May 9, 1961 F. SLAMAR 2,983,170

SYSTEM FOR CONTROLLING THE GAGE OF STRIP PRODUCED BY A CONTINUOUS ROLLING MILL

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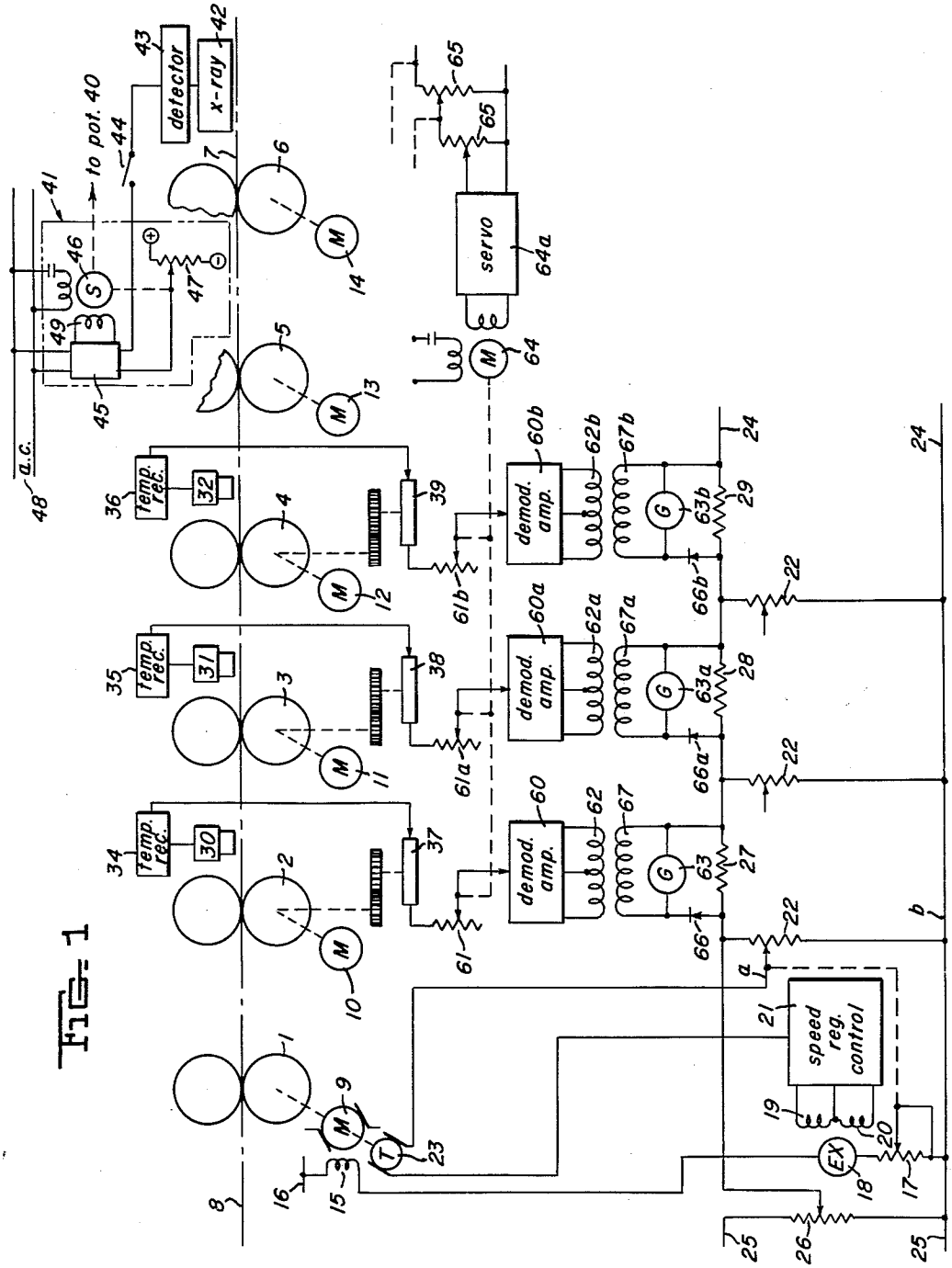


Fig. 1

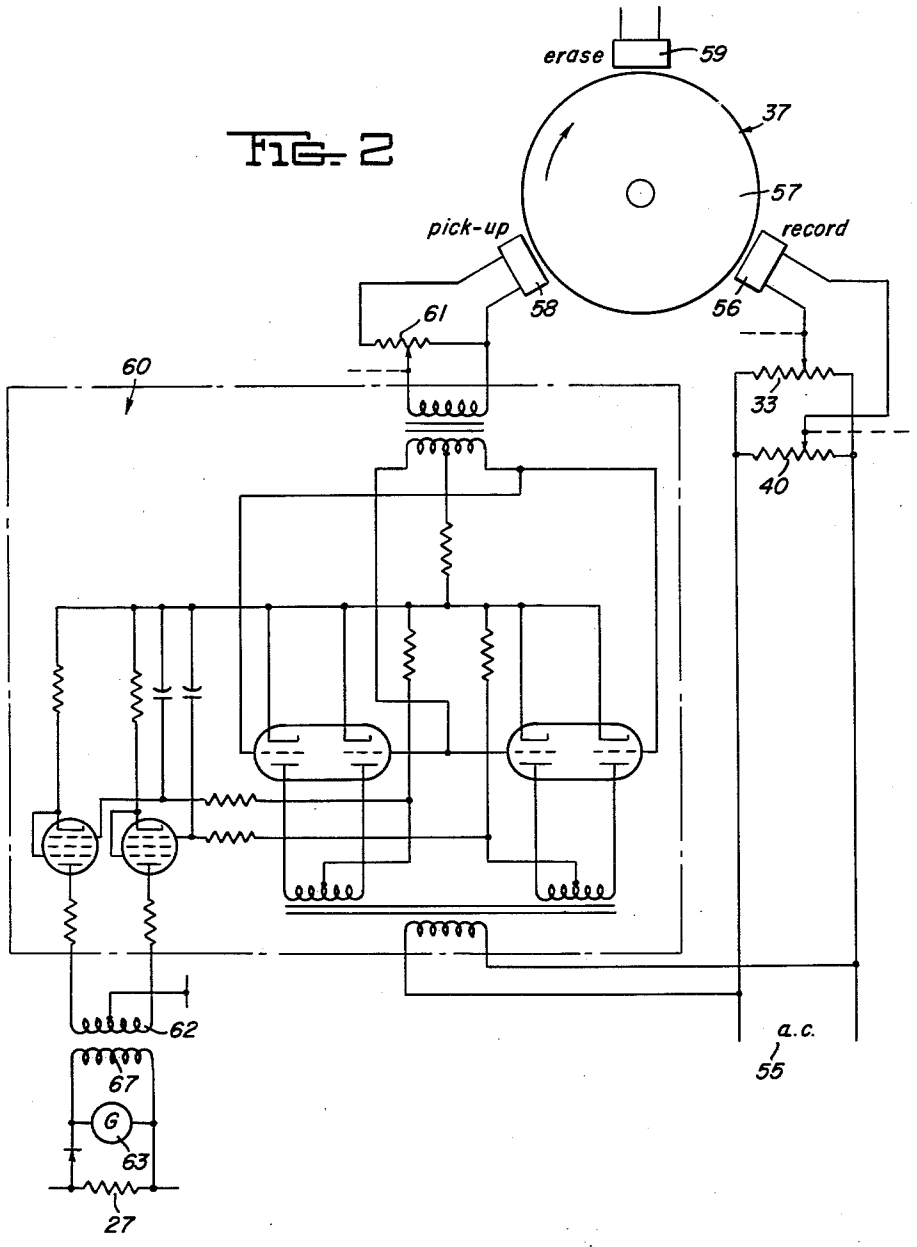
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SYSTEM FOR CONTROLLING THE GAGE OF STRIP PRODUCED BY A CONTINUOUS ROLLING MILL

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FIG. 2



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SYSTEM FOR CONTROLLING THE GAGE OF STRIP PRODUCED BY A CONTINUOUS ROLLING MILL

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This invention relates to the hot-rolling of metal strip in a continuous mill and, in particular, to apparatus controlling the speeds of the mill stands so that hot-rolled strip of uniform gage will be produced. More specifically, the invention concerns apparatus acting in response to temperature variations along the length of the strip passing through the mill to adjust the speeds of the several stands and, therefore, the tension on the strip between stands, so that the gage of the finished strip is held constant within narrow tolerances.

The gage of hot-rolled strip produced on a conventional multi-stand continuous rolling mill tends to increase from the leading end to the trailing end because of the loss of heat from the starting slab as it is rolled down and elongated. Other variations in gage result from the fact that the slabs are heated for rolling by passing them sidewise through furnaces on water cooled skids. This causes the slabs to have a lower temperature along the lines of contact with the skids than at other points. These temperature variations cause the finished strip to exhibit corresponding variations in gage along the length thereof. I have invented a control system for measuring the temperature of successive points along the strip as it is being rolled and correspondingly varying the speeds of the latter stands of the mill so as to effect changes in the inter-stand tension on the strip which will compensate for changes in the temperature of the strip from point to point therealong. I also employ a gager responsive to the thickness of the finished strip, to effect an adjustment of the temperature-measuring means as necessary. The variation in the speeds of the several mill stands is effected by modifying the action of conventional speed regulators for the motors individually driving the several stands.

A complete understanding of the invention may be obtained from the following detailed description and explanation which refer to the accompanying drawings illustrating the present preferred embodiment. In the drawings:

Figure 1 is a diagrammatic showing of the system of my invention applied to the six finishing stands of a continuous hot-strip mill; and

Figure 2 is a circuit diagram showing the details of a portion of Figure 1.

Referring now in detail to the drawings, the finishing stands of a continuous hot-strip mill are indicated at 1, 2, 3, 4, 5 and 6. These stands reduce progressively to finished strip 7 a breakdown bar 8 produced in three or four preceding roughing stands (not shown) from a starting slab of suitable dimensions, heated to a temperature of about 2200° F. Each finishing stand is driven by its own motor 9, 10, 11, 12, 13 or 14. Each motor has a speed-regulating system, known per se, that for motor 9 only being shown in Figure 1.

As there illustrated, the excitation of the field winding 15 of motor 9 is supplied from a constant-voltage source 16 under the control of a rheostat 17 and an exciter 18 both connected in series with the winding. The exciter has two field windings 19 and 20, connected in opposition. The energization of one relative to that of the other causes the exciter voltage to buck or boost the line

excitation voltage (that of source 16), thereby varying the net excitation voltage applied across winding 15.

The output of an amplifier 21 changes the relative energizations of windings 19 and 20, depending on the difference between a predetermined reference voltage provided by potentiometer 22 and the voltage produced by a tachometer 23 driven at a speed proportional to that of motor 9. The potentiometer and tachometer are connected in series opposition to the input side of the amplifier 21. Potentiometer 22 is connected across a control bus 24 energized from a source 25 under control of a master potentiometer 26.

The speed regulator described above tends to maintain the speed of motor 9 constant at a value determined by the setting of the movable contact of potentiometer 22. Any difference between the voltage of tachometer 23 and that applied by the potentiometer to amplifier 21 will produce an output from the latter tending to vary the motor speed in such direction as to restore the balance of voltages normally existing. That is, if motor 9 tends to decelerate for any reason, the voltage of tachometer 23 drops and amplifier 21 delivers an output which changes the relative excitations of the field windings 19 and 20 so that exciter 18 will supply voltage opposing that of line 16, thereby causing the motor to accelerate. The converse occurs when the motor accelerates. Field rheostat 17 is mechanically coupled to the movable contact of potentiometer 22 as indicated by a dotted line connecting them.

The apparatus described so far is conventional and forms no part of my invention. The latter, as will now be explained in detail, comprises means for modifying temporarily the reference voltage established by the potentiometers 22 for the motors of certain stands, to vary the tension on the strip between a given pair of stands in accordance with the temperature of the strip in the portions thereof entering the first stand of that pair. For this purpose, I provide means acting to produce a control voltage proportional to the temperature of the strip between a certain pair of stands, affecting the regulators of the first stand beyond that pair and all subsequent stands. Thus, a control voltage proportional to the strip temperature between stands 2 and 3 is applied to the regulators of the motors of stands 4, 5 and 6; a control voltage proportional to the strip temperature between stands 3 and 4 is applied to the regulators of the motors of stands 5 and 6, and so on. The control voltages corresponding to the temperatures of the strip portions between the pairs of stands 2—3, 3—4 and 4—5 are applied to bus 24 by resistors 27, 28 and 29 connected in one side thereof between the potentiometers 22 of pairs of stands 3—4, 4—5 and 5—6, respectively.

It will be apparent that, by this arrangement, any control voltage applied over resistor 27 will affect the regulators of stands 4, 5 and 6; a voltage applied over resistor 28 will affect the regulators of stands 5 and 6; while a voltage applied over resistor 29 will affect only the regulator of stand 6. The polarity of the added voltage is such as to produce the desired change in the speed of the second stand beyond the point of temperature measurement and subsequent stands. Thus, if the strip temperature measured between stands 2 and 3 drops, the speed of stands 4, 5 and 6 is increased. This causes greater tension to be applied to the strip between stands 3 and 4 but not to the strip between stands 4 and 5 or 5 and 6 since their speeds, relative to each other, are unchanged.

It now remains to describe the means for producing control voltages proportional to the temperature of the strip portions between pairs of stands 2—3, 3—4 and 4—5. Temperature-responsive means 30, 31 and 32 are

mounted in any convenient manner and located to be affected by the temperatures of the strip portions between these successive pairs of stands, respectively. Such means may conveniently be the "Rayotube" Temperature Detector made by Leeds & Northup, e.g., that designated No. 8891 on page 9 of its Catalog EN–S3. They may be obtained with a potentiometer 33 (see Figure 2) operated thereby to produce control voltages proportional to the temperatures of adjacent portions of the strip. The detectors **30, 31** and **32** are connected to automatic recorders **34, 35** and **36**, respectively, which may be Leeds & Northrup "Speedomax" Type G. The recorders **34, 35** and **36** compare the voltages from the potentiometers **33** of detectors **30, 31** and **32**, with a pre-established voltage, and apply the difference to one of a series of memory discs **37, 38** and **39**. These discs function to store an indication of the voltage difference for subsequent retrieval when a given point on the strip has passed through the succeeding stand so as to be subject to the tension between it and the next stand. The voltage indication is then utilized in a manner to be explained shortly, in modifying the action of the speed regulators of the stand motors to effect the desired change in inter-stand strip tension. A fixed voltage for comparison purposes is maintained in each recorder, as by adjustment of a potentiometer therein such as shown at **40** in Figure 2, by a set-point controller **41** mechanically coupled thereto.

Controller **41** is actuated by a gager **42** and a deviation detector **43** acting through an intermittent switch **44**. The gager and detector may be constituted by the "Betameter" made by Isotope Products of Buffalo, New York. The gager is located to measure the thickness of finished strip emerging from stand **6**. In case of any deviation from a predetermined value, the gager causes the detector **43** to provide a signal voltage, positive or negative, proportional to the magnitude and direction of the deviation. Switch **44** may be a General Electric TSA–18 timer, which operates continuously, having adjustable on and off periods..

Controller **41** is a form of measurement-storage device. It includes an electronic conversion amplifier **45**, a servomotor **46** and a potentiometer **47**, the moving contact of which is mechanically connected to the servomotor. The slide wire to potentiometer **47** is electrically connected to a suitable D.-C. source. The output of detector **43** is supplied to one input terminal of amplifier **45**, the other terminal thereof being connected to the movable contact of potentiometer **47**. Amplifier **45** and servomotor **46** are electrically connected to a suitable alternating-current source **48**. The output terminals of amplifier **43** are electrically connected to a quadrature field winding **49** of the servomotor. Depending on the indication from detector **43**, the servomotor **46** operates in one direction or the other when switch **44** is closed, until the resulting adjustment of potentiometer **47** balances such indication.

It will be evident that operation of the set-point controller **41** described above will vary the position of the movable contact of potentiometers **40** and that the temperature detectors **30, 31** and **32** will similarly operate the movable contacts of potentiometers **33**. These potentiometers are connected across an alternating-current source **55** (Figure 2) and any unbalance of the bridge circuit including them causes a voltage to be applied to a magnetizing head **56** of device **37**. This makes a record on the magnetizable periphery of disc **57** driven at a speed proportional to that of stand **2**. A pick-up head **58** is spaced from head **56** so that the temperature record of any point on the strip impressed on the disc **57** will reach head **58** by the time that point on the strip passes through stand **4**. On continued revolution of disc **57**, the record is erased by head **59**.

The output of memory device **37**, obtained as just described, is supplied to a demodulator amplifier **60** through a gain-control rheostat **61**. The output of the amplifier, shown in detail in Figure 2, is applied to the field winding **62** of a generator **63**. Rheostat **61** is operated by a servo-motor **64** under the control of devices (not shown) on which the desired width and gage of the strip may be set by the operator. Such devices actuate rheostats **65** which control the energization of the field of motor **64** through an amplifier **64***a*. Generator **63** supplies current to resistor **27** thereby introducing the supplemental control voltage into bus **24**. The generator load circuit includes a rectifier **66** to prevent reversal of its polarity. The generator has a feedback field winding **67** causing the generator voltage to be proportional to the excitation of winding **62**. The demodulator amplifier **60** for energizing field winding **62** is phase sensitive so the polarity of the amplifier output will correspond to the relative positions of the movable contacts of potentiometers **33** and **40**.

Recorders **35** and **36** control duplicates of the apparatus described above designated by the same numerals with the suffixes "*a*" and "*b*," respectively, e.g., **60***a*, **60***b*, **61***a*, **61***b*, etc.

It is apparent from the foregoing that, during the reduction of breakdown **8** into finished strip **7**, by passing through the six stands of the mill, the temperature of the strip is continuously measured at points between the stands of pairs **2—3, 3—4**, and **4—5**, by detectors **30, 31** and **32**, and that the speeds of the motors driving stands **4, 5** and **6** are varied to control the inter-stand tension on the strip so as to compensate for variations in temperature along the strip. In addition, an overall adjustment is made from time to time by gager **42**, as necessary to keep the gage of the finished strip within allowable tolerances. The invention has the advantage of utilizing known speed regulators for the motors and modifying their action by the introduction of supplemental control voltages which effect the desired correction when needed. The prime advantage, however, is that the invention operates automatically to reduce gage variations which cannot be done effectively by manual control.

Although I have disclosed herein the preferred embodiment of my invention, I intend to cover as well any change or modification therein which may be made without departing from the spirit and scope of the invention.

I claim:

1. In a speed-control system for the motors individually driving a plurality of stands, respectively, of a continuous mill, comprising a control bus, means maintaining a predetermined voltage across said bus, a potentiometer connected across said bus for each motor and means responsive to the setting of each potentiometer for controlling the speed of the respective motor, the combination therewith of a resistor in one side of said bus between the potentiometers of the motors of two adjacent stands after the first, and means responsive to the temperature of strip being rolled in said mill at a point between said two of said stands for circulating a supplemental current through said resistor in addition to that resulting from said predetermined voltage.

2. The combination as defined by claim 1, characterized by said supplemental-current circulating means including means for comparing the strip temperature with a predetermined value, a gager measuring the thickness of the strip leaving the last stand and means controlled by said gager effectve to change said value.

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