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F. GERTH ET AL

HIGH FREQUENCY FURNACE CIRCUIT

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Fig. 1

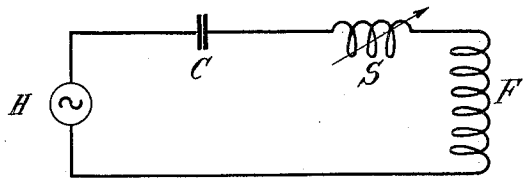


Fig. 2

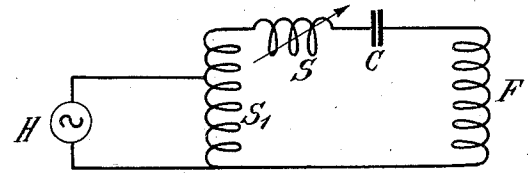


Fig. 3

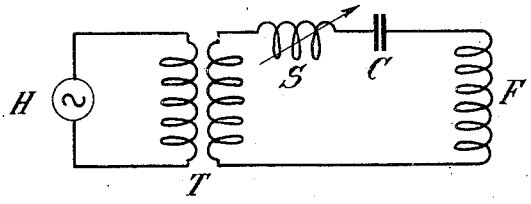
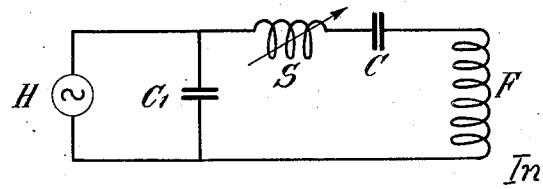


Fig. 4



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HIGH-FREQUENCY FURNACE CIRCUIT.

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This invention relates to high-frequency furnaces, but it may be understood that the invention is not limited to this special type of high-frequency loads, but may be applied to other types of load systems with which a high-frequency machine is to be connected.

It is well known to generate heat in electric conducting materials, in exposing them to the influence of the magnetic field of a surrounding coil carrying a high-frequency current. The material known as the resistor may thereby be regarded as the secondary of a transformer. The power transformed into heat is proportional to the square of the induced and consequently also of the inducing current. Moreover, the current in the secondary increases according to the number of turns surrounding the furnace crucible supposing the current in the primary to be at constant value.

Therefore a great number of primary turns is necessarily to be looked for. The high-frequency current may be obtained by arc or spark discharges, or may directly be supplied by a high-frequency alternator, for which latter mode of supply the connections given by the invention have a special practical importance.

However there are great disadvantages in supplying the furnace coil directly by the generator. As the coil of the furnace, because of its self-inductance, presents a considerable resistance to the high-frequency currents, it is unfavorable to connect the furnace coil directly with the terminals of the high-frequency generator. By connecting a variable condenser in the known manner in parallel relationship to the furnace coil and tuning the circuit thus obtained to the alternator frequency, the alternator may be freed from wattless currents and its efficiency improved, this connection being known under the term of "parallel resonance". Further it is well known that the efficiency of an electric system has its greatest value, if the inner resistance of the generator is equal to the resistance of the outer load circuit. This condition is obviously in the most cases not to be realized in connecting a given alternator with a given load according to the aforesaid manner.

Another method of connecting a high-frequency alternator with the heating coil of a high-frequency furnace hitherto known consists in inserting a condenser eventually in connection with a further tuning coil in series with the coil of the furnace, or in other words in employing a "series resonance" connection instead of the above mentioned "parallel resonance" connection. The advantage of this arrangement lies in that the generator may be designed for normal voltages and yet that the number of the furnace turns and consequently the efficiency of the latter may be increased. If the natural frequency of this circuit is tuned to the frequency of the current of the high-frequency generator, the working of the generator may be considerably improved. As has already been set forth the furnace coil requires a great number of ampere-turns i. e. very strong currents, if the resistor is to be heated to a very high temperature; when tuning to resonance, however, the value of the cos φ obtained by this connection is a very low one due to the high wattless currents which also pass through the generator producing considerable losses. The generator therefore, has to be designed with respect to the whole power output (apparent power) and its size will be a multiple of the size corresponding to its pure wattless power output.

It is the object of the present invention to overcome these disadvantages inherent to both a pure "parallel resonance" connection and a "series resonance" connection. The invention consists in that the generator is coupled to a part of a tuning means of a circuit containing the load impedance of the furnace coil and additional tuning means and being tuned to the generator frequency, so that in other words on the one hand the wattless currents of the furnace coil are compensated and on the other hand the inner resistance of the alternator may be adapted for the resistance of the load resistance by means of transformation. Most favorably a direct coupling is employed which may be made variable by means of tappings, this presenting the possibility to the alternator to supply only the pure watt power for the resonant circuit containing the load impedance of the heating coil. But an inductive or capacity coupling will do as well. In all of the cases a very great amplitude of the currents in the furnace coil is attained, if the circuit containing this coil is at least approximately resonant to the generator frequency and the alternator is counter-con-

nected only to a part of the voltage drop in this resonant circuit and at the same time has to supply only the watt power dissipated in the resonant circuit, and may be designed for normal values.

In order that the invention may be best understood reference should be taken to the accompanying drawings of which Fig. 1 represents the well known series resonance connection, and Figures 2, 3 and 4 connections according to the invention, Fig. 2 employing a direct coupling of the generator to a part of the circuit resonant to the generator frequency and consisting of the load impedance and additional tuning means, whereas Figures 3 and 4 show a corresponding inductive and capacity coupling. The references in the single figures corresponding to each other refer to like elements. H is a high-frequency alternator, which may be of the usual variable inductance type, F represents the heating coil of a high-frequency furnace, but which may be replaced by some other high-frequency load impedance, S represents an additional tuning self-induction coil and C a capacity placed in series with the furnace coil. Referring to Figure 1, the circuit H C S F is tuned to the alternator frequency and presents the disadvantages above referred to. According to Figure 2, the alternator is coupled directly with the part S_1 of a self-inductance forming part of the resonant circuit S_1 SCF, which part may be made variable by means of tappings for the reason to be described as follows. In Figure 3 the coupling is an inductive one by means of the transformer T and in Figure 4 there is employed a capacity coupling by means of capacity C_1. In Fig. 2 the circuit S_1 SCF, in Figure 3 the circuit FCS and secondary of T, and in Figure 4 the circuit $FCSC_1$ are tuned to the frequency of the high-frequency alternator H.

Further by suitably dimensioning the transformation ratio of the alternator to the resonant circuit i. e. the tapping at coil S_1 in Fig. 2, or the ratio of primary and secondary turns of the transformer T in Fig. 3 and the value of the capacity C_1 in Fig. 4, it may be obtained that the alternator works at its highest efficiency and is only loaded with wattless currents. This is apparently the case, when the terminal voltage of the alternator having a fixed value by its excitation and its number of revolutions is equal to the voltage drop at the terminals of the part of the resonant circuit to which it is counterconnected and may also be explained in that the circuit containing the load coil carries very high resonance currents, very high at least with respect to the current flowing through the alternator and the alternator is working upon this circuit like upon a supply line fed by other considerably stronger alternators, and that this terminal voltage having a constant fixed value it is forced to supply a leading or a lagging or a pure wattless current according to the voltage of the resonant circuit it is counterconnected to, the potentials at the alternator terminals and the coupling element of the resonant circuit being necessarily at equal value.

A high-frequency furnace included into a current circuit as has been set forth presents an impedance for the current. The value of the components of this impedance is dependant to an essential part of the mass of the material to be heated (resistor) and its temperature. Generally the value of inductance surpasses considerably that of the resistance. The inductance varies very strongly with the heating of the resistor especially if the latter consists of ferromagnetic material, and the tuning condition of the resonant circuit containing the furnace coil will only exist for a comparatively short time and the heating current and the melting action will therefore decrease continually.

According to a further feature of the invention this disadvantage is overcome by employing in the resonant circuit tuning means to be continuously varied during operation such as variometers, variable condensers eventually in connection with condensers and inductances provided with tappings, by means of which the variation of the impedance of the furnace coil may continuously be balanced in order to maintain the original tuning conditions. But it may be seen that the coupling of the alternator in this case must be regulated too accordingly and according to this novel feature of the invention the circuit parallel to the alternator must contain equally continuously variably tuning means, or the transformation ratio of the alternator to the resonant circuit is made variable. Referring to Figure 2—4 this latter condition may be obtained by substituting the self-inductance of Fig. 2 by a variable inductance (variometer, or by making the tapping continuously variable), or by making the coupling by transformer T Fig. 3 equally variable by use of a vario-coupler or by employing a variable condenser C_1 in the arrangement according to Fig. 4.

What we claim is:—

1. In current supplying means for high frequency melting furnaces, a high frequency alternator machine, a load impedance, a circuit including said impedance, said circuit having a natural frequency substantially resonant with the machine frequency, tuning means in said circuit in series with the load impedance, and tuning means in said circuit in parallel with the load impedance and variably connected with the terminals of the alternator machine.

2. In current supplying means for high frequency melting furnaces, a high frequency alternator machine, a heating coil, a circuit including said coil, said circuit having a natural frequency substantially resonant with the machine frequency, tuning means in said circuit in series with the heating coil, and tuning means in said circuit in parallel with the coil and variably connected with the terminals of the alternator machine.

3. In current supplying means for high frequency melting furnaces, a high frequency alternator machine, a load impedance, a circuit including said impedance, said circuit having a natural frequency substantially resonant with the machine frequency, tuning means in said circuit in series with the load impedance, and a variable inductance in said circuit in parallel with the load impedance and connected with the terminals of the alternator machine.

4. In a high-frequency current supply circuit for high-frequency melting furnaces, a high-frequency dynamo machine, a heating coil to be supplied by said machine, a circuit substantially resonant to the generator frequency and containing said heating coil, and a variable inductance forming part of said resonant circuit and connected to the terminals of the dynamo machine.

5. In a high-frequency feed circuit for high-frequency melting furnaces, a high-frequency dynamo machine, a heating coil to be supplied by said machine, a circuit substantially resonant to the machine frequency and containing said heating coil, tuning means in said circuit, and an inductance forming part of said resonant circuit and connected with the terminals of the dynamo machine.

6. In a high-frequency feed circuit for high-frequency melting furnaces, a high-frequency dynamo machine, a heating coil to be supplied by said machine, a circuit substantially resonant to the machine frequency and containing said heating coil, tuning means in said circuit, and coupling means between said circuit and the dynamo machine, said means being in parallel with said circuit and connected to the terminals of the dynamo machine.

7. In a high-frequency feed circuit for high-frequency melting furnaces, a high-frequency dynamo machine, a load impedance to be supplied by said machine, a circuit substantially resonant to the frequency of the machine and containing said load impedance, variable tuning means in said circuit, and variable coupling means between said dynamo machine and said circuit.

8. In a high-frequency feed circuit for high-frequency melting furnaces, a high-frequency dynamo machine, a heating coil to be supplied by said machine, a circuit substantially resonant to the machine frequency and containing said heating coil, tuning means in series in said circuit, an inductance shunted across said circuit, and means for variably connecting said inductance to the terminals of the dynamo machine.

9. In a high-frequency feed circuit for high-frequency melting furnaces, a high-frequency dynamo machine, a heating coil to be supplied by said machine, a circuit substantially resonant to the generator frequency and containing said heating coil, variable tuning means in said circuit, and a variable inductance coupling said circuit to the terminals of the dynamo machine.

10. In a high-frequency feed circuit for high-frequency melting furnaces, a high-frequency dynamo machine, a heating coil to be supplied by said machine, a circuit substantially resonant to the machine frequency and containing said heating coil, a variable inductance in said circuit, and a variable coupling between said circuit and the dynamo machine.

11. In a high-frequency feed circuit for high-frequency melting furnaces, a high-frequency dynamo machine, a heating coil to be supplied by said machine, a circuit substantially resonant to the machine frequency and containing said heating coil, variable tuning means in said circuit and in series with said coils, and a variable parallel coupling between said circuit and said dynamo machine.

In testimony whereof we have affixed our signatures.

DR. FELIX GERTH.
DR. WILHELM FISCHER.