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I. LANGMUIR

HIGH FREQUENCY APPARATUS AND METHOD OF HEATING

Filed May 23, 1924

Fig. 1.

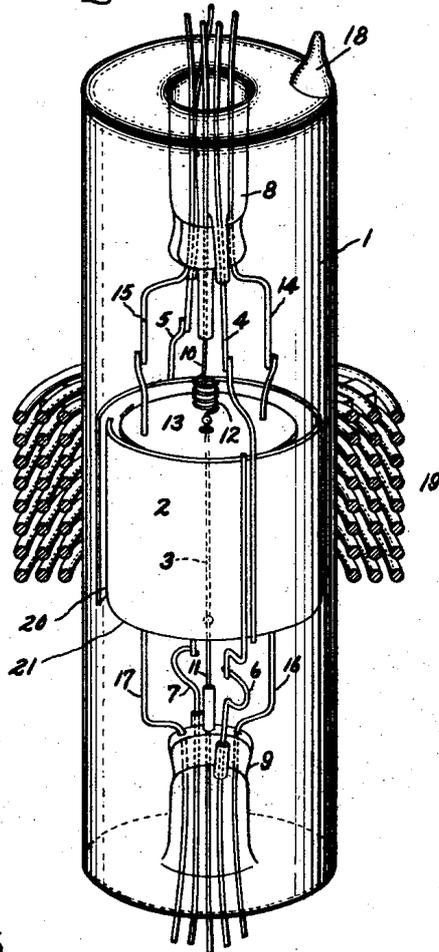


Fig. 2.

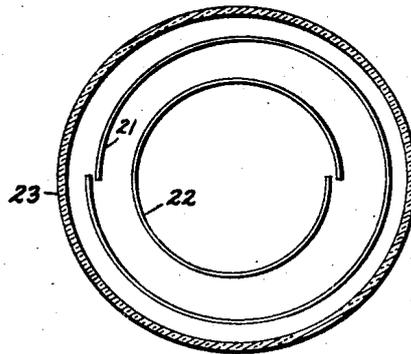
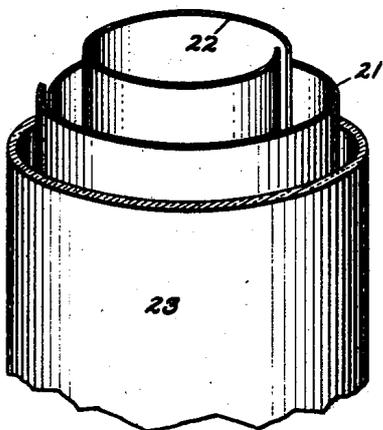


Fig. 3.



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# UNITED STATES PATENT OFFICE.

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## HIGH-FREQUENCY APPARATUS AND METHOD OF HEATING.

Application filed May 23, 1924. Serial No. 715,482.

*To all whom it may concern:*

Be it known that I, IRVING LANGMUIR, a citizen of the United States, residing at Schenectady, in the county of Schenectady, State of New York, have invented certain new and useful Improvements in High-Frequency Apparatus and Methods of Heating, of which the following is a specification.

The present invention relates to the heating of conductive bodies by a high frequency magnetic field. It is the object of my invention to improve the efficiency of heat production by high frequency induction.

My invention is based on the discovery that when the body to be heated by a high frequency field comprises a conductor closed upon itself, such, for example, as a cylinder, that the rate of heating is materially increased when a discontinuity is produced in the conductor in the direction of the current. Under the latter conditions the space within the enclosing body is no longer shielded from the magnetic field and hence in accordance with another feature of my invention heat may be generated by induction in a plurality of conductive bodies enclosed by one another.

My invention will be explained with greater particularity in connection with the accompanying drawings in which Fig. 1 illustrates in perspective an electron discharge device constructed to embody my invention; Figs. 2 and 3 constitute respectively a sectional view and a fragmental perspective view of a structure adapted to be heated by high frequency embodying a plurality of slotted cylinders respectively enclosed one within another.

The device shown in Fig. 1 comprises a glass container within which are disposed electrodes constituted by an anode 2 and a cathode 3, indicated by dotted lines, and being located within the anode. The anode consists of suitable sheet metal, for example, molybdenum, or nickel, bent upon itself in substantially cylindrical form, and being supported by the wires 4, 5 and 6, 7, which are sealed respectively into stems 8 and 9 at opposite ends of the envelope. The cathode 3 consists of a substantially linear filament consisting of a tungsten or other suitable material, and is connected to the sealed-in conductors 10, 11, the former being

coiled to form a spring 12, whereby the cathode filament is maintained taut. The cathode has been shown only to make the illustration complete. It has no direct relation to my invention.

Surrounding the cathode and extending substantially to the anode are plane disc-shaped plates, one of which is indicated at 13. These plates are supported respectively by the wires 14, 15 and 16, 17, and are located within the confines of the anode. The envelope may be evacuated or charged with gas, through a tube which is sealed off during manufacture as indicated at 18. Surrounding the device, and being cut away for the sake of simplicity in illustration, is a primary inducing coil 19 whereby a high frequency field may be generated. The source of high frequency current has not been shown as it forms no part of my invention. The frequency of the inducing currents should be so high that interlinkage with an iron core is not necessary, say higher than 10,000 cycles per second. The general theory of high frequency heating is described in Northrup patents U. S. 1,286,394 and 1,286,395 of December 3, 1918.

If the anode were constituted by a cylinder, or otherwise closed body heat could be generated in the cylinder by the high frequency field, as may be required during the manufacture of the device, for example, to remove gas. But little or no induction of current would occur in the end plates as these would be shielded by the enclosing cylinder. When the cylinder is discontinuous or slotted in a direction parallel to the magnetic field, as indicated at 20, the high frequency field can enter the space enclosed by the cylinder and in that case the end plates are heated by the current inducted therein by the field.

The surprising fact is that under these conditions the slotted cylinder 2 is heated at a materially greater rate, in fact, in order to reach a given temperature only about half the time is required for a slotted cylinder as compared with an unslotted cylinder, other conditions being equal. This phenomenon may be explained as being due to the "skin effect" whereby the current due to the field outside the cylinder is localized upon the outer surface and an equal current is induced localized upon the inner surface, the depth of "skin" in which current is flow-

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ing being governed by the frequency of the inducing field.

In order to obtain the benefit of my invention with respect to an increased rate of heating, the thickness of the body in which heat is induced should be chosen to exceed the thickness of the "skin" in which the current flows and preferably should be at least double the thickness of this "skin". The depth of the skin effect in turn depends upon the frequency of the inducing field in accordance with a known relation. Hence, for a given thickness of conductor a high frequency field may be chosen the periodicity of which is sufficiently high to produce a greater rate of heating in a slotted or open conductor as compared with a closed conductor.

As shown in Figs. 2 and 3, my invention may be employed for the heating of gases or liquids by discontinuous bodies, one of which is enclosed within another. As here shown slotted conductive cylinders 21, 22 are disposed within a container 23 consisting of glass or other suitable dielectric material. The container 23 may be constituted by a tube through which a gas or other medium to be heated is being passed. The inducing primary coil has not been illustrated.

What I claim as new and desire to secure by Letters Patent of the United States, is,—

1. An electric heating device adapted for operation with high frequency currents comprising a primary winding and a secondary inductively related to said primary without interlinkage with a core of magnetic material, said secondary being discontinuous in the direction in which currents are induced.

2. A high frequency heating device comprising a primary inducing coil and a conductive body which is partly closed upon itself in inductive relation to said coil, said body being discontinuous in the direction in which currents are induced.

3. A high frequency heating device com-

prising a plurality of bodies one of which is substantially enclosed by the other, the enclosing body being shaped to constitute an incomplete turn about said enclosed body.

4. The method of inducing heat in a conductor substantially returning upon itself by induction by a high frequency magnetic field which is linked with said conductor which consists in producing a discontinuity in said conductor thereby permitting the magnetic field to enter the space enclosed by said conductor and to induce in the inner surface a magnetic current equal to the current flowing in the outer surface of said conductor.

5. The method of inducing heat by a high frequency alternating magnetic field in a plate-shaped conductor which consists in arranging said conductor in such relation to said field that said conductor is discontinuous in the direction of current, and choosing the frequency of the inducing currents sufficiently high to cause depth of the "skin effect" in said conductor to be less than the thickness of said conductor, whereby high frequency currents are generated in opposite sides of said conductor, the heating occurring at a corresponding rate.

6. The method of denuding of gas by high frequency induction, the conductive members of an electrical discharge device when enclosed in an envelope and when one of said members is shielded from a high frequency electromagnetic field by another member looped upon itself which consists in producing a discontinuity in said looped member before mounting in the envelope and interlinking with said members a high frequency magnetic field of sufficient strength to heat said members to a temperature required for the elimination of gas.

In witness whereof, I have hereunto set my hand this 22nd day of May, 1924.

IRVING LANGMUIR.