United States Patent

[11] **3,604,359**

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[73] Assignee **Railway Maintenance Corporation**
Pittsburgh, Pa.

[54] **APPARATUS FOR CORRECTING RAILROAD TRACK**
15 Claims, 18 Drawing Figs.

[52] **U.S. Cl.** **104/8,** 33/144
[51] **Int. Cl.** **E01b 33/02**
[50] **Field of Search** .... 104/7, 7 B, 8; 33/143, 144, 145

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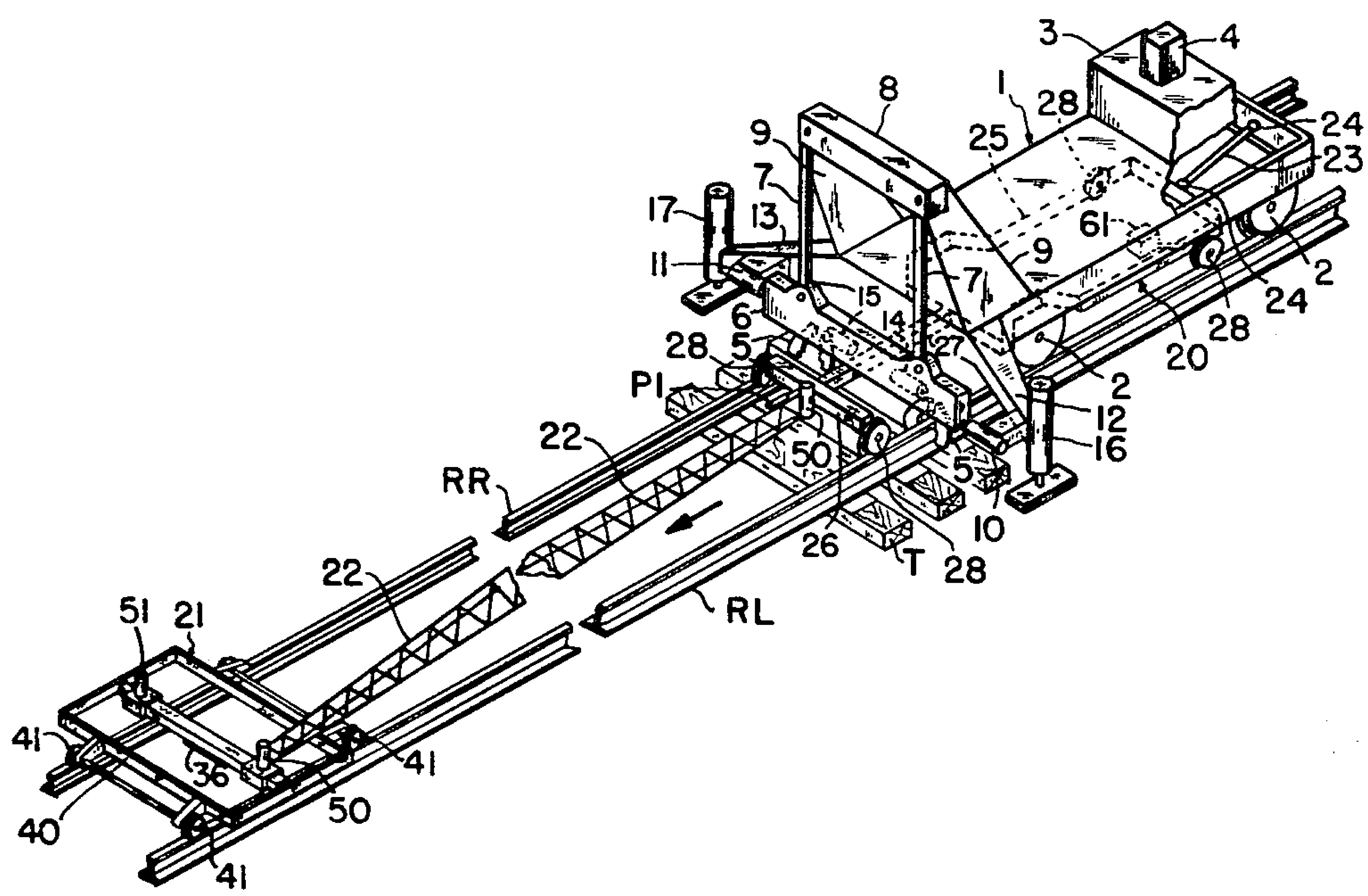
ABSTRACT: Apparatus for use in correcting the position of railroad track including an elongated vehicle carrying means responsive to a variation in electric current, at least one elongated rigid member extending forwardly from the vehicle and pivotally supported thereon and a second vehicle pivotally supporting the other end of the member for movement along the track. At least one variable resistor attached between the member and the elongated vehicle and connected in a bridge circuit with the means responsive to current variation so that angular displacement of the elongated vehicle and the member in at least one plane from a preset relationship varies the resistance of the variable resistor effecting a response by the means responsive to current variation.



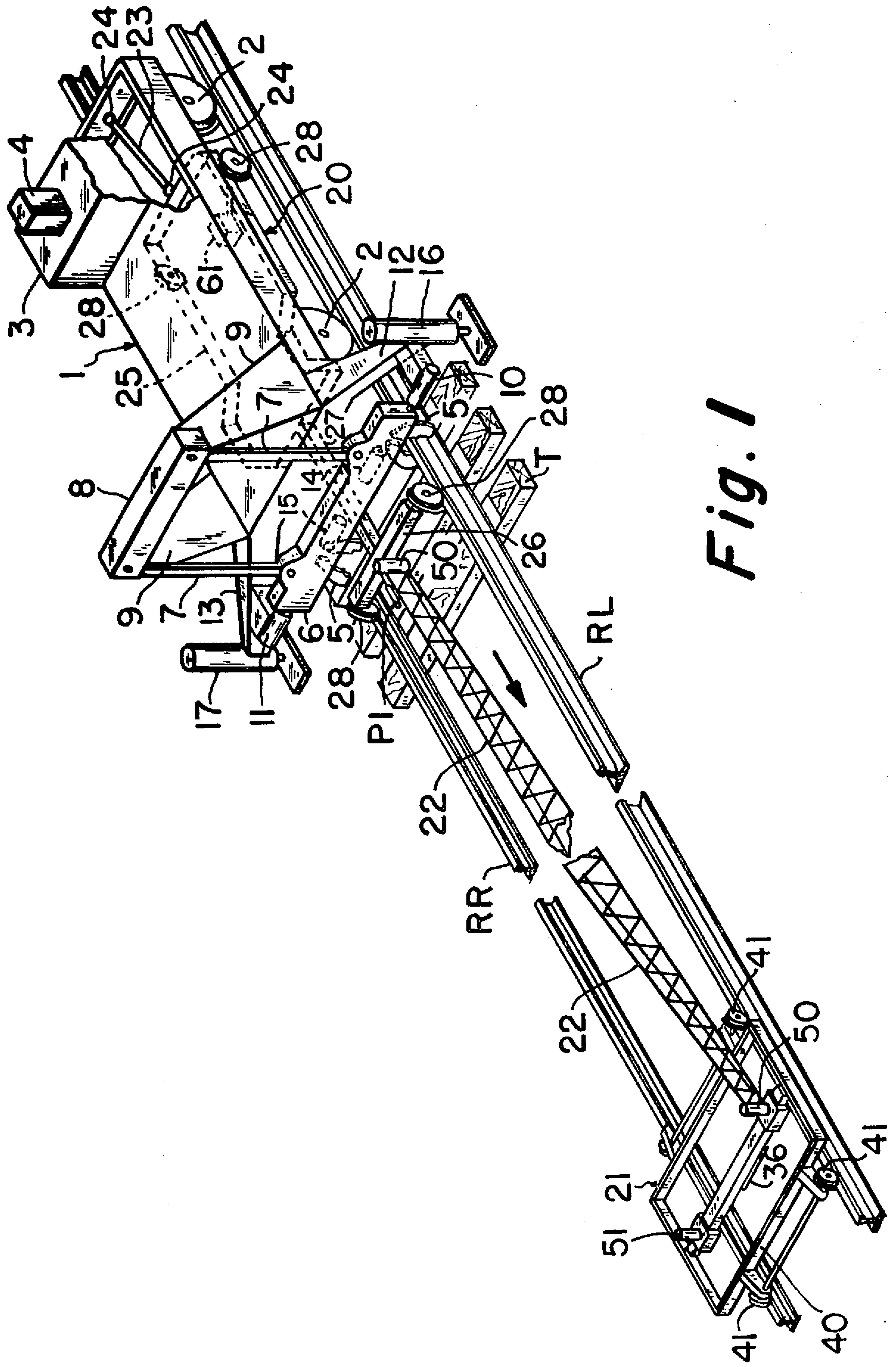


Fig. I

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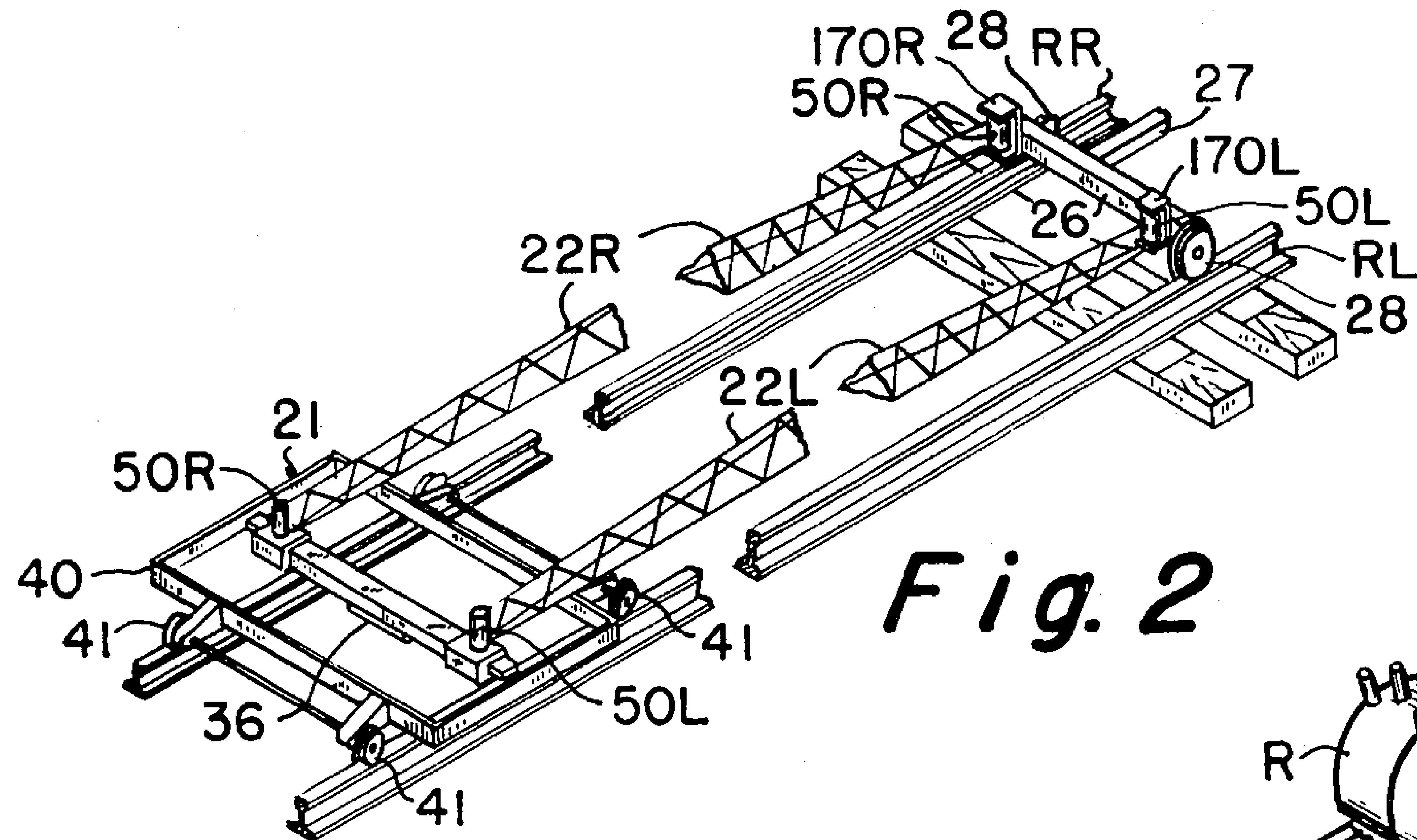

Fig. 2

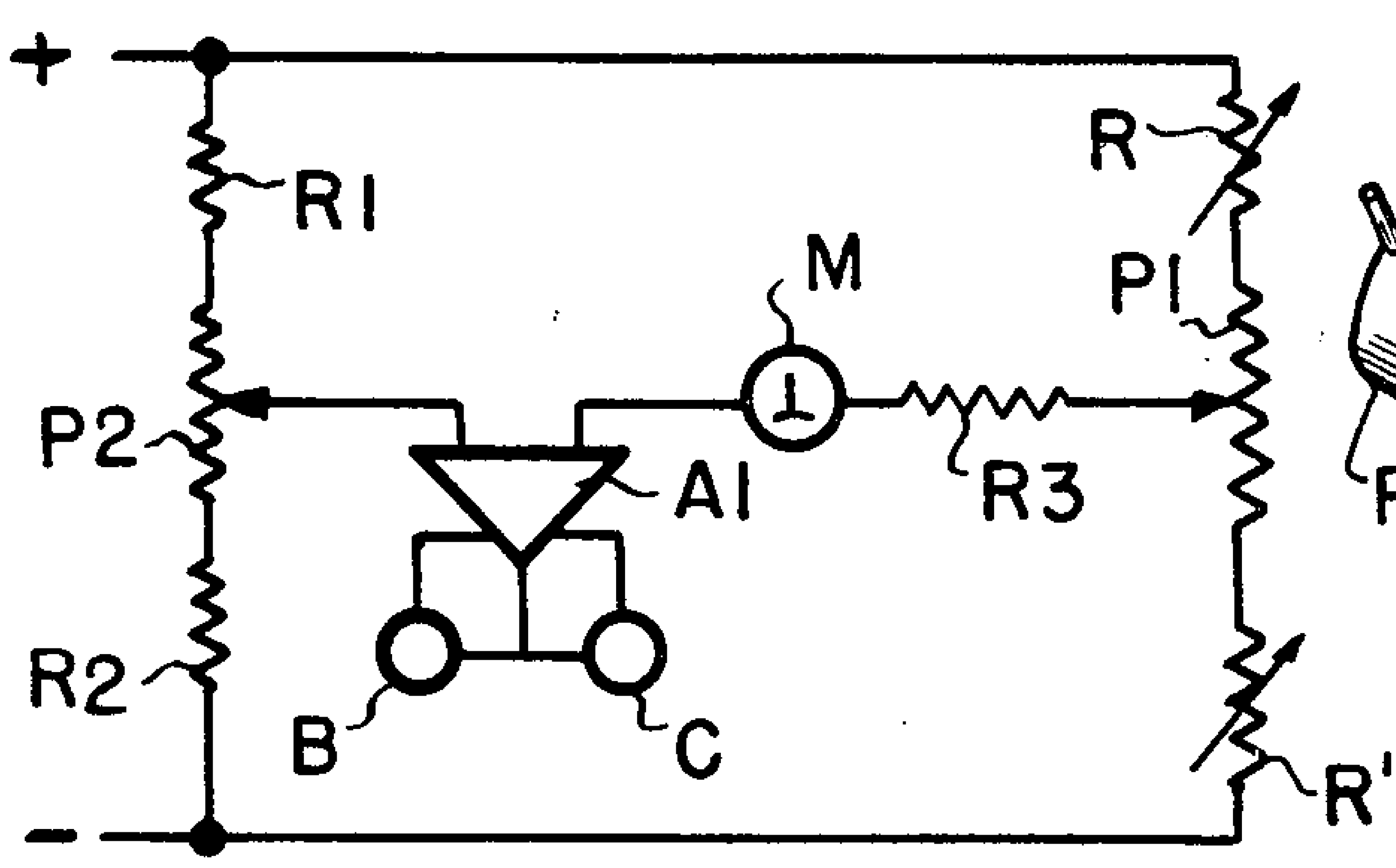

Fig. 3

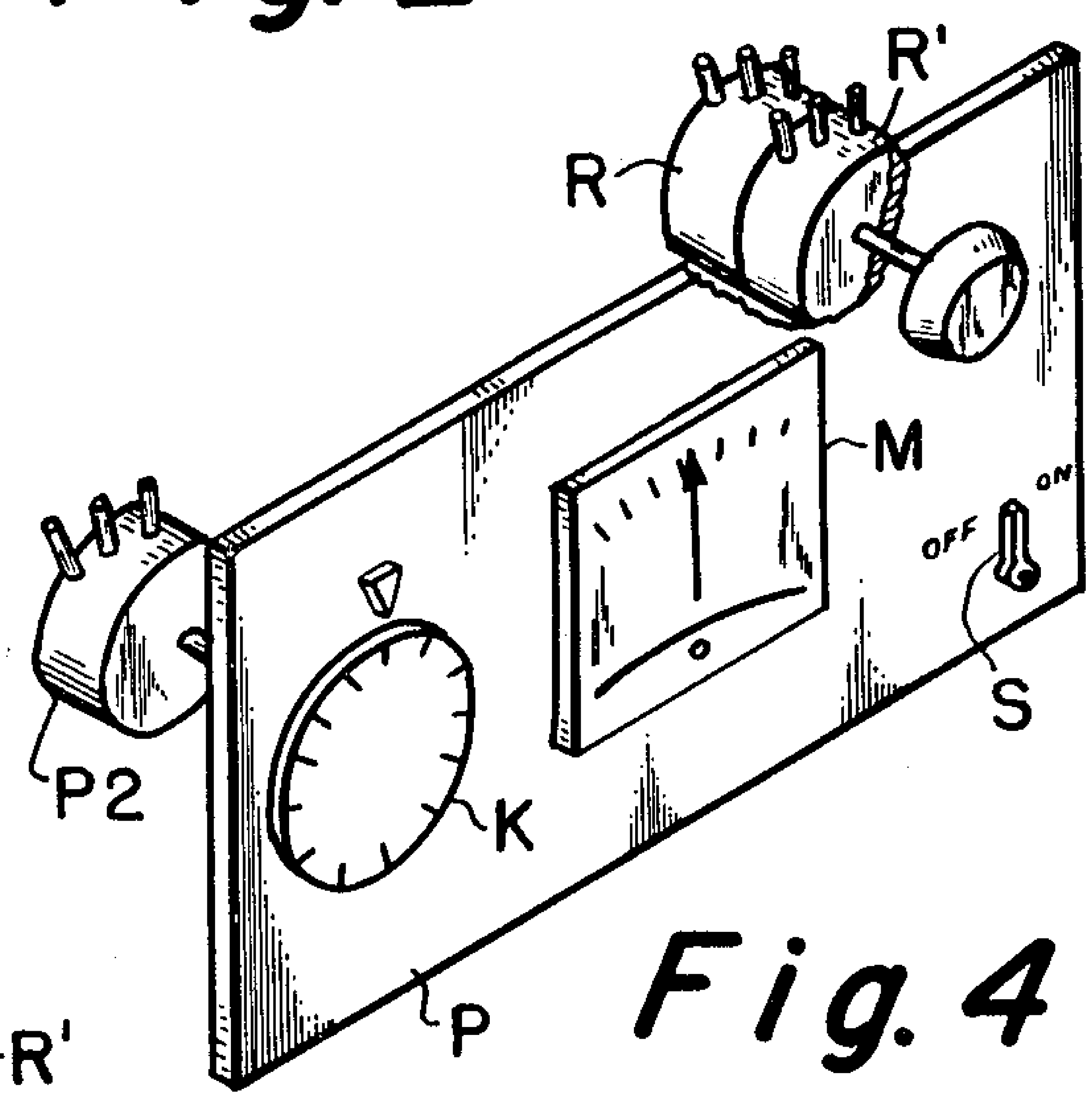

Fig. 4

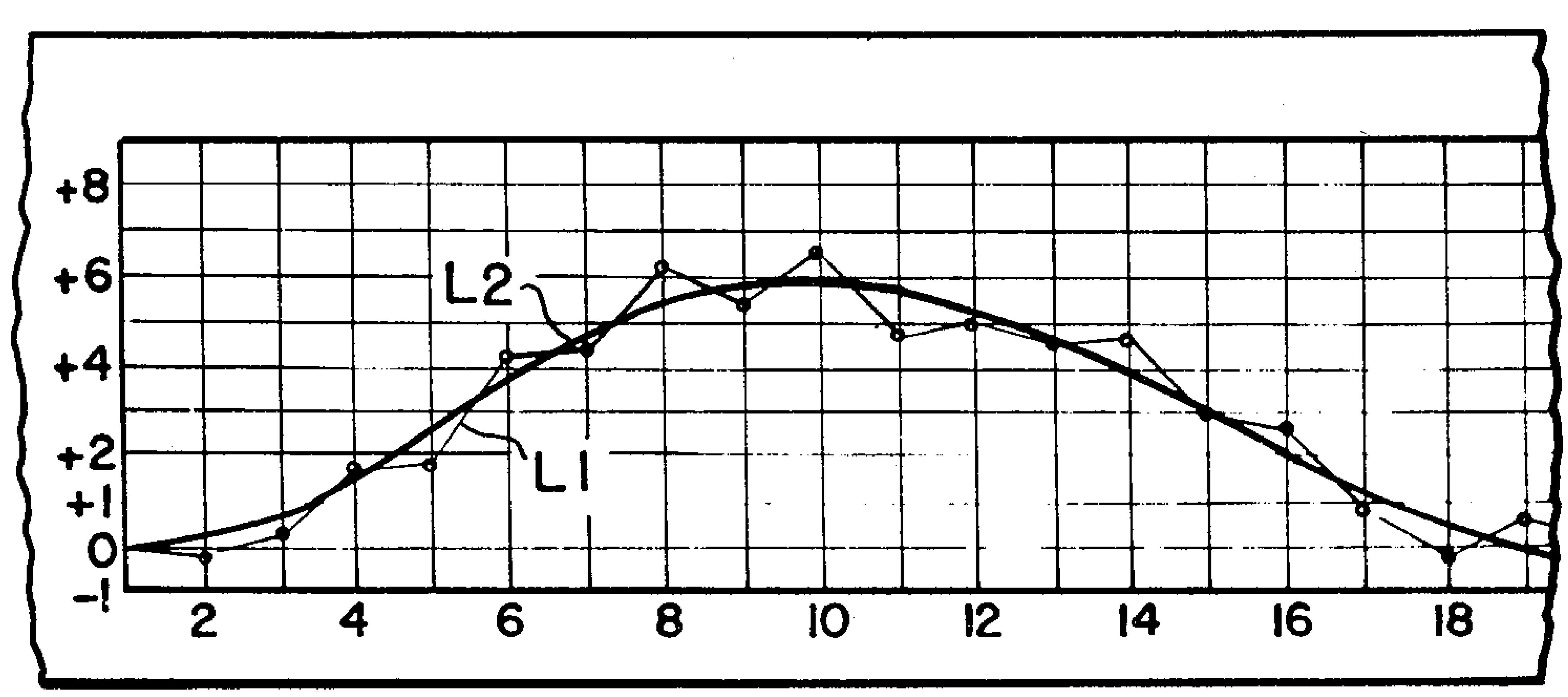

Fig. 5

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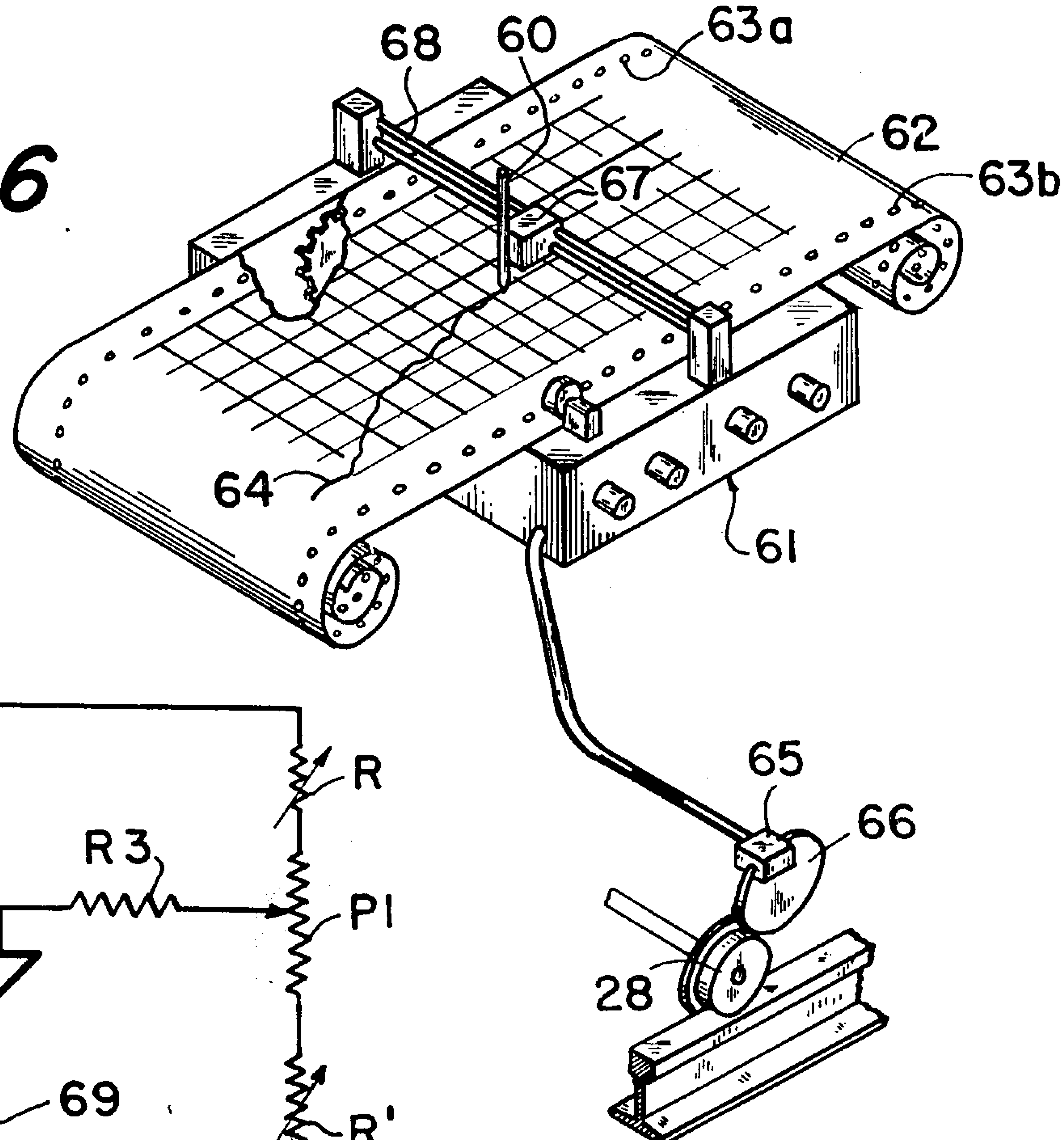
Fig. 6



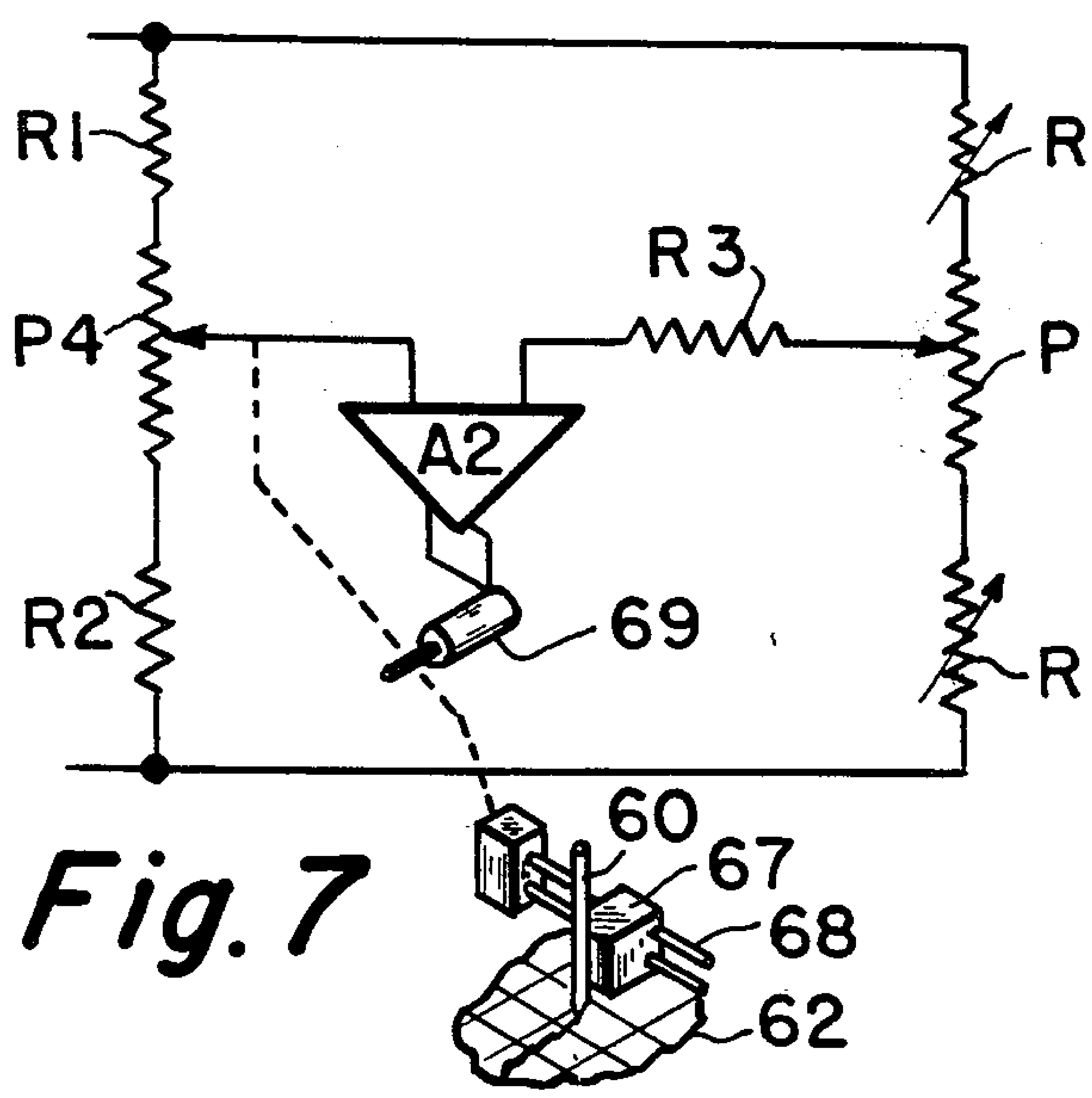


Fig. 7

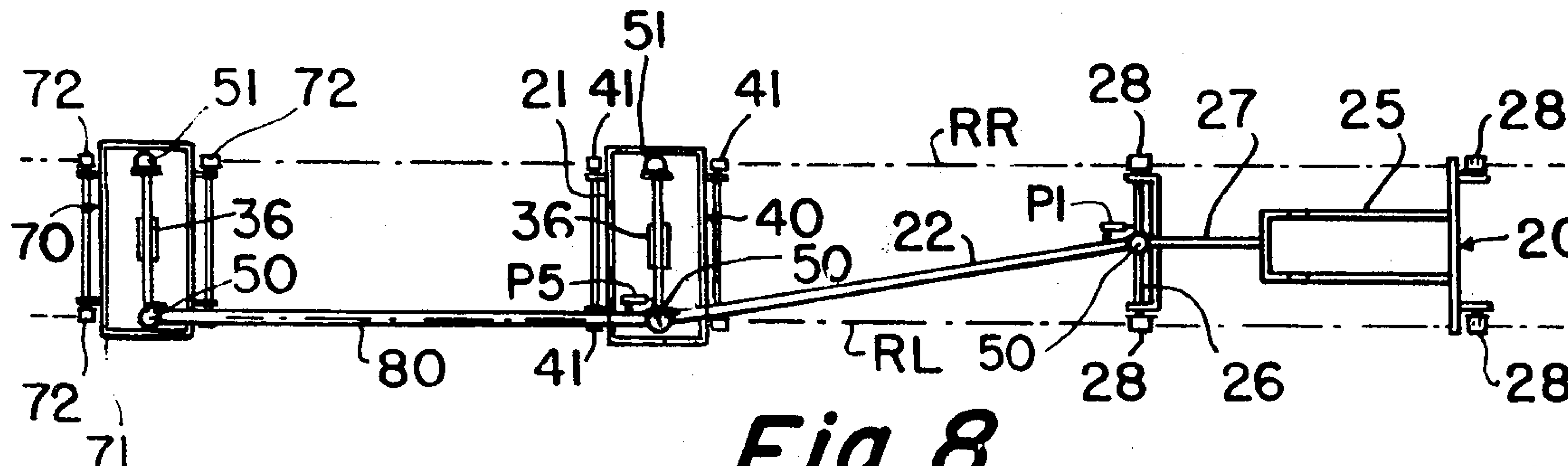


Fig. 8

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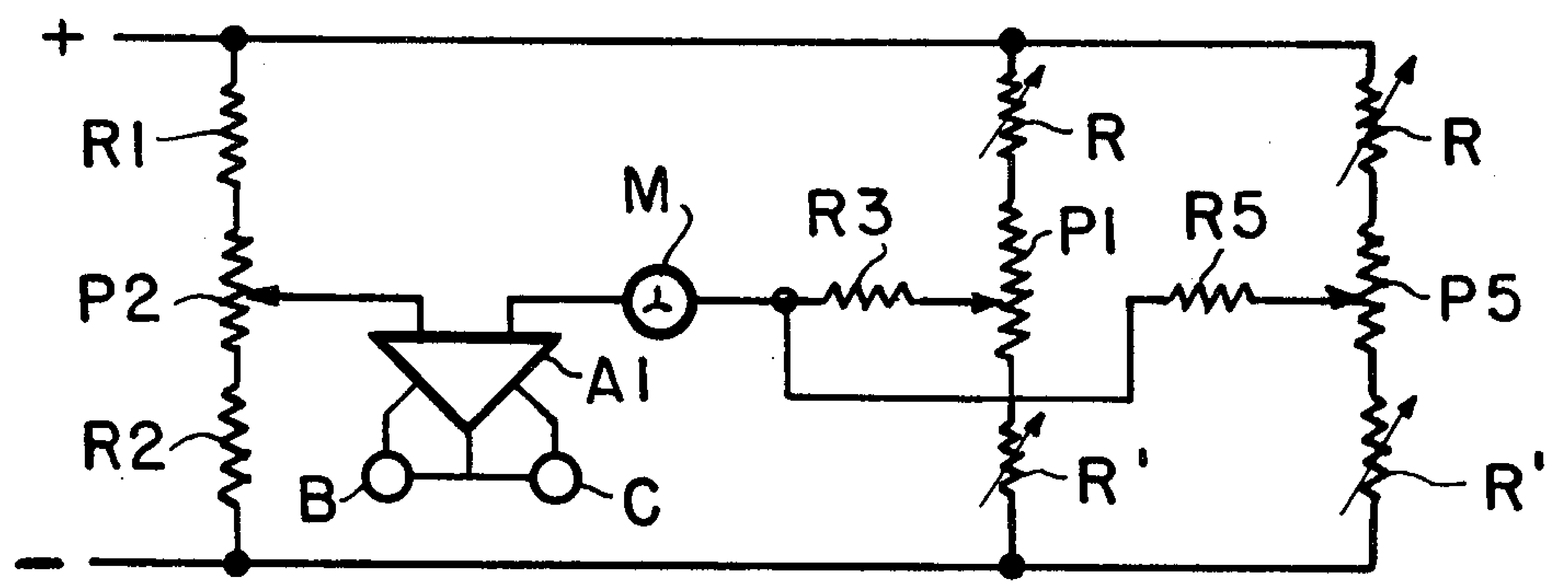

Fig. 9

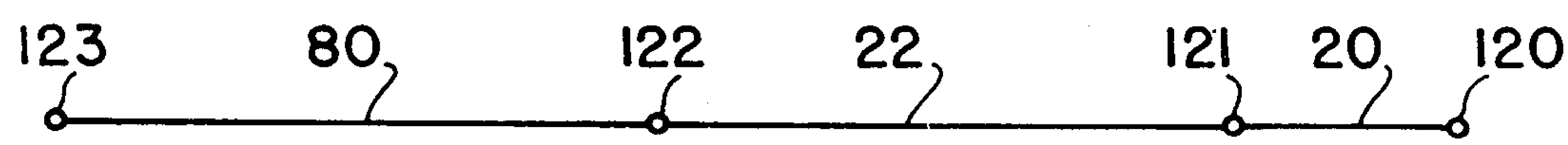

Fig. 10a

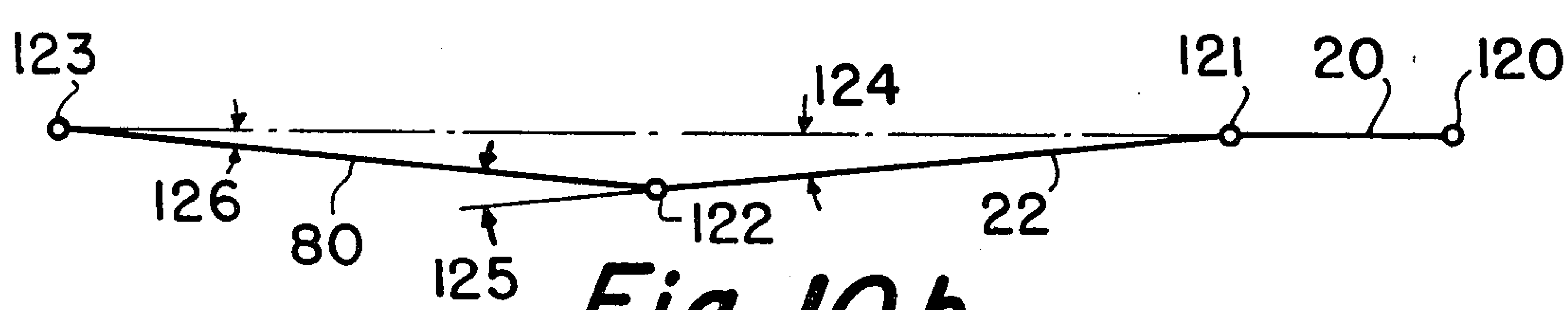

Fig. 10b

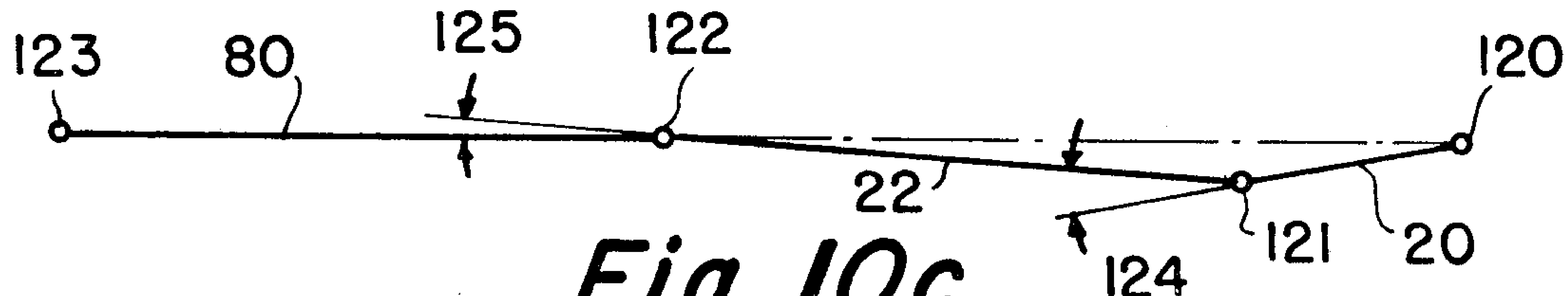

Fig. 10c

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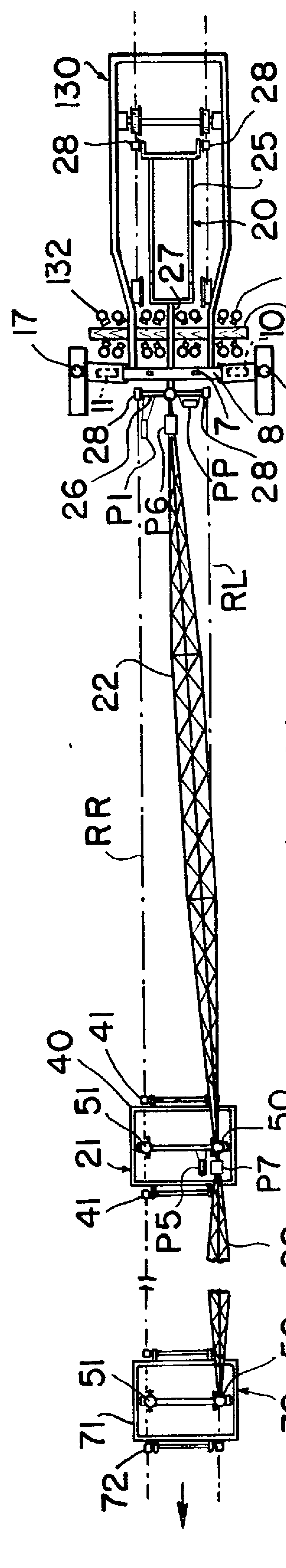

Fig. 11

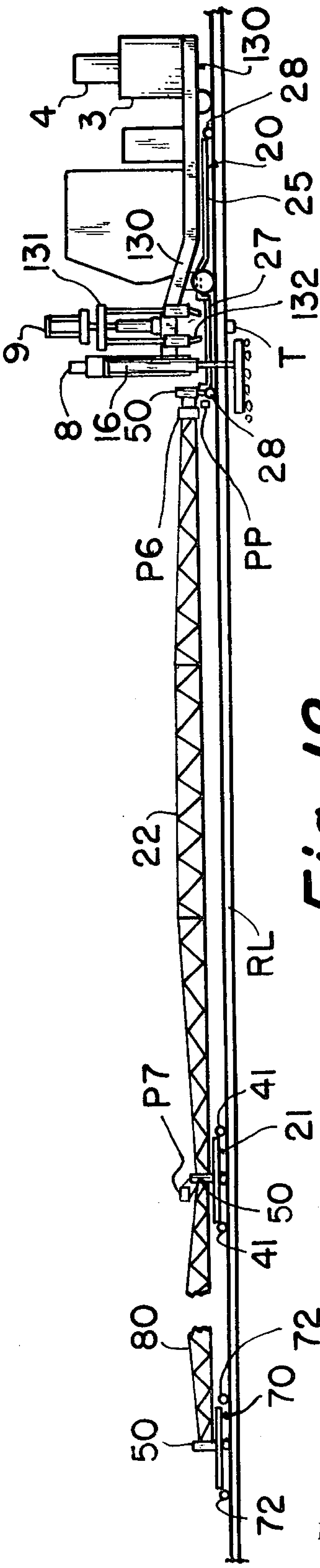

Fig. 12

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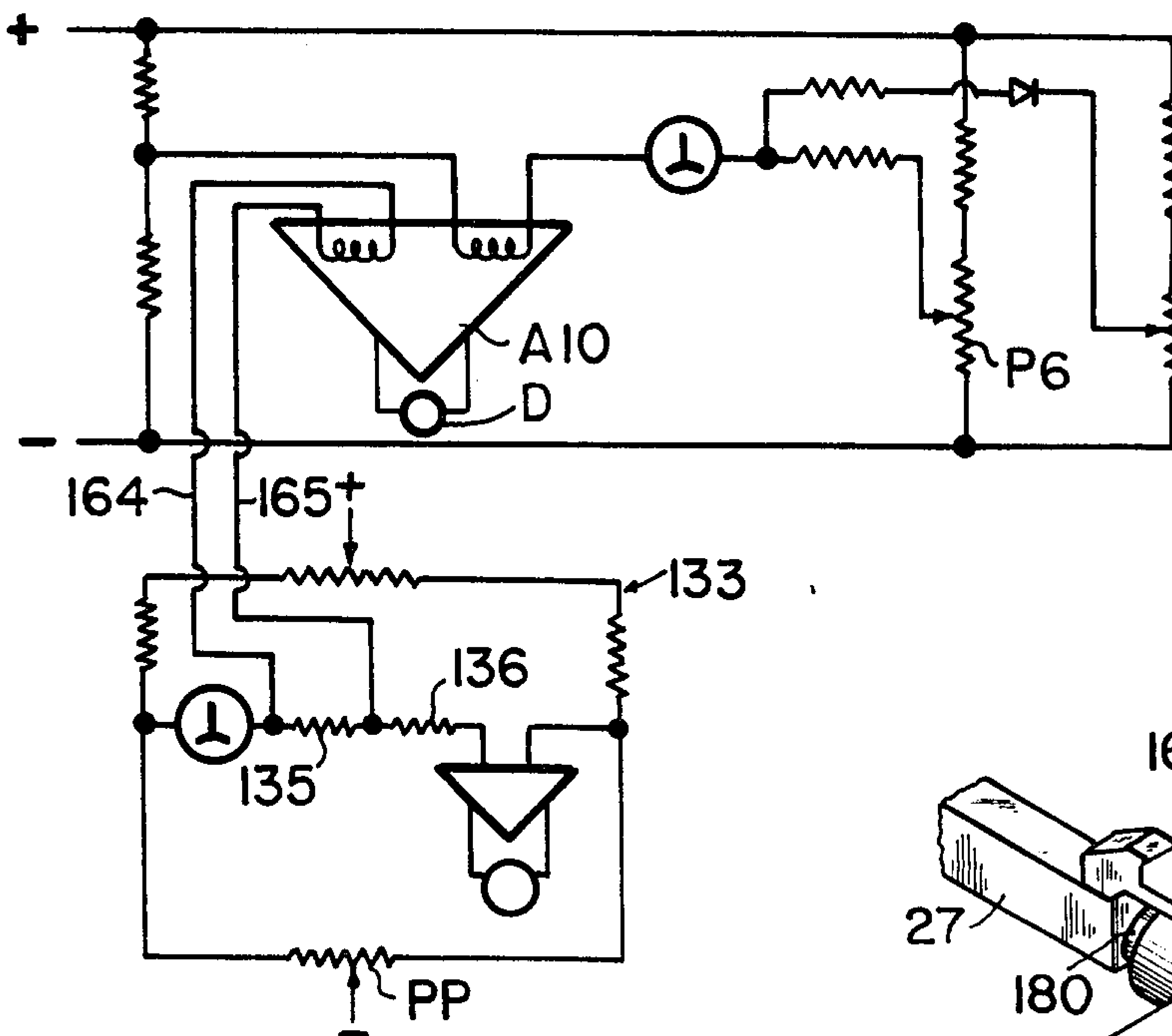

Fig. 13

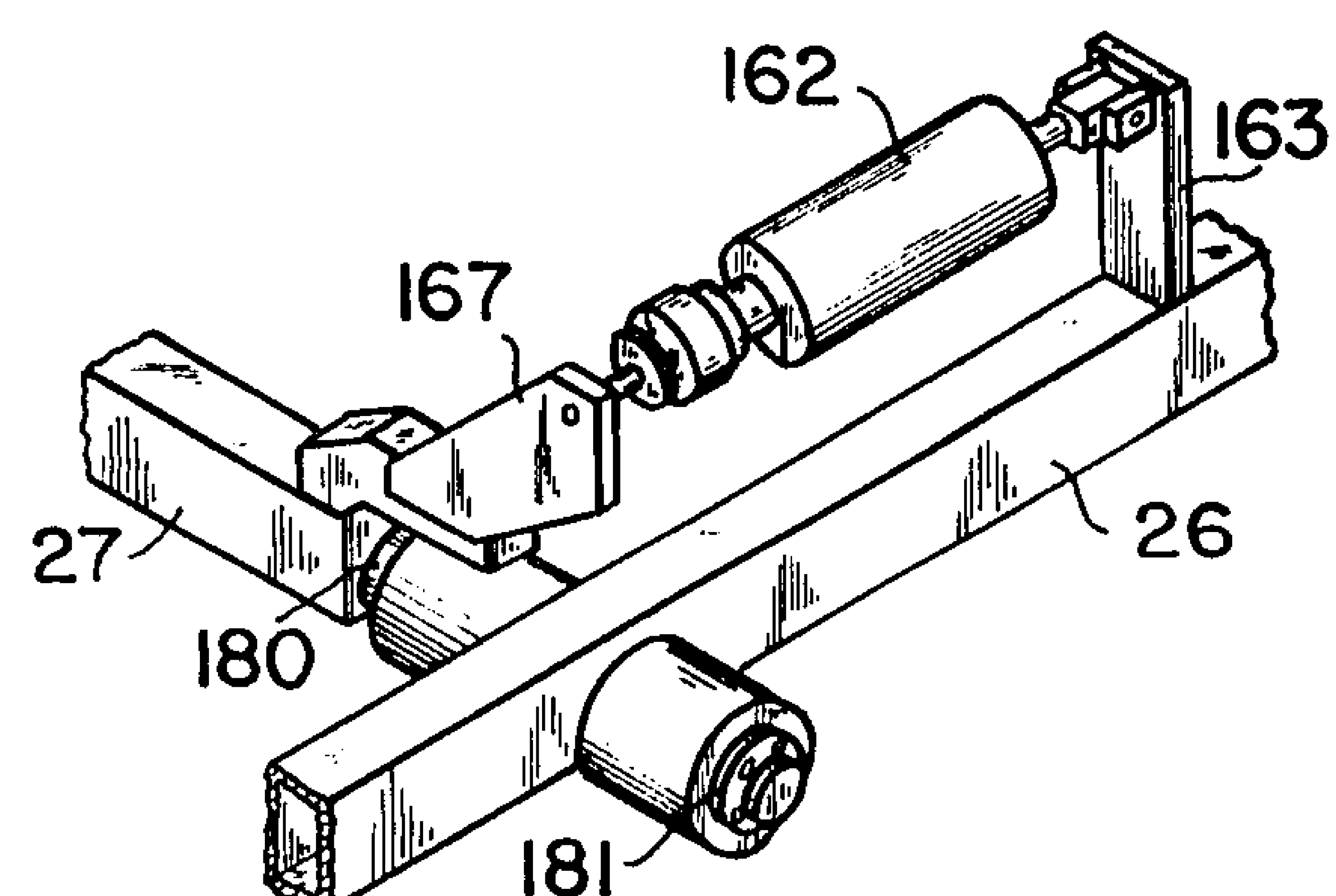

Fig. 15

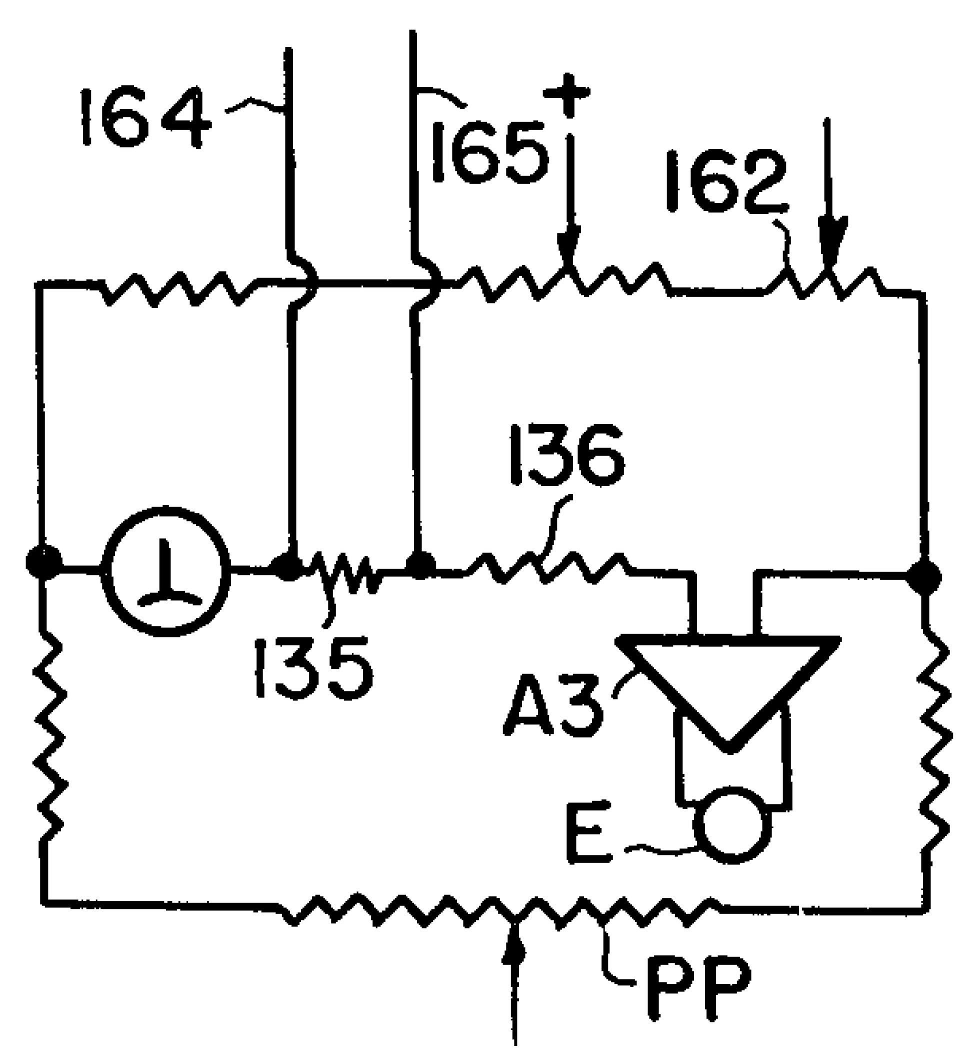

Fig. 16

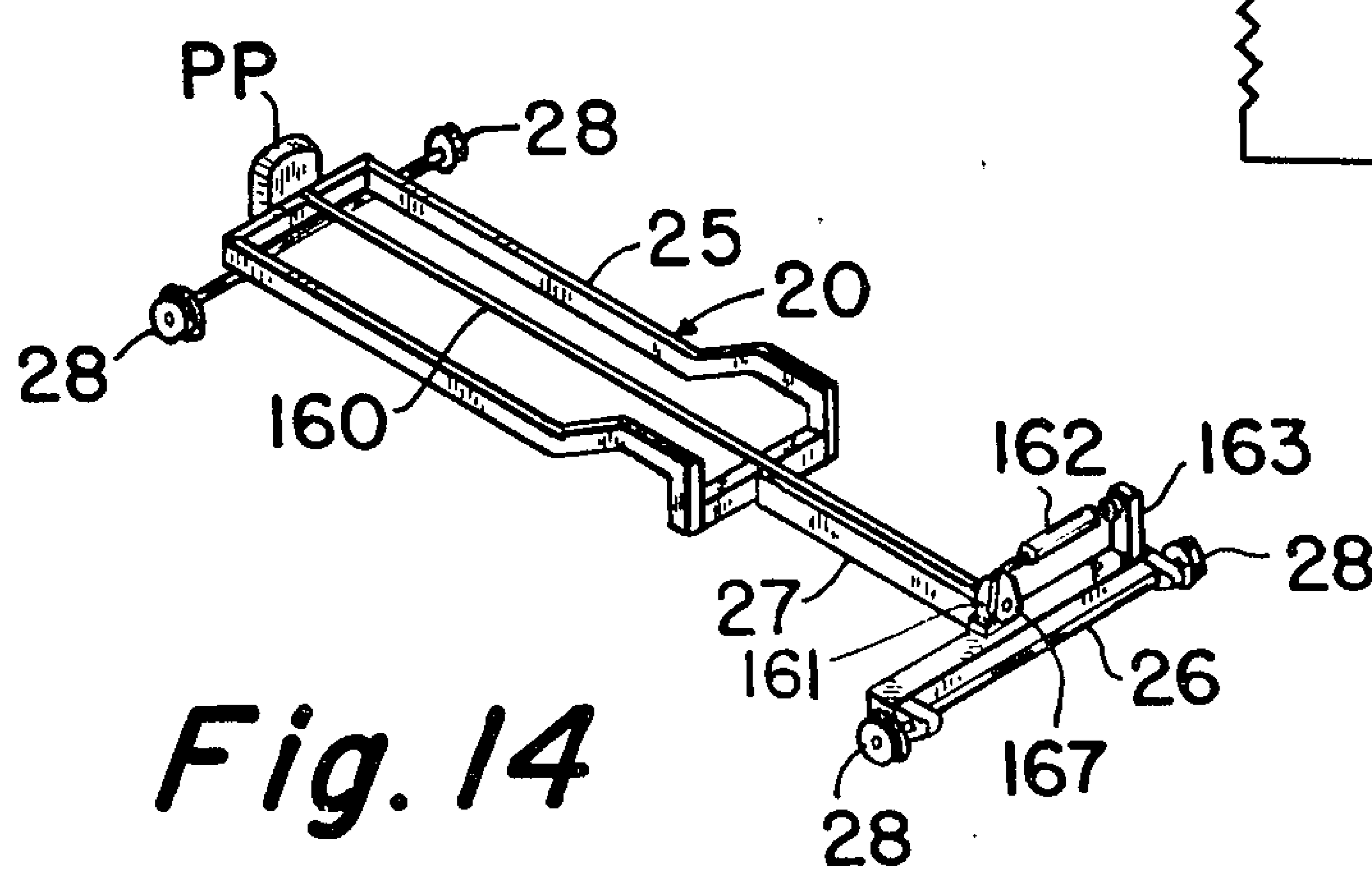

Fig. 14

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APPARATUS FOR CORRECTING RAILROAD TRACK

This invention relates to apparatus for accurately and rapidly measuring the position of railroad track so that the track may be corrected. More particularly, the invention relates to a determination of the original track condition and to the operation of track raising and shifting equipment in accordance with the uncorrected track condition to move the track into the desired position.

In its basic form, the invention is directed to track lining, although, as will appear hereinafter, a combination lining and surfacing operation may be performed. The most common method of lining curved track with mechanized equipment is to start at one end of the curve and work progressively around the curve without any prior measurement of the curve. An average ordinate is assumed for the curve based upon available engineering records. The lining machine carries a device of one form or another by which the actual curvature is measured at the working point which is usually at every tie. The track is then moved until the assumed average ordinate is obtained, and the machine is moved to the next work station where the operation is repeated.

Lining curved track in this way does not result in a smooth track condition since there is always a difference between the curvature shown by the engineering records from which the average ordinate is determined and the actual curvature of the track.

Actual curvature may be measured by stretching a string or wire as a chord between a point on the track ahead of the work station and a second point on the track behind the work station and measuring the ordinate of the subtended arc at the work station. The measured ordinate may be the midordinate or any other ordinate having a known relationship to the midordinate.

This "string line" method of measuring may be utilized to best advantage when used to determine actual curvature of an entire curve. This is accomplished by recording the midordinate of chords of uniform length at stations spaced along the track at one-half the chord length. Thus, the overall curvature is obtained and by a system of calculations an average ordinate is determined as the ordinate for all work stations. Alignment is then made based upon the calculated average ordinate rather then upon the assumed average ordinate. While this method is an improvement over the use of an assumed average ordinate, it still suffers from disadvantages, the principal ones of which are a lack of accuracy in measurement and calculation and a lack of speed.

Our invention overcomes the problems inherent in progressive lining as accurate measurements are obtained at either spaced intervals or continuously throughout the curve and a smooth track line is drawn on the basis of these measurements. The track is then lined continuously at spaced intervals in accordance with the smooth track line. Thus, the track is aligned for the full curve actually present and not on the basis of an assumption.

The accuracy of lined track is based to a large extent upon the accuracy of the measuring system, and we have determined that this accuracy is increased by a substantial degree on curved track by utilizing a plurality of chordal members and measuring the deflection angle defined by these members upon deviation from a preset condition to obtain a record of the unlined track condition which is then used to draw the representative smooth track line which is subsequently used for lining the track. The chordal members may be formed by light beams, cables, wires or rigid members, but more accurate results are obtained when rigid members are used and, therefore, our invention contemplates the use of rigid members. Cables and wires are not practical since they are subject to vibrations caused by wind and inherently sag. The amount of vibration and sag cannot be anticipated as it varies with the length between supports and with the elasticity of the cable or wire material. Light beams are not subject to change in linear dimension as are cables and wires, but they are affected by weather conditions, interference from other light sources and by obstructions along the track. Therefore, the use of both cables and light beams results in measuring errors, and the errors remain in the aligned track.

Our basic invention provides an apparatus for automatically measuring the alignment of railroad track. The invention may be used with both tangent and curved track but will have its greatest application with curved track and is, therefore, described in its important aspects in connection with curved track. The information obtained from measuring a curved section of track is used to plot a graph of original track alignment for subsequent use as a basis for drawing a line representing a smooth track condition. The track may be shifted to the position indicated by the smooth track line at a later time, or the information may be used to control a lining machine traveling along the track with the measuring apparatus for lining the section of track immediately after the section has been measured. The operation may be performed on both curved and tangent track, and generally tangent track will be lined as the measuring apparatus and a lining machine proceed along the track as a unit.

The lining apparatus may advantageously be used in combination with track surfacing apparatus such as that disclosed in U.S. Pat. No. 3,212,451, issued Oct. 19, 1965, and assigned to the assignee of the present application, and a combination lining and surfacing apparatus is within the scope of our invention. In the combination machine, numerous components perform dual functions, as explained hereinafter, and a considerable saving results. Additionally, the combination machine makes it possible to both line and surface track simultaneously which is obviously faster and less expensive than using two separate machines to perform independent operations.

The surfacing apparatus has a surface sensing mechanism associated with a machine including apparatus for raising and tamping the track. The surface sensing mechanism indicates the elevation of the reference rail beneath the machine and at a point along the track ahead of the machine. This sensing mechanism determines the amount of raise required at the work station immediately ahead of the machine to blend that portion of the track with smooth track behind the machine and thereby obtain a smooth track condition. A comparison is made between the highest forward reference point and the rearmost reference point, and an electric signal is produced as a result of this comparison. The signal is proportional to the amount of raise required to bring the rail at the work station up to a position where it is in the same plane as the track behind the work station and the track at the higher forward reference point. In other words, after raising the track at the work station, it is in the same plane as the rear reference point, and this plane is aligned with the higher forward point. When necessary, cross leveling of the other rail of the track is also carried out by raising the rail.

The cross level sensing device is included in the surfacing system at the work station to determine the position of the cross level rail relative to the reference rail. The cross level sensing device transmits an electric signal which is proportional to the angular deviation of the cross level rail from a predetermined plane. The cross level rail is then raised by an amount indicated by the signal emanating from the cross level device.

The machine is then moved forward until a comparison of the reference points indicates that it is again necessary to raise the track at the work station. In the surfacing system, the reference rail and cross level sensing devices are coupled to a device for actuating track raising jacks, and rapid and accurate track elevation is achieved.

The apparatus of our invention includes a plurality of pivotally connected rigid members which form chords extending along the track. Variable electric resistors are attached between adjacent members, and the direction and degree of angular displacement between the members are sensed by the variable resistors. The changes in electrical resistance caused by angular displacement influence control circuits to move the track or make a record of track condition. Our invention permits automatic measurement of track condition and automatic machine control, and an increase in speed and accuracy and less expensive lining operation are achieved.

In the accompanying drawings, we have shown preferred embodiments of our invention in which:

FIG. 1 is a schematic view of apparatus for measuring alignment in combination with a track lining machine;

FIG. 2 is a schematic view of apparatus similar to that shown in FIG. 1 but having a pair of measuring beams;

FIG. 3 is a bridge circuit for operating a lining machine in accordance with a smooth track line;

FIG. 4 is a perspective view of a control panel for use with the circuit of FIG. 3;

FIG. 5 is a plan view of a portion of a strip chart with a graphical representation of a section of uncorrected curved track and a representative smooth track line;

FIG. 6 is a perspective view of a device for automatically recording track alignment;

FIG. 7 is a bridge circuit for use with the device of FIG. 6;

FIG. 8 is a schematic plan view of a modification according to our invention;

FIG. 9 is an electric control circuit for use with the measuring apparatus shown in FIG. 8;

FIGS. 10*a*, 10 *b* and 10*c* are diagrammatic illustrations of the operation of the apparatus shown in FIG. 8;

FIG. 11 is a plan view of a combination lining and surfacing machine;

FIG. 12 is an elevation of the machine shown in FIG. 11;

FIG. 13 is an electric control circuit for use with the surfacing apparatus of FIGS. 11 and 12;

FIG. 14 is a modification of a cross level measuring apparatus according to our invention;

FIG. 15 is another embodiment of a modified cross level measuring apparatus according to our invention; and

FIG. 16 is an electric control circuit for use with the modified apparatus of FIGS. 14 and 15.

Referring to FIG. 1 of the drawings, a lining machine 1 having flanged wheels 2 and standard equipment shown schematically at 3 and 4 for providing power to the various components on the machine and for moving the machine along the track is shown in combination with apparatus for measuring track alignment. Movement of the machine along rails RR and RL is in the direction of the arrow. Scissors-type rail clamping members 5 are carried at the forward end of the machine by a laterally movable crossbar 6 which is pivotally attached to the lower ends of spaced hanger members 7. The upper end of each member 7 is pivotally attached to a crosshead 8 which is supported on the machine by cantilever members 9. Clamps 5, crossbar 6 and members 7 may be pivoted in an arc about the upper ends of members 7 by movement of the rods of lining cylinders 10 and 11 whose rod ends abut the outer ends of crossbar 6. The lining cylinders are mounted on arms 12 and 13 which project outwardly from the machine frame and extension of one of the cylinder rods shifts the crossbar and clamps away from that cylinder. A second pair of cylinders 14 and 15 is carried by the crossbar, and the rods of these cylinders are connected to clamps 5 so that extension of the rods closes the clamps about the heads of the rails to clamp the lining machine to the rails. Jacking cylinders 16 and 17 for raising the track from the ballast are mounted on the outer ends of arms 12 and 13.

The apparatus for determining track alignment shown in FIG. 1 includes an elongated rear cart 20, a forward cart 21 and a beam 22 extending between carts 20 and 21. Cart 20 is connected to the lining machine by a push rod 23 having universal joints 24 and its ends and consists of a frame portion 25, a forward portion 26 and a connector 27. These members are welded together so that the cart is rigid in both the vertical and horizontal planes. The cart is mounted on flanged wheels 28 which ride on the track rails. Forward cart 21 includes a frame 40 carrying rail wheels 41. The rear end of beam 22 is supported on member 26 midway of the rails, and the forward end of beam 22 is supported on cart 21 at the center line of the reference rail. The reference rail is the outside or high rail on curved track since this is the rail contacted by the train wheels. The wheels of cart 21 are firmly biased against the reference rail by mechanical means such as air cylinder 36 in a well known manner. Other means, such as springs or levers, may also be used to bias the cart wheels against the reference rail. A biasing arrangement may also be used on cart 20, and it is preferred to utilize a pair of air cylinders (not shown) extending between cart 20 and lining machine 1 to bias the cart wheels 28 against the reference rail.

Beam 22 carries mounting sockets 50 at its ends which cooperate with pins 51 on the carts to permit angular movement between he beam and the carts in a plane substantially parallel to the plane of the track. A potentiometer P1, having a sufficient stroke to span the desired range of deflection angles, is connected between beam 22 and cart 20. The output of this potentiometer is determined by the deviation of cart 20 and beam 22 from a predetermined relationship. Potentiometer P1 is electrically connected in the bridge circuit shown in FIG. 3. Cart 20 and beam 22 are considered as being in alignment when carts 20 and 21 are on straight track, and in this condition, the output from potentiometer P1 is zero and the bridge circuit is balanced.

The bridge circuit shown in FIG. 3 includes potentiometer P1 and a pair of variable resistances R and R′ in series therewith for calibrating the circuit. The circuit also includes a potentiometer P2 in series with fixed resistances R1 and R2 which is adjustable to null the output and balance the circuit. Potentiometer P2 has a calibrated adjustment knob K mounted on control panel P as shown in FIG. 4. Knob K is marked to indicate degrees of track curvature. An amplifier A1 is connected between potentiometers P1 and P2 and in series with a meter M and a fixed resistance R3. When lining, the amplifier is connected to relays B and C which control lining cylinders 10 and 11 respectively to shift crossbar 6 and clamps 5 and thereby shift the track laterally. Clamping cylinders 14 and 15 and jacking cylinders 16 and 17 are energized prior to the energization of a lining cylinder by their respective control systems (not shown). When the apparatus is measuring track alignment, amplifier A1 and relays B and C are disconnected from the circuit, and the circuit operates in the manner set forth immediately hereinafter.

As the measuring apparatus travels over curved track, angular deviation of cart 20 and beam 22 from the predetermined relationship occurs and shifts the slider of potentiometer P1 to produce an electrical output in phase and amount in proportion to the displacement. The bridge circuit becomes unbalanced and the slider of potentiometer P2 may be rotated manually by knob K to null the output and rebalance the bridge at which point a zero reading appears on meter M. The amount of rotation necessary to rebalance the bridge may be determined from the calibrations on knob K of potentiometer P2 when meter M reads zero. The value read from knob K indicates the degree of curvature of the track, as indicated by the relative positions of beam 22 and cart 20, and sequential values are used to plot a series of points which are connected to graphically represent the unlined track condition for subsequent use in lining the section of track under considerations.

An example of a record of the alignment of a section of curved track is shown in FIG. 5 and is obtained in the following manner. Forward cart 21 enters the section under consideration, and the chord defined by beam 22 is displaced from its original relationship with cart 20. The slider of potentiometer P1 is displaced in phase and amount proportional to the extent of the misalignment. Displacement of the slider unbalances the bridge circuit, and when switch S on panel P is in the "on" position, a reading is shown on meter M indicating that the circuit is unbalanced. The machine operator moves the slider of potentiometer P2 by knob K until the output is nulled and meter M indicates that the bridge circuit is rebalanced. The value on knob K, when the bridge is rebalanced, indicates the degree of track curvature as measured by the angular displacement of the beam relative to the car at the particular point on the track under consideration. The operator then enters the value on a chart similar to that shown in FIG. 5 of the drawings which is divided into work stations along its horizontal axis or abscissa and into degrees of angularity along its vertical axis or ordinate. As the measuring apparatus proceeds along the curved section of track under consideration, a value is determined in the above manner at successive stations for the full length of the section to be lined. After a point has been entered on the chart for each station, a line is drawn between successive points as indicated by line L1 in FIG. 5. A hand drawn best fit curve, designated L2 in FIG. 5, is then drawn through line L1, and this hand drawn curve represents the curve for smooth track and is used to line the track section.

When the section of track represented by line L1 in FIG. 5 is to be lined, amplifier A1 and relays B and C are connected in the circuit in the manner shown in FIG. 3 by a switch (not shown). The machine is positioned with clamps 5 at the first work station represented on the chart, and the operator reads the value of curve L2 for that work station from the vertical scale of the chart and adjusts the slider of potentiometer P2 to that value by rotating knob K. Adjustment of potentiometer P2 unbalances the circuit and actuates amplifier A1 to energize one of relays B or C which in turn actuates the corresponding lining cylinder to shift the track. When the track has moved the proper amount, the slider of potentiometer P1 will be at a new position, and the bridge circuit is balanced and amplifier A1 deenergizes the energized relay to deactuate the lining cylinder. The lining machine then proceeds along the track to successive work stations where the above operation is repeated to line the track throughout the section represented by curves L1 and L2.

It is within the scope of our invention to record track alignment automatically without hand plotting each point and drawing line L1 through successive points. Apparatus for automatic recording is shown in FIGS. 6 and 7. In FIG. 6 a recording device is shown by which a continuous line 64 representing unlined track condition is automatically drawn on a strip chart 62 by a pen 60. The apparatus for drawing line 64 includes a recorder 61, carrying pen 60, drive means for moving the pen and strip chart 62. Chart 62 is scaled in the same manner as the chart in FIG. 5 and is moved beneath the pen in accordance with the movement of the vehicle along the track by drive gears having circumferential teeth spaced to cooperate with perforations 63*a* and 63*b* in opposite edges of chart 62. The drive gears are driven in synchronism by an electric stepping motor (not shown) within recorder 61 which is responsive to electric pulses generated by a reed switch 65. Switch 65 is actuated by a magnet (not shown) on idler wheel 66 and generates a pulse for each complete rotation of the idler wheel. Idler wheel 66 is shown in frictional contact with a wheel 28 of cart 20, but it is to be understood that it may also be in direct contact with the railhead. The electric stepping motor advances the drive gears to move chart 62 beneath the pen according to the movement of cart 20 along the track. While the movement of the chart has been described in connection with an electric motor and reed switch 65, the chart may be driven through other means such as a mechanical linkage connecting idler wheel 66 with the drive gears.

Movement of pen 60 transversely of chart 62 is controlled by the circuit of FIG. 7, which is basically the same as the circuit of FIG. 3, except that the amplifier energizes a servomotor 69 instead of a relay. The circuit includes calibration resistors R and R′ and fixed resistors R1, R2 and R3. The signal from potentiometer P1, which responds to the angular displacement of cart 20 and beam 22, operates amplifier A2 which energizes servomotor 69. The servomotor is mechanically connected with the slider of a potentiometer P4 and moves the slider to balance the bridge circuit. The servomotor is also mechanically connected with the drive mechanism for a rotatable shaft 68. A pen mounting head 67 is threaded engagement with shaft 68 which extends transversely of chart 62

so that rotation of the shaft moves head 67 and lateral movement of the pen relative to chart 62 corresponds with the movement of the slider of potentiometer P4 to balance the bridge circuit. By this arrangement, line 64 indicating track alignment is automatically recorded on chart 62 as the measuring machine proceeds along the track. A best fit curve is hand drawn through line 64 on chart 62, and the track is lined to the best fit curve by means of the lining machine and control arrangement explained above.

The automatic method of drawing line 64 in FIG. 6 has advantages over the hand plotting of line L1 as the line may be drawn at a relatively high speed by an unskilled operator and is a more accurate representation of track condition than a hand plotted line. Due to the high speed with which line 64 can be drawn by the arrangement shown in FIGS. 6 and 7, a single measuring vehicle may travel along the track and create a graph of track condition which may subsequently be divided into a plurality of individual charts for use with a number of independent lining machines to simultaneously line different sections of track.

In lining with our mechanism the reference point at the forward end of cart 20 is the work station reference point, the point behind the work station is on corrected track, and the point ahead of the work station is on uncorrected track. If the track at the work station is shifted or thrown by an amount which would theoretically bring the work station into coincidence with the smooth track line as drawn on the chart, the track at the work station will actually be in error by an amount determined by the position of the track at the forward point, and the error will be a proportion of the offset distance between the uncorrected and smooth track lines at the forward point. This proportion is the ratio of the distance between the work station and the rear point to the distance between the rear and forward points. This error is of little consequence on tangent track and on relatively flat curves in low-speed track. The error will also have little significance if only a small throw is required at the work station to shift the track into a theoretically smooth condition. However, the error becomes important when either the track curvature or the offset distance at the forward point is great and/or the track is to be used by high-speed trains.

In order to compensate for this error, we have determined that the amount of throw at the work station indicated by the difference between the smooth track line on the chart and the uncorrected track line on the chart must be corrected. The extent of the correction is determined by the relative lengths of the chords (the rear cart and the beam), the difference between the uncorrected track line (L1 in FIG. 5) and the smooth track curve (L2 in FIG. 5) at the forward point and the location of the uncorrected track line relative to the smooth track line at the forward reference point. Thus, the amount of throw indicated on the graph by the displacement between the uncorrected line and the smooth track line at the work station is adjusted by a factor equal to the difference between the uncorrected line and the smooth track line at the forward reference point multiplied by the ratio of the rear chord length to the total length of both chords. The correction to be made to the throw at the work station as indicated on the graph is opposite directionally and equal to the above ratio of error produced by the forward reference point being on the uncorrected line. Of course, if the uncorrected and the smooth track lines are coincident at the forward point, no adjustment of the throw is necessary.

Our invention may also be embodied in the modified arrangement shown in FIG. 8 of the drawings in which the rear cart 20, cart 21 and beam 22 are identical with the corresponding parts in FIG. 1, and like parts are indicated by like reference numerals. The embodiment of FIG. 8 includes a second beam supporting cart 70 and a second beam 80 extending between cart 70 and cart 21. Cart 70 has a frame 71 and flanged wheels 72 and carries biasing means 36 identical with those on cart 21. Beam 80 is pivotally supported on the cart by a pin which receives a socket 50 on the end of the beam. The beam forms a third chord and provides an additional forward reference point which results in greater measuring accuracy. Forward beam **80** is attached to cart **21** at pivot pin **51** so that beams **22** and **80** may be displaced angularly relative to each other, and a potentiometer **P5** is located at the beam joint for response to changes in the angular relationship of the beams. The three chord embodiment of FIG. **8** is shown without the lining machine, as described in connection with FIG. **1**, and the explanation of FIGS. **9**, **10***a*, **10***b* and **10***c* assumes that a lining machine is operated in connection with the three chord measuring apparatus.

The electric circuit used with the embodiment of FIG. **8** to control a lining machine is shown in FIG. **9** of the drawings. The circuit operates in the same manner as the circuit of FIG. **3**, insofar as meter **M**, amplifier **A1**, potentiometers **P1** and **P2** and resistances **R**, **R'**, **R1**, **R2** and **R3** and relays **B** and **C** are concerned, and like parts are indicated by like reference letters and numerals. Potentiometer **P5** is included in the circuit, and fixed resistance **R5** is selected to have twice the resistance of **R3** so that the current outputs from potentiometers **P1** and **P5** are reduced by the proportion of **P1**/$_1$ to **P5**/$_2$.

The resistance of fixed resistance **R5** is twice the value of **R3** since beams **22** and **80** are of equal length. Where other length relationships between the two forward beams are used, the resistances R3 and R5 will be proportioned in accordance with the beam lengths and the reduction in the potentiometer outputs will be determined by the value of the resistances. The outputs of the potentiometers are added algebraically as they enter meter **M** and amplifier **A1**.

The operation of the three chord system is shown diagrammatically in FIGS. **10***a*, **10***b* and **10***c*. FIG. **10***a* shows the system with all of the chords in a preset condition as on straight track. When the chords are in this condition, the potentiometers **P1** and **P5** are calibrated to balance the circuit since the deviation of the chords is zero and no output is produced. In FIG. **10***b* points **120**, **121** and **123** are in alignment and point **122** is misaligned. Chords **22** and **80** form a triangle with a hypothetical line which is coincident with the reference rail. Angle **124** is equal to angle **126**, and angle **125** is twice the amount of either angle **124** or angle **126**. The output of potentiometer **P5** (at **122**) is, therefore, twice the output of potentiometer **P1** (at **121**) and is of opposite polarity since the angles are in opposite directions. As a result of the resistances **R3** and **R5**, the outputs of the potentiometers are reduced by a ratio of **P1**/$_1$ to **P5**/$_2$, and by adding the resulting outputs, they will cancel due to the opposite polarity and thus indicate that the track at the point **121** is in alignment with the track at points **120** and **123**. It is immaterial where point **122** is located laterally so long as it is within the measuring range of the potentiometers used in the system. For this reason, the forward reference point at cart **70** may be located as far ahead of the working station as is necessary to obtain the accuracy desired. FIG. **10***c* shows a situation wherein reference point **121** is out of alignment with points **120** and **122**. Angle **124** is considerably greater than one-half of angle **125** so that, in this case, summation of the outputs of potentiometers **P1** and **P5** at **121** and **122** will indicate on meter **M** and amplifier is unbalanced, and the system will respond to the difference in outputs.

The three chord embodiment may be used to obtain points and to plot a line graphically representing the uncorrected track condition, or a line representing this condition may be automatically recorded by replacing the relays **B** and **C** in FIG. **9** with a servomotor driving a pen as in FIG. **7**. A manually plotted line will be created in the manner explained in connection with the embodiment of FIGS. **4** and **5**.

The combination lining and surfacing embodiment of our invention is shown in FIGS. **11** and **12**. In this embodiment, many of the parts are identical with the apparatus shown in FIGS. **1** and **8**, and like reference numerals are used with like parts. As stated heretofore, the surfacing apparatus and method are basically the same as those disclosed in U.S. Pat. No. 3,212,451. However in the apparatus disclosed in the patent, the rear chordal members pass over the rails through the tamper. This arrangement is acceptable for surfacing only, but cannot be used for lining since the members passing through the machine cannot have both vertical and lateral stiffness as well as free travel to permit them to function as rigid chords for both surfacing and lining.

The arrangement shown in FIGS. **11** and **12** makes it possible to both line and surface with the same equipment. In the combination machine, a four-point system is used. Cart **20** is located beneath the combination track shifting and lifting machine **130**, and connecting member **27** extends forwardly from frame **25** between two groups of tamping tools **131** which are located over rails **RL** and **RR**. Each group of tamping tools consists of a plurality of individual tamping spades **132**. This construction of cart **20** makes it possible for the cart which forms the rear chordal member to be located beneath machine **130** and permits both lateral and vertical movement thereof. Beam **22** extends between cart **20** and forward cart **21**, and beam **80** extends between cart **21** and forward cart **70**. Potentiometer **P6** is mounted at the junction of cart **20** and beam **22**, and potentiometer **P7** is mounted at the junction of beams **22** and **80**. These potentiometers measure the angular deviation in the vertical direction and are used in surfacing. A cross level pendulum-type potentiometer **PP** is mounted on member **26** for determination of the relative heights of the reference rail and the cross level rail. Potentiometers **PP**, **P6** and **P7** are connected in the control circuit shown in FIG. **13**.

Since the rear end of beam **22** is positioned on the lateral center of cart **20**, errors in the surfacing rail (grade rail) measuring system result from the arrangement shown in FIGS. **11** and **12**. The error results because the junction of cart **20** and beam **22** is shifted vertically by an amount equal to only one-half of the amount by which the level of the cross level rail deviates from the level of the grade rail, and the grade rail reading will be in error by this amount since potentiometer **P6** is located midway of the rails at the junction of members **20** and **22**. Compensation for the error in grade rail measurement is made by the electrical circuit shown in FIG. **13** in the manner described hereinafter.

The circuit shown in FIG. **13** is composed of a cross level bridge circuit **133** and a surfacing bridge circuit **134** connected electrically by leads **164** and **165**. Circuit **134** is generally the same as that shown in FIG. **15** of Pat. No. 3,232,451, and circuit **133** is generally the same as that shown in FIG. **16** of the patent, and reference to the patent may be had for an explanation of the operation of the individual circuits. Since potentiometer **P6** is located midway of the track rails, the signal obtained from **P6** will be the summation of two variables; the surface irregularities and the cross level error. To correct the error in the signal from **P6** that is, remove the cross level signal and leave only the surfacing signal, a portion of the output of the cross level bridge circuit **133** is introduced into amplifier **A10** in circuit **134** with such polarity that, for example, a "low" cross level signal will be subtracted from the signal indicating the amount of raise required to place the grade rail in the desired smooth condition. The output from amplifier **A10** controls relay **D** to cause the surfacing jack to function.

In FIG. **13**, the output of cross level bridge circuit **133** is in phase and proportion to the measuring error which occurs at potentiometer **P6** due to the point being located midway of the track rails since the signal from **P6** is caused by the out-of-level condition. Resistors **135** and **136** are of such values that a fixed amount of the current flowing from the unbalanced cross level bridge circuit is supplied to grade rail amplifier **A10** in bridge circuit **134**. The amount and phase of the current supplied from circuit **133** to amplifier **A10** nullifies the false signal in the amplifier, and jacking of the grade rail is controlled in accordance with the corrected signal.

The embodiment of FIG. **2** has two parallel sensing beams **22R** and **22L** located directly over the track rails. This arrangement is an improvement over the arrangement of FIG. **1** wherein a single beam extends from the center of cart **20** diagonally to cart **21** since there is no interaction between the measured values for surface and level. The alternative arrangement of FIG. **2** requires a pair of pivot mechanisms **170R** and **170L** to receive beam sockets **50R** and **50L**. It should be understood that only the beam over the grade rail is connected into the electric circuit in the embodiment of FIG. **2**, and the circuit of FIG. **3** is used.

The combination machine makes it possible to simultaneously perform both surfacing and lining on a section of track. This is economical and rapid as a single machine can cover a long section of track in a shorter time and at less cost than when the surfacing and lining operations are carried out independently.

A modification which may be included in the combination lining and surfacing machine is an improved sensing device for more accurately determining cross level. This device is added to cart **20**, and one embodiment thereof is shown in FIG. **14** of the drawings. The reason for this modification is that the cross level measuring potentiometer PP is mounted on member **26** of cart **20** in the arrangement of FIGS. **11** and **12**, and since this potentiometer is gravity responsive, it reacts to any force within its operating plane including vibration and lateral lining movements. Reaction to these forces develops false out-of-level outputs in the potentiometer.

In the embodiment shown in FIG. **14**, a gravity responsive cross level potentiometer PP is located on the rear of cart **20** which is the most stable point in the system since it is located on level track. A torque rod **160** is connected to the frame of cart **20** near potentiometer PP and runs longitudinally of the cart to a bearing **161** carried on crossmember **26**. A potentiometer **162** is pivotally connected between a torque arm **167** on rod **160** and a lug **163** fixed on the end of crossmember **26**. The torque rod senses the twist imparted to cart **20** when the forward wheels **28** are located on nonlevel track, and the rear wheels are located on level or nearly level track and move the slider of potentiometer **162**. The summation of the twist, as determined by potentiometer **162**, and the rear axle level error, as measured by potentiometer PP, is analogous to the out-of-level measurement of the track at the front axle of cart **20** which is the work point.

FIG. **15** shows an alternative arrangement for accurately determining cross level. In this embodiment, cart **20** includes a bearing-pivot arrangement which permits the total amount of cart twist to occur at one point. Thus, the twist occurs at the bearing rather than along the length of torsional member **27**. In the embodiment of FIG. **15**, member **27** is altered by affixing a stub shaft **180** to its forward end, and the crossmember **26** is pivotally attached to the stub shaft by a bearing **181**. Crossmember **26** is free to rotate due to cart twist with all displacement taking place at the bearing. The torque arm **167** is attached to member **27** adjacent to stub shaft **180**, and potentiometer **162** extends between the torque arm and lug **163** which is attached to crossmember **26**. The embodiment of FIG. **15** operates in the same manner as the embodiment of FIG. **14**.

FIG. **16** is a schematic diagram of a bridge circuit including twist potentiometer **162** and pendulum potentiometer PP. This bridge circuit may be substituted for the cross level measuring and control circuit **133** in FIG. **13** when an increase in accuracy is desired, and the modification of FIG. **14** or FIG. **15** is included in the system.

In utilizing our novel method and apparatus, it is necessary to determine the location of the work station at which alignment is to be initiated and at which successive track shifts are to occur. The principal work stations will be marked along the track, and we have found that either paint markings for visual positioning or magnetic markings on the rail for automatic positioning may be utilized. When magnetic markings are used, they may be placed on the rails and read in the manner disclosed in U.S. Pat. No. 3,362,348, issued Jan. 9, 1968, and assigned to the assignee of the present application.

Although our track alignment measuring method has been described as being capable of forming a record on a strip chart, it is contemplated that the output from the measuring bridge circuit may also be punched or magnetically recorded on tape. By recording in this manner, it is possible to transmit the information directly to a central station where it can be interpreted manually, or by data processing means and a mathematical solution for theoretically completely smooth track can be made. The solution can then be furnished to the operator of a lining vehicle or supplied directly to the machine for automatic control thereof. It is also within the scope of our invention to provide a lining machine with the necessary data processing equipment to compute the best fit curve from the unlined track information.

While we have shown and described preferred embodiments of our invention, it is to be understood that it may be embodied within the scope of the appended claims.

We claim:

1. In combination with a track shifting machine, the improvement comprising apparatus for measuring lateral track alignment, said apparatus including an elongated cart on the track and attached to said track machine for movement therewith along the track, a forward cart located on the track ahead of said elongated cart and spaced therefrom, a rigid elongated beam extending between the forward end of said elongated cart and said forward cart and means pivotally connecting said beam to both of said carts to permit relative angular displacement between said elongated cart and said beam in a plane substantially parallel to the track in accordance with the alignment of the track, a first variable electric resistance means attached between said beam and the forward end of said elongated cart so that the electric resistance varies in accordance with angular displacement in the plane parallel to the track, a bridge circuit including said first variable resistance means and means responsive to a current change caused by a variation in the resistance of said first variable resistance means, said circuit being balanced when said elongated cart and said beam are located in a predetermined relationship and becoming unbalanced upon angular deviation of said elongated cart and said beam from said predetermined relationship which varies the resistance of said first variable resistance means, whereby unbalancing of said circuit causes a signal to pass to said means responsive to a current change to actuate said means.

2. Apparatus as set forth in claim **1** wherein said track machine includes means for shifting the track laterally and said means responsive to a current change is an amplifier, a pair of relays electrically connected to said amplifier and operatively connected to said means for shifting track, whereby upon receiving a signal said amplifier energizes one of said relays in accordance with the phase of said signal to actuate said track shifting means to move said track laterally until said predetermined relationship between said elongated cart and said beam is established at which point said circuit is rebalanced and said amplifier is deactuated to deenergize said energized relay and stop the operation of said track shifting means.

3. Apparatus as set forth in claim **1** wherein said means responsive to a current change is a meter and said circuit includes an adjustable resistance means, said meter being connected in said circuit between said first variable resistance means and said adjustable resistance means, whereby current passes to said meter when the resistance of said first variable resistance means varies due to angular displacement of said beam relative to said elongated cart and said meter deviates from a neutral setting in accordance with the magnitude and phase of the current, and a calibrated knob attached to said adjustable resistance means for adjusting said adjustable resistance means to rebalance said circuit and return said meter to said neutral setting, whereby the amount of adjustment required to rebalance said circuit may be determined from said calibrated knob.

4. Apparatus as set forth in claim **1** wherein said means pivotally mounting said beam on said elongated cart also permits relative movement between said carts in a plane substan-

tially perpendicular to a plane including the track caused by deviation of the track from a smooth condition, means to sense movement of said beam relative to said cart in said substantially perpendicular plane caused by nonsmooth track, and means for raising the track until it is in a smooth condition.

5. Apparatus as set forth in claim 1 wherein said rigid elongated beam extending between said elongated cart and said forward cart is located over one rail of said track, said apparatus including a second rigid elongated beam extending between the forward end of said elongated cart and said forward cart and located over the other rail of said track, means pivotally connecting said second beam to both of said carts to permit relative angular displacement between said elongated cart and said second beam in a plane substantially parallel to the track, a variable electric resistance means attached between said second elongated beam and the forward end of said elongated cart, whereby the variable electric resistance means connected with the elongated beam located over the grade rail is connected into said bridge circuit so that said means responsive to current is actuated by angular displacement between said elongated cart and the beam located over the grade rail.

6. Apparatus as set forth in claim 1 including a second forward cart on said track ahead of said forward cart, a second rigid beam extending between said forward carts and means pivotally connecting said second beam to both of said carts to permit relative movement between said forward carts in a plane substantially parallel to the track in response to angular deviation between said beams caused by the lateral condition of the track beneath said forward carts, a second variable electric resistance means attached between said beams and connected in said circuit, said second variable resistance means responsive to angular deviation of said beams form a predetermined relationship in a plane substantially parallel to the track, whereby a change in current in said circuit is created by a variation in the resistance of said second variable resistance means, and means in said circuit to proportion the current created by variations in said first and second variable resistance means, whereby angular deviation of said beams from said predetermined relationship changes the resistance of said second variable resistance means to unbalance the bridge circuit and causes a signal to pass to said means responsive to current to actuate said means.

7. Apparatus as set forth in claim 6 wherein said circuit includes an adjustable resistance means and wherein said means responsive to current change is a meter, said meter being connected in said circuit between said first and second variable resistance means and said adjustable resistance means, whereby current passes to said meter upon variation of said first and second variable resistance means to unbalance said circuit and causes said meter to deviate from a neutral position in accordance with the magnitude and phase of said current, and a calibrated knob attached to said adjustable resistance means for adjusting said adjustable resistance means to rebalance said circuit and return said meter to said neutral position, whereby the adjustment required to rebalance said circuit may be determined from said calibrated knob.

8. Apparatus as set forth in claim 6 wherein said means pivotally mounting said beams on said carts also permits relative movement between said carts in a plane substantially perpendicular to said track in response to the surface condition of said track, first variable resistor sensing means connected between said first beam and said elongated cart and second variable resistor sensing means connected between said first and second beams to indicate relative vertical angularity between said first beam and said cart and between said first and second beams, a bridge circuit including said first and second resistor sensing means and means in said circuit responsive to current caused by variations in the resistance of said first and second sensing means, said circuit being balanced when carts are located in a predetermined relationship and becoming unbalanced upon angular deviation of said cart and said beams in a vertical plane from said predetermined relationship which changes the resistance of said resistors, whereby unbalancing of said circuit causes a signal to pass to said means responsive to current to actuate said means.

9. Apparatus as set forth in claim 8 wherein said track machine includes means for raising the track and wherein said means responsive to current is an amplifier, a relay connected to said amplifier and operatively connected to said means for raising the track, whereby said amplifier energizes said relay upon receiving a signal in accordance with the magnitude of said signal to actuate said track raising means and raise said track until said predetermined relationship between said cart and said beams is established at which point said circuit is rebalanced and said amplifier is deactuated to deenergize said relay and stop the operation of said track raising means.

10. Apparatus as set forth in claim 9 including a cross level sensing variable resistor at the forward end of said elongated cart responsive to the lateral slope of said cart caused by the relative heights of the grade rail and cross level rail, a bridge circuit including said cross level sensing resistor and having means responsive to current caused by a variation in the resistance of said cross level sensing resistor, said circuit being balanced when said cross level sensing resistor indicates a predetermined relationship between said grade rail and said cross level rail and becoming unbalanced upon deviation of said rails from said predetermined relationship which varies the resistance of said cross level sensing resistor causing a signal to pass to said means responsive to current to actuate said means.

11. Apparatus as set forth in claim 9 including a cross level sensing variable resistor at the rear end of said elongated cart, a twist potentiometer at the forward end of said elongated cart responsive to the relative height of the grade rail and cross level rail, a torque rod having one end attached to the frame of said elongated cart adjacent said cross level sensing variable resistor and the other end operatively connected with said twist potentiometer, and a bridge circuit including said cross level sensing resistor and said twist potentiometer and means responsive to current caused by a variation in the resistance of said cross level sensing resistor and said twist potentiometer, said circuit being balanced when said cross level sensing resistor and said twist potentiometer indicate a predetermined relationship between said grade rail and said cross level rail and being unbalanced upon deviation of said rails from said predetermined relationship which varies the resistance of said cross level sensing resistor and said twist potentiometer causing a signal to pass to said means responsive to current to actuate said means.

12. Apparatus for measuring railroad track alignment comprising an elongated cart, a forward cart spaced along the track from said elongated cart, a rigid beam extending between the forward end of said elongated cart and said forward cart and means pivotally attaching said beam to said carts to permit relative angular displacement between said elongated cart and said beam in a plane substantially parallel to said track in accordance with the lateral alignment of said track, a first variable electric resistor attached between said beam and said elongated cart so that the resistance varies in accordance with angular displacement in the plane parallel to the track, said resistor being electrically connected in a bridge circuit with an adjustable resistance means and an amplifier, said amplifier being responsive to current caused by a change in the resistance of said variable resistor, means responsive to a signal generated by said amplifier, mechanical means connecting said signal responsive means and said adjustable resistance for adjusting said resistance in accordance with a signal, a pen connected to said mechanical means, means on said elongated cart for supporting a chart beneath said pen for movement in a direction parallel to the direction of movement of said carts and at a rate determined by the rate of travel of said carts along the track and a chart carried on said supporting means, whereby variation is said first variable resistor

caused by angular displacement between said elongated cart and said beam unbalances said circuit permitting current to pass to said amplifier to generate a signal actuating said signal responsive means to actuate said mechanical means to move said pen relative to said chart and to simultaneously adjust said adjustable resistance to rebalance said circuit.

13. Apparatus as set forth in claim **12** wherein said chart is formed with perforations along its longitudinal edges and wherein said supporting means includes drive gears with teeth spaced to cooperate with said perforations to move said chart, a motor connected to said gears, a pulse generating switch operatively connected to said motor, and an idler wheel for operating said switch, said idler wheel being in frictional contact with a wheel riding on a rail whereby rotation of said idler wheel by said wheel on the rail causes a pulse to pass from said switch to said motor to rotate said gears and move said chart beneath said pen.

14. Apparatus as set forth in claim **12** wherein said signal

responsive means for moving said pen and adjusting said adjustable resistance is a servomotor.

15. Apparatus as set forth in claim **12** including a second forward cart spaced along the track from said first forward cart, a second rigid beam extending between said forward carts and means pivotally attaching said second beam to said forward carts, a second variable electrical resistor attached between said beams and included in said circuit, means in said circuit to proportion the currents created by variations in said first and second variable resistors, whereby deviation of said second beam from a predetermined relation unbalances said circuit causing current to pass to said current proportioning means and to said amplifier and causing said amplifier to provide a signal to said signal responsive means in accordance with the deviation of both of said beams to move said pen relative to said chart and to adjust said adjustable resistance to rebalance said circuit.

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,604,359 Dated September 14, 1971

Inventor(s) Richard B. Doorley and Paul S. Settle, Jr.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 2 Line 52 after --forward-- insert --reference--. Column 3 Line 69 --and its ends-- should read --at its ends--. Column 4 Line 14 --he-- should read --the--. Column 5 Line 74 --is threaded-- should read --is in threaded--. Column 7 Line 8 after --machine,-- insert --but it is to be understood that it may be used with a lining machine,--. Column 7 Line 58 after --amplifier-- insert --A1 that the circuit--. Claim 8 - Column 11 Line 73 --second sensing means,-- should read --second resistor sensing means,--. Claim 8 - Column 11 Line 74 --when carts-- should read --when said carts--. Claim 11 - Column 12 Line 39 after --twist potentiometer-- insert --whereby said torque rod transmits the twist of the cart frame to the twist potentiometer,--.

Signed and sealed this 14th day of March 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents