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Crawford

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[54] **STRIP ANNEALING LINE TEMPERATURE CONTROL SYSTEM**

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[52] **U.S. Cl.** **432/45,** 236/1, 226/24

[51] **Int. Cl.**.....**F27b 9/28**

[58] **Field of Search**.....263/3; 266/3 R

[56] **References Cited**

UNITED STATES PATENTS

3,355,156	11/1967	Hanna	263/3
3,496,033	2/1970	Gilbreath	148/13 R

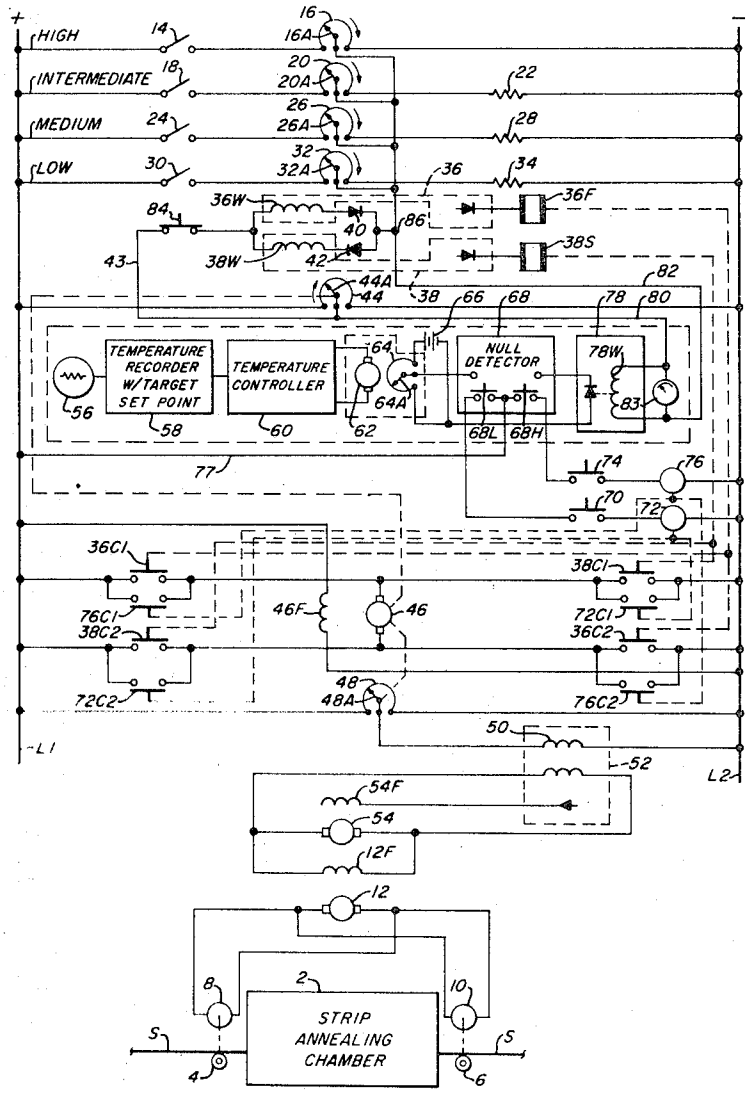
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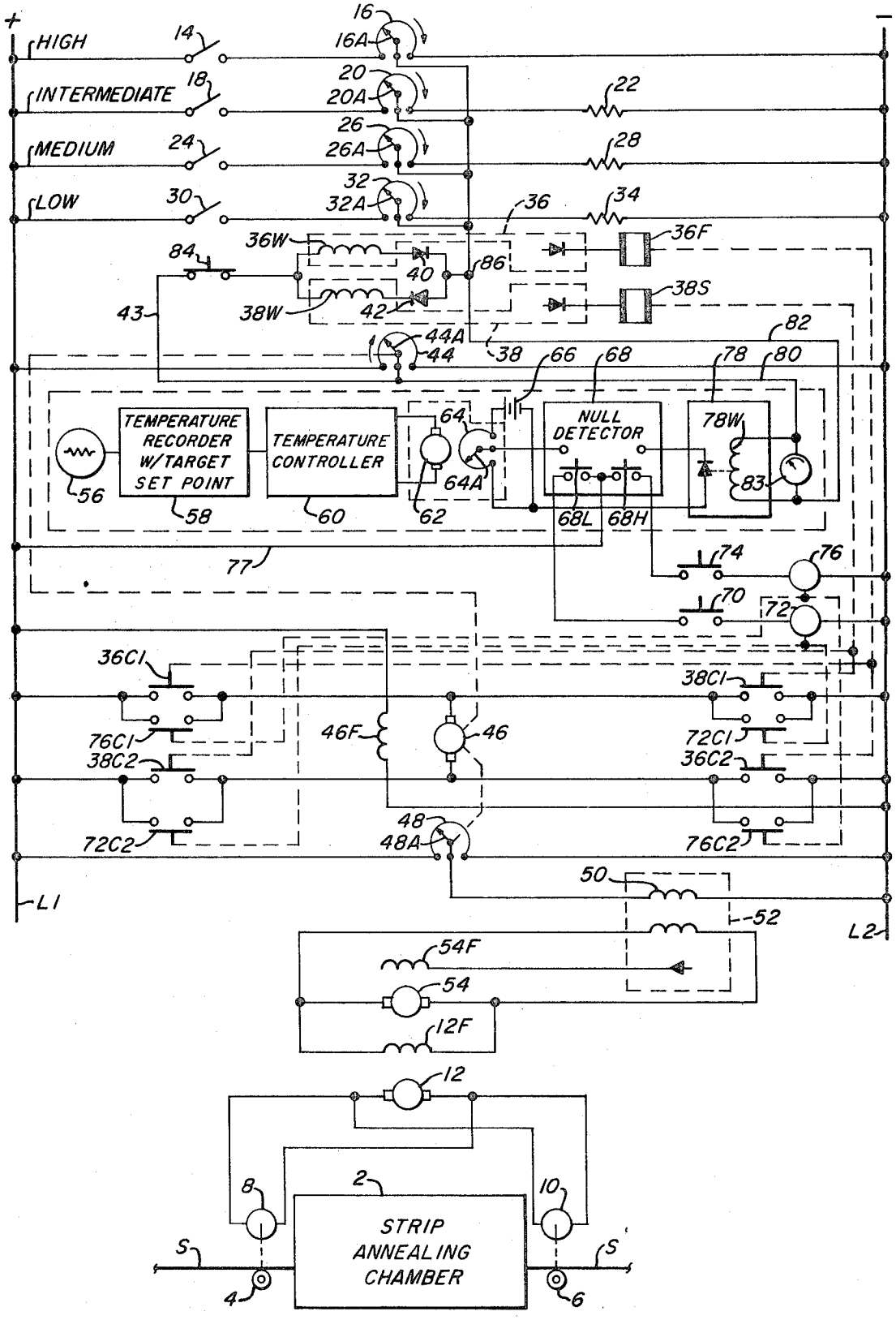
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[57] **ABSTRACT**

A continuous strip annealing line has potentiometers which determine the speed of the line, a pilot motor operating a first rheostat whose setting causes changes in line speed, a second rheostat operated by the pilot motor, and control means between the potentiometers and second rheostat operable when their voltages are unequal to cause rotation of the pilot motor in such direction to bring the voltages into balance. A temperature regulation control system includes a strip temperature sensor, a null detector connected to the output of the temperature sensor, and a magnetic amplifier having its output connected to the null detector and its input connected across the potentiometer and second rheostat. The null detector has two normally open contacts one closing when the strip temperature is too high so as to speed up the line by operating the pilot motor and the other closing when the strip temperature is too low to slow down the line. The contacts open when the two inputs to the null detector are in balance. Switches operable by the operator permit conventional operation or operation of the temperature regulation control and in conjunction with the potentiometers permit change from temperature regulation to conventional operation without changing line speed.

6 Claims, 1 Drawing Figure




+
HIGH
INTERMEDIATE
MEDIUM
LOW
14
16
16A
18
20
20A
22
24
26
26A
28
30
32
32A
34
36
36W
36F
84
40
86
38S
43
38W
42
44A
44
38
82
66
68
78
80
TEMPERATURE RECORDER W/TARGET SET POINT
TEMPERATURE CONTROLLER
64
64A
NULL DETECTOR
78W
83
56
58
60
62
68L
68H
77
74
76
70
72
36C1
38C1
76C1
38C2
72C1
36C2
46F
46
72C2
48
48A
76C2
50
52
L1
L2
54F
54
12F
12
8
2
10
STRIP ANNEALING CHAMBER
S
S
4
6

STRIP ANNEALING LINE TEMPERATURE CONTROL SYSTEM

This invention relates to a control system for a strip heating line and more particularly to a continuous steel strip annealing line such as shown in Gilbreath U.S. Pat. No. 3,496,033 dated Feb. 17, 1970, or on Pages 926 and 927 of the Eighth Edition of "The Making, Shaping and Treating of Steel." The strip to be annealed varies in width and thickness and for various reasons it is necessary or desirable to vary the strip speed. It has been recognized that the best way to obtain uniform strip temperature is to vary line speed rather than varying the heat input to suit strip volume as determined by strip size and line speed. One way of doing this is shown and described in the Gilbreath patent. Other pertinent art of which I have knowledge are:

Inventor	Patent No.	Date
Cockrell	2,303,110	Nov. 24, 1942
Bock	2,813,186	Nov. 12, 1957
Munker	2,872,173	Feb. 3, 1959

However, the controls of these patents have various shortcomings. These include the difficulty of adapting to existing speed control systems, the inability to change to and from conventional operation, and complexity of the control system. It is apparent that if the control is complex and/or requires considerable modification of existing equipment the cost will be high. It is not uncommon for emergencies to occur in line operation which require rapid speed changes, particularly to lower speeds. This makes it necessary to return to manual conventional operation. For successful operation it is necessary to have the cooperation of the operator and this cannot be obtained if the control does not permit him to make changes rapidly, and/or is not substantially foolproof and/or does not permit him to operate in any manner he desires. It is also necessary to obtain a good and uniform product.

It is therefore an object of my invention to provide a strip temperature control system which is relatively inexpensive and adaptable to existing conventional equipment.

Another object is to provide such a system which permits ready change to and from manual operation without change of speed when switching to manual operation.

A further object is to provide such a system which results in increased yield of good product and the production of a more uniform product.

These and other objects will be more apparent after referring to the following specification and attached claims, in which:

The single FIGURE is a schematic view of the system of my invention connected to a strip annealing line.

Referrring more particularly to the drawings, reference numeral 2 indicates a conventional strip annealing line or chamber. The strip S passes over roll 4 into the annealing chamber 2 and exits from the annealing chamber over roll 6. The rolls 4 and 6 are driven by motors 8 and 10, respectively, the speed of which is controlled by a generator 12 having a shunt field 12F. It will be understood that the strip S will pass over and will be driven by other rolls in addition to rolls 4 and 6 in the conventional manner and that their motors also will be energized by power from generator 12.

The speed of the line is determined by the voltage output of armature 12 which is determined by the excitation of the shunt field 12F. This is controlled by a circuit receiving power from D.C. power lines L1, L2. Four basic speed ranges are provided, these being high, intermediate, medium, and low. The high speed circuit includes a switch 14 connected in series with a potentiometer 16 having a slide wire or arm 16A. The intermediate circuit includes a switch 18 connected in series with a potentiometer 20 and a resistor 22. The medium circuit includes a switch 24 connected in series with a potentiometer 26 and resistor 28. The low speed circuit includes a switch 30 connected in series with a potentiometer 32 and resistor 34. The resistance of resistor 28 is greater than that of resistor 22 and less than that of resistor 34. Arms 16A, 20A, 26A and 32A are connected in parallel with each other in series with control windings 36W and 38W of switch type magnetic amplifiers 36 and 38, respectively, which control flow of current to relay coils 36F and 38S, respectively. The windings 36W and 38W are connected in parallel, with a rectifier 40 being connected in series with coil 36W and a rectifier 42 in series with coil 38W. The coil 36F operates two normally open contacts 36C1 and 36C2. The coil 38S operates two normally open contacts 38C1 and 38C2. A lead 43 connects windings 36W and 38W to arm 44A of a motor operated rheostat 44. The position of arm 44A is controlled by a pilot motor 46 which also controls the position of arm 48A of rheostat 48. The rheostats 44 and 48 are connected between lines L1, L2. Reference winding 50 of magnetic amplifier 52 is connected to arm 48A from line L2. The output of amplifier 52 is connected to a shunt field 54F of master exciter 54 which controls the excitation of field 12F. The parts so far described are conventional.

According to my invention I provide a silicon cell pyrometer 56 or other strip temperature sensing means for measuring the temperature of strip S at a desired position in the strip processing line. The output of pyrometer 56 is connected to a null-balance servo-type recorder 58 having a target set point. The output of recorder 58 is connected to a temperature controller 60, the output of which is connected to motor 62 of motor-operated rheostat 64 having an arm or slide wire 64A. Power is supplied to rheostat 64 from a battery or other D.C. power source 66. The arm 64A is connected to a null detector 68 having output relay contacts 68L and 68H. Contact 68L is connected between lines L1, L2 in series with a switch 70 and relay coil 72 and contact 68H is connected between leads L1, L2 in series with a switch 74 and relay coil 76. In place of switches 70 and 74, a single switch may be positioned in lead 77 between lead L1 and the contacts 68L and 68H. Relay coil 72 has normally open contacts 72C1 and 72C2 connected in parallel with contacts 38C1 and 38C2, respectively. Relay coil 76 has normally open contacts 76C1 and 76C2 connected in parallel with contacts 36C1 and 36C2, respectively. Magnetic amplifier 78 which is connected to rheostat 64 and to null detector 68, is connected to arm 44A by lead 80 and to magnetic amplifier 36 by lead 82. The amplifier 78 includes a control winding 78W having a voltmeter 83 connected across its input. A normally closed switch 84 is connected in line 43. In an actual installation switches 70, 74 and 84 are relay contacts operable from a

remote position since this is more convenient. However, from an operational standpoint the switches act in the same manner as the relay contacts.

The parts of my control are standard commercially available equipment. A particular installation has an Ircon 1100 Series Automatic Optical Pyrometer, Leeds and Northrup Speedomax W Recorder, Series 80 Three-Action PAT Temperature Controller, a 10260 Low Torque Electric Drive Unit with a 2,000 OHM Slidewire, a Leeds and Northrup M-Line 20 Millivolt Null Detector, Model C-1, and a Magnetics, Inc. Shunt Magnetic Amplifier, Model HC 2Z2-E2887. The null detector accepts bi-polar low level DC input, producing dry contact closure output corresponding to the input polarity. The magnetic amplifier has capability of output bias at 50 percent with swing to 0 percent output on full negative polarity input and swing to 100 percent output on full positive polarity input.

When starting the line in operation switches **70** and **74** are open and switch **84** is closed so that the line will operate in the conventional manner as follows: Heat is supplied to the annealing chamber **2** in the usual manner to deliver the amount of heat necessary to anneal the strip S traveling at the desired speed.

The line operator then closes one of switches **14, 18, 24** or **30** to select the desired line speed range and adjusts the corresponding potentiometer **16, 20, 26** or **32** to obtain the desired speed within that range. Regardless of which switch is closed a voltage is obtained proportional to desired line speed at point **86**. This voltage is compared with the voltage established on rheostat **44**. If the line speed is too low control winding **36W** will conduct to energize coil **36F** closing its contacts **36C1** and **36C2** to cause motor **46** to rotate in a direction to move arm **44A** clockwise until the voltage difference across winding **36W** approaches zero. At the same time motor **46** moves arm **48A** counterclockwise increasing the voltage on winding **50** to increase the excitation on field **54F** which in turn increases the armature voltage of exciter **54**. This in turn increases the feedback level to magnetic amplifier **52** and increases the excitation of generator field **12F**. The resulting increased output of generator **12** raises the voltage on motors **4** and **6** to increase line speed. If the line speed is too high control winding **38W** will conduct to energize coil **38S** closing its contacts **38C1** and **38C2** to cause motor **46** to rotate in the opposite direction with a resultant decrease in line speed. At any time during this operation the operator can increase or decrease line speed in the same manner by opening the closed switch **14, 18, 24** and **30** and closing a different one of these switches and/or by changing the position of the arm **16A, 20A, 26A** or **32A** associated with the closed switch.

After the operator has established a reasonable balance of desired temperature (the set point on recorder **58**) and the actual strip temperature by manual adjustment of line speed and furnace temperature, he closes switches **70** and **74** and opens switch **84**. This prevents operation of amplifiers **36** and **38** and hence control of line speed in the manner described above and enables operation of the temperature regulation system in the following manner:

Assuming that pyrometer **56** senses a rising temperature, a signal is supplied to controller **60** from recorder **58** indicating that the strip temperature is above the set point. The controller **60** then causes motor **62** to rotate in a direction to move arm **64A** clockwise increasing the potential on arm **64A**. This creates a potential of positive to negative across the null detector **68** closing its output relay contact **68H**. Closing of contact **68H** energizes relay coil **76** closing its contacts **76C1** and **76C2** to cause motor **46** to move arms **44A** and **48A** in the manner described above for conventional operation to increase line speed and to create a difference in potential between point **86** and arm **44A**. This difference of potential signal is fed to control winding **78W** of magnetic amplifier **78** which converts the signal to a uni-polar signal within the voltage range of rheostat **64**. This output signal is supplied to null detector **68** in opposition to the signal from rheostat **64** and when the two signals are balanced contact **68H** opens to end change in line speed due to temperature correction. This feedback of the speed reference signal to the temperature control system provides system balance during the unstable period of temperature return to set point after line speed correction. If the pyrometer **56** senses a falling temperature the speed is corrected in a similar but opposite manner with contact **68L** being closed instead of contact **68H**.

The voltage on voltmeter **83** indicates the net change in line speed during automatic temperature control. In the particular line mentioned above which has a top-rated speed of 1,650 feet per minute, this net voltage speed is ± 30 volts corresponding to ± 180 feet per minute change in speed from that at which automatic temperature control began. The meter **83** is graduated in feet per minute to enable the operator to observe the speed change.

If the temperature control system approaches a limit, either by motor-operated rheostat **64** reaching extreme travel clockwise or counter-clockwise and/or by the line speed reaching 180 feet per minute above or below original speed, mid-ranging of the control system is obtained by moving rheostat **64** to mid-position by manual pushbutton control (not shown) and by moving the arm of potentiometer **16, 20, 26** or **32**, corresponding to the selected speed range, to bring the indication of meter **83** to zero.

When it is desired to discontinue automatic temperature control for any reason and return to conventional operation this is done without change in line speed. The operator first adjusts the potentiometer **16, 20, 26** or **32** of the selected speed range until the meter **83** reads zero so that the voltage on the selected speed selection potentiometer is equal to that on rheostat **44**. Switches **70** and **74** are then opened and switch **84** closed. Since there is no voltage across windings **36W** or **38W** no speed change occurs.

While one embodiment of my invention has been shown and described, it will be apparent that other adaptations and modifications may be made without departing from the scope of the following claims.

I claim:

1. In a continuous strip line including motor driven rolls for conveying the strip, a generator for supplying power to said motors to control the speed of the line, a reversible pilot motor, a first set of contacts for supplying power to said reversible motor to rotate it one direction, a second set of contacts for supplying power

to said reversible motor to rotate it in the opposite direction, a first rheostat having an arm connected to be moved by said pilot motor, means operable by the voltage from said first rheostat to vary the output of said generator, a second rheostat having an arm connected to be moved by said pilot motor, a speed selection potentiometer having an arm, a first circuit between said potentiometer arm and the arm of said second rheostat, and control means in said first circuit between said potentiometer arm and the arm of said second rheostat for selectively closing said first and second sets of contacts when the voltage from said potentiometer arm is different than the voltage from the arm of said second rheostat; the improvement comprising contact breaking means in said first circuit between said control means and the arm of said second rheostat, a null detector having two normally open contacts, temperature sensing means for determining the temperature of said strip, second control means connected to said temperature sensing means and said null detector to close the first of said normally open contacts when the sensed temperature is above a preset temperature and to close the second of said normally open contacts when the sensed temperature is below the preset temperature, an amplifier having an input connected between said potentiometer arm and the arm of said second rheostat and an output connected to said null detector, a third set of contacts connected in parallel with said first set of contacts, means operative to close said third set of contacts when said first normally open contact is closed, a fourth set of contacts connected in parallel with said second set of contacts, means operative to close said fourth set of contacts when said second normally open contact is closed, a second circuit including said first normally open contact, and said first operative means connected in series, a third circuit including said second normally open contact and said second operative means connected in series, and means for breaking said second and third circuits.

2. The combination of claim 1 in which said second control means includes a temperature recorder connected to the output of said temperature sensing means and having said temperaure set point, a temperature controller having its input connected to the output of said recorder, and a motor operated rheostat having its motor connected to the output of said controller and its arm connected to said null detector.

3. The combination of claim 1 in which said amplifier is a magnetic amplifier having a control winding connected between said potentiometer arm and the arm of said second rheostat.

4. The combination of claim 1 including a voltmeter connected across said amplifier control winding.

5. The combination of claim 3 in which said second control means includes a temperature recorder connected to the output of said temperature sensing means and having said temperature set point, a temperature controller having its input connected to the output of said recorder, and a motor operated rheostat having its motor connected to the output of said controller and its arm connected to said null detector.

6. The combination of claim 5 including a voltmeter connected across said amplifier control winding.

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