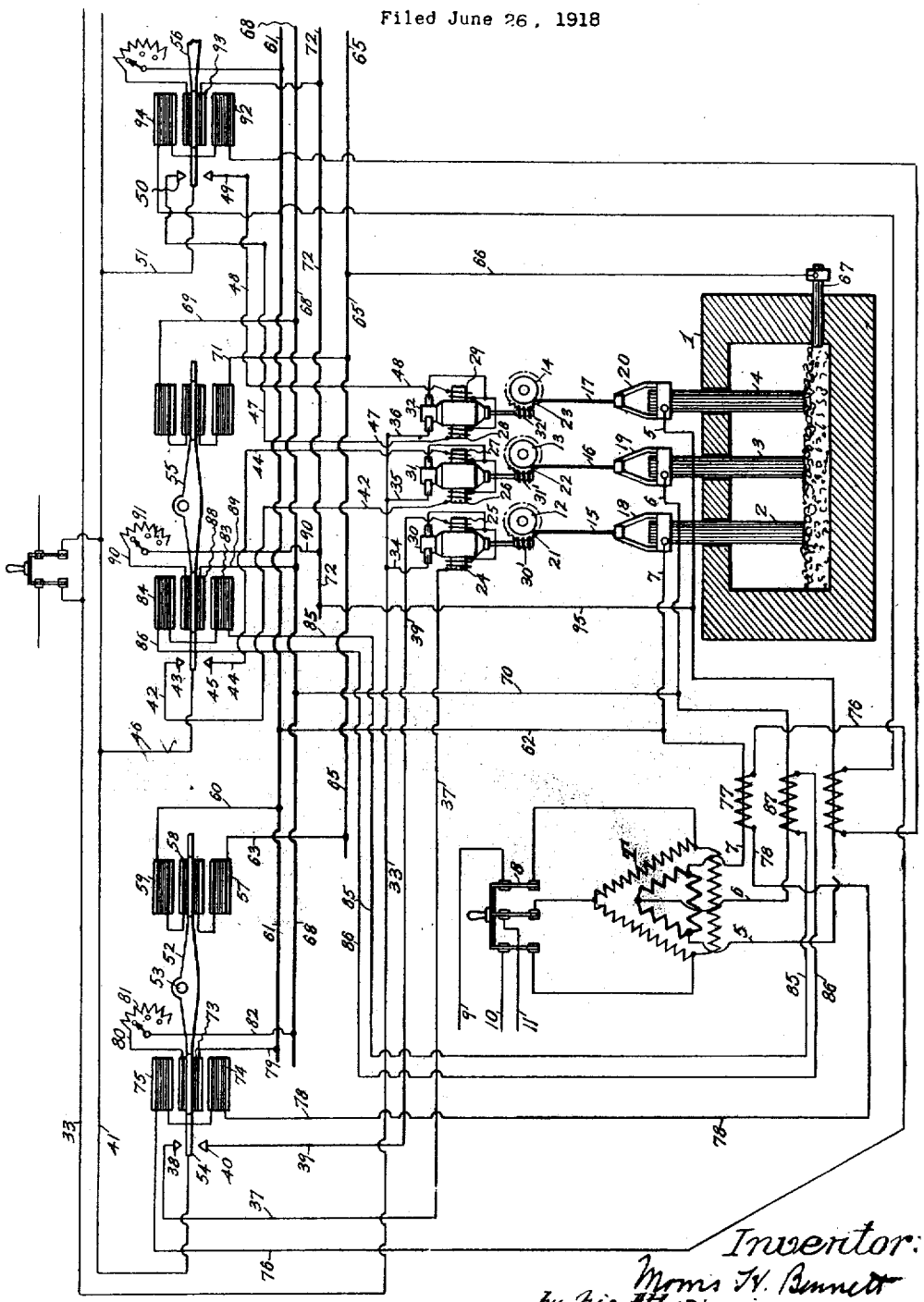
June 24, 1924. 1,498,903

M. H. BENNETT

ELECTRIC FURNACE

Filed June 26, 1918



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Patented June 24, 1924. 1,498,903

UNITED STATES PATENT OFFICE.

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ELECTRIC FURNACE.

Application filed June 26, 1918. Serial No. 241,913.

To all whom it may concern:

Be it known that I, MORRIS H. BENNETT, a citizen of the United States, residing at Waterbury, county of New Haven, and State of Connecticut, have invented certain new and useful Improvements in Electric Furnaces, fully described and represented in the following specification and the accompanying drawings, forming a part of the same.

This invention, specifically considered, relates to improvements in electric controlling or regulating mechanism for electric furnaces.

The amount of heat energy which can be economically delivered to a furnace which employs electric energy as its source of heat, said energy being delivered to the charge through electrodes, is limited by various factors, such as the size and material of the electrodes, the capacity of the charge to economically absorb the heat, and the capacity of the furnace walls to withstand radiated heat. As rapidity of operation is of the highest importance, the heat energy should be delivered to the furnace at the highest rate consistent with the limiting factors, and, where a plurality of electrodes are employed, each electrode should always deliver as nearly as possible its predetermined proportion of such energy. A furnace working on a three-phase system, for instance, and employing three electrodes, should be capacitated to so operate that a predetermined amount of heat energy will be delivered at a uniform rate by all the electrodes, that this predetermined heat input will be subdivided in a definite proportion among the electrodes, and that each electrode will uniformly deliver its proportion of the predetermined heat input.

As, however, metallurgical conditions are constantly changing during the furnace operation, the electrical conditions in the furnace are also constantly changing. It is, therefore, obvious that the delivery of energy to the furnace must be controlled or regulated with respect to these changing conditions, or losses will result which will seriously interfere with the economical operation of the furnace.

Attempts have heretofore been commercially made to meet the varying conditions in an electric furnace by automatically positioning the electrodes through devices which depend for their operation on variations in the amperage. The heat input does not, however, depend solely on the amperage delivered, but is affected by other factors, such, for instance, as changes in wattage, or changes in the potential affected by the resistance between electrode and charge, which will seriously interfere with the economical operation of the furnace and which would not be adjusted for by controlling devices which depend for their operation on changes in amperage. For instance, in a three-electrode furnace provided with a control depending solely upon variations in amperage, the amperage delivered by the three electrodes would be the predetermined quantity desired, but the proper distribution of the heat input between the electrodes might not be maintained. For example with such a furnace, one electrode may even be immersed and "frozen" in the charge, and yet the amperage indicating devices will show the proper amperage on the system. Of course, under such conditions, uniform distribution of the heat cannot be had. Again, in starting the melting of a charge, where amperage control is depended on, the electrodes must be initially set to determine the resistance by a manual operation. Under these conditions, it may be that an insufficient resistance will be established between the electrodes and the charge, and because of this insufficient resistance the resulting power factor will be too low for economical operation, and yet the amperage indicating devices will show the proper amperage on the system.

A primary object of this invention is to provide an improved electric controlling apparatus which, specifically considered, is specially applicable to electric furnaces, although it may be used in other relations, by which a plurality of energy delivering devices on a circuit are all caused to deliver and maintain the delivery of energy at a predetermined rate and each device to maintain the delivery of a predetermined proportion thereof.

A further object of the invention is to produce an improved electric controlling apparatus which, specifically considered, is specially applicable to electric furnaces, although it may be used in other relations,

by which a plurality of energy delivering devices on a working circuit shall, through proper automatic adjustment of resistance, all be caused to deliver and maintain the delivery of energy at a predetermined rate, and each device to maintain the delivery of a predetermined proportion thereof, the controlling mechanism adjusting for and tending to maintain constant the potential of the energy delivered by any device and also operating to regulate and control such other electrical conditions as affect the rate of effective energy input.

A further object of the invention is to produce a controlling mechanism for electric furnaces in which the potential of the energy delivered by the electrodes to the furnace is maintained substantially constant and such other electrical conditions as will affect the rate of effective heat input are so regulated and controlled as to cause said heat input to be at a predetermined rate, whereby rapidity of operation is attained without local overheating.

The invention has other objects in view not necessary to here specifically point out, but which will appear hereafter.

With the objects specifically referred to and others in view, the invention consists in certain elements, improvements and combinations as will be hereinafter described and then specifically pointed out.

The accompanying drawing represents diagrammatically a preferred embodiment of the improved controlling mechanism in connection with a furnace, the furnace selected for illustration being of the three-phase, three electrode type.

In the drawing, 1 represents a furnace which is of usual construction, the electrodes being indicated at 2, 3 and 4. A usual type of transformer is indicated at T, the circuits from the transformer to the electrodes being respectively marked 5, 6 and 7. The primary switch of the transformer is indicated at 8, and the connection with the high tension power lines at 9, 10 and 11.

Constructions embodying the invention will employ controlling mechanism of such a character that variations in the potential of the energy delivered will be adjusted for so that this potential is maintained substantially constant. In what are regarded as the best constructions, the controlling mechanism will be of such a character as to cause the electrodes to deliver and maintain the delivery of heat energy to the furnace at a predetermined rate and each electrode to deliver and maintain the delivery of a predetermined proportion thereof. While this may be accomplished in various ways, it will usually be accomplished by means which will adjust the resistance to meet varying conditions in the furnace. In preferred constructions embodying the invention, and where the invention is employed in connection with electric furnaces, the resistance adjusting means employed will be preferably such as to adjust the resistance between the electrodes and charge. While this may be variously accomplished, in the particular construction illustrated, the resistance is adjusted by shifting the position of the electrodes with respect to the charge. The devices illustrated for thus shifting or positioning the electrodes to adjust the resistance are well-known electrode shifting devices and include three electric motors, the drums of which are indicated at 12, 13, 14. Cable connections 15, 16 and 17 run from the motor drums to yokes 18, 19 and 20, these yokes being connected with the electrodes in an obvious way.

Where electric motor mechanisms, such as have been referred to, are employed for shifting the electrodes to adjust the resistance, the construction and connections should be such that the motors can be operated in either direction to raise or lower the electrodes. As shown, the drum shafts of the motors are provided with worm wheels 21, 22 and 23. The fields of the motors are indicated at 24, 25, at 26, 27, and at 28, 29, respectively, the commutators of the armatures being indicated at 30, 31 and 32. The worm shafts for driving the worm wheels are indicated at 30′, 31′ and 32′ respectively.

In the construction illustrated, the current for the motors is obtained from a main line circuit 33 which has branches 34, 35 and 36, these branches leading to the commutator brushes. In the particular construction illustrated, the returns from the motor fields of the motors are by way of circuits which are normally open. The return from the field 24 is by way of a wire 37 leading to a contact 38 and the return from the field 25 is by way of a wire 39 leading to a contact 40. The circuit is closed through either the contact 38 or 40 by devices which will be hereinafter described, the return main line circuit being marked 41. Similarly, the return from the field 26 is through a wire 42, terminating in contact 43. The return from the field 27 is through a wire 44 leading to a contact 45. According as the circuit is closed by the devices, which will be hereinafter described, through contact 43 or 45, the circuit will be completed by the branch 46 to the main line circuit.

The fields 28, 29 are connected by wires 47, 48 to the main line circuit through contacts 49, 50, the return to the main line circuit being marked 51.

The specific means for closing the motor circuits may be considerably varied. In the best constructions, and where motors and circuits such as have been described are employed, these means will include an actuator.

Many variations in actuator construction are possible and within the scope of the invention. In the particular construction shown, the actuator for the circuits including the contacts 38, 40 consists of a bar 52 pivoted at 53. The end of this bar is formed as a contact 54 which is in circuit with the branch 41.

Similar actuators 55 and 56 are provided for controlling the circuits leading from the fields of the other motors.

The means employed for effecting the movement of the actuators to close the circuits may be widely varied and will be varied in accordance with the type of actuator employed. Preferably, however, the operating means will be such that the actuator is differentially operated. In the best constructions embodying the invention, two controlling units will be employed for operating the actuator. As has been indicated, one of these units will be sensitive to changes in the potential affected by the resistance. The character of the other unit will depend upon the specific electrical factor or factors which it is regarded as important to control to effect the desired regulation. In furnace practice and where it is desired to obtain high economy in heat utilization, this unit will be sensitive to changes in the wattage of the circuit to be regulated.

In the particular construction illustrated, the unit which is sensitive to changes in the potential consists of three resistance-potential coils 57, 58, 59. The coil 58 is mounted on one end of the actuator bar 52 and the coils 57 and 59, respectively, are located below and above the coil 58. As shown, these potential coils 57, 58, 59 are connected in series and the coil 59 is connected by a wire 60 to a bus bar 61. From this bus bar a wire 62 leads to the power circuit wire 7. The coil 57 is connected by a wire 63 to a bus bar 65. This bus bar 65 is in circuit with the charge by a wire 66 and a suitable contact 67. The potential coils for the actuator 55, which controls the motor mechanism for the electrode 3, are connected to a bus bar 68 by a wire 69, this bus bar being in turn connected by a wire 70 to the circuit wire 6 of the electrode 3. These coils are also connected by a wire 71 to the bus bar 65 which, as before pointed out, is in circuit with the charge through wire 66 and contact 67.

A similar bus bar 72 is provided to which the potential coils for the actuator 56 for the motor mechanism for the electrode 4 are connected, these coils, however, not being shown, as they are duplicates of the others and symmetrically connected.

In the construction shown, the other controlling unit for the actuator is sensitive to changes in wattage. As illustrated, this unit comprises a power voltage-coil 73 and two power-ampere coils 74, 75. Where, as in the construction shown, the actuator is to be differentially operated, the power voltage-coil 73 will, as shown, be mounted on the end of the actuator bar opposite to that which carries the potential coil 58.

In the construction shown, the coils 74, 75 are connected in series. As these coils are amperage coils, and as the current flowing through them is intended to be proportional to the current on the power circuit, they should be connected up with this circuit. While this may be done in various ways, the coil 75 is connected by a wire 76 to current transformer 77 which is connected in the power feed wire 7. The other leg of the current transformer 77 is connected by a wire 78 to the coil 74. It will be apparent, therefore, that the current through the coils 74, 75 will vary in proportion to the current flowing through the power feed wire 7.

As has been stated, the coil 73 is a power-voltage coil, and, in the construction shown, the current flowing through it, is intended to vary in accordance with the voltage on the power circuit. The coil 73, therefore, should be connected to the power circuit. As shown, one side of this coil is connected by a wire 79 to the bus bar 61 which, as before described, is connected by a wire 62 to the power feed wire 7. In the best constructions, the circuit for this coil 73 will contain a voltage adjusting means for predetermining the voltage impressed on the coil. This may be accomplished by connecting a rheostat in the circuit. As shown, the coil 73 is connected by a wire 80 to a rheostat, indicated at 81. From this rheostat the wire 82 connects to the bus bar 68, which, as before stated, is connected by a wire 70 to the power feed wire 6.

The connections for the amperage coils which assist in controlling electrode 3 are similar to those which have just been described. The amperage coils for electrode 3 are connected in series and the upper and lower coils 83, 84 are connected by wires 85, 86 to a current transformer 87 connected in the power feed wire 6 for the electrode 3. The lower side of the voltage coil 88 is connected by a wire 89 to the bus bar 68 and the upper side of the coil is connected by a wire 90 to the bus bar 72. An adjusting rheostat 91 is connected into this wire.

The same instrumentalities may be employed for controlling the electrode 4 that are illustrated and have been described in connection with electrodes 2 and 3. The potential coils are not shown, but the amperage coils and the voltage coils are indicated at 92, 93, 94. The circuits for these coils are shown, but as the coils are symmetrically connected it is not regarded as necessary to specifically describe them.

In the operation of the mechanism, it be-

ing understood that the furnace is charged, that there is current on the motor circuit, that the electrodes are lifted so as to be clear of the charge, and that the actuator bars are in the position shown in the drawing, that is, so that the motor circuits are open, the power line is energized through the switch 8. As soon as the power line is energized the potential coils for all the actuators are energized. Current flows from the power feed wire 7 of the electrode 2 through the wire 62, the bus bar 61, the wire 60, the coils 59, 58, 57, the wire 63 and the bus bar 65. Similarly, the potential coils for the electrode 3 are energized through the wire 70, the bus bar 68, and the wires 69 and 71, the wire 71 connecting to the bus bar 65. The connection for the potential coils (not shown) which form a part of the control for the electrode 4 are symmetrical, the circuit wire leading from the power feed wire 5 for this electrode being, however, shown at 95. This wire 95 is connected to the bus bar 72 and the coils will be connected to this bus bar 72 and the bus bar 65. It will be observed that the groups of potential coils are Y connected.

The energizing of these potential coils causes the contact ends of the actuator bars to swing down against the lower contacts 40, 45 and 49 for the motor circuits. This closes the circuit through the fields 25, 27 and 29 of the motors. The motors, therefore, start and allow the electrodes to descend. At this time, it may be remarked, voltage is impressed on the voltage coils of the other controlling units, but there are no amperes flowing through the ampere coils of these units because of the high resistance between the ends of the electrodes and the charge. The watt elements of the control are, therefore, at this time doing no work, i. e., exerting no pull on the actuator bars. This condition continues, i. e., the motor circuits remain closed through the fields 25, 27, 29, until any one, any two, or all three of the electrodes make electrical connection with the charge. For the purposes of description, it will be assumed that electrode 2 makes connection with the charge ahead of the electrodes 3 and 4. As soon as the electrode 2 touches the charge, a circuit is established through the connection 67 and wire 66 to the bus bar 65, so that this bar 65 has the same potential as the feed wire 7. The potential coils 59, 58, 57 are, therefore, shunted and, consequently, deenergized. The actuator bar 52 will, therefore, swing away from the contact 40, thus breaking the motor circuit through the field 25 and stopping the motor. As pointed out, the stopping of the motor occurs as soon as the electrode is in contact with the charge, so that undue downward movement of the electrode which might have serious consequences is prevented. This feature is of importance in constructions in which the electrodes are positively driven down by the motors.

Proceeding on the assumption that the electrode 3 next makes contact with the charge, the same operations occur and the motor for this electrode is stopped as soon as the electrode 3 comes in contact with the charge.

When, however, electrode 3 comes in contact with the charge, electrode 2 being already in contact, current starts to flow in the main power circuit, with the result that the transformers 77, 87 are energized. This energizes the ampere coils 74 and 75. The voltage coil 73 of this unit was, of course, energized when the power feed wires 7, 6 were energized. As the potential coils are now deenergized, the result is that the actuator bars for the electrodes 2 and 3 will be swung up against the upper contacts 38 and 43, thus closing the motor circuits through the fields 24 and 26 of the motors. The motors, therefore, start to run in a reverse direction, and pull these electrodes up. As soon, however, as these electrodes move away from the charge, the resistance between the charge and these electrodes increases with the result that the potential coils begin to be energized, the potential increasing as the resistance increases. As the resistance increases, however, the amperes flowing through the ampere coils decreases. The result is, therefore, that the torque exerted by the potential coils increases as the resistance increases, and the torque exerted by the watt unit decreases as the resistance increases. When the electrodes have, by their upward movement been adjusted to obtain the calculated or predetermined resistance which should exist between the ends of the electrodes and the charge, the potential coils will overcome the pull of the watt unit on the actuator bars with the result that the actuator bars swing away from the upper contacts and thus break the circuits through the fields 24 and 26. These circuits will remain broken as long as the predetermined resistance between each electrode and the charge is maintained. It will be obvious that as the resistance between any electrode and the charge varies from the predetermined resistance either the ampere coils or the potential coils will be correspondingly energized or deenergized and the actuator bars will be correspondingly moved to readjust the resistance. These resistance adjusting operations will continue until the proper predetermined resistance exists between the electrodes and the charge. At this time, the torques of the two sets of controlling units will balance each other and the actuator bars will be held between the sets of motor circuit contacts.

The assumption so far has been that the

electrode 4 has not made contact with the charge. If this be the condition, it will happen that while the electrodes 2 and 3 are being moved up to adjust the resistance, the electrode 4 will be moving down. As soon, however, as this electrode makes contact with the charge, the same controlling operations will take place through its coils and actuator bar until the resistance between this electrode and the charge is properly adjusted.

While it has been assumed that the electrodes 2, 3 and 4 come down into contact with the charge in the order named, it is apparent that, through the mechanisms and by the constructions described, the resistance between each electrode and the charge will be properly adjusted so that the predetermined resistance is obtained no matter in what order the electrodes descend. The melting of the metal will start, therefore, under conditions where heat energy is being delivered to the charge by each electrode at a predetermined rate. It will further be apparent that if during the continued operation of the furnace anything occurs to change the resistance between any electrode and the charge and thus change the rate at which heat energy is being delivered by that electrode, the proper controlling unit for the electrode will be immediately brought into operation to readjust the resistance for that electrode. Further, if any change in the resistance between any electrode and the charge unbalances the proper distribution of voltage through the system, the proper controlling units for the electrodes affected will immediately effect the proper readjustment. All the electrodes will, therefore, maintain the delivery of the heat energy to the furnace at the predetermined rate, and each electrode will maintain the delivery of its proper proportion thereof.

As has been indicated throughout the specification, changes and variations may be made in the constructions by which this invention is carried into effect. The invention is not, therefore, to be limited to the particular construction illustrated and described.

What is claimed is:—

1. In an electric furnace, the combination of a plurality of power circuits and a plurality of electrodes, and means for maintaining such effective resistance in the circuits as will cause each electrode to deliver its proportion of energy and all the electrodes to deliver the energy at a predetermined rate.

2. In an electric furnace, the combination of a plurality of power circuits and a plurality of electrodes, and means for automatically maintaining such effective resistance in the circuits as will cause all the electrodes to deliver the energy at a predetermined rate and each electrode to deliver its proportion thereof, the resistance being automatically maintained at the maximum for these conditions.

3. In an electric furnace, the combination of a plurality of circuits and a plurality of electrodes, said electrodes being spaced from the charge and thereby providing a resistance across which the energy is delivered, and means for maintaining such spacing and resistance as will cause all the electrodes to deliver energy at a predetermined rate and each electrode to deliver its proportion thereof.

4. In an electric furnace, the combination with a source of electric energy, of a plurality of circuits and a plurality of electrodes, and an automatic controlling mechanism operated by any substantial variation in the power delivered for maintaining such resistance in each circuit as will cause all the electrodes to deliver energy at a predetermined rate and each electrode to deliver its proportion thereof.

5. In an electric furnace, the combination with a source of electric energy, of a plurality of circuits and a plurality of electrodes, and an automatic controlling mechanism thrown into operation by any substantial variation in the resistance between electrode and charge, said mechanism causing all the electrodes to deliver energy at a predetermined rate and each electrode to deliver its proportion thereof.

6. In an electric furnace, the combination with a source of electric energy, of a plurality of circuits and a plurality of electrodes, and an automatic controlling mechanism thrown into operation by any substantial variation either in the resistance or in the power delivered, said mechanism causing all the electrodes to deliver energy at a predetermined rate and each electrode to deliver its proportion thereof.

7. The combination, in an electric furnace, of suitable power circuits and electrodes, and a controlling mechanism operating to maintain substantially constant the potential of the energy delivered by the electrodes, and to so regulate and control the other electrical conditions affecting the rate of effective heat input as to enable a rapid heat input at a predermined rate to be had, whereby local overheating is avoided and rapidity of melting is attained.

8. The combination, in an electric furnace, of suitable power circuits and electrodes, and a controlling mechanism for so adjusting the resistance as to maintain substantially constant the potential of the energy delivered by the electrodes and to regulate the other electric conditions affecting the rate of effective heat input as to enable a rapid heat input at a predeter-

mined rate to be had, whereby local overheating is avoided and rapidity of melting is attained.

9. The combination, in an electric furnace, of suitable power circuits and electrodes, and a controlling mechanism for so adjusting the resistance between electrode and charge as to maintain substantially constant the potential of the energy delivered by the electrodes and to regulate the other electric conditions affecting the rate of effective heat input as to enable a rapid heat input at a predetermined rate to be had, whereby local overheating is avoided and rapidity of melting is attained.

10. The combination, in an electric furnace, of suitable power circuits and electrodes, said electrodes being so positioned with respect to the charge as to provide a resistance across which the energy is delivered, and a controlling mechanism, said controlling mechanism including means for adjusting the resistance to maintain substantially constant the potential of the energy delivered by the electrodes, and means for adjusting the resistance to so regulate and control the other electrical conditions affecting the rate of effective heat input as to enable a rapid heat input at a predetermined rate to be had, whereby local overheating is avoided and rapidity of melting is attained.

11. In an apparatus for delivering electric energy including a power delivering circuit having a plurality of electrodes, a controlling mechanism comprising an element rendered effective by a change in potential of the energy delivered by the electrodes, and an element rendered effective by change in the wattage of the power delivering circuit, said controlling mechanism operating to regulate the energy delivered by the electrodes.

12. In an apparatus for delivering electrical energy, the combination with a source of said energy, of a circuit including a plurality of devices for delivering the energy flowing into said circuit, and a controlling mechanism for causing all of said devices to deliver energy at a predetermined rate and each device to deliver a definite proportion thereof, said controlling mechanism including an element rendered effective by change in potential of the energy delivered by any device and an element rendered effective by a change in wattage.

13. In an apparatus for delivering electrical energy, the combination with a source of said energy, of a circuit including a plurality of devices for delivering the energy flowing through said circuit, and a control mechanism including an element rendered effective by change in potential in the energy delivered by any device, an element rendered effective by a change in wattage, and an actuator differentially controlled by said elements, said controlling mechanism causing all the devices to deliver energy at a predetermined rate and each device to deliver a definite proportion thereof.

14. In an apparatus for delivering electrical energy, the combination with a source of said energy, of a circuit including a plurality of devices for delivering the energy flowing through the circuit, and a control mechanism including an element rendered effective by a change in potential of the energy delivered by any device, an element rendered effective by change in wattage, an actuator differentially controlled by said elements, and resistance adjusting devices controlled by the actuator.

15. In an electric furnace, the combination of a source of electric energy, a circuit including a plurality of electrodes for delivering the energy flowing through the circuit to the furnace, and a control mechanism including an element rendered effective by a change in potential of the energy delivered by any electrode and an element rendered effective by a change in wattage, said control mechanism also including an actuator differentially controlled by the elements and operating through suitable means to adjust the resistance between the electrodes and the furnace charge, whereby the electrodes are caused to deliver energy at a predetermined rate and each electrode to deliver a definite proportion thereof.

16. In an apparatus for delivering electrical energy, the combination of a source of said energy, a circuit through which said energy flows, and a control mechanism for regulating the flow of energy, said mechanism including an element rendered effective by changes in potential, and a second element rendered effective by changes in wattage.

17. In an apparatus for delivering electrical energy, the combination of a source of said energy, a circuit through which said energy flows, and a control mechanism for regulating the flow of energy through said circuit, said mechanism including an element operating by change in potential, an element operated by change in wattage, an actuator differentially controlled by said elements, and resistance controlling mechanism controlled by the actuator.

18. In an electrical regulating apparatus, the combination with a resistance, of an electrically operated control including an element sensitive to changes in the potential affected by the resistance, an element sensitive to changes in wattage, and sets of circuit connections for each of said elements, whereby either a change in the potential or a change in wattage causes an adjustment of the resistance.

19. In the combination as claimed in 18,

an actuator through which the adjustment of the resistance is effected, said actuator being differentially controlled by said elements.

20. In an electric furnace, the combination with an electrode, of an electrically operated controlling mechanism for adjusting the resistance between electrode and charge, said mechanism including an element sensitive to changes in the potential affected by the resistance, an element sensitive to changes in wattage, and sets of circuit connections for said elements, whereby either a change in the potential or a change in wattage causes an adjustment of the resistance between the electrodes and charge.

21. In the combination as claimed in 19, an actuator through which the adjustment of the resistance is effected, said actuator being differentially controlled by said elements.

22. In an electric furnace, the combination with the electrodes, of electrically operated controller mechanism, said controller mechanism including mechanism for shifting the relative position of the electrodes and charge and thereby adjusting the resistance, said mechanism also including an element sensitive to change in the potential affected by the resistance and an element sensitive to changes in wattage, and sets of circuit connections for each of said elements, whereby either a change in the potential or a change in wattage causes an adjustment of the resistance.

23. In the combination as claimed in 22, an actuator for operating the shifting mechanism, said actuator being differentially controlled by said elements.

24. In an electric furnace, the combination with a plurality of electrodes, of a shifting mechanism, independent connections from the shifting mechanism to the electrodes, whereby the electrodes may be independently shifted to adjust the resistance between each electrode and charge, a set of controlling elements for each electrode, said elements including an element sensitive to changes in the potential affected by the resistance between the electrode and charge, and an element sensitive to changes in wattage, sets of circuit connections for said elements, and means whereby said elements effect the operation of the shifting mechanism.

25. The combination as claimed in 24, an actuator for each electrode differentially operated by the controlling elements for that electrode, and means whereby the actuator effects the operation of the shifting mechanism.

26. In an electric regulating apparatus the combination with operating circuits, of an actuator for controlling said circuits and operating units for the actuator, one of said operating units being rendered effective by changes in potential and the other of said units being rendered effective by changes in wattage, the arrangement of the actuator being such that it is differentially controlled by the units.

27. In an electric furnace, the combination with a plurality of electrodes, of a motor mechanism for shifting the electrodes to adjust the resistance between the electrodes and the charge, independent connections from the motor mechanism to the electrodes, whereby the electrodes may be independently shifted, suitable circuit connections for the motor mechanism whereby the motors may run in either direction, actuators for controlling said motor circuits, controlling units for the actuators sensitive to changes in the potential affected by the resistance between the electrodes and the charge, and controlling units for the actuators affected by changes in wattage, said units being arranged to differentially control the movement of the actuators.

28. In an electric regulating apparatus, the combination with a plurality of operating circuits, of a plurality of pivoted actuator bars one for each circuit for controlling the circuits, a controlling unit sensitive to changes in potential for moving the bar in one direction, and a controlling unit sensitive to changes in wattage for moving the bar in the opposite direction.

29. In an electric furnace, the combination with a plurality of electrodes, of a source of electric energy with which the electrodes are in circuit, a motor mechanism, connections between said motor mechanism and each electrode, whereby the electrodes may be independently shifted to adjust the resistance between the electrodes and the charge, normally open motor mechanism operating circuits one for each electrode, contacts in said circuts whereby the circuits may be closed in either direction through the motor mechanism, and a control mechanism for said operating circuits, said control mechanism including a plurality of actuator bars, a controlling unit for each actuator bar affected by changes in potential affected by the resistance between the electrodes and the charge and a controlling unit for each actuator bar affected by changes in wattage in the power circuit, said controlling units being arranged to differentially operate the actuator bars to close the circuits through the contacts, whereby changes in potential or wattage causes the actuator bars to so control the motor circuits as to cause the motors to run in the proper direction.

30. In an electric furnace, the combination with a power circuit, of a plurality of electrodes, means whereby the electrodes are caused to descend into contact with the charge when the power circuit is closed, and

a controlling mechanism including means for automatically stopping the downward movement of any electrode when that electrode comes in contact with the charge.

31. In an electric furnace, the combination with a power circuit, of a plurality of electrodes, means for moving the electrodes to bring them into contact with the charge and for thereafter shifting them to establish a predetermined resistance between each electrode and the charge, and a controlling mechanism operating to properly position the electrodes and establish a predetermined resistance between each electrode and the charge irrespective of the order in which the electrodes come in contact with the charge.

In testimony whereof, I have hereunto set my hand.

MORRIS H. BENNETT.