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METHOD AND ARRANGEMENT IN THE HEATING OF ELECTRIC FURNACES

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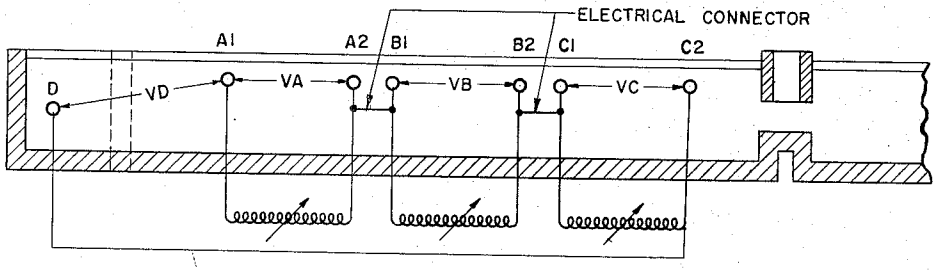



FIG. 1

VA VOLTAGE BETWEEN A1 & A2 FIG. 1
VB VOLTAGE BETWEEN B1 & B2 FIG. 1
VC VOLTAGE BETWEEN C1 & C2 FIG. 1
VD VOLTAGE BETWEEN D & A1 FIG. 1

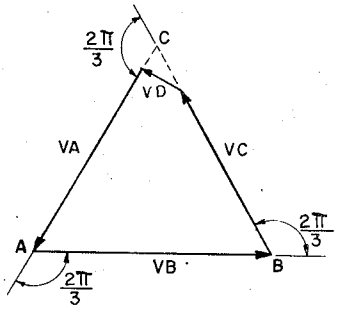



FIG. 2

VA VOLTAGE BETWEEN A1 & A2 FIG. 3
VB VOLTAGE BETWEEN B1 & B2 FIG. 3
VC VOLTAGE BETWEEN C1 & C2 FIG. 3
VD VOLTAGE BETWEEN A2 & B1 FIG. 3

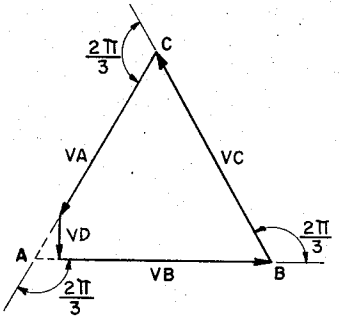



FIG. 4

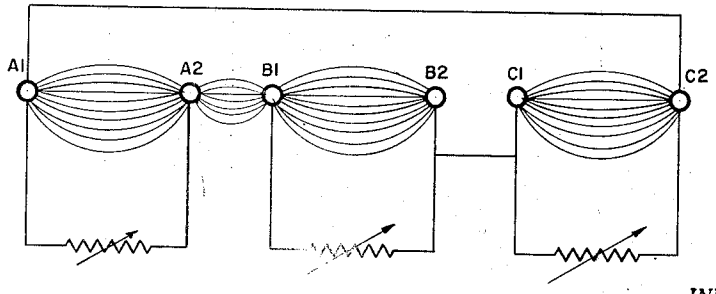



FIG. 3

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# METHOD AND ARRANGEMENT IN THE HEATING OF ELECTRIC FURNACES

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15 Claims. (Cl. 13—6)

The present invention concerns an arrangement for heating electrical furnaces by Joule effect and more especially glass furnaces.

It particularly relates to a heating method by polyphase currents, particularly triphase.

It is known that in a triphase mounting the three conductors should be charged equally in order that the resultant of the three voltages be always null without any current circulating in the coils of the supply transformer.

Thus, the current which circulates in a furnace between each group of electrodes, which is fed by two of the three conductors, should have the same intensity. Consequently the total power evolved in a glass melting furnace, for example, is distributed a priori in the furnace between different zones located between pairs of electrodes, and said distribution cannot be modified during the operation of the furnace. Thus, the management of the furnace lacks flexibility and the quantity of glass produced varies, because any variation of the rate at which the raw materials are loaded into the furnace produces a local variation of the temperatures which, in its turn, modifies the local conductivity of the glass bath and consequently requires a change in the distribution of power.

The arrangement which is the object of my invention, copes with this drawback and gives other advantages which will be described hereinafter. It consists in using in a furnace fed by polyphase currents and for each of the alternative components of the polyphase system, a voltage which may be variable and in using between two special points of the furnace the resulting voltage from the composition of those variable voltages.

In other words, the furnace is supplied with a plurality of phases, each of which is independently variable, and in which the circuit is not completely closed by electrical connections but in which a gap is left, in the part of the electrical circuit submerged in the melt, between two electrodes of adjacent phases, and through this gap a current may be made to flow from phase to phase. The leads and electrodes thus arranged produce a supplementary heated zone in a part of a furnace that would not be directly traversed by the primary current of any one phase, great flexibility is imparted to the heating of furnaces, and powers of different magnitude may be used in different phases without risk of damaging the transformer by short cut current built up through the plurality of phases.

In a disposition like that, when two electrodes, belonging to two adjacent phases, are next to each other in the bath, it is favorable to connect them, so that the two current intensities will differ in phase by the same angle

$$\frac{2\pi}{n}$$

and the electric load per square unit of the electrodes will, thus, be smaller than if the phases were completely independent. $n$ is the total number of phases.

With the above provisions of unequal voltages, and



uniform diphasing between phases the geometrical sum of the voltages is not zero; examples of such systems are in the graphs of Figs. 2 and 4, for three phase systems.

If the circuit was completely closed by electrical connections, such as between electrodes $A_2$ and $B_1$ in Fig. 1, a current resulting from the unbalanced voltages would circulate through the transformer, and as it may reach rather high values, would damage the transformer, but the invention provides a gap in the electrical circuit between two electrodes of two adjacent phases as at $A_2$ and $B_1$ of Fig. 3. The resulting voltage, thus, produces a current which flows through the portion of the bath constituting a resistor in the gap.

In Fig. 1, the "edges" of the gap are the electrodes $A_1$ and $C_2$ which are located far from each other. The current, which would circulate between these electrodes, would disturb the establishment of the main lines of force between the two pairs of electrodes. A feature of the invention consists in connecting the electrodes $C_2$ with an extra electrode D located next to $A_1$; the resulting current, thus, flows in the part of the bath between D and $A_1$ and gives, as above, a fourth heated zone in the furnace.

The resulting voltages are applied between electrodes in parts of the furnace not traversed directly by the currents flowing between the parts of the regular system and produce, in the glass bath, heating currents which are different.

The voltage resulting from the composition of the different variable voltages may be used to produce a heating current through the glass bath in any predetermined zone of the furnace.

An embodiment of my invention, for example in the case of a triphase mounting, consists in feeding three zones of a furnace with three monophase currents having different voltages the difference in phase between two of these voltages being an angle of

$$\frac{2\pi}{3}$$

and in feeding a fourth zone with the voltage that results from the composition of the three different voltages.

The whole constitutes a triphase system.

In the accompanying drawings, Figure 1 schematically illustrates the aforesaid embodiment of my invention, Figure 2 shows the triangle of the voltages in said embodiment, Figures 3 and 4 respectively represent another embodiment and the triangle related thereto.

Fig. 1 schematically represents a glass melting bank. The pairs of electrodes are designated by $A_1$, $A_2$—$B_1$, $B_2$—$C_1$, $C_2$. Each pair has its electrodes connected to the terminals of one of the three secondary coils of a transformer of which the primary is not shown. The arrows on the secondary coils indicate that their voltages are variable. This variation may be obtained by any known means.

The triangle of vectors A, B, C shown in Figure 2 is closed at its two apexes A and B because electrical connections join $A_2$ of Fig. 1 with $B_1$ and $B_2$ with $C_1$; and on the other hand, the triangle ABC is opened at its apex C on account of the inequalities in the voltages at the terminals of the three phases, so that a residual voltage exists between points $A_1$ and $C_2$ of Fig. 1.

The above triphase mounting which purposely is unbalanced, by having adjusted the voltage of the phases individually, would give rise to a considerable current of circulation in the coils and would be harmful to them if terminals $A_1$, $C_2$ were connected by a not very resistant conductor.

But the terminal $C_2$ is connected by a cable to a supplementary electrode D which may be placed near the loading zone. The residual voltage between the electrodes $A_1$ and $C_2$ is applied in those conditions between

electrode $A_1$ and electrode D and gives rise to a current which heats the glass therebetween.

If electrodes $C_2$ and D were not interconnected, a current would pass, in the glass bath, between electrodes $A_1$ and $C_2$ and its lines of electric force would impede the lines of electric force established between the electrodes $A_1$, $A_2$, $B_1$, $B_2$, $C_1$, $C_2$. It is known, indeed, that such lines of force cannot intercross but must find their places along side of each other.

The residual voltage between the electrodes $A_1$ and D differs according to circumstances: it is low when the three main voltages are not very different, but it can become important if they substantially differ from each other.

In all cases, the current to which the residual voltage gives rise contributes to heat the loading zone, in the case illustrated in Fig. 1, keeps up the fluidity of the glass and consequently insures the necessary mobility of the medium on which the raw materials float. The power which is necessary thereto is low and nearly as great as the losses through the walls of the loading zone thus compensating for those losses.

There is no drawback to using an excess of electrical energy in the part of the furnace thus supplied because this excess contributes to heat the raw materials.

Said arrangement enables one to control at will the power spent in the different zones of the glass bath according to the requirements of particular zones, and permits the production of glass at a temperature that does not vary with its production.

In the arrangement of Fig. 3, the resulting voltage is used for heating a zone of the glass bath which is not the loading zone, for example, the zone comprised between the two electrodes $A_2$, $B_1$ which is between two zones $A_1$, $A_2$ and $B_1$, $B_2$ heated by the unbalanced voltages; in that mounting, the electrode D of the Figure 1 is removed and electrode $A_1$ is connected to electrode $C_2$ by a conductor that is outside the glass bath.

Figure 4 illustrates the voltage triangle of the mounting shown in Figure 3. This triangle is closed at its apexes B and C, owing to the electrical connections which join $B_2$ with $C_1$ and $C_2$ with $A_1$. On the other hand, the triangle ABC is open at its apex A in consequence of the inequality of voltages at the terminals of the three phases, which produces a residual voltage between the points $A_2$ and $B_1$.

In the two above described embodiments, the electrodes are horizontal, but vertical or inclined electrodes may be used within my invention.

It is understood that these embodiments are not restrictive; for example, a greater number of pairs of electrodes may be used, with polyphase current that is other than triphase current.

The following are examples of the invention:

An arrangement for the heating of electric furnaces by Joule effect and more particularly of melting glass furnaces, by polyphase currents, which consists in using for each alternative phase of the polyphase system, a voltage which is made variable and in using between two particular points of the furnace the residual voltage resulting from the composition of said variable voltages.

A triphase mounting for the heating of electric furnaces by Joule effect, and more particularly of melting glass furnaces, which consists in feeding three zones of the furnace with three monophase currents having variable voltages, each voltage being differing of

$$\frac{2\pi}{3}$$

in phase from the preceding voltage, and in feeding a fourth zone with the residual voltage resulting from the composition of the three variable voltages.

A triphase mounting according to the foregoing wherein the fourth zone lies outside the three zones which



are fed with monophase currents differing of an angle of

$$\frac{2\pi}{3}$$

in phase from each other, for example, near the loading zone.

A triphase mounting according to the foregoing wherein the fourth zone lies between two of the three other zones which are fed with monophase currents differing of an angle of

$$\frac{2\pi}{3}$$

from each other.

A polyphase mounting according to the foregoing wherein each of the polyphase phases feeds a zone of the furnace with a monophase current, the variable tension differs of an angle of

$$\frac{2\pi}{n}$$

from the preceding and in feeding a supplementary zone lying outside the said other zones.

A polyphase mounting according to the foregoing wherein each of the polyphase phases feeds a zone of the furnace with a monophase current, the variable tension differs of an angle of

$$\frac{2\pi}{n}$$

from the preceding zone and feeding a supplementary zone lying between two of the said zones.

What I claim is:

1. An electric furnace having a plurality of pairs of electrodes, current supply means supplying each pair with a phase of alternating current differing from each adjacent pair by

$$\frac{2\pi}{n}$$

$n$ being the number of pairs, voltage varying means independently connected to each pair, electrical connections other than the melt interposed between adjacent electrodes of certain different pairs, the sole connection between adjacent electrodes of another pair being the melt.

2. An electric furnace having three pairs of electrodes, means to supply each pair with a phase of alternating current differing by

$$\frac{2\pi}{3}$$

from its adjacent pair, connecting means other than the melt connecting the adjacent electrodes of two phases, the third phase having an electrode adjacent an electrode of another phase but connected thereto only by the melt, and means to vary the voltages of the phases individually whereby to flow current through the melt between those electrodes of the different phases which are connected only by the melt.

3. An electric furnace for the heating of molten materials by the passage therethrough of electric current introduced by electrodes which comprises a tank adapted to hold the molten materials, a plurality of pairs of electrodes adapted to engage the molten materials, means to supply one pair of electrodes with alternating current, a second pair of electrodes adjacent the said one pair in said furnace, means to supply said second pair with alternating current differing in phase by

$$\frac{2\pi}{n}$$

from the said one pair, $n$ being the total number of phases, an electrical connection other than the molten materials connecting adjacent electrodes of the first and second pair, one electrode of said one pair being adjacent an electrode of another phase and electrically con-

nected thereto solely by the molten material, voltage varying means connected to a said pair of electrodes carrying a said phase, and independently variable voltage varying means connected to a pair of electrodes carrying another phase.

4. The method of heating molten materials by the passage of electric current therethrough that comprises passing through a plurality of paths in said molten materials a plurality of phases of alternating current differing from each other by about

$$\frac{2\pi}{n}$$

$n$ being the total number of phases, producing unbalanced voltage in at least one said phase, and flowing such unbalanced voltage through said molten material from one phase to another.

5. A method for heating the contents of a melting furnace by electric current passing through the molten charge which comprises passing separate phases of current through separate paths in the molten materials, said phases differing from each other by

$$\frac{2\pi}{n}$$

$n$ being the total number of separate phases, controlling the voltage of each phase separately and thereby producing an unbalanced voltage, and passing said unbalanced voltage through a portion of the melt other than said paths.

6. A method according to claim 4 in which there are three phases passing through three paths, in which the currents differ in phase by

$$\frac{2\pi}{3}$$

and in which the unbalanced voltage is passed through a fourth path.

7. A furnace according to claim 1 in which an extra electrode is immersed in the melt, in proximity to an electrode of one phase, and is connected with an electrode of a different phase.

8. The method of heating a molten mass that comprises passing a plurality of phases of electricity through it, unbalancing the phases, and passing the unbalanced current through a part of the molten mass not directly traversed by the current of the said phases.

9. An electric furnace having $n$ pairs of electrodes, current supply means supplying each pair with a phase of alternating current with voltage differing from the preceding one by

$$\frac{2\pi}{n}$$

varying means independently acting on each phase voltage, electrical connections other than the melt interposed between adjacent electrodes of certain successive pairs, the sole connection between adjacent electrodes of another pair being the melt.

10. An electric furnace having three pairs of electrodes, means to supply each pair with single phase alternating current differing in voltage from each other pair by 120°, connecting means other than the melt between the adjacent electrodes of two pairs, the third pair having an electrode adjacent an electrode of another pair but connected thereto only by the melt, and means to vary the voltages of the three phases individually, whereby to flow the resulting current through the melt between those electrodes of the diffeernt pairs which are connected only by said melt.

11. An electric furnace for the heating of molten materials by the passage therethrough of electric current introduced by electrodes, which comprises a tank adapted to hold the molten materials, $n$ pairs of electrodes adapted to be immersed in the molten materials, means to supply



one pair of electrodes with one phase of alternating current, a second pair of electrodes adjacent the preceding pair of electrodes in said furnace, means to supply said second pair with another phase of alternating current differing in voltage by

$$\frac{2\pi}{n}$$

from the preceding voltage phase, an electrical connection other than the molten materials connecting electrodes of two pairs, an electrode of said one pair being adjacent an electrode of another pair and electrically connected thereto solely by the molten material, voltage varying means connected to one of said pair of electrodes and independently variable voltage varying means connected to the second pair of electrodes.

12. A method for heating the content of a melting furnace by electric current passing through the molten charge which comprises passing separate phases of current through separate paths of the molten materials, the voltages of each phase differing from the preceding one through an angle of

$$\frac{2\pi}{n}$$

$n$ being the total number of phases of current, controlling the voltage of each phase separately and thereby producing a current of which the voltage is the result of the $n$ unbalance voltages, and passing said current through a portion of the melt other than said paths.

13. A method according to claim 12 in which there are three phases of current passing through three paths, the voltages of the three phases differing by 120 degrees, and in which the current produced by the voltage resulting from the unbalancing of the voltages of the three phases is passed through a fourth path.

14. A method for heating the content of a melting furnace, by electric current passing through the molten materials, said current being supplied by a plurality of $n$ phases of alternating current, which $n$ voltages differ in phase through an angle of

$$\frac{2\pi}{n}$$

that comprises separately controlling the voltage of each phase, and using the voltage resulting from the composition of the unbalanced $n$ voltages of the different phases in a portion of the bath not already traversed by any one of the $n$ phases.

15. A method for heating three zones of a melting furnace which comprises passing three phases of alternating current through the melt, of which the voltages differ in phase through an angle of 120 degrees, and are of unequal value, separately controlling the phases, and heating a fourth zone by the current resulting from the composition of the three unequal voltages.


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