vacuum conditions and because of its special gas-tight casing features the furnace is also well adapted for use under the condition in which a special gas atmosphere is maintained in the furnace chamber at a pressure substantially equal to that of the atmosphere.

While in accordance with the provisions of the statutes, I have illustrated and described the best forms of embodiment of my invention now known to me, it will be apparent to those skilled in the art that changes may be made in the form of the apparatus disclosed without departing from the spirit of my invention, as set forth in the appended claims and that in some cases certain features of my invention may be used to advantage without a corresponding use of other features.

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

1. An electric arc furnace comprising a refractory furnace wall enclosing a furnace chamber and formed with electrode openings, longitudinally movable electrodes extending through said openings and each comprising a plurality of end to end sections and a threaded connection between each adjacent pair of said sections, the outer end section of each electrode being in the form of a metal bar, a metallic casing enclosing said refractory wall and comprising a tubular casing portion for each electrode including a separable outer end section of a length greater than the electrode section length through the outer end of which the corresponding metal bar section extends, and means at the outer end of each such tubular casing section cooperating with the metallic bar section of the corresponding electrode to prevent leakage into or out of said tubular casing at said outer end.

2. An electric arc furnace comprising a refractory furnace wall enclosing a furnace chamber and formed with electrode openings, longitudinally movable electrodes extending through said openings and each comprising a plurality of end to end sections and a threaded connection between each adjacent pair of said sections, the outer end section of each electrode being in the form of a metal bar, a metallic casing enclosing said refractory wall and comprising a tubular casing portion for each electrode through the outer end of which the corresponding metal bar section extends, each such tubular casing portion comprising separable end to end sections and means associated with the inner of said casing sections for detachably securing therein an electrode section at the inner end of said metallic bar section, whereby when said casing sections are separated a new electrode section can be incorporated in the electrode between said bar section and an electrode section detachably secured in said inner casing section.

3. An electric arc furnace comprising a refractory furnace wall enclosing a furnace chamber and formed with electrode openings, longitudinally movable electrodes extending through said openings and each comprising a plurality of end to end sections and a threaded connection between each adjacent pair of said sections, the outer end section of each electrode being in the form of a metal bar, a metallic casing enclosing said refractory wall and comprising a tubular casing portion for each electrode through the outer end of which the corresponding metal bar section extends, each such tubular casing comprising separable end to end sections, means associated with the inner of said casing sections for detachably securing therein an electrode section adjacent said metallic bar section whereby when said casing sections are separated a new electrode section can be incorporated in the electrode between said bar section and an electrode section detachably secured in said inner casing section, and electric insulation between the inner and outer end portions of said inner casing section.

4. An electric arc furnace comprising a refractory furnace wall enclosing a furnace chamber and formed with electrode openings, longitudinally movable electrodes extending through said openings and each comprising a plurality of end to end sections and a threaded connection between each adjacent pair of said sections, a metallic casing enclosing said refractory wall and comprising a body portion and a tubular electrode casing portion for each electrode, each of said electrode casing portions comprising an inner section adjacent and connected to said body portion and an outer section normally in end to end relation with and detachably connected to said inner section, said inner casing section being shaped to receive electrode locking wedges acting between the inner wall of said section and the portion of an electrode extending through said inner section.

5. An electric arc furnace comprising a refractory furnace wall enclosing a furnace chamber and formed with electrode openings, longitudinally movable electrodes extending through said openings and each comprising a plurality of end to end sections of predetermined length and a threaded connection between each adjacent pair of said sections of a length greater than the electrode section length, and a metallic casing enclosing said refractory wall and comprising a body portion and a tubular electrode casing portion for each electrode, each of said electrode casing portions comprising a section adjacent and connected to said body portion and an outer section normally in end to end relation with and connected to said inner section, but separable therefrom to permit the addition of an electrode section to an electrode passing through said inner casing section.

6. An electric arc furnace comprising a refractory furnace wall enclosing a furnace chamber and formed with electrode openings, longitudinally movable electrodes extending through said openings and each comprising a plurality of end to end sections and a threaded connection between each adjacent pair of said sections, and a metallic casing enclosing said refractory wall and comprising a body portion and a tubular electrode casing portion for each electrode, each of said electrode casing portions comprising a section adjacent and connected to said body portion and an outer section normally in end to end relation with and connected to said inner section, but separable therefrom to permit the addition of an electrode section to an electrode passing through said inner casing section and each of said electrode casing portions having an inlet for the introduction of gas to displace air entering said outer casing section when separated from said inner section.

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