March 23, 1926. 1,578,027

J. W. HARSCH

ELECTRIC FURNACE SYSTEM

Filed Feb. 20, 1925 4 Sheets-Sheet 1

Fig. 1.

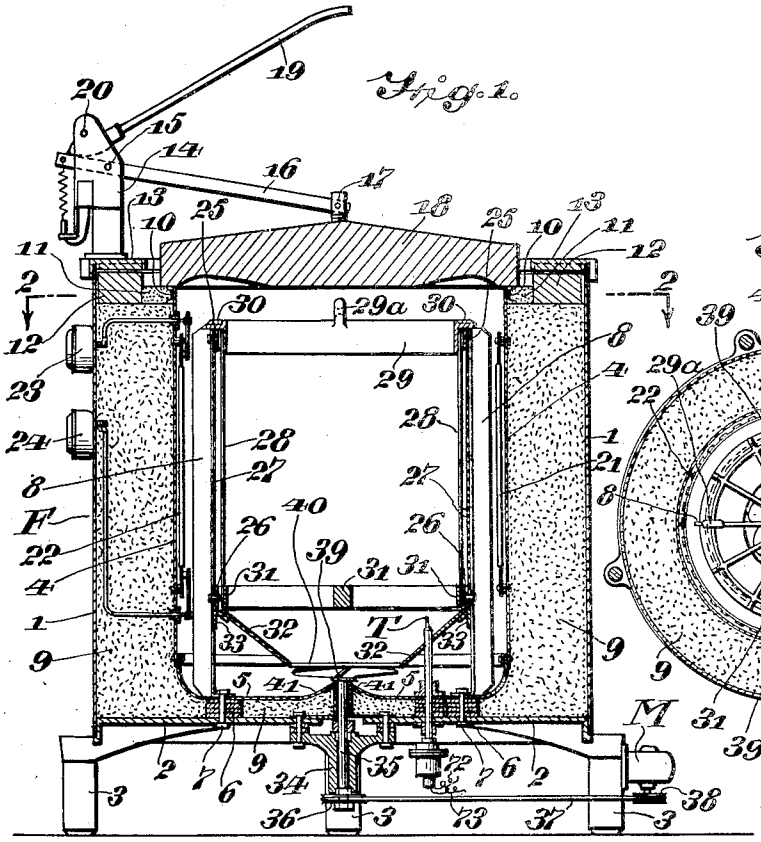


Fig. 2.

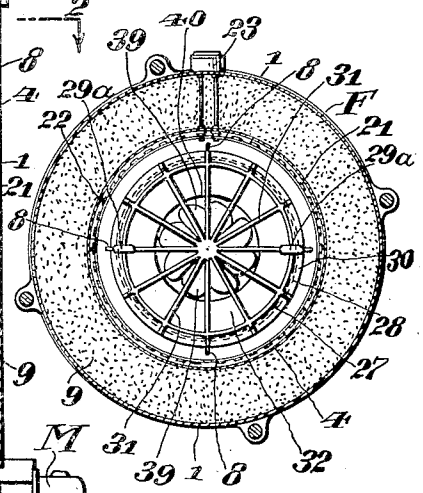
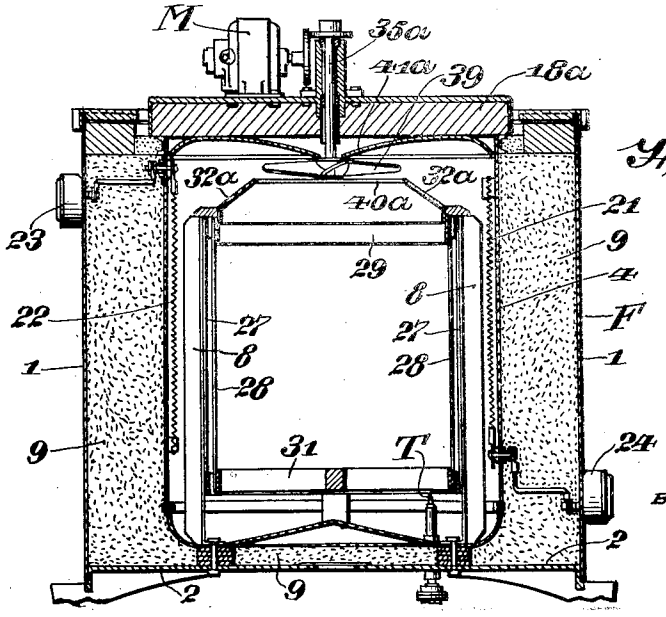


Fig. 3.



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ELECTRIC FURNACE SYSTEM

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Fig. 4.

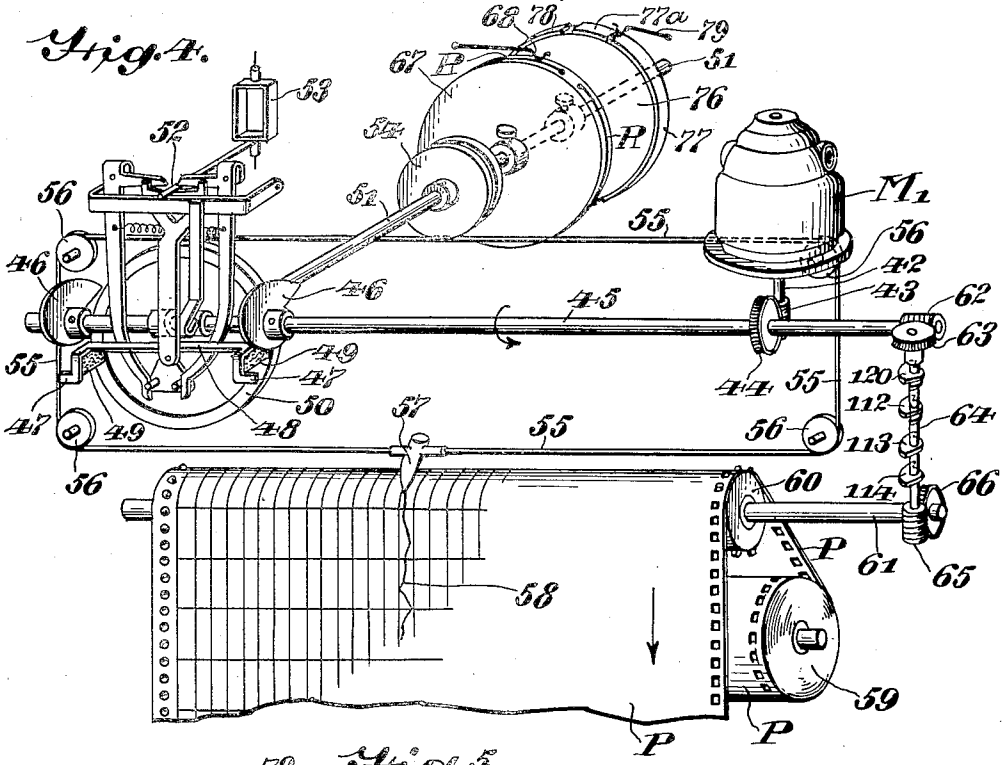
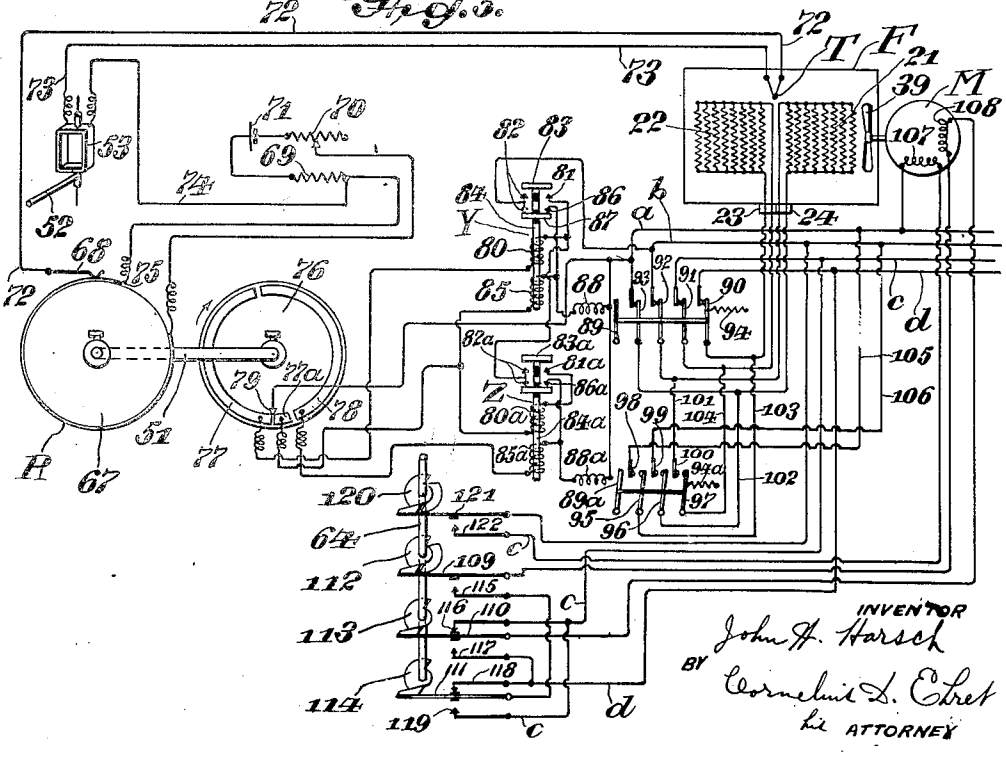



Fig. 5.




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ELECTRIC FURNACE SYSTEM

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Fig. 6.

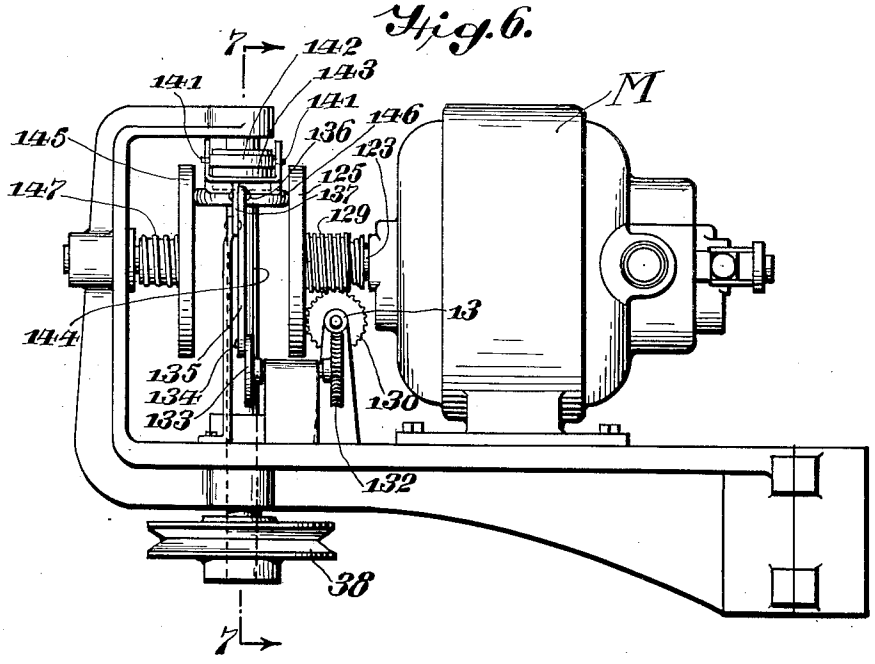



Fig. 7.

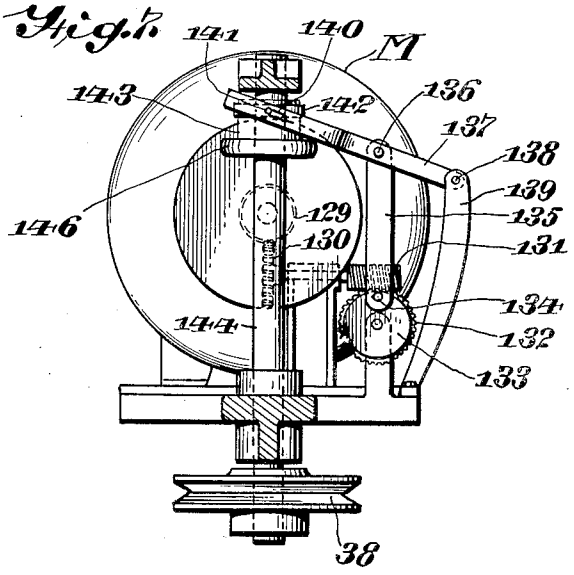
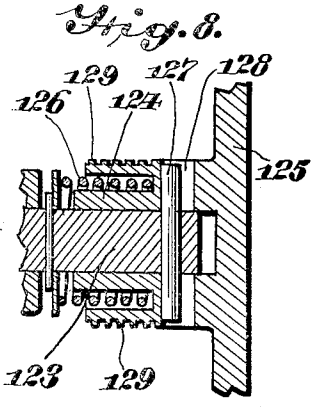



Fig. 8.




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ELECTRIC FURNACE SYSTEM

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Fig. 9.

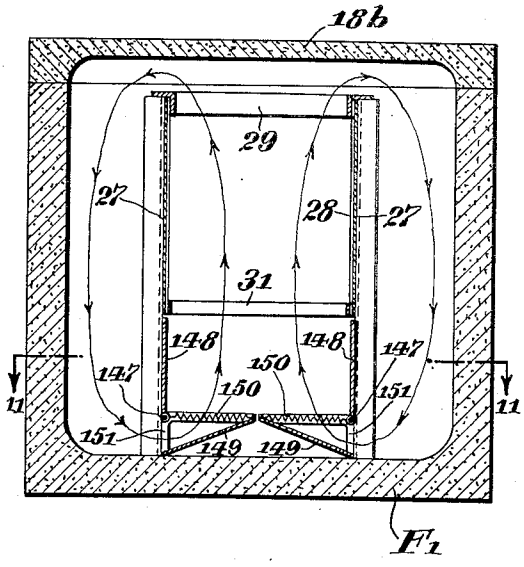



Fig. 10.

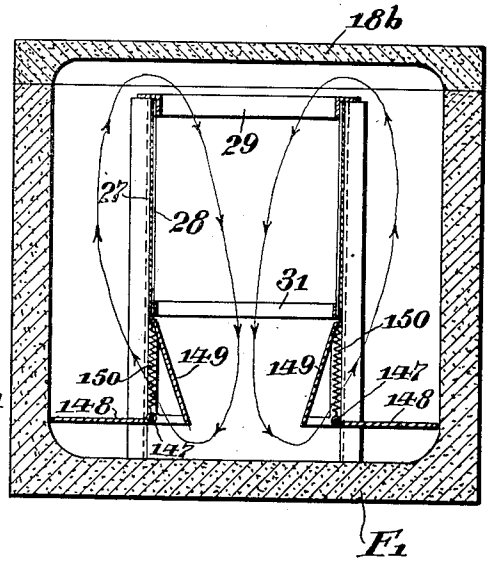
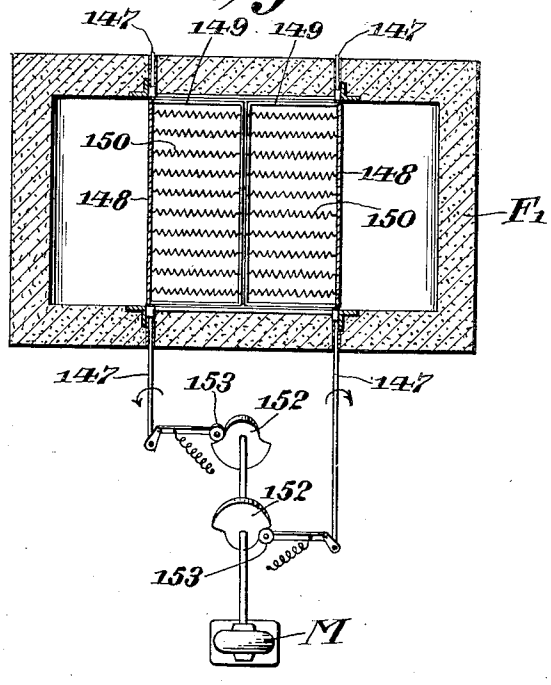



Fig. 11.




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Patented Mar. 23, 1926. 1,578,027

# UNITED STATES PATENT OFFICE.

JOHN W. HARSCH, OF PHILADELPHIA, PENNSYLVANIA, ASSIGNOR TO LEEDS & NORTHRUP COMPANY, OF PHILADELPHIA, PENNSYLVANIA, A CORPORATION OF PENNSYLVANIA.

## ELECTRIC-FURNACE SYSTEM.

Application filed February 20, 1925. Serial No. 10,486.

*To all whom it may concern:*

Be it known that I, JOHN W. HARSCH, a citizen of the United States, residing in the city and county of Philadelphia, State of Pennsylvania, have invented certain new and useful Improvements in Electric-Furnace Systems, of which the following is a specification.

My invention relates to heating apparatus, such as furnaces, and more particularly electrically heated furnaces; and my invention relates to a method of operating the heating apparatus or furnace, and more particularly to a method of heat treatment of steel and kindred materials, as for example, for drawing or tempering steel or the like.

In accordance with my invention, substantial uniformity of temperature throughout the heating chamber, and more particularly throughout the contents thereof treated therein, and high rate of heating to bring the heating chamber and its contents rapidly up to a desired or control temperature without overshooting that temperature, are procured by effecting reversals of the convection or forced circulation within the heating chamber or furnace of the air or other gas therein.

Certain of the subject matter herein disclosed but not claimed, and more particularly that not relating generally to the reversal of the direction of circulation of the air or gas within the furnace, is described and claimed in application Serial No. 65,715, filed by Irving B. Smith on October 30, 1925.

My invention resides in the method, system and apparatus of the character hereinafter described and claimed.

For an understanding of my method, and for an illustration of some of the various forms my invention may take, reference is to be had to the accompanying drawings, in which:

Fig. 1 is a vertical sectional view, partly in elevation, of an electric furnace embodying my invention.

Fig. 2 is a horizontal sectional view, partly in plan, on the line 2—2 of Fig. 1.

Fig. 3 is a vertical sectional view of a modified form of furnace.

Fig. 4 is a perspective view of control or recording apparatus utilizable in my system.

Fig. 5 is a diagrammatic view comprising a part of the structure of Fig. 4 and one of the circuit arrangements and controls utilizable in accordance with my invention;

Fig. 6 is a side elevational view of a motor and associated reversing mechanism.

Fig. 7 is a vertical sectional view, partly in elevation, on the line 7—7 of Fig. 6.

Fig. 8 is a cross section of a portion of the structure of Fig. 6.

Figs. 9 and 10 are vertical sectional views of a furnace adapted for convection circulation with parts in positions to cause circulation in opposite directions.

Fig. 11 is in part a horizontal section on line 11—11 of Fig. 9.

Referring to Figs. 1 and 2, there is shown a furnace or heat-treating appartus F, adapted for forced circulation, comprising the metal jacket or housing 1, which may be cylindrical, secured at its lower end to the bottom member 2, carried by a frame having the legs 3. Disposed within and spaced from the jacket 1 is the shell or inner lining 4, whose bottom 5 is spaced from the bottom 2 by the blocks 6, through which extend the bolts 7 which secure the member 5 and also the vertically extending supporting members 8 to the bottom 2. Between the shells 1 and 4, and between the bottoms 2 and 5, is disposed any suitable filling 9, of refractory material of preferably low heat conductivity. The upper end of the lining 4 is secured to the annular member 10, surrounded by the ring 11 of refractory material, which in turn is surrounded by the brick ring 12, upon which latter rests the top annular casting 13, upon which is carried the support 14, to which there is pivoted at 15 the arm 16, to which is pivoted at 17 the lid or cover member 18, which may be be raised by pressing downwardly upon the lever 19, pivoted at 20 and engaging the arm 16 to the left of its pivot 15.

In so far as concerns some of the features of my invention, heat may be developed within the furnace by any suitable method, as by combustion of gas or oil. In the ex-

ample illustrated, however, and as regards other aspects of my invention, the heat is generated electrically by passage of current through the resistances or resistors 21 and 22 of any suitable type or character, either embedded in refractory material, or as illustrated, disposed in the open within the furnace chamber adjacent the inner lining 4. As indicated, in Figs. 2 and 5, there are two sets of resistances, each comprising a plurality of parallel connected resistors or resistance conductors extending vertically adjacent and insulated from the lining 4. Connections are made to the resistors through conductors having terminals in the terminal boxes 23 and 24. In the example illustrated, the resistance elements 21 and 22 are exposed to direct contact therewith of the air or other gas within the furnace chamber.

Between the upper and lower rings 25 and 26 and the standards or members 8 is secured the shell or basket support 27, of sheet metal, preferably circumferentially and vertically continuous or substantially uninterrupted by perforations or openings, to exclude radiant heat from the interior of the shell 27.

The removable basket or container for the material to be heated comprises the closed shell 28 secured at its upper end to the ring 29, having the eyes $29^a$ for reception of crane hooks, and having the outwardly extending flange 30 resting upon the upper end of the shell 27 and members 8. At its lower end the shell 28 is secured to the spider 31.

Disposed below the basket and its spider 31 and forming a bottom for the shell 27 is the conical or funnel-shaped member 32 secured upon a ring or pieces 33 secured to the member 8.

Bolted to the bottom 2 is the fan shaft bearing member 34, in which is disposed the shaft 35, upon which is secured the pulley 36 driven through belt 37 by the pulley 38 secured upon the shaft of the electric motor M, preferably reversible as hereinafter described, for driving the fan or blower 39, disposed at the opening 40 at the bottom of the member 32. The bottom 5 of the inner lining 4 preferably deflects upwardly, as at 41, to form a passage leading to the lower side of the fan 39.

In the modification illustrated in Fig. 3, the overall height of the structure is materially diminished by mounting the motor M upon the lid or cover $18^a$, which carries the fan shaft $35^a$ driven by the motor M, preferably reversible, and carrying at its lower end the propeller fan 39, which with the motor M is removable as a unit with the lid $18^a$. Disposed above the fan is the downwardly extending air-guiding surface $41^a$, and beneath the fan is disposed the conical or funnel-shaped member $32^a$ carried by the upper ring 29 of the basket or work container 28. The opening $40^a$ of the member $32^a$ is disposed adjacent the fan 39.

The work or material to be heated is placed within the basket 28, resting upon the lower grating or spider 31. The work may be a single piece, or a plurality of pieces either carefully or symmetrically piled within the basket or placed therein irregularly. For example, the contents of the basket may be a plurality of gears of steel or alloy steel to receive heat treatment of any suitable character, for example, for drawing or tempering.

With the furnace cold, it is brought rapidly to the desired temperature, as, for example, a temperature of a predetermined magnitude at which the chamber is to be maintained, as by automatic control system hereinafter described, by passing current through the sets of resistors 21 and 22 in parallel. During this preliminary stage of heating the fan 39 is driven by the motor M at suitable speed, effecting circulation of the hot gases or air downwardly between the shells 4 and 27, past the resistors 21 and 22, thence between the members 32 and 41 to the under side of the fan 39, which forces the air or gases upwardly through the member 32, spider 31, through the basket or shell 28, upwardly through and between the gears or other pieces therein, and thence outwardly over the edge of the basket and thence downwardly again between the shells 4 and 27. This circulation of the heated air or gas serves to maintain the temperature rise substantially uniform throughout the basket and its contents and serves also to expedite the rise in temperature of the furnace.

The fan 39 is from time to time, preferably periodically, and preferably at relatively short intervals, as of the order of a minute or two, reversed, by reversal of the direction of rotation of the rotatable element of the motor M, or, as hereinafter described in connection with Figs. 6–8, by mechanical means.

In either case, the direction of circulation of the air is from time to time reversed, with the result that the temperature rise is substantially uniform throughout the contents of the basket and the furnace as a whole, with the added advantage of increased uniformity of heating and prevention of over-shooting of the temperature beyond the desired or predetermined control temperature, as compared with the cases where there is no circulation, and compared also with the case where the circulation is always in one direction.

I have found that by so circulating the air or gases within the furnace and by effecting reversal of the direction of circulation from time to time, the temperature of the work or contents of the basket is for all

practical purposes uniform throughout, with the resultant advantage that all the pieces or the entire contents attain a given temperature at the same time and all remain at substantially the same temperature during the control period, with the effect that the results of the heat treatment effected upon the various pieces or throughout the entire contents is to all intents and purposes exactly the same, thereby yielding products uniform in their characteristics so far as affected by the heat treatment.

The desired uniformity of temperature of the contents of the basket is the more readily obtainable from the fact that the basket 28 or the shell 27, or both, intercept the radiant heat which would otherwise be absorbed by those parts of the contents lying adjacent the wall or shell 28, causing them locally to attain a temperature higher than is due to the heating effects of convection or conduction of or from the hot air or gases. In other words, it is preferred that the heating shall be effected substantially exclusively by convection or conduction, and that heating effects due to radiant heat should be minimized.

While there is hereinafter described a use of my method and apparatus in a system of control for maintaining substantially constant the temperature of the contents of the basket, it shall be understood that my apparatus and method are not limited to employment in such a system, but that my furnace may be operated, so to speak, manually as regards control of the heating current, maintaining, however, the circulation of the air and gases and the reversal, preferably periodically of the direction of circulation. The furnace may be so utilized for any purpose, including, for example, the heat treatment of steel and the like in accordance with the method described in Letters Patent to Wrighton No. 1,188,128, in which case the thermo-couple T, Figs. 1 and 2, disposed within the furnace chamber, may be utilized to control a recorder, of the character indicated in Fig. 4, or equivalent, for drawing a curve in the nature of a time-temperature curve for making observable by inflections of the curve the time when the material passes through a decalescence stage. By my method and apparatus the various pieces or the entire contents of the basket change in temperature substantially uniformly, ensuring that the curve drawn by the recording apparatus represents change of temperature alike in all pieces or contents of the basket.

For controlling the temperature within the heating chamber, as for maintaining it substantially constant, there may be utilized any suitable automatic control mechanism, one example of which is shown in Fig. 4, illustrating a mechanism of the character disclosed in prior Letters Patent of the United States to Leeds No. 1,125,699, supplemented by means for effecting automatically periodic reversals of direction of rotation of the propeller or fan 39 to effect reversal of the direction of circulation of the air or gases within the furnace chamber.

Referring to Fig. 4, $M^1$ is an electric motor, or any other suitable source of power, which rotates at substantially constant speed the shaft 42, upon which is secured the worm 43 meshing with the gear 44 secured upon the shaft 45, upon which are secured the cams 46, 46 co-acting with the ears or lugs 47, 47 upon the pivoted lever 48, which carries the friction shoes 49, 49 co-acting with the disk 50 secured upon the shaft 51 for rotating it in the one direction or the other, depending upon the direction of deflection of the needle or pointer 52 attached to the coil 53 of a galvanometer. The magnitudes of the increments of rotation of the shaft 51 are further determined by the extent of deflection of the needle 52 from its normal or mid position illustrated, all in accordance with the mode of operation of apparatus of this character, as described in the aforesaid Patent 1,125,699. Secured upon the shaft 51 is the wheel or pulley 54, around which is wrapped the cord 55 passing over the idler rollers 56 and secured to the pin or marker 57, which draws upon the record sheet or paper P a time-temperature curve 58. The paper P is fed from the roller 59 by the roller 60, whose teeth engage in marginal perforations in the paper P. The roller 60 is driven by the shaft 61, driven from the shaft 45 through the worm 62, gear 63, shaft 64, worm 65 and gear 66.

Upon the shaft 51 is secured the disk 67, upon which is disposed the resistance R, with which co-acts the stationary contact 68. The resistance R is connected in series with the resistance 69, as shown in Fig. 5, adjustable resistance 70 and source of current or battery 71, this circuit forming a portion of a potentiometer. The contact 68 is connected by conductor 72 with the thermo-couple T disposed, as indicated in Figs. 1 and 3, within the heating chamber subjected to the temperature thereof and utilized through the mechanism described for controlling that temperature. The other terminal of the couple T is connected through conductor 73 with one terminal of the galvanometer coil 53, whose other terminal connects through conductor 74 with the terminal 75 of the resistance R, between which and the contact 68, for balanced condition of the circuit as effected automatically by the apparatus of Fig. 4, there is a fall of potential equal to the thermo-electric motive force developed by the thermo-couple T.

Secured upon shaft 51 is a second disk 76,

upon which are secured the three arcuate contacts 77, 77ª and 78, co-acting with the stationary contact 79, which connects with the conductor *a* of the two conductors *a* and *b* of one phase of a source of two phase alternating current; the current of the other phase is supplied over the conductors *c* and *d*.

The gap between contacts, 77 and 77ª is slight so that one of them engages brush 79 when the other leaves that brush. The contact 77 connects through the coil 80 of relay Y with the fixed contact 81, adapted to be brought into communication with the contact 82, connected with the conductor *b*, by the bridging member 83, movable with and insulated from the core or movable system 84 energized by the coil 80. The contact 81 is connected with the contacts 82ª of a second relay Z having the contact 81ª co-acting with the bridging member 83ª on core structure 84ª. The disc contact 77ª connects through the second coil 85 with the contact 86 adapted to be brought into connection with the contact 82 by the second bridging member 87 of relay Y. The contact 86 connects also through the magnet winding 88 with the conductor *a*. Contact 77ª connects also through the coil 80ª of relay Z with the contact 81ª adapted to be brought into connection with contact 82ª by the bridging member 83ª. The disc contact 78 connects through the coil 85ª with the contact 86ª and through the second magnet winding 88ª with the conductor *a*.

Each of the relays Y and Z is of a character such that its core 84 or 84ª remains in that position to which last attracted by either of its coils.

Co-acting with the magnet 88 is the armature 89 which actuates in unison the movable contacts 90, 91, 92 and 93 co-acting with stationary contacts connected respectively with the different conductors of the two-phase supply circuit. A spring 94 opposes attraction of the armature 89 by coil 88 and returns the movable contact members 90–93 to open circuit position when coil 88 is deenergized. The furnace resistor 21 is controlled by movable contacts 92 and 93 and resistor 22 is controlled by contacts 90 and 91, whereby when the movable contacts 90–93 are in their circuit-closing position indicated, the resistors 21, 22 are in effect in parallel on the two-phase supply circuit. The second magnet 88ª when energized attracts its armature 89ª in opposition to spring 94ª to move the contacts 95, 96 and 97 into engagement with their co-acting stationary contacts 98, 99 and 100, respectively. The two terminals of the resistor 21 are connected by conductors 101 and 102 with the contacts 100 and 96 respectively; the terminals of resistor 22 are connected by conductors 103 and 104 with the contacts 95 and 97 respectively; and the supply conductors *a* and *b* are connected by conductors 105 and 106 with the contacts 98 and 99 respectively. Briefly, the two switches controlled respectively by the magnets 88 and 88ª serve to bring the resistors 21 and 22 into parallel or series with respect to the supply circuit whereby either high or low rate of heating of the furnace is effected.

The automatic control system effects either high or low rate of heating in the furnace F depending upon the position of the contacts 77, 77ª and 78 with respect to the brush 79. As viewed in Fig. 5, the disc 67 is rotated in clockwise direction to effect balance of the galvanometer for increase of temperature, and in opposite direction for decrease of temperature. The disc 76 moves with the disc 67 and accordingly for furnace temperature materially below the desired or control temperature the contact 77 is in engagement with the brush 79, and the relays Y and Z are accordingly in such positions that the contacts 90–93 are in circuit closing position and the contacts 95–97, of the lower switch, are in open circuit position, and accordingly both resistors 21 and 22 are traversed by maximum current, causing greatest rate of production of heat in the furnace F, causing its temperature rapidly to rise. As the temperature rises to predetermined magnitude the contact 77ª comes into engagement with brush 79, causing the relays Y and Z to be in such positions that the upper switch is open and the lower switch closed, bringing the two resistors 21 and 22 into series with each other, with resultant reduced rate of production of heat in the furnace sufficient however for purposes of effecting the desired or control temperature for which the position of the disc 76 is such that the gap between the contacts 77ª and 78 is opposite the brush 79. Should the temperature continue to increase, the disc 76 rotates still further in clockwise direction, causing contact 78 to engage brush 79, whereupon the relays Y and Z are in such positions that both the upper and lower switches are open, and neither of the resistors 21, 22 is in circuit, with the result that production of heat within the furnace is discontinued. As a result the temperature will eventually fall, the disc 79 will rotate in counter-clockwise direction causing contact 77ª to engage brush 79 and bring both resistors into series, with resumption of production of heat in the furnace; and similarly should the temperature nevertheless further fall, eventually the contact 77 will engage brush 79 and the resistors will again be in parallel, further increasing the rate of production of heat.

When the source of electric current is a two phase system, as in the example illustrated, the propeller-driving motor M may

be a self-starting induction motor whose field or stator windings 107 and 108 are connected to the different phases of the supply circuit. To effect reversal of the propeller 39 by the motor M, the latter is reversed from time to time by reversing the source of connection of the winding 108, for example, with respect to that phase of the supply whose conductors are *c* and *d*. This is accomplished by the movable contact levers 109, 110 and 111, controlled, respectively, by the cams 112, 113 and 114 continuously rotated, as by mounting them upon the shaft 64 of the recorder or controller mechanism. The contact lever 109 co-acts with the contact lever 115, connected with the contact lever 111; the contact lever 110 co-acts, respectively, with the contact lever 116, connected to the conductor *c* and alternately with the contact lever 117 connected with the conductor *d*. Similarly, the contact lever 111 co-acts with the contact lever 118 connected with the conductor *d* and alternately with the contact lever 119 connected to the conductor *c*. By this cam-operated switching mechanism described, the sense of traverse of the field winding 108 by the current is reversed twice per revolution of the cam shaft 64, while the winding 107 is always excited in the same sense from conductors *a* and *b*, but its circuit is also opened and closed twice per revolution of the shaft 64 by the cam 120, which actuates the contact lever 121 co-acting with the contact lever 122, the circuit breaking taking place just before closure of circuit through the other winding 108, for purposes of reducing sparking and arcing.

Whether or not the automatic system of recording or control be utilized, the reversal of the motor M as described may be employed.

Furthermore, it shall be understood that the reversal of the fan or propeller may be effected mechanically when the motor itself rotates always in the same direction. This is exemplified in Figs. 6 to 8 inclusive, wherein the rotor of the motor M, revolving always in the same direction, drives the rotor shaft 123, upon which is longitudinally movable the hub 124 on the friction disk 125, a spring 126 opposing movement of the disk 125 longitudinally of the shaft 123, though rotated thereby by the pin 127 extending through the shaft into a longitudinally extending slot 128 in the hub 124. Upon the hub 124 is disposed the worm thread 129, which meshes with and drives the worm gear 130 secured upon the same shaft with the worm 131, which meshes with and drives the worm gear 132, upon whose shaft is secured the crank disk 133 having the crank pin 134, upon which is pivoted the link 135 pivoted at 136 to the link 137, pivoted at 138 to the bracket 139. At its one end the lever 137 is bifurcated, and slotted at 140 to receive the pins 141 upon the collar 142 engaging loosely in a groove in the member 143, which is splined for longitudinal movement upon the shaft 144, upon which is secured the fan or blower-driving pulley 38, for use in arrangements such as Fig. 1, and upon which may be directly secured the propeller or fan 39, as, for example, when utilized in an engagement of the character indicated in Fig. 3. Spaced from the friction disk 125 is the idler friction disk 145, the former engaged by the shoe or rim 146 upon the member 143, to drive the latter, and therefore the propeller-driving shaft 144. The shoe or rim 146 also engages the idler friction disk 145, which may yield longitudinally of its axis in opposition to the spring 147.

The friction disk 125 is driven at the speed of the motor M, and effects driving of the shaft 144 through the friction member 146, movable longitudinally of the shaft 144 from one side of the axis of revolution of the disk 125 to the opposite side, thereby effecting reversal of the shaft 144. This movement of the member 146 backwardly and forwardly is accomplished by the reduction gearing above described, which operates to move the link 135 upwardly and downwardly and thereby shift the member 146 longitudinally of the shaft 144 across the axis of disk 125. In case it is desirable that the transfer from one extreme position to the other of the member 146 shall be effected rapidly, any of the well known quick transfer or snap mechanisms may be utilized, disposed and operating between the crank pin 134 and the lever 137.

While in the example illustrated the source of current for the heaters 21 and 22 is described as polyphase alternating current, it will be understood that direct current or single phase alternating current may be employed. Furthermore, the motor M may be energized by either single phase alternating current or direct current, and in either case its reversal may be periodically effected by reversing switch mechanism actuated or controlled manually, or periodically by a continuously rotating staft, which shaft may, when desired, be a shaft of the recorder or control mechanism, as, for example, the shaft 64.

It is desirable that the heater or heating element, for example the resistors or resistance elements 21 and 22, shall have low heat capacity in the sense that they are either directly or substantially directly exposed to the air or gas within the furnace, or, if imbedded, the mass shall be small enough to store only relatively small amount of heat; or, shall have a heat capacity which is low as compared with the heat capacity of the work to be heated. This low heat

capacity of the heater or heating element is desirable from the standpoint of ability rapidly to change in temperature, thereby contributing with the circulation of the air, to reduction or elimination, of the aforementioned overshooting either when bringing the heating chamber up to desired or control temperature, or while the control system is in operation for maintaining a substantially constant or predetermined temperature.

For brevity in the appended claims, the term "air" is employed generically to include air, gas and vapor within the heating chamber.

As hereinbefore described the circulation of air within the furnace has been forced, as by a blower, fan or equivalent. It will be understood however that the circulation may be that of convection.

For circulation by convection the apparatus may take a form indicated in Figs. 9, 10 and 11 wherein the furnace body $F^1$ is provided with a removable cover $18^b$. Within the furnace is disposed the shell 27, within which is the removable basket 28 having the open ring top 29 and the bottom grate 31 upon which the work rests. Upon each of the pivotal shafts 147 is mounted a structure comprising the plates 148 and 149 and resistance conductors 150, which it will be understood may be controlled as are the resistors 21 and 22 hereinbefore described. As indicated in Figs. 9 and 10 there is a passage 151 between the pivot 147 and the outer edge of plate 149 whereby when the parts are in the position indicated in Figs. 9 and 11 the heated air rises from the conductors 150 upwardly through the chamber formed by the members 148, through the basket and its open top 29, thence downwardly outside through the passages 151 and upwardly between the resistance conductors 150. This is a convection circuit effecting uniformity of heating of the work. The direction of the convection circulation is reversed by moving the parts to the position indicated in Fig. 10, by rotation of the pivotal shafts 147. This may be accomplished manually or, as indicated in Fig. 11, by a continuously rotating motor M, which, through suitable reduction gearing, drives a shaft upon which are the cams 152 upon which bear the followers 153 through and by which the shafts 147 are periodically rotated to reverse the direction of circulation.

What I claim is:

1. In the art of heating materials in a heating chamber, the method which comprises circulating air in the heating chamber to and away from the material to be heated, and reversing the direction of circulation.

2. In the art of heating materials in a heating chamber, the method which comprises circulating air in the heating chamber to and away from the material to be heated, and periodically reversing the direction of circulation.

3. In the art of heating materials in a heating chamber, the method which comprises circulating air between a source of heat in the heating chamber and the material therein to be heated, shielding said material from radiant heat from said source, and reversing the direction of circulation.

4. In the art of heating materials in a heating chamber, the method which comprises circulating air between a source of heat in the heating chamber and the material therein to be heated, shielding said material from radiant heat from said source, and periodically reversing the direction of circulation.

5. The method of operating a heating chamber containing material to be heated, which comprises increasing the temperature of the chamber toward desired magnitude by a high rate of application of heating agent, simultaneously circulating the air within the chamber, and reversing the direction of circulation.

6. The method of operating a heating chamber containing material to be heated, which comprises increasing the temperature of the chamber toward desired magnitude by a high rate of application of heating agent, simultaneously circulating the air within the chamber, and reversing the circulation at intervals short as compared with the time required for the heating chamber to reach a temperature of the desired magnitude.

7. The method of operating a heating chamber containing material to be heated, which comprises increasing the temperature of the chamber toward desired magnitude by a high rate of application of heating agent, simultaneously circulating air within the chamber, reversing the direction of circulation, and thereafter applying the heating agent at lower rate while continuing said circulation.

8. The method of operating a heating chamber containing material to be heated, which comprises increasing the temperature of the chamber toward desired magnitude by a high rate of application of heating agent, simultaneously circulating the air within the chamber, reversing the circulation at intervals short as compared with the time required for the heating chamber to reach a temperature of the desired magnitude, and thereafter applying the heating agent at lower rate while continuing said circulation.

9. The method of heat-treating steel or the like, which comprises controlling the temperature thereof while in a heating

chamber, circulating the air in said chamber, and reversing the direction of air circulation.

10. The method of heat-treating steel or the like, which comprises controlling the temperature thereof while in a heating chamber, circulating the air in said chamber, and periodically reversing the direction of air circulation.

11. The method of heat-treating steel or the like, which comprises controlling the temperature thereof while in a heating chamber, circulating the air in said chamber, reversing the direction of air circulation, and shielding the steel or the like from absorption of radiant heat.

12. The method of heat-treating steel or the like, which comprises controlling the temperature thereof while in a heating chamber, circulating the air in said chamber, periodically reversing the direction of air circulation, and shielding the steel or the like from absorption of radiant heat.

13. A furnace comprising a heating chamber adapted to contain material to be heated, a source of heat, means for circulating the air in said chamber with respect to said material and said source of heat, and means for reversing the direction of the circulation.

14. A furnace comprising a heating chamber adapted to contain material to be heated, a source of heat, means for circulating the air in said chamber with respect to said material and said source of heat, and means for periodically reversing the direction of the circulation.

15. A furnace comprising a heating chamber adapted to contain material to be heated, a source of heat, means disposed between said source of heat and said material to intercept radiant heat, means for circulating the air in said chamber with respect to said material and said source of heat, and means for reversing the direction of the circulation.

16. A furnace comprising a heating chamber, a container therein spaced from the wall thereof and adapted to hold material to be heated, said container at one end communicating with the space between it and said heating chamber, an air propeller disposed adjacent an opening at the other end of said container for circulating air therethrough and through the space between said container and said chamber, and means for reversing said propeller to reverse the direction of circulation.

17. A furnace comprising a heating chamber, a container therein spaced from the wall thereof and adapted to hold material to be heated, said container at one end communicating with the space between it and said heating chamber, an air propeller disposed adjacent an opening at the other end of said container for circulating air therethrough and through the space between said container and said chamber, a motor for driving said propeller, and means for reversing said motor to reverse the direction of circulation.

18. A furnace comprising a heating chamber, a container within said chamber and spaced therefrom for holding the material to be heated, an electric heater within said chamber in the space between it and said container, means for circulating air through said container and said space, and means for reversing the direction of circulation.

19. The combination with a furnace, of means responsive to the temperature thereof, a source of power, a movable structure, a disengageable connection between said source of power and said movable structure controlled by said temperature-responsive means, means for circulating air in said furnace, and means actuated by said source of power controlling said air-circulating means.

20. The combination with a furnace, of means responsive to the temperature thereof, a source of power, a movable structure, a disengageable connection between said source of power and said movable structure controlled by said temperature-responsive means, means for circulating air in said furnace, and means actuated by said source of power controlling reversal of the direction of air circulation.

21. The combination with a furnace, of means responsive to the temperature thereof, a source of power, a movable structure, a disengageable connection between said source of power and said movable structure controlled by said temperature-responsive means, means for circulating air in said furnace, a motor for driving said air-circulating means, and means actuated by said source of power for effecting reversals of said motor.

22. The combination with a furnace, of means responsive to the temperature thereof, a source of power, a movable structure, a disengageable connection between said source of power and said movable structure controlled by said temperature-responsive means, means for circulating air in said furnace, means actuated by said source of power controlling said air-circulating means, and means controlling the temperature of said furnace controlled by said movable structure.

23. The combination with a furnace, of means responsive to the temperature thereof, a source of power, a movable structure, a disengageable connection between said source of power and said movable structure controlled by said temperature-responsive means, means for circulating air in said furnace, means actuated by said source of power controlling reversal of the direction of air circulation, and means controlling the

temperature of said furnace controlled by said movable structure.

24. The combination with a furnace, of means responsive to the temperature thereof, a source of power, a movable structure, a disengageable connection between said source of power and said movable structure controlled by said temperature-responsive means, means for circulating air in said furnace, a motor for driving said air-circulating means, means actuated by said source of power for effecting reversals of said motor, and means controlling the temperature of said furnace controlled by said movable structure.

25. The combination with a furnace, of means responsive to the temperature thereof, a source of power, a movable structure, a disengageable connection between said source of power and said movable structure controlled by said temperature-responsive means, means for circulating air in said furnace, means actuated by said source of power controlling said air-circulating means, and means for recording the temperature of said furnace controlled by said movable structure.

26. The combination with a furnace, of means responsive to the temperature thereof, a source of power, a movable structure, a disengageable connection between said source of power and said movable structure controlled by said temperature-responsive means, means for circulating air in said furnace, means actuated by said source of power controlling reversal of the direction of air circulation, and means for recording the temperature of said furnace controlled by said movable structure.

27. The combination with a furnace, of means responsive to the temperature thereof, a source of power, a movable structure, a disengageable connection between said source of power and said movable structure controlled by said temperature-responsive means, means for circulating air in said furnace, a motor for driving said air-circulating means, means actuated by said source of power for effecting reversals of said motor, and means for recording the temperature of said furnace controlled by said movable structure.

28. The combination with a furnace having a plurality of electric heaters, of a temperature responsive device, and mechanism controlling said heaters and controlled by said temperature responsive device comprising a moving system whose positions correspond with different temperatures of said furnace, and means controlled by said system for causing production of heat at different rates by said heaters for different positions of said system, and means rendering said heaters inoperative for another position of said system.

29. The combination with a furnace having a plurality of electric heaters, of a temperature responsive device, a galvanometer controlled thereby, a source of power, a movable system operated by said source of power under the control of said galvanometer, and switching mechanism comprising relatively movable contacts, one of said contacts causing said heaters to simultaneously produce heat at high rate, another of said contacts rendering said heaters inoperative, and an intermediate contact for bringing said heaters into series with each other for effecting heat production at low rate.

In testimony whereof I have hereunto affixed my signature this 19th day of February, 1925.

JOHN W. HARSCH.