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(54) SINGLE BEAM REFERENCE SYSTEM FOR RAILWAY SURVEYING

(71) We, CANRON CORP., a company organized and existing under the laws of the State of New York, United States of America, whose address is c/o Sullivan and Cromwell, 48 Wall Street, New York, New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to railroad track surveying apparatus.

In Canadian Patent No. 762,044 to John Stewart and Helmuth R.E. von Beckmann issued June 27, 1967 there is described a railway track surveying apparatus comprising a light frequency beam transmitter mounted for movement along a track and for transmitting a light frequency beam substantially longitudinally of the track. A pair of beam receivers are provided, one for each rail of the track, mounted for movement along the track in spaced relationship to the transmitter within the transmitted beam, a shadowboard for each receiver is mounted for movement along the track and located intermediate the transmitter and receivers and substantially nearer to the receivers than to the transmitter, means is provided for adjusting the vertical height of the receivers, controlled by a gravity sensing means, so that the vertical height of a selected one of the receivers may be adjusted to maintain the receivers in cross level relative to the grade rail.

The present invention is concerned with improvements in systems of this type.

According to one aspect of the present invention there is provided railway track adjusting apparatus comprising means for establishing a reference line extending longitudinally of and above a railway track between leading and trailing track-surveying stations at a fixed position transversely of the track, means for determining vertical deviations in the track relatively to the reference line at a surveying station intermediate the leading and trailing stations, track adjusting tools for adjusting the track at the intermediate station, means for measuring the cross level of the track at the leading station and control means having respective inputs for the determined vertical deviations, a reference cross level at the leading station and a transverse position of a datum line which extends longitudinally of and in the plane of the track and an output connected to the tools for adjustment of the track to correct the determined vertical deviations and to adjust vertically the datum line at the intermediate station to a desired position with respect to a line extending between the trailing station and the higher rail relative to the reference cross level at the leading station.

The present invention also provides a method of adjusting a railway track, comprising the steps of establishing a reference line extending longitudinally of and above a railway track between leading and trailing track-surveying stations at a fixed position transversely of the track, advancing the stations along the track, determining vertical deviations in the track relatively to the reference line at an intermediate station as the leading and trailing stations are so advanced, measuring the cross level of the track at the leading station and adjusting the track at the intermediate station to compensate for the determined vertical deviations and adjust vertically a datum line at the intermediate station to a desired position with respect to a line extending between the trailing station and the higher rail relative to a reference cross level at the leading station, the datum line extending longitudinally of and in the plane of the track.

Preferably, the means for establishing a reference line comprise a beam transmitter at one of the leading and trailing stations and the means for determining vertical deviations comprise a beam receiver at the other one of the leading and trailing stations and a beam interference means arranged to vary the beam intensity at the receiver in correspondence with vertical deviations in the track relatively to the reference line at the intermediate station, an output of the receiver being connected to the respective input of the control means. Thus, the beam interference means may be mounted for movement along the track for following vertical deviations in the track level and intercepting at least a portion of the beam so as to vary the portion thereof received by the receiver.

Conveniently, the reference line is established substantially above the centre line of the track. The use of a single transmitter, a single receiver and a single beam interference means, conveniently a shadow board, substantially above the track centerline permits the use of the present apparatus in places where limited available space would prevent the use of prior devices.

The following is a description by way of example of an embodiment of the present invention being had to the accompanying drawings in which:

Figure 1 is a schematic perspective view of a surveying apparatus in accordance with the invention;

Figure 2 is a schematic side elevation showing a surveying apparatus associated with a track jacking and ballast tamping machine;

Figure 3 is a view along line III-III in Figure 2;

Figure 4 is a view along IV-IV in Figure 2;

Figure 5 is a view along V-V in Figure 2; and

Figure 6 is a schematic drawing of a control system, some elements of which are shown in Figures 1, 3, 4 and 5.

Referring to the drawings, and particularly to Figures 1 to 5, there is illustrated a railway track 10 with parallel rails 12 and 14. Mounted on the rails at a leading station A is an infra-red light transmitter 16 for transmitting a beam of infra-red light along the track. As illustrated most particularly in Figure 3, transmitter 16 is mounted on the top end of a standard 17 of a buggy 18 with flanged wheels 19 mounted on the rails 12 and 14 of track 10. The transmitter is located above an imaginary line 48 along track 10, midway between the rails 12 and 14 and intersecting with lines across the track on the tops of the rails. For the purposes of this specification, such a line may be referred to hereinafter as the track centerline. A pendulum 112 is mounted on the buggy 18 to generate a signal representing the cross level condition of the track at station A.

Spaced a distance "a" along the track from the transmitter 16 is a shadow board 20 mounted on the upper end of a frame 21 of a buggy 22 with flanged wheels 23 supporting it on rails 12 and 14. As can be seen most readily from Figure 4, the shadow board 20 is mounted on the top end of the frame 21 by an adjusting mechanism 25 that permits both vertical and side-to-side tilting adjustments of the board 20. This adjusting mechanism consists of a housing 35 mounted on the top of the frame 21, a jackscrew 34 projecting from the top housing 35 and threaded into a rotatable nut (not shown) within the housing. The nut is driven by an electric motor 98 (Figures 1 and 6). A cylindrical housing 36 is secured to the upper end of the jackscrew 34 and is prevented from rotating with respect to housing 35 by a lug 37 sliding in a mating slot in an arm 39 projecting upwardly from housing 35. Housing 36 carries an arm 38 which extends upwardly from the housing 36 to a position centrally above the housings 35 and 36 and the jackscrew 34. At that position, the arm 38 is pivotally connected to the center of the shadow board 20 by a pivot 40.

A further jackscrew 43 is threaded into the housing 36, concentrically with screw 34. This second screw is threaded through a rotating nut in housing 36 (not shown) where it is coupled to a drive mechanism (not shown). The upper end of the jackscrew 42 is fixed to an arm 44 which projects radially and upwardly to a position where it is pivotally and slidably connected to the shadow board 20 by a pivot pin 46. By driving the jackscrew 34, the entire assembly consisting of housing 36, arm 38, jackscrew 42, arm 44 and shadow board 20 is lifted and lowered along the axis 47 of the adjustment mechanism. As will be understood, lifting and lowering of the shadow board 20 is this fashion does not alter its lateral tilt, that is its side-to-side orientation with respect to horizontal. Tilting of the shadow board is achieved by means of the jackscrew 43 which, when extended or retracted, pivots the shadow board 20 clockwise or counter clockwise about the pin 40. This tilting adjustment is used to orient the shadow board 20 horizontally in passing through curves where one of the rails is super-elevated in relation to the other. This is illustrated in Figures 3, 4 and 5 where the left rail is super-elevated in relation to the right.

As illustrated in Figures 1 and 5, an infra-red receiver 24 is positioned at a station C, a distance "b" along the track from the location of the shadow board at station B. The receiver 24 is mounted on the top end of a standard 27 of a buggy 26. The buggy has flanged wheels 29 mounting it on the rails 12 and 14 for movement therealong. The receiver 24 is positioned above the centerline 48 of the track, as are the shadow board 20 and the transmitter 16.

Returning to Figure 1, there is a shaft 28 having one of its ends fixed to the buggy 22 at the intermediate station B and its other end coupled to a twist transducer 30 fixed to the buggy 26 at trailing station C. The transducer 30 is an inductive measuring feeler that measures the relative angular positions of the buggies to generate a signal representative of the difference between the track cross level conditions at the intermediate and trailing stations, B and C respectively. To determine the absolute cross level condition of the track at station C, the trailing buggy 26 carries a pendulum device 32 which produces a signal representative of the cross level condition at the trailing station C. As will hereinafter be discussed in somewhat greater detail, the signals from the pendulum 32 and the twist transducer 30 may be combined to determine the cross level at intermediate station B.

Figure 2 of the drawings illustrates the surveying apparatus associated with a track jacking and ballast tamping apparatus of known configuration. The jacking and tamping tools (not illustrated) are located adjacent the buggy 22 supporting the shadow board 20 as is normal in the art.

Figure 6 illustrates the control system for the apparatus. This will be described in conjunction with the operations that can be performed.

In operation, the quantity of the light transmitted by transmitter 16 that is received by the receiver 24 is represented by a signal produced by the receiver and supplied to an analog circuit 54 (Figure 6) to produce a voltage in a manner similar to that of previous apparatus. The light quantity and therefore the voltage vary with the vertical position of the shadow board 20 with respect to a reference line 15 (Figure 2) from the transmitter 16 to the receiver 24. Because the shadow board 20 is carried by the buggy 22 which rides on rails 12 and 14 to sense vertical deviations in the track levels, variations in its vertical position are representative of the vertical deviations of the track level at station B. Thus, the voltage from circuit 54 may be used to represent the vertical deviation (ΔL, Figure 2) of the actual track centerline 48 at station B from a datum centerline 49 from the front buggy 18 to rear buggy 26, parallel to reference line 15. If no deviation exists, then the voltage is zero. The direction of the deviation is given by the polarity of the voltage.

As will be apparent, adjustment of the shadow board 20 ensures that the measured deviations (ΔL) will have the proper value for the existing position of the track. To provide for vertical adjustment of the shadow board a manual switch (not shown) is used to operate a small electric motor 92 (Figure 6) to rotate a potentiometer 94 to produce a voltage representative of the desired vertical position of the shadow board relative to the track at station B. A lift dial 96 indicates this value.

The voltage from potentiometer 94 is used to adjust the shadow board. The adjustment is done by another electric motor 98 which is connected through a flexible shaft to the screw 34 of the shadow board 20. The motor 98 is connected to a potentiometer 100, to produce a voltage output representative of the actual position of the shadow board. This output is constantly compared with the voltage from potentiometer 94 in circuit 102. This latter voltage is supplied to circuit 102 via adder 110, the function of which will be subsequently described. The shadow board motor 98 is controlled by the output of circuit 102 so as to follow the desired adjustment.

When the apparatus is used in conjunction with a track jacking and ballast tamping machine (Figure 2) the station B, as previously noted is adjacent the position where the track level is to be corrected. The quantity ΔL therefore indicates the magnitude of the vertical correction to be made. The buggy 26 at station C rides on corrected track and the buggy 18 at station A is sufficiently far forward of station B that track errors at station A can be neglected and therefore, errors in the vertical height of transmitter 16 have an insignificant effect on the vertical position on the reference line 15 at station B.

The pendulum 32 on the buggy 26 delivers instantly and directly a voltage in accordance with the existing cross level condition to a filter and gain circuit 62 (Figure 6) which generates a voltage representing the cross level condition at station C (γ_C). At the exact horizontal cross level condition this voltage is zero. In other cases, the direction of super elevation will be indicated by the polarity.

Twist transducer 30 is an inductive measuring feeler. It is supplied with an AC voltage from generator 56. This voltage is modulated by the transducer and subsequently supplied to converter 58 where it is converted to a DC signal. This signal is adjusted by circuitry 60 to produce a voltage signal proportional to the twist of the track between stations B and (γ_B - γ_C). This may also be referred to as the difference between the track cross level conditions at stations B and C. Should there be no twist, then this voltage is zero, if there is any twist then its direction will be indicated by the polarity of the voltage.

A voltage representative of the cross level condition of the track at station B (γ_B) is generated by supplying the voltages representing γ_C, the cross level condition at station C, and γ_B - γ_C, the difference in the cross level conditions at stations B and C to the electronic adder 64 which produces an output representative of:

$$\gamma_B = \gamma_C + \gamma_B - \gamma_C.$$

From the above description it will be seen that the voltage representative of γ_B will be zero if the track at station B is horizontal and also that the direction of the super-elevation, if any, can be identified by the polarity of the voltage.

A potentiometer 66 (Figure 6) is connected to the jackscrew 43 and housing 36 of shadowboard adjustment mechanism 25 to produce a voltage signal representative of the side-to-side tilt applied to the shadow board. This tilt is equal in magnitude and opposite in sense to the desired superelevation (γ_{BS}) at station B so that under the desired cross level conditions, the shadow board will be horizontal. Consequently, the voltage signal from potentiometer 66 represents the desired cross level condition at station B, γ_{BS}. This voltage will ideally be zero if there is zero desired superelevation. The direction of superelevation is again indicated by the polarity of the voltage

The voltages representing γ_B and γ_{BS}, are supplied to the electronic sub-traction or summation element 72 to obtain a voltage representing the error ($\Delta\gamma_B$) between the desired and existing cross level conditions at station B. The function performed by element 72 is $\Delta\gamma_B = \gamma_{BS} - \gamma_B$. Again, the voltage is zero if there is no error and, if there is any, then, the direction of such will be indicated by the polarity.

With the values $\Delta\gamma_B$ from element 72 and ΔL from analog circuit 54, it is possible to determine the error between the vertical position of the track from its desired position at station B. This information may be used to control the lifting cylinders of a track jacking and ballast tamping apparatus. The quantities Δh_R and Δh_L, representing the magnitudes of the desired changes in elevation of the right and left rails respectively, are calculated electronically in circuits 76 and 78 respectively. The functions performed are:

$$\Delta h_R = \Delta L + \frac{\Delta\gamma_B}{2} \text{ and } \Delta h_L = \Delta L - \frac{\Delta\gamma_B}{2}.$$

The factor 1/2 is introduced because the track centre-line is used as a datumline with respecto which one rail will be raised and the other lowered to remove the cross level error γ_B. Each of the voltages obtained (Δh) is equal to zero if the appropriate rail is in the exact desired position. Should there be an error, then the voltage indicates its magnitude and the polarity its sense.

Through calibration amplifiers 80 and 82, instruments 84 and 86 respectively will show the errors in the levels of the left and right rails respectively at station B in units of length, such as millimeters or inches.

Other calibration amplifiers 88 and 90 can be used to control directional valves (not shown) for a track lifting operation by the jacking cylinders.

The design of the apparatus with transmitter 16, receiver 24 and shadow board 20 above the center of the track results in the center-line 48 between stations A and C being used as a datum or grade line for track levelling.

Should it be desired to use the right or left hand rail as a reference or grade rail so that the datum line extends along that rail, the shadow board has to be adjusted vertically with respect to the transmitter and receiver to compensate for the fact that the points on the grade rail at stations A and C to which the grade rail position at station B is related, may be either higher or lower than the corresponding points on the centreline thus requiring a higher or lower lift to correct rail errors. The adjustment also compensates for the cross levelling of the track to the grade rail rather than the centreline. The magnitude of the adjustment is given by a parameter Z_{BX}. The formula for this value is

$$Z_{BX} = 1/2 \ \frac{b}{a+b}\gamma_A + \frac{a}{a+b}\gamma_C - \gamma_{BS}$$

where:

γ_A indicates the cross level condition at station A;
γ_C indicates the cross level condition at station C;
γ_{BS} indicates the desired or a set cross level condition at station B;
a is the distance from A to B and
b is the distance from B to C.

Z_{BX}, γ_A, γ_C, and γ_{BS}, along with the other parameters of the same general nature can be considered as angles with respect to horizontal or elevation in linear dimensions above horizontal since the two are dependent upon and determine one another.

γ_A is measured by the pendulum 112 carried by the transmitter buggy 18, γ_C is measured by pendulum 32 on buggy 26 and γ_{BS} is measured by shadow board potentiometer 66, these elements generating appropriate voltage signals for use in the control system.

Z_{BX} is calculated in circuit 106 and is fed via adder 108 to adder 110 with the outputs of potentiometers 94 to 100 to control shadow board motor 98.

A selector switch 114 is operative to select one of two values of Z_{BX}, or zero, corresponding to the selection of:

1. The left rail as reference or grade rail. Z_{BX} has its calculated magnitude and polarity.
2. The right rail as grade rail. Z_{BX} has its calculated magnitude with reversed polarity.
3. The centreline of the track as a datum line. The Z_{BX} value is zero.

The reversal of polarity from left to right rails is to be consistent with the use of voltage polarity to indicate the sense of a parameter represented by the voltage. In some cases it is an advantage to level a track to a reference point on the higher rail at the station A, for example, if only small lifts are required, if errors in the track are encountered, or in tracks with offset rail joints. In order to achieve this automatically, a "high point" control is used to monitor the cross level condition at station A and to adjust the vertical position of shadow point 20 in accordance with those cross level conditions so that the higher rail is used as a grade rail at station A, while stations B and C refer to whichever of the rails or the centerline is selected as the datum line by switch 114. The "high point" control is switched on by switch 116. When this is done, a parameter Z_{BHP} will be used as a shadow board adjustment factor. This parameter is calculated as follows:

Where switch 114 is used to select either the left or right rail as a grade rail

$$Z_{BHP} = \frac{b}{a+b}(\gamma_A - \gamma_{AS})$$

which is calculated by circuit 118.

This value is used only if γ_A is larger than γ_{AS}. That is, Z_{BHP} will only be used if positive.

γ_{AS} is a reference cross level condition of the track at station A. A voltage representing this value is set by a potentiometer 122 and is supplied to circuits 118 and 120.

γ_A is the actual cross level condition of the track at station A, as determined by pendulum 112, which generates a voltage representative of this condition for supply to circuits 118 and 120. Where the left rail is grade rail, the calculated value is used directly and where the right rail is selected as the grade rail, the calculated value is used with reversed polarity, to ensure consistency with the voltage polarities employed.

If the centerline is selected as the reference line, circuit 120 is used to calculate Z_{BHP} according to:

$$Z_{BHP} = 1/2\,\frac{b}{a+b}(\gamma_A - \gamma_{AS}).$$

The selector switch 114 has a second set of contacts 114″ operative to select the desired value of Z_{BHP} from circuits 118 and 120 and supply it to adder 108 for summation with the parameter Z_{BX}. That sum is added to the shadow board adjustment voltage from potentiometer 94 in adder 110. The combined voltage is supplied to circuit 102 to control the shadow board motor 98 in the manner described above with reference to motors 92 and 98 and potentiometers 94 and 100.

When the apparatus is used with the "high point" control and in conjunction with the track leveling machine, the track will be levelled at station B to bring the datum line, whether one of the rails or the centerline, into a desired vertical position with respect to the reference point on the high rail at station A and the datum line for the corrected rail at station C. The "high rail" at station A is which ever of the rails is for the time being higher than the other with respect to the selected cross level condition represented by γ_{AS}.

While the embodiment of the present invention has been described as using an infrared transmitter and an infrared receiver for generating the reference line 15 this line can be generated in various other ways, for example with other forms of radiation or with a wire.

Further aspects of the railway track surveying and adjusting apparatus described hereinbefore and shown in the drawings are claimed in application No. 23927/78 (Serial No. 1604564).

WHAT WE CLAIM IS:-

1. Railway track adjusting apparatus comprising means for establishing a reference line extending longitudinally of and above a railway track between leading and trailing track-surveying stations at a fixed position transversely of the track, means for determining vertical deviations in the track relatively to the reference line at a surveying station

intermediate the leading and trailing stations, track adjusting tools for adjusting the track at the intermediate station, means for measuring the cross level of the track at the leading station and control means having respective inputs for the determined vertical deviations, a reference cross level at the leading station and a transverse position of a datum line which extends longitudinally of and in the plane of the track and an output connected to the tools for adjustment of the track to correct the determined vertical deviations and to adjust vertically the datum line at the intermediate station to a desired position with respect to a line extending between the trailing station and the higher rail relative to the reference cross level at the leading station.

2. Apparatus according to claim 1, in which the means for establishing a reference line comprise a beam transmitter at one of the leading and trailing stations and the means for determining vertical deviations comprise a beam receiver at the other one of the leading and trailing stations and a beam interference means arranged to vary the beam intensity to the receiver in correspondence with vertical deviations in the track relatively to the reference line at the intermediate station, an output of the receiver being connected to the respective input of the control means.

3. Apparatus according to claim 2, in which the beam is of infrared light.

4. Apparatus according to claim 2 or 3, in which at least one of the interference means, transmitter and receiver is mounted on a wheeled buggy.

5. Apparatus according to any of claims 2 to 4, in which the beam interference means comprise a shadowboard.

6. Apparatus according to any of claims 1 to 5, in which the cross level measuring means comprise a transducer which includes a pendulum.

7. Apparatus according to any of claims 1 to 6, in which the transverse position of the datum line can be selected from the respective positions of the centre line and the rails of the track.

8. Apparatus according to any of claims 1 to 7, in which the reference line is established substantially above the centre line of the track.

9. A method of adjusting a railway track, comprising the steps of establishing a reference line extending longitudinally of and above a railway track between leading and trailing track-surveying stations at a fixed position transversely of the track, advancing the stations along the track, determining vertical deviations in the track relatively to the reference line at an intermediate station as the leading and trailing stations are so advanced, measuring the cross level of the track at the leading station and adjusting the track at the intermediate station to compensate for the determined vertical deviations and adjust vertically a datum line at the intermediate station to a desired position with respect to a line extending between the trailing station and the higher rail relative to a reference cross level at the leading station, the datum line extending longitudinally of and in the plane of the track.

10. A method according to claim 9, in which the reference line is established substantially above the centre line of the track.

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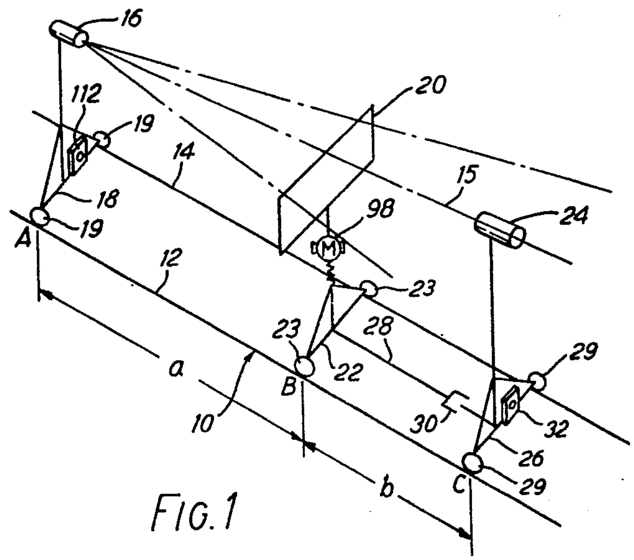
16
20
112
19
14
15
18
19
A
98
24
12
23
23
28
29
a
B
22
10
30
32
26
C
29
b

FIG. 1

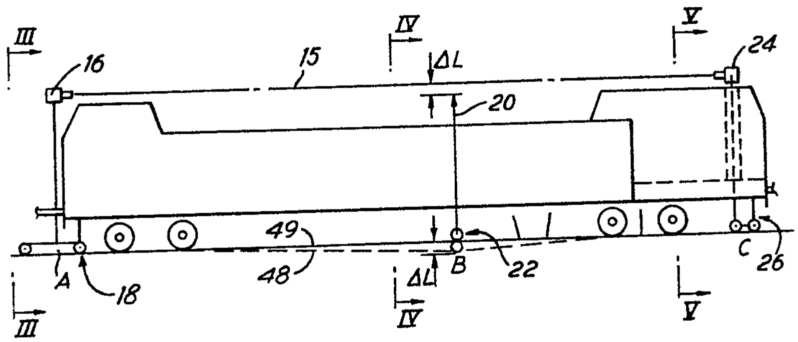
III
IV
V
16
15
ΔL
24
20
49
48
A
18
B
22
C
26
ΔL
III
IV
V

FIG. 2

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Sheet 2

FIG.3

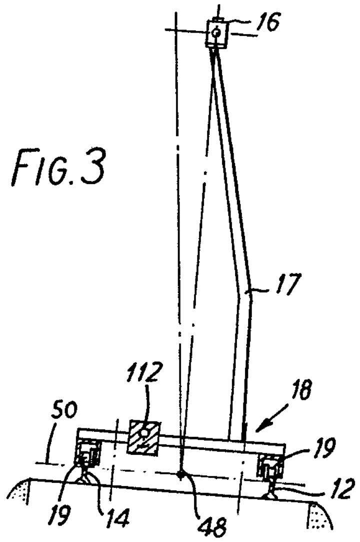


FIG.4

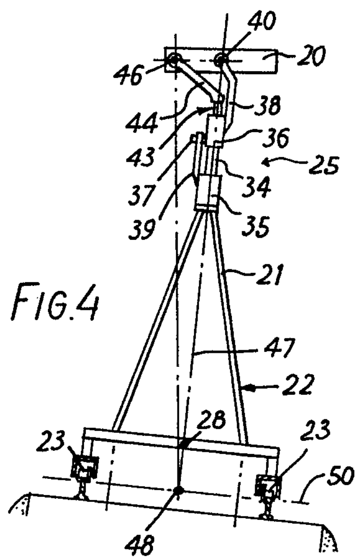
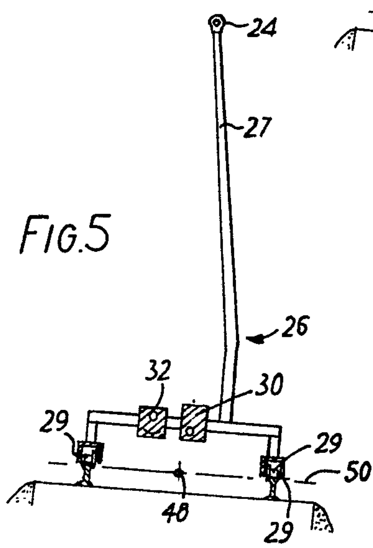


FIG.5



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Sheet 3

FIG.6