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ELECTRIC RESISTANCE FURNACE

1,979,052

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FIG. 2

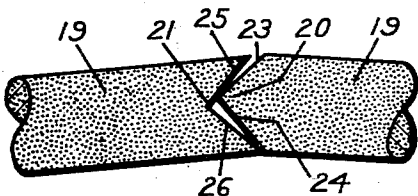
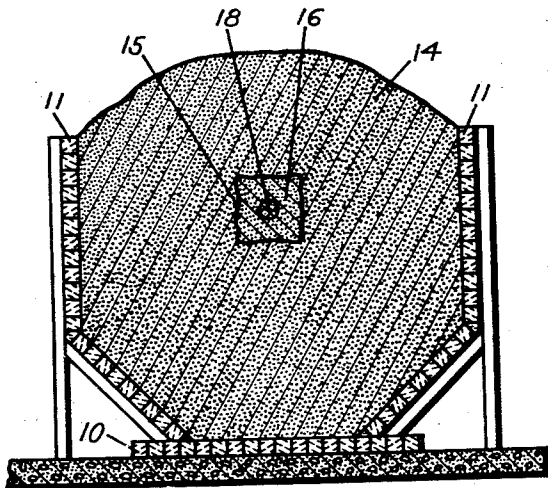


FIG. 3

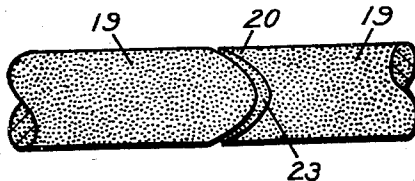


FIG. 4

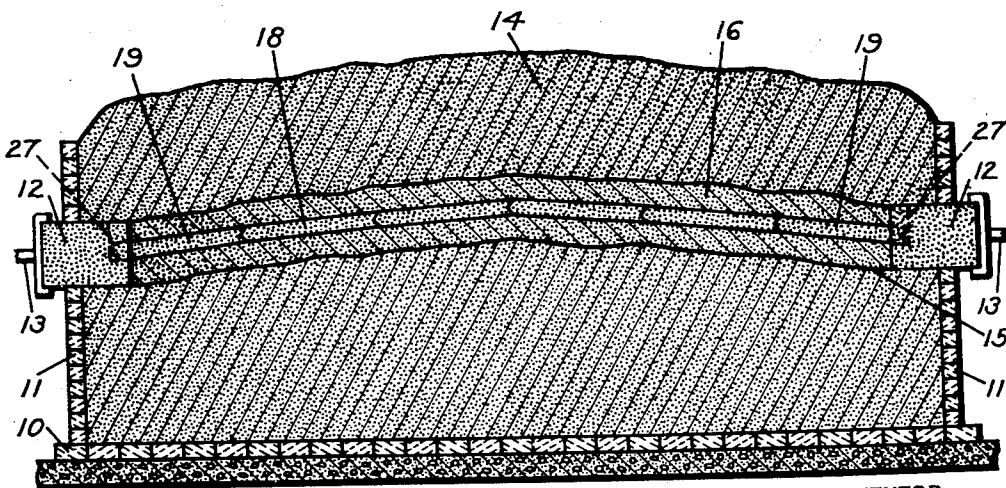


FIG. 1

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ELECTRIC RESISTANCE FURNACE

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8 Claims. (Cl. 13-20)

This invention relates to electric resistance furnaces, such as those which are designed for synthetically making abrasive metal carbides, such as silicon and boron carbides and similar materials.

In order that the invention may be understood, it will be specifically described with reference to the manufacture of silicon carbide. Heretofore, the customary method of making silicon carbide consisted in heating a charge, such as a mixture of coke, sand and sawdust, to a high temperature in an electric resistance furnace by passing an electric current of a required power input through a central resistance conductor of granular carbon, such as metallurgical coke embedded within and extending longitudinally through the charge to form an electrical conducting path or core from one electrode to the other to obtain the heat of reaction. Since the specific conductivity of the core material is low it is necessary to employ a core of considerable diameter to carry the requisite current. As the heating of the charge proceeds, some of the core is consumed by the reaction and the remainder becomes graphitized and is more or less intermixed with the portions of silicon carbide adjacent thereto when the furnace run has been completed.

The prior practice has involved various disadvantages, due largely to the use of this large core of granular carbon. One problem is found in the difficulty involved in separating the layers of high and low grade silicon carbide which are formed in the respective temperature zones adjacent to the core and from the outer covering layer comprising the unconverted charge, as well as from the graphitized coke which remains in the core. Moreover, this core has occupied the central hottest portion of the furnace and so wastes valuable space, leaving a large void within the mass of crystallized silicon carbide. It is furthermore found that the electrical resistance per unit length of the granular core of coke is irregular along the longitudinal axis of this core, particularly because its cross section of path, its density of packing and the pressure of contact between the various particles of the core are not uniform. Hence, when such procedure is employed, there are necessarily points of high and low resistance and consequently considerable localized overheating. Also, at these highly heated spots, silicon carbide tends to form more rapidly, since the rate of reaction within the mixture takes place in proportion to the amount of power concentrated in a given area.

In this highly heated localized zone, the core will be cut down in size and the charge in its immediate neighborhood may then mechanically settle and shift in position and so produce a pig of very uneven shape and distribution, with the consequent difficulties involved in separating the various layers of the converted and unconverted portions of the charge.

It is, therefore, a primary object of this invention to overcome such difficulties and to provide an electric resistance furnace construction which will be highly efficient and commercially economical in operation for the manufacture of various materials, such as silicon carbide, boron carbide, and other similar materials, and particularly to provide a resistor for such furnaces which is so constructed and assembled in the furnace that the operation of the furnace is materially improved and the cost thereof is lessened.

With this and other objects in view, as will be apparent in the following disclosure, my invention resides in the combination of parts and the construction herein described and set forth in the claims appended hereto.

Referring to the drawing:

Fig. 1 is a longitudinal section through a furnace and its charge before the run;

Fig. 2 is a cross sectional view of the furnace and its charge before the run;

Fig. 3 is an enlarged fragmentary view, in elevation, of the preferred form of the arched resistor rod joint; and

Fig. 4 is an enlarged fragmentary plan view of the preferred form of the arched resistor rod joint.

In accordance with the invention, as set forth in my copending application Serial No. 578,547, filed December 2, 1931, relating to a method of making abrasive metal carbides, I have found that silicon carbide is a satisfactory conductor of electricity when heated at the high temperature required during its manufacture and that it can be employed as the resistor element in an electric furnace for carrying the heavy electric current necessary to form the charge therein. However, silicon carbide has a high negative temperature coefficient of resistance and so has a poor conductivity in the cold state, although it is an excellent conductor when heated. Hence, the employment of a mass of silicon carbide alone as the resistor, although feasible, is found to require a high voltage to start the charge and it necessarily involves the further use of a suitable furnace transformer of a wide and variable

voltage range to impress sufficient voltage on the metal carbide core to cause current to flow through the cold material. As the material becomes heated and as the ingot of metal carbide builds up, the furnace resistance decreases. The transformer is accordingly regulated to maintain the desired power input.

It is, however, desirable to keep the voltage range of the furnace operation within practical limits, hence, in accordance with a further feature of my invention, it is my preferred practice to utilize with the metal carbide core a highly conductive resistor, such as carbon, and preferably one of small cross section extending along the longitudinal axis of the furnace between the opposed terminal electrodes and thereby to quickly heat the carbide core therearound to a temperature at which it will readily carry the entire current load under a low voltage and continue the furnace operation.

In the furnace construction described in the above entitled application, a two inch carbon resistor rod approximately 20 feet long is utilized, the rod being disposed in the center of the furnace and extending longitudinally thereof between the terminal electrodes for initially carrying the current load and having sufficient conductivity and the correct resistance to develop a temperature satisfactory for starting the reaction. Such a rod has a high ratio of length to cross sectional area which is preferably in excess of 100 to 1, but the dimensions will necessarily be calculated in accordance with the energy requirements of the furnace. A rod of such extreme dimensions is necessarily fragile and both difficult to manufacture and liable to be broken prior to use in the furnace. Moreover, the weight of the charge on this rod in the furnace and the fact that the furnace charge settles and sags during the heating causes the rod to break fairly soon during the early stages of the furnace operation and thus interferes with the conductance of the current through the furnace during the initial heating period before the silicon carbide about the rod is sufficiently hot to conduct the current itself.

A further feature of this invention involves making an electric resistance furnace in which the resistance conductor comprising a rod of carbon, such as graphite, or other suitable electrically conductive material and located in the central high temperature zone of the charge, is built up of a series of short sections comprising a plurality of resistor rod units capable of withstanding temperatures above 1200° C. and assembled and arranged in the furnace so as to form a continuous conducting path for the current, and particularly one in which the resistor length is longer than its diameter by a ratio of more than 100 to 1. In the preferred construction, the resistor pieces or rods are so shaped at their ends that they will keep in contact as the furnace charge settles during the initial stages of the furnace operation before the resistor has been consumed and yet be independently and freely movable as required by conditions in the furnace.

In carrying out this feature the end rods are supported on or against the furnace terminals, and the assembled rods are arranged in contact end to end to form a span therebetween, and they are so shaped at their ends as to keep in contact as they change in their positions. It is preferred that these separately movable sections be so arranged that they form an arch which is

supported at the lower ends on the terminal blocks so that as the sections settle downwardly during the initial furnace operation, the arched portions maintain proper mechanical and electrical contact. The rod sections are preferably so shaped as to form interfitting parts, such as tongue and groove joints, which are so arranged that they may wedgingly abut against each other, the individual rod units resting wedgingly on each other and being held in arched alignment throughout the span and wedgingly abutting the furnace electrode terminals at their lower ends. When such units are placed in this position in the furnace, they are mutually supported and held together by the weight of the charge on the core and the influence of gravity during the settling and mechanical shifting of the furnace charge which aid in keeping the sections in firm and close electrical conducting contact. Also, by the arched arrangement, in which the rod resistors are held in alignment between the electrodes by the forces of compression, the tendency under this influence also serves to increase the conductivity of the assembled structure.

My preferred construction for accomplishing this purpose involves providing the ends of the resistor core units with tongue and recessed connections which interfit so loosely as to form joints which are flexible enough to permit the core to accommodate itself to change in shape and dimensions of the furnace charge due to expansion and contraction. The core parts may be arched so that the charge may sag as required without producing any untoward strain on the resistor and so permit the joints to remain always in proper conducting contact.

This invention further contemplates the provision of a loose granular resistor core of previously converted abrasive metal carbide which closely surrounds the resistor rod and is capable of developing into an auxiliary electrical resistor when heated to a sufficient temperature to form a highly conductive path for the current, so that the combination of the resistor rod and the outer granular core develops into an autogenous or self-forming resistor during the initial heating of the furnace charge, and serves as a protector for the carbon rod resistor against oxidation by reaction with the charge to be converted. It also acts as a protector against localized high power liberation, since it is in contact with, and parallel to the rod throughout its length. Any localized high resistance which develops in the rod due to defects of assembly, manufacture or disturbance of the charge is automatically compensated for. As the carbon rod volatilizes or gradually disintegrates during the furnace operation, a higher temperature is generated at points of fracture in the rod or at the joints between the sections of the resistor rod and so locally heats the surrounding granular material of the outer core containing a sufficient amount of previously converted material, such as silicon carbide, and thus renders this material more electrically conductive so that it will ultimately serve as a parallel conductor taking part of the load and serving to provide for continuity of power through the charge until the furnace run is completed. In this way, the combination of the carbon resistor and the core of material which becomes conductive when heated also forms a self-healing resistor, in that when the rod or a joint in the rod becomes overheated due to the higher resistance of the air gap, the silicon carbide of the core adjacent to the gap in turn becomes

heated and so becomes conductive. Hence, the silicon carbide core, when heated, will form an electrical circuit in parallel with the carbon resistor rod and so maintain the current load in spite of any localized increased resistance in the rod tending to reduce the current flow, and carry all of the current when the rod ultimately fails and maintain the temperature required to convert the charge to silicon carbide. In the case of the manufacture of boron carbide, the core may be formed of the incompletely crystallized boron carbide obtained from a previous furnace run but which is made up of a large percentage of the crystalline material capable of conducting the current when raised to a sufficiently high temperature and the reaction will go on successfully. In other words, the boron carbide granules are capable of conducting current at a low temperature but when heated fuse or coalesce into a substantially solid body which is a much better conductor.

Referring now to the drawing, I have there illustrated diagrammatically a furnace suitable for the manufacture of silicon carbide, comprising the base 10 and the walls 11 made of suitable material, including an iron frame work and refractory bricks, so that the structure constitutes a receptacle for the charge, as is customary in the art. A pair of terminal electrodes 12 made of graphite is suitably located in the opposite end walls of the furnace chamber, and they are suitably connected with conductors 13 for the application of an electric current thereto from a power supply. The charge of material to be treated or converted, which may comprise a mixture 14 of sand, coke, sodium chloride and sawdust, in accordance with the prior practice, or any desired mixture of material suitable for the purpose and proportioned for the synthesis of silicon carbide, is initially placed within the walls of the furnace to fill it about half full, and preferably to a point at which it can be distributed about the terminal electrodes 12. A trench 15 is formed in this charge, within which a further charge 16 of silicon carbide or other desired conducting material is placed to form a supplemental electrically conducting core about the carbon rod. Prior to completely filling the trench 15 with the material 16, the sectional carbon core 18 is placed in position between the graphite electrode terminals 12, as indicated in Fig. 1, and preferably in an upwardly bowed or arched relation as there shown, so as to form a continuous electrical conducting path between the two terminals. The remainder of the supplemental charge 16 of electrically conducting silicon carbide or other suitable material is then placed over the sectional core 18 to embed the carbon resistor and fill the trench. This core of silicon carbide is distributed symmetrically and packed together to give a high density so that it will conduct current readily upon being heated. Thereafter, the trench is covered with the remaining materials of the unconverted charge the same as that below the rod to fill the furnace, as is customary in this method of making silicon carbide.

In accordance with this invention, the electric resistor core 18 is composed of a plurality of resistor units 19, which may comprise carbon or graphite rods, as shown in Fig. 3, which may be made without specification as to warpage and are so shaped that they may be individually joined together in an interlocking but separable fashion. To this end, the alternate ends of the individual rods are cut with interfitting parts, such as ex-

terior and interior acute angle sections, so that the pieces may be readily joined and fitted together with a wedging action in the furnace and may stay in conducting contact during the seating of the charge. As illustrated, the abutting ends of the individual resistor rods 19 are respectively provided with a tongue 20 on one end and a recessed portion 21 on the other, whereby the adjacent ends of the contiguous rods may interfit with one another when the elements are assembled together to form an arch in the manner illustrated in Fig. 1. Thus, the tongue 20 on one rod may be pointed or cone-shaped in form wherein it may be accommodated in a V-shaped groove or a recess of corresponding shape in the other rod. In other words, the respective ends of each rod are so made that each is substantially the complement of the other. In the preferred form, as shown in Figs. 3 and 4 in exaggerated form, the tongue 20 is formed by slicing or beveling the end of a cylindrical graphite rod so as to form a tapered or wedge shaped end having its side faces 23 and 24 meeting in an edge at a suitable angle with each other, such as 90°. Likewise, the recess 21 is cut out in any suitable manner to provide inner faces 25 and 26 inclined and meeting at substantially the same angle as do the wedge-shaped faces 23 and 24. If desired, the recessed angle may be slightly greater than the angle of the tongue so as to provide for extra play in the joint. In either case, when the units are assembled, there will be a loose fit between the parts, permitting the assembly to be arranged in the form of an arch, in which the tongue 20 will make firm electrical contact with the recess 21 on the contiguous section. In practice, the rods are so assembled that the tongue edges of the respective rods, which are formed by the meeting of the side faces 23 and 24, will lie in horizontal planes so that as the assembly of the arched resistor units sags during the furnace operation, there will always be continuous electrical contact maintained at the resistor junctions and throughout a portion of contact of the pointed end with the surface of the recess.

One may make other types of joints within the scope of this invention, but it is desirable that there be sufficient play or looseness between the rod units to permit them to be assembled in the form of an arch, as shown in Fig. 1, and yet be maintained in good electrical contact so that it may carry the initial current load until the charge has been sufficiently heated for the secondary core of silicon carbide to become a permanent conductor for the charge.

The resistor units employed in the arch and made for a furnace for producing silicon carbide may be made from carbon or graphite rods two inches in diameter and from two to four feet in length arranged end to end to form a span extending between the terminal electrodes. As shown in Fig. 1, the end rods of the span may be supported by suitable sockets or channels 27 adapted to fit the rods and formed in the electrode terminals 12, whereby the conducting core 18, when assembled in the furnace, is mechanically held in its proper position arched between the terminal supports and electrically connected at its ends thereto. It will be apparent that these sections of rod resistors may be of such sizes and lengths that several pieces will complete a circuit between the electrodes. In a typical SiC furnace thus constructed, the assembly of rods, SiC core and charge showed an effective resistance

of 0.05 ohm cold at the start of the run. This value rose to a maximum of 0.10 ohm during the first 30 minutes of the run while the current was shifting from the small fragile rod to the autogenous SiC resistor as the rod was consumed. In a run operating to the most efficient length of time, the resistance fell to a minimum of 0.03 ohm at the end of the run. Thus, an ordinary furnace transformer with a voltage range no greater than four to one from highest to lowest voltage will serve to regulate the current flow through the resistor core 18 and the furnace charge. Since the carbon rod is small in cross section, it is greatly overpowered and soon consumed, but the supplemental silicon carbide core serves as a secondary conducting path for the current. However, the carbon rod of these dimensions will stand the temperature conditions and the excessive power input for a sufficient length of time and cause the core of silicon carbide to become heated enough to carry the current after the rod has been consumed or broken down. It has been found that a two inch starting resistor assembled in this manner and supported by the surrounding furnace charge can be operated at a current density of from 1000 to 5000 amperes per square inch of cross section and with sufficient length of life to cause the silicon carbide reaction to start within the furnace charge and to permit the inner core of silicon carbide to become sufficiently heated so that it will itself take up the duty of carrying the required amperage.

The limiting range of current is largely determined by the rate at which the resistor is reacted upon by the surrounding charge, but since the resistor rod is surrounded only by silicon carbide and is not in contact with silica or other oxidizing agents, its life is materially increased over that which would be had if it contacted directly with the charge of unconverted material. The silicon carbide also acts as a protector against localized high power liberation, since it is in contact with and parallel to the carbon rod throughout its entire length. Hence, it shares the current by forming a multiple circuit, and any localized high resistance which develops in the rod due to defects of assembly or manufacture or to disturbance of the charge is automatically compensated for. The localized overheating increases the conductivity of the surrounding silicon carbide and causes it to act as a parallel resistor and take more of the current load from the carbon resistor.

It will now be apparent that this silicon carbide core placed in the center of the furnace charge accomplishes various purposes. It serves as a conductor during the major portion of the furnace run and thus makes it unnecessary for one to employ the granular core of metallurgical coke or graphitized carbon heretofore provided which had to be carefully separated from the silicon carbide after the furnace run has been completed. This core of silicon carbide, whether or not contaminated with impurities, is located in the hottest zone and it may be recrystallized or even distilled into the surrounding reactive zone as the power input is regulated. This distillation results in an ingot of large crystals and of great density and uniformity. The greater density of the charge lying in the high temperature zone of the furnace gives a greater product density and consequently a greater yield with the same power expenditure.

By thus using what we may term a self-forming

resistor, namely, the silicon carbide present in the central zone around a carbon rod, various other advantages will be derived. As above stated, this silicon carbide keeps the unreduced silica in the outer charge from contacting with the carbon electrode and so prevents reaction therebetween. It furthermore serves to protect the carbon rod, to minimize and prevent oxidation of the material. Furthermore, this innermost core of silicon carbide serves to distribute electric current to a large area within the furnace and so absorbs the load thermally and electrically. There is no large cavity developed within the ingot, as has been the case in the prior practice, since the silicon carbide in the core has been previously shrunk to substantially its maximum density and this inner core material therefore remains practically solid. Also, as above explained, the silicon carbide or boron carbide, as the case may be, of the core adjacent to any breaks or joints in the resistor rod on becoming overheated, due to the localized increased resistance of the rod at the gap, serves to conduct the current and thus bridge the gap and thereby develop into a self-forming or self-healing resistor which on continued heating becomes more electrically conductive as to ultimately form a parallel conducting path for the current and maintain a continuity of power during the furnace run.

It will be understood that this invention applies to various other types of electric resistance furnaces besides that employed for the manufacture of silicon carbide. For example, it may be used in connection with the manufacture of boron carbide from a charge of boron oxide mixed with petroleum coke. This application for the manufacture of various other materials will be readily apparent to one skilled in the art. It is also within the scope of this invention to make the rod of various other materials besides carbon, such as a resistor made of silicon carbide granules which may be mixed with or without a binder and with or without electrically conducting materials, such as silicon metal or carbon particles. Various resistor rods of the type which are standard in the industry may be employed in this manner. The size of the resistor and the nature of its composition will, of course, depend upon the type of material being treated in the furnace in order to meet its electrical requirements.

The present construction embodying the jointed resistor in mutual arched relation is particularly desirable because it allows the rod units to be interchanged throughout the span of the arch; hence, the resistor units 19 may all comprise rod resistors of shorter commercial sizes of random lengths and warpage. Also, an advantage of this form of interlocking construction is that it serves to prevent displacement of the abutting ends. The arched arrangement of all of the resistor units enables mutual support as long as they are held in alignment. The construction further provides a contact junction between the sections of greater cross sectional area than that of a continuous rod, when the charge has become seated. It also has the advantage that the arrangement involves a certain amount of firmness and is one which is both simple and inexpensive to build.

In view of the above disclosure, various modifications of this invention will be apparent to one skilled in the art, and these are considered as embodied in the above invention and expressed in the claims appended hereto.

Having thus described the invention, what is

claimed as new and desired to secure by Letters Patent is:

1. An electric resistance furnace for making an abrasive metal carbide comprising a receptacle for the furnace charge to be heated, spaced electrode terminals therein, and a continuous electric resistor of electrically conductive material supported within and by the charge and extending between and connected at its ends to said terminals which is capable of developing a high temperature within the furnace charge, said resistor comprising a series of separable, independently movable resistance pieces loosely touching one another end to end and having inter-fitting tongues and grooves which are arranged to form an upwardly bowed but not self-supporting arch and serving to provide continuous conducting contact through the joints as the charge settles.

2. In an electric resistance furnace for making abrasive metal carbides having a receptacle for a charge to be heated and a pair of electrode terminals spaced widely apart therein provided with sockets, a resistor arranged between said terminals and comprising a span of a plurality of separately and freely movable resistance units having inter-fitting wedge shaped tongued and grooved ends, said units being supported by the charge and assembled with their edges in horizontal planes and arched in wedging contact with one another and with the terminal sockets so that the resistor units will be maintained in electrical contact as the charge settles.

3. An electric resistance furnace for making an abrasive metal carbide comprising a receptacle for the furnace charge, spaced electrode terminals therein, a resistance element composed of a series of freely movable, shaped pieces of highly conductive resistance material arranged to form a continuous conductor and disposed between said terminals for carrying the current load of the furnace only during the initial heating of the charge, and a core supported within and by the charge comprising said abrasive metal carbide in a loose, granular condition which surrounds and carries the resistance element and is present in an amount sufficient to become highly conductive when heated by the resistance material and form the main heating resistor and so carry the entire current load for the synthesis of the carbide from the furnace charge.

4. An electric furnace for making silicon carbide comprising a receptacle arranged to carry a charge containing silica and carbon, spaced electrode terminals, a resistor composed of solid electrically conductive resistance material disposed between and connecting said terminals which is capable of developing a high temperature within the furnace charge, and a core of loose, granular silicon carbide in contact with and surrounding the resistor, said resistor and said core which surrounds it being supported within and solely by the furnace charge.

5. An electric furnace for making silicon carbide comprising a receptacle for a charge containing silica and carbon proportioned for the synthetic formation of silicon carbide, spaced electrode terminals, a carbon resistor rod connecting said terminals which is capable of developing a high temperature within the furnace charge for initially heating the same, and a granular core of impure silicon carbide supported

by said charge and lying in contact with and surrounding said rod, said core being proportioned in an amount sufficient to become highly conductive and capable of carrying the current load of the furnace when heated by the said resistor rod and so become the principal resistor for forming said carbide from the charge.

6. In an electric resistance furnace for making an abrasive metal carbide from a granular charge of unconverted reagents, a receptacle for the charge, a carbon resistor embedded in the charge and having such a conductivity and dimensions that it will serve initially to heat the charge, and a loose, granular core which closely surrounds and carries the carbon resistor, said core being supported within and by the furnace charge and containing a sufficient amount of previously converted carbide so that it will serve during the initial heating of the charge to develop into a self-forming resistance conductor at points of localized high resistance in the carbon resistor and maintain a resultant high temperature for forming the carbide from the charge and so that it will protect the carbon resistor from reaction with the furnace charge and carry the current load of the furnace as the carbon resistor gradually disintegrates.

7. An electric resistance furnace of the type covered by claim 6 in which the resistor disposed between the electrode terminals comprises a series of separable, independently movable resistance pieces arranged in contact end to end to form a continuous conductor, the adjacent ends of the resistance pieces being provided with interfitting parts which are so shaped and fit so loosely as to provide joints which are flexible enough to permit the individual pieces to move freely, whereby the resistor may accommodate itself to changes in position during the settling of the charge in the furnace and yet maintain electrical conducting contact at the joints between the pieces during the initial stages of the furnace operation.

8. In an electric furnace for converting a granular charge of silica and carbon to silicon carbide, a receptacle for the charge, spaced electrode terminals, a carbon resistor embedded in the charge to be heated and disposed between the electrode terminals in the form of an arch, said resistor comprising a series of resistance rods which are arranged in contact end to end to form a continuous conductor, the adjacent ends of the contiguous rods being provided with interfitting tongues and grooves which are so arranged that the rod sections may be individually and freely movable as the charge settles in position in the furnace and yet maintain electrical contact between the resistor sections at the joints, and a core of loose, granular material supported within and by the charge which closely surrounds and carries the resistor, said core containing sufficient silicon carbide so that it will serve during the initial heating of the charge to conduct the current at the joints between the rod sections or other points of localized high temperature and form an electrical circuit in parallel with the resistor rod and so maintain the current load in spite of any localized increased resistance in the rod tending to reduce the current flow, and carry all of the current when the rod ultimately fails and maintain the temperature required to convert the charge to silicon carbide.

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