July 28, 1931. R. P. BROWN 1,816,174

BLAST FURNACE CONTROL SYSTEM

Filed April 16, 1928 4 Sheets-Sheet 1

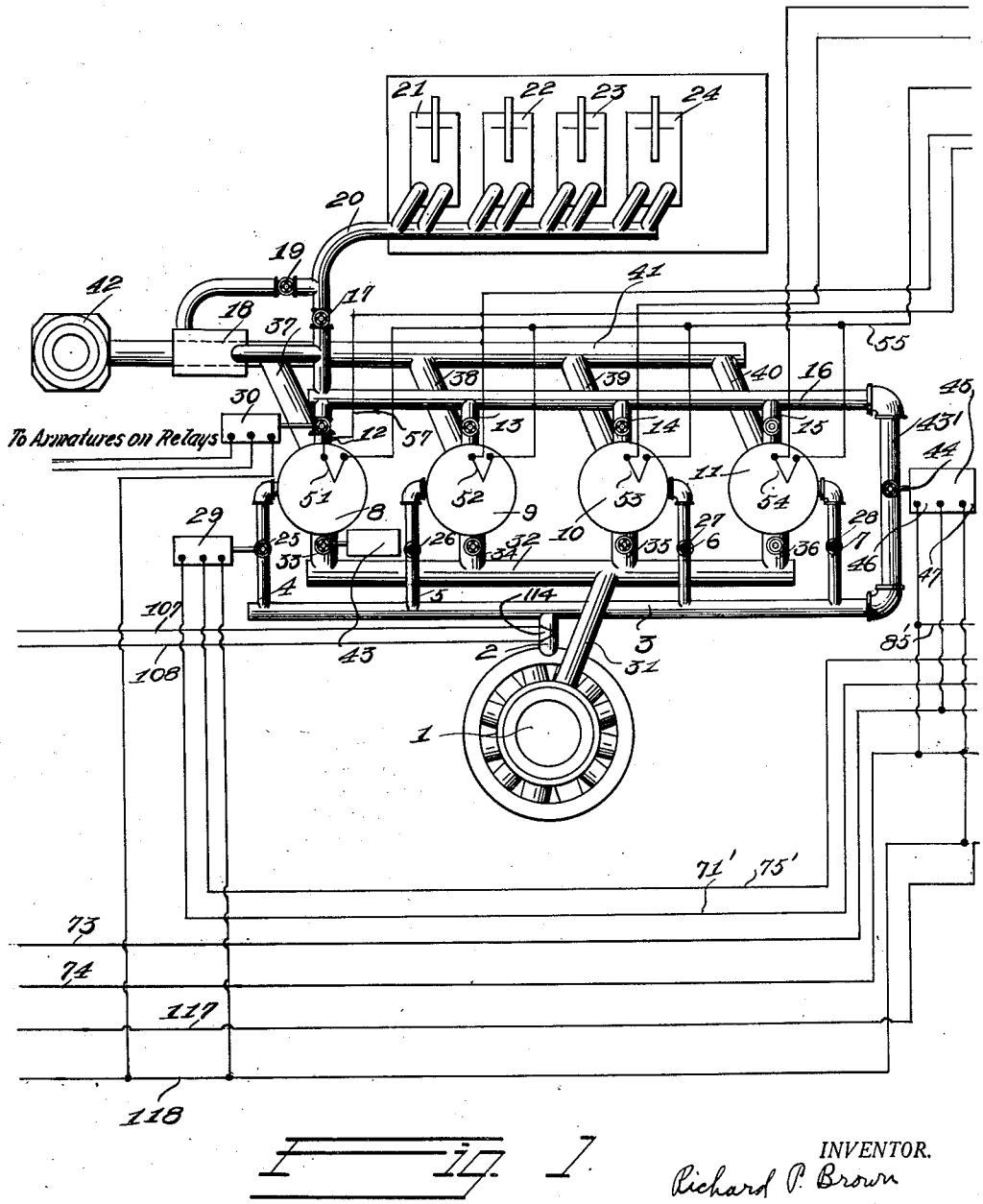


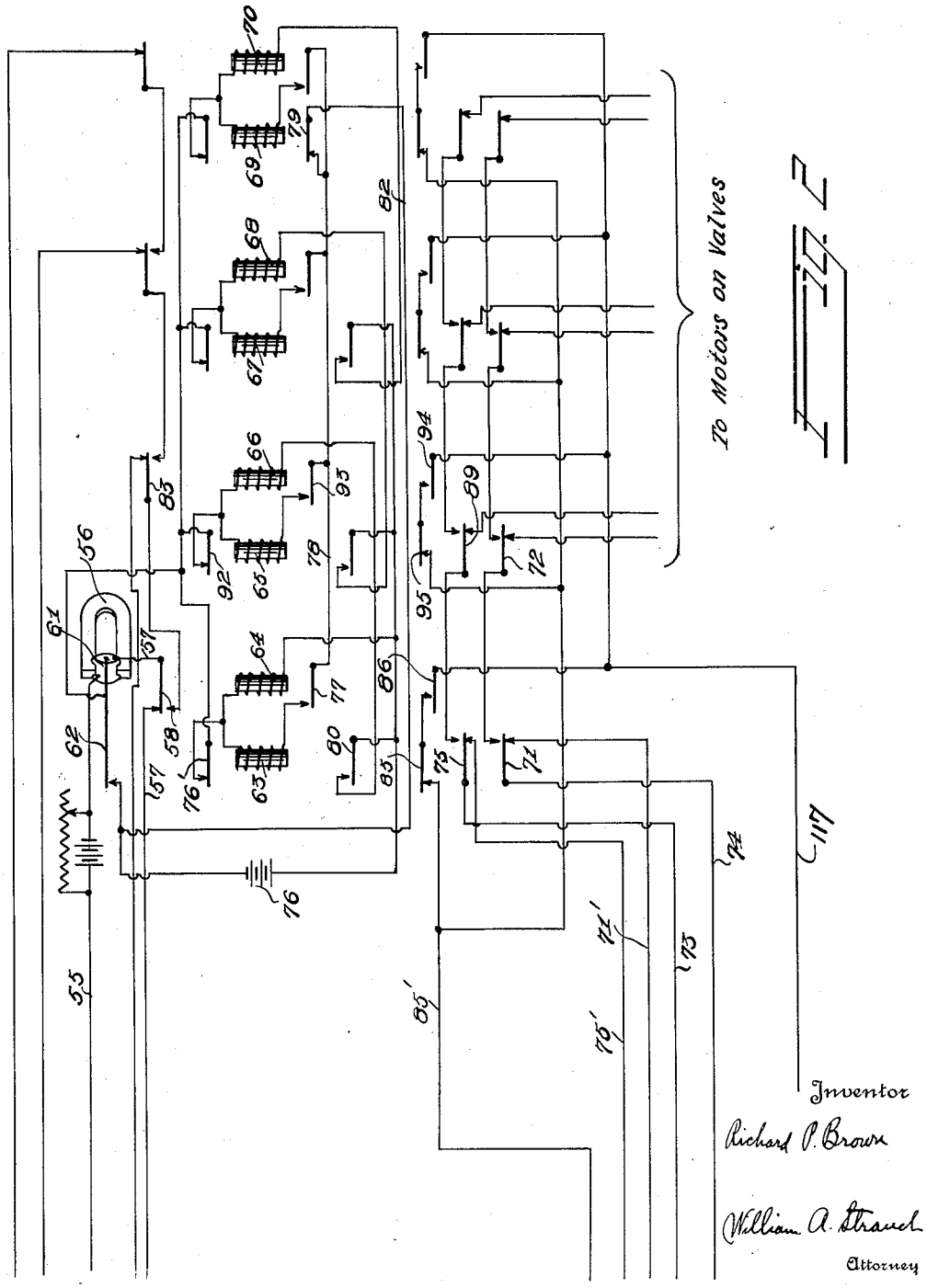
Fig. 1.

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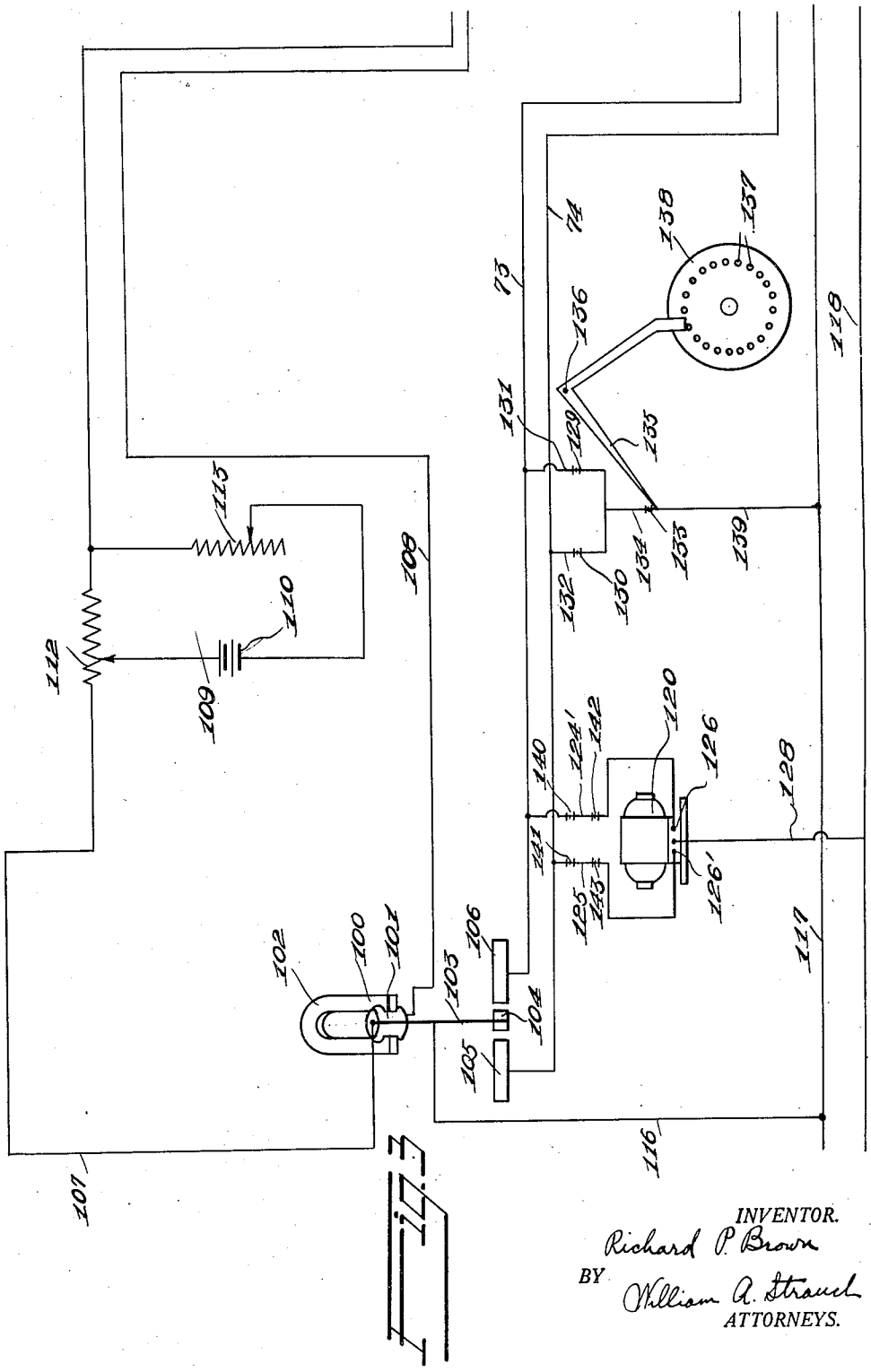
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BLAST FURNACE CONTROL SYSTEM

Filed April 16, 1928 4 Sheets-Sheet 3

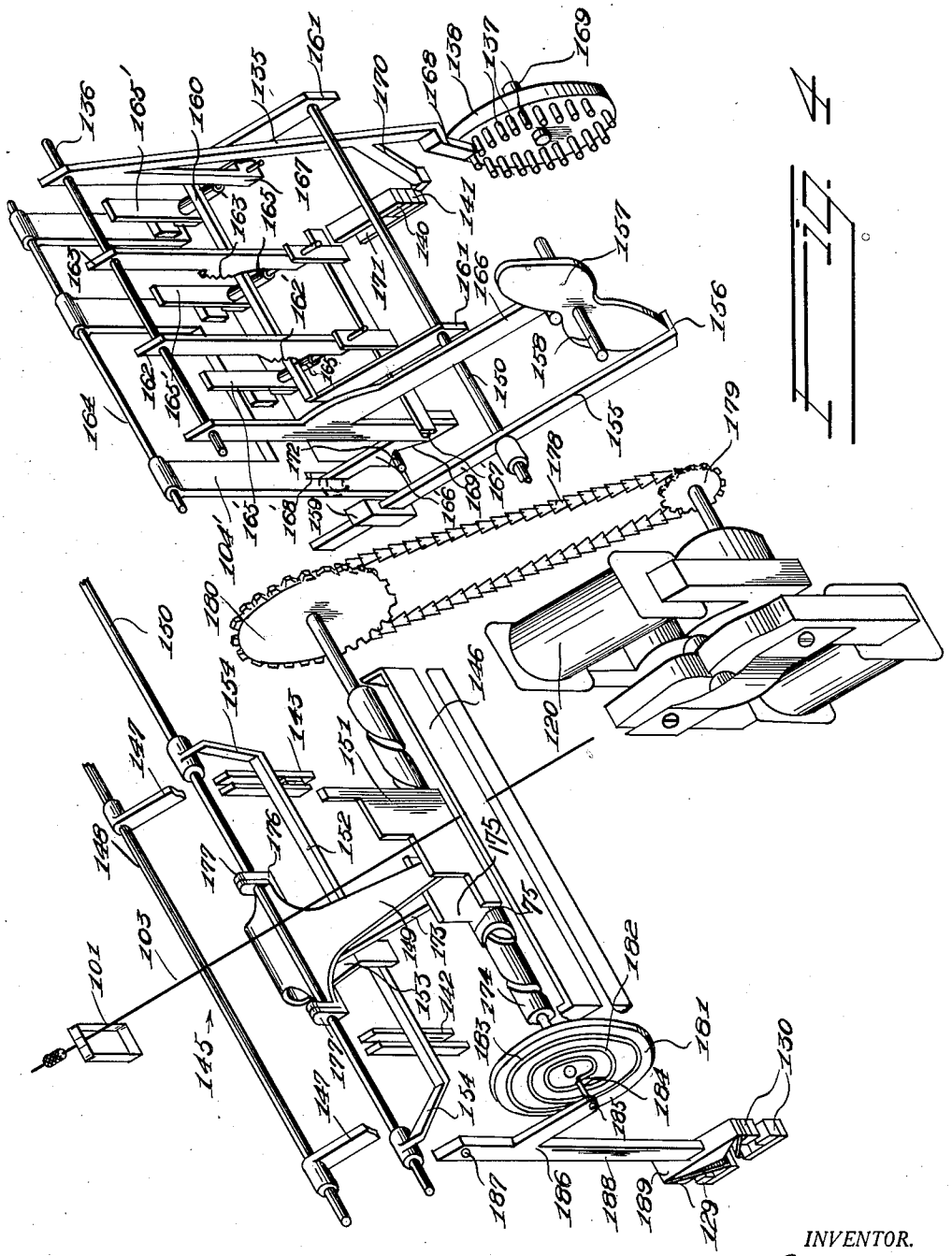


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Filed April 16, 1928 4 Sheets-Sheet 4



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UNITED STATES PATENT OFFICE

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BLAST FURNACE CONTROL SYSTEM

Application filed April 16, 1928. Serial No. 270,528.

My present invention relates to control methods and apparatus and more particularly to control methods and apparatus for maintaining predetermined physical conditions of a hot blast fed to a blast furnace within predetermined narrow limits.

In operating a blast furnace the air supplied thereto for carrying out the chemical actions should preferably maintain a uniform high temperature in order to obtain the highest possible operating efficiency and the optimum conditions. This heated air is ordinarily obtained from a battery of heating stoves associated with each blast furnace, which are in turn heated by the hot exhaust gases from the blast furnace. In the ordinary operation the hot air from one of these heating stoves is mixed with a cold blast in such proportions as to give a desired temperature of the air blast fed into the blast furnace for maximum efficient operation. When all of the heat has been drawn from one of the heating stoves, it is cut off from the conduit leading to the blast furnace and a fresh stove substituted therefor. In switching over to the fresh supply of hot air in the usual manner it is evident that the air supply will suddenly rise to a considerably higher temperature than the temperature of the last air supplied from the preceding stove, and as a result wide temperature variations occur resulting in inefficient operation.

It is accordingly desirable to maintain the temperature of the air supply to a blast furnace substantially constant and while more or less inaccurate automatic temperature control apparatus has been proposed heretofore for maintaining the temperature of the air supply approximately constant while said supply is being drawn from one of the stoves, it has been considered that no control apparatus can maintain this constant temperature condition during the extreme condition met while switching over from one to a succeeding stove. Accordingly, such prior proposed controls have been semi-automatic, as manual control is required during part of the operating period. Semi-automatic control is accordingly subject to the disadvantages of manual control.

Accordingly an object of my invention is to provide control methods and apparatus to automatically maintain the temperature of hot air blast to a blast furnace substantially uniform during the entire operating period.

Another object of my invention is to provide improved means for disconnecting one stove and connecting in a second stove to the conduit conducting the heated air to a blast furnace and simultaneously varying the amount of cold air supply to maintain a substantially uniform temperature of air supply to the furnace.

A further object of my invention is to provide novel and simple control methods and apparatus for controlling the temperature of a blast mixture to a blast furnace by the use of which hunting of the air temperature is substantially eliminated.

Other objects of my invention will appear in the following detailed description of the preferred embodiment of my invention and are such as may be attained by utilization of the various principles, combinations and sub-combinations hereinafter set forth and defined by the terms of the appended claims.

Referring to the drawings:

Figure 1 is a diagrammatic view of a blast furnace system with its associated stoves.

Figure 2 is a diagrammatic illustration of the circuits and apparatus for switching the controlled apparatus from one to the succeeding heating stove.

Figure 3 is a diagrammatic illustration of one form of control apparatus and circuit arrangements employed in carrying out my invention.

Figure 4 is a perspective view with parts broken away of a preferred form of the control apparatus which may be employed in the control systems shown in Figures 1 and 2.

As shown in Figure 1, a blast furnace 1 is connected by a pipe 2 to a manifold 3 to which are connected in multiple the feed pipes 4 to 7. Feed pipes 4 to 7 are con-

nected to the heating stoves 8 to 11 in which air is heated to a high temperature in a manner to be described hereinafter, and thereafter fed through pipes 4 to 7 to the manifold 3 and thence through connecting pipe 2 to the blast furnace 1. The stoves 8 to 11 are each provided with individual connecting pipes 12 to 15 connected to the manifold 16 which in turn is connected in multiple through valve 17 and the heat exchange device 18 and valve 19 and through discharge pipe 20 to the air compressors 21 to 24. The air blast which is first heated in the stoves 8 to 11 to be later fed to the blast furnace is supplied to the stoves by these air compressors 21 to 24. Connected in each of the lines 4 to 7 are valves 25 to 28, each controlled by an individual motor of which only one motor 29 controlling valve 25 is shown. These motors are variably operated to permit variable rates of hot air blast flow from their respective stoves by control apparatus in a manner to be described in more detail hereinafter. Similar motor operated valves only one motor 30 of which is shown are connected in the inlet pipes 12 to 15 for supplying air to the various stoves when they are in operation for supplying hot blast. The valves of the hot blast stove are shown conventionally and may in practise take the form of motor driven valves regulating the supply of water to hydraulic rams for operating the valves proper of the hot blast stove.

The stoves 8 to 11 are heated from exhaust or waste gases obtained from the blast furnace 1 through the discharge conduit 31 connected to the manifold 32 to which the inlet pipes 33 to 36, individual to the stoves 8 to 11 are connected in multiple. Outlet pipes 37 to 40 from the stoves 8 to 11 are connected to the conduit 41 for carrying away the waste gases which pass thence through the heat exchange device 18 to the chimney 42.

A by-pass conduit 43′ from the manifold 16 to the inlet manifold 3 provides the necessary cold blast for mixture with the hot blast from the stoves. A valve 44, controlled by the motor 45 is connected in this bi-pass section for controlling the rate of flow of cold blast. Motor 45 comprises two windings 46 and 47, one of which when energized rotates the motor in one direction, and the other when energized rotates the motor in opposite direction. As will be described in detail hereinafter when the motor 29 is operated by the control apparatus to increase the rate of the hot blast flow from the heating stove 8, the same control will operate the motor 45 to rotate it, and with it valve 44 in such direction as to decrease the rate of cold blast flowing through the by-pass conduit 43. When, however, one of the stoves is shut down and the succeeding stove is connected to supply the hot blast, winding 47 of motor 45 is energized to reverse the direction of rotation of motor 45 opening the valve 44 to its maximum position and permitting a sudden increase of the proportion of cold blast to counter-balance the sudden rise in temperature due to the connection to a fresh heating stove.

It will be obvious that in order to make the entire operations of a battery of furnaces automatic it will be necessary not only to control the rate of hot blasts obtained from the heating stoves, but also to automatically disconnect one of the stoves when substantially all its heat has been withdrawn and connect in a succeeding stove. To accomplish this, I provide thermocouples 51 to 54, one located in each of the stoves 8 to 11 to measure the temperature therein. Each of the thermocouples, it will be noted, is connected over common conductor 55 to the galvanometer 56. The opposite terminal of the galvanometer 56 is connected to the first thermocouple 51 over conductor 57 and armature 58. As will be described in more detail hereinafter, circuit connections of galvanometer 56 is switched from one to the succeeding thermocouples as the temperature of each of the stoves drops below a predetermined value by the removal of all the heat therein.

The galvanometer 56 comprises the usual coil 61 and the pointer 62 which is connected to the relays 63 to 70 for completing energizing circuits therefor in a step by step manner to be described in detail heerinafter.

As the relays 63 to 70 are energized in a step by step manner, they in turn switch the circuit for the galvanometer coil 61 from one to the succeeding thermocouples 51 to 54 and simultaneously switch the control apparatus to be described from one to the succeeding motors 29 for controlling their respective valves of their associated stoves 8 to 11.

With the apparatus and circuit in the condition shown the control conductors 73 and 74 connected to the control apparatus in a manner to be described in detail hereinafter, are connected over armatures 75 and 71 to the first motor 29 associated with valve 25 of the hot stove 8. The operations of this much of the apparatus thus far described will now be given.

It will be assumed that in the manner well known in the art, control apparatus produce currents which flow over conductors 73 and 74 and over armatures 75 and 71 and conductors 75′ and 71′ to the motor 29 for varying the operation thereof to operate valve 25 in accordance with temperature changes in the inlet pipe 2. These control currents also flow directly through windings 46 for regulating valve 44. During this period the valve in the conduit 33 is closed.

While the stove 8 is at a sufficiently high

temperature to provide the necessary temperature in the inlet pipe 2, the galvanometer needle 62 of galvanometer 61 is in its disengaged position as shown. As soon, however, as the temperature in the stove 8 drops below a predetermined value, the change in voltage brings galvanometer needle 62 into engagement with its contact and a circuit is completed for the relay 64 from one terminal of the battery 76 through the first contact and galvanometer needle 62, the armature 76′ and its back contact, through winding of the relay 64 back to battery 76. It will be observed that at this time the circuits for all of the other relays in the chain are open at armature 80 of relay 63.

Upon energization of relay 64 its armature 77 is moved into engagement with its front contact to prepare an energizing circuit for the relay 63 which is completed from one terminal of battery 76 through the winding of the relay 64 and 63 in series, armature 77 and conductor 78 armature 79 and conductor 82 to the opposite terminal of the battery 76. However, at this time, the relay 63 is short circuited over the back contact of armature 76′ which provides a return path to the battery 76 and the winding 63 will, therefore, not energize at this time.

A further result, however, of the energization of relay 64 is to operate its armature 58 to engagement with its front contact thereby switching the winding of the galvanometer 61 from connection with the thermocouple 51 in the stove 8 to a circuit connection with a thermocouple 52 in the hot stove 9, the circuit being completed over conductor 57, armature 58 and its front contact, the armature 83 and its back contact to the thermocouple 52. Due to the higher temperature in stove 9 in which thermocouple 52 is located, the galvanometer needle 62 will disengage its contact and thereby open the short circuit for the winding 63. As a result, the energizing circuit for the winding 63 in series with 64 now becomes effective and the relay 63 energizes operating thereby its armatures 71, 75, 76′, 80 and 85.

It will also be observed that upon the energization of relay 64, it moves its armature 86 into engagement with its front contact and as a result an obvious energizing circuit is completed over the armatures 85 and 86 and conductors 85′ and 117 for one winding 47 of the motor 45. The energization of this winding of motor 45 is in such a direction as to rotate the motor 45 and valve 44 in a direction for opening the valve 44 to its extreme position. Upon the energization of the relay 63 as described above, the armature 85 is disengaged from its contact thereby opening this circuit. This circuit, although only momentarily completed is energized for a sufficient time to enable the motor to completely open the valve providing thereby a maximum supply of cold blast simultaneously with the switching to a new stove 9. In multiple with this, a circuit is completed for motor 30 controlling the valve in line 12 to close the same and shut off the supply of air blast to the hot blast stove. Simultaneously the motor 29 is operated to close valve 25 and thereby disconnect the supply of hot blast from stove 8 to the blast furnace. When the supply of hot blast from stove 8 has been stopped, the motor 43 is operated to open valve 33 and thereby admit gas from the blast furnace to be burned in the stove for heating the checker work thereof.

A further result of the energization of the relay 63 is to switch the control circuits 73 and 74 from motor 29 to the motor associated with valve 26 from armature 75 to armature 89 from armature 71 to armature 72. This motor is not shown for purposes of convenience but it will be understood that it is similar in construction to motor 29. As a result of the operation of armature 76′, the original energizing circuit for the relay 64 is opened so that this relay can no longer be energized although as will be noted above, a locking circuit from battery 76 through coil 64, coil 63, armature 77, line 78, armature 79, line 82, and back to the battery 76 is now completed which maintains relays 63 and 64 energized.

Control impulses now transmitted over the conductors 73 and 74 through armatures 75 and 71 and their front contacts and the armatures 89 and 72 and their back contacts operates the motor connected to the valve 26 in accordance with the temperature variations in the inlet pipe 2 and simultaneously controls the winding 46 for varying the amount of air from the cold blast through the bi-pass conduit 43. It will be understood that the winding 46 is in such relation to the motor connected to the valve 26 that as the valve 26 is opened the valve 44 is closed and vice versa. That is, when the temperature of the blast is below the predetermined value, the control will operate to open the valve 26 to increase the rate of flow of hot air and will close valve 44 in accordance with the extent of temperature variation to decrease the rate of flow of cold air in the event of a temperature rise above the predetermined value, the opposite operations will occur.

These operations will now continue until the heat supply from the stove has been substantially exhausted and the temperature of the air in the conduit 2 cannot be maintained at the desired predetermined value even when the valve 44 is entirely closed and the valve 26 at its maximum opening.

The control circuit for galvanometer 61 is at this time such that the pointer 62 is

again moved into engagement with its contact whereupon a circuit is now completed from one terminal of battery 76 to the contact of the galvanometer pointer 62, the armature 92 and its back contact through the winding of relay 66 and armature 80 to the battery 76. Upon energization of the winding 66, a locking circuit for itself and relay 65 is completed with the relays 66 and 65 in series from one terminal of the battery 76 over armature 80 and its front contact through the windings 66 and 65 in series, the front contact and armature 93 over conductor 78, the back contact and armature 79 and over conductor 82 to the opposite terminal of the battery. However, at this time, the winding 65 is short circuited by a circuit over the back contact and armature 92, and current will not, therefore, flow through the winding 65.

As a result, however, of the energization of relay 66, the armature 83 moves into engagement with its front contact thereby disconnecting the galvanometer 61 from the thermocouple 52 in the cold stove 9 and switching to the thermocouple 53 in the hot stove 10 and as a result the galvanometer needle 62 moves from engagement with its contact, thereby opening the short circuited path described above and the energizing circuit for the relays 65 and 66 in series becomes effective.

It will be noted, that upon the energization of the relay 66 the armature 94 is moved into engagement with its contact and as a result, a momentary circuit is completed again for the motor winding 47 which again opens the valve 44 to its maximum open position in preparation for the sudden rise in temperature of the air blast from the succeeding stove which is now to be put into operation. At the same time, armatures 94 and 95 complete a multiple circuit (not shown) for the motor controlling the valve in line 13 and air to be heated is then forced into the stove 9 by blowers 21 to 24. A multiple circuit is completed for the motor controlling the valve in line 33 for admitting the heating waste gases from the blast furnace 1. A timing mechanism of any of the well known types can be arranged to rotate the motor in the opposite direction for reclosing the valve after a period sufficiently long to heat the air in the stove. It will be understood, however, that such operation may also be automatic in response to a predetermined temperature of the air in the stove.

From the above it will now be clear that an interval of time after the valves in lines 13 and 34 are opened, they automatically close or if preferred the closing of these valves may be controlled from the relay chain in the manner of opening them as described above. The galvanometer 61 is now connected through armature 58 and 83 to the third thermocouple 53 measuring the temperature in stove 10 and the operations described above will be repeated.

When the last stove 11 has been depleted of its heat, the galvanometer 62 engages its contact to energize the relay 70 and thereafter relay 69 in the manner described above. The energization of relay 69 will operate armature 79 to open its contact and as a result all of the locking circuits described above for the relays 63, and 64, 65 and 66, 67 and 68, and 69 and 70 are opened and accordingly all the relays in the chain will drop back to the position shown in the drawing and the galvanometer will then again be connected to the first stove 8 for operation in the manner described above. Thereafter, the cycle of operation is repeated.

The control apparatus connected in the circuits 73 and 74 for transmitting impulses thereover to operate the motors shown in Figure 1 will now be described. Although a preferred controller is here shown, it will be understood that any control which is provided with proper equipment for eliminating hunting may be employed.

A control galvanometer 100 is provided comprising a movable coil 101 suspended between the poles of a permanent magnet 102. Secured to the coil is a pointer 103 provided with a contacting portion 104 adapted to coact with contacts 105 and 106. It will be understood that this is a diagrammatic illustration of the contacts operation, the actual contacting being preferably accomplished by a periodically operating control mechanism shown in Figure 4 and described in detail hereinafter. The galvanometer coil 101 is connected by means of conductors 107 and 108, a potentiometer 109 embodying a battery 110, and adjustable resistances 112 and 113 to the thermocouple 114. The thermocouple 114 is located in inlet conduit 2, the temperature of which is to be maintained constant.

The galvanometer circuit including the potentiometer 109 is so adjusted that when a predetermined desired temperature is obtained in the furnace, the voltage generated by the thermocouple 114 balances that of the potentiometer circuit 109 and the galvanometer point 103 remains at its neutral position, intermediate the contacts 105 and 106. When a drop in temperature below the predetermined value occurs, the voltage generated by the thermocouple 114 is less than that in the potentiometer circuit and a resultant current flows through the coil 101 to deflect the pointer 103 clockwise, the extent of deflection being proportional to the variation of the temperature from the predetermined value and contact 104 of the pointer 102 engages contact 105. Similarly,

when a rise in temperature above the predetermined value occurs in the conduit 2, the current generated by the thermocouple 114 exceeds that in the potentiometer circuit 109 producing an unbalance and current flows through the coil 101 in a direction to deflect the pointer 103 counter-clockwise causing engagement of contacts 104 and 106.

The pointer 103 establishes a connection by means of conductor 116 to one side of 117 of a power line which supplies the necessary electrical energy for operations hereinafter described. Contacts 105 and 106 are connected by means of conductors 74 and 73 respectively through the relay circuit above described to terminals of the reversible motor 29 which operates the blast supply valve 25 in line 4 connected to stove 8. Motor 29 is connected to the power line 118. When the galvanometer pointer 103 operates to cause contacts 104 and 105 to engage in response to a drop in temperature as described above, a circuit is completed for the motor 29 over armature 75 as described above. As a result of this circuit, the motor 29 rotates in a predetermined direction for increasing the opening of the valve 25 to increase the rate of hot blast supplied to the furnace. A multiple circuit is completed for motor winding 46, as a result of which the motor is rotated to close valve 44 decreasing the rate of supply of cold blast. When the pointer 103 operates to cause contacts 104 and 106 to engage in response to a rise in furnace temperature above the predetermined value, a circuit is completed for motor 29, to partially close the valve 25 and decrease the rate of hot blast supply from the stove 8 and a multiple circuit for winding 46 increases the rate of supply of cold blast.

Connected in multiple with the conductors 73 and 74, leading to motor 120, are conductors 124′ and 125 respectively connected to terminals 126 and 126′ of the windings (not shown) of a reversible motor 120. The mid-terminal of winding of motor 127 is connected by conductor 128 to the side 118 of the power line.

When pointer 103 causes contacts 104 and 106 to engage and a circuit is completed for motor 29 as above described, a multiple circuit is completed over conductor 124′, a winding of the motor 120 and conductor 128 to line 118. Motor 120 thereupon rotates to vary the contacting position of the pointer 103 and contacts 105 and 106 through any suitable mechanism, such for example as more fully hereinafter set forth, in such manner that pointer 103 is prevented from causing immediate re-engagement of contacts 104 and 106 notwithstanding that pointer 103 is still in deflected position. A similar circuit is completed through the other winding of motor 120 to rotate the motor in the reverse direction and operating through said mechanism to prevent immediate engagement of contacts 104 and 105.

In each of the above mentioned operations caused by reversible motor 120, re-engagement of contacts 104 with 105 and 106 respectively is preferably prevented by shifting the relationship of the contacts and pointer 103 so that pointer 103 will again be intermediate contacts 105 and 106 and will, therefore, fail to reclose the contacts 104 and 105 or 106 as the case may be, even though pointer 103 is still in a deflected position. A suitable contacting galvanometer mechanism with a follow-up control to perform this function is disclosed in co-pending application Serial No. 198,298, filed June 11, 1927, as will be more fully hereinafter disclosed.

Two sets of contacting members 129 and 130 are connected by conductors 131 and 132 respectively to conductors 73 and 74 leading to motor 120. The opposite terminals of contacting members 129 and 130 are joined and connected to a contacting member 133 by means of conductor 134. One of the contacts of contacting member 133 is fixed and the other is actuated by a lever mechanism 135 controlled by pins 137 of disk 138 suitably mounted for rotation. As disk 138 rotates, lever 135 is engaged by successive pins 137 and is rocked on its pivot 136 to alternately close and open contacts 133. The intervals of closing and opening contacts 133 is variably adjusted as desired by controlling the rate of rotation of disk 138. The lever controlled contact 133 is connected by means of conductor 139 to line 117 providing an energizing circuit for motors 29 and 45 independently of contacts 104, 105 and 106.

Contacting mechanisms 129 and 130 are controlled by any suitable mechanism, preferably in the manner hereinafter set forth in connection with Figure 4, so that contact 129 will close following the engagement of contacts 104 and 106 and the corresponding operation of motors 29, 45 and 120 above set forth and so that contacts 129 will close following the operation of motors 29 and 120 as a result of the engagement of contacts 104 and 106.

It will be noted that contacts 129 and 130 control circuits to the motors 29 and 45 which are independent of the galvanometer pointer circuits and accordingly these motors are operated independently of the position of the galvanometer pointer 103 with respect to the contacts 105 and 106.

Connected in the circuits of the conductors 124′ and 125 are contact or switch members 140 and 141 respectively, also controlled by disk 138 through any suitable mechanism such for example, as is described in detail in connection with Figure 4, to simultaneously open with the closing of contact 133

and to close with the opening of contact 133. When, therefore, circuits for motors 29 and 45 are completed through either contacts 129 or 130 as described above, no circuit is completed for windings 126 and 126′ of the motor 120. The purpose for this will be explained more fully in the description of operation following. In series with contacts 140 and 141 are normally closed limit contacts 142 and 143 opened respectively, when the mechanism operated by motor 120 to vary the contacting position of contacts 104, 105 and 106 and pointer 103 has reached the limits of its movement to prevent further operation of motors 29 and 45 through suitable devices such for example as hereinafter set forth in connection with Figure 4.

During operation of the mechanism so far described, in response to a drop in temperature below the predetermined value, contacts 104 and 105 are periodically closed to operate motors 29 and 45 which increases the opening of the hot blast supply valve 25 and decreases the opening of the cold air valve 44 to oppose the temperature change. Simultaneously, motor 120 operates in effect to shift the contacting position of contacts 104, 105 and 106 in the direction of the pointer deflection to decrease the extent of correction in the succeeding periods of operation or to prevent operation of the contacts depending upon the adjustment of the apparatus.

If the air blast temperature in conduit 2 changes at a slow rate the first change in the hot blast valve 25 in response to the engagement of contacts 104 and 105 will cause the temperature to restore towards normal with the result that the pointer 103 will tend to restore towards its neutral position and as the contacts 105 and 106 have in effect followed the original deflection of the pointer 103 the contact 106 will be engaged by contact 104 as the galvanometer pointer 103 moves towards its neutral position. Engagement of contacts 104 and 106 will complete a circuit for reversing the operation of the motors 29 and 45 to decrease the opening of hot blast valve 25 and increase the opening of valve 44 and for motor 120 to again adjust the contacting in the direction of the galvanometer pointer movement. From the above assumed operation, it is evident that the follow-up control of the table responds rapidly to the rate of change of temperature to oppose such change.

It will be recalled that one result of the operation of motor 120 by the circuit through contacts 104 and 105 was to close contacts 130. When now disk 138 engages contact 133 a multiple circuit is completed for the motors 29 and 45 through contacts 130 and 133 as traced above, whereupon these motors operate to further increase the opening of the hot blast valve 25 and decrease the opening of valve 44 independently of the control of pointer 103 and contacts 104 and 105 and the contact 133 will then disengage under control of wheel 138. During this operation of the hot blast supply valve 25, windings 126 and 126′ of motor 120 are momentarily disconnected by disengagement of contacts 140 and 141 under control of wheel 138 to prevent operation of the contact adjusting mechanism. We have, therefore, on and off control now of motors 29 and 45, which is independent of the relative position of the galvanometer needle 103 and the table. By this on and off control, the fuel supply is varied in accordance solely with the temperature of the furnace and acts to restore the temperature to normal.

It will be evident from the above description that two controls, each acting in its own particular manner are interrelated in such a way as to produce a rapid control with substantially no hunting. The follow-up control responds rapidly to the rate of temperature change to prevent such change. It acts as a stabilizer of a blast temperature to prevent it from changing from the particular temperature it has at that time obtained. It is evident, however, that this in itself would not suffice inasmuch as a change from the predetermined value will have occurred before the follow-up succeeds in stopping further change and, therefore, some arrangement is necessary to bring the temperature back to its original value. This is accomplished by the on and off control which functions independently of the pointer 103 but in response to the actual temperature variation from the predetermined value to restore the temperature.

The details of a preferred form of control mechanism for carrying out these operations as well as others will now be set forth. As shown in Figure 4, this mechanism comprises a controller 145 embodying a galvanometer coil 101 and pointer 103 in operative relation therewith, as described in connection with Figure 3. Pointer 103 is periodically depressed by rail 146 mounted in such a manner that it normally tends to move downward under the action of gravity in which it depresses the galvanometer pointer 103. Rail 146 is supported on the outer ends of arms 147, the inner ends of which are rigidly secured to the shaft 148 which is oscillated by any suitable mechanism (not shown) and preferably a cam actuated mechanism of the character described in detail in the above mentioned copending application.

Associated with the pointer 103 is a control table 149 which is slidably and pivotally supported on a rock shaft 150 suitably journalled in the instrument frame work

(not shown). The control table 149 is freely rotatable on the rock shaft 150 and may be adjusted longitudinally of the latter in response to deflections of the pointer 103 as hereinafter explained. At its front end, the control table 149 is provided with an upturned contacting portion 151 for engaging the pointer 103. The upper edge of portion 151 is formed in steps which may be regularly arranged as shown, or any suitable stepped or sloping arrangement thereof may be employed to permit the desired variable movement of table 149 before engaging the pointer in accordance with the extent of deflection thereof.

The control table 149 is periodically oscillated to lift the portion 151 and to bring the upper edges thereof in contact with the pointer 103 by an actuator in the form of a bar 152 co-acting with a tail portion or extension 153 of the table 149. Bar 152 extends parallel to the shaft 150 and is supported on the outer end of arms 154, rigidly secured to and rotatable with rock shaft 150. Secured to the shaft 150 is a lever 155 provided with an end projection 156 in engagement with the surface of cam 157 for oscillating shaft 150 as cam 157 rotates. It will accordingly be seen that table 149 is oscillated under control of cam 157 by means of extension 153 and bar 152 and that counter-clockwise turning movement of the rock shaft 150 and table 149 under influence of cam 157 and weight 159 is arrested by the engagement of contacting portion 151 with the galvanometer pointer 103. The angular position of the rock shaft 150 when its motion is thus interrupted determines which of the control contacts 105 and 106 is to be engaged by the control contact 104 and also determines the duration of such engagement.

In the form of mechanism illustrated, the means whereby the position of the rock shaft 150 determines the control contact engagement includes a selector member comprising a bar 160 carried by arms 161 mounted on and yieldably coupled to shaft 150 in the manner shown in detail in said co-pending application. This connection rotates the selector member with shaft 150 but yields to permit said selector member to be held stationary when it is operatively engaged by the separated sloping control sections 162′ and 163′ of either of a pair of contact actuating levers 162 and 163, the full details of which are shown and described in said co-pending application.

The contact actuating levers 162 and 163 are mounted on and depend from stationary shaft 136 and carry at their lower ends adjustable contact engaging parts 165 which force the contacts 106 and 105 respectively into engagement with contacts 104, mounted on the contact carrier frame 104′ which is pivotally mounted on shaft 164. Each of the contact engaging parts 165 co-operates with a spring supporting member 165′ shaped to normally hold the contact 105 and 106 disengaged from the co-operating contacts 104 which are periodically shifted to engage the selected contacts 105 and 106 at a point in its cycle of operation determined by the position of bar 160. Contact 104 is periodically moved toward the contacts 105 and 106 by means of a lever 166 fulcrumed on the shaft 136 and engaging the upper side of the cam 157 carried by the shaft 158. A latch 166′ is pivotally connected at one end 167′ to the lower portion of the lever 166, the other end of said latch being slidably connected to the contact carrier frame 104′ at 168′. The lower edge of the latch 166′ has formed thereon the cam surface 169′ which rides on the rod 172. As the lever 166 is turned counter-clockwise by the cam 157, the latch 166′ causes the contact carrier frame 104′ to swing about the shaft 164 moving contact 104 toward contacts 105 and 106 to be engaged by one or another of these bar contacts as described above. The parts are so relatively arranged and timed that the levers 162 and 163 are held out of position to engage the selector bar 160 during the periods in which the rock shaft is rotating. The details of the contact operation are fully disclosed in said co-pending application to which reference may be had for a more detailed disclosure thereof.

As will more fully appear from said co-pending application, the bar portion 160 of the selector serves as a stop against which the separated sloping control sections of one or both of the levers 162 and 163 may bear so that one or the other of the levers is prevented from moving the corresponding contact is predetermined while at the same time the other lever may or may not be held at a predetermined distance away therefrom. The particular lever 162 or 163 thus held in predetermined operative position controls the point of engagement of the selected contact 105 or 106 with the contact 104 in the cycle of movement of contact 104 while the disengagement of the contacts occur invariably at the end of a cycle of periodic operation of the mechanism. When the bar 160 is in the position in which the shaft 150 tends to hold it when the control table elevating movement of the shaft 150 is arrested by the engagement of the pointer 103 with the control table 149 at the lower side of the neutral point of the control table 149, the bar 160 is in position to be engaged by the lever 162. The lever 163 is then moved so as to permit the contacts 104 and 106 to engage.

The third pair of contacts 133 is controlled by a lever 135 pivotally mounted and depending from the stationary shaft 136 and

carrying at its lower end a contact operating member 167 controlling contacts 133. Lever 135 is provided with a cam member 168 arranged to engage pins 137 projecting from disk 138. The disk 138 is secured to and rotatable with shaft 169. Lever 135 is rocked by gravity to move the contacts 133 into engagement. As the disk 138 rotates clockwise, cam 168 is engaged by a pin 137 which is moved outward so that lever 135 is rocked on its pivot 136 to move the contacts 133 out of engagement with each other. As disk 138 continues to rotate, the pin 137 in engagement with cam 168 will pass thereunder, permitting cam member 168 and the end of lever 135 to drop under the force of gravity reengaging contacts 133. The timing of the operation of contacts 133 may be varied by varying the spacing of pins 137 and the speed of rotation of disk 138. In one commercial form of tubular oil still control, three minute intervals between contacting was found satisfactory, although this will depend on many factors met in practice. Secured to lever 135 is an extending bar 170 which actuates fixed contact springs 171 upon which contacts 140 and 141 are carried to cause the contacts 140 and 141 to engage when contacts 133 are separated and to separate when contacts 133 is engaged.

In operation, the position of the control table 149 longitudinally of the rock shaft 150 depends upon the deflecting pointer 103, and the means by which adjustment of the table 149 longitudinally of the shaft 150 is effected, comprises a carriage 173 mounted on shaft 174, and provided with a projection 175 entering a helical groove formed in shaft 174. Carriage 173 is provided with an extension 176 carrying apertured ears 177 located at opposite sides of the table 149 and through which the shaft 150 extends. In consequence, the carriage 173 and control table 149 are shifted longitudinally of shaft 150 when shaft 174 is rotated by motor 120 suitably supported on the frame work (not shown) and comprising coils 126 and 126′ when energized, through chain 178 and sprockets 179 and 180 which rotates the shaft 174 in a direction depending on which of the coils 126 or 126′ of the motor is energized as described hereinbefore in connection with Figure 1.

Secured to the end of shaft 174 opposite sprocket 180 and driven thereby is a disk 181 with spiral grooves 182 and 183 which merge into each other at 184. A switch arm 186 depending from a pivot at 187 is provided with a cam follower 185 riding in grooves 182 and 183. Secured to extension 188 of the lever 186 is a contact carrying member 189, carrying contact sets 129 and 130. With the mechanism neutral, the lever 186 is so positioned that neither set of contacts 129 and 130 is in engagement. Rotation of the shaft 174 as described above in one direction will, however, cause closing of contacts 129 whereas rotation of the shaft in the opposite direction will cause closing of contacts 130.

Suitably supported from the frame work of the mechanism (not shown) are sets of contacts 142 and 143 in the path of movement of extension 153 of the table 149. As the table 149 reaches its limit of movement to the left, contact 142 will be opened by engagement with extension 153. Similarly, upon movement of the table to its right limit contact 143 will be disengaged.

The operation of the mechanism disclosed in Figure 4 for carrying out operations described in connection with Figure 3 will now be evident from a brief summary. In operation, shafts 148, 158 and 169 are driven from a common motor (not shown) and bails 146 and 152 are periodically raised and lowered to periodically depress the galvanometer pointer 103 and to raise table 149 as will appear from said co-pending application. With the pointer 103 undeflected, table 149 will be in the neutral position shown, lever arm 186 will be positioned to maintain contacts 129 and 130 disengaged and with the pointer 103 of the galvanometer 101 at neutral position, as table 149 is raised and lowered the movement of bar 160 is such that neither contact 105 nor 106 is positioned to be engaged by contact 104. If now pointer 103 deflects from its neutral position sufficiently, upon the next upward periodic operation of the table 149 pointer 103 will be positioned to be engaged by a different stop of contacting member 151, and the table together with shaft 150 and bar 160 will be arrested in position to cause engagement of contact 104 with contact 105 or 106, depending upon the direction of deflection of pointer 103, to complete a circuit for the fuel valve motor 45, and winding 126 or 126′ of motor 120. The motor 120 rotates to increase or decrease the opening of the fuel valve 125 as above set forth and motor 120 operates to move the table 149 longitudinally with respect to the shaft 150 in the direction of the pointer galvanometer deflection. Rotation of shaft 174 rocks the lever 186 about its pivot 187 to close contacts 129 or 130. In the particular form of invention shown, the adjustment is such that upon the next periodic operation of the table 149, if pointer 103 does not restore towards normal, neither contacts 105 nor 106 are closed inasmuch as as the neutral position of the table 149 is shifted directly under the galvanometer pointer 103 and no engagement of contacts 104 with 105 or 106 can occur.

It is manifest from the above description that when the galvanometer pointer 103 deflects in response to the temperature change, the rate of hot blast supply is varied

through operation of the hot blast valve 25 to prevent further change in the temperature and simultaneously the table is moved with respect to the pointer 103 so that pointer 103 assumes a neutral position with respect to the table 149. Since, however, the table 149 is in an off normal position, contacts 129 or 130 close depending upon the position of the table and further variations in the rate of hot blast supply are brought about by the operation of the motor 120. As the temperature is restored, the pointer 103 returns to normal and is, therefore, off normal with respect to the table 149 thereby causing completion of a circuit for the motor 45 and the motor 120 for rotating them in the opposite direction, which will thereupon tend to move the table back towards its normal position. Operation of motors 29 and 45 tends to prevent a temperature change towards normal, but this tendency is overcome by the opposite action of the motors 29 and 45 as a result of a circuit completed, therefore, over the contact 129 or 130.

Although in the above, I have described a preferred control apparatus applied in carrying out my invention, it will be understood that any similar control employing any type of controller combined with follow-up and escapement return for eliminating hunting can be employed. It will further be understood that if preferred, the continuous blast supply method may be employed in which, as the temperature in one stove drops below a predetermined value, a succeeding stove is immediately opened, the blasts of the two being then mixed to provide the blast of desired temperature.

It will be further understood, by those skilled in the art, that my invention is not necessarily limited to the preferred embodiment thereof disclosed inasmuch as the principle of successively controlling the heat supply from a plurality of sources at a single point to be maintained at a predetermined temperature is here broadly disclosed. I, therefore, do not intend to limit myself by the specific adaptation of this principle except as set forth in the appended claims.

1. In a control system, a blast furnace, a plurality of sources of heated blasts for said furnace, a common conductor for said heated blasts, automatic means responsive to the temperature of one of said sources for automatically switching said common conductor from said source to the succeeding source, a source of air supply for said source of heated blasts and means responsive to said automatic means for connecting said supply thereto.

2. In a control system, a blast furnace, a plurality of hot blast stoves, heat supply means and air supply means for each stove, hot blast supply means for conducting said hot blast to said furnace, automatic means responsive to the temperature of hot blast supplied from a stove for stopping the supply of hot blast from and the air supply to said stove.

3. In a control system, a blast furnace, a plurality of hot blast stoves, heat supply means and air supply means for each stove, hot blast supply means for conducting said hot blast to said furnace, automatic means responsive to the temperature of hot blast supplied from a stove for stopping the supply of hot blast from and the air supply to said stove, control means actuated by said automatic means for connecting the air supply means to another stove and for connecting the hot blast therefrom to the furnace.

4. In a control system, a blast furnace, a plurality of hot blast stoves, heat supply means and air supply means for each stove, hot blast supply means for conducting said hot blast to said furnace, automatic means responsive to the temperature of hot blast supplied from a stove for stopping the supply of hot blast from and the air supply to said stove, control means actuated by said automatic means for connecting the air supply means to another stove and for connecting the hot blast therefrom to the furnace, second control means actuated by said automatic means for connecting the heat supply means to the first stove after the hot blast therefrom and air supply thereto has ceased.

5. In a control system, comprising a plurality of sources of heat supply, a blast furnace, a source of cold supply and control apparatus, the method of maintaining the heat supply to said furnace at a predetermined temperature which comprises mixing the supply from one of said heated sources and from the cold source under control of said control apparatus and automatically switching from an exhausted heat supply to a fresh heat supply and simultaneously opening said cold supply to its maximum.

6. In combination, a blast furnace, a plurality of hot blast supplies for said furnace, a valve associated with each of said supplies, a control apparatus, means for associating said control apparatus with one of said valves, said means being operative to switch said control apparatus successively to the succeeding valve, and a temperature responsive means responsive to the temperature of said blast fed to the furnace for operating said control apparatus to vary the opening of the valve to which the control apparatus is at that time associated.

7. In combination, a plurality of sources of heat supply, a control apparatus, a device to be maintained at a predetermined temperature associated with said control apparatus, means for successively switching said device from one to another of said

sources, said control apparatus being arranged to simultaneously vary the rate of heat flow from said source to which said device is at the time connected in accordance with variations of temperature of said device from a predetermined temperature.

8. In combination, a plurality of sources of heat supply, a device to be maintained at a predetermined temperature, means for successively associating said device with each of said sources, and a control apparatus for varying the rate of heat supply from said sources to said device in accordance with the variations of temperature of said device from a predetermined temperature.

9. In combination, a plurality of sources of heating supply, a source of cooling supply, a device to be maintained at a predetermined temperature, means for successively associating said device with each of said heating supplies, control apparatus for varying the proportions of heat from said heating supply to which said device is at that time associated, and the cooling supply in accordance with the variations of said device from a predetermined temperature and means for opening said cooling supply to its maximum while switching from one to a succeeding source of heating supply.

10. In a temperature control system, a furnace to be maintained at a predetermined temperature, a plurality of sources of temperature changing mediums therefor, temperature responsive means in operative relation with said furnace, means for associating one of said sources with said furnace and means controlled by said temperature responsive means for controlling the last mentioned means in accordance with variations of the temperature of the furnace from a predetermined value.

11. In a temperature control system, a furnace to be maintained at a predetermined temperature, a plurality of sources of temperature changing mediums therefor, temperature responsive means in operative relation with said furnace, means for associating one of said sources with said furnace, and means controlled by said temperature responsive means for controlling the last mentioned means in accordance with variations of the temperature of the furnace from a predetermined value, said associating means being adapted to disassociate said source from said furnace and associate another of said sources with said furnace.

12. In a control system, a furnace to be maintained at a predetermined temperature, a temperature responsive means, a plurality of sources of temperature changing mediums for the furnace and a common controller for all of said sources and operated by said temperature responsive means for varying a pre-determined one of said sources in accordance with the variations in temperature of said temperature responsive means.

13. In a control system, a furnace to be maintained at a predetermined temperature, a temperature responsive means, a plurality of sources of temperature changing mediums for the furnace, a common controller for all of said sources and operated by said temperature responsive means for varying a predetermined one of said sources in accordance with the variations of temperature of said temperature responsive means and means for automatically disconnecting one of said sources and for connecting another of said sources whereby the controller is switched to control the second of said sources.

14. In a temperature control system, a furnace to be maintained at a predetermined temperature, a temperature responsive means, a controller controlled by said temperature responsive means, a plurality of sources of temperature changing mediums means responsive to said controller for variably operating one of said sources for varying the supply therefrom to said furnace, a temperature responsive means at each of said sources, a controller operated by said temperature responsive means and means controlled by said controller for switching the supply to the furnace from one to the other of said sources.

15. In a temperature control system, a furnace, a plurality of sources of temperature changing mediums for said furnace, means for associating one of said sources with said furnace, means for varying the rate of supply from said source to said furnace in accordance with the variations of temperature of said furnace from a predetermined value, means operative responsive to the temperature of said source for disassociating said source from said furnace and for associating a second of said sources with said furnace and means operative while temperature changing medium from said second source is being fed to said furnace at a rate in accordance with the variations of the temperature of said furnace for recharging said first source in preparation for its second association with said furnace.

16. In a temperature control system, a furnace to be maintained at a predetermined temperature, a temperature responsive means, a plurality of sources of temperature changing medium control apparatus, means for associating one of said plurality of sources with said furnace, means controlled by said control apparatus for varying the supply from said source associated with said furnace in accordance with the variations of said furnace from a predetermined temperature, temperature responsive means associated with each of said sources, means controlled individual to said plurality

of temperature responsive means for associating said controller with the source which is supplying the temperature changing medium to the furnace at the time and means controlled by said controller for disassociating said source from said furnace in accordance with the change in temperature of said source and for associating another of said sources with said furnace.

17. In a temperature control system, a furnace to be maintained at a predetermined temperature, a plurality of sources of temperature changing medium therefor, means responsive to variations in temperature of said furnace, a control mechanism, means for controlling the rate of supply from said various sources means for associating said control mechanism with one of said supply control means whereby said supply control means is variably operated in accordance with the variations in temperature of said furnace, a second control mechanism common to all of said sources said second control mechanism being associated with the source which is at the time supplying temperature changing medium to said furnace by said first mentioned associating means, said second control mechanism operating in response to variations in temperature of said source for operating said associating means to switch said first control mechanism to operate the control means of a second source and for simultaneously associating said second control mechanism with said second source.

18. In a temperature control system, a furnace to be maintained at a predetermined temperature, a plurality of sources of temperature changing medium therefor, means responsive to variations in temperature of said furnace, a control mechanism, means for varying the rate of supply from said various sources, means for associating said control mechanism with one of said sources, means for associating said control mechanism with one of said sources whereby said source is controlled in accordance with the variations in temperature of said furnace, a second control mechanism common to all of said sources said second control mechanism being associated with the source which is at the time supplying temperature changing medium to said furnace, said second control mechanism operating responsive to variations in temperature of said source for operating said associating means to switch said first control mechanism to operate the control means of a second source and for simultaneously associating said second control mechanism with said second source, a heat exhaust line extending from said furnace to each of said sources and means for varying the supply from said exhaust line to said source, said associating means connecting said exhaust line with the source which has previously been disassociated from said furnace.

19. In combination, a furnace, a plurality of sources of hot blast, a variable source of cool air, means for conducting a mixture of the hot blast and the cool air to the furnace, a second means responsive to the temperature of the source of hot blast supplying the furnace for substituting a succeeding source of hot blast therefor when a predetermined low temperature is reached in the first source of hot blast, and means operated by said second means for increasing the supply of air to a maximum simultaneously with said substitution.

20. In combination, a furnace, a plurality of hot blast stoves, a source of cool air, means for conducting a mixture of the hot blast and the cool air to the furnace, means for varying the ratio between the rate of hot blast supply and the rate of cool air supply, means responsive to the temperature of the mixture for adjusting the ratio varying means to tend to maintain a constant mixture temperature, means for substituting a succeeding hot blast stove when the preceding stove has been exhausted to a predetermined degree, the substituting means and the ratio varying means being operatively associated so that the rate of cool air supply is adjusted to a maximum simultaneously with the substitution.

In testimony whereof I affix my signature.

RICHARD P. BROWN.