Aug. 1, 1944. A. E. KROGH 2,354,997

CONTROL SYSTEM

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FIG. 2

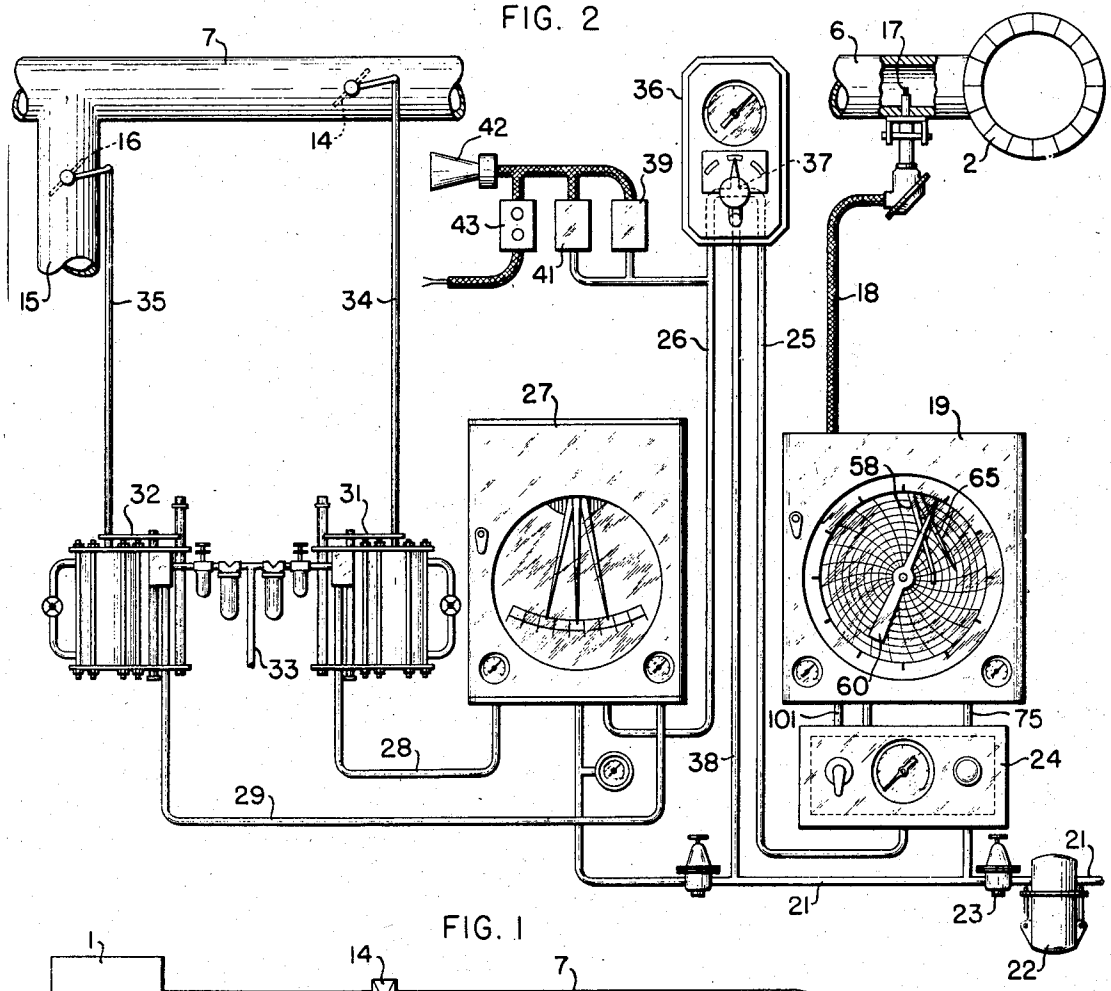
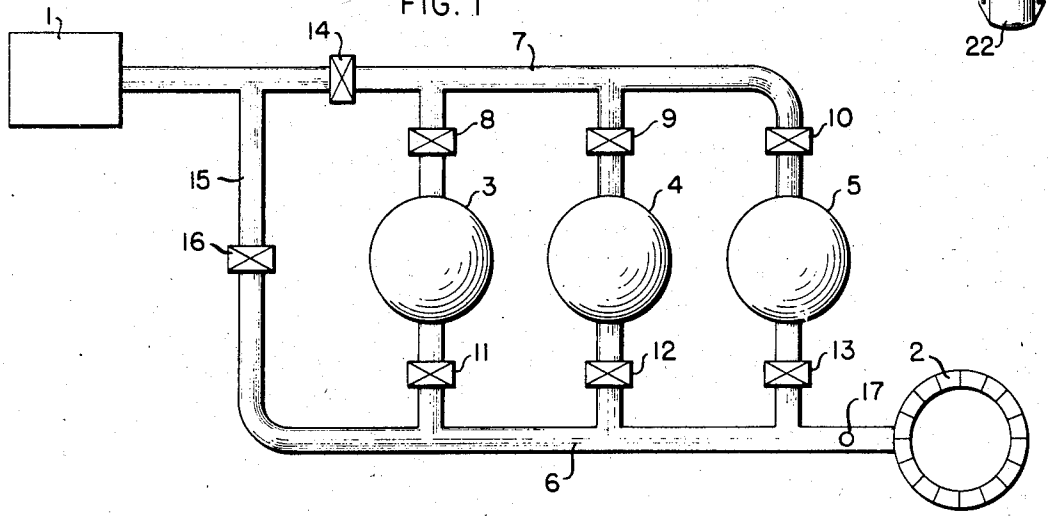


FIG. 1



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CONTROL SYSTEM

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FIG. 4

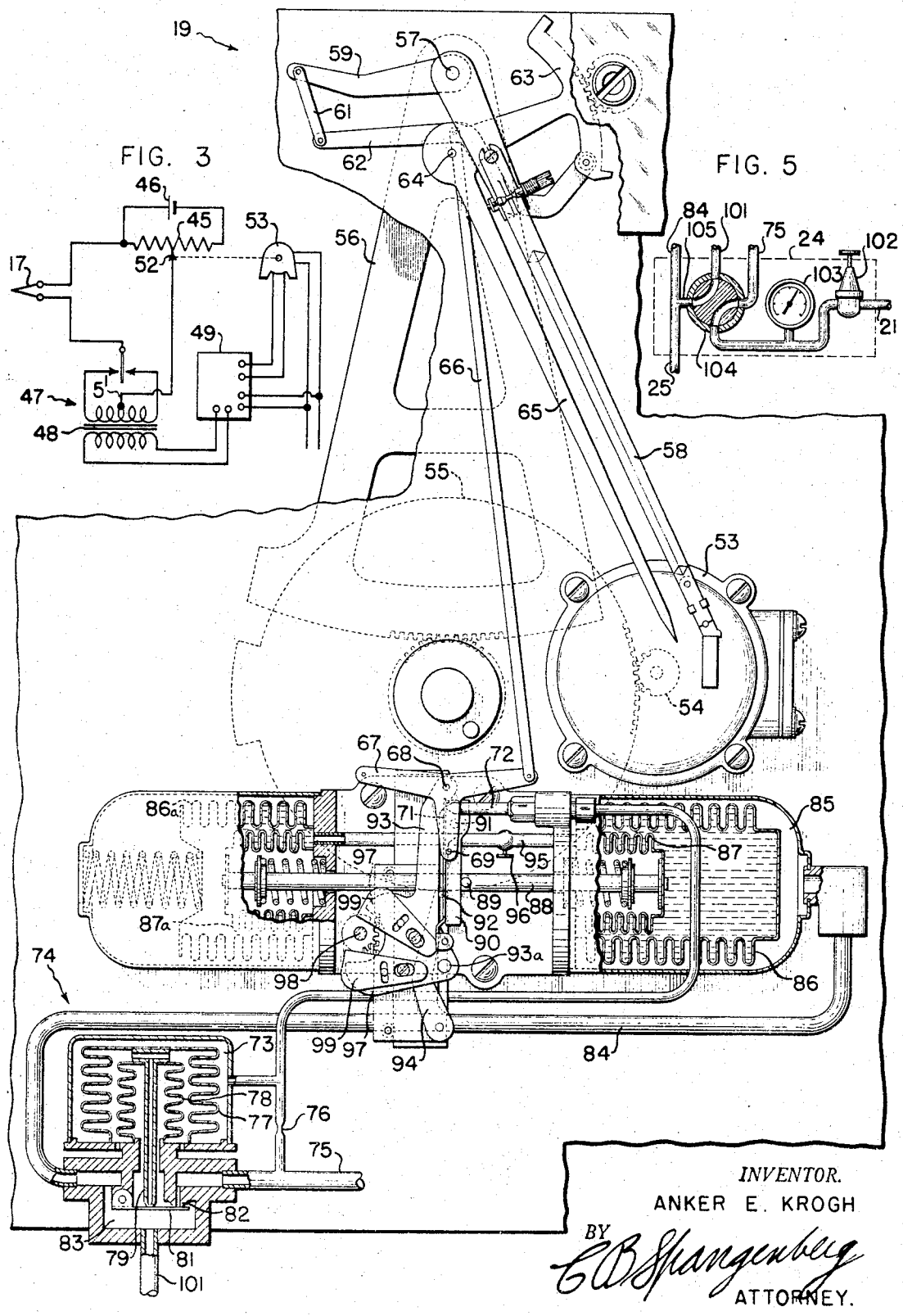

FIG. 3

FIG. 5

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CONTROL SYSTEM

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FIG. 6

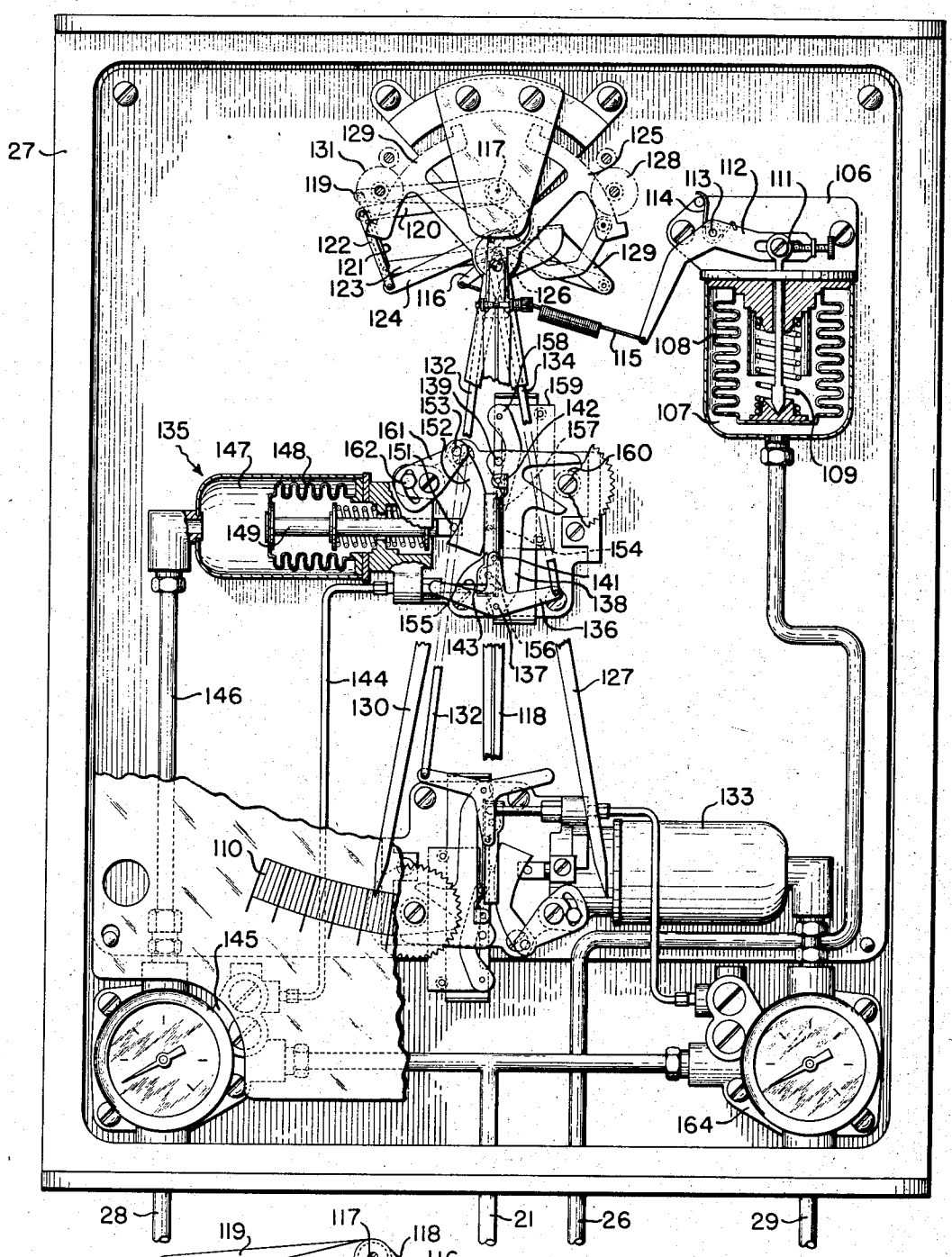
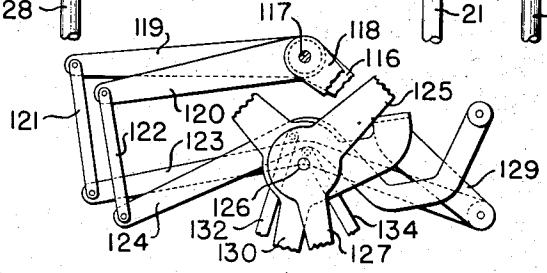


FIG. 7



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UNITED STATES PATENT OFFICE

2,354,997

CONTROL SYSTEM

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Application June 25, 1943, Serial No. 492,243

5 Claims. (Cl. 236—12)

The present invention relates to automatic temperature controlling systems, and is particularly designed to regulate within very narrow limits the temperature of the hot blast supplied to a blast furnace.

In the operation of a blast furnace the air for combustion is heated in one of a plurality of stoves that are connected in parallel between the air supply, or cold blast, and the air to the furnace, or hot blast. Air for the furnace is heated by forcing it through one of the stoves at a time. While the stove through which air is being forced is cooled down by the air the rest of the stoves are being heated. In order to keep the air at a constant temperature as the stove temperature varies a by-pass pipe between the hot blast main and the cold blast main is used, and a valve in this by-pass is adjusted so that more or less of the air is passed through the stove.

Some systems, such as the one disclosed herein, have two valves, one in the cold blast main and one in the by-pass, which are alternately or simultaneously adjusted to vary the amount of air passing through the stove. In this manner as the stove cools down a larger percentage of the total air passes through it until such time as the stove is too cool to properly heat the air. At that time the air is directed to another stove that has been heated up and the cold stove is heated. When shifting from one stove to another there will be a sudden surge of hot air to the blast furnace while the valves are being moved from one extreme position to the other. It is advisable therefore to provide some means to reverse rapidly the position of the valves when a stove change takes place.

It is an object of the present invention to provide a system for hot blast control which will be capable of adjusting the air valves in such a manner that a substantially constant temperature of the air is maintained at the blast furnace. It is a further object of the invention to provide a hot blast control system in which means is provided to operate individually each of the valves in sequence or in such a manner that one may begin to operate when the other is in any predetermined portion of its range of movement.

It is a further object of the invention to provide a hot blast control system that will operate the valves slowly as the temperature of the air in the blast remains within a given amount of the control point, but which will operate to move the valves quickly whenever the blast temperature deviates more than a predetermined amount from the said control point.

The various features of novelty which characterize this invention are pointed out with particularity in the claims annexed to and forming a part of this specification. For a better understanding of the invention, however, its advantages and specific objects obtained with its use, reference should be had to the accompanying drawings and descriptive matter in which is illustrated and described a preferred embodiment of the invention.

In the drawings:

Figure 1 is a diagrammatic view of a blast furnace system,

Figure 2 is a view of a control system for a blast furnace,

Figure 3 is a schematic wiring diagram of a potentiometer circuit,

Figure 4 is a view, partly in section, of a potentiometer air control instrument,

Figure 5 is a view of a by-pass assembly to be used with the instrument of Figure 4,

Figure 6 is a view, partly in section, of an air pressure regulating instrument, and

Figure 7 is a view on an enlarged scale of certain levers of Figure 6.

There is shown in Figure 1 a diagram of a blast furnace system indicating the manner in which combustion air is supplied to this furnace. There is shown at 1 a blowing engine which forces air into the blast furnace 2. The air is forced through a pipe 7 known as a cold blast main and then through one of the stoves 3, 4 and 5 that are connected in parallel between the cold blast main and the hot blast main 6 which supplies air to the furnace. The cold blast main has branches leading from it to the other stoves and each of these branches is supplied with a valve 8, 9 or 10. In a like manner, the hot blast main is supplied with air through branches leading to that main from the stoves and these branches have in them valves 11, 12 or 13 respectively. There is also provided in the cold blast main a valve 14 which controls the air flowing through this main to the stoves, and there is provided a by-pass 15 extending between the cold blast and the hot blast mains which by-pass has a valve 16 in it to control the amount of air flowing through the same. It is noted that in their closed positions these valves do not entirely shut off the flow of air through the pipes in which they are located.

In the normal operation of a blast furnace system a blower 1 is used to force a given volume of air to the furnace through the by-pass 15 and through one of the stoves, while the other

two stoves are being heated up so that in their turn they can be used to heat the air supplied to the furnace. If, for example, the air is being heated by stove 3, the valves 8 and 11 would be open while valves 9, 10, 12 and 13 would be closed. The valves 14 and 16 would then be adjusted by apparatus to be described below in order that the proper proportion of the total amount of air will pass through the stove so that it will reach the proper temperature. The temperature of the air flowing through the hot blast main 6 is measured by a thermocouple 17 to which the above mentioned apparatus is responsive, in order that the valves may be properly operated.

In order to regulate the air temperature, the valves 14 and 16 are adjusted by apparatus set up in a control layout as shown in Figure 2. The details of the various instruments are disclosed in the remaining figures of the case. In Figure 2 the thermocouple 17 which is located in the hot blast main is shown as being connected by means of a thermocouple lead wire 18 to a potentiometer type of air controller 19. This controller is supplied with air under a regulated pressure through a pipe 21 which contains in it a filter 22 and a pressure regulator 23. The air passes through a so called by-pass panel 24 to the instrument 19 which serves to vary the pressure of this air and apply it through pipes 25 and 26 to an air control instrument 27. This latter instrument is also supplied with air from the pipe 21 and is provided with apparatus which serves to adjust this air and apply a regulated air pressure through pipes 28 and 29 which pressures are varied in accordance with the pressure supplied by the instrument 19. Pipes 28 and 29 lead respectively to piston positioning mechanisms 31 and 32 that serve to adjust the valves 14 and 16. These mechanisms may take the form of the piston positioner shown in Moore Patent 2,237,038, granted April 1, 1941, and which are supplied with a suitably regulated air pressure, that is generally considerably higher than that in pipe 21, through a pipe 33. The piston positioners 31 and 32 are connected by means of suitable links 34 and 35 with the valves 14 and 16 respectively.

Located between pipes 25 and 26 is a so-called manual-automatic station 36 which includes a pressure regulator and a three-way valve 37. This manual-automatic station is generally located at some point adjacent the blast furnace itself while the instruments 19 and 27 may be located in a control house containing the rest of the apparatus and control instruments that are needed for the proper operation of the furnace. In the normal operation of the instrument the three-way valve 37 is adjusted to the position shown in which pipes 25 and 26 are connected so that changes in the temperature of the thermocouple as measured by the instrument 19 will be converted into air pressure of a suitable value and applied to the control point changing mechanism of the instrument 27. At times, however, it may be advisable to adjust the instrument 27 manually, in which case valve 37 is moved 90° in a counter-clockwise direction in order to connect the pipe 26 with a pipe 38 that forms a branch of the air supply pipe 21. When this is done, the pressure regulator in the station 36 may be adjusted to apply any desired pressure direct from the pipe 21 through pipe 26 to the instrument 27. Also connected to the pipe 26 are a pair of pressure operated switches 39 and 41 which are connected in circuit with an alarm device 42. One of the switches 39 or 41 is designed to close the circuit for the alarm when a predetermined minimum of pressure occurs in the pipe 26, while the other of the switches is designed to close the circuit when a predetermined maximum pressure occurs in the pipe 26. Thus the attendant will be notified that one of the limits of the instrument system is being approached and he can take the proper steps to correct this condition. This usually occurs when the stove which has been heating the air supplied to the blast furnace has cooled to such a degree that it is necessary to place a new stove in the line. A pushing button station 43 is also provided so that the alarm may be operated manually if for some reason it is desired to call the operator's attention to a condition of the furnace.

The instrument 19 may be any type of air control potentiometer but is shown herein as being of the continuous balance type disclosed in the application of W. P. Wills, Serial No. 421,173, which was filed December 1, 1941. In that instrument there is provided, as shown in Figure 3, a slide wire 45 across which a potential drop is obtained by means of a battery 46. One end of the slide wire is connected with one terminal of the thermocouple 17 whose other terminal is connected to the central contact of a vibrator 47, the cooperating contacts of which are connected to the ends of the primary winding of transformer 48. The secondary winding of the transformer is connected to an amplifier 49. A center tap 51 of the primary winding of the transformer 48 is connected to a slide wire contact 52 which is shifted along the slide wire by means of a motor 53 to which it is mechanically connected. When the temperature in the hot blast main 6 is constant, no current will flow in the potentiometer circuit. When, however, a change in temperature occurs, a current flow in one direction or the other will be set up in the potentiometer circuit, and this current flow will be amplified through the transformer 48 and the amplifier 49 to energize the motor 53 for rotation in one direction or the other. The motor which is connected to the contact 52 serves to move this contact along the slide wire until such time as the flow of current is balanced by the potential drop across a portion of the slide wire, at which time the potentiometer circuit will be balanced and the motor will again be de-energized.

As shown in Figure 4, the motor 53 is provided with a pinion 54 that meshes with and rotates a large gear 55 as the motor rotates. This gear is mechanically connected in a suitable fashion with the slide wire contact 52 and also serves to move a segment member 56 around a pivot which is formed by a shaft 57 to which this segment is attached. Also fastened to the shaft 57 is a pen arm 58 that is moved by the segment across a suitable calibrated chart to make a record of the temperature of the hot blast. An indicator 60 which is shown in Figure 2 is also connected to the gear 55 so that this indicator is moved in synchronism with the pen arm.

A second arm 59 is attached to the shaft 57 and serves by means of a link 61 to raise or lower the left end of a differential floating lever 62 whose other end is supported by means of a segment 63. This segment is pivoted at 64 and has an index member 65 movable with it. In the operation of the instrument, the segment 63 is moved around its pivot to raise or lower the right end

of the differential lever 62 until the index 65 is at a position across the chart corresponding to the temperature at which it is desired to maintain the hot blast. Thereafter, as the temperature deviates from this point, the left end of the differential lever will be moved up or down to operate an air control instrument which may be of any suitable type but which is shown herein as taking the form of a control instrument which may be of the type that is fully disclosed in Moore Patent 2,125,081, that was granted on July 26, 1938.

To this end, the lever 62 is connected by means of a link 66 with one arm of a three-armed lever 67 that is pivoted at 68. This lever has a pin 69 on it which serves to move a flapper 71 against a suitable biasing force away from or permit the flapper to move toward a nozzle 72 to throttle the flow of air through this nozzle. The nozzle, along with a chamber 73 that is formed in a pilot valve 74, is supplied with air from a pipe 75 that is connected to the pipe 21. A restriction 76 is formed in the supply pipe to the nozzle and chamber so that air is supplied thereto at a slow rate.

As the pressure in the chamber 73 varies due to the throttling of the flow through nozzle 72 the size of this chamber is varied due to the expansion and contraction of a bellows 77 that forms one wall of this chamber. The bellows 77 and a second and smaller bellows 78 that is attached to it each serve to raise or lower an exhaust nozzle 79 which is connected with the atmosphere through the inter-bellows space. This nozzle operates in connection with a valve 81, that is biased in a counter-clockwise direction, to either open or close this nozzle and to simultaneously close or open a supply nozzle 82 which is connected directly with the pipe 75 and which terminates in a second chamber 83 of the pilot valve 74. The chamber 83 is connected by means of a pipe 84 with a chamber 85 formed in the air control unit. This pressure acts through a pair of liquid filled bellows 86 and 87 to move these bellows and a rod 88 which is fastened thereto. The rod extends across the unit and into engagement with a second bellows 87*a* that forms one wall of a second liquid filled chamber whose other wall is formed by a bellows 86*a*. The liquid filled bellows chambers are connected by means of a pipe 95 having a variable restriction 96 in it.

As the pressure in chamber 85 is varied, a follow-up movement is given to the flapper 71. This is accomplished by means of the action of the rod 88 and a projection 89 thereon on a first lever 90 that is pivoted at 91, a pin 92, and a second lever 93 that is pivoted at 93*a*, which second lever supports the three-armed lever 67. The pin 92 is attached to a supporting arm 94 and may be moved upwardly and downwardly between levers 90 and 93 to change the throttling range of the instrument. As the lever 93 is moved, the flapper is shifted in a direction opposite to its original movement in order to bring the instrument back to equilibrium. This second or follow-up movement is followed by a third compensating or reset movement as the pressure of the liquid in the chambers between bellows 86 and 87 and bellows 86*a* and 87*a* is equalized through the connection 95. The speed at which this reset movement can take place is dependent upon the adjustment of the restriction 96.

The total amount of follow-up movement that can be obtained may be limited by the amount of movement that can be imparted to the lever 93. To this end the lever 93 is formed with a pair of fingers 97 which extend on either side of a shaft 98. Each of these fingers has adjustably attached to it a member 99 that can be used to, in effect, change the spacing between the fingers 97 and the shaft 98.

In the operation of the instrument, if for example, the temperature of the hot blast has been increased, the pen 58 will be moved in a counter-clockwise direction outwardly across its chart. This same movement will cause the left end of the differential lever 62 to be lowered so that link 66 will move lever 67 in a clockwise direction. Such a movement will move the pin 69 to the left so that flapper 71 will be moved away from nozzle 72 permitting more air to escape from this nozzle with a consequent decrease in pressure in the chamber 73. The bellows 77 and 78 will accordingly be elongated so that nozzle 79 will move upwardly away from the valve 81 permitting air to escape from chamber 83 to the atmosphere. The escaping of this air will also cause a reduction of pressure in the chamber 85 thereby permitting the rod 88 with its projection 89 to move to the right. The levers 90 and 93 and the pin 92 will therefore cause a movement of the pivot point 68 and lever 67 to the right so that the flapper 71 will be given a follow-up movement toward the nozzle 72. If the temperature of the hot blast deviates a considerable amount from the control point of the instrument, the lever 93 will be forced to move in a clockwise direction until the lower one of the members 99 engages the rod 98 to stop further movement of this lever. Thereafter, the control instrument operation in that direction will behave as an on-off instrument, since no further follow-up can be obtained.

In a like manner, a decrease in the temperature of the hot blast in main 6 will cause a reverse operation to that above described so that an increase in pressure is obtained throughout the system with the lever 93 moving in a counter-clockwise direction to an extent limited by engagement between the upper member 99 and the shaft 98. It will therefore be seen that an air pressure corresponding to the temperature of the hot blast will be set up in the chamber 83 of the pilot valve 74, and this pressure will be varied as the hot blast changes in temperature within reasonable limits on either side of its control point. When the temperature changes beyond these limits, however, further follow-up movement cannot be obtained due to engagement of one of the members 99 with the shaft 98. Thereafter, the pressure in the chamber 83 will go immediately to one of its limits. The amount of deviation from the control point which is permitted the temperature of the hot blast prior to the time that the members 99 engage the shaft 98 can be varied by adjusting these members on their supporting fingers 97. Air is also supplied from chamber 83 through a pipe 101 which is connected to pipe 25 and to the instrument 27.

The above description of the air control connections was made with the assumption that no by-pass panel 24 was used. If such a panel is used as is shown in Figure 2 the operation of the instrument will be the same, but the pipe connections will be slightly different. In this case, as shown in Figure 5, the supply pipe 21 to the panel 24 has in it a pressure regulator 102 and has connected to it a pressure gauge 103. The pipe 21 terminates in one connection of a four-way valve 104 to which the pipes 75 and 101 and

a fourth pipe 105 are also connected. The pipe 105 has two branches, the first one 84 connects with the follow-up provisions of the air control unit while the second branch is the pipe 25 leading toward the instrument 27.

The valve 104 is shown in Figure 5 in the position it will assume when the control is automatic. Air is supplied through pipe 21 the valve 104 and pipe 75 to the air control unit. Air is supplied from the pilot valve through pipe 101 through the valve 104 to the air control unit and to the instrument 27. If it is desired to control the process manually from a point near the instrument 19 the valve 104 is rotated 90° in either direction. This will connect pipes 75 and 101 so that the pilot valve will have no function in the apparatus. At the same time, pipes 21 and 105 are connected so that the pressure applied through pipe 25 may be manually adjusted by manipulation of the pressure regulator 102. At this time the operator will use the pressure gauge 103 to determine the adjustment of the pressure in pipe 25. It is noted that because of the arrangement of the pipes 84 and 25, air will be applied to the follow-up and reset provisions of the air control unit both when the process is on manual as well as when it is on automatic control. The reason for this is to prevent reset from building up in the instrument so that it will control properly when the system is returned to automatic control. It may be advisable at times to control the process manually for various reasons, but it is particularly important that a by-pass panel of this type be used with a potentiometer, since when the instrument is being standardized, the control will be upset unless the air pressure from the instrument is disconnected from the controlled valve.

Pressure is applied through pipes 25 and 26 to a receiving unit 106 in the instrument 27. This receiving unit consists of an expansible chamber 107, one wall of which is formed by a bellows 108 that is biased toward its elongated position by means of a spring 109. Received within a socket on the end of the bellows 108 is a bellows rod 111 whose upper end is connected with a lever 112 that is pivoted at 113 and that is biased in a clockwise direction by means of a spring 114. The other arm of the lever 112 is connected by means of a link 115 to the lower end of a curved arm 116 that is attached to a pivoted shaft 117. Also attached to the shaft are a pointer 118 which moves across a suitable scale 110 on this instrument and a pair of arms 119 and 120. The latter arms are connected respectively by links 121 and 122 with the left end of differential levers 123 and 124. The former of the differential levers or lever 123 has its right end attached to a segment 125 that is pivoted at 126. This segment has fastened to it an index 127 so that as the segment is rotated by means of gearing 128, the index 127 will be moved across the scale 110. The right end of the differential lever 124 is attached to the end of an arm 129 whose left end has also a segment formed on it. The arm 129 is formed with a pointer 130, which pointer is moved with the lever as the gearing 131 is rotated. The differential lever 123 is connected by a link 132 to an air control unit 133. The differential lever 124 is connected by means of a link 134 to an air control unit 135. These air control units are similar and a description of one will suffice for the purposes of this disclosure.

The lower end of the link 134 is connected to one arm of a lever 138 which is in turn pivoted at point 139. The lever 136 is provided with a pin 141 that serves to move a flapper 142 against its normal bias and away from a nozzle 143 or which serves to permit the flapper to move toward the nozzle. This nozzle is connected by means of a pipe 144 to a pilot valve 145 which is identical in form with the pilot valve 74 that was described above in connection with instrument 19. As air pressure in the pilot valve chamber corresponding to chamber 73 is varied due to a change in the flapper position, a variable pressure is applied through a pipe 146 to a chamber 147 in the control unit 135. A wall of this chamber is formed of a bellows 148 that has attached to its end wall a rod 149, that is axially moved as the pressure in the chamber 147 is varied. Movement of the rod serves to give a follow-up movement to the flapper. This is accomplished by having a pin 151 on the right end of the rod 149 bear against one side of a cam 152 that is pivoted at 153. The right side of the cam acts on a pin 154 projecting from the rear surface of a lever 155 that is pivoted at 156. Movement of the lever 155 is imparted to the lever 138 through a pin 157 projecting from a supporting arm which pin extends between the edges of levers 155 and 138. The support 158 for the pin 157 is mounted on a rack member 159 that may be raised and lowered by means of a pinion 160 to shift the position of the pin relative to the levers 155 and 138. It is noted that the cam 152 may be raised and lowered to adjust the distance between pins 151 and 154 by rotating around its pivot a member 161 upon which the cam is supported. The member 161 is held in place by a clamp screw 162 that extends through an arcuate slot in the support 161.

The pipe 28 extends from the pilot valve 145 to the power positioning mechanism 31 for the valve 14. A second pilot valve 164 is located in the instrument 27 and cooperates with the unit 133 in exactly the same manner that the pilot valve 145 cooperates with the unit 135. The pipe 29 extends from the pilot valve 164 to apply variable pressure air to the piston positioning unit 32 for the valve 16.

It will be noted that a change in the pressure supplied to the unit 106 will actuate the lever system in such a fashion that the units 133 and 135 will be operated in opposite directions. If for example the pressure is increased in chamber 107, the shaft 117 will be moved in a counter-clockwise direction so that the left ends of levers 123 and 124 will be moved downwardly. This movement of the lever 123 will shift link 134 downwardly to move flapper 142 of the unit 135 away from the nozzle 143, therefore decreasing the pressure supplied by that unit. In a like manner, a downward movement of the link 132 by the lever 124 will operate the flapper of the unit 133 in a direction to permit this flapper to move toward the nozzle of that unit, and thereby increase the pressure that is produced thereby.

In the operation of the control system that has been described, and of the blast furnace air system, a certain total amount of air is forced by the blowing engine 1 to the blast furnace 2 and the valves 14 and 16 serve to determine which proportion of this air is forced through the heater and which proportion of the air goes through the by-pass pipe 15. When a new stove has been put on the line its temperature is very high so that only a small proportion of the air will flow through the stove then being used, whereas a large proportion of the air will flow through the by-pass. As the stove cools down a larger proportion of the air will have to be forced through the stove in

order that the air in the hot blast main 6 will be brought to the proper temperature. Therefore, when a new stove is put on the line the valve 14 will be substantially closed and the valve 16 will be substantially open. As the stove cools down the valve 16 will first be closed to force more of the air through the valve 14 and the stove, and later on the valve 14 will begin to open so that an even greater percentage of the air will flow through the stove. This operation is possible with the instruments of the present invention because of the fact that the units 133 and 135 are purely throttling instruments which serve to set up a pressure which is proportional to the position of the actuating lever and the adjustment of the throttling range of the unit. The throttling range of each of the units 133 and 135 may be adjusted by moving the pin 157 upwardly or downwardly with respect to levers 155 and 138. The higher the pin the smaller the throttling range. In other words the higher the pin 157 is between the two levers 155 and 138 the smaller the change in pressure in the chamber 147 that is necessary to move the lever 138 through its full range. When the unit 135 is adjusted so that its throttling range is 100%, this means that a maximum pressure change in chamber 107 will produce a complete pressure change by the unit 135 for full scale movement of the instrument. If the throttling range of the unit 135 is at 50%, this means that a maximum change in pressure in the chamber 107 will cause the unit 135 to produce its maximum pressure change through one half of the scale of the instrument.

Suppose it is desired to have the valve 14 begin to open only after the valve 16 has completely closed. In such a case the index for the unit 133 would be 25% of the scale while the index for the unit 135 would be set to 75% of the scale and the throttling range of each unit would be set for 50%. Therefore, starting from a minimum and changing to a maximum pressure in the chamber 107, the unit 133 would operate to move the valve 16 from its completely open to its completely closed position, and thereafter the unit 135 would operate to move the valve 14 from its completely closed to its completely open position. Generally speaking, however, the instrument is so arranged that there will be overlapping of the operation of valves 14 and 16. This means that the control indices 127 and 130 would be moved respectively to slightly above 25% and slightly below 75% of the scale 110, while the throttling range of the two units 133 and 135 would be set to slightly more than 50%. Therefore, during the operation of the instrument, the unit 135 would begin to increase the pressure in pipe 28 before the unit 133 had reached its maximum pressure so that the valve 14 would begin to open before the valve 16 had completely closed.

The above operation will continue until such time as the temperature of the stove which is then on the line has been reduced to a point at which it is unable to maintain the temperature of the hot blast. The attendant of the blast furnace system will then close off that stove and put one of the hot stoves on the line. When this operation takes place the valves 16 and 14 which have each been gradually closed and opened respectively must be rapidly reversed in their positions in order to properly control the temperature of the hot blast. When the hot stove is placed on the line there will be a rapid rise in the temperature of the hot blast above the control point for which the instrument 19 has been set. When the temperature of the blast reaches a certain number of degrees above the control point, one of the members 99 will engage the rod 98 on that instrument to give that instrument, in effect, an on-off operation so that the air pressure will go completely to one of its limits substantially instantaneously. The pressure in the chamber 107 will then be rapidly changed from one of its limits to the other so that the valves 14 and 16 will be rapidly operated to their opposite positions in order that they may control the flow of air through the new stove in a manner above described. Thereafter the operation will be such that the valve 16 gradually closes as the valve 14 is gradually opened.

From the above description it will be seen that I have provided instruments for and a system maintaining constant the temperature of the hot blast for a blast furnace in such a fashion that the valves will be either sequentially or simultaneously operated to maintain the temperature of the hot blast at some desired value. It will also be seen that I have provided a temperature responsive instrument which will act to move rapidly the valves from one extreme position to the other when a change in stoves takes place. The ability of the instruments of my invention to rapidly reverse the position of the valves 14 and 16 when a new stove is placed on the line is of the utmost importance, since it will quickly bring the temperature of the hot blast back to the desired point with a minimum upset when a new stove is placed on the line.

While in accordance with the provisions of the statutes, I have illustrated and described the best form of my invention now known to me, it will be apparent to those skilled in the art that changes may be made in the form of the apparatus disclosed without departing from the spirit of my invention as set forth in the appended claims, and that in some cases certain features of my invention may sometimes be used to advantage without a corresponding use of other features.

Having now described my invention, what I claim as new and desire to secure by Letters Patent is:

1. In a hot blast control system having means including a plurality of paths to supply air to a blast furnace, one of said paths being provided with means to heat the air, the combination of a plurality of control devices each operative to vary the air going through one of said paths, means to measure the temperature of the air after it has passed through said paths, an air control mechanism responsive to the temperature of said air as measured by said measuring means operative to set up an air pressure proportional to said temperature, an air control instrument operative to set up a plurality of air pressures each varying throughout a given range, means responsive to each one of said last mentioned air pressures and operative to adjust one of said control devices, and means responsive to the air pressure set up by said air control mechanism to adjust said air control instrument.

2. In a blast furnace control system having means including a plurality of paths through which air may be supplied to a blast furnace, one of said paths having in it means to heat the air passing therethrough, the combination of a control device in each path operative to vary the amount of air passing through that path, means to measure the temperature of the air after it has passed through said paths, a control mecha-

nism responsive to said measuring means and operative to set up an air pressure proportional to the value of the temperature of the air, an air control instrument operative to set up a plurality of air pressures each of which may vary throughout a given range of said instrument, means to vary individually the point in the range of said instrument where each of the pressures produced thereby will be at a maximum and a minimum, means responsive to each of the air pressures produced by said air control instrument to adjust said control devices individually, and means to apply the air pressure produced by said air control mechanism to operate said air control instrument.

3. In a hot blast control system having means including a plurality of paths through which air is supplied to a blast furnace, one of said paths having means in it to heat the air passing therethrough, the combination of a control device in each path operative to vary the amount of air passing through that path, means to measure the temperature of the air after it has passed through said paths, a control mechanism responsive to said measuring means and operative to set up an air pressure varying in accordance with said temperature throughout a portion of a range, means in said mechanism operative upon the deviation of said temperature a given amount from a predetermined value to run said air pressure to one of its limits, an air control instrument operative to set up a plurality of air pressures, means to operate each of said control devices from one of said last mentioned air pressures, and means to transmit the air pressure set up by said air control mechanism to said air control instrument to operate the latter.

4. In a hot blast control system having means including a plurality of paths through which air is supplied to a blast furnace, one of said paths having means in it to heat the air passing therethrough, the combination of a control device in each path operative to vary the amount of air passing through that path, means to measure the temperature of the air after it has passed through said paths, a control mechanism responsive to said measuring means and operative to set up an air pressure varying throughout a given range as said temperature varies, means in said mechanism to run said air pressure to the end of its range immediately upon the deviation of said temperature beyond a given amount from a predetermined control point, an air control instrument operative to set up a plurality of air pressures each of which may vary through a given range, regulating means operated individually by the air pressures set up by said control instrument to adjust said control devices, means in said instrument to vary the point in the range thereof at which the air pressures set up thereby may be a maximum and a minimum whereby the points at which each of said control devices is operated may be varied, and means to operate said control instrument by the air pressure produced by said control mechanism.

5. In a hot blast control system having means to supply a given amount of air to a blast furnace including a plurality of paths through which the air passes, one of said paths having in it a means to heat the air passing therethrough, the combination of control devices in said paths operable to vary the proportion of the total air passing through each path, mechanism to measure the temperature of the air and set up an air pressure proportional thereto, pressure responsive means to operate said control devices, an air control instrument provided with a plurality of pressure regulating units each operative to supply an air pressure through a given range to said pressure responsive means, means to apply the air pressure produced by said mechanism to said air control instrument to operate the same, and means to adjust individually each of said units so that they will vary the air pressure produced thereby for given values of air pressure produced by said mechanism.

ANKER E. KROGH.