June 5, 1934. E. F. NORTHRUP 1,961,621

INDUCTION ELECTRIC FURNACE

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Fig.1.

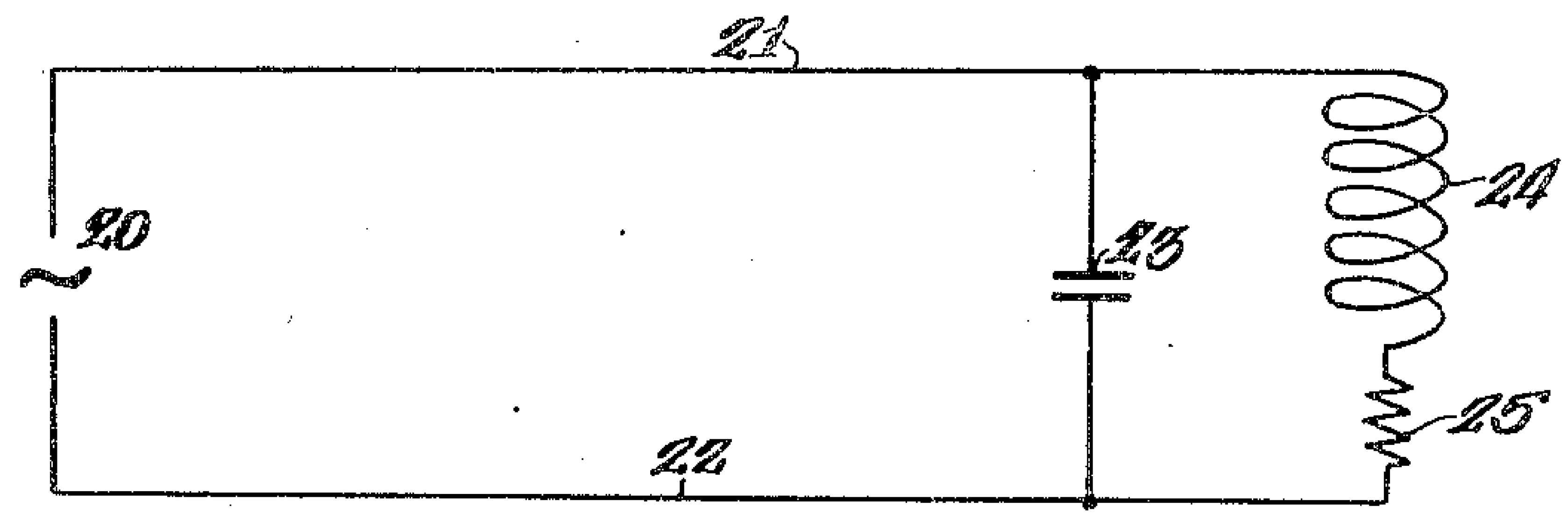


Fig.2.

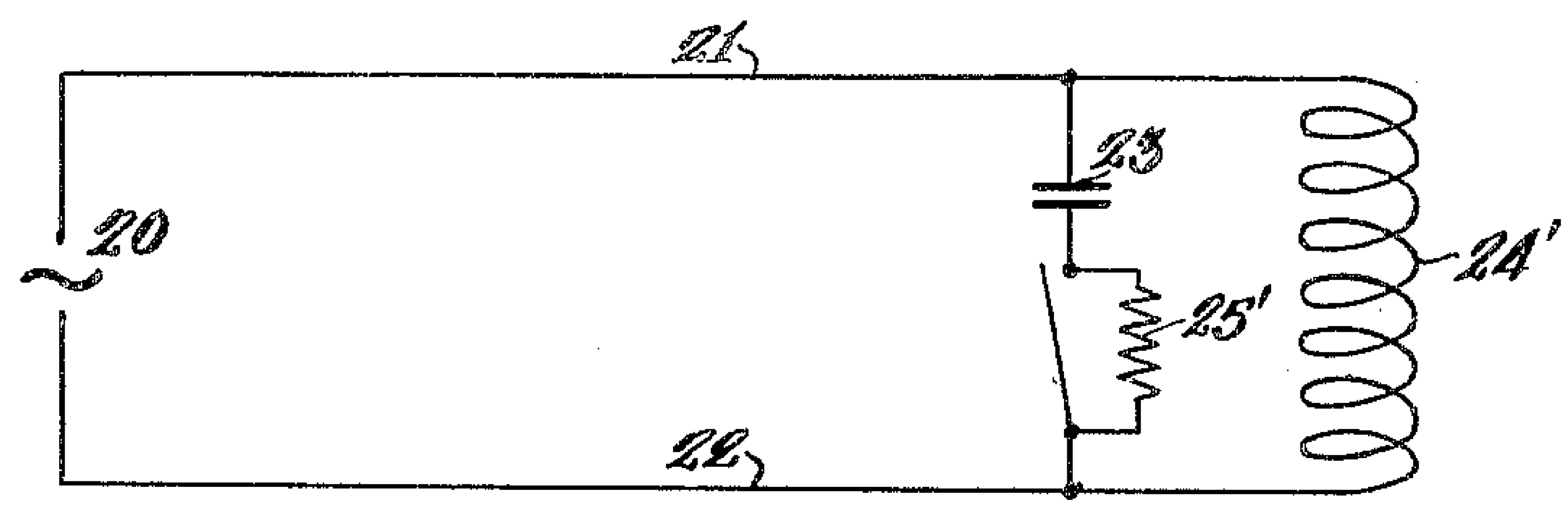


Fig.3.

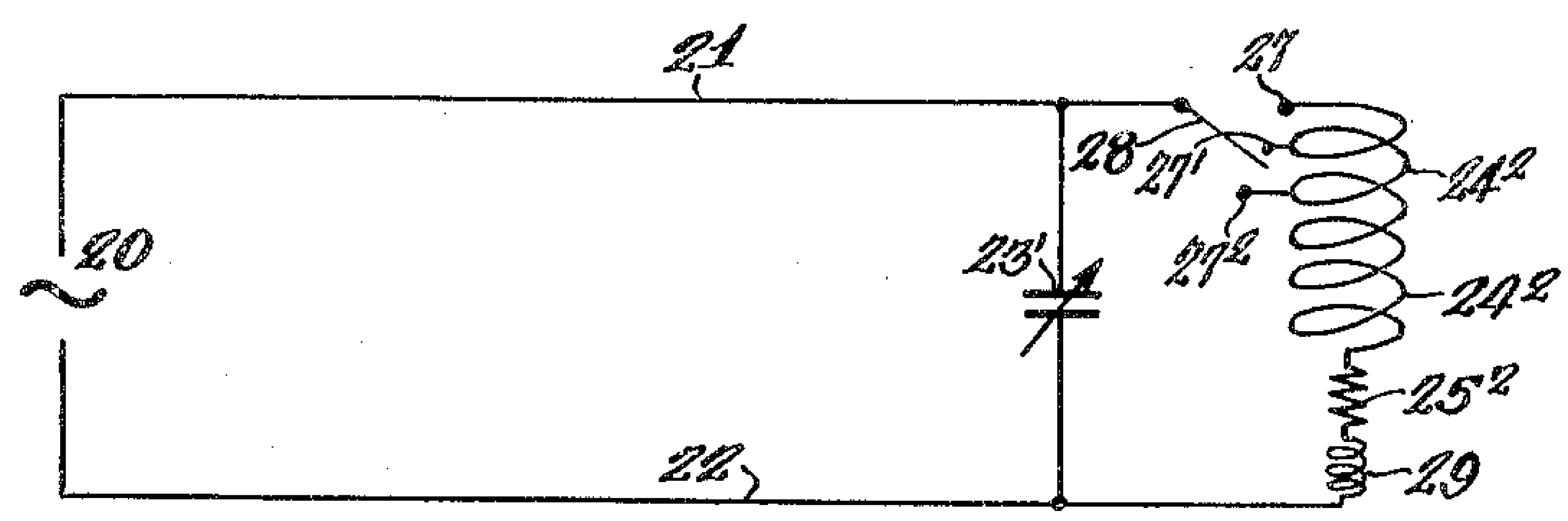


Fig.4.

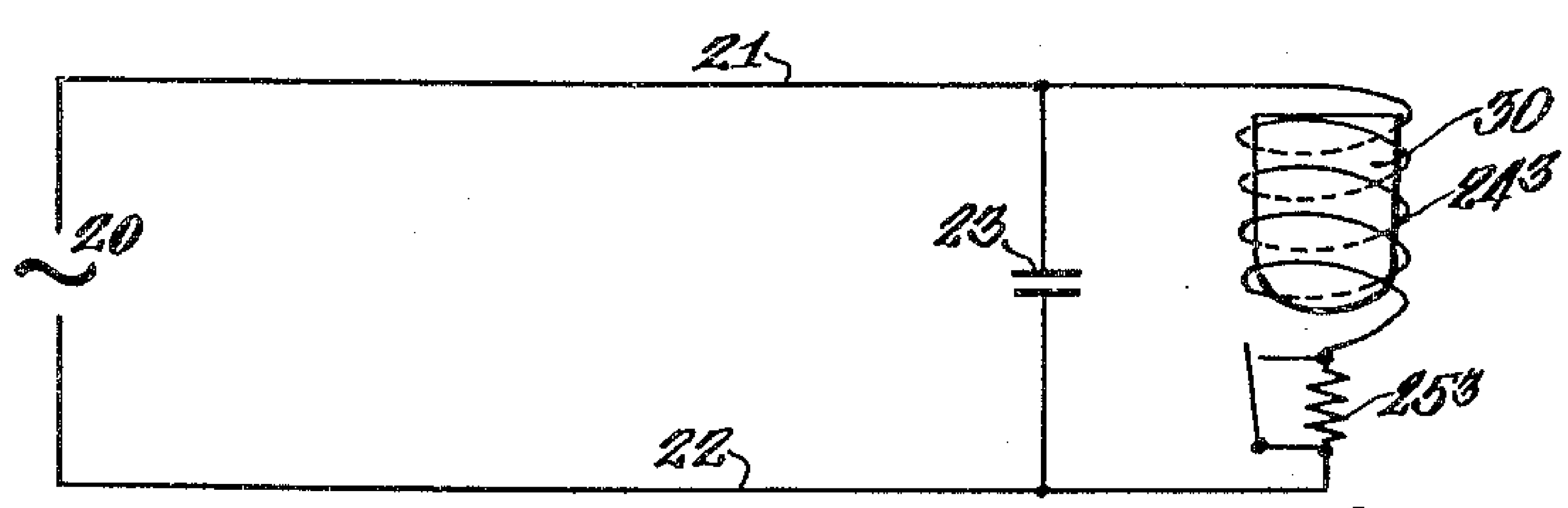


Fig.5.

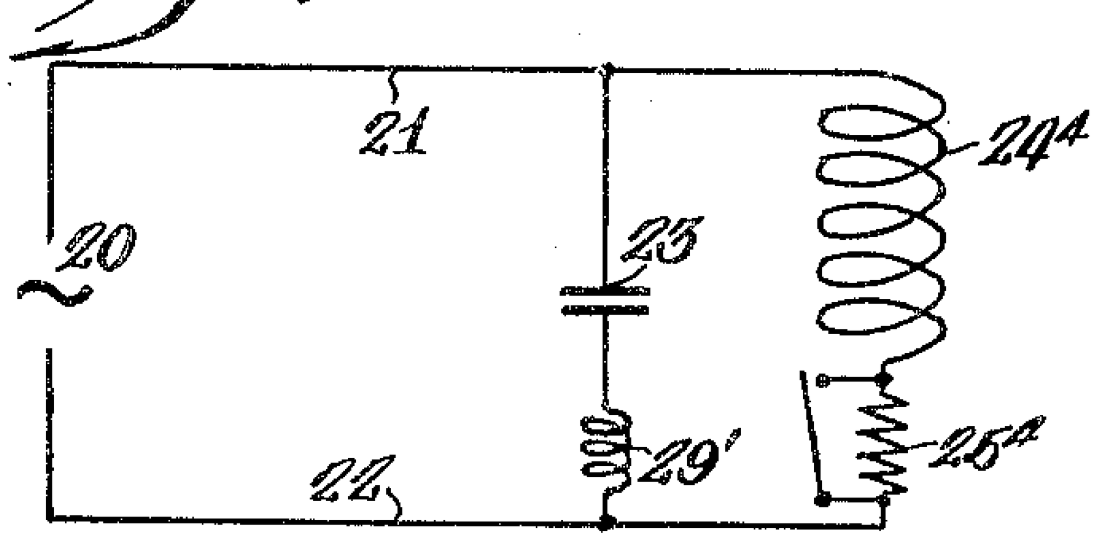
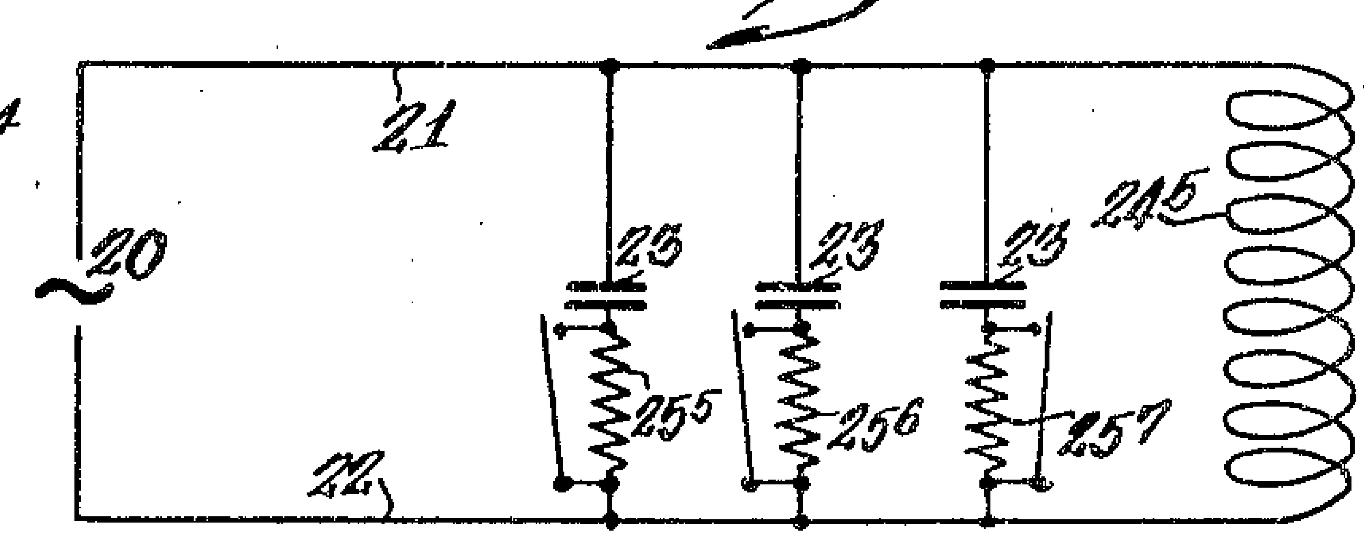


Fig.6.



Inventor:
Edwin F. Northrup
by
Attorney.

Witness:

INDUCTION ELECTRIC FURNACE

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Fig. 10

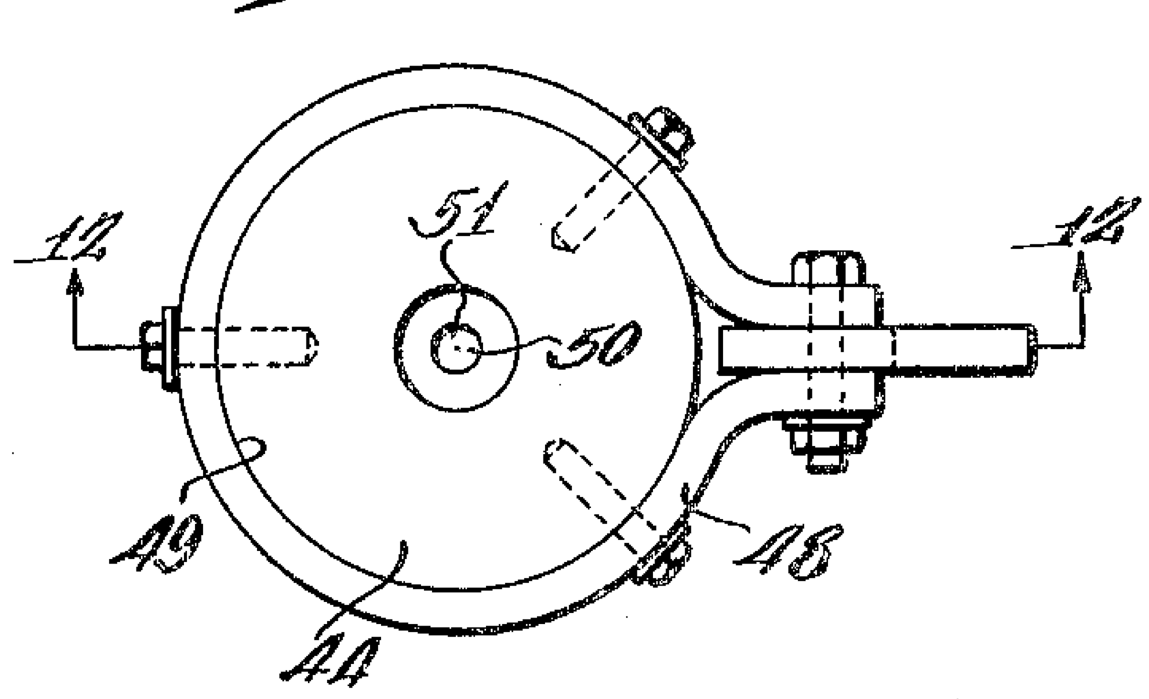


Fig. 7.

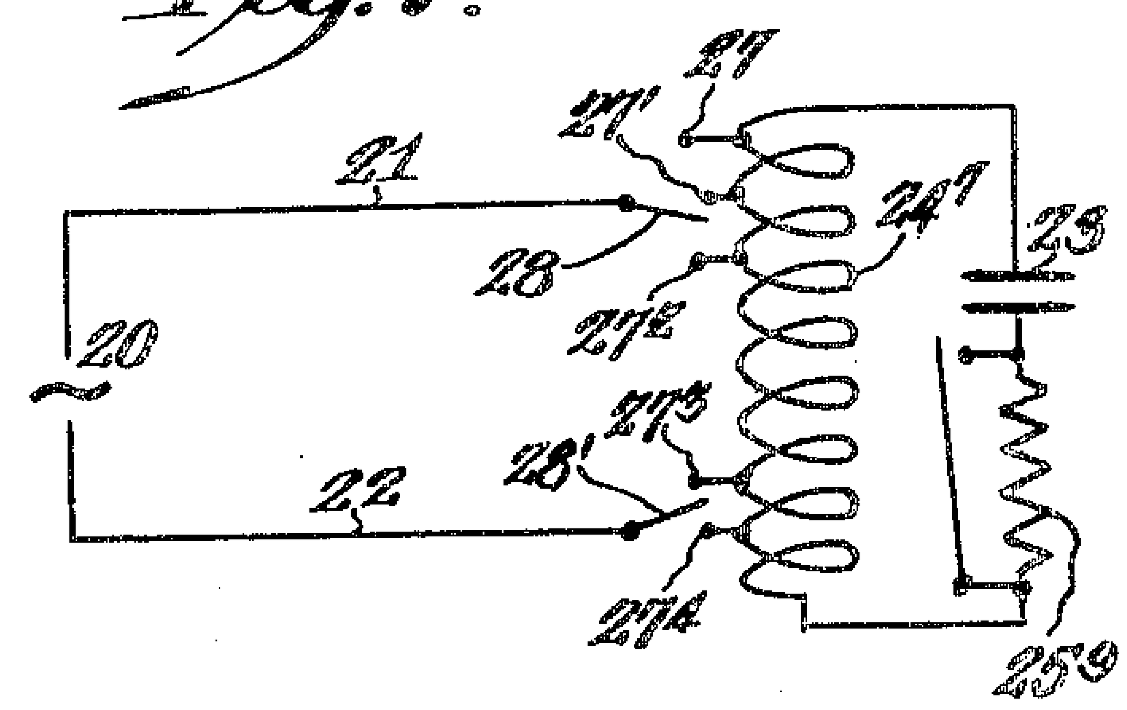


Fig. 8.

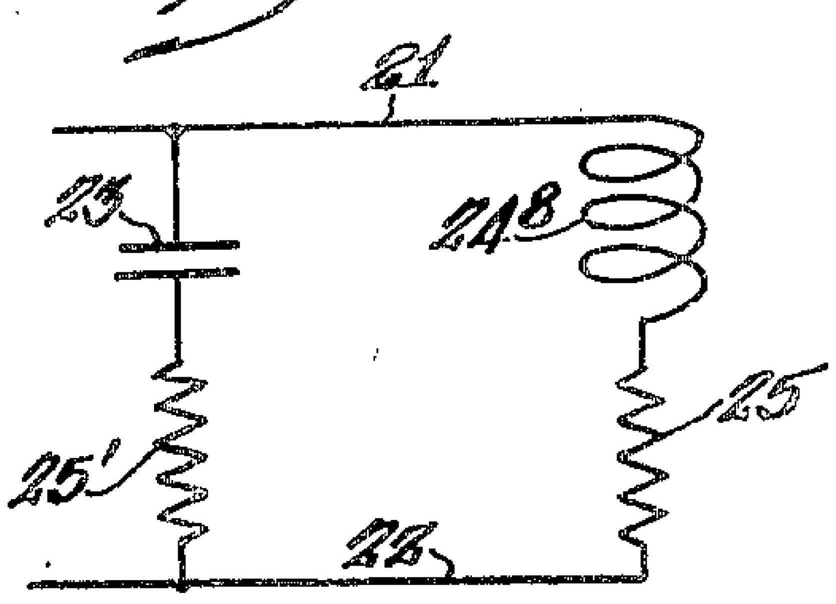
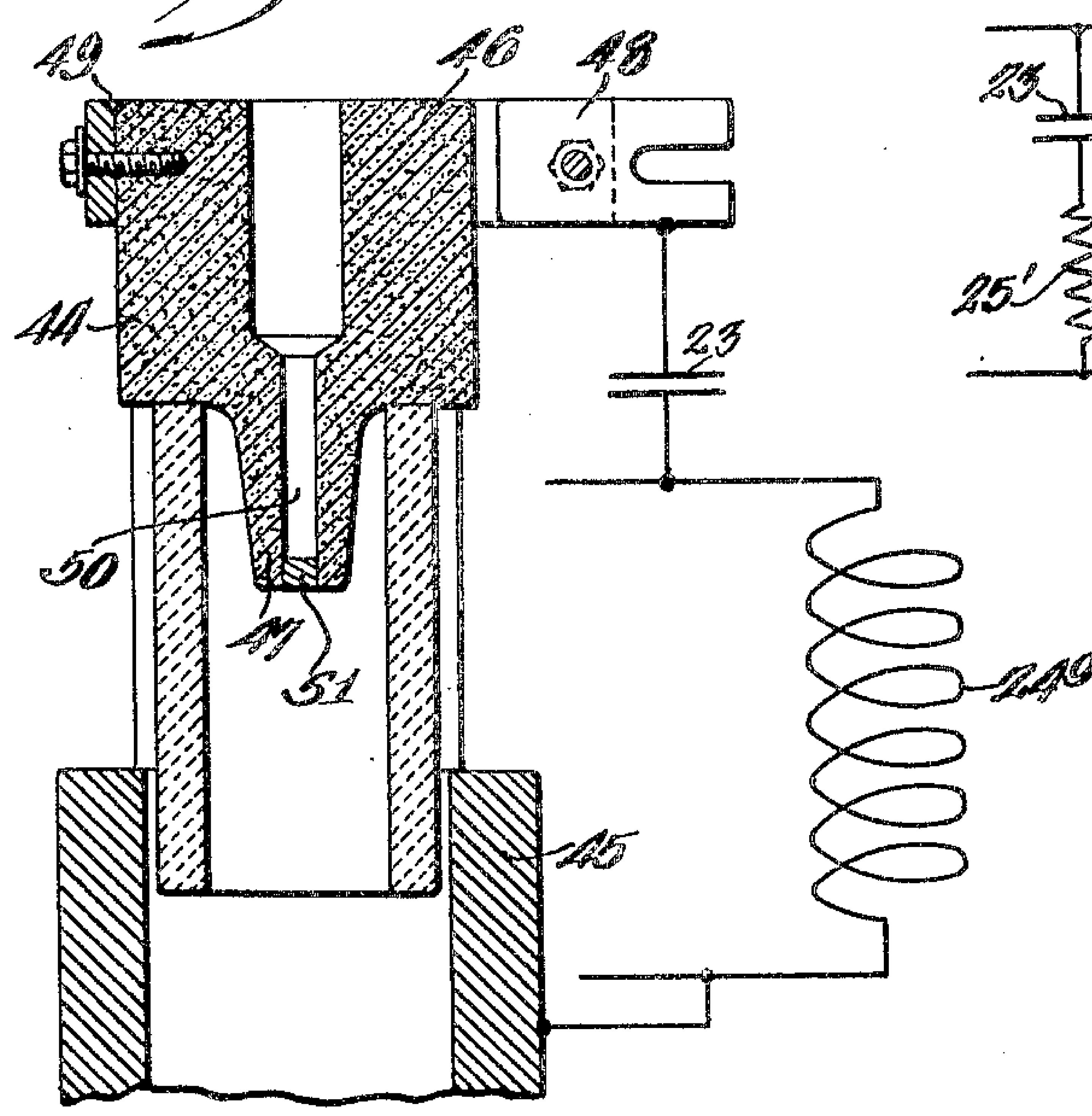


Fig. 11



Inventor.
Edwin F. Northrup.

by [illegible]
Attorney.

Witness:
Walter Chism

INDUCTION ELECTRIC FURNACE

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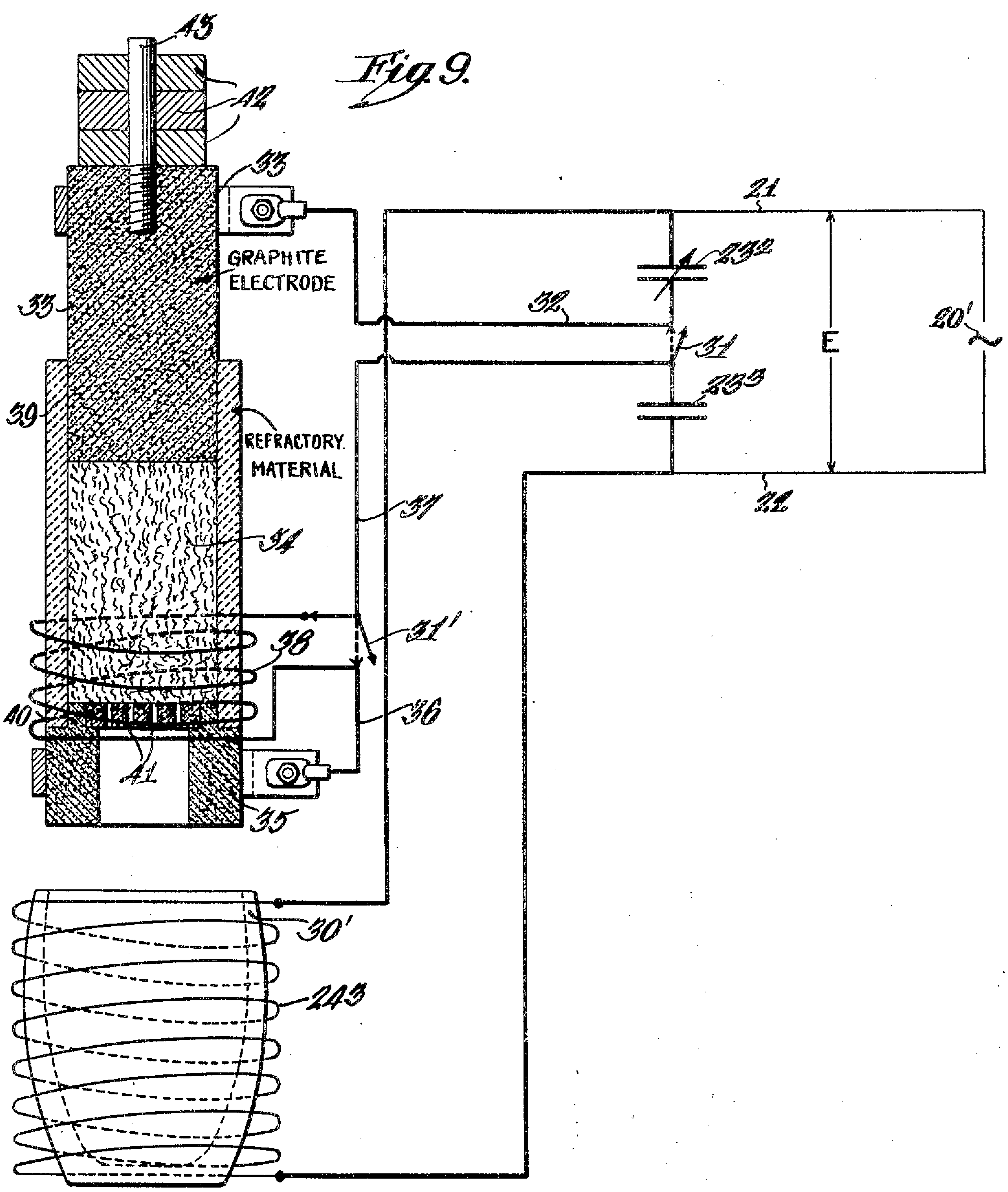
Fig. 9.



Inventor
Edwin F. Northrup.
by [signature]
Attorney.

Witness:
Walter Chism

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UNITED STATES PATENT OFFICE

1,961,621

INDUCTION ELECTRIC FURNACE

Edwin Fitch Northrup, Princeton, N. J., assignor to Ajax Electrothermic Corporation, Ajax Park, N. J., a corporation of New Jersey

Application July 19, 1929, Serial No. 379,516

12 Claims. (Cl. 13—26)

The invention relates to methods and apparatus for utilizing resistance and other loads in resonant circuits.

A purpose of the invention is to make use of an existing high frequency circuit having tuned inductive and capacitative branches to pass the large current thus available through an auxiliary resistance load in any part of the circuit to secure the advantages of the large current for the resistance load.

A further purpose is to utilize a normally tuned high frequency circuit having an inductive load to pass current through a supplemental load for any one of the many uses to which the large current thus made available or the high frequency desirably used may suit it.

A further purpose is to utilize a normally tuned high frequency circuit having an inductive load to pass current through a load having resistance and inductance, correcting for unbalance in the tuning to pass a high current through the circuit.

A further purpose is to utilize a furnace circuit normally for furnace purposes and when not so required or when the furnace does not require the full current to utilize the furnace coil as an inductor coil to tune a circuit so that a large current may be passed through another load such as a hot top or preliminary melting furnace.

A further purpose is to utilize a furnace circuit for other purposes gaining the benefit of the high current available through tuning of the circuit to overcome a high resistance load.

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

My invention relates both to methods involved and to apparatus by which the methods may be carried out.

The tuning of a circuit supplied by a generator or other source of alternating current supply results in a very much higher flow of current through the circuit so tuned than through the supply lines to the circuit, the current flow through the inductor and paralleling capacity of an inductor furnace circuit, for example, frequently being ten times the current through the leads by which the current is supplied. This is true whatever the frequency and gives opportunity to take advantage of the high current secured without sacrifice of the advantages of high frequency where this is utilized. One of the purposes of the present invention is to adapt this large current supply to use in other arts as well as in the induction furnace art and to other loads than inductive loads as well as to inductive loads.

In the drawings I have preferred to show a few only of the many forms in which my invention may appear, selecting forms which are practical, efficient and inexpensive and which at the same time well illustrate the principles involved.

Figures 1–6, 7 and 8 are diagrammatic illustrations showing my invention applied to current transformer forms in which an auxiliary load is included in a resonant or approximately resonant circuit.

Figures 9 and 11 are central sectional views with diagrammatic connections showing application of my invention to particular uses.

Figure 10 is a top plan view of the structure seen in Figure 11.

My invention is applicable not only to by-product use of existing tuned circuits for other purposes than their initial purposes when the energy is not required, or is not all required for the initial intended purpose, but also to installations in which the tuned circuit is created for the purpose of increasing the current beyond that which would be available from the main current supply. Both the new and by-product applications of the invention are illustrated.

In Figure 1 I show a source of alternating current supply 20. Though the principle of the invention may be applied to circuits having commercial frequencies the costs of condensers and inductances for such circuits is so high that frequencies much higher than commercial frequencies will ordinarily be desirable. I show these "high" frequencies as conventionally supplied through leads 21 and 22 to a circuit having condenser branch 23 across inductive branch 24. When the capacity and inductance are tuned or approximately tuned the current circulating through these two branches will be very high as compared with that through the supply conductors and the resonance will be little affected by resistance in the circuit. For this reason an auxiliary load 25 high in resistance can be placed in one of the branches so that the large current thus available will pass through it.

In Figures 1, 3, 4 and 5 the loads, for the present viewed as resistance loads 25, 25^2, 25^3 and 25^4 are in the inductive branches and in Figures 2, 6 and 7 the resistance loads 25′, 25^5, 25^6, 25^7, and 25^9 are in the capacitive branches. The positions in one or other of these branches are not controlling. In either event a very large current can be passed through the load.

In Figure 1 the inductance 24 is a comparatively pure inductance whereas in Figures 2, 3, 4 and 5 the inductances 24′, 24^2, 24^3 and 24^4 represent, or may represent, inductances which may themselves to be used for induction of current in some charge or for treatment, either at the same time that the current is being passed through the auxiliary load or alternatively to the passage of this current through the auxiliary load.

In Figure 2 the switch 16 is used for cutting out the auxiliary load, which in most of the figures is treated as a resistance load, when it is desired to operate the inductive load alone.

The auxiliary loads in the other figures can be short-circuited similarly at 16 wherever it is desired to utilize the inductance for its own value as a coil; for example, as an inductor coupled with a secondary to be heated or treated or otherwise acted upon.

In Figure 2 the inductance 24′ as stated may be an inductor operated for its own value and in which in connection with its use or when not so used switch 16 may be opened to apply the current to the resistance load 25′.

Figure 3 shows the capacity 23′ as adjustable, as may be the case with the capacities in the other figures also, and shows taps 27, 27′, 27^2 by which the current from line 21 may be applied through a switch 28 so as to utilize different lengths or numbers of turns of the inductance, giving a wide range of adjustability by making both the capacity and inductance of the circuit variable.

In this figure also I have shown supplemental inductance 29 for the purpose of indicating that where the use of an inductor is limited, as by intended use for specific inductor purposes, a supplemental inductance may be inserted within the same circuit to perform special inductor functions with but little change, if any in the circuit characteristics.

The inductance 29 may be purely supplemental inductance or may be the inductance of a load having resistance 25^2. Where inductance is introduced by the load, it is added to the inductance of the inductor 24^2, for example, and the larger total inductance requires a correspondingly smaller capacity for resonance.

As seen in Figure 5 the supplemental inductance 29′ can be placed within the capacitative branch if desired. In some locations of use such as, for example, in heating the interior of a surrounding automobile cylinder, or for concentration of power within a small coil-surrounded charge, the limitations of space are such that the diameter, and in many cases the number of turns must be quite limited. Though the inductance of a coil of permissible size, under these circumstances, may be so low as to be almost negligible it is possible to concentrate a tremendous amount of energy in the automobile cylinder wall, or other charge, through my present invention, because of the large current values which make the ampere turns large.

In Figure 4 the inductance 24^3 used is an electric furnace inductor about a crucible 30, which inductor will, of course, offer different inductance according to whether the furnace be loaded or not loaded, and, if the furnace load be iron or steel, according to whether the load be above or below its recalescence point. The switch 16 makes it possible to by-pass the resistance load during normal furnace operation but to operate the resistance load at such times as may prove desirable during or in place of the operation of the furnace.

In Figure 6 for the same inductance 24^5 the capacity branch of the tuned circuit is split up into a plurality of parts in parallel and separate resistance loads 25^5, 25^6, 25^7 are inserted in series within the capacitative branches. As the capacities are quite large relatively to the resistances the currents in the capacitative branches in Figure 6 are approximately equal notwithstanding wide variation in the resistances.

In Figure 7 much the same connections are shown as in Figure 3, except that the capacity 23 is thrown across the entire circuit and the line is, or by taps 27, 27′, 27^2, 27^3, 27^4 and switches 28, 28′ may be, connected with the coil 24^7 at intermediate points so that the voltage upon the condensers of the capacity is raised as the number of turns spanned by the source of current supply is lowered. The load 25^9 here as in other figures generally may contain inductance or may be substituted by an inductance load.

In the operation of all of these forms the auxiliary load obtains the advantage of the high current within the tuned circuit independently of whether the inductance be provided separately for this purpose or have other utility at the same or at another time.

In Figure 8 I show a diagrammatic illustration of the way in which the power absorbed may be increased from the same available kv-a of condensers. I have assumed that the resistance 25 with the inductance 24^8 incorporated in it is the same as the resistance 25′, comprising an auxiliary load in series with the capacity. Under these circumstances with the inductance and the capacity balanced the power factor will be unity and there will be approximately twice the resistance or work current as compared with that for the same condenser kv-a available if the resistance load 25′ be omitted.

In an actual test made the ratio of condenser kv-a needed for straight furnace connections to condenser kv-a needed for a resistance inserted was as 69 to 33. Otherwise expressed, only 47.8% as much condenser kv-a was required with added resistance as without it for equal power input in the two cases.

In Figure 9 I have shown adaptation of a furnace circuit to the melting of metals which are to be heated further in a crucible. This is given merely by way of example of one auxiliary load which may be utilized in carrying out my invention and is not intended to suggest restriction of the invention to this art since very much broader application of the invention to electric circuits generally is intended herein.

In this Figure 9 a source of high frequency energy is shown at 20′ which supplies current through leads 21 and 22 for a furnace inductor 24^3 surrounding a crucible 30′. The connections for supply of this inductor are completed when switch 31 is closed, placing condensers 23^2, 23^3 across the line in parallel with the inductor. During this operation of the furnace the other electric circuits shown will be short-circuited so long as switch 31 is closed.

When switch 31 is opened and the switch at 31′ is closed the current from the generator line 21 will pass through condenser 23^2, conductor 32, an electrically conducting electrode 33, such as graphite, any desired charge 34, to graphite lower terminal 35 and back through conductors 36 and 37 and condenser 23^3 to the line 22.

The circuit just described will be in parallel with the furnace circuit and will constitute an auxiliary load within in this case the capacitative branch of the tuned circuit thus formed. As so far described the auxiliary load comprises a resistance load, but this is not essential as there may be capacity or inductance forming a part of the auxiliary load.

In the auxiliary load shown in Figure 9 this is illustrated by including an auxiliary furnace inductor 38 within the circuit when switch 31' is opened. In this event the positive inductance added by the coil will require corresponding adjustment of the capacity if the tuning is to be maintained. The tuning need not be exact.

The auxiliary load shown is well adapted for auxiliary use in connection with furnace operation in that it is intended to melt metal which is subsequently to be additionally heated or heat-treated in the crucible.

Though this interrelation between the two loads is convenient and desirable it is not essential as the auxiliary load may be of very different character including such diverse uses as welding, arc lighting, resistance furnace heating or chemical treatment, without capacitative or inductive component as in these cases or with such component as may be desired. If the capacity or inductance introduced disturb the tuning objectionably it can be corrected to secure sufficient approximation to the tuning.

In the particular furnace shown the crucible 39 may have refractory walls and the bottom 40 of the furnace is apertured at 41 to permit the molten metal to fall through into the crucible.

The electrode 33 may carry weights such as 42 held in place in the illustration by pin 43 so as to insure the following up of the charge by the electrode to maintain contact between them.

This form corresponds in part with Figures 2 and 5 in that the auxiliary load is within the capacitative branch. When the auxiliary inductor is short-circuited by closing switch 31' the circuit corresponds nearly with that of Figure 2 in that there is a resistance load in series with the bridging corrective capacity; but when the auxiliary inductor is in circuit the auxiliary load includes within the capacitative branch not only the resistance load of Figure 2 but the inductive load of Figure 5.

The invention may be applied in many other places, either in conjunction with a special inductance or with an inductance in the form of inductor. I show one other application of the invention to use in connection with an induction furnace in the hot-top application of Figures 10 and 11. Here the purpose is to prevent piping in cast metal ingots, billets, etc. due to metal shrinkage. Currents of a higher frequency than normal line currents are most useful and it is quite desirable to get the high current flow which is available for use in connection with the inductor.

In the present illustration it is the intention to apply this as an auxiliary circuit connected with a main furnace circuit using the furnace inductor 24^9 to secure the inductance necessary.

In this form the auxiliary hot top circuit is placed in the capacitative branch of the circuit. The connections are made through an electrode 44 preferably graphite, carbon or other electrically conducting material at one end of the load and an electrically conducting mould 45, or its content, at the other end.

The billet is cast according to the usual practice until the metal is nearly up to the top of the mould. The hot-top is then applied. It consists of the electrode and a cylinder or top 46 of refractory material filled with the normal slag which is of high resistivity as compared with that of the metal. The electrode is extended downwardly at 47 so as to be immersed in the slag. An electric current of high potential is applied, as with the connections shown, giving a practically constant current. It is passed through the slag and metal to the mould.

Because of the high resistivity of the slag in the hot-top, sufficient heat is generated to keep the top of the metal molten while the metal cast cools from the bottom up. By gradually decreasing the power the metal is allowed to cool and the formation of the pipe is prevented.

The slag and metal may be connected in series with the inductor branch instead of with the capacitative branch, if desired. Since the load is a practically pure resistance load it has no appreciable effect on the phase of the supply circuit.

As shown the current supply is provided through a clamp 48 secured to the electrode at 49.

The electrode can be made as shown with a hole 50 running through it lengthwise into which a short piece of transparent fused quartz 51 can be inserted. This permits determination of the temperature by sighting the quartz with a disappearing filament pyrometer or other suitable optical temperature measuring instrument. The invention shown in these figures involves both the new and successful method of preventing piping and the novel method of temperature determination by which the temperature of a bath can be determined at a point below the surface of the molten metal.

With whatever form of invention a very much increased current for either a resistance or inductive load by forming a tuned circuit in which the load is included with capacity and inductance or additional inductance, by utilizing an existing tuned circuit or by increasing the inductance and capacity of an existing tuned circuit so that an increased power input may be available.

Even where the main inductance of the tuned circuit is not itself utilized for application to a load, and is thus in a way artificial to the circuit, the separate existence of this inductance from the resistance load or inductive load makes the load auxiliary to this main inductance and the load may be treated as an auxiliary load.

The term "high frequency" in this specification refers to frequencies higher than normal including what have been termed for some purposes intermediate frequencies and is not intended to require that the frequency shall be of a very high order.

In view of the invention and disclosure variations and modifications to meet individual whim or particular need will doubtless become evident to others skilled in the art, to obtain all or part of the benefits of my invention without copying the structure shown, and I, therefore, claim all such in so far as they fall within the reasonable spirit and scope of my invention.

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

1. In an alternating current circuit, a source of current supply, a tuned electric circuit supplied thereby and including a furnace inductor and resistance means for changing electrical energy into heat energy and for usefully applying the heat energy, connected in said circuit and adapted to receive the resonant current due to the tuning of the circuit.

2. In an alternating current circuit, a current supply, a tuned electric circuit supplied thereby and including a furnace inductor, a resistance load in series with the tuned circuit and separate from the furnace whereby the current of the tuned circuit is available for the resistance load.

3. In an alternating current circuit, a source of alternating current supply, a furnace inductor connected therewith, power-factor corrective capacity in parallel with the inductor therefor forming a tuned circuit and an auxiliary furnace of resistance type in series with one of the parallel paths of said tuned circuit.

4. A hot-top adapted for resistance heating of the metal in a mould, a tuned circuit with which the hot top is connected and a furnace inductor forming part of the tuned circuit.

5. The method of securing large current flow through an electric load containing a resistance, which consists in utilizing an existing tuned induction furnace circuit and inserting the load containing resistance in one of the branches of said circuit as a supplemental load.

6. In electric heating, a high frequency alternating current source of supply, a tuned circuit connected therewith including capacity, inductance and inductive means separate from the said inductance for changing electrical energy into heat energy and for usefully applying the heat energy, the inductive means having an inductive reactance which is small compared with the total inductive reactance of the tuned circuit, whereby a high energy input may be secured through the inductive means.

7. The method of securing large current flow in changing electrical energy into heat energy, using a furnace inductor, which consists in passing alternating current through the furnace inductor, in resonating the current and in changing electrical energy into heat energy by passing the resonant current through heating means independent of the inductor.

8. The method of securing large current flow in changing electrical energy into heat energy, which consists in selectively passing resonant alternating current in inductive relation to a charge to heat the charge, while using the inductive reactance encountered by the current to contribute to resonance and in changing electrical energy into heat energy outside of the said charge, while using the same inductive reactance to contribute to resonance.

9. The method of securing large current flow through an electric load containing resistance, using inductive reactance, which consists in passing alternating current through the inductive reactance in inductive relation to a charge to be heated, in resonating the inductive reactance by capacitative reactance, changing electrical energy into heat energy by passing the resonant current through heating means outside of the inductive reactance while using the inductive reactance to contribute to resonance.

10. In an alternating current circuit, a source of alternating current, a main inductor connected therewith, power-factor corrective capacity therefor, forming a tuned circuit and a load-concentrating furnace of inductor type having lower inductive reactance than said main inductor in series in said tuned circuit, whereby a high current is caused to flow through the load-concentrating furnace which could not be obtained economically if that furnace were tuned separately.

11. The method of heating a charge by an inductor coil of small inductance, which consists in inserting a relatively very much larger inductance in series with the inductor coil, in shunting the circuit branch including the inductor coil and the larger inductance by a capacity of proper size to produce a condition of approximate parallel resonance, in supplying alternating current to the resonant circuit and in passing the resonant current through the inductor coil to heat the charge.

12. In an electric induction furnace, an inductor coil in inductive relation to a charge to be heated, an approximately resonant circuit including the inductor coil, an inductance having inductive reactance relatively very much larger than that of the inductor coil and capacitative reactance of a size suitable to produce approximate resonance, and a source of alternating current connected in parallel with the resonant circuit, whereby a high current is caused to flow through the inductor coil which could not be obtained economically if that coil were tuned separately.

EDWIN F. NORTHRUP.