Sept. 29, 1964 R. S. BROWN ETAL 3,150,608

SURFACE SMOOTHING MACHINE

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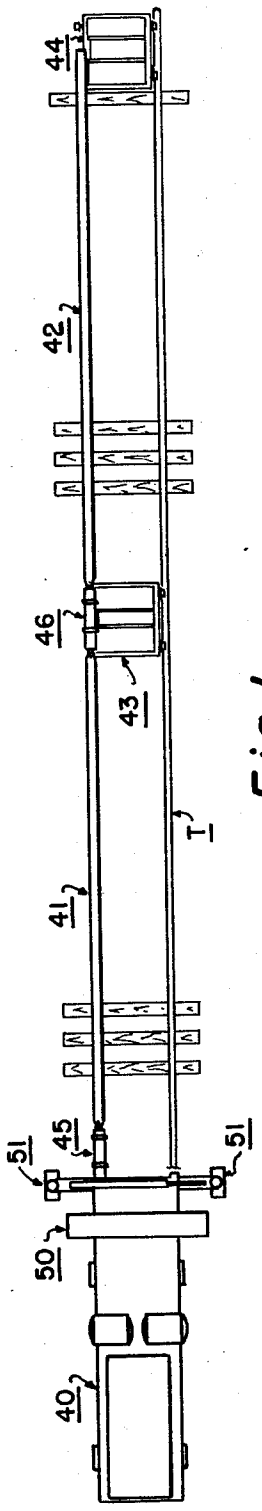


Fig. 1

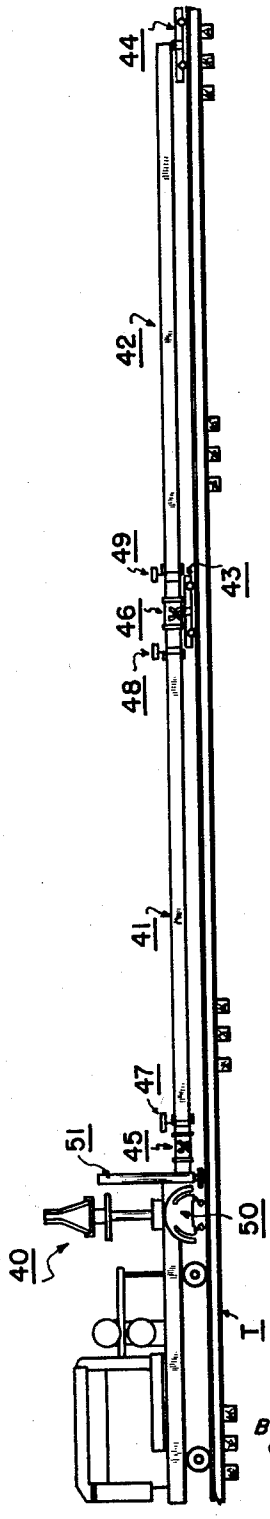


Fig. 2

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SURFACE SMOOTHING MACHINE

Filed May 31, 1960 8 Sheets-Sheet 2

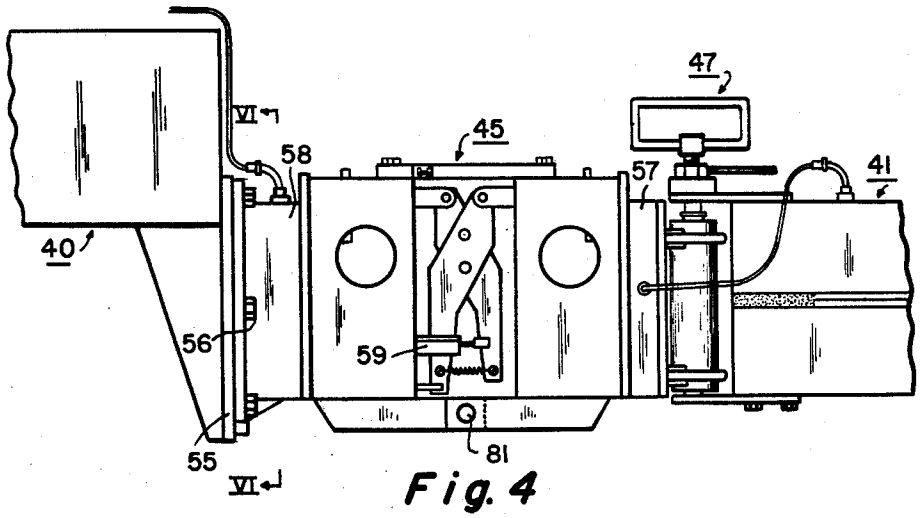


Fig. 4

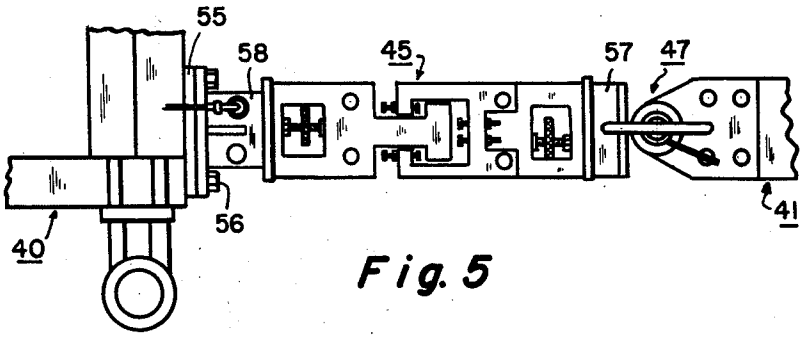


Fig. 5

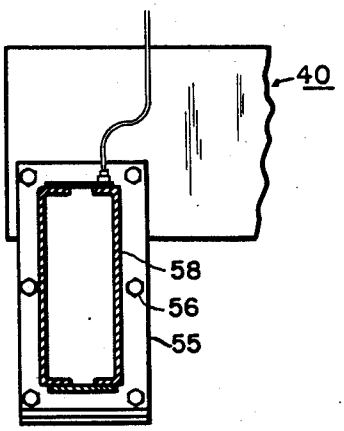


Fig. 6

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SURFACE SMOOTHING MACHINE

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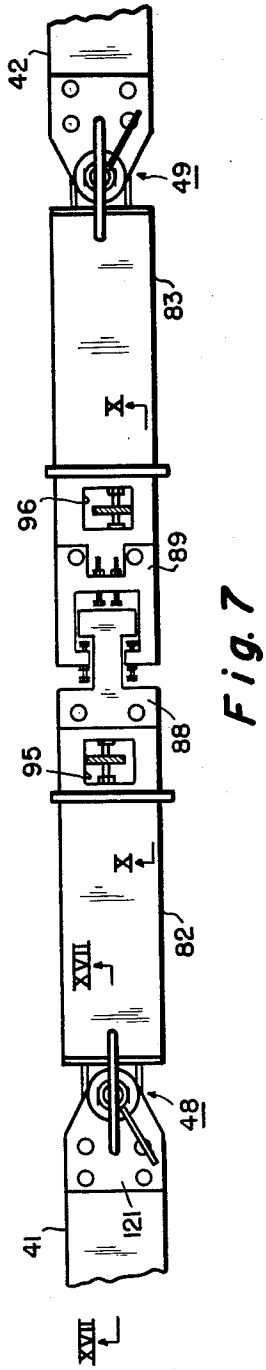


Fig. 7

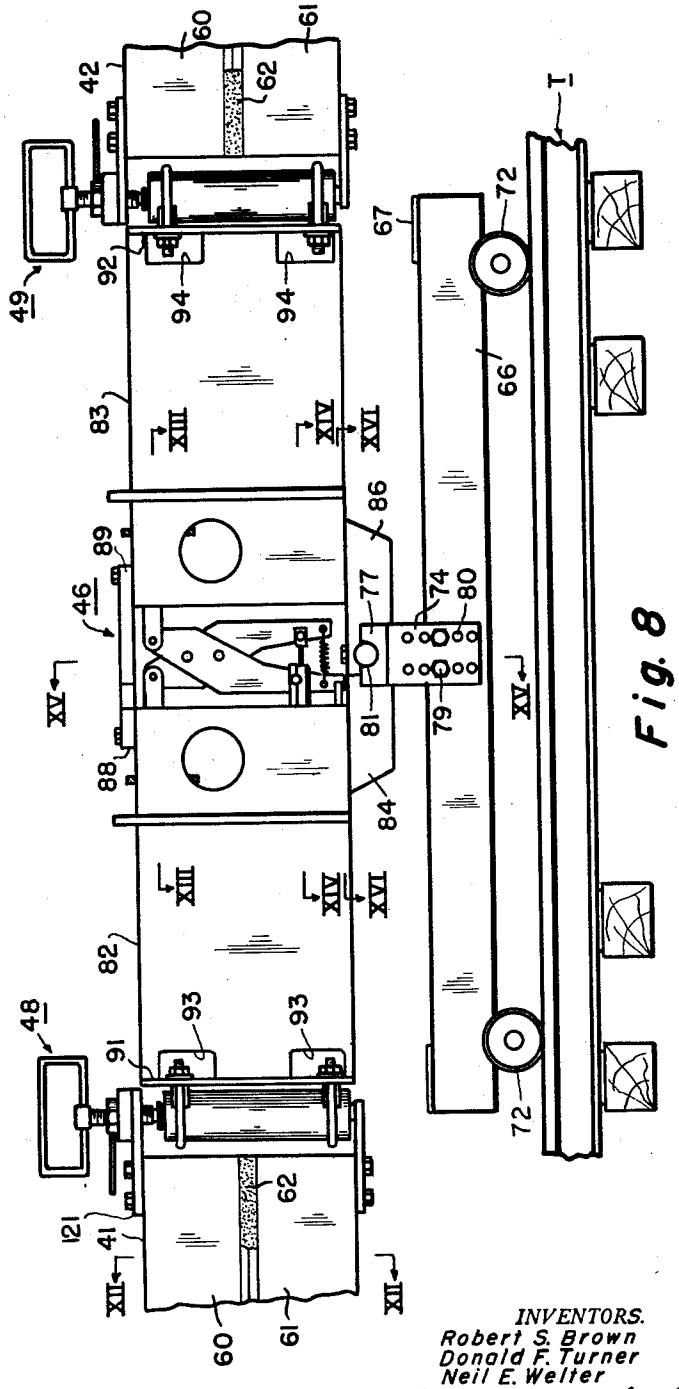


Fig. 8

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SURFACE SMOOTHING MACHINE

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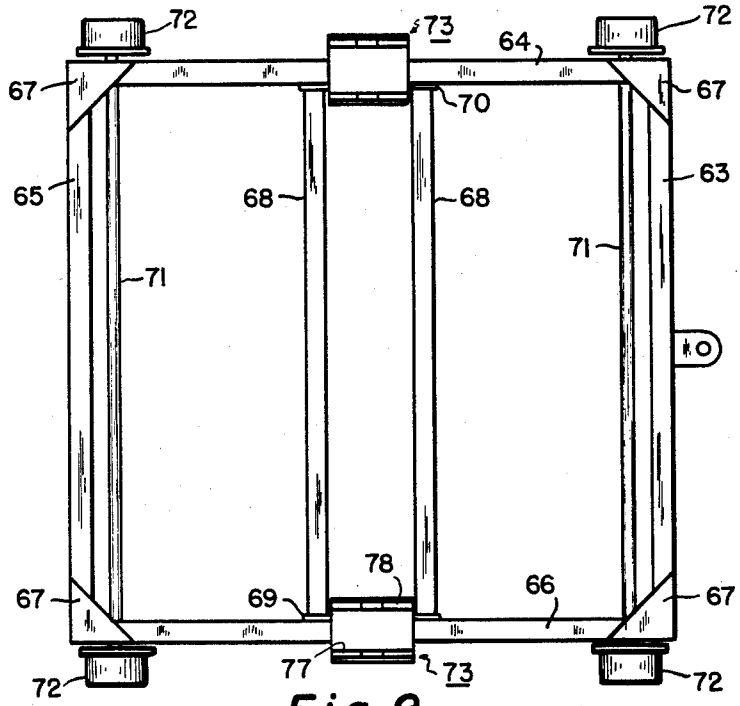


Fig. 9

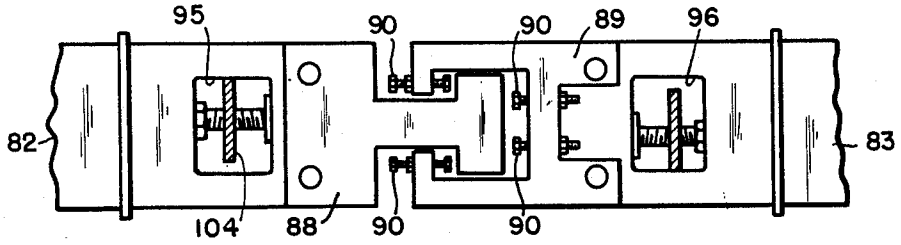


Fig. 11

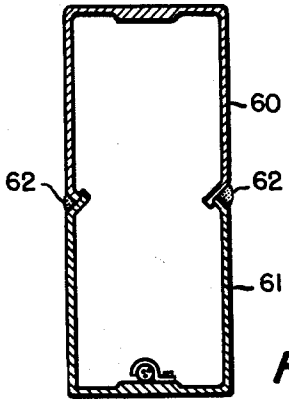


Fig. 12

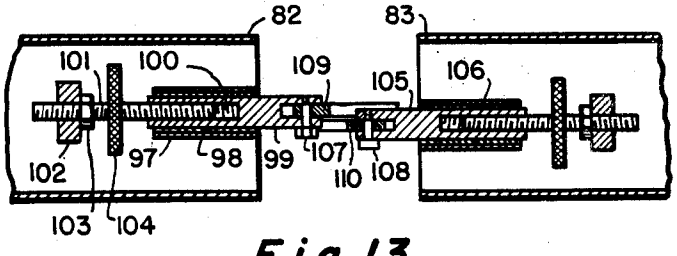


Fig. 13

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SURFACE SMOOTHING MACHINE

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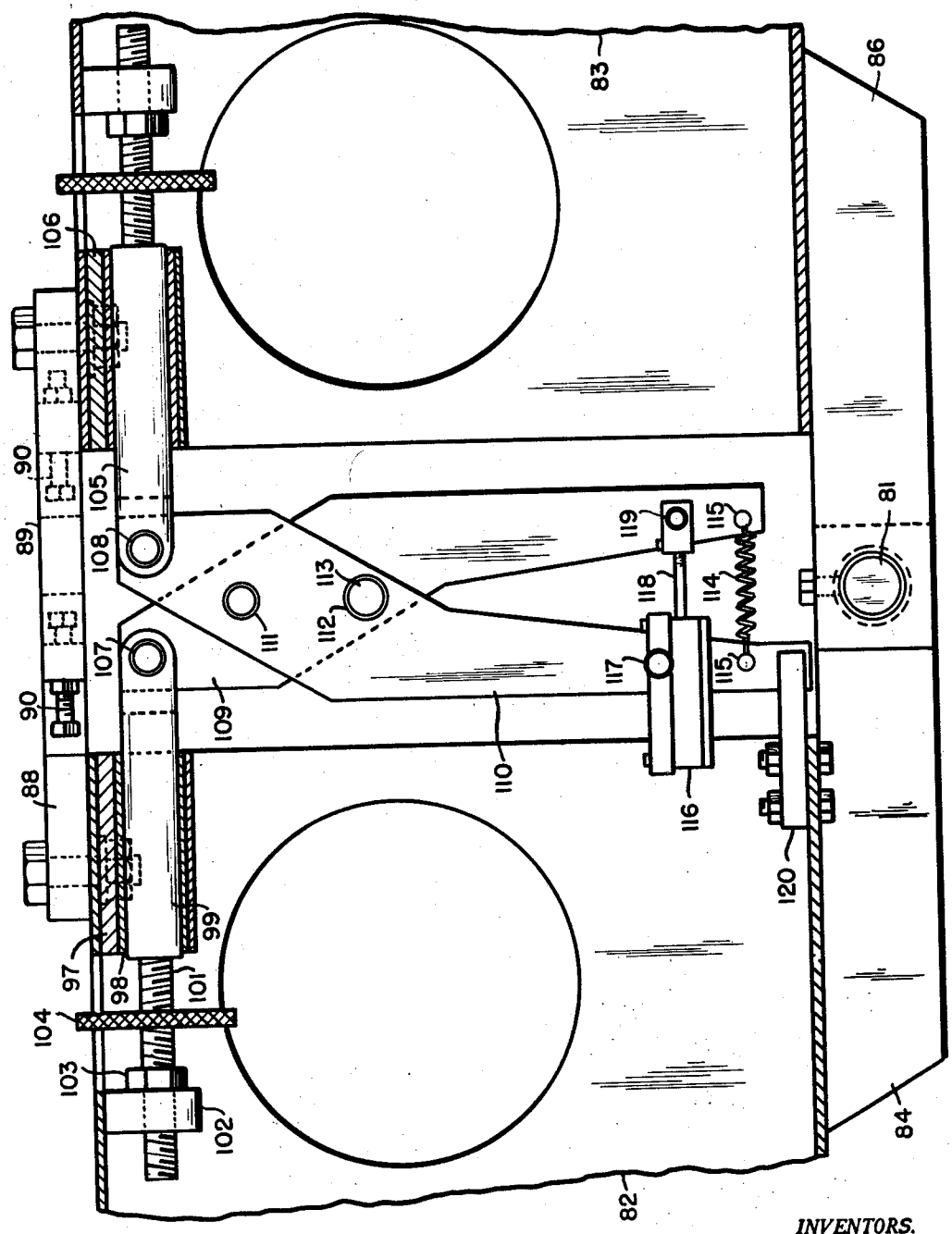


Fig. 10

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SURFACE SMOOTHING MACHINE

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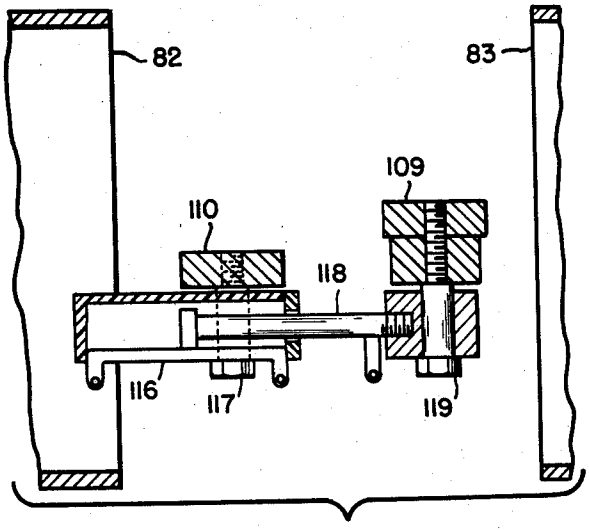


Fig. 14

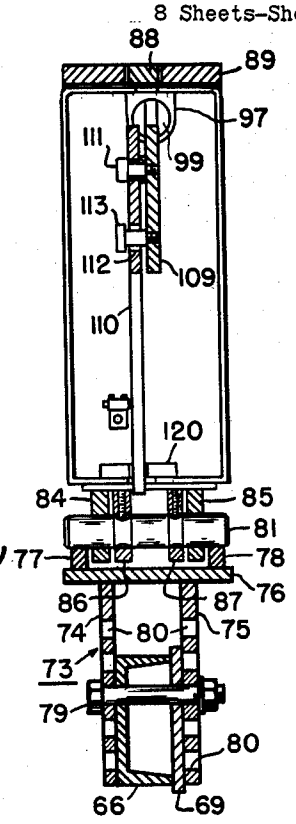


Fig. 15

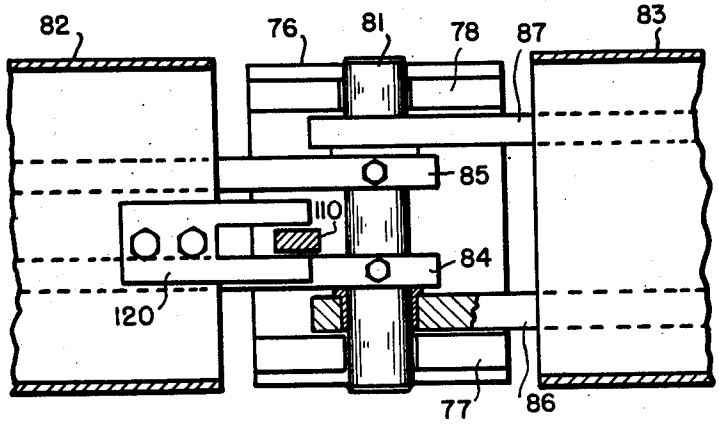


Fig. 16

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SURFACE SMOOTHING MACHINE

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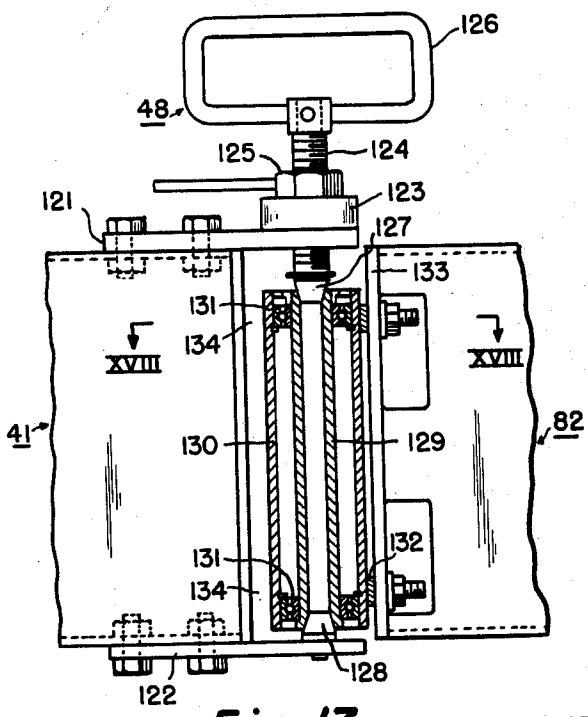


Fig. 17

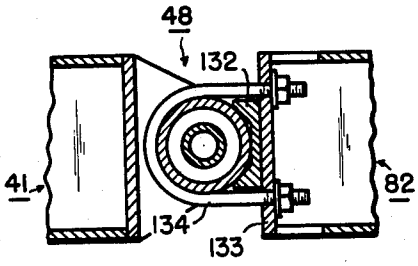


Fig. 18

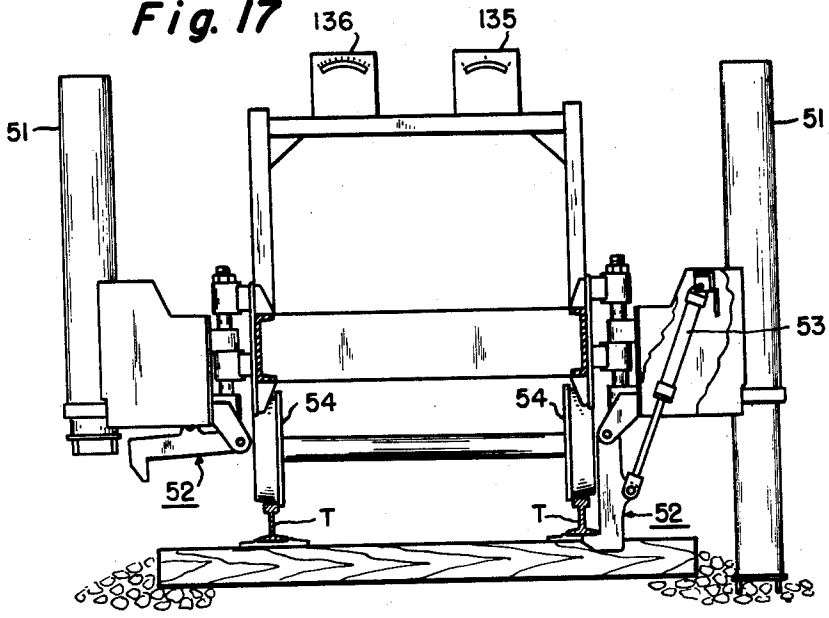


Fig. 19

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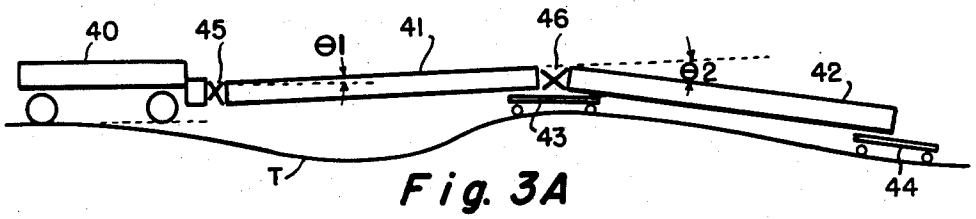


Fig. 3A

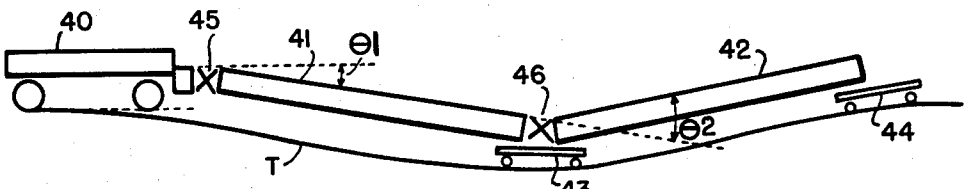


Fig. 3B

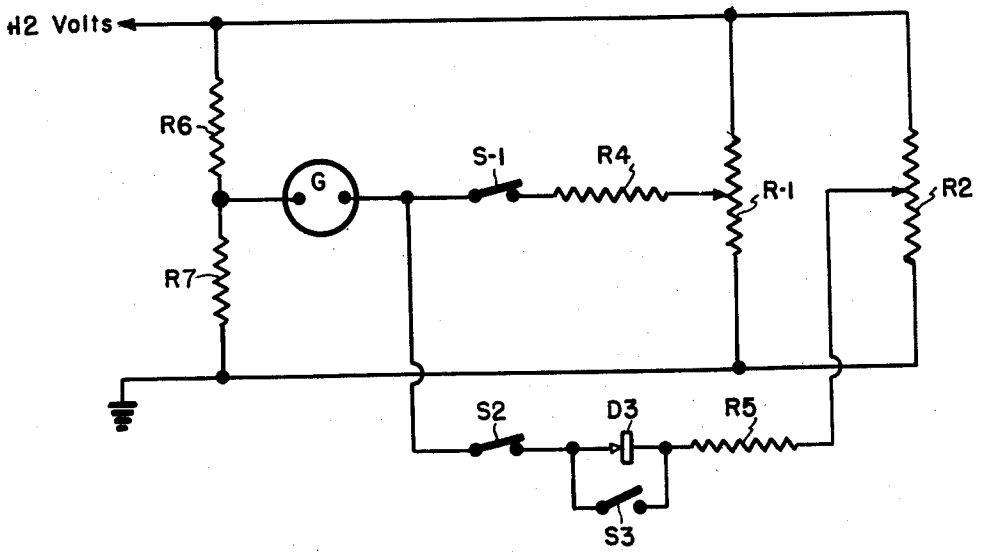


Fig. 20

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United States Patent Office 3,150,608 Patented Sept. 29, 1964

3,150,608

SURFACE SMOOTHING MACHINE

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Filed May 31, 1960, Ser. No. 32,961
24 Claims. (Cl. 104—7)

A major problem in transportation today is the effect that an irregular surface has on vehicles moving over the surface. Inertial forces are produced in the moving vehicles by these irregular surfaces, which forces have a detrimental effect upon the surface itself. Technical efforts to date have been directed toward the design of suspension systems to reduce the adverse effect on the vehicle and surface caused by the surface irregularities. However, the present invention is directed to reducing the surface irregularity such that these adverse effects of the irregular surface are minimized or substantially reduced.

Our invention is particularly directed to the reduction of surface irregularities and undulations in railway tracks and the description herein is primarily directed to this use of our invention. However, the basic concepts contained in the following description can readily be used to reduce undulations and irregularities in any vehicular surface. For example, the basic concepts of this invention may be employed with equal facility in reducing undulations and irregularities in vehicular roads or airport runways by means of grading devices or the like.

In reducing the undulation in a railway track surface, several factors must be observed to attain the desired end result in an economically practical manner. The first factor is that any surfacing machine used on railway track cannot be required to lower the track but must raise the track to make surface corrections; and, second, it is not economical to remove all surface undulations. A practical device removes only those undulations which have a wave length short enough to produce detrimental inertial forces on the vehicle and damage to the surface or which contribute to passenger discomfort.

The stiffness of the rail itself and a small overall raise in the railway track has been found to effectively eliminate surface irregularities of shorter wave lengths less than about 20 feet. Thus, our invention is primarily directed to achieving both a small overall raise in the railway track and a removal of surface irregularities having longer wave lengths. Our invention is also usable for leveling and smoothing new track or smoothing old track at only isolated spots.

It has further been found that it is desirable to raise old railway track a short vertical distance, possibly one-half inch to two inches, to give new resiliency to the railway track. Ballast supporting railway track packs down and becomes rigid thereby lacking resiliency. This lack of resiliency in the track supporting ballast is detrimental to the vehicles and loads on the vehicles passing over the track since the ballast does not absorb shock. Our invention provides a predetermined average raise in the railway track while simultaneously effectively removing surface irregularities.

Our invention is based on a surfacing concept which utilizes at least one reference point in front of the track jacking position (the point at which the track is being elevated), and preferably two or more such front reference points; and one reference point on the previously surfaced track behind the track jacking position. The smoothness of the surfaced track is progressively improved as the number of reference points in front of the track jacking position increase while the distance between

the reference points remains constant, since the greater the distance which is considered in front of the jacking position in determining the elevation at the jacking position, the greater will be the "smoothing" effect on the track; however, we have found that two front reference points, preferably spaced as described hereinafter, are most effective and practical in removing the most detrimental undulations from the railway track. However, we do not exclude from the scope of our invention, any devices which utilize the concepts disclosed herein but have more than two front reference points.

In using our invention, a comparison is made between the highest forward reference point in front of the jacking position and the rear reference point behind the track jacking position. A signal is produced from this comparison which is proportional to the amount of raise required to bring the surface at the jacking position up to lie on a line between the forward and the rear reference points. Thus, the track from the rear reference point to the jacking position is tangential to the highest forward reference point. The rear wheels of the jacking vehicle function as a reference point behind the jacking position since the rear wheels are on a portion of the track which is at the desired grade or has been previously properly surfaced. Thus, the surfaced track is made up of a series of straight line tangents.

It will be apparent from the above discussion of our invention as directed to reducing the undulations in railway track that the same concepts are applicable to vehicular road surfacing, whether it be resurfacing an existing road, or in the construction of a new road.

The drawings attached hereto show a present preferred embodiment of our invention:

FIGURE 1 is a top elevation view of our invention positioned for operation on a railway track;

FIGURE 2 is a side elevation view of our invention positioned for operation of a railway track;

FIGURE 3A is a schematic of our invention positioned for operation on a railway track in a first condition requiring smoothing;

FIGURE 3B is similar to FIGURE 3A but shows a second condition of the railway track requiring smoothing;

FIGURE 4 is an enlarged side elevation view of a rear potentiometer assembly;

FIGURE 5 is a plan view of the rear potentiometer assembly of FIGURE 4;

FIGURE 6 is a cross-section taken on line VI—VI of FIGURE 4;

FIGURE 7 is an enlarged plan view of a front potentiometer assembly and beam connection;

FIGURE 8 is an enlarged side view of the front potentiometer assembly and beam connection of FIGURE 7;

FIGURE 9 is a plan view of a cart with the beam removed;

FIGURE 10 is an enlarged side view similar to FIGURE 8 taken on line X—X of FIGURE 7 with the side plates removed for clarity;

FIGURE 11 is an enlarged top view similar to FIGURE 7;

FIGURE 12 is a vertical cross-section through a beam taken on line XII—XII of FIGURE 8;

FIGURE 13 is a horizontal cross-section taken on line XIII—XIII of FIGURE 8;

FIGURE 14 is a horizontal cross-section taken on line XIV—XIV of FIGURE 8;

FIGURE 15 is a vertical cross-section taken on line XV—XV of FIGURE 8;

FIGURE 16 is a horizontal cross-section taken on line XVI—XVI of FIGURE 8;

FIGURE 17 is a vertical cross-section taken on line XVII—XVII of FIGURE 7;

FIGURE 18 is a horizontal cross-section taken on line XVIII—XVIII of FIGURE 17;

FIGURE 19 is a view taken on line XIX—XIX of FIGURE 1 with parts removed for clarity; and

FIGURE 20 is a schematic of the electrical circuits of our invention.

Our invention is described herein as particularly applicable for use in leveling, spotting, lining and smoothing railway track. Briefly our invention includes a jack tamper apparatus 40 of well-known construction, as shown in Hursh and McWilliams Patent No. 2,843,055 and United States application Serial No. 687,577 filed October 1, 1957, now abandoned; connected to a first elongated beam 41 which is affixed to a second elongated beam 42. The two beams overlie one of the rails of the railway track in the manner shown in FIGURE 1. The beams are supported and moved along the track by vehicles or carts 43 and 44. A rear sensing device 45 is positioned between the jack tamper 40 and the first beam 41 and a front sensing device 46 is positioned between the rear beam 41 and the front beam 42. Preferably, each of the sensing devices include a precision linear potentiometer which produces a signal proportional to the angle between the jack tamper and the first beam and between the first beam and the second beam. The jack tamper 40 and first beam 41 are coupled together by a connector 47 and the first and second beams are coupled together by connectors 48 and 49.

The sensing devices 45 and 46 and the beams 41 and 42 can be positioned to overlie either rail of the track.

The jack tamper includes vertically movable tamping heads 50 having tamping tools which enter the ballast beneath the railway track T; and a pair of jacks 51 which are movable downward into contact with the surface of the ballast to elevate the jack tamper and track to the desired elevation. The position of the jacks 51 are referred to in this application as the "jacking position." FIGURE 19 shows a view of the jacks 51 and rail clamping devices 52. The jacks 51 are preferably hydraulic cylinders which move downwardly into contact with the ballast and elevate the tamping machine and track to the desired elevation. The rail clamping devices 52 include hydraulic cylinders 53 which actuate L-shaped plates to engage the underside of the rail and thereby securely lock the rail against the wheels 54 of the tamping machine. The left side of FIGURE 19 shows the jack 51 and rail clamp 52 in raised position and the right side of FIGURE 19 shows the jack 51 and rail clamp 52 in operable lowered position. The construction and operation of the jacks 51, tampers 50, and rail clamps 52 are well-known and, thus, will not be further described herein.

Welded to the front of the tamping machine is a vertically extending connecting plate 55 having holes (not shown) therethrough. A rear sensing device assembly 45 is affixed to plate 55 by bolts 56, as shown in FIGURES 4–6. The sensing device assembly includes front and rear stub beam assemblies 57 and 58, respectively, which house a potentiometer 59 and associated link mechanisms. The front and rear stub beam assemblies are pivotally mounted on axle 81, for pivotal movement in a vertical plane relative to each other. The rear sensing device assembly 45 is identical to the front sensing device assembly 46 which will be described in more detail hereinafter. The front stub beam assembly 57 is affixed to the center beam 41 by connector 47. The connector 47 is identical to connector 48 and connector 49 which will be described in more detail hereinafter.

The beam 41 extends forward to the front sensing assembly 46 which consists of a rear stub beam 82 and a front stub beam 83. The rear stub beam 82 has a pair of spaced vertically extending plates 84 and 85 welded to the underside of the beam. Each of these plates has a hole which is in alignment with the hole in the other plate and through which a pivot pin 81 passes, as shown in FIGURE 15. Each of the plates 84 and 85 has a flanged oilite bearing positioned in the opening through which the pivot pin 81 passes. A pair of similar spaced plates 86 and 87 are welded to the underside of stub beam 83 and have openings through which the pivot pin 81 passes. Each of the plates 86 and 87 is affixed to the pivot pin 81 by set screws as shown in FIGURE 15.

Thus, the stub beams 82 and 83 can pivot relative to each other about the pivot pin 81. The pivoting movement is in a plane substantially perpendicular to the plane of the track.

The pivotal movement of the stub beams 82 and 83 relative to each other is limited by a pair of horizontally extending plates affixed to the upper side of the stub beams as shown in FIGURE 11. A T-shaped male limit plate 88 is bolted to the upper side of stub beam 82 and a female limit plate 89 is bolted to the upper side of stub beam 83. The T-portion of plate 88 fits inside of the plate 89 as shown in FIGURE 11. Bolts 90 are threaded into threaded horizontally extending openings in the female limit plate 89. These bolts 90 are positioned to allow about a ¼" gap between the ends of the bolts and the peripheral portion of the T-shaped plate 88, thereby permitting approximately ½" movement of the T-shaped member within the female limit plate 89. Lock nuts are provided on each of the bolts 90 to maintain the bolts in the desired position.

Each of the stub beams 82 and 83 have vertically extending end cover plates 91 and 92, respectively, welded thereto. Spaced cutouts 93 and 94 in each of the stub beams provide access to the interior of the stub beams for purposes to be described hereinafter.

The central portion between the stub beams 82 and 83 house a potentiometer and associated links. Openings 95 and 96 are provided in the upper side of the stub beams 82 and 83, respectively, to provide access to adjusting means to be described hereinafter.

A hollow tube 97 is welded to the upper inside surface of stub beam 82 and has a bronze oilite sleeve bearing 98 affixed therein in which a pivot bar support link 99 can reciprocate. Referring specifically to FIGURE 10, the left end of the pivot bar link 99 is bored and threaded at 100 to receive a threaded end of adjustment screw 101. The opposite threaded end (left) of adjustment screw 101 is threaded into a tongue 102 which has an internally threaded hole. Tongue 102 is welded to beam 82 in alignment with tube 97. The threads on opposite ends of adjustment screw 101 are opposite hand. A lock nut 103 is threaded on the adjustment screw 101 between the tongue 102 and a knurled disc 104 which is rigidly affixed to the adjustment screw 101. The opening 96 provides access to the knurled disc 104, whereby upon rotation of the disc 104 the pivot bar link 99 is reciprocated in either desired direction within tube 97 to move the link toward or away from tongue 102.

The stub beam 83 has an adjustment mechanism identical to that just described with respect to stub beam 82. A pivot bar link 105 is reciprocated by a threaded adjustment screw in a hollow tube 106 affixed to the inside top face of stub beam 83. The inner ends of each pivot bar link 99 and 105 have openings which slidably receive stripper bolts 107, 108, respectively. The stripper bolt 107 is threaded into the upper end of a potentiometer shaft link 109. Thus, the potentiometer shaft link 109 can pivot relative to pivot bar link 99. The stripper bolt 108 threadably engages a hole in the upper end of a potentiometer link 110. Thus, link 110 can pivot relative to pivot bar link 105.

The link 109 and link 110 are pivoted together at a bearing pivot point 111 by a stripper bolt as shown in FIGURE 15. The link 110 and 111 have a scissor-like action about the stripper bolt at point 111.

Immediately below the stripper bolt 111, the link 110 has an enlarged opening 112 in which is loosely positioned a bolt 113. The inner end of bolt 113 threads into a threaded hole in link 109 as shown in FIGURE

turning handle **126** thereby bringing the truncated cone **127** upward out of the inner tube **129** until the tube **129** can be lifted off the lower truncated cone **128** and the beam and stub beam being separated. Reassembly is merely the reverse of these steps. Such separation is necessary to remove the beams from the track to permit passage of a train or for transportation of the beams.

The beams and the stub beams to which the beams are connected must function as a unitary beam without any deflection or "give" at the connector since otherwise, the operation of the machine would be inaccurate.

FIGURES 3A and 3B illustrate the theory and mode of operation of our invention. FIGURE 3A illustrates the operation of our invention when cart **43** is at a higher point on the track than cart **44**. FIGURE 3B illustrates the operation of our invention when cart **43** is at a lower point on the track than cart **44**. These are the only two conditions that can exist in smoothing track, with our machine.

As viewed in FIGURES 3A and 3B, the rear wheels (left wheels in figures) of the tamper **40** are maintained on a portion of the track which has been previously surfaced, i.e., is at proper grade and free of undulations. The "jacking position" of the tamper is immediately forward of the front wheels (right wheels in figures) of the tamper **40**, however, the "jacking position" can be any position between the rear wheels of the tamper and the sensing assembly **45**.

The position of the rear wheels of the tamper is the rear reference point and the left end of beam **41** is the first forward reference point. The angle θ_1 is the angle between the longitudinal plane passing through the frame of the tamper and the longitudinal plane passing through the beam **41**.

The sensing assembly **46** indicates the angular relationship θ_2 between the beam **41** and beam **42**. The angle θ_2 is the angle formed between longitudinal planes passing through each beam **41** and **42**. The outer right end of beam **41** is the second forward reference point and the outer right end of beam **42** is the third forward reference point.

It is apparent that when θ_1 and θ_2 equal zero, the track is smooth since the tamper and beams are in longitudinal planar alignment.

In the condition illustrated in FIGURE 3A, it is necessary that the front (right) end of the tamper and the underlying track be jacked up until the track is tangential to the portion of the track underlying the forward end of beam **41**, i.e., second forward reference point. The proper elevation of the front end of the tamper and underlying track is achieved (called "smooth track condition") when θ_1 is zero and this condition exists when the Wheatstone bridge to be described hereinafter is balanced and no current is flowing through the galvanometer of the bridge. Since it is imperative to use only the highest forward reference point in determining the elevation necessary for the described tangential condition of the track underlying the tamper, it is necessary to disregard the reading obtained from sensing assembly **46** (which depicts the θ_2 condition) when the assembly is positioned on track as shown in FIGURE 3A. The electrical circuit to be described hereinafter provides for this situation.

In the condition illustrated in FIGURE 3B, the outer front end of beam **42** (third front reference point) is higher than the outer front end of beam **41** (second front reference point). Therefore, it is necessary to utilize both θ_1 and θ_2 in determining the proper elevation ("smooth track condition") to which the front end of the tamper and underlying track must be jacked to have the underlying track tangential to the track underlying the outer front end of beam **42**. We have found that this tangential, and consequently "smooth track condition," exists when θ_2 equals $2\theta_1$ for the assembly shown in FIGURE 3B. The electrical circuit described hereinafter provides for this situation.

It is pointed out that when θ_1 and θ_2 are zero, the beams and tamper are in longitudinal planar alignment. This means that the pivot mechanisms (particularly pin **81**) between the tamper and beam **41**, beams **41** and **42**, and at the outer end of beam **42** are all at the same elevation from the track. It is also important that the sensing assemblies be identical in construction and located in the same positions relative to the rail to avoid complex correlations between the sensing devices.

Before using the machine, it is necessary to place the entire machine on a section of track which is known to be level and smooth. The adjustment screws on the potentiometer links are than rotated until a zero reading is obtained on the galvanometer in the Wheatstone bridge to be described. Each potentiometer is calibrated separately with the other potentiometer switched out of the circuit, or one potentiometer is calibrated with the other potentiometer switched out of the circuit and then both potentiometers are switched into the circuit to calibrate the second potentiometer.

The operator of the machine has easy access to all switches and other equipment necessary for operation of the machine. Preferably the switches, etc. are mounted near a galvanometer **135** and level **136** shown in FIGURE 19. The level **136** is of well-known construction and is used to determine and correct cross-level of the tracks.

The various electrical wiring necessary to provide the electrical connections on the machine have not been described herein since such wiring is well-known. The electrical circuit is shown in FIGURE 20 and thus, the proper wiring of the machine is readily apparent. Preferably the wiring is placed inside the beams for protection against weathering. Plug connections are provided in the beams to permit disassembly of the beams and sensing assemblies for easy removal from the track.

As stated, the adjoining stub beams are mechanically linked to the slide shaft **118** and potentiometer **116**. The position of the slide contact within the potentiometer varies the voltage in an electrical circuit in accordance with the angular position of the beams relative to each other. The electrical circuit also includes a galvanometer **135** which indicates to the operator when the beams are in the desired position and a "smooth track" condition exists. FIGURE 20 is a schematic diagram of the electrical circuit which includes the two potentiometers R_1 and R_2 and the galvanometer.

R_1 is the potentiometer of sensing assembly **45** and thus is varied according to θ_1; and R_2 is the potentiometer of sensing assembly **46** and thus is varied according to θ_2. In essence the electrical circuit comprises a double Wheatstone bridge in which one branch comprises the two fixed resistances R_6 and R_7 and each of the other branches include either potentiometer R_1 or R_2 which are connected in parallel across the source of current. The power source is preferably a 12-volt battery. In the situation depicted in FIGURE 3A, only θ_1 is used. Therefore, only the potentiometer R_1 is effective in the circuit. When angle θ_1 is zero the slide contact in the potentiometer R_1 is located in the middle of the resistance R_1 so that the resistance on each side of the slide contact is equal and since the resistances R_6 and R_7 are equal, no current flows in the galvanometer. This indicates to the operater when θ_1 is zero. Under these circumstances, the angle θ_2 will be negative and the slide contact in potentiometer R_2 will be positioned such as to create a potential difference between the contact of the potentiometer R_2 and the junction of the resistances R_6 and R_7 with the galvanometer. This tends to cause a current to flow through the galvanometer but the current is blocked by the diode **D3**. The diode **D3** is oriented to prevent this current flow under the condition of FIGURE 3A.

In the situation depicted in FIGURE 3B, both angles θ_1 and θ_2 are considered. The angles θ_1 and θ_2 extend in opposite directions and therefore impress opposite voltages on the galvanometer. In this condition the desired

15. The bolt 113 in opening 112 acts as a stop and restricts the scissor action of the links 109 and 110 about the pivot point 111. However, the links 109 and 110 have sufficient movement toward and away from each other (about point 111) to effect the desired result described hereinafter.

The lower end of the links 109 and 110 are connected by a spring 114 to bias the links toward each other. The spring 114 is suitably connected by screws 115 to each of the links 109 and 110.

A potentiometer 116 is pivotally mounted on a stripper bolt 117 which threads into a threaded opening in link 110, as shown in FIGURE 14. A slide shaft 118 extends outwardly from the potentiometer and is pivotally mounted on a stripper bolt 119 which threads into a threaded opening in link 109. The slide shaft 118 carries a sliding contact inside the potentiometer to vary the point of contact on the resistor therein.

The potentiometer 116 which we have used on our apparatus is made by Bourns Laboratories, Inc., and has a mechanical travel of 1.00 plus or minus 1/64" and a resistance of 500 ohms plus or minus 5%. The construction of the potentiometer 116 is well-known and will not be described herein. We have also found that a potentiometer having a 2" mechanical travel is advantageous in avoiding the possibility of erroneous readings of the potentiometer due to the slide contact reaching one extreme end of the resistance in the potentiometer.

The lower end of link 110 is positioned in a U-shaped plate 120 which is bolted to the inside lower face of stub beam 82. This U-shaped plate guides the lower end of link 110 and prevents deviation or binding of the links which could cause a malfunction in the potentiometer.

Thus, as the stub beams 82 and 83 pivot about pivot pin 81 relative to each other the potentiometer shaft 118 is moved in or out of the potentiometer 116 thereby varying the point of contact of the slide contact along the resistor of the potentiometer.

While I have described only the front potentiometer and associated links, it should be understood that the rear sensing assembly 45 is identical in construction and operation.

Each of the beams 41 and 42 are approximately 33 feet long. The distance from connector 47 to connector 48 is about 36 feet and the distance from connector 49 to the front end of beam 42 is about 34½ feet. The distance between the axles on the tamping machine is between 12–14 feet and preferably about 12½ feet. The length of the beams and tamping machine can vary over a wide range but we prefer to use the lengths stated above because the standard rail is 39 feet long and, thus, our beam lengths reasonably insure proper surfacing of the rail without missing any rail joints.

The beam 41 is shown in cross-section in FIGURE 12. Beams 41, 42 and the stub beams are of substantially the same construction. FIGURE 6 shows a slightly modified form of stub beam 58 but we prefer the same construction for all the beams. The beams preferably are extruded aluminum to reduce the weight of the beam. Their length is such that they can be easily lifted by several men on and off from the track. We have found that the lengths given above conform with this practical consideration of weight.

The beam shown in FIGURE 12 consists of two U-shaped extruded aluminum lengths which are spot welded together at 62 along each side to form an elongated hollow tube. The beams must have sufficient rigidity to prevent any substantial deflection of the beam between its points of support. The inside of each beam has small cable clamps to hold the electrical cables which pass through the beams.

The beams are supported by carts 43 and 44. FIGURE 9 shows an enlarged view of the carts 43 and 44. Each cart consists of a square or rectangular frame fabricated from channels 63, 64, 65 and 66. These channels are welded together at the corners of the cart and reinforced by gusset plates 67. A pair of cross-channel braces 68 are welded as shown in FIGURE 9 to give sufficient rigidity to the cart frame. A pair of plates 69 and 70 are welded to the inside of the cart for a purpose to be described hereinafter. Pillow blocks are bolted to the underside of channels 64 and 66 to provide supports for front and rear axles 71 in a well-known manner. The axles 71 have flanged wheels 72 affixed at each end. The wheels 72 are properly spaced to permit rotary movement of the wheels along the track T.

Each cart has an adjustable beam pivot plate 73 affixed thereto as shown in FIGURE 15. The beam pivot plate consists of a pair of vertically extending spaced plates 74 and 75 having a horizontally extending plate 76 welded thereto to form a T-shaped structure, a pair of spaced U-shaped pivot pin support plates 77 and 78 are welded to the upper side of plate 76. Plates 77 and 78 support pivot pin 81. The beam pivot plate 73 is affixed by a nut and bolt 79 in a vertical position with plates 74 and 75 straddling channel 66 and plate 69 as shown in FIGURE 15. Each of the plates 74 and 75 have openings 80 therethrough to permit adjustment of the beam pivot plate in the vertical direction. If a one inch raise in the entire track is desired, the bolt 79 is inserted through the proper hole 80 to provide this raise. Otherwise the machine operates as described herein.

The front cart 44 is identical in construction to that hereinbefore described with the exception that only the outer end of beam 42 is pivoted on the pivot pin 81 supported on cart 44, but in all other respects the pivotal connection and the end of the beam are identical to that described hereinbefore.

The connectors 47, 48 and 49 are identical in construction. Referring specifically to FIGURES 17 and 18, each connector includes an upper support plate 121 bolted to the top side of the beam and a lower support plate 122 bolted to the bottom side of the beam. Each of these support plates extend beyond the end of the beam and have openings therethrough. The upper support plate 121 has a circular plate 123 welded thereto. Plate 123 has a threaded opening concentric with the opening in plates 121 and 122. A screw jack 124 is threaded into the threaded opening in plate 123. A lock nut 125 having an outwardly extending handle is threaded on the screw jack 124 between the plate 123 and a handle 126. The handle 126 is integrally affixed to the upper end of the screw jack 124. After the screw jack 124 has been threaded through the opening in plate 123 to the desired elevation the lock nut 125 is rotated to lock the screw jack 124 in its proper position. The lower end of screw jack 124 contains an integral truncated cone-shaped metallic member 127 directed in a downward direction. The opening in plate 122 receives a second truncated cone-shaped metallic member 128 which is positioned in an upward direction. A continuous inner tube member 129 engages and is fitted between the truncated cones 127 and 128. An outer bearing tube 130 is concentric with the inner tube 129. Bearings, oil-seals, and lock nuts 131 are positioned in well-known manner between the tubes 129 and 130 to permit free rotation of the tubes 129 and 130 relative to each other.

The outer tube 130 is positioned in a generally U-shaped horizontally extending plate 132 which is welded to each of the end plates 133 to the beam. Plates 132 provide a seat for the tube 130 against plate 133. A pair of spaced U-bolts 134 are positioned around and in engagement with the outer tube 130. The ends of bolts 134 pass through openings in the end wall 133. Nuts are threaded tightly on the ends of bolts 134 to securely maintain the tubes 129 and 130 against the end wall 133.

In disconnecting the beams, the lock nut 125 is loosened away from plate 123, the screw jack 124 is rotated by

position of the beams is such that θ_2 must equal $2\theta_1$ and therefore if no current is to flow through the galvanometer the potential difference between the slide arm contact in potentiometer R_1 and the junction of the resistances R_6, R_7 and the galvanometer must equal the potential difference between the slide arm in the potentiometer R_2 and the same junction point. This is accomplished by the resistances R_4 and R_5, the value of the resistance R_5 being twice that of the value of the resistance of R_4.

As will be apparent from the diagram, when the galvanometer reading is zero (and a "smooth track" condition exists), then the relationship of θ_2 equals $2\theta_1$ will be reached for the condition depicted in FIGURE 3B.

The switches **S1**, **S2** and **S3** are used for initially aligning the machine. Prior to commencing track smoothing operations, the entire machine is placed on a section of track known to be smooth. The switch **S1** is then closed and switch **S2** opened. The adjustment screws **101** on sensing assembly **45** are then manipulated to bring the galvanometer reading to zero. The switch **S1** is then opened and switches **S2** and **S3** closed, and the adjustment screws **101** on sensing assembly **46** are manipulated to again bring the galvanometer reading to zero. The switch **S1** is then closed and switch **S3** opened. The machine is now ready for smoothing track.

Each potentiometer resistances R_1 and R_2 have 500 ohms resistance plus or minus 5%.

The galvanometer G is a 50–0–50 microammeter, 4½" diameter, with a special scale made by Phaostron Company.

The diode D3 is a 1N305 Germanium diode made by Raytheon.

The resistance R_4 is 25,000 ohms and 0.5 watt.

The resistance R_5 is 50,000 ohms and 0.5 watt.

The switches S–1, S–2 and S–3 are 2PB4 microswitches made by Minneapolis-Honeywell.

Pilot lights (not shown) are preferably provided in the circuit to indicate when the switches are open or closed.

The resistors R_4, R_5, R_6 and R_7 are precision resistors made by International Resistance Co.

While we have indicated that the ratio of θ_1 to θ_2 should preferably be: $\theta_2=2\theta_1$ when a situation such as FIGURE 3B is encountered, this is only true when beams **41** and **42** are approximately the same length. However if the beams **41** and **42** differ in length, the following ratios must be used:

$$\theta_2=\frac{l_{41}+l_{42}}{l_{41}}\theta_1$$

wherein:

l_{41}=length of beam **41**
l_{42}=length of beam **42**

It is also necessary to change resistors R_4 and R_5 to conform to the following:

$$R_5=\frac{l_{41}+l_{42}}{l_{41}}R_4$$

While we have described certain preferred embodiments of our invention, it is to be understood that it may be otherwise embodied within the scope of the following claims.

We claim:

1. A railway track smoothing machine including a vehicle having means to clamp the vehicle to the track and means to swingingly elevate one end of the vehicle and the underlying track simultaneously at the location of the end of the vehicle on the track; said vehicle being mounted on wheels for movement along the rails of the tracks; a first beam affixed to one end of the vehicle and normally extending substantially parallel to the longitudinal axis of the track, the outer end of the beam being swingable vertically relative to the vehicle about its point of affixation to the vehicle; a wheel-mounted cart movable along the rails of the track; the outer end of said beam being pivotally mounted on said cart; and a first sensing means operatively affixed to the vehicle and beam to indicate relative vertical angularity between the vehicle and beam.

2. A machine according to claim 1 including a second beam pivotally mounted on said cart and normally extending substantially parallel to the longitudinal axis of the track in alignment with said first beam; a second wheel-mounted cart movable along the rails of the track, the outer end of said second beam being pivotally mounted on the second cart; a second sensing means affixed to the beams to indicate relative vertical angularity between the beams.

3. A machine according to claim 2 including indicator means on the vehicle responsive to said first and second sensing means; said indicator means being so constructed and arranged that it is responsive only to said first sensing means when the outer end of said first beam is higher than the outer end of said second beam, and responsive to the first and second sensing means when the outer end of the second beam is higher than the outer end of the first beam.

4. A railway track machine to reduce undulations in railway track, including a vehicle movable over the track; power means operatively related to the vehicle to elevate the vehicle and underlying track; a first sensing assembly integral with the front of the vehicle; the sensing assembly including a pair of stub beams pivotally mounted on a horizontal axis, the stub beams being pivotal in a vertical plane relative to each other; one of the stub beams being integral with the front of the vehicle; a first elongated beam positioned over and extending substantially parallel to the longitudinal axis of one of the rails, and the other stub beam being integral with said elongated beam; a first cart having wheels movable over the track; the outer end of the elongated beam being pivotally mounted on said cart; a variable resistance integral with said stub beams such that upon pivotal movement of the stub means relative to each other the variable resistance is activated to indicate the amount of said pivotal movement; indicator means on the vehicle responsive to the activated variable resistance to indicate the elevation of the vehicle and tracks required to reduce said pivotal movement to zero.

5. A machine according to claim 4 including a second pair of stub beams; one of said stub beams being integrally affixed to said outer end of the first elongated beam, a second elongated beam normally in approximate longitudinal alignment with said first elongated beam; the other of said second pair of stub beams being integrally affixed to the inner end of said second elongated beam; said second pair of stub beams being pivotal in a vertical plane relative to each other about a horizontal axis; a second cart having wheels movable over the track; the outer end of the second elongated beam being pivotally mounted on the second cart; a second variable resistance integral with said second pair of stub beams such that upon pivotal movement of these stub beams relative to each other the second variable resistance is activated to indicate the amount of said pivotal movement; and said indicator means being responsive to the second variable resistance to indicate the elevation of the vehicle and tracks required for alignment with the outer end of said second elongated beam.

6. A machine according to claim 4 wherein said indicator means includes a Wheatstone bridge with a galvanometer and said galvanometer indicates the amount of said pivotal movement.

7. A machine according to claim 5 wherein said indicator means includes a double Wheatstone bridge with a galvanometer; and said galvanometer indicates a zero value when the track underlying the vehicle is tangential to the outer end of said second elongated beam.

8. A machine according to claim 5 wherein said variable resistances are potentiometers, each of the potentiometers having a movable contact; said indicator means

having a double Wheatstone bridge with a galvanometer; two branches of one of said bridges being formed by the first variable resistance; two branches of the other of said bridges being formed by the second variable resistance; two known resistors forming two branches of the bridge, the last mentioned branches being common to both bridges; the galvanometer being connected between the two known resistors and to each of the movable contacts; a first standard resistor operatively connected between the galvanometer and the movable contact of the second variable resistance; a second standard resistor operatively connected between the galvanometer and the movable contact of the first variable resistance; said first standard resistor having twice the resistance of the said second standard resistor; a diode operatively connected between the galvanometer and said first standard resistor; the diode preventing current flow from the galvanometer to the movable contact of the second variable resistance.

9. A railway track smoothing machine comprising a first wheel-mounted vehicle movable along the track, a second wheel-mounted vehicle movable along the track, said vehicles being structurally connected and pivotally mounted relative to each other; a potentiometer operatively affixed between the vehicles to indicate the vertical position of the vehicles relative to each other; and means to swingingly elevate one end of one of the vehicles and underlying track to provide for planar alignment of the vehicles after one of the vehicles has encountered an undulation in the track.

10. A method of reducing undulations in a surface comprising designating a rear reference point on a previously properly corrected surface; designating a first forward reference point at an undulated portion of the surface spaced from said rear point; establishing a plane between said rear and first forward reference points; designating a second forward reference point along the surface spaced ahead of the first forward point; establishing a plane between said first and second forward points; designating a third forward reference point along the surface spaced ahead of the second forward point; establishing a plane between said second and third forward points; determining that said third forward reference point is above said second forward reference point; determining a first angular relationship between said first mentioned and second mentioned planes and a second angular relationship between said second mentioned and last mentioned planes; and elevating the surface in the area of the first forward point until the angular relationship between the first and second mentioned planes is one-half the angular relationship between the second and last mentioned planes.

11. A method according to claim 10 comprising designating said reference points along a railway track so that the method is applied to reducing surface irregularities in the railway track.

12. A machine for indicating undulation in a surface, including: a first vehicle movable over said surface; a second vehicle movable over said surface and spaced from said first vehicle; elongated means extending between said first and second vehicles, one end of said elongated means supported by said second vehicle and the other end being swingably connected to said first vehicle at a first junction to permit movement of said vehicles relative to each other in a vertical plane; a third vehicle movable over said surface and spaced from said second vehicle; elongated means extending between said second and third vehicles, one end of said means supported by said third vehicle and the other end being swingably connected to the second vehicle at a second junction remote from the first junction; said second junction permitting movement of the second and third vehicles relative to each other in a vertical plane; a first sensing device on the machine responsive to swinging movements between said first and second vehicles at the first junction to indicate the extent of said movements designated as angle θ_1; a second sensing device on the machine responsive to swinging movements between said second and third vehicles at the second junction to indicate the extent of the last mentioned movements designated as angle θ_2; and means on the machine to correlate θ_1 and θ_2 such that a smooth surface condition exists when:

$$\theta_2=\frac{l_2+l_3}{l_2}\theta_1$$

wherein:

l_2=the distance between the first and second junctions;
l_3=the distance between the second junction and the free end of the third vehicle.

13. A machine according to claim 12 wherein each of said first and second sensing devices includes a potentiometer having a contact movable along a resistance in response to changes in θ_1 and θ_2; indicator means mounted on the machine; said indicator means including a double Wheatstone bridge with a galvanometer; each of said resistances in the potentiometers forming two branches of said bridge; two known resistors being two other branches of said bridge, said other branches being common to both bridges; the galvanometer being connected between the two known resistors and to each of the movable contacts; and first additional resistor R_4 operatively connected between the galvanometer and the movable contact of the sensing device for θ_1; a second additional resistor R_5 operatively connected between the galvanometer and the movable contact of the sensing device for θ_2; R_4 and R_5 having the following relationship:

$$R_5=\frac{l_2+l_3}{l_2}R_4$$

and means operatively connected between the galvanometer and R_4 to prevent current flow from the galvanometer to resistor R_4.

14. A device to indicate undulations in a surface while moving longitudinally over said surface; including: a first vehicle movable over said surface; a second vehicle movable over said surface and connected to the first vehicle; said first and second vehicles being swingably connected to each other at a first juncture to permit movement relative to each other in a vertical plane located substantially perpendicular to said surface; means adjacent said juncture comprising a first reference point; means on said second vehicle located remote from said juncture comprising a second reference point; a first sensing means located at said juncture to indicate the vertical position of said second reference point relative to said first reference point; a third vehicle movable over said surface and connected to the second vehicle at a second juncture remote from the first juncture; said second and third vehicles being swingably connected at the second juncture to permit movement relative to each other in said vertical plane; means on said third vehicle located remote from the second juncture comprising a third reference point; and a second sensing means located at the second juncture to indicate the vertical position of said third reference point relative to said second reference point.

15. A method of smoothing railway track comprising establishing a rear reference point on a previously smoothed portion of the track, establishing first, second and third reference points along an unsmoothed portion of the track, said reference points being spaced from each other and the second point being between the first and third points; determining that the second reference point is located at a portion of the track above the third point; and elevating said first reference point and the portion of the track immediately adjacent said first reference point until said portion of the track lies tangential to the track at the second point.

16. A method of reducing undulations in railway track comprising: establishing a rear reference point on a smooth portion of the track; establishing first, second and

third reference points along an unsmooth portion of the track; said points being spaced from each other and the second point being positioned between the first and third points; determining that the third reference point is above the second reference point relative to the first reference point; establishing a first plane between said rear and first points, a second plane between said first and second points and a third plane between said second and third points; determining a first angular relationship θ_1 between the first plane and the second plane; determining a second angular relationship θ_2 between the second plane and the third plane; raising the first reference point and underlying track until the track is tangential to the portion of the track underlying the third reference point and the relationship of θ_2 to θ_1 is:

$$\theta_2=\frac{l_1+l_2}{l_1}\theta_1$$

wherein:

l_1=the distance between the first and second reference points; and

l_2=the distance between the second and third reference points.

17. A method according to claim 16 including: adjusting the electrical value of a first component operatively associated with a resistor R_4 proportional to θ_1; adjusting the electrical value of a second component operatively associated with a resistor R_5 proportional to θ_2; the resistances R_4 and R_5 being in the following relationship:

$$R_5=\frac{l_1+l_2}{l_1}R_4$$

opposing the electrical effect of the first adjusted component and R_4 against the electrical effect of the second adjusted component and R_5; and raising said first reference point and underlying track until the electrical effects are balanced.

18. A machine to indicate surface undulations, including a first vehicle mounted on wheels at each end; an elongated rigid beam affixed to one of said ends of the first vehicle, the beam being pivotally mounted to the vehicle and movable in a vertical swinging movement about the pivotal mounting; a wheel affixed to the free end of the beam; sensing means affixed between the vehicle and the beam responsive to said swinging movement; said sensing means being preset to indicate a planar condition of said surface; and the vehicle and beam being movable in longitudinal alignment over said surface with the wheels contacting the surface until a surface undulation is encountered by a wheel to cause vertical swinging movement between the vehicle and beam, and activation of the sensing means in response to the swinging movement.

19. A machine according to claim 18 including power means on the vehicle to raise one end of the vehicle and the underlying surface, when the wheels at said end are in a surface undulation, until said planar condition is indicated by the sensing means.

20. The method of reducing irregularities in a surface, characterized by the steps of locating a rear reference point on a portion of the surface having a desired disposition; locating a first forward reference point in the area of a surface undulation removed from said rear point; locating a second forward reference point along said surface; the first forward point being between the rear and second forward points; determining that the second forward point is located above the first forward point; establishing a first plane extending between said rear and first forward points; establishing a second plane extending between said first and second forward points; swingably connecting said first and second planes at about said first forward point so that an angular relationship is assumed by said planes depending upon the surface irregularities underlying said points; and raising said first forward point and underlying surface until the three points are located in the same plane and the angular relationship between said first and second planes is zero.

21. The method according to claim 20, characterized by the further steps of locating a third forward reference point along the surface remote from said second forward point and on a side of said second forward point opposite to said first forward point; establishing a third plane extending between said second and third forward points; swingably connecting said second and third planes at about said second forward point so that a second angular relationship is assumed by said second and third planes depending upon the surface irregularities underlying said forward points; determining that said third forward point is above said second forward point; determining said second angular relationship; and elevating said first forward point and underlying surface until the last mentioned underlying surface is tangential to the surface at said third forward point.

22. The method according to claim 20 when applied to the smoothening of a railway track, characterized by the use of a first vehicle having front and rear wheels to the vehicle constituting said first point, a second vehicle to elevate the front of the vehicle and underlying track, the rear wheels of the vehicle constituting said rear reference point, the end of said second plane adjacent to the vehicle constituting said first pont, a second vehicle having wheels spaced from the front wheels of the first vehicle and the second vehicle being swingably affixed to the front of the first vehicle; the second reference point being located above the wheels of the second vehicle; and said angular relationship between said first and second planes being based upon the relative vertical positions of said vehicles.

23. A machine to indicate surface irregularities including a vehicle, a first elongated beam having one end adjacent said vehicle and extending longitudinally from said vehicle, connecting means between said vehicle and said beam connecting said vehicle and said one end of the beam, said connecting means including a pivot member for pivotal movement of said beam in a vertical plane relative to said vehicle and a sensing means to sense relative vertical angularity between said beam and said vehicle, means to support the other end of said elongated beam in spaced relation to the surface, indicator means mounted on said vehicle and operatively connected to said sensing means to indicate the relative vertical angularity between said beam and said vehicle which is sensed by said sensing means, and power operated means associated with said machine to move said vehicle vertically until said indicator means indicates that said vehicle and beam are in predetermined alignment.

24. A machine to indicate surface irregularities including a first vehicle, a first beam pivotally connected to said first vehicle and extending longitudinally therefrom, said first beam being movable in a vertical plane relative to said vehicle, means to support the outer end of said first beam in spaced relation to the surface, a second beam pivotally connected to the front end of said first beam and extending longitudinally therefrom, said second beam being movable in a vertical plane relative to said first beam, means to support the outer end of said second beam in spaced relation to said surface, means associated with said vehicle and with said first beam to indicate relative vertical angularity between said vehicle and said first beam, means associated with said first beam and said second beam to indicate relative vertical angularity between said first beam and said second beam, and power means associated with said machine and operable to move said vehicle in a vertical direction when the outer end of said first beam is lower than the outer end of said second beam until said vehicle and the outer end of said second beam are in predetermined alignment.

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