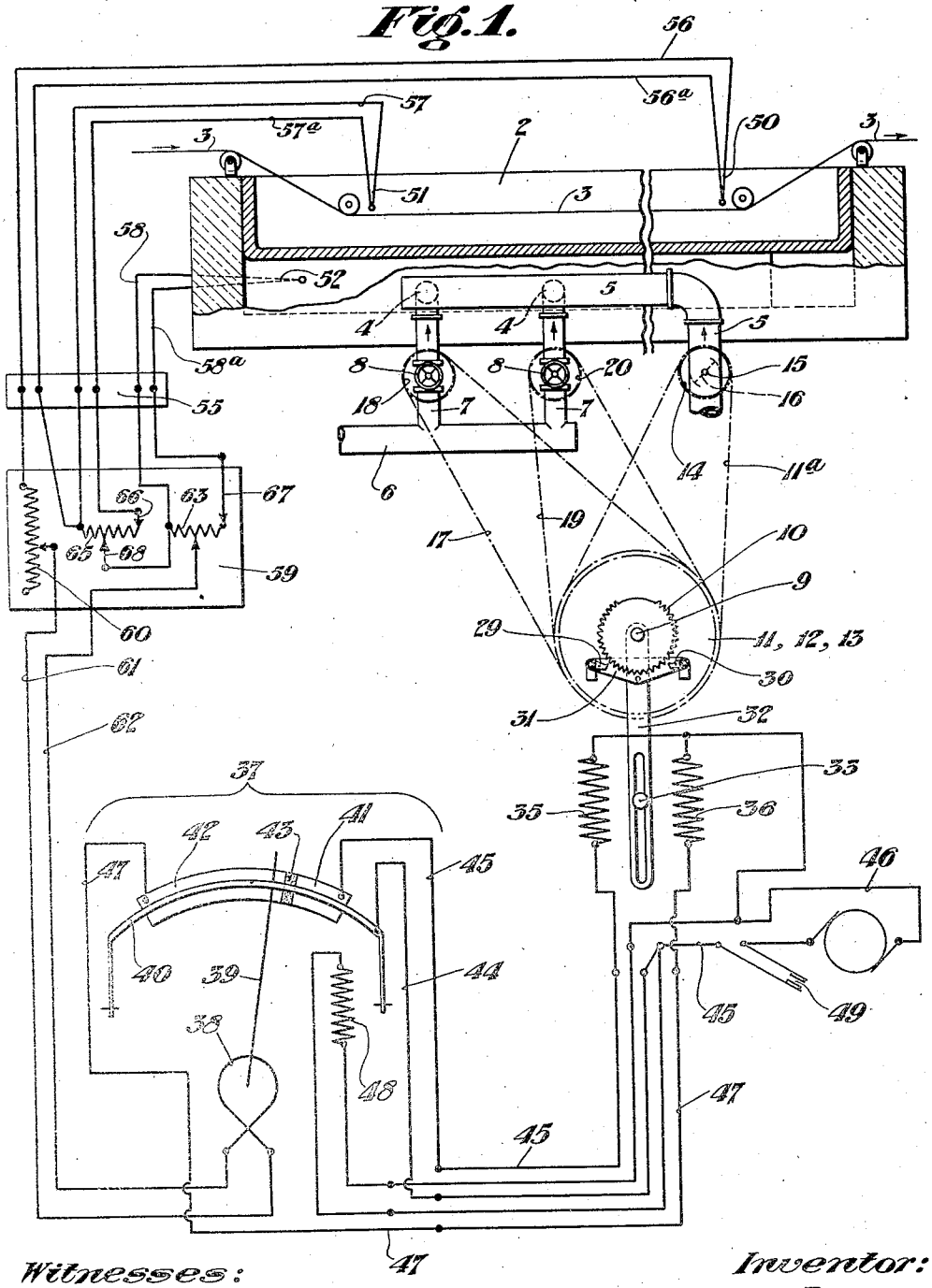
April 3, 1928. 1,664,965

A. BONDS

APPARATUS FOR TEMPERATURE CONTROL

Filed May 19. 1926 2 Sheets-Sheet 1

Fig. 1.



Witnesses:
Edwin Trueb

Inventor:
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April 3, 1928. 1,664,965

A. BONDS

APPARATUS FOR TEMPERATURE CONTROL

Filed May 19. 1926 2 Sheets-Sheet 2

Fig. 2.

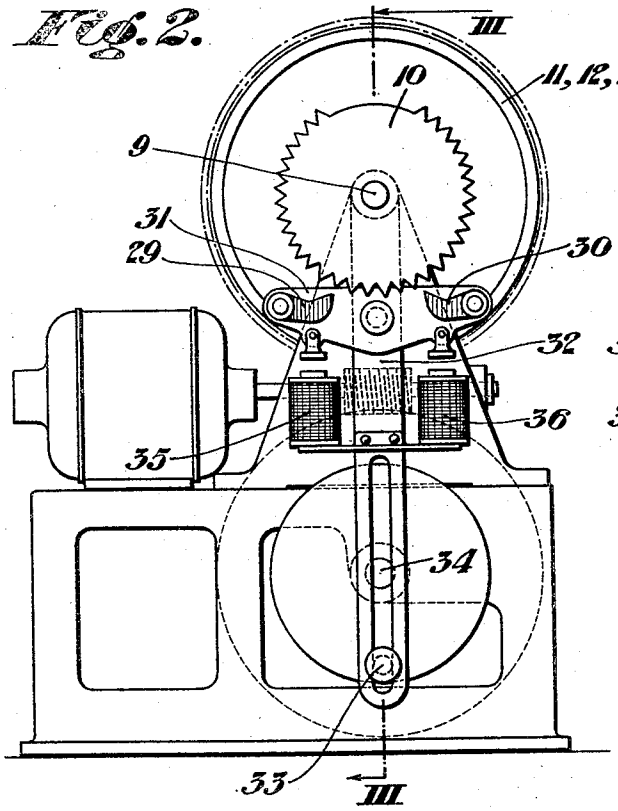


Fig. 3.

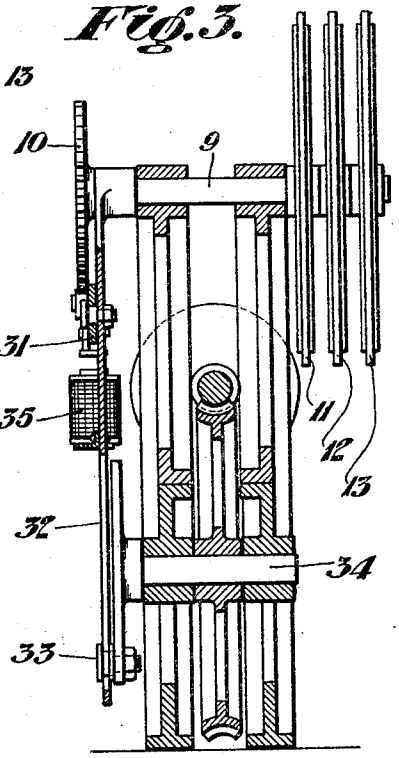
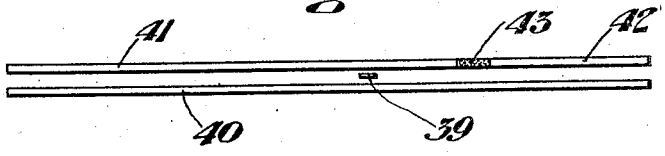


Fig. 4.



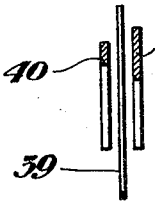


Fig. 5.

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Patented Apr. 3, 1928.

1,664,965

UNITED STATES PATENT OFFICE.

ALBERT BONDS, OF CLEVELAND, OHIO.

APPARATUS FOR TEMPERATURE CONTROL.

Application filed May 19, 1926. Serial No. 110,303.

This invention relates to apparatus for maintaining a constant temperature at a predetermined point in a heated receptacle containing gaseous or liquid matter, molten metal and the like, and has for its object the provision of a sensitive control of the temperature, and the elimination of what is commonly called "lag" from the temperature control.

The invention will be described in detail as applied to a spelter bath for galvanizing wire, although it will be understood that its use is in nowise limited to controlling the temperature of a spelter bath since it may be used to control the temperature of many other objects.

In the drawings:

Figure 1 is a diagrammatic plan of a temperature control apparatus applied to a galvanizing pan, for carrying out the novel method of this application.

Figure 2 is a side elevation of the burner regulating mechanism.

Figure 3 is a sectional elevation on the line III—III of Figure 2.

Figure 4 is a top plan of the contact and depressor elements of the relay instrument.

Figure 5 is a transverse section through the elements of Figure 4.

Referring more particularly to the drawings, the numeral 2 designates a spelter-pan containing the molten spelter through which wires 3 are continually passed to be coated. The spelter-pan 2 is adapted to be heated by gas or oil burners 4 adjacent the entrance end of the pan. The burners 4 may be of any usual design and receive air from an air main 5 and fuel from a fuel supply pipe 6 having branches 7 leading to the separate burners. The branch pipes 7 are each provided with valves 8 to control the feed of fuel to the respective burners.

A burner control or regulating apparatus is provided for regulating the fuel and air supply to the burners. This apparatus is of standard commercial design obtainable on the open market and, therefore, will only be diagrammatically illustrated and generally described. The burner regulating apparatus comprises a main drive-shaft 9 having a drive ratchet-wheel 10 secured thereon at one end and having sprocket-wheels 11, 12 and 13 secured thereon. No teeth are formed on a portion of the periphery of the ratchet-wheel 10, so as to limit its movement; that is, so that when this portion of the ratchet-wheel is opposite the operating pawls, to be described, the pawls will not effect a movement of the wheel, thereby providing a limit to the burner operation.

The sprocket-wheel 11 is connected by a chain 11^a to a sprocket-wheel 14 on a damper-shaft 15 of a damper or valve 16 in the air main 5, so that rotation of the shaft 9 will operate the damper or valve 16.

The sprocket-wheel 12 is connected by a chain 17 to a sprocket-wheel 18 on the shaft of one of the valves 8, while the sprocket-wheel 13 is connected by a sprocket-chain 19 to a sprocket-wheel 20 on the other valve 8, so that rotation of the shaft 9 will also operate the fuel valves 8.

The ratchet-wheel 10 is adapted to be operated by pawls 29 and 30 carried by a pawl-yoke 31 which is pivotally mounted on a rocking-lever 32 adapted to be continually rocked by an eccentric 33 carried by a constantly driven shaft 34. A pair of solenoids 35 and 36 are mounted on the lever 32 below the yoke 31, and are adapted to be energized to rock the yoke 31 so as to engage either of the pawls 29 or 30 which, due to the continuous rocking movement of the lever 32, will cause a step by step rotation of the ratchet 10 and shaft 9 as long as the solenoid remains energized.

The solenoids 35 and 36 are adapted to be energized by an electric circuit which is controlled by a galvanometer type of relay instrument 37. The instrument 37 is of standard design and has a coil 38 energizable by

a temperature controlled electric current, and adapted to deflect an indicator-needle 39 to one side or the other of a neutral point in response to the rise and fall of the temperature in the spelter-pot 2.

The needle 39 is adapted to move in a space between a depressor-bar 40 and a pair of contact plates 41 and 42 which are separated by an insulated gap 43.

The depressor-bar 40 is connected to one line 44 of the solenoid energizing circuit, while the contact plate 41 is connected by a wire 45 to the one end of the solenoid coil 35, and the other end of the coil 35 is connected to the other line 46 of the solenoid energizing circuit. The contact plate 42 is connected by a wire 47 to the one end of the solenoid coil 36, and the other end of the coil 36 is connected to the line 46 of the solenoid energizing circuit.

A solenoid coil 48 is connected to the lines 44 and 46 and is adapted to be energized to depress the depressor-bar 40.

The ratchet-wheel 10 is adapted to be operated by pawls 29 and 30 carried by a pawl-yoke 31 which is pivotally mounted on a rocking-lever 32 adapted to be continually rocked by an eccentric 33 carried by a constantly driven shaft 34. A pair of solenoids 35 and 36 are mounted on the lever 32 below the yoke 31, and are adapted to be energized to rock the yoke 31 so as to engage either of the pawls 29 or 30 which, due to the continuous rocking movement of the lever 32, will cause a step by step rotation of the ratchet 10 and shaft 9 as long as the solenoid remains energized, or until the smooth portion of the ratchet-wheel 10 is reached.

The solenoids 35 and 36 are adapted to be energized by an electric circuit which is controlled by a galvanometer type of relay instrument 37. The instrument 37 is of standard design and has a coil 38 energizable by a temperature controlled electric current, and adapted to deflect an indicator-needle 39 to one side or the other of a neutral point in response to the rise and fall of the temperature in the spelter-pot 2.

The needle 39 is adapted to move in a space between a depressor-bar 40 and a pair of contact plates 41 and 42 which are separated by an insulated gap 43.

The depressor-bar 40 is connected to one line 44 of the solenoid energizing circuit, while the contact plate 41 is connected by a wire 45 to the one end of the solenoid coil 35, and the other end of the coil 35 is connected to the other line 46 of the solenoid energizing circuit. The contact plate 42 is connected by a wire 47 to the one end of the solenoid coil 36, and the other end of the coil 36 is connected to the line 46 of the solenoid energizing circuit.

A solenoid coil 48 is connected to the lines 44 and 46 and is adapted to be energized to depress the depressor-bar 40. The circuit through the lines 44 and 46 is adapted to be regularly made and broken by a timed make and break device represented by the contactor 49, so that the depressor-bar 40 will be regularly depressed.

The operation of the mechanism above described is as follows—

Assuming that the needle 39 is in neutral position the depressor-bar 40 will be regularly depressed by the energization of the coil 48, without energizing or affecting the solenoids 35 or 36. However, should the coil 38 be energized to move or deflect the needle to the left so as to be positioned between the depressor-bar 40 and the plate 42, when the depressor-bar is depressed, a circuit will be completed from the line 44 through the depressor-bar 40, needle 39, plate 42, wire 47, solenoil coil 36 and line 46, thus energizing solenoid coil 36 and rocking the yoke 31 so as to engage the pawl 29 with the ratchet-wheel 10. The above circuit will continue to be made as the depressor-bar is depressed until the needle 39 is moved to the right by a change in the energization of the coil 38 so as to move the needle 39 either to its neutral position or to the right between the plate 41 and depressor-bar 40.

When the pawl 29 is engaged in the ratchet-wheel 10, the rocking of the lever 32 will cause operation of the burner regulating apparatus.

Now assuming that the coil 38 be reversely energized, or its value of energization be changed. so that the needle 39 is moved to the right and between the plate 41 and depressor-bar 40, when the depressor-bar 40 is depressed a circuit will be completed from the line 44 through the depressor-bar 40, needle 39, plate 41, wire 45, solenoid coil 35 and line 46, thus energizing solenoid coil 35 and rocking yoke 31 so as to engage the pawl 30 with the ratchet-wheel 10. This last described circuit will continue to be made as the depressor-bar is depressed until the needle 39 is moved to the left by a change in the energization of the coil 38 so as to move the needle 39 either to its neutral position or to the left of its neutral position between the plate 42 and depressor-bar 40.

When the pawl 30 is engaged in the ratchet-wheel 10, the rocking of the lever 32 will cause an operation of the burner regulating apparatus in a reverse manner to that when the pawl 29 is engaged.

From the above, it will be understood that by controlling the operation of the needle 39, or in other words, the energization of the coil 38, the desired operation of the burn-

ers and consequent desired temperature may be had, and it is to this that my novel invention pertains.

The mechanism above described is all standard mechanism in common use and well known to those versed in the art to which this invention pertains and, therefore, will not be further illustrated or described.

The coil 38 of the galvanometer-type relay 37 is adapted to be energized by current produced by a combination of thermo-couples 50, 51 and 52. Therefore, the position of the needle 39 varies according to the current produced by these thermo-couples.

The thermo-couple 50 is positioned at the exit end of the pot 2 at which point a constant temperature is desired to be maintained, this thermo-couple has a major effect on the coil 38. The thermo-couples 51 and 52 are located near the entrance end of the pot 2 close to the burners 4, one in the heated medium, and the other in the furnace or flue, respectively, and both of these thermo-couples have minor effects on the coil 38.

The thermo-couple 50 has the prime effect on the coil 38 to cause the needle 39 to move in accordance with temperature changes at the point where the thermo-couple 50 is located toward or away from the gap 43. However, the thermo-couple 50 is always assisted by the other thermo-couples 51 and 52. The thermo-couple 51 intercepts the temperature changes due to the changes in the heat requirements, as for example, change in the size or speed of travel of the wires. The thermo-couple 52 quickly responds to changes in flue temperatures due primarily to changes in rate of heat evolution or heat supplied, and tends always to energize the coil 38 so as to quickly move the needle 39 towards or away from the gap 43, depending on whether the burners have been turned on or off, resulting in raising or lowering the flue temperature. The thermo-couple 52 is most sensitive so far as time is concerned, but has a small total effect.

As the load or heat requirement varies very little, the thermo-couple 51 has little to do with the control or regulation. However, it is essential to effect a proper regulation of the pointer in response to changes in size or speed of the wires, or the addition of cold spelter.

Mathematically the control can be illustrated as follows—

Let: Ld=effect of the thermo-couple 51.
Fd=effect of the thermo-couple 52.
Cd=effect of the thermo-couple 50.

Assume Cd=constant.
$Ld+Fd$=constant.

Then $Cd+Ld+Fd$=constant (or setting of the gap 43).

Now assume that Cd remains constant but Ld decreases, then Fd must increase.

The above corresponds to the case of increasing speed or size of wires. The condition lowers the temperature of the thermo-couple 51 at the entrance end of the bath which will cause the needle to move into position to make the necessary circuit to cause more fuel to be turned on. The increased fuel causes an immediate rise of temperature in the flue and increases the energization from the thermo-couple 52 so that the drop of the thermo-couple 51 is compensated for. The control is effected and no material change is noted at the control point or thermo-couple 50.

The thermo-couples 50, 51 and 52 are connected by leads 56 and 56^a, 57 and 57^a, 58 and 58^a from the opposite sides of the respective thermo-couples through a junction or cold-end box 55 to a potentiometer unit 59.

The wire 56 from one side of the thermo-couple 50 is connected to a rheostat or resistance coil 60 and a wire 61 leads from the coil 60 to the one end of the coil 38 of the relay 37. The other end of the coil 38 is connected by a wire 62 to a movable contact adapted to engage with a potentiometer resistance coil 63. The wire 56^a from the other side of the thermo-couple 50 is connected to one end of a potentiometer resistance coil 65.

The wire 57 leading from one side of the thermo-couple 51 is connected to the same end of coil 65 as the wire 56^a, while the wire 57^a from the opposite side of the thermo-couple 51 is connected to a movable contact 66 adapted to have a movable contact with the coil 65.

The wire 58 from one side of the thermo-couple 52 is connected to the one end of the coil 63, while the other wire 58^a from the opposite side is connected to a movable contact 67 adapted to have a movable contact with the coil 63.

A movable or adjustable contact 68 is connected to the end of the coil 63 to which the wire 58 is connected and is adapted to have movable or adjustable contact with the coil 65.

The potentiometer unit 59 provides for the interconnecting of the currents from the thermo-couples 50, 51 and 52, so as to obtain desired proportionate amounts of said currents and accumulating said proportionate amounts of said currents into a single current to operate the relay 37.

By omitting or neglecting the resistances of lead wires and other necessary connectors, for the sake of simplicity, in order to determine the proper design or value of potential reducers or potentiometers the fol-

lowing algebraic equations and their solutions are necessary—

Let C=thermo-couple 50.
L=thermo-couple 51.
F=thermo-couple 52.
Cr=resistance of coil 38.
Lr=total resistance of potentiometer coil 65.
Fr=total resistance of potentiometer coil 63.
Lp=resistance parallel to Cr in the circuit of thermo-couple 51.
Fp=resistance parallel to Cr in the circuit of thermo-couple 52.
Z=resistance coil 60 for offsetting effects of thermo-couples 51 and 52.
Ct=temperature desired to control—cold end deducted.
Lt=approximate load temperature—cold end deducted.
Ft=approximate flue temperature—cold end deducted.
Cd=deflection in degrees F. caused by thermo-couple 50.
Ld=deflection in degrees F. caused by thermo-couple 51.
Fd=deflection in degrees F. caused by thermo-couple 52.
Ls=resistance of sections of potentiometer coil 65 in parallel.
Fs=resistance of sections of potentiometer coil 63 in parallel.
Ce=cold end temperature of thermo-couple 50.

All resistance is expressed in ohms.

All temperatures are expressed in degrees Fahrenheit.

Using the above symbols the equations are as follows—

$$\frac{Lp(Cr+Z+Fs)}{Lp+Cr+Z+Fs}$$

$$Ld=\frac{Cr}{Cr+Z+Fs}\times\frac{Lp(Cr+Z+Fs)+(Lr-Lp)(Lp+Cr+Z+Fs)}{Lp+Cr+Z+Fs}\times Lt$$

$$=\frac{CrLp}{Lp(Cr+Z+Fs)+(Lr-Lp)(Lp+Cr+Z+Fs)}\times Lt \text{ (clearing)}$$

$$=\frac{CrLp}{LrLp+LrCr+LrZ+LrFs-L^2p}\times Lt \text{ (clearing)}$$

$$=\frac{CrLp}{Lr\left(Lp+Cr+Z+\frac{Fp(Fr-Fp)}{Fr}\right)-L^2p}\times Lt\left(\text{substituting } Fs=\frac{Fp(Fr-Fp)}{Fr}\right)$$

$$Ld=\frac{CrLpFr}{Lr[Fr(Lp+Cr+Z)+Fp(Fr-Fp)]-FrL^2p}\times Lt \text{ (clearing)}$$

$$Fd=\frac{CrFpLr}{Fr[Lr(Fp+Cr+Z)+Lp(Lr-Lp)]-LrF^2p}\times Ft \text{ (clearing)}$$

$$Cd=\frac{Cr}{Cr+Z+Fs+Ls}\times Ct$$

$$Cd=\frac{CrFrLr}{FrLr(Cr+Z)+FpLr(Fr-Fp)+LpFr(Lr-Lp)}\times Ct \text{ (substituting for } Fs \text{ and } Ls \text{ as shown above and clearing)}$$

Total deflection=$Ld+Fd+Cd$.

Relay instrument setting or setting of insulated gap in relay=$Ld+Fd+Cd+Ce$.

As an example with approximate values as follows substituted in the formulæ an idea of relative effects can be obtained—

Cr=180, Z=30, Fp=11, Fr=91, Lp=12, Lr=88, Ct=800, Ft=1225, Lt=825, Ce=100.

Ld= 80 degrees Fahrenheit.
Fd=120 degrees Fahrenheit.
Cd=625 degrees Fahrenheit.
Ce=100 degrees Fahrenheit.

Total=925=insulated gap setting of relay 37 for obtaining temperature of 900 at "C," ($Ct+Ce$=900).

The preceding values are approximately what have been employed in controlling the temperature of a thirty-four foot spelter bath containing approximately sixty tons of molten spelter and used in the commercial production of galvanized wire.

By adjusting the various potentiometer coils, that is by adjusting the movable contacts along the coils so as to change their resistance values in the several thermo-couple circuits, and by adjusting the insulated gap 43 in the relay instrument 37 almost any desired temperature may be controlled, and by shifting the position of the gap 43 alone, the desired temperature setting may be obtained in changing from one operating

temperature to another as it is only necessary to shift gap 43 in accordance with the desired change of temperature.

While I have described my invention as applied to the regulation of the temperature of a bath of molten spelter in a spelter pan, it will be understood that its use is in nowise limited thereto, but it may be used to regulate the temperature of many other forms of furnaces, fluid bodies and the like, wherever a constant temperature is desired.

It will be understood also, that while I have shown and described one specific embodiment of my invention, that I do not wish to be limited thereto since various modifications may be made without departing from the scope of my invention as defined in the appended claims.

I claim:

1. A temperature control mechanism comprising the combination with a source of heat, of a plurality of temperature responsive elements, one of said elements being located at the point to be regulated, and other of said elements being located at spaced points relatively closer to said source of heat than said first named element, said elements being adapted to supply varying independent electric currents in accordance with temperature changes, and means for interconnecting said currents so as to obtain a desired proportionate amount of each of said currents, and for accumulating said proportionate amounts of current into a single current, and means operable by said single current for varying the heat supplied.

2. A temperature control mechanism comprising the combination with a source of heat, of a plurality of temperature responsive elements, one of said elements being located at the point to be regulated, and other of said elements being located at spaced points from said first named element and adjacent the source of heat supplied and required respectively, said elements being adapted to supply varying independent electric currents in accordance with temperature changes, and means for interconnecting said currents so as to obtain a desired proportionate amount of each of said currents, and for accumulating said proportionate amounts of current into a single current, and means operable by said single current for varying the heat supplied.

3. A temperature control mechanism comprising the combination with a source of heat, of a plurality of temperature responsive elements, one of said elements being located at the point to be regulated, a second element spaced from said first element and adjacent the source of heat supplied, and a third element spaced from said first element and adjacent the point at which heat is required, said elements being adapted to supply varying independent electric currents in accordance with temperature changes, and means for interconnecting said currents so as to obtain a desired proportionate amount of each of said currents, and for accumulating said proportionate amounts of current into a single current, and means operable by said single current for varying the heat supplied.

4. An electrical temperature control apparatus comprising the combination with a receptacle for containing material to be heated, and a source of heat for heating said material, of a temperature responsive element located in the material to be heated at approximately the point at which the temperature of the material is to be controlled, a second temperature responsive element located in the material closely relative to the source of heat, and a third heat responsive element located in the path of the heat from said source of heat so as to respond to the varying quantities of heat evolved from said source of heat, said temperature responsive elements being adapted to supply varying independent electric currents in accordance with temperature changes, and means for interconnecting said currents so as to obtain a desired proportionate amount of each of said currents, and for accumulating said proportionate amounts of current into a single current, and means including a single galvanometer operable by said single current for varying the heat supplied.

5. An electrical temperature control apparatus comprising the combination with a receptacle for containing material to be heated, and a source of heat for heating said material, of a thermo-couple located in the material to be heated at approximately the point at which the temperature of the material is to be controlled, a second thermocouple located in the material to be heated closely relative to the source of heat, and a third thermo-couple located in the path of the heat from said source of heat so as to respond to the varying quantities of heat evolved from said source of heat, said thermo-couples being adapted to supply varying independent electric currents in accordance with temperature changes, and means for interconnecting said currents so as to obtain a desired proportionate amount of each of said currents, and for accumulating said proportionate amounts of current into a single current, and means including a single galvanometer operable by said single current for varying the heat supplied.

6. An electrical temperature control apparatus comprising the combination with a receptacle for containing material to be heated, and a source of heat for heating said material, of a thermo-couple located in the material to be heated at approximately the point at which the temperature of the material is

to be controlled, a second thermo-couple located in the material to be heated closely relative to the source of heat, and a third thermo-couple located in the path of the heat from said source of heat so as to respond to the varying quantities of heat evolved from said source of heat, said thermo-couples being adapted to supply electric currents varying in quantity in proportion to the varying temperatures affecting the thermo-couples, a potentiometer unit having means for interconnecting and accumulating said currents from said thermo-couples, said means being adjustable to obtain various proportionate amounts of at least some of said currents, and means operable by the accumulated current for varying the source of heat.

7. In a temperature control apparatus including a plurality of sources of electric current and means for varying the electric currents in proportion to temperature changes, of a potentiometer unit having means for interconnecting and accumulating said currents, said means being adjustable to accumulate various proportionate amounts of at least some of said currents.

8. In a temperature control apparatus including a plurality of thermo-couples affected by the temperatures to be controlled so as to provide electric currents varying in proportion to the temperature changes, of a potentiometer unit having means for interconnecting and accumulating said currents, said means being adjustable to accumulate various proportionate amounts of at least some of said currents.

9. In a temperature control apparatus including a plurality of thermo-couples affected by the temperatures to be controlled so as to provide electric currents varying in proportion to the temperature changes, of a potentiometer unit having means for interconnecting and accumulating said currents, said means being adjustable to accumulate various proportionate amounts of at least some of said currents, electrically controlled means for varying the source of heat, and magnetically operative means energizable by said accumulated current from said potentiometer for controlling the electric current to said electrically controlled means.

10. The combination with a source of heat, of a temperature control system comprising a movable control, a plurality of thermo-couples cooperating to determine the position of said control, one of said thermo-couples being located at a point at which a predetermined constant temperature is desired and representing a constant, and the other of said thermo-couples being more closely adjacent the source of heat and in the path of the heat required and supplied respectively, the sum of the effect of said last named thermo-couples representing a constant, and means operated by said control to regulate said source of heat to oppositely influence said last mentioned thermo-couples.

11. In a temperature control system, a galvanometer, a plurality of thermo-couple circuits cooperating to determine the position of said galvanometer, one of said thermo-couple circuits representing a constant, and the sum of the other circuits representing a constant, and a fuel control operated by said galvanometer to oppositely influence said last mentioned circuits.

In testimony whereof, I have hereunto signed my name.

ALBERT BONDS.