

March 11, 1930.

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TUNNEL KILN AND METHOD OF OPERATING THE SAME

Filed June 10, 1925

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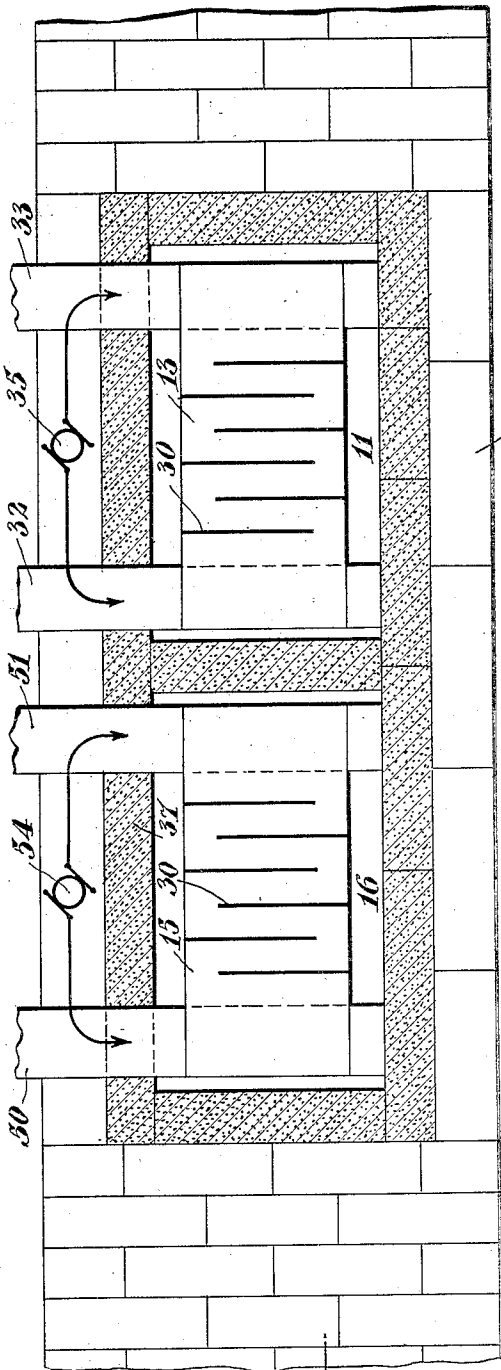


Fig. 2.

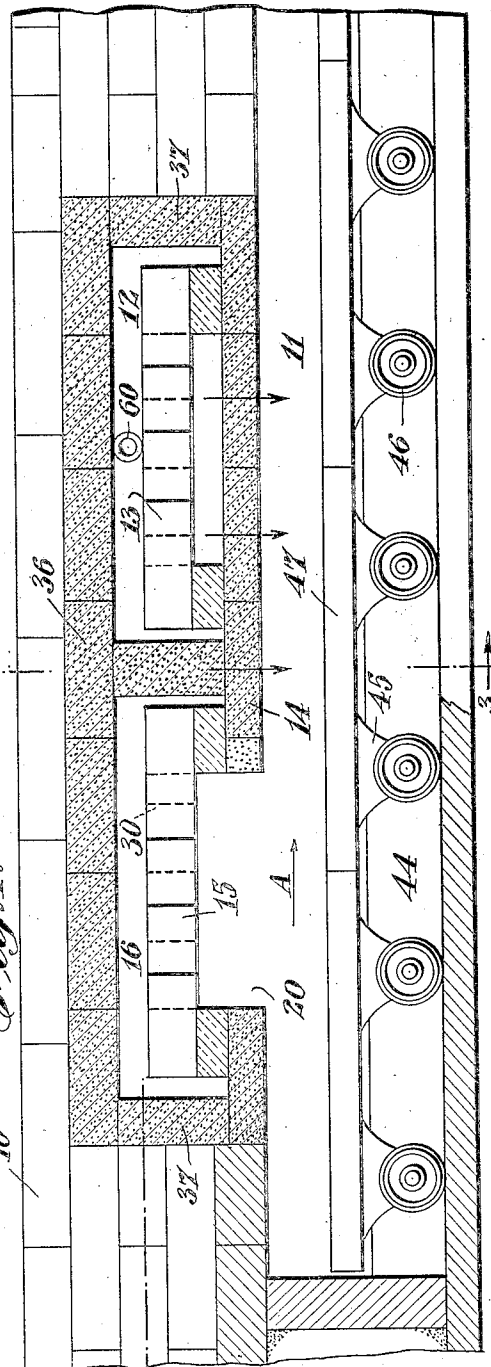


Fig. 1.

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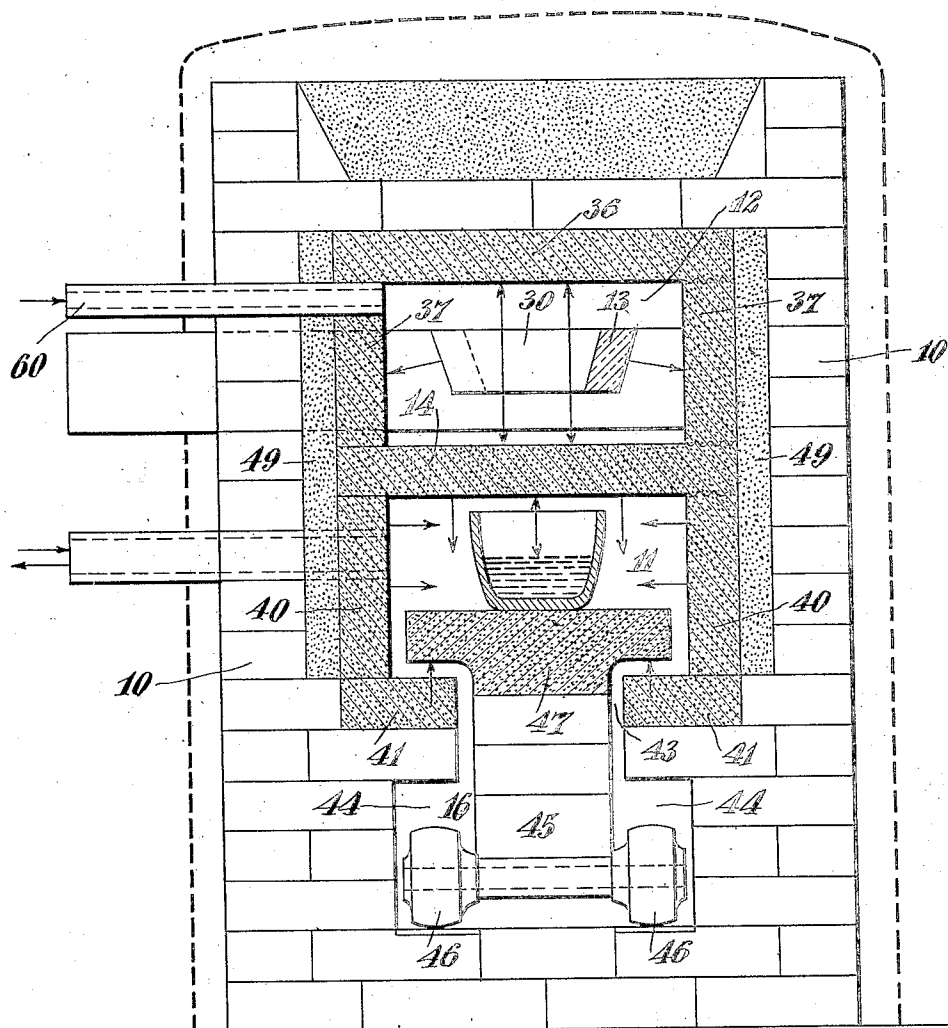
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TUNNEL KILN AND METHOD OF OPERATING THE SAME.

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*Fig. 3.*



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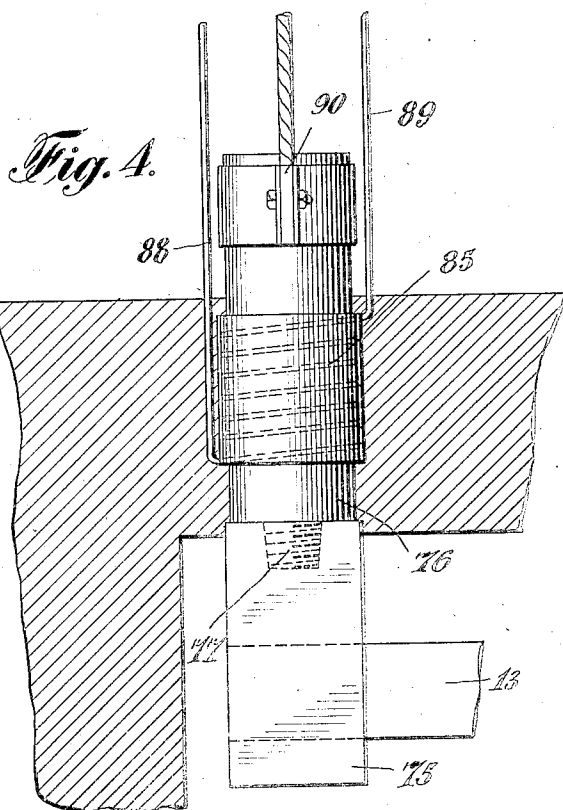
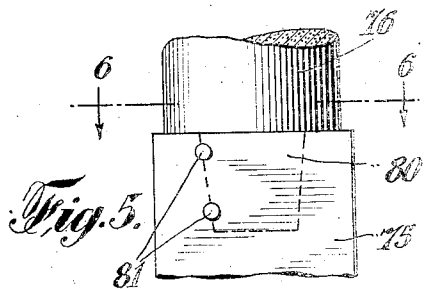
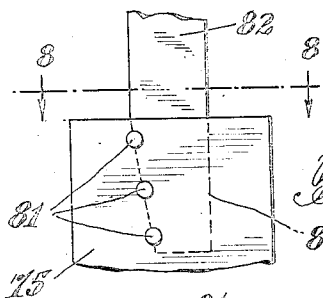
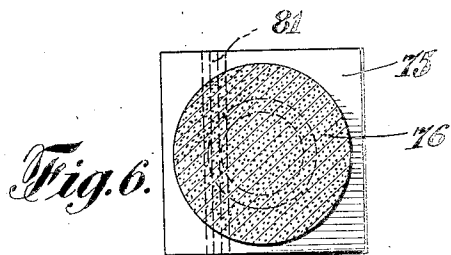
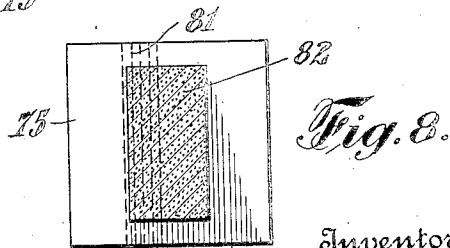
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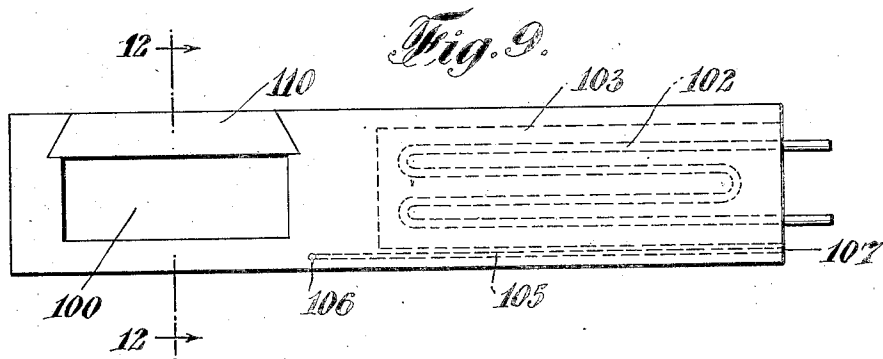
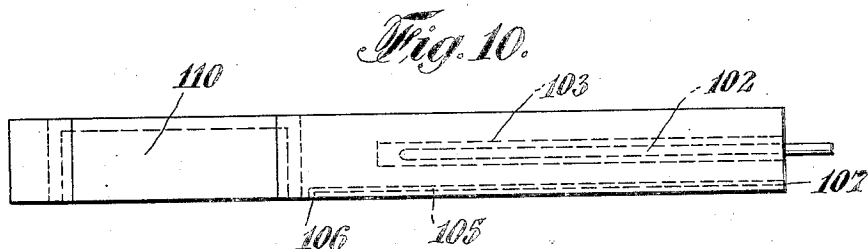
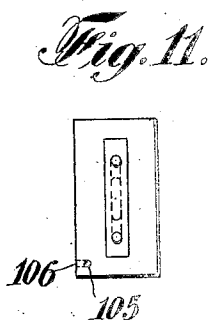
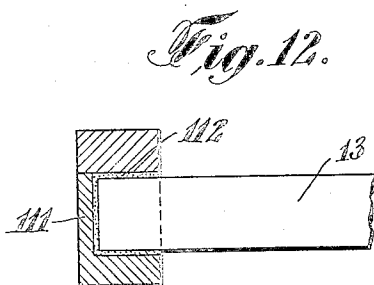
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TUNNEL KILN AND METHOD OF OPERATING THE SAME

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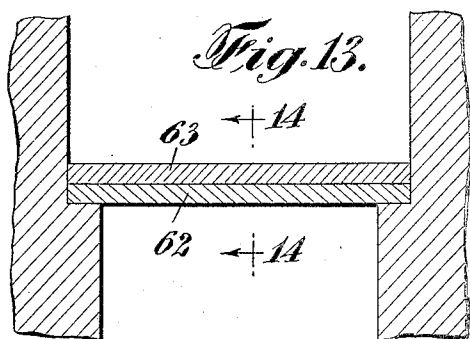
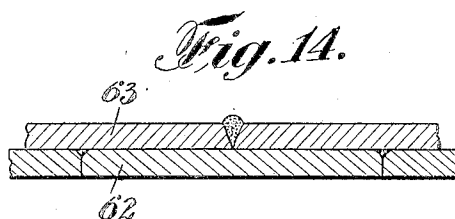
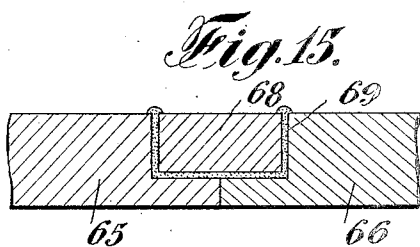
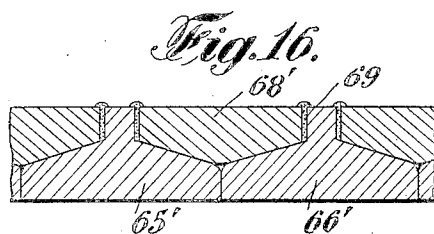
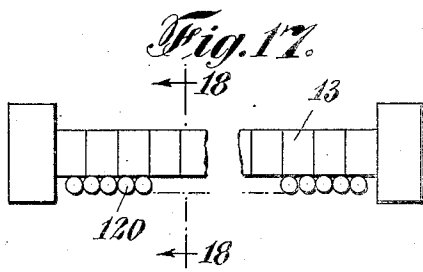
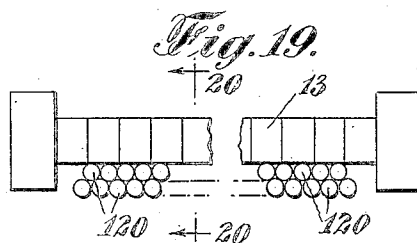
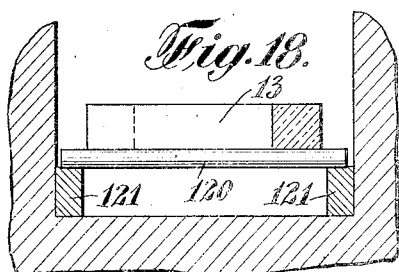
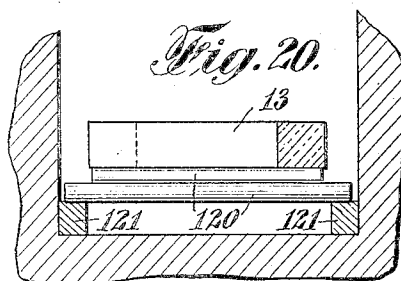
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## UNITED STATES PATENT OFFICE

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## TUNNEL KILN AND METHOD OF OPERATING THE SAME

Application filed June 10, 1925. Serial No. 36,086.

This invention relates to tunnel kilns which are heated by electric resistors. In such kilns, where high temperatures are required, it is impossible to use metallic resistors alone because even the most refractory of these suffers deterioration after a certain temperature is reached. Higher temperatures may be obtained by the use of other resistors, for example, those having a base of silicon carbide, but where the highest temperatures are required it is necessary to use a carbonaceous material such, for example, as carbon or graphite. Except in unusual cases, it is necessary to enclose the carbonaceous resistor in a chamber or compartment, in order to protect it from oxidation. In a tunnel kiln, where the tunnel can be kept completely filled with a reducing or absolutely inert atmosphere, the carbonaceous resistor may be exposed, but in the usual cases the atmosphere of the tunnel will be oxidizing and if the resistor is exposed to such atmosphere it will rapidly deteriorate. When the carbonaceous resistor is enclosed in any manner, whether by means of a protective coating or by enclosure in a compartment kept filled with an inert or reducing gas, or maintained in a gas-tight condition to prevent ingress of air, the thermo-efficiency of the furnace is correspondingly diminished since heat radiated by the resistor must be forced through walls of the enclosure before it reaches the material passing through the tunnel for heat-treatment. The construction and maintenance of such a heating means involves expense that is saved when the resistor is of such a nature that it may be allowed to radiate directly to the material under treatment.

Let it be assumed by way of illustration that an electric tunnel is used for heat-treatment of material which must be raised to a maximum temperature of  $1500^{\circ}\text{C}$ . To reach this temperature it is necessary to use a carbonaceous resistor. In accordance with our invention, the carbonaceous resistor is only used at temperatures where its use is imperative. At the entrance end of the tunnel and for a certain distance a metallic resistor is used. We find that the metallic resistor may be used to raise the material to a temperature of  $900^{\circ}$  to  $1000^{\circ}\text{C}$ . Beyond the metallic re-

sistor we employ a carbonaceous resistor which extends to that part of the kiln where the temperature of the material reaches the desired point of  $1500^{\circ}\text{C}$ . We however do not confine ourselves to the combination of metallic and carbonaceous resistors, for we may use instead of the metallic resistor a resistor having a silicon carbide base, or the like, in which case the transition from such resistor to the carbonaceous resistor may be at a point where the material under treatment reaches a temperature of  $1200$  or  $1300^{\circ}\text{C}$ ., or we may use a combination consisting of a metallic resistor to a material temperature of  $900$  to  $1000^{\circ}\text{C}$ ., a silicon carbide resistor or the like to a material temperature of  $1200$  to  $1300^{\circ}\text{C}$ ., and a carbonaceous resistor for higher temperatures.

Other features of our invention comprise improvements in the resistor terminals and in the construction of the chamber enclosing the carbonaceous resistor, and an improved means for preventing or minimizing the deterioration of the carbonaceous resistor when subjected to continued use.

Numerous other objects and advantages of our invention will appear from the following description, taken in connection with the accompanying drawing, wherein

Fig. 1 is a diagrammatic view of an electric furnace, partly in section on the line 1— of Fig. 2, partly in elevation and partly broken away, showing one embodiment of our invention.

Fig. 2 is a section taken on the line 2— of Fig. 1.

Fig. 3 is a transverse section taken on the line 3—3 of Fig. 1.

Fig. 4 is a detail elevation, partly in section, showing an electric terminal passing through the wall of the furnace and adapted to supply current to the heating resistor.

Fig. 5 is a detail elevation of a portion of the structure shown in Fig. 4 showing a slight modification.

Fig. 6 is a sectional view taken on the line 6—6 of Fig. 5.

Fig. 7 is a view similar to Fig. 5 but showing a still further modification.

Fig. 8 is a sectional view taken on the line 8—8 of Fig. 7.

Fig. 9 is a side elevation of another form of terminal showing an improved means for securing the resistor thereto.

Fig. 10 is a top plan view of the structure shown in Fig. 9.

Fig. 11 is an end elevation of the outer end of the terminal shown in Fig. 9.

Fig. 12 is a section taken on the line 12—12 of Fig. 9, showing a portion of the resistor in elevation.

Fig. 13 is a detail transverse section through the furnace showing an improved construction of the septum or partition which divides the chamber containing the carbonaceous resistor from the chamber which contains the material to be heated.

Fig. 14 is a section taken on the line 14—14 of Fig. 13.

Figs. 15 and 16 are views similar to Fig. 14 but showing separate modifications of the septum construction.

Fig. 17 is a diagrammatic view showing an improved means for electrically connecting the heating resistor with the walls of its enclosing chamber so as to prevent deterioration of the resistor when subject to continued use in the chamber.

Fig. 18 is a detail section taken on the line 18—18 of Fig. 17.

Fig. 19 is a view similar to Fig. 17 but showing a modification.

Fig. 20 is a view taken on the line 20—20 of Fig. 19.

Referring to the drawing, the walls 10 of the furnace form an interior space which is divided into a chamber 11 adapted to contain the material being treated, a chamber 12 containing the carbonaceous resistor 13, which chamber is closed from the chamber 11 by a septum 14, and a chamber 16 containing a metallic resistor or the like 15, which is adapted to radiate heat directly on the material being treated through an opening 20 forming a connection between the chambers 11 and 16.

The heat-producing element 13 is preferably a so-called graphitized carbon zigzag resistor formed by cutting a series of blind-staggered slits 30 transversely of a graphitized carbon slab. The resistor 13 is preferably supported in carbonaceous terminals 32, 33 projecting through the side wall of the furnace. The construction of these terminals will be more particularly described hereafter. In the construction shown, the resistor 13 is supported between its terminal connections. A source of current 35 may be employed to supply current to the terminals 32 and 33 for the purpose of heating the resistor 13.

The resistor chamber 12 is bounded by relatively massive roof slabs or tiles 36, side slabs 37, and floor plates forming the septum 14,

all supported by a series of silicon carbide uprights 40 and foot-blocks 41, leaving an interposed gap 43 in the chamber 11 connecting with an enlarged runway 44 to receive a car or series of cars 45 mounted on wheels 46 and whose upper plates or platforms 47 are formed of silicon carbide. These cars are adapted to be moved through the chamber 11 in the direction of the arrow A, at the proper rate to permit the material or articles carried by the cars to receive the proper heat treatment. The silicon carbide septum 14 forms a heat-transferring medium between the chambers 12 and 11. Paralleling the outer surfaces of the chamber walls are wall gaps filled with sand 49 of silicon carbide. The chamber 16 may be lined similarly to the chamber 12, except as previously stated such chamber 16 opens directly into chamber 11. The outer roof of the furnace may be suitably formed to receive pulverized non-heat-conductive refractory material, and the entire furnace may then be further enveloped with material most effective to resist the outward flow of low temperature heat.

The metallic or similar resistor 15 may be of any desired form and may be supported by terminals 50 and 51 extending through the wall of the furnace, which terminals are suitably connected with a source of current 54 for heating the resistor 15.

In forming the silicon carbide lining for the chambers 11 and 12, as well as the septum 14, we preferably employ blocks of a silicon carbide composition which have been prepared from recrystallized silicon carbide. These blocks are then placed in position to form the linings and septum of the furnace, and they are then electrically fired as a result of which they coalesce at their junctures. We may provide means such as a tube 60 for supplying to the chamber 12, containing the carbonaceous resistor 13, an inert gas.

In Figs. 13 to 16 inclusive, we have shown several forms of septum construction designed to prevent leakage of air into the resistor chamber or leakage of gas outwardly from the chamber. The septum shown in Figs. 13 and 14 consists of a lower series of plates 62 and an upper series of plates 63 lying upon the lower series and so arranged that the junctures between successive plates of the lower series are in a staggered relationship with the junctures of the upper series. It will be apparent that if a joint between two of the plates 62 is not perfect, a plate 63 of the upper series which covers this joint will effectively compensate for this defect, and similarly the plates of the lower series will compensate for a defect in a joint of the upper series and form an effective baffle to the air.

During the heating-up period of the furnace, all of the plates will expand, and on

cooling they will contract. As the plates rest on the walls of the furnace, they are liable to stick to the walls with the result that openings in the joints will be formed, but since each joint is covered by a plate this opening, which is relatively small, will be effectively closed.

Fig. 15 represents a joint between two thick plates where the same principle is embodied. Plates 65 and 66 are so made that when they are butted together they have on their upper surface a recess slightly larger than the refractory insert 68. This insert, which is the same length as the plates, is rubbed into place in the recess and a tight joint made with packing material 69, which is similar in composition to the plates 65, 66 and the insert 68.

When the distance to be spanned by the insert is great, a construction shown in Fig. 16 may be employed, wherein the bottoms of the recesses formed by plates 65' and 66' are inclined downwardly toward the center and the insert plates 68' are formed with downwardly tapered lower faces adapted to fit the bottoms of the recesses. This construction is in effect a combination of the structures shown in Figs. 14 and 15. Each of the structures disclosed may be used in any one furnace, depending upon the mechanical necessities of the furnace, and combinations of the above may be used without departing from the spirit of the invention.

In Figs. 4 to 12 inclusive, we have shown certain improved forms of electric terminals which are adapted to support the heating resistor and to supply current to such resistor through the furnace walls. The constructions disclosed in these figures comprise the subject matter of a divisional application which has eventuated in U. S. Patent No. 1,657,671, granted January 31, 1928.

In electric furnaces of the resistance type it is often desirable to use a terminal having different cross section and shape throughout its length. These terminals are often formed of Acheson graphite or some other form of carbon. When the portion of the terminal inside the furnace has to be larger, due to mechanical necessity, than actually required for carrying current, the cost of making these terminals out of large blocks of graphite becomes great. The heat loss is also greater through a large heavy terminal. In the forms of terminals shown in Figs. 4 to 8, we have provided an improved construction whereby the terminals may be made of two or more differently shaped pieces, such pieces giving the desired mechanical design, good electrical properties, and permitting easy water-cooling facilities, which are generally necessary to prevent oxidation of the terminal.

Referring to Fig. 4, the resistor 13 is adapted to be supported on a resistor-carry-

ing block 75 of squared cross section, which in turn is connected, both mechanically and electrically, to the cylindrical portion 76 of the terminal by means of a threaded tapered extension 77 formed on the cylindrical portion 76 and which fits into a threaded recess in the resistor-carrying block 75. This joint, although mechanically and electrically good, is still a poor conductor of heat and serves to prevent considerable heat loss from the resistor 13. This joint may, if desired, be formed as shown in Figs. 5 and 6, wherein the cylindrical member 76 carries a tapered lug 80 adapted to be seated in a recess in the resistor-carrying block, and the two portions held together with carbonaceous half-pins 81. In case it is desired to form the terminal portion which passes through the furnace wall of rectangular section, it may be formed as shown at 82 in Figs. 7 and 8, and secured in the angular recess 83 by the half-pins 81.

In order to prevent the outer portion of the terminal from burning, the coil of pipe 85 is wound around the portion 76 as shown in Fig. 4, and lead or other easily cast metal is poured around it so as to make good heating contact between portion 76 and the coil 85. Water enters this coil at 88 and leaves it at 89. Electrical connection with the portion 76 may be made at 90 by some suitable means. The lead surrounding the coil 85 may have its outer surface cast to any shape suitable to be built into the refractory brickwork of the furnace.

It will be seen how readily this form of construction may be suited to fit different furnaces and the shapes employed may be altered without departing from the general scope of the invention.

If the cross section of the copper pipe 85 is made sufficiently large, the current required by the resistor 13 may be conducted through pipes 85 to the terminal portion 76. This permits an even shorter terminal and also allows the whole to be bedded solidly in the brickwork and eliminates the necessity of the electrical connection 90.

In Figs. 9 to 12, we have shown another form of terminal which is provided with an improved means for securing the resistor thereto and which is further provided with cooling means and means whereby an inert gas may be supplied to the resistor chamber through the body of the terminal. This terminal consists of Acheson graphite or some other carbonaceous material and is provided near its inner end with an inner pocket or space 100 into which the end of the resistor 13 fits. A coil of pipe 102 designed to carry water or other cooling medium is seated in a deep slot or cavity 103 cut or moulded into the terminal. The cooling medium circulated in the pipe 102 serves to keep that part of the terminal which is subjected to the oxidizing effects of gases or material below a

temperature where oxidation occurs. That part of the slot 103 which is not filled with the pipe is packed with some good heat-conducting material such as graphite powder, or it may be filled with metal such as lead, etc.

The long narrow passage 105 is drilled, cut or moulded into the terminal and has an outlet 106 which, when the terminal is built into the kiln, is inside the chamber in which the resistor is located and an inlet 107 opening outside of the kiln. This passage is employed to supply an inert gas or vapor to the resistor chamber. The passage 105 may, if desired, be lined with some hard inert substance such as porcelain, glass or other material to prevent erosion of the terminal by the rapidly moving gases.

As stated, the resistor 13 is seated in the recess or pocket 100 of the terminal, and in order to permit the placing and removing of this resistor in an easy manner we provide a removable plate 110 of the same material as the terminal, which is adapted to be seated in bevelled or dove tailed grooves formed in the side walls of the recess 100. As shown in Fig. 12, a wall 111 is left at one side of the recess 100.

When it is desired to place a new resistor in the terminal, plate 110 is removed, the resistor dropped into the recess 100, and the space between the end of the resistor and the terminal packed with some such material as graphite, so as to make good electrical contact. In placing this packing, the web or wall 111 is of great help and the web also helps to reinforce the terminal at that part of the recess. When the sides are packed, the plate 110 is slipped into position and the space 112, Fig. 12, is packed in a similar manner with graphite.

While we have described the terminals disclosed in Figs. 4 to 12 as adapted for use in the furnace of the type shown in Fig. 1, it will be apparent that such terminals are of general application and may be employed for a variety of purposes as will suggest themselves to those skilled in the art.

In Figs. 17 to 20, we have shown an improved means whereby the life of the carbonaceous resistor is greatly prolonged. It has been found that when a carbonaceous resistor is operated for a considerable length of time, deterioration occurs even though the resistor is fully protected from oxidation by being immersed in an inert atmosphere. The material of which the resistor is composed undergoes a change in character after a certain amount of use and when such use is continued for a sufficient length of time the resistor fails by breaking, although no appreciable oxidation has taken place. We have discovered that this deterioration of the resistor can be prevented by providing means for electrically connecting the radiating surface of the resistor with its surroundings.

Thus, while deterioration takes place when the terminals of the resistor which pass through the walls of the chamber or box in which the resistor is located are electrically insulated from such walls, if one terminal of the resistor is electrically connected to the walls this deterioration is less marked, particularly toward the end of the resistor at which this electrical connection is made. If the center of the resistor is electrically connected with the walls of the chamber, as by means of a carbon block in contact with both resistor and walls, the deterioration is less marked, particularly in those parts near the center of the resistor, and if all parts of the resistor throughout its length are electrically connected with the walls of the chamber the deterioration is effectively prevented.

Referring to Figs. 17 and 18, the resistor 13 is connected with the walls of the chamber 12 by a row of carbon rods 120 resting on supports 121 mounted on the bottom of the chamber 12. This construction, because of the high contact resistance between the rods themselves, between the rods and the resistor, and between the rods and the supports 121, reduces to a minimum the leakage of heating current from the resistor to the walls of the chamber.

In the form shown in Figs. 19 and 20, we employ two layers of rods 120 beneath the resistor 13.

While not shown in the drawings, it is preferable to place one or more layers of rods on the upper side of the resistor and completely cover it, the lower layer being sufficiently long to come in contact with the side walls of the resistor chamber.

While we do not desire to limit ourselves to any particular theory as to how the constructions shown in Figs. 17 to 20 prevent the deterioration of the resistor, it appears that such deterioration is due to an electric discharge from the resistor to the surrounding walls of the resistor chamber, and the structures disclosed operate to eliminate or prevent this discharge, to some extent at least, by equalizing the potentials of the resistor and the walls of the chamber. It will be evident to those familiar with the construction of electric furnaces that the method of protection described above is by no means the only one that can be used, for many other arrangements can be devised without departing from the general principles of the invention.

We claim:

1. In an electric kiln furnace, a chamber through which material to be heated to a high temperature is moved, a resistor exposed to the atmosphere of said chamber and adapted to heat such material to a temperature less than said high temperature, and an enclosed resistor adapted to heat said mate-

rial from said second-named temperature to said high temperature.

2. In an electric kiln furnace, a chamber through which material to be heated to a high temperature is moved, a resistor exposed to the atmosphere of said chamber and adapted to heat such material to a temperature less than said high temperature, a resistor adapted to heat said material from said second-named temperature to said high temperature, and a silicon carbide enclosure for said second-named resistor.

3. In an electric kiln furnace, a chamber through which material to be heated to a high temperature is moved, a resistor exposed to the atmosphere of said chamber and adapted to heat such material to a temperature less than said high temperature, a carbonaceous resistor adapted to heat said material from said second-named temperature to said high temperature, a silicon carbide enclosure for said second-named resistor, and means to form an inert atmosphere within said enclosure.

4. In an electric kiln furnace, a chamber through which material to be heated to a high temperature is moved, a metallic resistor exposed to the atmosphere of said chamber and adapted to heat such material to a temperature less than said high temperature, and an enclosed carbonaceous resistor adapted to heat said material from said second-named temperature to said high temperature.

5. In an electric kiln furnace, a chamber, means for moving material to be heated to a high temperature through said chamber, a metallic resistor located above the path of said material and adapted to radiate heat directly to said material for the purpose of heating said material to a temperature below said high temperature, a carbonaceous resistor located above the path of said material as it moves from under the influence of said first-named resistor, said carbonaceous resistor being adapted to raise the temperature of said material to said high temperature, a gas-tight chamber enclosing said carbonaceous resistor and formed with walls spaced from said resistor, said walls being formed of dense, self-sustaining refractory material of high heat-conductivity.

6. The method of heating material to a high temperature which consists in heating such material to a lower temperature by direct radiation from an exposed metallic resistor and subsequently raising the temperature of said material to said high temperature by means of a carbonaceous resistor by radiation and conduction through the walls of a chamber containing said resistor while maintaining said resistor in an inert atmosphere.

7. An electric furnace having a chamber, a carbonaceous resistor self-supported in said chamber and a connecting means between

said resistor and the walls of said chamber of high electrical resistance and of low heat resistance.

8. An electric furnace having a chamber, a resistor supported in said chamber spaced from the walls thereof, and a separately supported means within said chamber to equalize the potentials of said resistor and the walls of said chamber throughout substantially the length of said resistor without obstructing the flow of heat from said resistor to the walls of said chamber.

9. An electric furnace having a chamber, a carbonaceous resistor supported in said chamber spaced from the walls thereof, and carbonaceous material separately supported within said chamber from said resistor forming a high resistance electrical connection between said resistor and the walls of said chamber without obstructing the flow of heat from the resistor to the walls of said chamber.

10. An electric furnace having a chamber containing an inert atmosphere, a carbonaceous resistor supported in said chamber spaced from the walls thereof, and carbonaceous material within said chamber separately supported from said resistor forming a high resistance electrical connection between said resistor and the walls of said chamber without obstructing the flow of heat from the resistor to the walls of said chamber.

11. An electric furnace having a chamber, a graphite resistor in said chamber, and a series of carbonaceous rods resting against said resistor and forming a high-resistance current path between said resistor and the walls of said chamber.

12. An electric furnace having a chamber, a carbonaceous resistor in said chamber, and means forming a high resistance electrical connection with a plurality of points along the length of said resistor and with the walls of said chamber without obstructing the flow of heat from the resistor to the walls of said chamber.

13. An electric furnace having a chamber, a carbonaceous resistor in said chamber spaced from the walls thereof, and a plurality of carbonaceous rods resting in contact with substantially all portions of the external surface of said resistor and forming an electrical connection between said portions and the walls of said chamber.

14. An electric resistor furnace having a chamber, a resistor formed of a carbonaceous block in said chamber, a terminal for said resistor extending through the wall of said chamber, said terminal being formed with a passage therethrough for supplying fluid to said chamber.

15. An electric resistor furnace having a chamber, a resistor in said chamber, a terminal for said resistor formed of a carbonaceous

ceous block extending through the wall of said chamber, said block being formed with a passage therethrough for supplying fluid to said chamber, said passage having a lining of hard, inert material.

- 5 16. A carbonaceous resistor and a carbonaceous terminal therefor formed with a recess in which one end of said resistor is seated, and an electrically contacting pulverized carbonaceous packing material between the end  
10 of said resistor and the walls of said recess.

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