Oct. 2, 1934. V. J. C. SORREL 1,975,437

INDUCTION HEATED FURNACE

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Fig. 1

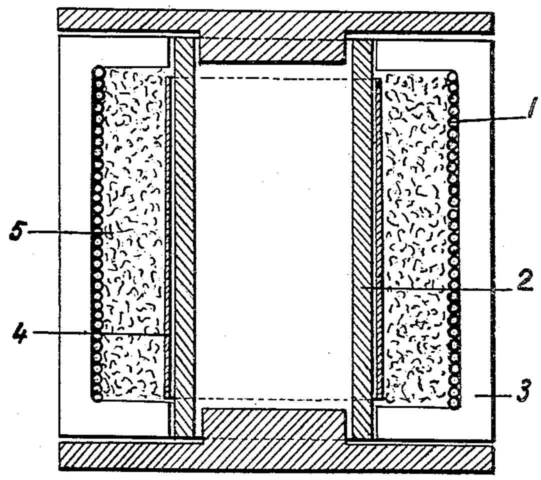

Fig. 3

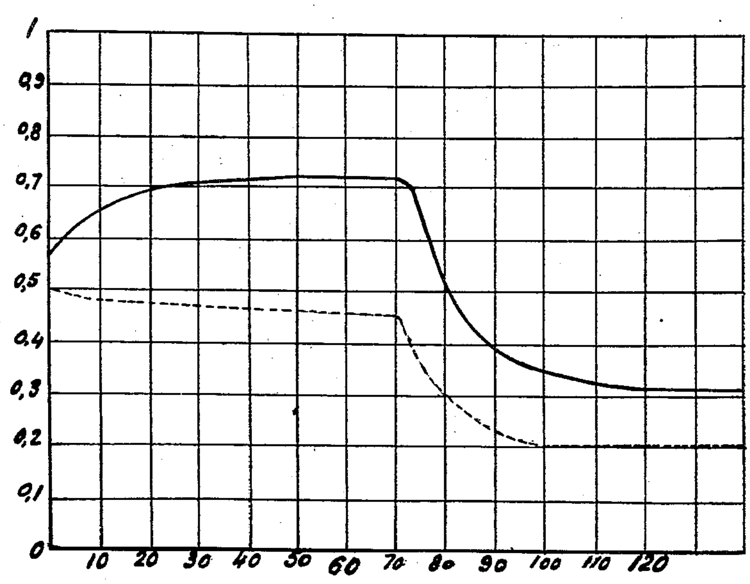

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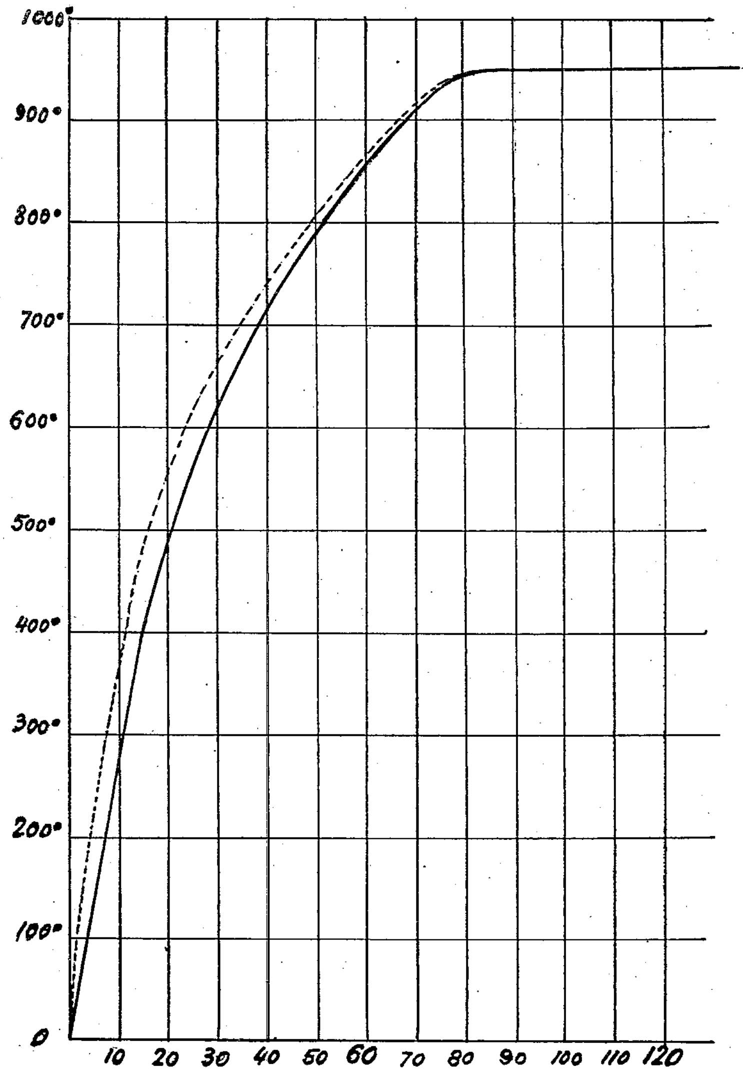
Fig. 2.



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INDUCTION HEATED FURNACE

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4 Claims. (Cl. 219—13)

Induction-heated furnaces are already well known, whereof the muffle consists of a magnetic metal or alloy and it is likewise known that a suitable selection of said metal or alloy of the muffle and a suitable adjustment of the furnace characteristics and of the induction current characteristics permit the temperature of said muffle to be maintained automatically at a constant value.

In furnaces of this type already available, the increase of temperature of the muffle is partly due to currents induced within the latter by the inductive field said currents being usually produced by means of a solenoid through which flows an alternating current of industrial periodicity, but said increase of temperature is also due to a great extent to hysteretic cycles or loops.

The intensity of the induced currents and the quantities of heat generated in said hysteretic cycles are functions of the permeability and of the hysteretic coefficient of the material constituting said muffle. Automatic regulation of temperature is based, in furnaces of this type, upon the principle that the permeability and hysteresis of the material of the muffle, fall greatly when the temperature of the furnace reaches that of disappearance of the strong magnetism of said material.

According to this invention, it is proposed to make use of the property inherent in ferro-magnetic materials whereby the induction of said materials falls greatly when their temperature reaches and exceeds that at which their strong magnetism disappears.

The ferro-magnetic muffle of a furnace constructed in accordance with this invention comprises to this end a heating jacket consisting of a non-magnetic metal of high conductivity or whose strong magnetism disappears at a temperature lower than that which it is proposed to secure and to maintain within the furnace, within which jacket the alternating induction flux flowing through the ferro-magnetic muffle causes induced currents to be set up, said induced currents being a function of the muffle inductance and likewise, of course, of the electric characteristics of the conductor circuit, its ohmic resistance, self-induction, capacity and the like.

The induced currents thus generated within said heating jacket produce heat therein which in turn heats the furnace muffle, the ferro-magnetic material whereof has been so selected that the temperatures at which the disappearance of its strong magnetism begins and ends include within their range the constant temperature which it is desired to secure and to maintain within the furnace. If said induced currents are adequate to generate a quantity of heat greater than the losses of the furnace through radiation and transmission, then the temperature of said furnace rises.

The currents set up within the heating jacket depend in the main upon the inductance of said muffle, so long as it has not reached the temperature at which the strong magnetism of the material whereof it is constituted disappears. Thus, when the muffle reaches the temperature at which the strong magnetism of its constituent materials disappears, the currents induced in the heating jacket fall greatly, together with the inductance of said muffle, provided always that the electric characteristics of the inducing circuit remain substantially constant within the range of temperature at which said disappearance of the strong magnetism occurs. If, after disappearance of the strong magnetism of the constituent material of the muffle, the currents set up in and flowing through said heating jacket are, at that moment, inadequate to generate a quantity of heat equal to the heat lost by the furnace through radiation and transmission, a circumstance which is collateral to a judicious selection of the electric characteristics of the inducing circuit of said furnace, then the temperature of the muffle falls, passes through that at which its strong magnetism disappears and, upon said strong magnetism reappearing, the inductance of the muffle rises together with the heating action of said heating jacket. The temperature of the muffle will therefore attain equilibrium at a value, intermediate between that at which magnetic conversion began and that at which it ended, such that at said temperature the inductance of the magnetic core is adequate to generate within the heating jacket induced currents adapted to generate a quantity of heat equal to the caloric losses of the furnace. The automatic regulation of the furnace will then have been secured.

Fig. 1 of the attached drawings exemplifies diagrammatically, without limiting the same, a constructional embodiment of a furnace according to this invention.

Figs. 2 and 3 are charts or diagrams illustrating the automatic thermic action of the furnace.

Within a solenoid 1 through which flows an alternating current is arranged a muffle 2 of ferro-magnetic metal or alloy having suitable cross-section and thickness. The constituent material of said muffle is so chosen that the temperatures at which the disappearance of its strong magnetism begins and ends comprise within their range the constant temperature which it is desired to secure and to maintain within the furnace. The efficiency of said magnetic muffle is enhanced if it displays the smallest possible number of high reluctance traverse gaps, i. e. at a right angle to the axial direction of the winding of solenoid 1, whereas, on the other hand, longitudinal crevices therein are immaterial.

It may furthermore be desirable to close the magnetic circuit outwardly by means of preferably laminated masses 3 of iron or the like.

The muffle is surrounded throughout its effective height by a heating jacket 4 in contact with or adjacent thereto, adapted to constitute a non-magnetic conductor at the working temperatures of the muffle.

The space between solenoid 1 and jacket 4 is filled with a suitable insulating material 5.

The characteristics of the furnace must be so chosen that the quantity of heat generated within heating jacket 4 is greater than the losses of the furnace by radiation and transmission before the temperature is reached at which magnetic conversion occurs, and smaller than said losses after the strong magnetism has entirely disappeared.

To this end it is necessary to suitably predetermine the voltage and periodicity of the current fed to the terminals of solenoid 1, the mass and nature of magnetic muffle 2, the nature, resistivity and thickness of the conductor jacket 4 and the nature and thickness of the thermic insulator.

As an example, among many, of a constructional embodiment of a furnace according to this invention, which example does not limit the same and is not a preferred form of construction since a better selection of the characteristics of said furnace would enable a higher degree of efficiency to be attained therein, said furnace may comprise a muffle of ferro-cobalt containing approximately 30% cobalt and 70% iron, together with a small percentage of carbon. The muffle is 12 mm. in thickness and its inner diameter is approximately 150 mm.; 350 mm. of its height is surrounded by a nickel conductor jacket having a thickness of 3 mm.

Since the temperature of equilibrium of the muffle is 960° C. and that at which the strong magnetism of nickel disappears is in the neighbourhood of 350° C., it may be considered that said nickel jacket is a non-magnetic conductor throughout the range of temperature comprised between 350° C. and 960° C., which is in practice the working range of the furnace.

The inducing circuit is constituted by a winding consisting of four layers of copper ribbon having a width of 10 mm. and a thickness of 3 mm., said layers being insulated from each other by means of braided asbestos and of sheets of mica.

The space enclosed between the inducing winding and the nickel jacket is filled with a suitable thermic insulating material, asbestos packing, magnesia, or the like.

The magnetic circuit is outwardly closed by means of six laminated iron cores such as 3.

If a continuous voltage of 130 volts is fed to the terminals of the induction circuit, the nickel jacket and the muffle become heated and the curve of ascending temperature (ordinates) as a function of time (abscissae) is shown by the full line curve of Fig. 2. It will be seen that the temperature of the muffle rises rapidly and becomes stabilized at 960° C., whereat automatic regulation is secured since the inductance of the core is then just sufficient to generate within the nickel jacket induced currents producing a quantity of heat equal to the caloric losses of the furnace. In Fig. 3 (full lines) the power factor has likewise been shown, the values of cos. ϕ at any moment being denoted by ordinates. It will be seen shown starting from 0.57 said cos. ϕ increases rapidly and remains substantially constant adjacent 0.72 within the range extending from 350° C. at which temperature the strong magnetism of nickel disappears, to approximately 950° C., at which temperature the strong magnetism of ferro-cobalt begins to disappear.

The above example of an application of the invention will serve to make clear the advantage which its improvements offer over the process wherein the sole source of heat used in the muffle consists of the hysteretic phenomena and the currents induced in said ferro-magnetic muffle.

To this end and with the same furnace, it has been sought to secure a like equilibrium of temperature at 960° C. within the same period of time, but without the nickel jacket; the muffle being heated only by Foucault currents and by hysteretic loops or cycles.

In Fig. 2 the dotted line denotes the curve of variations of temperature as a function of time, and Fig. 3 exhibits the values of cos. ϕ at the like moments.

In order to reach the same equilibrium temperature within the same period of time and hence to obtain the generation of the like quantities of heat within the muffle, it was necessary to feed a voltage of 165 volts to the terminals of the induction circuit, instead of a voltage of 130 volts.

The reason for this will become manifest from a comparison of the curves of cos. ϕ, which show that the values of the dotted curve decrease steadily from 0.52 and are considerably lower than the corresponding values of the full-line curve relative to the nickel-jacketed muffle.

It may be noted from Fig. 2 that the dotted curve is slightly above the full-line curve, both curves uniting slightly before the temperature of equilibrium. This admits of a simple explanation if it be considered that the cos. ϕ of the dotted curve decreases steadily and that it is therefore necessary to supply greater initial power in order to reach the like temperature within the like period of time than in the case where cos. ϕ remains practically constant.

It will be realized therefore that the process pursuant to this invention constitutes an improvement upon those ferro-magnetic muffle furnaces which are solely heated by Foucault currents and hysteretic cycles since, even in the case of small muffles, it permits the power factor to be greatly improved.

In order that the regulation of the furnace temperature may be secured with great accuracy, ferro-magnetic bodies must be selected whose inductance changes rapidly as a function of temperature in the neighbourhood of the point of magnetic conversion. It is therefore particularly desirable to make use of ferro-magnetic bodies, such, for example, as certain ferro-cobalts, whose inductance drops abruptly in the neighbourhood of the temperature of conversion, owing to the inversion of their ferro-magnetic and paramagnetic properties at the said temperature.

If it is desired to secure a predetermined distribution of temperature within the furnace, the muffle may be formed in several successive sections consisting of metals or alloys the strong magnetism of each of which disappears at a different temperature. In this manner, since each section of the muffle has a different temperature of equilibrium, the desired distribution of temperatures may be secured throughout the length of the muffle without it being necessary to change the inductive field at the respective levels. The heating jacket may likewise be divided into sections having different natures or thicknesses and, in conjunction with a muffle similarly divided, this would result in the equilibrium conditions being changed along the latter. The latter alternative would prove useful when conditions governing cooling or the transmission of heat at a constant temperature vary in the length of the muffle.

Furthermore, in the case of a muffle constructed of different ferro-magnetic bodies, each such body or ring might be surrounded by a heating jacket having varying characteristics and thicknesses and it would be possible by this means to secure in each zone conditions of equilibrium in accordance with the conditions of temperature and of cooling initially laid down in regard to the length of said muffle.

I claim:

1. An induction-heated furnace comprising a muffle composed of magnetic metal or alloy whose induction falls greatly at the temperature at which its strong magnetism disappears, means for generating induced currents therein and a heating jacket located between said muffle and said means, said jacket being composed of metal which is conductive but non-magnetic at the operating temperature of the furnace.

2. An induction-heated furnace comprising a muffle composed of magnetic metal or alloy whose induction falls greatly at the temperature at which its strong magnetism disappears, a heating jacket enclosing said muffle, said jacket being composed of metal which is conductive but non-magnetic at the operating temperature of the furnace, and means for inducing within said jacket currents such that the heat generated thereby before the magnetic conversion temperature is reached is greater than the losses by radiation and transmission and is less than such losses after the magnetism has disappeared.

3. An induction-heated furnace as specified in claim 1, wherein the heating jacket is divided into sections of different characteristics and thicknesses.

4. An induction-heated furnace as specified in claim 1 wherein the muffle is constituted of successive sections of magnetic metals or alloys, the temperature at which the strong magnetism of each of said sections disappears being individual thereto and different from that of each of the other sections.

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