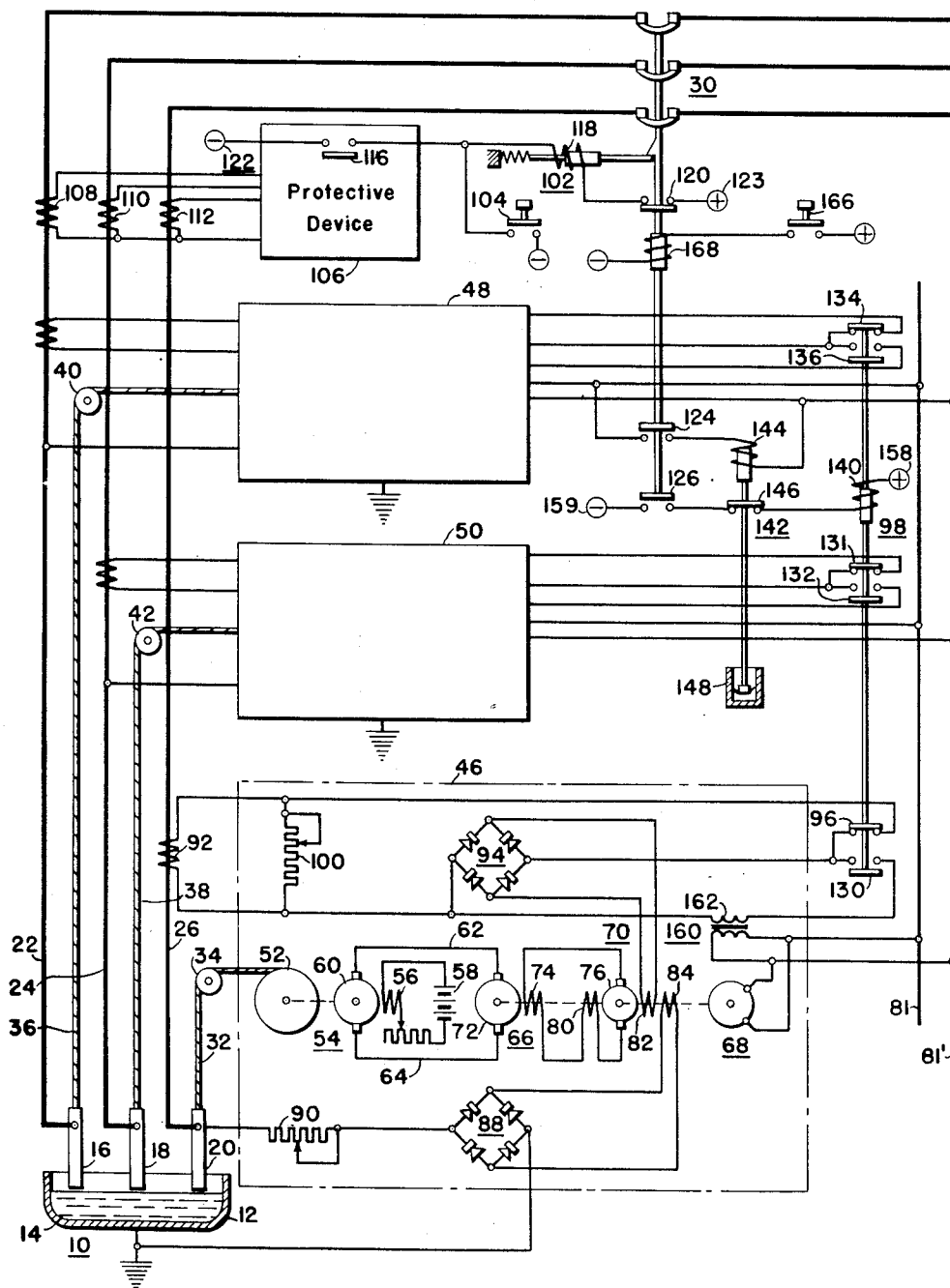


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ARC FURNACE CONTROL SYSTEM

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ARC FURNACE CONTROL SYSTEM

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This invention relates to control systems and, particularly, to control systems for governing the operation of movable electrodes of electric arc furnaces.

When the movable electrodes of an arc furnace are operated in close proximity to the molten bath, as is normally the case, certain undesirable features result. For instance, if the electrodes come in contact with the molten bath, the material of the electrodes contaminate the bath. This can even occur after the power to the electrodes is discontinued since the level of the molten bath continues to rise due to further melting of the charge contained therein. Further, if the electrodes remain in contact with the molten bath for a sufficient time to allow the cooling of the bath, the movable electrodes may freeze to the bath.

In an arc furnace system the movable electrodes are normally connected to the source of power supply through a circuit breaker. This circuit breaker during the operation of the arc furnace may be interrupted a plurality of times during each hour of operation. Each time the circuit breaker is interrupted the operator often actuates the circuit breaker to the closed position under load, that is, when either the source of power is normally supplying energy to the movable electrodes, or when a short circuit condition exists. The actuation of the circuit breaker to the closed position under load a plurality of times each hour shortens the life of the circuit breaker considerably.

An object of this invention is to provide for actuating an electrode of an arc furnace a predetermined distance from its associated molten bath once the main power supply to the electrode has been interrupted to thereby prevent both contamination of the molten bath by the electrode and freezing of the electrode in the molten bath, by rendering a control relay and timing means responsive to the circuit interruption of the power supply to the electrode so that the control relay initiates the movement of electrode away from the molten bath and the timing means stops such movement after a predetermined time.

Another object of this invention is to provide for lengthening the life of circuit interrupting means connected between a movable electrode of an arc furnace and its source of power, by moving the electrode a predetermined distance from the molten bath when the flow of current is interrupted so that the circuit interrupting means is not closed under load when initiating an arc furnace operation.

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Other objects of this invention will become apparent from the following description when taken in conjunction with the accompanying drawing, in which the single figure is a schematic diagram of circuits and apparatus illustrating an embodiment of the teachings of this invention.

Referring to the drawing there is illustrated an arc furnace 10, comprising a container 12, having disposed therein a molten bath 14. As illustrated, a plurality of movable electrodes 16, 18 and 20 are disposed in close proximity to the upper surface of the molten bath 14. In this instance the movable electrodes 16, 18 and 20 are directly connected to load conductors 22, 24 and 26, respectively, which in turn are connected to a suitable source of power supply (not shown) through circuit interrupting means 30. A flexible cable 32 is connected to the movable electrode 20 and is disposed around a suitable pulley 34 so as to raise and lower the movable electrode 20 in accordance with predetermined conditions which will be explained hereinafter. The movable electrodes 16 and 18 also have associated therewith flexible cables 36 and 38 respectively, and pulleys 40 and 42, respectively.

Since the operating mechanism for each of the three phases supplying the arc furnace 10 is identical, the operating mechanism for only one phase is illustrated in detail and is shown enclosed in the rectangular area 46. As can be seen from the drawing, the operating mechanism enclosed within the rectangular area 46 is associated with the movable electrode 20. The corresponding operating mechanism for the movable electrodes 16 and 18 is disposed within the rectangular areas 48 and 50, respectively.

Referring more particularly to the operating mechanism within the rectangular area 46, the flexible cable 32 may be wound upon a winding drum 52, operated by a reversible electrode motor 54. The motor 54 comprises a field winding 56 disposed to be energized from any suitable direct current source, such as the battery 58, and an armature winding 60 connected by conductors 62 and 64 to be supplied with energy from a main generator 66 that is driven by an alternating current motor 68 and excited by an exciter generator 70.

The main generator 66 comprises an armature winding 72 connected to the conductors 62 and 64, and a field winding 74 disposed to be supplied with energy from the armature winding 76 of the exciter generator 70 through a self-exciting field winding 80. In this instance the motor 68 receives alternating current energy from line con-

ductors 81 and 81', which in turn are connected to a suitable source of alternating current power (not shown).

As illustrated, the exciter generator 70 is also provided with two control field windings 82 and 84, which are disposed to be so energized as to oppose each other and to cooperate in controlling the excitation of the exciter generator 70. In order to render the control winding 84 of the exciter generator 70 responsive to the arc voltage of the movable electrode 20, one of the input terminals of a full-wave rectifier 88 is connected to the container 12 and the other input terminal of the rectifier 88 is connected to the movable electrode 20 through an adjustable resistor 90, the function of which will be described hereinafter. As illustrated the output terminals of the rectifier 88 are connected to the control field winding 84 of the exciter generator 70.

On the other hand, in order to obtain a measure of the current flow through the movable electrode 20, a current transformer 92 is disposed in inductive relationship with the load conductor 26. As can be seen from the drawing, the current transformer 92 is connected to the input terminals of a full-wave rectifier 94, through normally closed contact members 96 of a control relay 98, the function of which will be described hereinafter. In order to render the control field winding 82 responsive to the arc current of the movable electrode 20, the output terminals of the rectifier 94 are connected to the control field winding 82. In this instance an adjustable resistor 100 is connected across the current transformer 92, which adjustable resistor in conjunction with the adjustable resistor 90 provide the necessary adjustments for obtaining a balance between the control field windings 82 and 84 of the exciter generator 70, when the movable electrode 20 is disposed a proper distance from the molten bath 14 for operating conditions.

During the normal operation of the arc furnace 10 the movable electrode 20 is maintained in a substantially constant regulated position relative to the molten bath 14. When so positioned the control field windings 82 and 84 have an equal and opposite effect and thus the effects neutralize each other. However, if the movable electrode 20 moves closer to the molten bath 14 than its regulated position, the current flow through the load conductor 26 increases to thereby increase the output of the current transformer 92, which in turn increases the current flow through the control field winding 82. On the other hand, the lowering of the movable electrode 20 below its regulated position decreases the arc voltage as applied to the control field winding 84 through the rectifier 88. Thus, when the movable electrode 20 is located below its regulated position, the flux produced by the field winding 82 is greater in magnitude than the flux produced by the field winding 84. When the flux produced by the field winding 82 is greater in magnitude than the flux produced by the field winding 84, the resultant flux will cause the exciter generator 70 to develop a voltage of such polarity as to energize the main generator field winding 74 in a direction to impress a voltage on the motor armature 60, having a polarity to cause the motor 54 to operate in a direction to raise the movable electrode 20, to thereby return it to its regulated position. However, if the flux produced by the control field winding 84 is greater in magnitude than the flux produced by the control field winding 82, due to the fact that the movable elec-

trode 20 is above its regulated position, the resultant flux produced by the control field windings 82 and 84 will effect a lowering of the movable electrode 20, to thereby return it to its regulated position.

As hereinbefore mentioned, circuit interrupting means 30 is connected between the movable electrodes 16, 18 and 20 and their source of power supply (not shown). In this instance, the circuit interrupting means 30 comprises a trip device 102, which can either be manually energized by a pushbutton 104, or energized in response to a short circuit condition, to thereby trip the circuit interrupting means 30, and thus disconnect the movable electrodes 16, 18 and 20 from their source of power (not shown). In particular, a protective device 106 is disposed to be responsive to the outputs of current transformers 108, 110 and 112, which are disposed in inductive relationship with the load conductors 22, 24 and 26, respectively. In order to render the trip device 102 responsive to the output currents of the current transformers 108, 110 and 112, normally open contact members 116 are disposed to be actuated in response to these output currents of the current transformers 108, 110, and 112. A circuit for energizing the trip device 102 extends from a negative terminal 122 of a suitable direct current source (not shown) through the normally open contact members 116 of the protective device 106, an energizing winding 118 of the trip device 102, and auxiliary contact members 120 of the circuit interrupting means 30, to a positive terminal 123 of the source of direct current (not shown). The circuit interrupting means 30 also controls auxiliary contact members 124 and 126, the function of which will be described hereinafter.

In accordance with the teachings of this invention, in order to initiate the actuation of the movable electrode 20 in a direction away from the molten bath 14 once the circuit interrupting means 30 has been actuated to the circuit interrupting position, the control relay 98 is provided. In this instance, the control relay 98 comprises the normally closed contacts 96 and normally open contacts 130, associated with the operating mechanism disposed within the rectangular area 46. The control relay 98 also comprises a corresponding set of contact members 131 and 132 associated with the operating mechanism disposed within the rectangular area 50, and a corresponding set of contact members 134 and 136 associated with the operating mechanism disposed within the rectangular area 48. In order to actuate the normally open contact members 130, 132 and 136 to the closed position, an operating coil 140 of the relay 98 is provided.

For the purpose of deenergizing the operating coil 140 of the control relay 98 once the movable electrode 20 has been raised a predetermined distance above its regulated position so that the material of the electrode 20 cannot contaminate the molten bath 14 and cannot become frozen thereto, a time delay 142 is provided. In this instance, the time delay relay 142 comprises an operating coil 144, normally closed contact members 146 and a dashpot 148 for effecting the time delay of the relay 142.

In operation when the circuit interrupting means 30 is tripped in response to excessive load current or is manually tripped by means of the pushbutton 104, the auxiliary contact members 124 and 126 are actuated to the closed position. When this occurs, a direct-current circuit is com-

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pleted to the operating coil 140 of the control relay 98, which circuit extends from a positive terminal 153 of a direct current source of energy through the operating coil 140 of the relay 98, the contact members 146 of the relay 142, and the contact members 126 of the circuit interrupting means 30 to a negative terminal 159 of the direct current source of energy. Once this energizing circuit is completed the normally open contact members 130, 132 and 136 are actuated to the closed position, and the normally closed contact members 96 are actuated to the open position by the relay 98 to thereby disconnect the current transformer 92 from the input terminals of the rectifier 94. By closing the contact members 130 of the relay 98 alternating current is supplied to the input terminals of the rectifier 94 through a potential transformer 160 whose secondary winding 162 is connected across the input terminals of the rectifier 94, when the contact members 130 are closed. However, since the contact member 96 of the relay 98 is now in the open position energy is not consumed in passing current from the secondary winding 162 of the transformer 160 to the current transformer 92 and variable resistor 100.

With the secondary winding 162 of the transformer 160 connected to the input terminals of the rectifier 94, the current flow through the control field winding 82 of the exciter generator 70 is such as to effect a raising of the movable electrode 20 above its regulated position, which movement takes place until the action of the time delay relay 142 stops such movement.

In particular, when the circuit interrupting means 30 is tripped open, the auxiliary contact members 124 of the circuit interrupting means 30 are actuated to the closed position, thereby completing an alternating current circuit to the operating coil 144 of the time delay relay 142. After a predetermined time, as determined by the setting of the time delay relay 142, the normally closed contact members 146 of the time delay relay 142 are actuated to the open position, thereby interrupting the direct-current circuit to the operating coil 140 of the control relay 98. The deenergizing of the operating coil 140 causes the normally open contact members 130, 132 and 136 to be actuated to their open position. By actuating the contact members 130, 132 and 136 to the open position, the circuit from the secondary winding 162 of the transformer 160 to the input terminals of the rectifier 94 is interrupted, to thereby deenergize the control field winding 82 of the exciter generator 70, and thus stop the movement of the movable electrode 20. It is to be noted that the control field windings 82 and 84 of the exciter generator 70 do not receive current from the current transformer 92, or from the effect of the voltage between the movable electrode 20 and the container 12, since both the arc current and arc voltage are zero when the circuit interrupting means is in the open position.

In order to reclose the circuit interrupting means 30 and restore the system to its normal operating condition, a pushbutton 166 is disposed to be actuated to thereby complete an energizing circuit to an energizing winding 168 associated with the circuit interrupting means 30.

The apparatus embodying the teachings of this invention has several advantages. For instance, the length of life of the circuit interrupting means 30 is greatly increased. Further, the material of the movable electrodes 16, 18 and 20

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cannot possibly contaminate the molten bath 14 once the circuit interrupting means 30 is actuated to the open position. In addition, by practicing this invention the movable electrodes 16, 18 and 20 cannot freeze to the molten bath 14 once it has cooled sufficiently.

Since certain changes may be made in the above apparatus and circuits, and different embodiments of this invention may be made without departing from the spirit and scope thereof, it is intended that all the matter contained in the above description or shown in the accompanying drawing shall be interpreted as illustrative and not in a limiting sense.

We claim as our invention:

1. In an arc furnace control system for controlling the positioning of a movable electrode with respect to a molten bath in which the arc receives energy from a source of power, the combination comprising, circuit interrupting means connected between the source of power and the movable electrode, a motor for moving the electrode with respect to the molten bath, control means including a control relay responsive to the opening of the circuit interrupting means for so energizing the motor as to actuate the movable electrode in a direction away from the molten bath whereby the material of the electrode cannot contaminate the molten bath, and timing means also responsive to the opening of the circuit interrupting means for deenergizing the control relay once the motor has actuated the movable electrode a predetermined distance from the molten bath to thereby stop the movement of the movable electrode.

2. In an arc furnace control system for controlling the positioning of a movable electrode with respect to a molten bath in which the arc receives energy from a source of power, the combination comprising, circuit interrupting means connected between the source of power and the movable electrode, a motor for moving the movable electrode with respect to the molten bath, means responsive to the current flow through the movable electrode for actuating the circuit interrupting means to the open position, control means including a control relay responsive to the opening of the circuit interrupting means for so energizing the motor as to actuate the movable electrode in a direction away from the molten bath whereby the material of the electrode cannot contaminate the molten bath, and a time delay relay also responsive to the opening of the circuit interrupting means for deenergizing the control relay once the motor has actuated the movable electrode a predetermined distance from the molten bath to thereby stop the movement of the movable electrode.

3. In an arc furnace control system for controlling the positioning of a movable electrode with respect to a molten bath in which the arc receives energy from a source of power, the combination comprising, circuit interrupting means connected between the source of power and the movable electrode, a motor for moving the electrode with respect to the molten bath, a generator for supplying power to the motor, a control winding for the generator, a full-wave rectifier having input and output terminals, the output terminals being connected to the control winding, a source of alternating current, circuit means including a control relay for connecting the source of alternating current to the input terminals of the rectifier, the control relay being responsive to the opening of the circuit interrupting means

to thereby connect the source of alternating current to the input terminals of the rectifier to thus so energize the motor as to actuate the movable electrode in a direction away from the molten bath whereby the material of the movable electrode cannot contaminate the molten bath, and a time delay relay also responsive to the opening of the circuit interrupting means for deenergizing the control relay once a predetermined distance has been established between the movable electrode and the molten bath to thereby interrupt the circuit between the source of alternating-current and the input terminals of the rectifier to thereby stop the movement of the movable electrode.

4. In an arc furnace control system for controlling the positioning of a movable electrode with respect to a molten bath in which the arc receives energy from a source of power, the combination comprising, circuit interrupting means connected between the source of power and the movable electrode, a motor for moving the electrode with respect to the molten bath, a generator for supplying power to the motor, a control winding for the generator, a full-wave rectifier having input and output terminals, the output termi-

nals being connected to the control winding, a source of alternating current, circuit means including a control relay for connecting the source of alternating-current to the input terminals of the rectifier, manual trip means for actuating the circuit interrupting means to the open position, the control relay being responsive to the opening of the circuit interrupting means to thereby connect the source of alternating current to the input terminals of the rectifier to thus so energize the motor as to actuate the movable electrode in a direction away from the molten bath whereby the material of the movable electrode cannot contaminate the molten bath, and timing means also responsive to the opening of the circuit interrupting means for deenergizing the control relay once a predetermined distance has been established between the movable electrode and the molten bath to thereby interrupt the circuit between the source of alternating current and the input terminals of the rectifier to thereby stop the movement of the movable electrode.

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