C. HERING.

ELECTRIC FURNACE ELECTRODE.

APPLICATION FILED FEB. 17, 1911.

999,719. Patented Aug. 1, 1911.

FIG. 1.

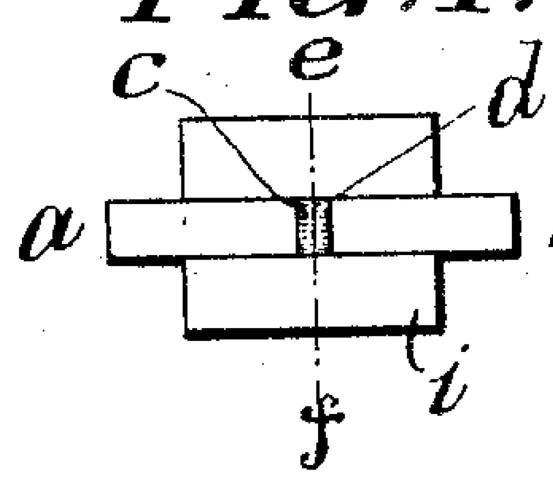


FIG. 2.

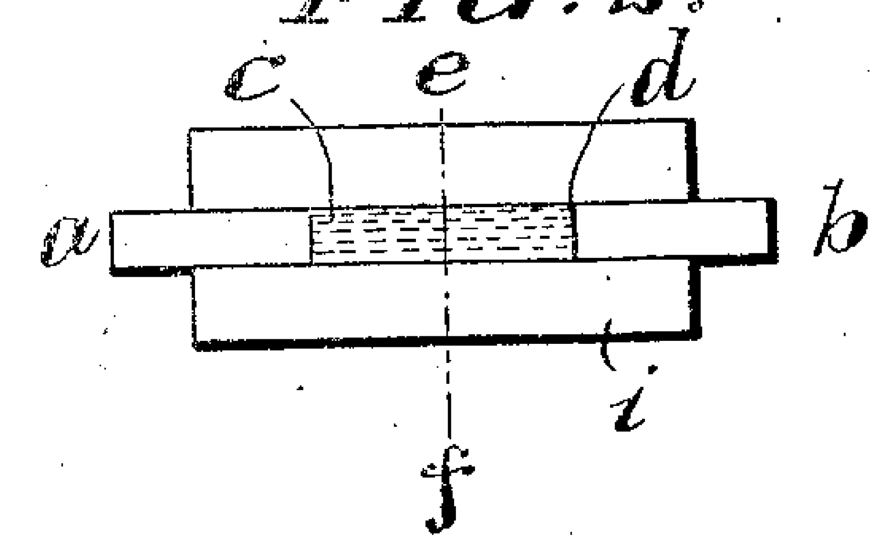


FIG. 3.

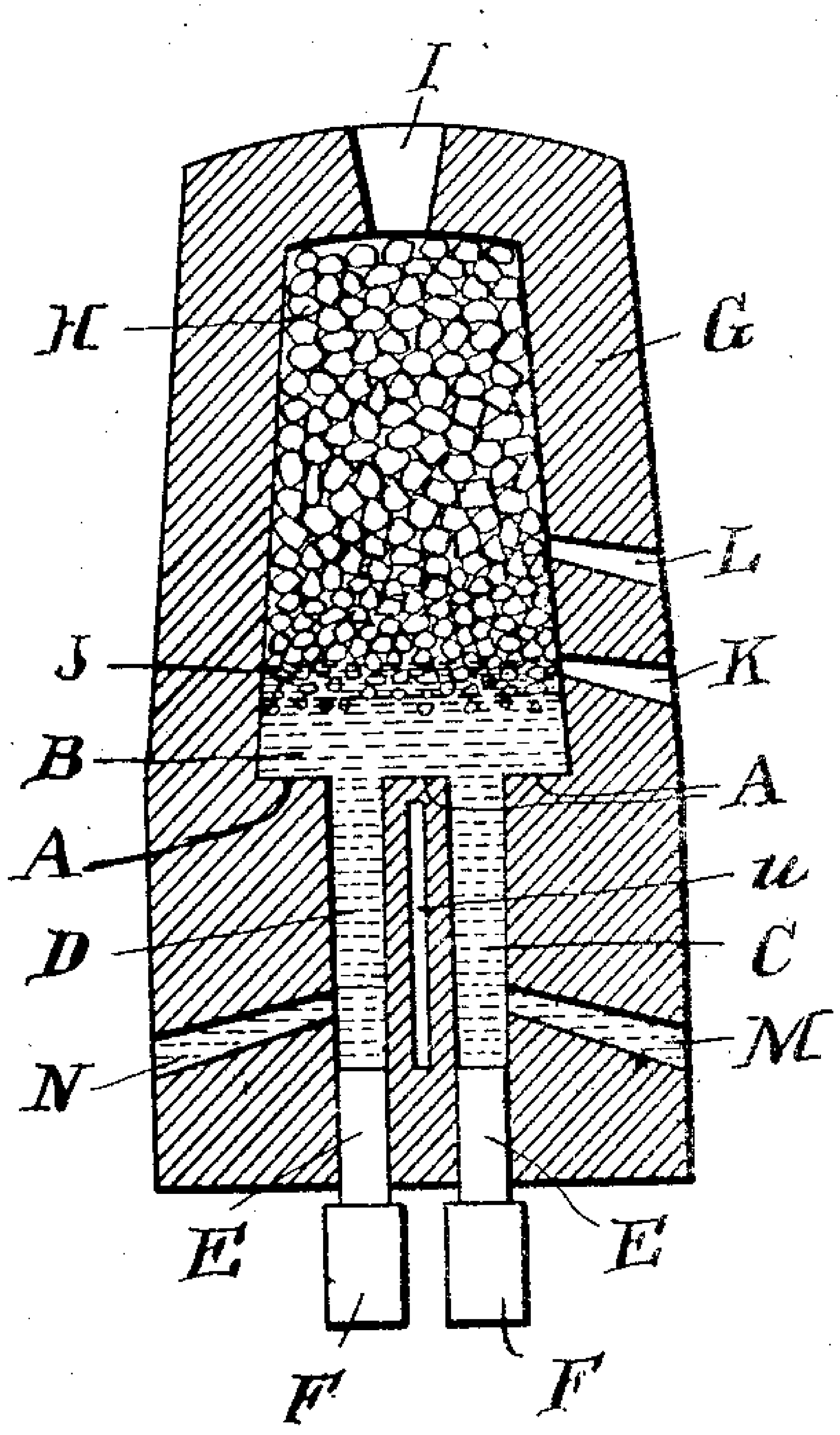


FIG. 4.

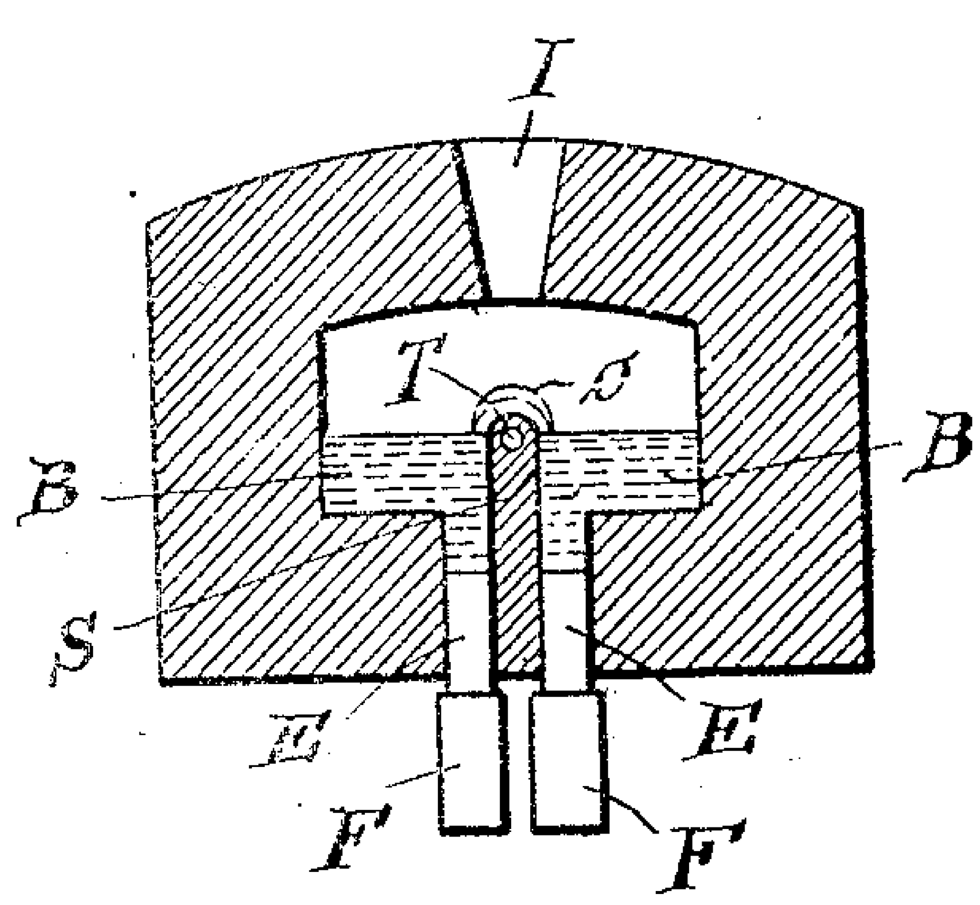
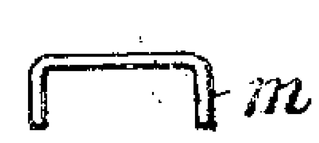


FIG. 5.



INVENTOR

Carl Hering

WITNESSES

Daniel Webster Jr.

Anna E. Steinbock

BY Cornelius D. Ehret

his ATTORNEY

UNITED STATES PATENT OFFICE.

CARL HERING, OF PHILADELPHIA, PENNSYLVANIA.

ELECTRIC-FURNACE ELECTRODE.

999,719. Specification of Letters Patent. Patented Aug. 1, 1911.

Original application filed July 6, 1909, Serial No. 505,963. Divided and this application filed February 17, 1911. Serial No. 609,123.

To all whom it may concern:

Be it known that I, Carl Hering, a citizen of the United States, residing in the city of Philadelphia, county of Philadelphia, and State of Pennsylvania, have invented a certain new and useful Electric-Furnace Electrode, of which the following is a specification.

My invention relates to electrodes and more particularly to electrodes for conducting current to another conductor, such, for example, as a heated conductor or a conductor within an electric furnace.

My invention resides in an electrode whose opposite ends are at substantially different temperatures while current is passed through the electrode, and is so constructed that the current passing therethrough will prevent heat conduction from its hotter to its cooler end of heat generated externally to the electrode at its hotter end. To this end I so relate the cross section of my electrode to its length that its resistance is such that the current passed therethrough will prevent such heat conduction, by maintaining the hotter end of the electrode at a temperature substantially equal to the temperature maintained externally to the hotter end of the electrode.

By my improved electrode construction, for a given set of conditions, my electrode is far smaller and cheaper as compared with former practice; and by my improved construction I secure practically minimum electrode losses.

My invention resides in the electrode hereinafter described and claimed.

For an understanding of my invention, and for an illustration of some of the applications of my invention, reference is to be had to the accompanying drawing, in which:

Figures 1 and 2 are views illustrative of the principle underlying my improved electrodes. Fig. 3 is a vertical sectional view of an electric furnace in which the resistor is in the form of a column or columns of molten material contacting with my improved electrodes. Fig. 4 is a vertical sectional view of an electric arc furnace, involving also resistors in contact with my improved electrodes. Fig. 5 is a side elevational view of a metallic or conducting starter.

I have found that the energy loss in the electrodes of an electric furnace may be reduced greatly below what has heretofore been common practice. I have discovered the law of the electrode losses and from it I have found that for a minimum amount of loss in the electrodes, such electrodes must be so proportioned that the C^2R loss (heat generated by current in the resistance of the electrodes) shall be equal substantially or approximately to twice the heat conduction loss of the electrodes. By heat conduction loss I mean the loss of heat from the interior of the furnace through the electrodes by heat conduction, when no current is flowing. I have found that for any other relation between these two losses the combined loss becomes greater. As a result of proportioning the electrodes so that this relation shall hold, the losses of energy in and through the electrodes become very small as compared with prior practice. The total loss in the electrodes will then be equal to the electrical resistance loss only, (C^2R loss) as there will then be no heat lost by conduction, because the temperature of the hot end of the electrode will then be equal to that of the furnace, and the electrode will therefore be the equivalent of a perfect heat insulator, allowing no heat to pass through it from the furnace, although the electrode remains a very good electrical conductor. No material is known which has these two qualities combined, namely, heat insulation and electrical conductivity; but by proportioning the electrodes according to the laws which I have discovered, the practical equivalent of these two properties can nevertheless be realized. This may be better understood by reference to Fig. 1, in which *a*, *b*, is a conductor of heat and electricity, say an iron rod, embedded in a block of perfect heat insulating material *i*, except at the ends, which are kept at a low temperature, as by water cooling. Let so large a current be passed through *a*, *b*, that it will be melted for a short distance, *c* to *d*, at the middle. Under these conditions and when the stable state is reached, the only loss will be the C^2R loss which will flow out as heat at the two ends. If this block *i* be now supposed to be cut in two at the middle plane *e*, *f*, and separated to form the two walls of a furnace which contains that same material in a melted state, as illustrated in

Fig. 2, the rods now forming the two electrodes, there will evidently be no more heat conducted by the electrodes from the melted mass in the interior of the furnace to the outside than there was before, because the ends of the electrodes and the melted material are at the same temperature. I find that it follows from the laws of heat and electricity that the conduction loss when the current stops, would then be equal to approximately half the C^2R loss, as heretofore pointed out. Also that for any other than these conditions, the electrode loss will be increased and not be a minimum. While the equations and proportions herein given are for electrode materials with ideal properties, such as zero temperature co-efficients for both electric and heat conductivities, these co-efficients of actual materials available vary somewhat and, therefore, the results in practice are not exactly those indicated by the equations and proportions given, but are, for all practical purposes, substantially those indicated by the equations and proportions given. I have found that for each electrode material, this minimum loss is a constant per ampere of current and per degree of furnace temperature. Also that for a given material this minimum electrode loss is dependent upon the furnace temperature and the current, but not on the electrode dimensions, except that the ratio of the length to the cross section of the electrode must be a certain quantity, as hereinafter pointed out. For any given electrode material, temperature, and current, this minimum electrode loss is fixed and cannot be further reduced by any change in the dimensions of the electrode. For different materials I find that this minimum loss is proportional to the square root of the ratio of the thermal to the electrical conductivities of the electrodes. From these laws I find that the minimum loss is generally least for the metals, and that it is very considerably less than for the usual materials carbon and graphite.

It is a part of my invention, therefore, that metal electrodes are employed, preferably of the same metal as is melted in the furnace, or of metal or material which does not contaminate the material or metal fused in the furnace, and thereby I can greatly reduce the electrode losses. To obtain this advantage of a lower minimum loss for metal electrodes they must be proportioned so that the heat conduction loss, with no current flowing, will be equal to half the C^2R loss approximately or substantially. But my improvement is not limited to metal electrodes, for, by observing the novel proportions herein described, carbon and graphite electrodes, giving minimum losses for those materials, may be employed, and the loss will be found to be much smaller than for the carbon and graphite electrodes as heretofore used. I have stated above that this minimum loss is independent of the actual dimensions of the electrodes, that is, they may be large or small and yet have the same minimum loss. To get this minimum loss, however, I find that they must have a certain proportion between their length and their cross section. In order to obtain the best economy of electrode material, therefore, the electrode should be made as short as possible, as the economy increases inversely as the square of the length. The cross section is then made to correspond with this length in accordance with the laws which I have discovered, in order to obtain the minimum loss. From the laws which I have discovered it follows that this economy of material will be greatest, that is, for any given length the cross section will be least, when the square root of the product of the electrical and the thermal conductivities is greatest. Hence, I find that as far as economy of material is concerned, those materials are best in which this product is greatest. In any given material, therefore, the desirable qualities are, to a certain extent, opposed, with respect to economy of power as compared with economy of material. I have discovered that if K and k represent the electrical and thermal conductivities of the material, then the minimum power loss in them, in the form of the heat which leaves them at the outside terminals, is least when K divided by k is greatest. On the other hand, the economy of material is best when the product of k and K is greatest. It is, therefore, the quotient and the product of the electrical and thermal conductivities which determine their suitability for electrode materials, and not either of these alone. In comparing different materials quantitatively with each other, it is the square root of this quotient or this product which must be compared and not the quotients and products directly. From the conductivities of different materials as far as they are known, I find, from the law which I have discovered, that the square root of these quotients and products are as a rule greatest for the metals as distinguished from the usual electrode materials, carbon and graphite. The difference is great. Hence, I have found it much more economical to use metal electrodes whenever possible.

When metal electrodes are used and proportioned in accordance with the laws which I have discovered, they will remain solid at the external ends although they will be at the temperature of fusion at the inside or furnace ends. The reason is that when so proportioned there will be no heat conducted by the electrodes from the interior of the furnace, and all the heat generated in them by the current will be led off at the cool or outside end just as fast as it is generated in it; hence their temperature will not increase and they will remain unfused except at their extreme inside ends. If continuously covered with fused metal at their inside or hot ends they will not be consumed and if made of the same metal as that fused in the furnace, or of one which is nonmiscible with the fused material, they will not contaminate the latter. This state, as I have found, is also the state of least total loss in the electrodes.

From the laws above stated I have deduced the following formula:

$$X = 2.894C\sqrt{krT}$$

in which X is the total minimum loss in watts in or through the electrodes, 2.894 is a constant involving no physical properties, C is the current in amperes, k is the heat conductivity in gram calories per second, cubic inch units, r the electrical resistivity in ohms, cubic inch units, and T the temperature difference between the inside and outside ends of the electrode in centigrade degrees. And I have deduced the following formula for determining the condition of proper proportions of the electrodes for minimum loss:

$$\frac{S}{L} = 0.3456\,C\sqrt{\frac{r}{kT}}$$

in which S is the cross section of the electrodes in square inches, L their length in inches, C the current in amperes, r, k and T being the same as above. The electrodes must have this proportion in order to obtain the minimum loss given in the first formula.

When the thermal conductivity k in the above formulæ is expressed in watts in place of in calories per second, the numerical constants in these formulæ, namely, 2,894 and 0.3456, disappear, and a factor 2 accompanies the factor k, so that these formulæ take the form, respectively, as follows:

$$X = C\sqrt{2krT}$$

$$\frac{S}{L} = C\sqrt{\frac{r}{2kT}}$$

This second formula gives the ratio of the section to the length of the electrodes and therefore leaves a choice of either, but not of both. The length should be made as short as possible; it is usually determined by the general design and thickness of the furnace walls or other considerations. The quantity of electrode material increases as the square of the length. It follows, therefore, that in accordance with my discoveries and invention, I may greatly reduce the size of, and therefore cheapen, the electrodes heretofore used in the art and at the same time secure a minimum loss of energy in the electrodes, thus leaving greater amounts of energy for useful work within the furnace and, in consequence, increasing the efficiency of the furnace.

If by the electrode efficiency is meant the ratio of the energy set free in the interior of the furnace, that is, between the hot ends of the two electrodes, divided by the total energy between the two cold ends, then for a given minimum loss in the electrodes, this efficiency will evidently be higher the greater the drop of voltage between the hot ends, as compared with the drop of voltage in one of the electrodes. By my invention the latter may be made very small, much smaller than heretofore, hence for a given current and voltage of a furnace there will be more useful heat generated in the furnace. But to increase this efficiency still more the drop of voltage between the two hot ends should be made as great as possible. To do this with a liquid resistor may require this resistor to be made long and small in section, hence I may in those cases prefer to use the arc as this has a relatively high drop of potential in a small space. Or still better I may use several arcs in series. My improved electrodes may therefore be used in any electric furnace irrespective of whether the resistor is a column of molten material, an arc, or what its form or character may be.

In Fig. 3 is shown an electric furnace in vertical section, having a hearth A; this hearth may take any suitable or desired form, as the heat producing resistor is practically independent of the proportions of this hearth or the amount of molten material in it. Upon the hearth A is a mass B, of molten iron or other material under treatment, the molten material extending also downwardly into the columns C and D, the molten material in these columns making electrical end-on contact with the furnace electrodes E, E, proportioned and constructed as hereinbefore described, which extend through the bottom or wall of the furnace, and may terminate outside in conducting enlargements F, F, which may be cooled, if desired, by a water jacket. The furnace extends upwardly in the form of a dome G, preferably enlarging toward the bottom, such dome being preferably filled with the charging material H, as iron ore or other material, which may be introduced through the opening I at the top, which is thereby preheated.

The furnace may be started by a charge of molten material or by a casting of preferably the same material as that to be treated, extending downwardly in the columns C and D into contact with the electrodes E, E, such casting being continuous and bridging the columns C and D at the top. When the current is turned on, it flows from one electrode through one of the columns and out through the other column and other electrode, the casting, when such as employed for starting, becoming hotter and hotter until finally melted. Then the usual mixture of ore, carbon and flux is introduced, it being in preferably sufficient quantity above the hearth to force masses of it into the molten mass, whereupon the heat of the molten mass B is rapidly conveyed to it, thereby hastening the chemical action, such as the combination of iron and carbon on the one hand, and the combination of the carbid, thus formed, with the iron oxid on the other hand, as is well understood in the art. J represents the slag. And a further opening L may be provided for the introduction of air, as by a blast, for burning any possible unburned gases which may be formed, like carbon monoxid, thus preheating the ore and increasing the economy of heat of the furnace.

M is a tap hole communicating with the column C for drawing off the finished material, and a similar tap hole N may be provided for communicating with the other column D for the same purpose, if desired. Or the tap hole may communicate with the bottom of the hearth, if desired, or tap holes may be placed at both places.

In operation, a minimum amount of energy is lost in the electrodes E, E, and the heat is produced by the current in the columns C and D, the molten masses in these columns constituting the resistor. This heat is then supplied to the mass B by the columns C and D.

In Fig. 4, I have shown an arc furnace having the electrodes E, E, in accordance with my invention, which may be metallic, communicating with the separated baths B and B′ of molten material, a dividing wall or member S being provided. The arc may be started by a bridge piece *m*, such as shown in Fig. 5, made of the same metal as that in the baths B and B′, by placing the same over the dividing member S; the member then melts and an arc *o* is formed between the two baths B and B′. Or the arc may be started by granular conducting material extending over the member S into contact with the two baths, or the baths may be agitated to come momentarily into contact with each other above the member S, or any other means may be employed. The dividing member S may be kept from fusing by a circulation of water or other cooling material through the opening or tube T. Or the magnetic blow-out principle may be used to keep the arcs farther from the dividing member S.

In both the forms of furnaces herein shown, it will be noticed that the two terminals or electrodes may be brought out close together, because of their small size, due to my invention, thereby facilitating the connections to the transformer and thus increasing the power factor, when alternating current is used, since the area inclosed by the conducting loop formed within the furnace is greatly reduced.

The electrodes are not consumed and therefore do not contaminate the fused product and do not have to be advanced into the furnace. In consequence, the construction of the furnace is greatly simplified and cheapened. Unless proportioned as I have shown, the losses through metal electrodes may become very large, due to their high heat conductivity.

By constructing a furnace electrode as hereinbefore described, the electrode section is not so large that heat conduction can occur therethrough from the furnace; nor is the section of the electrode so small that the electrode is raised within the furnace wall to a temperature higher than the furnace temperature.

This application is a division from my application Serial No. 505,963, filed July 6, 1909, upon which was issued Letters Patent of the United States No. 988,936.

While I have herein shown and described my improved electrodes applied in several relations in electric furnaces, I claim herein my improved electrode only, and in my copending application Serial No. 624,616, filed May 2, 1911, I claim my said improved electrode in those relations in electric furnaces disclosed but not claimed herein.

What I claim is:

1. In an electric furnace, an electrode having a resistance such that the C^2R heat developed therein by current transmitted therethrough to said furnace shall be substantially equal to twice the heat conduction loss when no current flows.

2. In an electric furnace, an electrode having such length and cross section that the furnace current flowing through said electrode raises said electrode at its furnace end by its own resistance to a temperature substantially equal to furnace temperature.

3. In an electric furnace, an electrode having the ratio of its electrical to its thermal conductivities and the product of its electrical and thermal conductivities great, and such that the C^2R heat developed therein by furnace current is substantially equal to twice the heat conduction loss through said electrode when no current is flowing.

4. An electric furnace electrode having an electrical resistance sufficient to cause the generation, throughout its whole length between its outer and inner terminals, by the passage therethrough of furnace current of the heat necessary to prevent loss by conduction toward its outer terminal, of the heat generated in the furnace.

5. An electric furnace electrode having a substantially uniform cross section and hav-

ing an electrical resistance sufficient to cause the generation, by the passage therethrough of furnace current, of the heat necessary to prevent loss by conduction toward its outer end, of the heat generated in the interior of the furnace.

6. An electric furnace electrode having such a thermal resistance that during normal furnace operation only that heat is conducted to its outer terminal which is generated within said electrode by the passage therethrough of furnace current.

7. An electric furnace electrode having such a length and uniform cross section that substantially no heat will flow into or out of the furnace through the hot end of said electrode.

8. In an electric furnace, an electrode for communicating current to the material in the furnace, the relation of the cross section of said electrode to its length determining the resistance of said electrode such as to cause the generation of heat throughout the whole length of said electrode, by the passage therethrough of the furnace current, preventing heat conduction from the material in said furnace outwardly through said electrode.

9. An electrode adapted to conduct current to a heated conductor, said electrode having such relation of its cross section to its length, substantially as described, that the current passing through said electrode to said heated conductor raises said electrode at its end in communication with said heated conductor by the resistance of said electrode to a temperature substantially equal to that of said heated conductor.

10. An electrode for carrying current while its opposite ends are at different temperatures having such resistance that the C^2R heat developed therein by the current transmitted therethrough shall be substantially equal to twice the heat conduction loss through said electrode when no current is flowing through said electrode.

11. An electrode for carrying current while its opposite ends are at different temperatures, said electrode having such relation of its cross section to its length, substantially as described, that the current flowing through said electrode raises said electrode at its hotter end to a temperature preventing conduction through said electrode of heat generated external to said electrode at its hotter end.

In testimony whereof I have hereunto affixed my signature in the presence of the two subscribing witnesses.

CARL HERING.

Witnesses:
ANNA E. STEINBOCK,
ELEANOR T. McCALL.