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ELECTRIC ARC FURNACES AND METHOD

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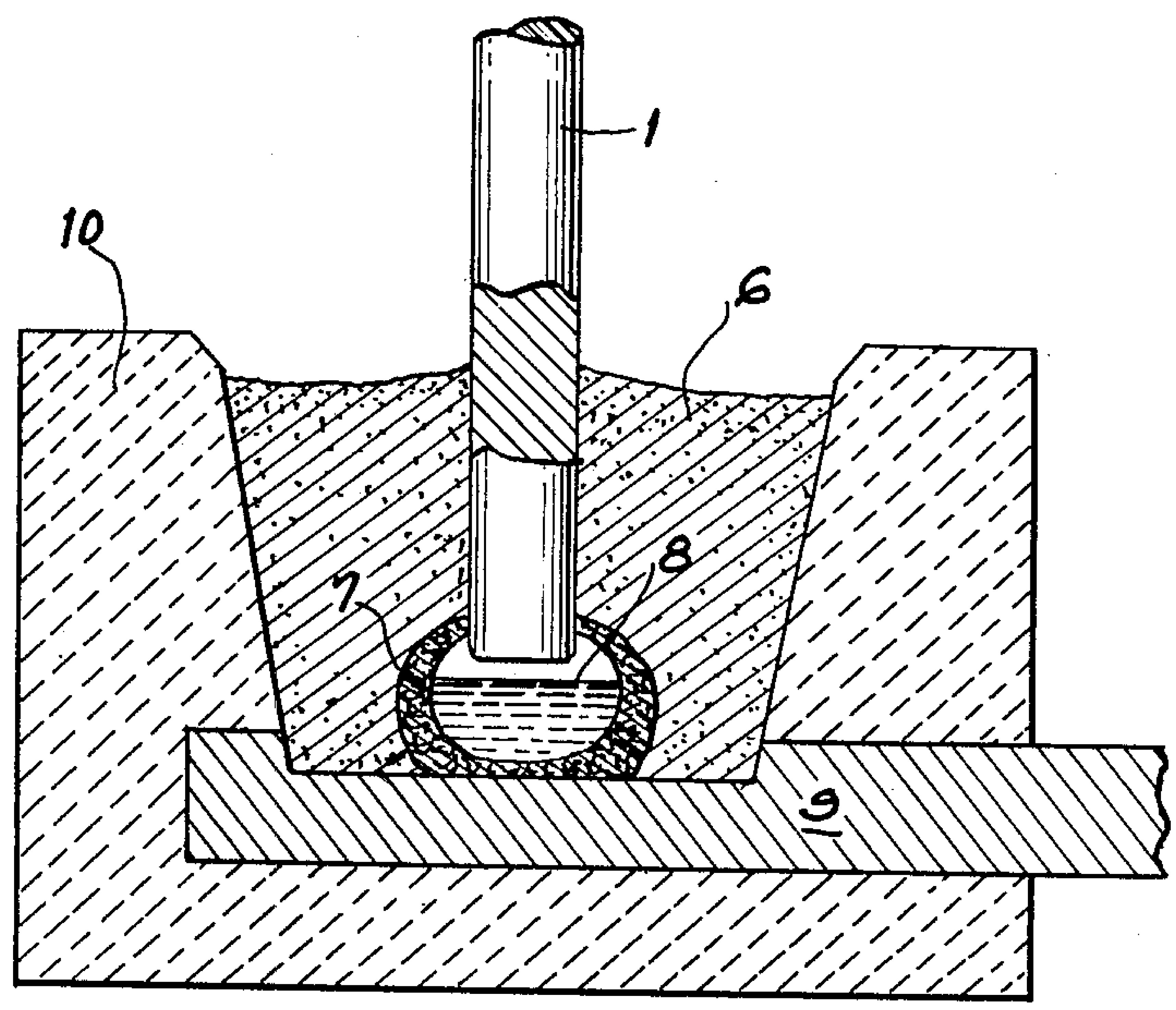

FIG. 1

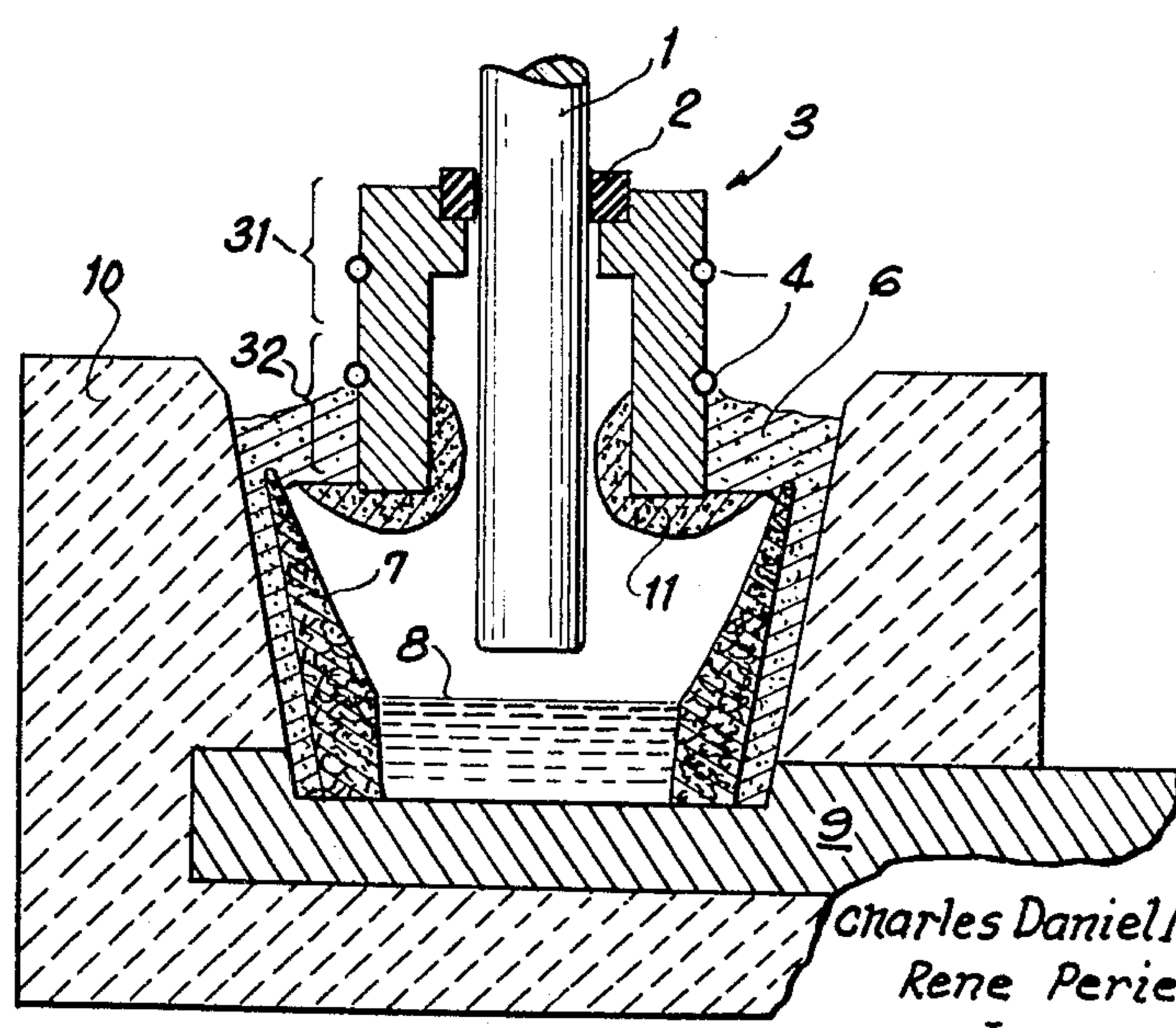

FIG. 2

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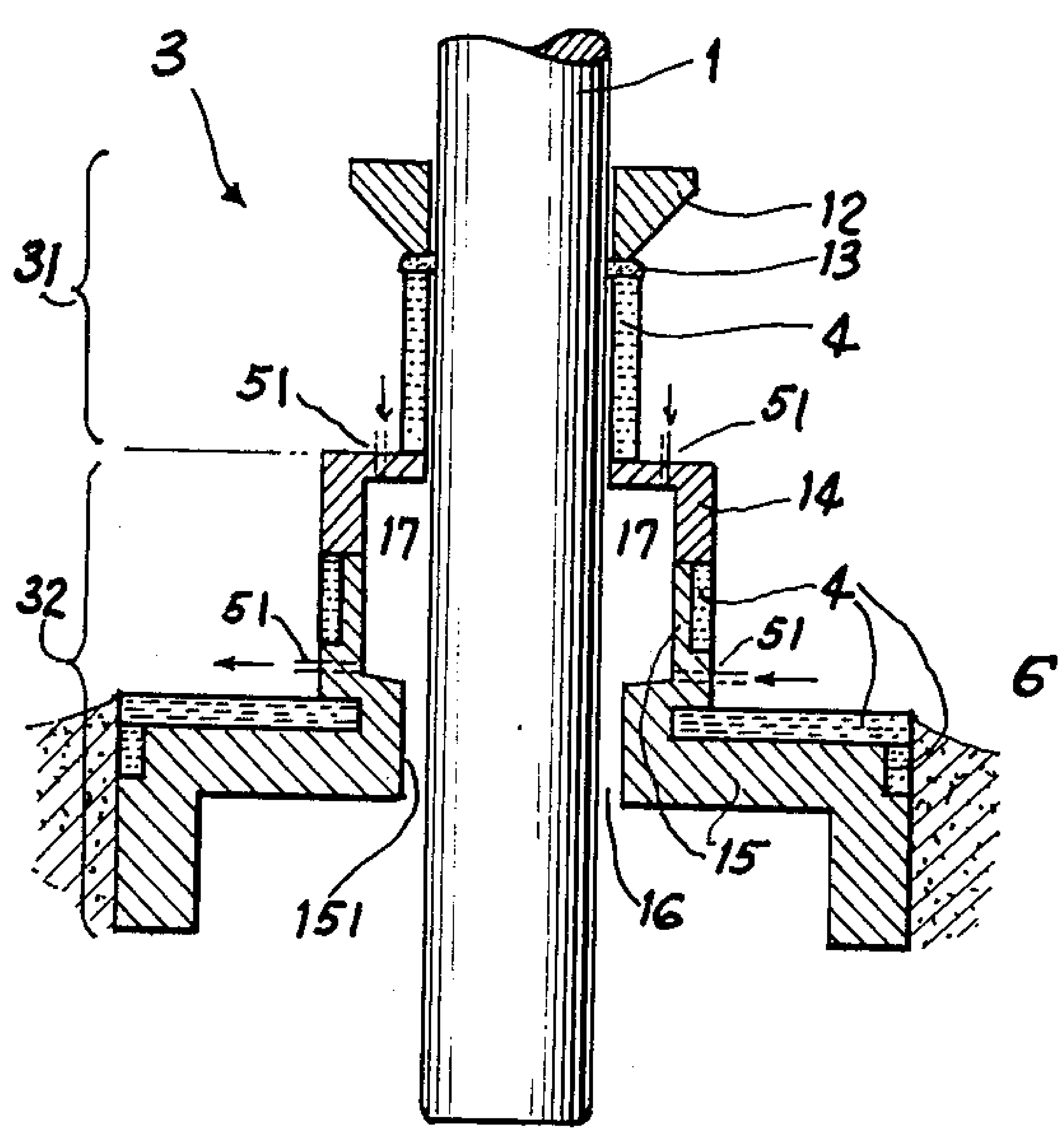

FIG. 3

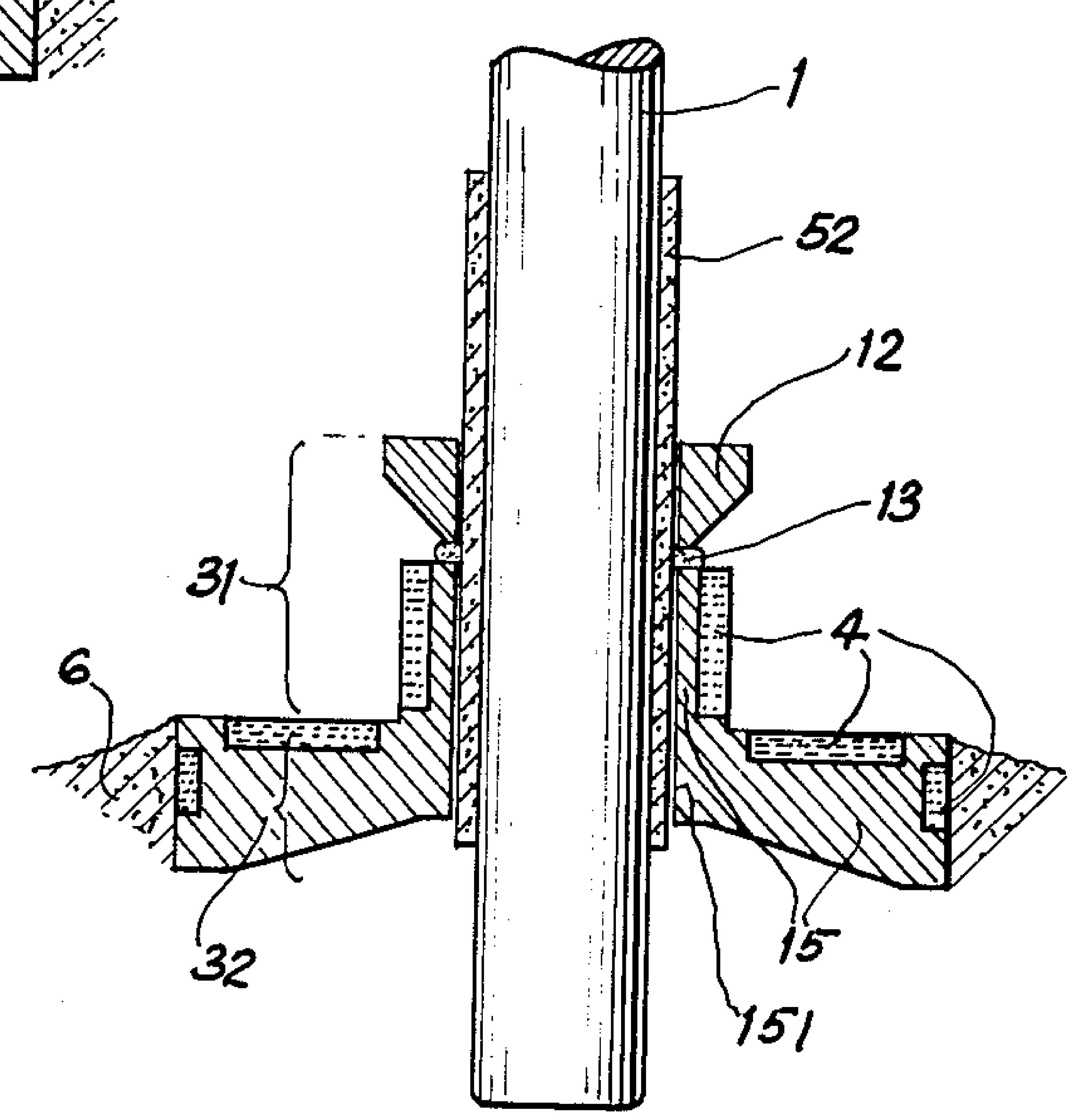

FIG. 4

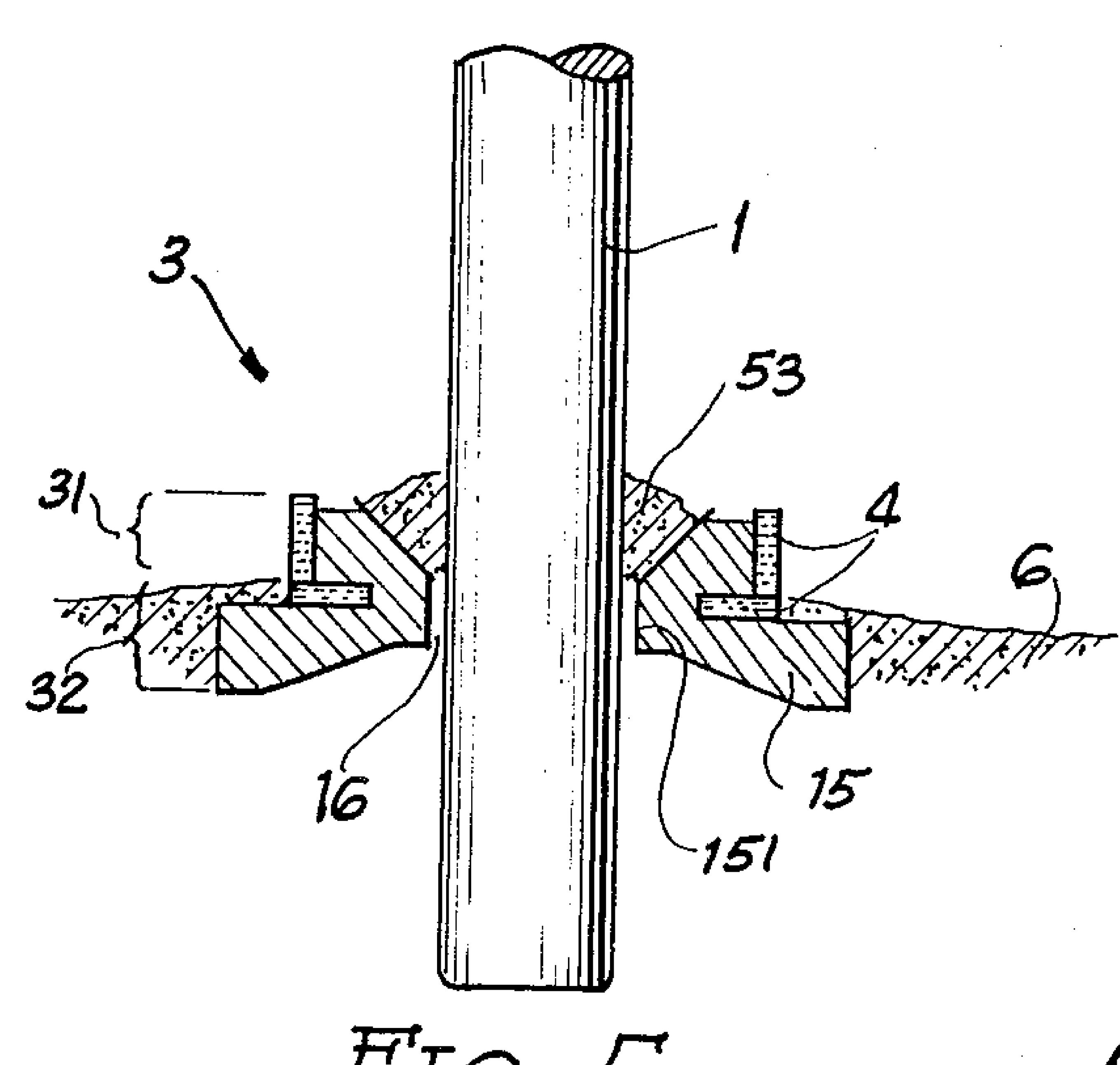

FIG. 5

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ELECTRIC ARC FURNACES AND METHOD

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9 Claims. (Cl. 13—9)

This invention relats to electric arc furnaces and more particularly to reduction furnaces, that is, furnaces for effecting the reduction of ores treated in the form of metallic oxides. It also relates to a process for the use of furnaces in the carbothermic reduction of the said oxidized ores.

Such furnaces are operated at the present time with an arc extending throughout the charge with the charge being introduced between one or more electrodes and the inner wall of the furnace.

This embodiment of the technique has been found to present several drawbacks which become more serious where the prevailing temperature in the earth furnace is much higher.

If any of the raw materials, the intermediate products, or finished products of the carbothermic reaction are volatilizable at the temperature conditions existing in the furnace reaction, such material can escape from the reactional medium. Condensation of the component volatilized can occur in whole or in part in and through the charge which covers the arc. Such condensation often can cause the formation of a compact aggregate such as to define a crust of portions of the charge which are nearest to the earth furnace. Under the weight of the charge, the formed crust often collapses, causing jolts in the descent of the charge as well as irregularities in the passage of the current, thereby materially to disturb the operation of the furnace.

Also, it frequently occurs that the volatilized component is not recovered by the charge with the result that loss of all or part of the particular component or components is experienced thereby to reduce the yield. Incidentally, these condensates are frequently found to be too good an electrical conductor. This is most noticeable when the furnaces operate on a bath presenting a high pressure of metallic vapor.

Frequently, the machine parts of the apparatus, provided to assure the electrical insulation and vapor tightness around the electrodes, become covered by such crusts or condensates. These may cause serious diversions of the electrical current from between the electrode and the liquid bath or hearth. These parts become heated to high temperatures which often lead to rapid deterioration.

Moreover, these diversions of current often cause serious disturbances in the electrical system of the furnace. The current more or less tends to pass directly by way of the crusts instead of between the electrode and the reaction mass in the fused state, with the result that the voltage of the arc diminishes as well as the power of the arc. The temperature of the reaction mass correspondingly decreases and the reaction may slow down or even stop and some times the arc is entirely extinguished. An attempt has been made to rectify some of the problems inherent in this technique by increasing the intensity, but this arrangement produces a density of current in the electrode which exceeds industrially practical considerations. Moreover, even if the re-establishment of the initial power becomes successful, sufficient temperature in the earth furnace cannot be maintained because the power is not sufficiently concentrated.

It is an object of this invention to produce an arc furnace of the type described which obviates many of the defects heretofore described.

It is a further object of this invention to produce an electric arc furnace which automatically and systematically provides for the return or the recycling towards the earth furnace of the products volatilized from the reactive mixture. Such recycling has a very favorable repercussion on the yield of the reaction realized by the use of the furnace.

Other objects are to provide a means for avoiding the diversions of the electrical current; means for permitting a high concentration of calorific power in the earth furnace, as well as a regular supply of raw materials and thereby to establish the stability of the length and of the voltage of the arc as well as its power.

By such means the reactional mass, at the time of fusion, is made stable and, more particularly, the reduction of the oxidized ore is caused to take place regularly, substantially uniformly and practically completely.

An electric furnace embodying the features of this invention has been found to be effective in resisting the destructive action of high temperatures even in those parts of the furnace which are more directly exposed to the arc, particularly even in the presence of condensations which might otherwise be good electrical conductors, thereby to provide a lasting watertightness and satisfactory electrical insulation.

Other objects and advantages of this invention will hereinafter appear and, for purposes of illustration, but not of limitation, embodiments of the invention are shown in the accompanying drawings, in which:

FIG. 1 is a schematic sectional elevational view through a cross-section of an arc furnace representative of conditions existing in previous practice;

FIG. 2 is a schematic sectional elevational view through a cross-section of an arc furnace embodying the features of this invention; and

FIGS. 3, 4 and 5 are vertical, sectional views in greater detail of elements of the furnace shown in FIG. 2.

The electric arc furnace, embodying the features of this invention, is equipped with a shaft and one or more electrodes and is modified to include an insulating device which comprises:

An upper, relatively cold and electrically insulating portion which is arranged in contact with and enveloping, so as to be practically gas-tight, the upper portion of the one or the several electrodes adjacent the higher level of the shaft;

A lower, relatively warm portion, fabricated of a refractory and heat conducting material, preferably graphite, and cooled, as by circulation of a fluid, preferably water; the lower portion is joined in a substantially vapor-tight manner with the upper portion but out of contact with any of the electrodes and arranged to define an annular space about the electrodes;

And means to maintain the annular space substantially free from electrically conductive crusts.

The elements described operate in a manner whereby the material constituting the charge and introduced into the furnace remain practically on the exterior of the device without contacting any one of the one or more electrodes. This permits the arc freely to pass between the electrodes and the stripped-bath, as represented by the portion of the bath not covered by the charge.

The lower portion of the device, which is exposed directly to the radiations and vapors issuing from the furnace, functions notably to protect, either in whole or in part, the upper portion of the device from these radiations and vapors.

In the figures, the same numerals will be used to define the same elements. The numeral 1 designates one or several electrodes which may be formed of a material such as graphite. The numeral 10 designates the walls of the furnace; 9 is the current conductive sole plate of the furnace; 6 represents the materials constituting the charge introduced into the furnace, and the numeral 8 represents the reaction mass or fused bath. Referring now more specifically to FIGS. 2–5, the numeral 3 represents the device embodying an important feature of this invention with the numeral 31 representing the upper, relatively cold portion of the device and 32 representing the lower, relatively warm portion, and 4 represents the cooling system such as tubing or a jacket through which a coolant fluid such as water is circulated. In FIGS. 1 and 2, the numeral 7 represents the current conducting crusts that are formed.

In FIG. 2, the numeral 11 represents a solid condensate of the vapors escaping from the reaction mass in the fused bath and which forms as a lining on the portion of the device indicated. The numeral 2 represents insulating elements separating the electrode 1 and the upper portion 31 of the device and which functions to provide a substantially vapor-tight seal therebetween while still providing relative sliding movement between the electrode and the device.

In FIG. 3, the numeral 12 represents a means for applying pressure onto an asbestos band to provide a vapor-tight seal. The device is formed of one part 14 of a refractory insulating material while the part 15 is of graphite. The numeral 16 represents an annular space around the electrode adjacent the lower portion of the device and 151 represents the inner wall of the part 15 which extends inwardly toward the electrode to define the annular space and to function as the bottom wall of a chamber 17 constituting a free space of larger dimension about the electrode. The parts 14 and 15 are provided with passages through which tubing 51 extends for the introduction of a cleaning gas into the chamber.

In FIG. 4, the numeral 52 represents a sheath of a refractory and insulating material formed into a compact mass surrounding the electrode 1.

In this modification, the annular space 16, defined in FIG. 3, is substantially completely occupied by a sheath 52. In FIG. 5, the numeral 53 represents a tight fitting, insulating and flowing mass.

The fundamental advantages achieved by the invention, by comparison with the previous methods, can be easily ascertained, especially by comparison of FIGS. 1 and 2. In FIG. 1, the charge 6 is shown as being in direct contact with the electrode 1 whereby a diversion of the current, which often occurs to the detriment of the arc and power, can occur between the electrode and the conducting sole plate of the furnace through the pathway of the electrically conductive crusts 7. The arc can pass between the electrode 1 and the reaction mass of the fused bath 8 but because of these diversions, the voltage is lowered beneath the value permitting the formation of the arc, as previously explained.

On the other hand, in the construction of FIG. 2, it will be seen that the charge 6 is not in direct contact with the electrode 1 but is separated therefrom by the exterior wall of the device 3 whereby in its natural angle of repose, the feed material does not intersect the electrode thereby to prevent conductive contact between the conducting crusts 7 and the electrode. As a result, the crusts 7 are unable to function in a manner to divert the electrical current and practically the entire intensity is then concentrated in the arc which is able to pass directly between the lower tip of the electrode and the sole plate of the furnace 9 or the reactional mass in the fused bath 8. There is no important decrease of the voltage by reason of the suppression of the diversions of the current.

Through the cooling effect produced by the circulation of fluid through the conduit 4, any condensate will collect eventually to cover the lower portion 32 of the device 3. This is an area otherwise exposed to intense radiations due to the proximity of the arc. The condensate collects as a lining 11 on the device thereby to protect the device against such radiations.

Vapor-tightness can also more or less be enhanced by the condensate 11 since the lining formed by the condensate can increase in thickness until it closely approaches the wall of the electrode; however, it cannot come into direct contact with the electrode since such portions as are near the electrode are consumed by the small local arcs which pass therebetween.

The device 3 also operates in the manner of a reflex condenser for the volatilized products otherwise escaping from the molten reactive mixture 8.

The device 3 embodying important features of this invention further embodies a number of other desirable characteristics which will hereinafter be described.

(1) The device 3 is not integrally joined with the electrodes so that the electrodes can be moved freely within the device along or about the electrode access.

(2) Means are provided maintain the annular space 16 substantially free of conductive crusts comprising a system for projecting continuous or intermittent blasts, into said space, of a cleaning gas through the inlets 51 which are generally placed in the lower portion 32 of the device 3, as shown in FIG. 3. The cleaning gas is preferably selected of a non-oxidizing gas such as nitrogen, hydrogen, carbon monoxide and the like, which may or may not also contain a small proportion of normally oxidizing gases and/or vapors, such as steam.

The inclination of the gas inlets is selected in such a manner, preferably located above the level of the annular space 16, that the injected gas operates substantially to keep the vapors escaping from the bath 8 of the furnace from passing through said annular space. It operates thus to sweep away the main part of the conductive crusts which might have formed deposists on the walls defining the annular space.

(3) The annular space 16 is provided in its upper portion with a wider section or chamber 17 which envelops the electrode. An impervious and insulating contact between the lower portion and the upper portion of the device is provided by the walls of the chamber. To prevent too much of the cleaning gases from penetrating into the furnace, an exhaust channel for part of these gases may be provided in the walls of the chamber 17.

(4) The device 3, and more particularly chamber 17, may employ an insulated lateral wall which is cooled by a water joint enveloping each electrode. Said water joint comprises a circular drain, integral with the lower part 32 of the device 3 and containing circulating water. A cylindrical wall, integral with the upper part 31 of the device 3, is diving into said circular drain; thus a vapor-tight joint is formed, said joint separating the atmosphere of the chamber from the external atmosphere. The water passing through the unit preferably directly communicates with the atmosphere of the chamber so that the circulating water draws away the condensable products provided by that portion of the atmosphere so that the water joint remains practically clean.

(5) The means to keep wall 151, defining the annular space, practically free of conductive crusts comprises, as shown in FIG. 4, a refractory insulating sheath 52 in the form of a compact mass which may be formulated of an aluminate cement, for example, and which is adapted to envelop each electrode like a sleeve, and which may or may not be formed integrally therewith. The sheath operates to sweep away conductive crusts which might be deposited on the wall 151 during axial movement of the sheath with the electrode. The sheath melts as it reaches a level below that of the lower part of the device, that is, near the warmest area of the furnace.

(6) Means are also provided to keep the annular space 16 substantially free of conductive crusts as shown in FIG. 5. Such means comprises an impervious, insulating

and relatively flowing mass 53 preferably formulated of the same oxide as that which is included in the composition charged to the furnace. This impervious, insulating and relatively flowing mass can include a binder, such as water, and eventually, in addition, an insulating binder. For example, the mass can be formed of the oxide of aluminum bonded with water and eventually also bonded with sodium aluminate.

(7) The means for freeing the annular space comprises mechanical arrangements, such as a scraping tool.

It should be pointed out that the foregoing means described for freeing the annular space of crusts can advantageously be operated without disassembly of the chamber **17** of the furnace and which can be cleaned without stopping the flow of electrical current in the furnace.

(8) The device **3** is preferably shaped in the form of a skirt, as illustrated in FIGS. 2 and 3. The position of device **3** can be adjusted with reference to its depth in the shaft of the furnace.

As used herein, the term "relatively cold portion" means a portion of the device, the surface temperature of which is below or equal to about 600° C. in the area which contacts the electrode. The term "relatively hot portion" means a portion of the device, the surface temperature of which is equal to or above about 600° C. in the area which is closest to the electrode.

The present process also includes the operation of an electric furnace of the type described above in which the voltage of the electric current is kept high enough for the current to pass substantially and exclusively through the arc as distinguished from passage through the arc and through the charge. In accordance with the process of this invention, the charge is gradually introduced into the furnace and maintained at a level slightly above that of the lower level of the device so that the charge will not practically contact the electrode or the electrodes and so that the arc can pass freely between the electrode and the stripped bath.

The invention also embodies any application of the electric arc furnace or the process as applied to the carbothermic reduction of oxidized ores adapted to be carried out at high temperatures and at which the vapor tension of the metal or one of its oxides is high and also to the reduction process of aluminum oxide by carbon to obtain pure aluminum, as described in applicants' Patent No. 2,974,032, issued March 7, 1961.

It will be understood that changes may be made in the details of construction, arrangement and operation without departing from the spirit of the invention, especially as defined in the following claims.

We claim:

1. An electric arc furnace having an elongate electrode extending downwardly into the furnace and a feed inlet spaced from the electrode for the introduction of solid particulate feed material into the furnace, a stationary housing located about the electrode such that, in the natural angle of repose, the charge does not intersect the electrode, said housing having an upper portion and a lower portion and in which said portions are spaced from the electrode to define an annular space therebetween, means interconnecting the upper portion of the housing with the electrode for sliding engagement with the electrode to enable relative lengthwise movement of the electrode relative to the housing, said means electrically insulating the housing from the electrode and providing a sealing relationship therebetween, cooling means for extracting heat from the housing, and injection ports in the housing in communication with the annular space between the electrode and the housing for the introduction of blasts of gaseous material into said space for cleaning same.

2. An electric arc furnace as claimed in claim 1 in which the blasts of gaseous material are intermittent.

3. An electric arc furnace as claimed in claim 1 in which the blast of gaseous material is continuous.

4. An electric arc furnace as claimed in claim 1 in which the lower portion of the housing has a portion which is spaced a lesser distance from the electrode than the upper portion to define an annular space about the electrode of larger cross-section in the upper portion than in the lower portion.

5. An electric arc furnace as claimed in claim 1 in which the housing has a lower portion having a section extending outwardly beyond the electrode by an amount greater than the upper portion.

6. In the operation of an electric arc furnace having an electrode which extends downwardly into the furnace and means for feeding the furnace from an area spaced from the electrode and including the steps of feeding particulate feed material into the furnace and lowering the electrode into the furnace during operation to maintain an arc, the improvement comprising protecting the portion of the electrode extending downwardly into the furnace thereby to prevent crust formation about the electrode to short circuit the arc by enclosing portions of the electrode within a housing positioned about the electrode such that, in its natural angle of repose, the feed material will not intersect the electrode but in which the housing is in closely spaced relationship with the electrode to define an opening in between, cooling the housing, introducing gaseous blasts through the housing into the space therebetween to clean the space from accumulated dusts and condensates, and sealing the upper end portion of the housing with the electrode.

7. The method of operation of an electric arc furnace as claimed in claim 6 which includes the step of allowing condensates to form on the lower portion of the housing partially to seal the space between the lower portion of the housing and the electrode.

8. The method of operation of an electric arc furnace as claimed in claim 6 in which the gaseous blasts are introduced intermittently.

9. The method of operation of an electric arc furnace as claimed in claim 6 in which the gaseous blasts are introduced continuously.

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