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CONTROL CIRCUIT FOR AUTOMATIC POSITIONING OF PAIRS OF ELECTRODES IN SMELTING FURNACES

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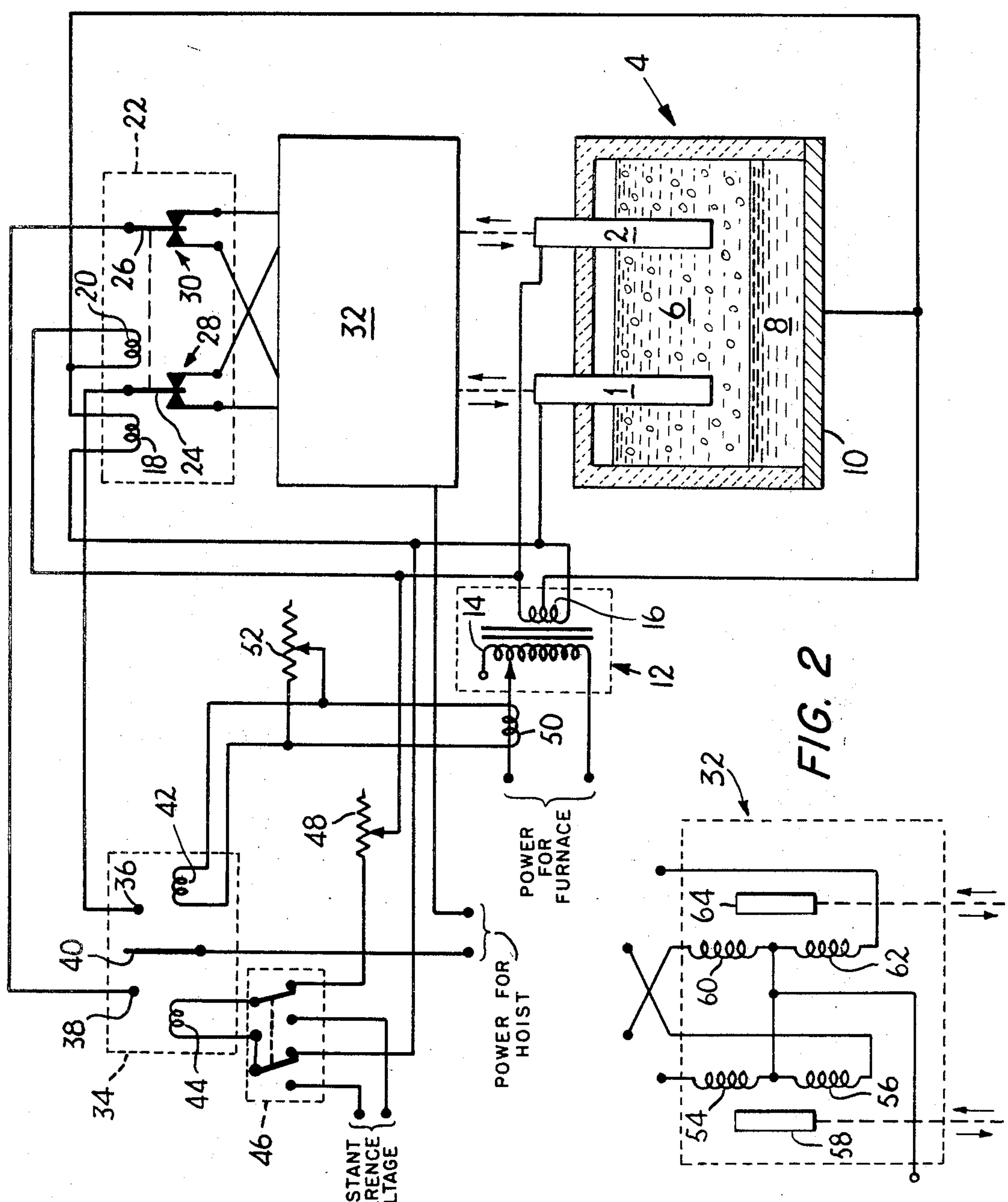

FIG. 1

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CONTROL CIRCUIT FOR AUTOMATIC POSITIONING OF PAIRS OF ELECTRODES IN SMELTING FURNACES

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ABSTRACT OF THE DISCLOSURE

A control circuit which will adjust the position of pairs of series-connected electrodes or of either one of the electrodes in each pair, including a first differential relay for controlling the direction of movement of the electrodes and a second differential relay which determines whether the position of both electrodes or of a single electrode of the pair is to be adjusted.

The present invention relates to controls for automatically positioning pairs of electrodes which are series-connected to either several single-phase transformers or to one multi-phase transformer. Specifically, pairs of electrodes are series-connected within each single-phase system or sub-system, with a single regulator serving to control the position of each electrode of each pair so as to control the current through the smelting furnace.

In the past, control of electrode positions in smelting furnaces usually required a regulator for each individual electrode, which regulated according to constant impedance by measuring the potential between each electrode and the furnace bottom. Regulation based on constant furnace current has heretofore not been utilized in multi-electrode smelting furnaces in which pairs of electrodes are connected in series within each single-phase system or sub-system. With such an arrangement, current could remain constant although there might be a wide divergence in the positions of the series-connected electrodes, i.e., the degree of immersion of one electrode in the furnace charge may result in a very high effective resistance between the electrode and the furnace bottom, while the degree of immersion of the other electrode may be such that a very low effective resistance exists between the electrode and the furnace bottom.

The present invention is directed toward preventing such a disparity between the degrees of immersion of pairs of series-connected electrodes. This is accomplished by comparing the potentials between the furnace bottom and each electrode and actuating a differential relay in response to a sufficiently large difference between these two potentials. The differential relay thus actuated controls the electrode hoist mechanism and causes this mechanism to adjust the position of only one electrode so as to maintain a substantially equal degree of immersion of each electrode of the pair within a predetermined range. A second differential relay responds to differences between the current in the primary winding of the furnace transformer and the voltage across the secondary winding to determine the direction in which the electrodes or the selected electrode must be moved.

A better understanding of the presenting invention may

be had with reference to the accompanying drawing, of which:

FIG. 1 is a schematic diagram of a control circuit embodying the present invention; and

FIG. 2 is a schematic diagram of an electromagnetic hoist.

In FIG. 1, electrodes **1** and **2** are inserted into a furnace **4** so as to be partially immersed in a charge **6**. Below the charge is a melt **8** which is formed electrothermically as a result of current flowing between electrodes **1** and **2** and the furnace bottom **10**. Power transformer **12** has its adjustable primary winding **14** connected to a suitable source of power. The secondary winding **16** of power transformer **12** has its first and second terminals connected to the upper ends of electrodes **1** and **2**, respectively. The potentials between electrodes **1** and **2** and the furnace bottom **10** are impressed across the coils **18** and **20**, respectively, of differential relay **22**, which also includes ganged armatures **24** and **26** which are normally pressed between contact pairs **28** and **30**. Contact pairs **28** and **30** are connected to the electrode hoist mechanism **32**.

A second differential relay **34** includes contacts **36** and **38** which are connected respectively to armatures **24** and **26** of relay **22**. Relay **34** further includes an armature **40** which is normally in a neutral position, i.e., not in contact with either of contacts **36** or **38**, and coils **42** and **44**. A double-pole, double-throw switch **46** enables coil **44** to be connected either across secondary winding **16** of power transformer **12** in series with a variable resistance **48** as shown, or, when constant furnace current is d sired, across a constant reference voltage. Coil **42** is connected across a current-sensing coil **50**, which detects the current flowing in the primary winding **14** of power transformer **12**. Current-sensing coil **50** is shunted by a variable resistance **52** to enable adjustment of the current through coil **42**. Armature **40** of the differential relay **34** is connected to one of the power input terminals for the electrode hoist mechanism **32**.

In operation, power is applied across the primary winding **14** of power transformer **12** to produce a relatively low voltage-high current output in the secondary winding **16**. Current flows between electrode **1** and the furnace bottom **10** and between electrode **2** and the furnace bottom **10**, the paths of these currents being through the charge **6** and the melt **8**. When the potential between electrode **1** and the furnace bottom **10** does not differ from the potential between electrode **2** and the furnace bottom **10** by more than a predetermined amount, differential relay **22** will not be actuated, i.e., the net flux produced by the currents through coils **18** and **20** will not be sufficient to attract armature **24**, which is ganged with armature **26**. Thus, if armature **40** of differential relay **34** should be drawn against contact **38** as a result of decreased furnace current causing increased voltage output across secondary winding **16**, then power would be applied to the electrode hoist mechanism **32** through armature **40** and contact **38** of relay **34** and through armature **26** and both contacts of contact pair **30** of relay **32** to lower both electrodes **1** and **2** in order to increase furnace current. If furnace current should be too high, thereby causing a decreased voltage output across secondary winding **16**, then armature **40** of relay **34** will be drawn against contact **36**, and power will be applied to the hoist mechanism **32** through armature **40** and contact **36** of relay **34** and through armature **24** and both contacts of contact pair **28** of relay **22** to raise both electrodes **1** and **2** in order to decrease furnace current.

It might happen that electrode **1** is immersed more deeply in the charge **6** than electrode **2**, thus causing the current and the potential between electrode **1** and the furnace bottom **10** to exceed the current and the potential between electrode **2** and the furnace bottom **10**. If these two potentials differ by a sufficiently large increment, the flux produced by coil **18** of relay **22** will be lessened to a level at which armature **24** will be drawn toward coil **20**, thus breaking the contact between armature **24** and the left contact of contact pair **28** while maintaining contact with the right contact. Similarly, ganged armature **26** will break contact with the left contact of contact pair **30** while maintaining contact with the right contact. Thus, when armature **40** of relay **34** is drawn against contact **36** as a result of the increased furnace current, power will be applied only to that portion of the hoist mechanism **32** which operates to raise electrode **1**. Power will be applied to the hoist mechanism **32** through armature **40** and contact **36** of relay **34** and through armature **24** and the right contact of contact pair **28** of relay **22** to effect the adjustment of the position of electrode **1** only. If it is electrode **2** that is immersed too deeply in charge **6**, a similar adjustment would be made for this electrode by movement of the armatures **24** and **26** leftward so as to break contact with the right contacts of contact pair **28** and **30** while maintaining contact with the left contacts. If either or both electrodes **1** and **2** are not immersed far enough into the charge **6**, armature **40** of relay **34** will be drawn against contact **38** as a consequence of the decrease in furnace current and the resultant increase in voltage across the secondary winding **16** of transformer **12**.

FIG. 2 schematically illustrates one possible form of the hoist apparatus **32**. Specifically, this figure illustrates an electromagnetic type of hoist apparatus, which, when connected into the circuit of FIG. 1, as shown therein, will serve to raise or lower both of the electrodes **1** and **2** or a selected one of the electrode pair. This hoist apparatus consists of a first pair of windings **54** and **56** associated with a moveable magnetic core **58** which is mechanically connected to electrode **1**; and a second pair of windings **60** and **62** associated with a moveable magnetic core **64** which is mechanically connected to electrode **2**. Winding **54** is connected in series between the left contact of contact pair **28** and ground; winding **56** is connected in series between the left contact of contact pair **30** and ground; winding **60** is connected in series between the right contact of contact pair **28** and ground; and winding **62** is connected in series between the right contact of contact pair **30** and ground. Thus, when armature **40** of relay **34** is urged against contact **36** as a result of increased furnace current, each of the windings **54** and **60** will be energized through armature **24** of relay **22** and contact pair **28** and the moveable cores **58** and **64** will be drawn upward, thus raising both electrodes **1** and **2** to decrease furnace current. This assumes, of course, that the difference between the potentials between the furnace bottom **10** and the electrodes **1** and **2** is not above the predetermined threshold value which will actuate relay **22**, thus causing only the electrode conducting the most current to be raised.

Similarly, if armature **40** of relay **34** is urged against contact **38** as a result of decreased furnace current, then windings **56** and **62** will be energized through armature **26** and contact pair **30** of relay **22**, thereby urging the moveable cores **58** and **64** downward and thus lowering electrodes **1** and **2** in order to increase furnace current. Again, if there should be a sufficiently large difference between the electrode-to-floor potentials, only the electrode carrying the lightest current will be lowered.

Although the present invention is primarily concerned with electrical reduction furnaces in which the resistant medium is formed by a charge introduced into the furnace, it should be understood that the invention has applications in other fields. For example, it could be utilized in electric boilers. Also, the present invention may be employed with either an alternating current powered furnace or a direct current powered furnace. Various equivalents of the control circuit components will be obvious to one knowledgable in the art.

The advantages of the present invention, as well as certain changes and modifications to the disclosed embodiment thereof, will be readily apparent to those skilled in the art. It is the applicant's intention to cover all those changes and modifications which could be made to the embodiment of the invention herein chosen for the purposes of the disclosure without departing from the spirit and scope of the invention.

What I claim is:

1. An automatically-controlled electric smelting furnace system comprising:

(1) an electric furnace having at least one pair of electrodes;

(2) means for applying electric potential between the bottom of said electric furnace and each of said at least one pair of electrodes;

(3) hoist means for adjusting the position of said at least one pair of electrodes or of either one of said at least one pair of electrodes;

(4) relay means responsive to a predetermined minimum difference between the potentials between the bottom of said furnace and each of said at least one pair of electrodes to enable said hoist means to adjust only a selected one of said at least one pair of electrodes, and responsive to a difference between said potentials less than said predetermined minimum difference to enable said hoist means to adjust both of said at least one pair of electrodes; and

(5) means responsive to fluctuation in furnace current to provide to said hoist means through said relay means an input which causes said hoist means to adjust the positions of said at least one pair of electrodes or of a selected one of said at least one pair of electrodes so as to stabilize the value of furnace current.

2. The furnace system according to claim **1** wherein said means for applying electric potential is a transformer having a core and primary and secondary windings, said at least one pair of electrodes being connected in series with said secondary winding and with each other.

3. The furnace system according to claim **2** wherein said means responsive to fluctuations in furnace current comprises:

(1) a differential relay having an armature connected to one power input terminal of said hoist means, first and second normally-open contacts, and first and second coils;

(2) a current-sensing coil for sensing primary winding current in said transformer, and a variable resistance for shunting a portion of the output current of said sensing coil, said first coil of said differential relay being connected across said current-sensing coil; and

(3) switching means for selectively connecting said second coil of said differential relay either in series with a variable resistance across said secondary winding of said transformer or across a constant reference voltage source.

4. The furnace system according to claim **3** wherein said relay means responsive to differences in the potentials from the electrodes to the furnace bottom comprises first and second ganged armatures, a pair of normally-closed contacts associated with each of said armatures, and first and second coils associated with at least one of said armatures, said first and second armatures being electrically connected respectively to said first and second contacts of said differential relay of said means responsive to fluctuations in furnace current, said contact pairs being electrically connected to said hoist means, and said first and second coils being connected across said furnace bottom and the first and second electrodes, respectively, of said at least one pair of electrodes.

5. The furnace system according to claim **4** wherein said hoist means comprises:

(1) first and second windings and an associated movable core which is mechanically connected to said first electrode, said first and second windings being operative when energized to move said movable core upwardly and downwardly, respectively;

(2) third and fourth windings and an associated movable core which is mechanically connected to said second electrode, said third and fourth windings being operative when energized to move said movable core upwardly and downwardly, respectively.

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