

March 7, 1933.

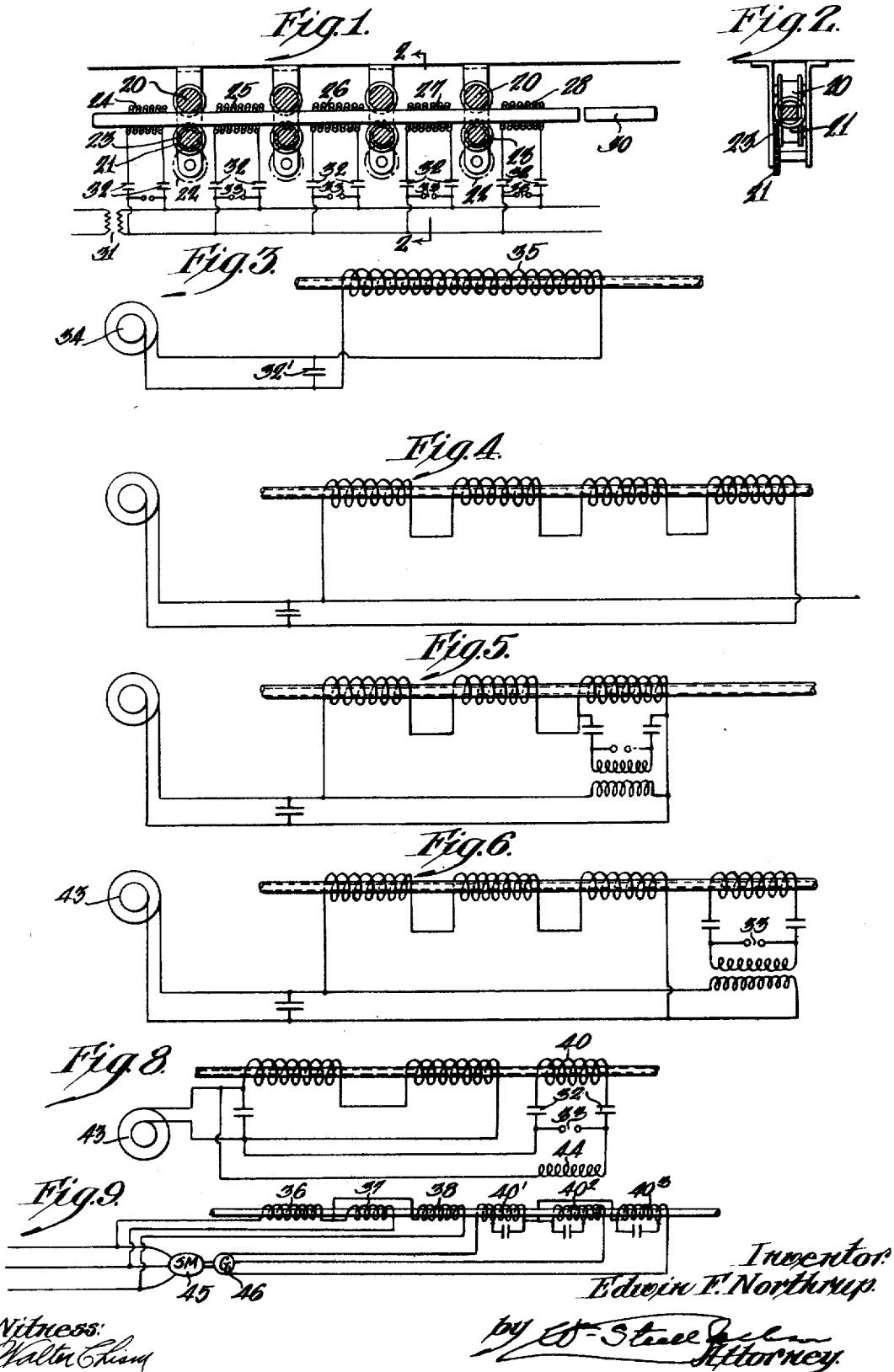
E. F. NORTHRUP

1,900,842

HEATER FOR RODS AND TUBES

Filed Dec. 21, 1925

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

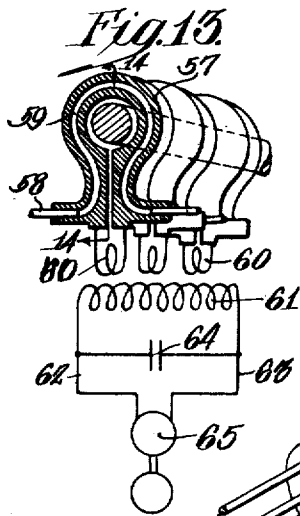
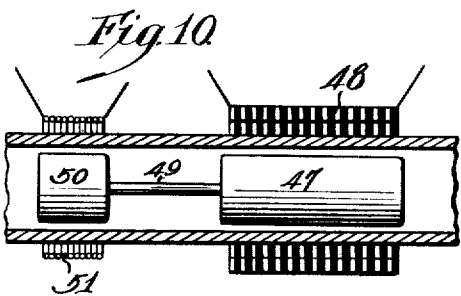
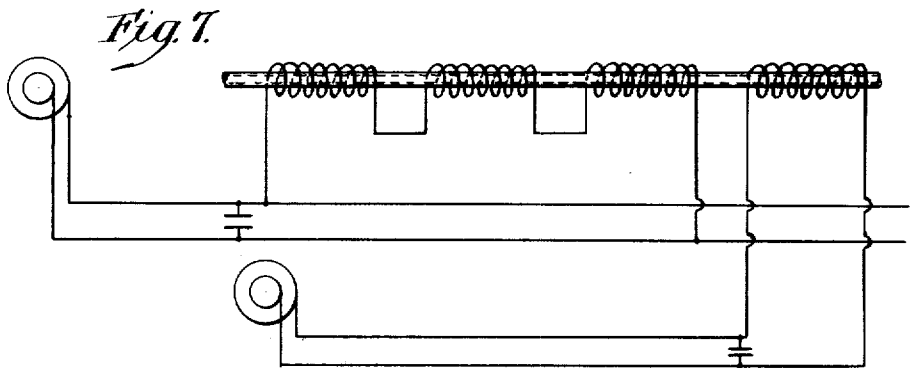


Fig. 11.

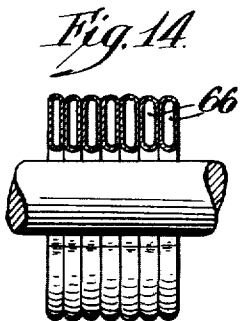
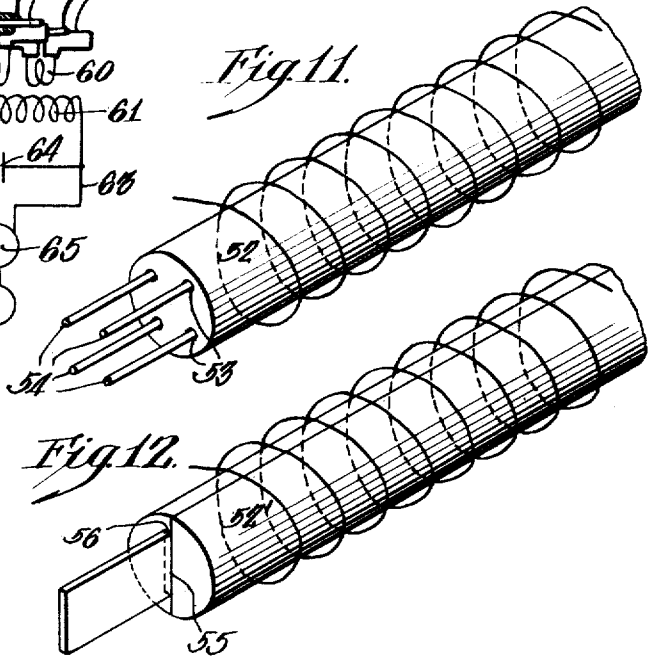


Fig. 12.

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UNITED STATES PATENT OFFICE

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HEATER FOR RODS AND TUBES

Application filed December 21, 1925. Serial No. 76,878.

My invention relates to the inductive heating of solid and tubular articles both fixed and movable and to apparatus by which these methods may be practiced.

5 One of the purposes of my invention is to surround solid or tubular articles with a conductor through which high frequency current is to be passed and to heat them by the current induced preferably while they are passing through the coils but permissibly during stops in step-by-step feeding.

10 A further purpose is to apply induction to a moving rod or tube by a coil or coils surrounding the rod or tube and through which current is passed having a frequency above normal frequencies and a corrected power factor.

15 A further purpose is to provide parallel coils or turns all fed from the same source of high frequency current and all operating successively upon the same tube or rod fed through them for the purpose of adding successively increments of heat to the rod, strip or tube passing through them.

20 A further purpose is to heat a magnetic rod, strip or tube by successive increments from induction at different frequencies.

25 A further purpose is to use a relatively low frequency for inductive heating of rods, strips or tubes of magnetic material up to nearly the point at which they lose this property, to heat them beyond this point by a higher frequency using the same inductor or part of the same inductor for both, either at the same time or separate times.

30 A further purpose is to supply part of the inductor for a heating system from a line from which a synchronous motor is driven, to provide excess KVA in the synchronous motor in order to correct the power factor of this portion of the inductor and to supply the remainder of the inductor from a generator driven by the synchronous motor and having the power factor corrected by condensers.

35 A further purpose is to correct the power-factor of alternating current coils carrying high frequency current and forming a plurality of heating zones, performing part of

the heating function cumulatively in each of successive zones.

A further purpose is to provide a plurality of inductors in series within the same secondary winding, preferably with the axes of their zones of inductance parallel. 55

Further purposes will appear in the specification and in the claims.

I have preferred to illustrate a few forms only among many in which my invention may appear, selecting forms which best illustrate the principles of my invention. 60

Figure 1 is a longitudinal section of one form of inductor applied to a travelling bar or rod. 65

Figure 2 is a section of Figure 1 taken upon line 2—2.

Figures 3, 4, 5, 6, 7, 8 and 9 are diagrammatic forms showing different circuit connections. 70

Figure 10 is a longitudinal section showing a core anchorage.

Figures 11 and 12 are perspective views largely diagrammatic showing muffles. 75

Figure 13 is a side sectional perspective showing another form. 80

Figure 14 is an elevation corresponding to section 14—14 of Figure 13 but showing a plurality of conductors to the single turn.

In the drawing similar numerals indicate like parts. 85

Though I prefer to operate at a higher frequency than that of existing current supplies and gain considerable advantage from this, features of my invention are of advantage whatever the frequency and are claimed accordingly. 90

In Figures 1 to 9 I have shown different ways in which current at more than normal frequency can be supplied to an inductor comprising a single coil or spaced coils operating upon the same moving bar, rod, strip or tube of regular or irregular shape, or to a conducting content, to raise it to the required temperature as for rivet heating, tube or strip annealing or for other operations. By these different illustrations I have intended to indicate that the application of abnormal frequency to this duty involves invention in 100

addition to whatever merit may lie in the manner of applying it.

In Figures 1 and 2 I have shown a method of integrating the heating effects of successive coils through which high frequency current is passed in the heating of a bar or rod which is advanced to progress either continuously or intermittently as preferred, as by a set of rollers 20 and 21 suitably mounted and one of them driven by any suitable gearing, here typified by gears 22 and 23 of which 23 is on the same shaft as the feed rollers 21. The coils 24, 25, 26, 27 and 28 are here shown as helical coils nearly fitting the bar, wire, rod or strip 29 of which a section 30 has just been cut for use. I have not considered it necessary to illustrate the protecting covers for preventing undue cooling of the bar etc., between the coils, as these could exist in great variety. The coils could be water-cooled if desired as in the case of the annular coils shown in my patents.

The coils are shown as separate and as separately supplied with high frequency current through transformers 31 whose primaries receive current at existing frequencies. The secondaries are connected to the coils through condensers 32 which when charged discharge across gaps 33. They can be one long coil or a series of coils depending upon the rate of speed of the charge.

Such a mechanism as described is suitable, for example, for heating a bar, rod, strip or wire from which nails or spikes are to be made and the one portion 30 of the bar or rod is separated as would be the case in the making of spikes. Both hysteresis and eddy currents may be present and the bar, rod, strip or wire would be delivered continuously or intermittently to the cutting mechanism of the nail or spike machine at any temperature designed, as required for the heading mechanism.

It will be evident that the methods and mechanism herewith are capable of use generally or to heat treat electrically conducting objects in motion or which are moved step by step between treatments, whether they be magnetizable or not; and that the treatment may be applied to the special form of objects to be treated by accommodation of the coils in shape to these forms. The materials primarily to be treated when not electrically conducting may be treated by mounting them on or incasing them within electrically conducting objects in which the heat is developed. Muffle heating is claimed by me in a separate application.

Whereas in Figures 1 and 2 the supply of current to the primary of the transformer may have any frequency such as normal 60 cycle line frequency, in the structure shown in most of the other diagrammatic figures direct connection with a generator is contemplated for some at least of the inductor

coils, and the frequency chosen will depend largely upon the temperature to which the charge is to be heated, the desirability of using direct line current or current from a special generator, and the cost of power factor correction.

Where the temperature intended to be reached is below the point at which iron or steel loses its magnetic properties a much lower frequency will suffice than is required where the final temperature intended is above this point, with the result that a choice is offered for these higher temperatures between raising the frequency of the entire equipment to a frequency which will be effective above the recalcence point or raising the temperature in a part of the range required by an inductor operating at one frequency and utilizing another higher frequency through the same or a separate inductor coil or coils to attain the higher temperatures.

It is very desirable that the frequency shall be high enough so that the energy induced shall not pass appreciably beyond the center of a solid bar or rod operated upon nor tend to pass appreciably beyond the inner wall of a tube which is being heated, and, as later pointed out, the size of stock operated upon therefore materially affects the choice of frequency. However, alternators of the standard rotary multi-polar type are now available giving frequencies of well over 500 cycles which brings direct supply from the alternators within the range of frequency most desirable for present purposes, and frequency changers free from movable parts have made it possible to double or quadruple the frequencies without excessive cost and at a low loss in efficiency.

It is my intention to include within my generator supply such generators and such use of frequency changers as may best suit the needs of the individual installation.

In Figure 3 I show a generator 34 having its power factor corrected directly, supplying an inductor 35 whose positive inductance is balanced by capacity 32', capable, as in the other illustrations, of any required adjustments. The tube is fed through the inductor continuously or intermittently as best suits the purpose for which the tube is heated and the needs of a particular installation.

The coil in Figure 3 is intended to represent any single turn coil, or multiple turn coil or combination thereof fed from a single circuit and interrupted if desired for supporting mechanical or other structure as indicated diagrammatically in Figure 4.

Instead of the direct generator shown in Figure 3 and in other figures herein continuous oscillations can be produced by making use of vacuum electron tubes, complying with the conditions for obtaining oscillations, in that inductive reactance (condensers) and positive reactance (inductance coils) are

combined in the same circuit. I have not considered it necessary to illustrate this mode of securing current.

In Figure 5 I have shown direct alternator feed with power factor correction for all of the inductor coil sections 36, 37, 38 shown, in conjunction with transformer and discharge gap connections corresponding generally with those of Figure 1 for applying high frequency to the last section, 38 of the coil. In this case the high frequency is superimposed upon the lower frequency in the same coil. They may be operated separately. The primary 39 feeds a high frequency circuit corresponding with any of the high frequency circuits shown in Figure 1.

In this form stock, whether solid or tubular, regular or irregular can be raised to a temperature of say 675°C . in the other coils and is lifted in the last coil to say 800°C . or 1100°C . as may be required for the work intended.

In Figure 6 the lower frequency is used as in Figure 4 for operation upon iron or steel which has lost its magnetic properties, and a wholly separate high frequency coil 40 is provided, fed by transformer 41 having its primary 42 across the lower frequency lines and corresponding from this point with one of the high frequency circuits shown in Figure 1.

In Figure 7 separate lower and higher frequency generators 43 and 43' are provided, the lower frequency and the higher frequency each supplying one or a plurality of inductor coil sections 24, 25, 26 and 40 as shown in Figures 3 and 4. The higher frequency has been shown as utilizing a shorter inductor section as would very possibly be the case.

The form shown in Figure 6 would be used where the voltage of the supply line is not high enough to operate the discharge gap.

Where the voltage of the generator 43 is high enough to operate the discharge gap 33, the arrangement shown in Figure 8 is permissible. Here part of the inductor 24, 25 is supplied directly from the generator, with power factor correction, corresponding generally with Figure 3 or Figure 4 and a further part 40 of the inductor is fed through condensers 32. Suitable inductance 44 and discharge gap 33 complete the circuit.

In the form shown in Figure 9 a three-phase current supply at say 60 cycles and any desirable voltage, operates a synchronous motor 45 driving a generator 46 having any frequency and voltage desired, preferably a much higher frequency and voltage.

From the low frequency circuit inductor coils or sections 36, 37 and 38 are fed. The high frequency generator 46 is also shown as three-phase and is connected to inductor coils or sections 40', 40" and 40³. Condensers are shown to correct the power factor of these

coils or sections. All six inductor sections or coils are shown as operating upon the same charge in the form of a bar, rod, strip or tube to be heated by them.

Assuming a power factor initially of the circuit feeding the synchronous motor of 50%, if this motor be given an excess KVA the power factor of the current supply circuit here will be corrected to 100%.

Since a synchronous motor will be needed in any event for driving the high frequency generator the additional cost of doubling the generator KVA is not nearly as great as for the initial KVA required. This power factor correction by excess synchronous motor KVA is in the nature of a by-product advantage. The power factor of the high frequency circuit can also be corrected to 100% by the condensers, giving a two-step means of lifting the temperature, both steps of which operate at 100% power factor.

In order to avoid the objection of the induction passing through or tending to pass through the walls of thin tubing, to obtain the advantage of increase of inductance in the coil when heating tubing of either magnetic or non-magnetic metal and to heat non-magnetic metal with lower frequencies than would otherwise be effective, I provide (Figure 10) an iron core 47 preferably of nichrome or of a steel which has a high recalcrescence point. It is located within the tubing where it is surrounded by the inductor 48, which may be, for example, of hollow edge wound copper, water cooled. The iron core may be held within the pipe by a wire extending to the end of the pipe. Whether operating upon iron or steel pipe or pipe of non-magnetic material the core can be anchored electromagnetically. It can be floated within the tubing at this point by attaching it through wire 49 to an armature 50 held in position against longitudinal movement by a fixed solenoidal winding 51 supplied with direct current. When in operation the inductor coil would tend to hold the core against longitudinal movement. The core can be heated to a temperature of about 675°C . by 60 cycle current and to higher temperatures by higher frequency. It correspondingly heats the tube. This is the more efficient because it heats from the inside and there is no way of escape of the heat except into the pipe.

Where the size of the stock is too small for convenient inductive heating, requiring relatively an excessive frequency, or because of the desirability of heating a number of wires or small rods at the same time or for any other reason, I provide a steel or nichrome muffle 52 (Figures 11, 12) which may be used in many different forms. I have shown but two. In one (Figure 11) the muffle is provided with a plurality of holes 53 through which the rods or wires 54 to be

heated are passed. The muffle can readily be raised to approximately the temperature of recalcence by relatively low frequency current and can be raised to a much higher

5 temperature by high frequency current by means and methods already explained. The wires can be passed through the muffle continuously or step-by-step, or can be heated and withdrawn therefrom.

10 In Figure 12 I show the coil as surrounding a steel muffle 52' which has been longitudinally split at 55 so that it can be grooved to provide a passage 56 through the muffle. The passage in cross section is much longer

15 than it is wide suiting it to the reception of band saw-blade material or other like strips to be heated as for annealing or tempering purposes. Obviously as many passages may be used as desired with the preference, however, that they shall not cut through to the surface, since it is desirable to have the magnetic induction in the steel pass circumferentially about the outlines of the passage. The strip can be heated entirely by heat conduction and radiation from the muffle or it can be placed where part of the induction passes through it. The muffle form is illustrated because it comes within the broader claims of my invention, notwithstanding that subject-matter specific to it is taken care of in a separate application. The same is also true of condenser and discharge gap source of supply.

Heat insulation is provided between the muffle and the coil.

25 In all of the forms where a plurality of turns per coil is used, I prefer to use a single layer coil of edgewound flattened copper tubing and find water cooling of the tubing very desirable.

30 In Figure 13 I have shown a plurality of inductor loops 57 in parallel each capable of being water cooled through pipe connections 58 and conduits 59 and each having a considerable extension along the length of the charge. These loops are shown as having separate secondaries 60 cooperating with the same primary 61 of a transformer fed from any line 62, 63 across which the capacity 64 is thrown in condenser form. In order to provide for higher frequency which will ordinarily be desirable I show the line as fed from motor generator 65.

35 In Figure 14 inductor loops from a given secondary 60 are shown in parallel and as edgewound flattened copper tubes 66 which require no insulation between them as they comprise part of the same turn or loop, differing in this from the edgewound coils such as are shown in Figure 10. Not only electric current but the water flows in parallel through these turns. The edgewise winding of the flattened copper tubing gives a very

40 much larger surface of contact of copper

with the cooling water than in the form shown in Figure 13.

In operation upon stock of the character treated herein, whether it be solid or hollow, of uniform or of irregular cross-section, and whether a core or muffle be used or not, the coupling increases with increased diameter of the stock as the gap required is approximately constant.

The frequency desirable reduces with increase of the diameter or with increased thickness of the stock since it is desirable not to have effective induction extend beyond the center of the stock. This would apply also to the center of the core or muffle where these are used. The formula for determining this frequency is

$$N = \frac{25 \times 10^{-6} \rho}{\mu l_p^2}$$

where N is the frequency, ρ the resistivity of the material, μ the permeability and l_p is the "depth of penetration", approximating one-third of the distance to which the induction extends.

The higher frequencies have the advantage of requiring less capacity to correct the power factor, but have the disadvantage of requiring special generators or other equipment to supply the current. With magnetic materials low frequencies can be used even on relatively small diameters of stock; but when the stock is non-magnetic, unless it be large in diameter, high frequencies must be used if too deep penetration of induction into the stock is to be avoided.

My invention is independent of the number of turns per coil and of the detail of the coil and can be applied with loops as distinguished from turns, with loops in series or in parallel, with coils, single, in series or in parallel and with great variety of current supply. I prefer to water cool the coils and where the inductor coil comprises more than one turn, I prefer to use conductors having one dimension considerably greater than the other in cross-section and with the greater dimension radial to the axis of the coil, whether the coil be water cooled or not.

My invention is applicable to magnetic or non-magnetic materials whether solid or otherwise and to heating of hollow or solid materials directly by the C²R heat development in the materials themselves, wholly or in part, by heat conduction and radiation from a casing or core or muffle within which C²R heat is developed.

In operation the material to be heated may be progressed through the coil or through or about the muffle, step-by-step or continuously or, much less desirably, may be inserted therein and withdrawn. Considering the continuous operation, by odds the most advantageous form, the object or material to be

heated is fed through at a rate such that with the energy available and at the frequency determined upon, it will reach the required temperature or a temperature just high enough to be at the proper temperature at the point of use as it emerges from the final coil or turn. Heating magnetic material to the point at which it begins to lose its magnetism may be effective at a relatively low frequency though, with small stock, or because of expense of power factor correction, very desirably at a frequency higher than available from line sources of supply and heating beyond the recalcrescence point will be performed at a much higher frequency. Where the material is non-magnetic and unless assisted by the inclusion of magnetic material in the form of a muffle or core the heating will be performed wholly at a higher frequency than that of available line sources of supply.

In view of my disclosure herein other forms and uses of my invention will undoubtedly occur to those skilled in the art differing from mine in adaptation to special uses, suiting the preference or whim of the individual designer or for the purpose merely of avoiding copying of my forms and it is my purpose to include herein all such as come within the reasonable spirit and scope of what I regard as a very broad invention.

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

1. In the art of inductive electric heating, a hollow helical coil, a source of high frequency electric current applied to the terminals of the coil and means for moving an article to be heated having much greater length than width or thickness through the coil while it is being subjected to the heating effect of the coil, the coupling between the article and the coil being close.

2. In the art of inductive electric heating a plurality of spaced, helical coils having their axes in line, in combination with a source of high frequency electric current applied to the terminals and means for moving a long article to be heated longitudinally through the coils, the coupling between the article and the coils being close.

3. In the art of inductive electric heating a plurality of helical coils axially in line, means for supplying high frequency current separately to each coil, comprising an alternating current circuit and connections from the circuit to the terminals of the different coils and means for moving a long article to be heated longitudinally through the coil, the coupling between the article and the coils being close.

4. In the art of inductive electric heating, an alternating current generator of standard rotary type having a frequency above normal line frequencies, a plurality of coils

axially in line fed from said generator, means having capacity, applied across the line to improve the power factor, means for continuous or step-by-step progression of a metal article to be heated through the coils to receive successive increments of heat from currents induced by the current passing through the coils, the coupling between the article and the coils being close.

5. In the art of inductive heating, an inductor coil, sources of alternating currents of different frequency, connections for applying the currents through the coil and means for moving a long article to be heated longitudinally through the coil, the coupling between the article and the coil being close.

6. In the art of inductive electric heating, a plurality of inductor coils axially in line, in combination with means applied to the coil terminals for passing current of one frequency through all of the inductor coils and means applied to the terminals of one coil for applying a current of different frequency through one of said coils.

7. In the art of inductive electric heating, an alternating current supply having commercial frequency, an inductor coil fed therefrom and an overexcited synchronous motor run by said current supply connected within the circuit holding the said and adapted to correct the power factor for said circuit, a high frequency generator driven by said synchronous motor, a second inductor coil fed from said generator and means having capacity connected in the circuit of the second inductor coil for power factor correction for the second circuit and means for passing an electrically conductive article to be heated through said coil to receive successive increments of heat by induction from the current therein.

8. An alternating current supply circuit of commercial frequency, an overexcited synchronous motor fed therefrom, an inductor coil fed from said current supply in circuit with said motor and whose power factor is adapted to be corrected by said synchronous motor, a generator driven by the synchronous motor, a second inductor coil in inductive relation with the same charge as the first, connections from the generator to the terminals of said coil and means having capacity for power factor correction for said second coil.

9. A multiphase source of alternating current supply of commercial frequency, a plurality of inductor coils fed therefrom, surrounding and adapted to operate upon the same charge, a synchronous motor driven by said multiphase current supply, a generator driven by the motor, an inductor coil fed from said generator and surrounding the same charge as the other coils and means effective for power factor correction for the circuit of said inductor coil.

10. A multiphase source of alternating cur-

- rent supply of commercial frequency, a plurality of inductor coils fed therefrom adapted to surround and operate upon the same charge, a synchronous motor driven by said multi-phase current supply, a multi-phase generator driven by said motor, a plurality of inductor coils fed from said generator and surrounding the same charge and means for power factor correction for each of the phases of said circuit.
11. A multiphase source of alternating current supply of commercial frequency, a plurality of inductor coils fed therefrom surrounding and adapted to operate upon the same charge, a synchronous motor driven by said multiphase current supply, a generator driven by the motor, and delivering current at a higher frequency than the frequency of the motor supply, a plurality of inductor coils fed from said generator and surrounding the same charge, means for power factor correction for each of the phases of said circuit and means for passing a charge through the coils to receive successive increments of heat by induction from the current therein.
12. In the art of inductive heating, a synchronous motor commercial frequency current supply therefor, a generator driven therefrom delivering a higher frequency than that of the current supply for said motor, a current supply for the motor, a heating inductor coil to whose terminals currents of both frequencies are applied.
13. In the art of inductive electric heating, a plurality of inductor coils adapted to operate successively on the same charge, two separate sources of alternating current supply applied to the terminals of the coils operating at two different frequencies and means for power factor correction of electro-magnetic and capacity character respectively for the circuits of the coils having different frequencies.
14. In the art of electric inductive heating, a heating inductor comprising spaced hollow helical inductor coil sections having a common axis, rotary guides located generally in line with the common axis and adapted to support an article to be heated having greater length than the width or thickness, so that it may be passed through the hollow coils, and a common source of high frequency current connected to pass the current through all of the coils concurrently.
15. The method of heating travelling stock which consists in progressing the stock and coincidentally passing high frequency current around the stock with close coupling to heat the circumference of the stock.
16. The method of heating travelling stock which consists in providing the stock with a definite line of travel and in surrounding the line of travel at close coupling with high frequency current at intervals along its length.
17. The method of heating normally magnetic stock which includes moving the stock, passing about it relatively low frequency current and impressing high frequency oscillations upon the low frequency current where the stock loses its magnetic properties.
18. The method of heating stock of material magnetic at lower temperatures and non-magnetic above a critical temperature which consists in moving the stock, in passing about it at the same point in its travel both high and low frequency current and in allowing the proportion of the induction in it from the two currents to be determined by the permeability of the stock.
19. The method of heating traveling stock, which consists in moving the stock and subjecting it to the induction of high frequency current passing about the surface of the stock at close coupling thereby confining the flow of current to a thickness of the stock at the surface inversely proportional to the square root of the frequency, increasing the resistance and reducing the length of stock necessarily within the coil for a required resistance.
20. The method of heating travelling stock, which consists in moving the stock and in applying increments of heat to it successively by successive inductions of high frequency current at its surface, the coupling of the inducing and induced currents being close.
21. The method of reducing the length of travelling stock through which it is necessary to pass an electric current in order to heat the stock by the I^2R secondary loss, which consists in increasing the frequency of the current above normal and making the coupling with the stock close in order that the proportion of the cross-section of the stock through which the current actually travels may be reduced and its resistance increased.

EDWIN F. NORTHRUP.

CERTIFICATE OF CORRECTION.**Patent No. 1,900,842.****March 7, 1933.****EDWIN F. NORTHRUP.**

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, line 25, after "has" insert the word "not"; page 5, line 95, claim 7, for "holding the said" read "including the coil"; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 19th day of September, A. D. 1933.

M. J. Moore.**(Seal)****Acting Commissioner of Patents.**