E. F. NORTHRUP.

OSCILLATION SPIRAL COIL AND CONNECTION.

APPLICATION FILED JUNE 18, 1917.

1,330,133. Patented Feb. 10, 1920.

FIG. 1.

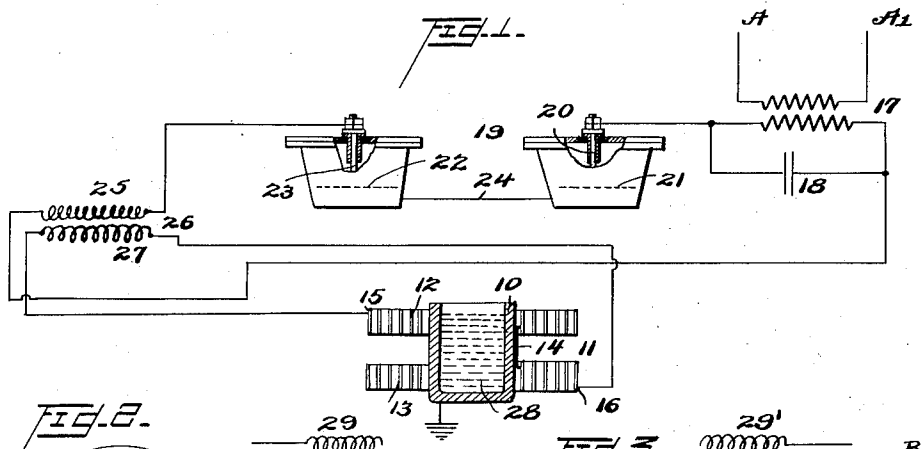


FIG. 2.

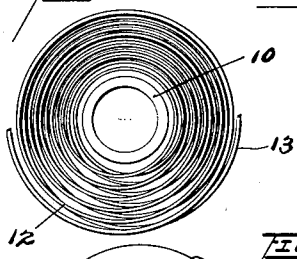


FIG. 3.

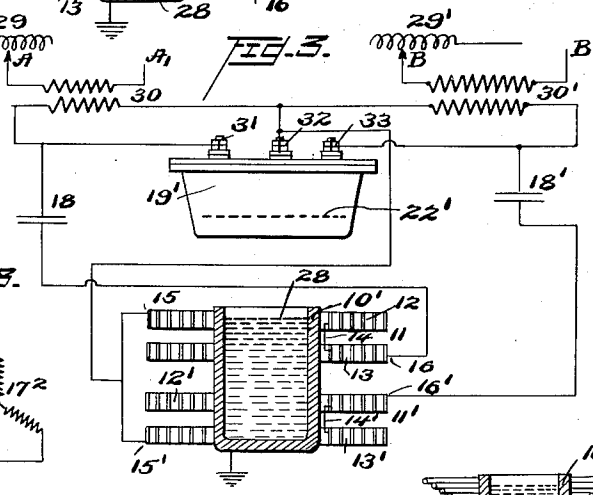


FIG. 8.

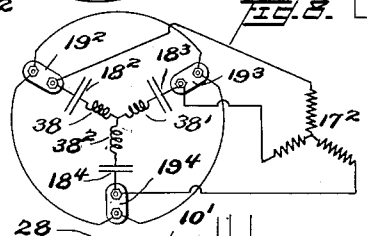


FIG. 4.

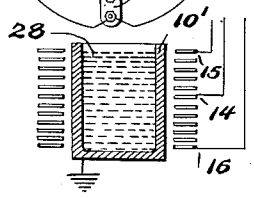


FIG. 7.

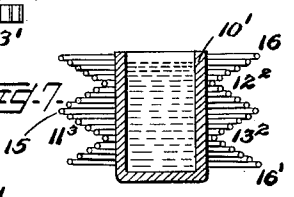


FIG. 5.

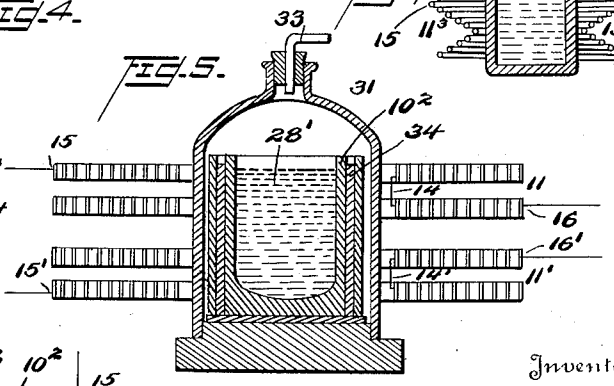


FIG. 6.

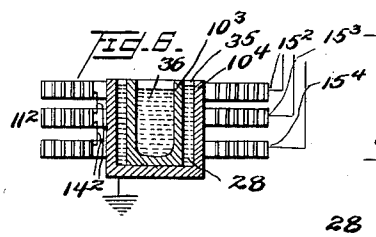


FIG. 6a.

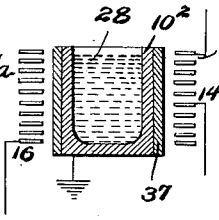
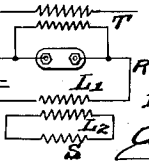


FIG. 9.



Witness

A. Strauss

Inventor

R. Edwin F. Northrup

By

Steell Jackson

Attorney

UNITED STATES PATENT OFFICE.

EDWIN F. NORTHRUP, OF PRINCETON, NEW JERSEY, ASSIGNOR TO THE AJAX METAL COMPANY, OF PHILADELPHIA, PENNSYLVANIA, A CORPORATION OF PENNSYLVANIA.

OSCILLATION SPIRAL COIL AND CONNECTION.

1,330,133. Specification of Letters Patent. Patented Feb. 10, 1920.

Application filed June 18, 1917. Serial No. 175,519.

To all whom it may concern:

Be it known that I, EDWIN F. NORTHRUP, a citizen of the United States, residing at 30 Wiggins street, Princeton, in the county of Mercer and State of New Jersey, have invented certain new and useful Oscillation Spiral Coils and Connections, of which the following is a specification.

The purpose of my invention is to concentrate the energy of an oscillation heating coil upon the resistor to be heated.

A further purpose is to provide an oscillation coil winding having a minimum voltage fall between the resistor or its container and the adjacent parts of the coil.

A further purpose is to so wind an oscillation coil as to bring the approximate center of the coil, having most nearly the potential of the earth, closest to the object to be heated.

A further purpose is to reduce the difference in potential between windings of an oscillation coil and the object to be heated so that the point of highest temperature, where the air is most ionized, will be the point of lowest voltage difference.

A further purpose is to wind oscillation coils in pancake spiral form, coupling them in pairs and utilizing the outer extremities of the spirals as the pair terminals.

A further purpose is to place the condenser and discharge gap mechanism of an oscillation heating coil system in a primary circuit whose secondary feeds an oscillation heating coil, freeing the secondary thereof and the oscillation coil from these features.

A further purpose is to apply the heat to a non-conducting or poorly conducting object to be heated by inclosing the object within a resistor separate from a crucible or the resistor within the object and heating the resistor by induced currents.

A further purpose of my invention is to produce an electric furnace which takes a leading current, enabling me to use the lagging current usually available to advantage and to compensate by positive reactance so as to secure unity power factor.

Further purposes relate to the processes or methods involved, as well as to other benefits which flow from the mechanism whereby they may be performed, and will be found in the specification and in the claims.

I have preferred to illustrate my invention by but a few of the forms in which it may be practised, selecting therefor forms which, in use, have proved to be safe, practical, efficient and capable of heating to very high temperature and which at the same time well illustrate the principles of my invention.

Figure 1 is a vertical section of one form of my invention with diagrammatic connections showing one source of oscillatory current supply for it.

Fig. 2 is a top plan view of the coil and crucible structure seen in Fig. 1.

Fig. 3 is a diagrammatic view showing two-phase connections for energizing two sets of coils similar to the set in Fig. 1.

Fig. 4 is a diagrammatic illustration showing the application of the arrangement shown in Fig. 3 to another type of a helical oscillation heating coil.

Figs. 5, 6, 6^a and 7 are sectional views showing several other means of applying my invention.

Fig. 8 is a diagrammatic view showing circuit connections.

Fig. 9 is a diagrammatic view used in explanation of theory discussed herein.

Similar numerals of reference indicate like parts.

In the use of oscillation currents for electric furnace-work the oscillation current has been passed through a coil of helical coil form surrounding the resistor, as disclosed and claimed in my copending application for oscillation current method and apparatus, Serial No. 133,474, filed November 25, 1916.

The electric energy stored in the condenser, discharging through this coil, oscillates until the energy is finally dissipated in electric radiation, work and heat. The enormous rate of change of the induction

$$\left(\frac{dB}{dt}\right)$$

results in very rapid transfer of energy to the resistor. This sets up large currents

in it, giving high heating effect and a desirable stirring action which latter has been ample to secure good circulation.

The form of spiral shown in my copending application has given excellent results in melting and treating many different metals and solids, at the same time providing the circulation desired and has attained very high temperatures. However, for some special uses such as the melting of platinum and other metals having a very high melting point, or in which so small a depth of material is to be treated that but few turns of the helical coil can conveniently be applied, it is desirable to attain a higher concentration of oscillatory current about the resistor than can conveniently be obtained by the helical coil form.

For this purpose I have invented a form using a pan-cake spiral which gives a much higher concentration within the "belt" affected than can be attained by the helical spiral and which, arranged in series in pairs connected at their inner ends, possess the additional advantage of having the points of highest potential farthest from the crucible or resistor.

The concentration of the field at the center of a pan-cake spiral coil will be appreciated from a brief discussion of the theory applying thereto.

The intensity of the field at the center of a circular coil of one turn carrying a current i is

$$F=\frac{2\pi i}{r}$$

where r is the radius of the coil. Let the coil be wound with n turns to unit length measured along the radius, then the field due to these n turns of average radius r_a is

$$F=\frac{2\pi in}{r_a}.$$

The field due to a coil of radial depth dr is

$$dF=\frac{2\pi indr}{r}.$$

Hence

$$F=2\pi in\int_{R_1}^{R_2}\frac{dr}{r}=in\log_e\frac{R_2}{R_1}.$$

Or again, if r_a be the mean radius of a spiral coil having a total number of turns N, then

$$F=\frac{2iN}{r_a}.$$

This gives, within a belt of very short vertical height, substantially the same energy as would be distributed over the entire axial length of a helical coil having the same number of turns, greatly concentrating the heating effect and increasing the circulation.

When high temperatures are required, the heat of the resistor, here illustrated as metal in a crucible, reacts upon the coil and also causes ionization of the air immediately about the resistor affording a ready path of leakage from coil to the resistor or the crucible, where one is used, or even from one portion of the coil to another. This is objectionable because of the danger of injury to workmen by reason of the high voltage leakage and also because of the waste of energy which then does not pass through the entire coil. My pan-cake spiral form is practically unaffected by the ionization of the air about the resistor.

I show several sets of circuit connections for my coils, presenting forms which differ both in the number of phases of current utilized and in the location of the condenser and the discharge gap. These are placed in a separate circuit from that including the coil in Fig. 1 though the two circuits are inductively connected. They are located in the same circuit with the coils in Fig. 3.

Again I show condensers charged and discharged separately in Figs. 1 and 3 and series connections between the condensers in Fig. 8. In each case the single condenser shown is intended to be a representative of the total capacity whatever the number of condensers used.

The differences in these illustrations are intended to illustrate the independence of my coils of the character of connections by which the oscillatory current is supplied, as the variety of circuits suitable for the purpose is recognized by me to be very great.

In Figs. 1 and 2 I show the crucible 10 as surrounded by an oscillation coil 11 intended for single phase use, comprising two concentric, superimposed, oppositely wound pan-cake spirals 12, 13, joined at their inner ends and inductively disposed as at 14 and connected with the supply circuit at their respective outer ends 15, 16, so that the oscillation current used enters one coil at its circumference and flows in spirals of decreasing radius toward its inner end and thence flows out in spirals of increasing radius to the extremity of the other coil.

In all of these coils I find lamination desirable in the reduction of losses due to eddy currents and may use laminated strips or wires here.

The energy furnished is derived from any commercial alternating current circuit, represented generally by the single phase primary circuit A A_1. I have successfully used 220 volt current of 60 cycles frequency. With other than the desired voltage, I transform the current at 17 to charge condenser 18, which, at the required voltage, could be charged directly. The condenser discharges through any discharge gap 19. I

have secured the best results with a voltage of from 8,000 to 10,000 and a high voltage double discharge gap across from a solid electrode 20 to mercury 21 at one gap and across from a second pool of mercury 22 to a solid electrode 23 at the other, in one direction of travel and across similar gaps in the opposite direction. The mercury electrodes are electrically connected at 24. The high negative electrode resistance of mercury is thus utilized in both directions of current travel. This is an excellent type of gap but, *per se*, is not claimed in my present application, being embodied in a separate application for patent for discharge gap, Serial No. 175,518, filed June 18, 1917.

The condenser discharges through one winding 25 of a mutual inductance 26 whose other winding 27 is in series with and supplies the pan-cake spiral coil 11.

For the reason that the outer ends of the spirals are at maximum and opposite potential as indicated and their inner connected ends are, as a result, at substantially zero potential, the pan-cake coils of the pair are inductively wound as appears from Fig. 2.

Though the character of the resistor to which the pan-cake spiral coils are applied does not affect their theory of operation as coils, the prospect of immediate and highly desirable practical use in melting metals having high melting points has led me to illustrate my invention in the figures as applied to crucibles 10, 10^1, 10^2, 10^3 and their contents 28.

Obviously the number of pairs of pan-cake spirals used, whether with single phase or multi-phase supply, will depend upon the height of the crucible content, the desired depth and spacing of the individual spiral coils and other factors of material treated, special conditions met, etc., such as determine the design in individual cases.

In Fig. 3 the oscillation coil 11 in Fig. 1 has been duplicated at 11′, at another point along the height of the crucible and is used with any of a large variety of two-phase connections.

The two phases A, A_1, B, B_1 of the primary current source are shown as provided with adjustable inductances 29, 29′ and as transformed at 30, 30′ to charge condensers 18, 18′. The condensers discharge through discharge gaps here illustrated as plural gaps passing from a solid electrode to mercury and from the mercury to a solid electrode in each phase and in each direction of impulse travel. These gaps are shown as contained in a single pot 19′, having three solid electrodes 31, 32 and 33 of which 32 is shown as connected to the neutral point. These discharge gaps utilize a common mercury pool 22′.

One terminal of each of the two spiral coil furnace pairs is connected as at 16, 16′ with one of the condensers and the other terminal of each, as 15, 15′ is connected with the common solid electrode.

Obviously the two pairs of pan-cake spirals could be arranged separately as in Fig. 4, or in multiple using single phase supply; and also the same two-phase connections can be used with other spiral coils, of which one helical oscillatory heating coil illustration is given in Fig. 4. Both spiral forms offer some advantage with multi-phase connection, particularly as the commercial alternating current supply in many cases is multi-phase and single phase users are penalized for unbalancing the multi-phase circuits. With the connections shown, the required current is drawn equally from both phases and no unbalancing takes place.

I believe that I am the first to produce an electric furnace circuit which takes a leading current—*i. e.* in which the secondaries of the transformers or the primary current supply leads into an initial negative reactance. This condition in my furnace makes it possible to secure unity power factor by means of the adjustable positive reactances; and those can be placed either in the primary or the secondary circuit. Most commercial circuits have a lagging current. The user can sometimes purchase power more cheaply if supplying a load that has an initial leading current.

If it be desired to connect the coil in Fig. 4 in such a circuit as that in Fig. 3, the terminals 15^2 will correspond with terminals 15, 15′ of Fig. 3 and terminals 16^2, 16^3 will correspond with terminals 16, 16′.

Because of the extreme difficulty in melting platinum in an electric furnace, I have illustrated one construction in Fig. 5 intended especially for this use. This metal is melted, commercially, in small quantities and most desirably in a vacuum. The platinum 28′ to be melted is therefore inclosed within a quartz bell jar 31 resting upon a base 32 and provided with vacuum connection through tube 33. The metal is contained in a refractory crucible 10^2 for which I have preferred to use a mixture of CaO and MgO which is conducting when hot. In this illustration, I surround the crucible by a cylinder 34 of compressed tungsten powder and that in turn by a refractory lining of silex which possesses high heat insulating properties.

Other substances than tungsten may be used. Molybdenum gives good results, and the range of suitable substances increases as the temperature to be attained reduces. Whatever the material used for this auxiliary or supplemental resistor, it may be used to assist in the heating of the platinum or other material treated. When treating substances which are non-conductors of elec-

tricity, this resistor may become the chief or only effective heater and the only resistor.

The electrical connections shown are for two independent electrical sources of supply, but the coil may obviously be connected to any two-phase source where desired.

In Fig. 6 I have shown a set 11^2 of three pan-cake coils connected at their inner ends at 14^2 and having their outer terminals 15^2, 15^3, 15^4 adapted for three phase star current supply, which may be furnished by such connections, for example, as in Fig. 8.

In Fig. 6 I have shown the positions of the material being treated and the auxiliary or main resistor as reversed with respect to the arrangement in Fig. 5. The crucible 10^3 is placed within a crucible 10^4 leaving a space 35 between them, within which space the material to be treated is inserted. The auxiliary or main resistor, as the case may be, is placed within the inner crucible and may be in the form of grains or small pieces of tungsten, molybdenum or even iron. I have successfully used steel nails for this purpose where the temperature to be secured was not too high.

Whatever the material composing the resistor 36, it may evidently be disposed in various ways with respect to the material which is to be heat-treated.

In Fig. 6^a I have shown a molybdenum cylinder 37 as surrounding the crucible 10^2. The helical spiral form of winding is shown with two-phase connections.

In Fig. 7 the truncated conical windings partake in part of the nature of each of the two types of spiral previously discussed, in that the successive turns continuously vary in radius at the same time that they progress axially along the resistor. A part of the benefit of each of the other two windings is thus secured. The cross section of the coil 11^8 is here circular, permitting lamination as with the other conductors and with the same advantage.

In Fig. 8 connections are shown for one form of three phase star winding. The secondary of a three phase star transformer is shown at 17^2 and is connected with discharge gaps 19^2 19^3 and 19^4. Each of these gaps is of my preferred double-gap form of solid-to-mercury and mercury-to-solid type, the second solid electrodes in all three gaps being connected together so that these double gaps discharge in series in each case.

Three condensers 18^2, 18^3, 18^4 are charged from the transformer secondary in series of two and discharge in series through two furnace coils and two double-gap discharge gaps in each case in the illustration. Three star-connected furnace coils 38, 38′, 38^2, are shown and any of the forms of winding of the coils may be used.

It will be seen that all of the forms of my invention permit maintenance of vacuum conditions or any desired pressure of gas or gases or liquid or mixture thereof while the material treated is subjected to the heating effects of my coils, but that a greater intensity of induction in the resistor can be obtained with the pan-cake spiral form. The pressures of the "atmosphere" of treatment may be above or below normal air pressure.

It will also be evident that I can obtain all the advantage of the use of an electrically conducting crucible while actually holding the material treated in a crucible of non-conducting material for heat-treatment of a non-conductor of electricity; and that independently of the character of crucible desired, I can obtain the benefit of a highly refractory conductor to improve the heating effect of an oscillation coil upon an electrically conducting resistor having a high melting point.

In all of the uses of my invention it is desirable to apply the induction at a maximum rate of transfer of energy between the oscillation heating coil and the resistor to be treated. I have therefore studied the conditions determining the ohmic resistance which the resistor should have for maximum rate of transfer and give the result of my investigation in a simple case.

Referring to the diagram in Fig. 9, let T be a transformer supplying current to charge condenser C through resistance R and one of mutual inductance coils having inductance L_1. Let L_2 be the inductance of the other of these coils, S the resistance to be determined for the resistor and N the frequency of the alternating current supplied. Then

$$S = 2\pi N L_2 \text{ and } N = \frac{1}{2\pi\sqrt{L_1 C}}$$

Substituting the value of N,

$$S = \frac{L_2}{\sqrt{L_1 C}} = \text{Value of S for maximum rate of energy-transfer to resistor circuit.}$$

With the pancake spiral form I obtain a number of advantages which I believe cannot be secured to the same extent by any other form of coil:—

One of its chief advantages for oscillatory currents is its freedom from leakage and break-down at the parts nearest to the resistor where the high temperatures attained have ionized the air and the danger of leakage or breakdown is greatest with other forms of coil. Being midway between the outer extremities of the pancake coils, the inner turns are substantially at zero potential. I may furthermore ground the crucible or resistor as indicated in some of the figures, giving additional security to the workmen.

All the points of high potential are distant

from the crucible or resistor, where there is no ionization of the air and where the temperature is low enough for good insulation to be easily secured.

An intense field can be produced in a small volume of resistor adapting oscillation current treatment to resistors of short length.

Because of the low potential of the inner turns of the coil, the latter can be made to hug the crucible or resistor much more closely than would otherwise be permissible, making possible a larger number of turns for a given diameter and axial length than could otherwise be used.

In each pair of spirals any desired rate of increase of vertical spacing between turns of correspondingly increasing radii and potential difference may be obtained by double cone-frustum construction. This will be true as shown in the pairs 12^2, 13^2 in Fig. 7; and pairs of such pairs may be joined as there shown, using two-phase supply with the neutral at 15 and the phase terminal connections at 16, 16'.

As a result of the advantages set out above, my invention has great utility in studying the melting points and properties at high temperatures of various metals, refractories and refractory oxids under special conditions as to pressure and atmosphere, the making of fine glass and enamel, which can be done readily within an iron sagger, the testing of materials to determine their gaseous contents and preserve the residuums unchanged except for the removal of the gas, and a great many other uses, too numerous to mention but which will occur to those skilled in the various arts in view of my disclosures herein.

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

1. A hollow pancake heating coil adapted to stand a high temperature and having the interior end of the coil spaced much farther from the center thereof than the spacing of adjacent turns of the coil from each other.

2. A hollow pancake heating coil and a furnace inclosed thereby.

3. Two superimposed connected pancake heating coils connected together at their inner ends, a furnace crucible within the coils and a source of electrical energy applied to the outer ends of the coils.

4. A hollow pancake heating coil continuously varying in diameter and having the interior end of the coil spaced much farther from the center thereof than the spacing of adjacent turns of the coil from each other.

5. Two superimposed connected air-insulated pancake heating coils having the interior ends of the coils spaced farther from the center thereof than adjacent turns of each coil are spaced from each other.

6. Two superimposed air-insulated inductively-wound hollow heating coils connected at their inner ends and having the interior ends of the coils spaced farther from the center thereof than adjacent turns of each coil are spaced from each other.

7. Two hollow pancake heating coils, electrically connected at their inner ends in combination with electrically-conducting material within the hollow of the coil.

8. A pair of coaxial pancake heating coils connected in series in combination with electrically-conducting material within the hollow of the coil.

9. A pancake heating coil in combination with oscillation current supply therefor.

10. A heating coil having both of its terminals located radially at a considerable distance from some of its turns in combination with a source of high frequency current supply therefor.

11. Two pancake spiral heating coils in superimposed position having the inner ends of the coils spaced much farther from the centers therefor than the spacing adjacent turns of each coil from each other and means for passing electric current through both coils from the same source.

12. A pancake heating coil, means for passing oscillating electric current therethrough and a resistor at the center of the coil receiving the induction therefrom.

13. A crucible and a hollow oscillation heating coil thereabout comprising a pair of spirals connected in proximity to their inner ends and progressively increasing in diameter toward their terminals.

14. A pair of spiral coils progressively increasing in diameter and connected at their inner ends, a crucible within the coils and a source of oscillation current discharge connecting with the terminals of the coils.

15. In an electrical furnace, an alternating electric circuit, a mutual inductance coil, a condenser and a discharge gap arranged in series and together in series with one winding of said mutual inductance coil, and an oscillation heating coil in series with the other winding of said mutual inductance coil.

16. In an electric furnace, an alternating current transformer, a condenser charged by the secondary of said transformer, a mutual inductance, one winding of which is in series with said charging circuit, a discharge gap thrown across the condenser and an oscillation heating coil in series with the other winding of said mutual inductance.

17. In an electric furnace, a mutual inductance, a condenser arranged to discharge through one winding of said mutual inductance, charging means for said condenser, a discharge gap adapted to discharge said condenser through said winding, and an oscillation heating coil in series with the other winding of said mutual inductance.

18. In an electric furnace, a condenser and discharge gap therefor in one circuit and an oscillation heating coil in a second circuit in inductive relation to the first circuit.

19. In an oscillation coil furnace, a mutual inductance, means for impressing an oscillatory current upon the terminals of one winding thereof and a heating coil in circuit with the other winding thereof.

20. In an oscillation coil furnace, a mutual inductance, means for supplying an oscillating current to one winding thereof and a heating means in circuit with the other winding thereof.

21. A heating coil and oscillatory inductive means for supplying current to the coil.

22. In an electric furnace, a pair of crucibles providing two resistor spaces, one within the inner crucible and the other between the crucibles, in combination with a conducting refractory in one of the spaces and oscillation means for inducing electric current flow in the refractory.

23. In an electric furnace, a pair of crucibles providing two resistor spaces, one within the inner crucible and the other between the crucibles, in combination with a conducting refractory in one of the spaces.

24. In an electric furnace, a pair of nested crucibles providing a space between the crucibles and a space within the inner crucible in combination with an auxiliary resistor in one of the spaces adapted to assist in the heating or treating of a resistor in the other of said spaces and oscillation means for inducing electric current flow in the refractory.

25. In an electric furnace, a pair of nested crucibles providing a space between the crucibles and a space within the inner crucible, in combination with an auxiliary resistor in one of the spaces adapted to assist in the heating or treating of a resistor in the other of said spaces.

26. In an electric furnace, an oscillation coil, a crucible therein adapted to hold a material to be heated or heat-treated and a resistor surrounding the crucible and adapted to assist in heating the material in the crucible.

27. The method of applying oscillation currents to the heating of resistors which consists in applying the highest potential of said oscillation currents at a distance from the resistor and causing it to circulate about the resistor at distances becoming less as the potential lowers.

28. The method of applying oscillation currents to the heating of resistors which consists in applying the highest potential of said oscillation currents at a distance from the resistor and causing it to circulate about the resistor at distances becoming less as the potential lowers and maintaining approximately the potential of the earth at the point of closest approach to the resistor.

29. The method of applying oscillation currents to the heating of a resistor which consists in applying the highest potentials of said oscillation currents at the greatest distances from the resistor to be heated and causing the currents to circulate about the resistor at decreasing radial distances as the resistor is approached.

30. The method of heating a resistor by an oscillation current circulating about the resistor in inductive relation thereto, which consists in reversely directing the oscillation current between the two terminals in different planes, approaching and receding from the resistor as the current circulates about it and forming a connection between the two paths of current flow in proximity to the resistor.

31. The method of heating a resistor to high temperature by oscillation currents which consists in circulating oscillation current about it, maintaining the highest potential of oscillation current at the points of lowest temperature and reducing the potential of the oscillation current as the points of higher temperature are approached.

32. In the method of heating a resistor to a very high temperature, the step which consists in applying an oscillation current to terminals at a distance from the resistor of separate windings which encircle and approach the resistor and joining the windings at the point of nearest approach to the resistor and highest temperature.

33. The method of avoiding the injurious effects of air ionization in proximity to a resistor of very high temperature in oscillation coil heating thereof which consists in placing a part of the coil having the approximate of the earth potential in the position of highest temperature and in disposing the parts of the coil of higher potential at increasing distances from the resistor.

34. The method of heating by oscillation currents which consists in forming an oscillation current in one circuit, in transforming said current into a second circuit and utilizing the oscillation current for heating purposes in said second circuit.

35. The method of utilizing oscillatory currents for heating uses, which consists in charging and discharging a condenser through a different circuit from that in which the heat utilizing means is included and in inductively coupling the two circuits.

EDWIN F. NORTHRUP.