Fig. 4

Fig. 5

INVENTORS
REEFORD R. SHEA
CHARLES RAUDENBUSH

Herbert C. Rider
AGENT
The present invention relates to automatic leveling controls for use in any mechanism, such as grading or material spreading equipment, where it is desirable to maintain a blade or other movable part horizontal or at a predetermined angle of inclination. While the invention is not limited in any way to grading or spreading equipment, it is particularly useful in that class of machines, and will herein be described as embodied in a road grader; it being understood that this is purely illustrative of one use for the invention.

In mobile road grading machinery, it is desirable to be able to maintain the scraper blade or mold board at a predetermined angle of inclination with a high degree of accuracy, independent of any rocking or tilting movement of the supporting frame as the grader travels forwardly over the surface being graded. Heretofore, it has been necessary for the operator to gauge any shift in the tilt of the grader and to attempt to compensate for such shift by manually adjusting the blade controls to hold the blade at the desired angle, which requires the close attention of the operator and a considerable amount of skill.

The primary object of the present invention, therefore, is to provide an automatic, self-leveling control mechanism which functions to hold the scraper blade at any predetermined angle of inclination with a high degree of accuracy, and requires little attention on the part of the operator.

Another object of the invention is to provide an arrangement whereby the desired angle of inclination of the scraper blade can be accurately pre-set or adjusted by remote control from the operator's station on the machine.

A further object is to provide a control mechanism wherein adjustment of the inclination of the scraper blade is quickly and easily effected by merely turning a control handle or knob located at the operator's station. By virtue of this feature, the operator can reverse the direction of slope of the blade at each end of a run so as to throw the material to one side of the road for both directions of travel, without leaving his seat or stopping the machine.

Another object is to provide an automatic, self-leveling control mechanism which is capable of adjusting a movable member through an infinite number of angular positions, without incremental steps, as in certain prior devices.

Still another object of the invention is to provide a remote-indicating clinometer, whereby the angle of the scraper blade with respect to the horizontal can be accurately determined from the operator's station on the implement.

The foregoing and other objects are attained by means of an arrangement embodying a clinometer which is in effect, attached to the scraper blade or its equivalent, the said clinometer comprising a resistance element and a conductor that are bridged by a tilt-responsive contact medium. Electrical current applied to the ends of the resistance element is picked up by the contact medium and transmitted through the conductor to complete a suitable circuit, such as a Wheatstone bridge for example. Unbalance of the bridge circuit due to tilting of the clinometer produces a meter deflection that can be calibrated to read directly in terms of angle of inclination, or the current flow can be amplified to operate hydraulic valves or servo motors that control the angle of inclination of the blade.

The principles of the invention are disclosed in several illustrative embodiments, which are schematically shown in the accompanying drawings, and the advantageous features of the invention will immediately become apparent to those skilled in the art.

Figure 1 is a schematic drawing, showing one embodiment of the invention;

Figure 2 is an enlarged transverse sectional view through the tilt-responsive unit, taken at 2—2 in Figure 1;

Figure 3 shows another form of the invention;

Figure 4 is another embodiment of the invention; and

Figure 5 shows still another form.

Referring now to Figures 1 and 2 of the drawings, the invention is illustrated as embodied in a road grader, wherein the scraper blade or mold board is designated by the reference numeral 10. The blade 10 extends generally transverse to the direction of forward travel of the machine, and is conventionally mounted on the grader frame for tilting movement about a fore and aft extending axis. A motor 11 is connected to the blade 10 in a manner to control the angle of inclination of the blade. In actual practice, there are usually two motors controlling the tilt of the blade, the said motors being located at opposite ends of the blade and working in opposition to one another, and in the present case the motor 11 represents one or more motors.

The motor 11 may be in the form of a reversible, variable speed electric motor driving a screw jack or the like, or it may be in the form of one or more hydraulic cylinders operated by solenoid-actuated or motor-driven valves. Preferably, the motor 11 is of a type such that its speed is proportional to the current supplied thereto. The automatic leveling control mechanism, which will be described presently, supplies current to the motor at a rate proportional to the amount of angular deflection of the blade from the pre-set position, and this combination has the desirable characteristic of providing a quick-acting correction to the blade, with rapid traverse while the blade is considerably deflected from the pre-set position, and slowing down as the blade approaches the said pre-set position.

Mounted on the blade 10 and movable therewith is a tilt-responsive unit 12, which may be in the form of an accurately curved tube 13 of non-conductive material, such as glass or plastic, having a central bore or passageway 14. The curvature of the tube 13 is preferably circular and of the order of 30° radius, although it is not necessarily circular and may be of any other desired radius. For example, the curvature of the tube might be parabolic, or elliptical, or any other mathematical or empirical curve giving operational characteristics especially suited to the type of work with which the unit is to be used.

Disposed within the bore of the tube 13 and extending lengthwise thereof is a resistance element 15 and a parallel conductor 16. The elements 15 and 16 are preferably embedded in the bottom of the passageway 14, as shown in Figure 2, and their ends project through the closed ends of the tube.

A contact medium in the form of a metal ball 20 rests on the two elements 15 and 16, and is freely movable along the length thereof. The ball 20 forms an electrical connection between the resistance element and the conductor, which shifts in position as the unit 20 is tilted,
always seeking the lowest level. Instead of a metal ball, a pool of mercury or other electrically conductive fluid may be used as a contact medium, although the metal ball appears to have certain advantages and is here illustrated. To damp out oscillations of the ball, the passageway 14 is preferably filled with a non-conductive fluid of suitable viscosity, and as the ball moves in one direction or the other, the said fluid is forced through the clearance between the ball and the surface of the passageway 14.

Connected to the ends of the resistance element 15 by lines 21 and 22 is a source of electrical energy, such as the battery 23, which impresses a voltage drop across the ends of the element. The voltage drop on the resistance element is regulated by a variable resistance voltage adjuster 24, which is connected into line 21 extending from the battery to one end of the element.

A second resistance element 25 is connected across the lines 21 and 22, and wiping on the element 25 is a sliding contact 26. The resistance element 25, and the contact 26 are preferably in the form of a rotary potentiometer, wherein the contact 26 is turned by means of a knob 27 having a pointer 28 which indicates degrees of tilt or linear measurements of blade inclination. The contact 26 is connected to the terminal end of the conductor 16, and a wire 30, and connected in series with the wire 30 is a variable resistor 31 and an amplifier 32. If the invention is to be used solely as aclinometer for indicating the angle of inclination of the blade, the amplifier 32 may be omitted; or if it is to be used solely as an automatic leveling control mechanism, the meter 31 may be omitted. However, for most purposes, it will be desirable to have both the meter 31 and the amplifier 32 connected into the line 30.

It will be recognized that the resistances 15 and 25, battery 23, conductor 16, wire 30 and meter 31 are connected in a Wheatstone bridge circuit, wherein the resistance of the portions of the element 25 on either side of the contact 26 are balanced against the resistance of the portions of element 15 on either side of the contact ball 20.

Assuming that the blade 10 is horizontal and the ball 20 is centered in the passageway 14, the meter 31 will be zeroed when the contact 26 is at the center of the resistance 25. Tilting of the unit 12 in either direction causes the contact ball 20 to roll one way or the other, which produces an unbalanced condition in the circuit, causing current to flow through the meter. The amount of meter deflection is directly proportional to the amount of tilt of the unit 12, and the direction of its deflection to one side or the other of the zero position whether the contact ball 20 is to the left or right of the null position on the resistance element 15. The meter calibration can be made to read directly in terms of angle of tilt of the blade 10.

Current passing through the amplifier 32 is amplified sufficiently to operate the valves or other controls of the motor 11, thereby rocking the blade 10 back to the horizontal position. As the blade 10 tilts back to the horizontal position, the ball 20 rolls back toward the center or null position of the resistance element 15, causing it to diminish and finally cease when the ball reaches the null position. As mentioned earlier, the speed of the motor 11 is determined by the amount of current supplied thereto, and consequently as the current diminishes, the motor slows down to a gradual stop.

If it is desired to tilt the blade to some predetermined angle of inclination, it is necessary only to shift the contact 26 along the length of the resistance element 25. This has the effect of moving the null point on the resistance element 15 in one direction or the other, and the resulting unbalance in the circuit causes current to flow through the amplifier 32 to operate the motor in the proper direction until the ball 20 comes to rest at the new null position.

A zero adjustment variable resistor 33 is connected in series in the line 22 for the purpose of shifting the null point on the variable resistor, and for this purpose the null point of the variable resistor is moved by changing the resistance of the resistor 33. The zero adjustment variable resistor 33 is preferably used in conjunction with a zero adjustments variable resistor 33 which is connected in series in the line 22 for the purpose of shifting the null point of the variable resistor. The zero adjustment variable resistor 33 is preferably connected in series in the line 22 for the purpose of shifting the null point of the variable resistor. The zero adjustment variable resistor 33 is preferably connected in series in the line 22 for the purpose of shifting the null point of the variable resistor.
ends thereof are enlarged to form reservoir bulbs 54. Extending down through the central bore or passageway of the two tubes are resistance elements 55 and 56, which extend through the closed top ends of the tubes and are connected to lines 21 and 22 respectively.

The two tubes 52, 53 are partially filled with volumes 60 and 61 of electrically conductive fluid, such as mercury, which extend up to approximately the midpoint of their respective tubes. Projecting into the bulb 54 of the two tubes 52, 53 are contacts 62 and 63 which are jointly connected to the conductor wire 30 leading to the amplifier and meter.

Tilting of the unit 59 causes one of the tubes 52, 53 to approach the vertical position, while the other tube approaches the horizontal position. In the lower tube approaching vertical position, the conductive fluid sinks down to its lowest level in the passageway, leaving the maximum length of resistance element exposed, and producing increased resistance in that leg of the bridge circuit. In the higher tube approaching horizontal position, the conductive fluid tends to reach up toward the top end of the tube, shortening the length of resistance element exposed, and producing reduced resistance in that leg of the bridge circuit. With the unbalanced condition just described, current flows in one direction or the other through conductors 30, 31, deflector 50, motor, and operating the motor to bring the blade back to the horizontal or other pre-set angle of inclination.

In Figure 5, the tilt-responsive unit is designated in its entirety by the reference numeral 70, and comprises a tube or other body of non-conductive material having a V-shaped passageway provided therein. The legs 71 and 72 of the tube are at equal angles to the horizontal, and extending through the V-shaped passageway from one end to the other is a resistance element 73, 74. The passageway is partially filled with electrically conductive fluid 75, such as mercury, which extends approximately half way up each leg of the tube and submerges the intermediate portion of the resistance element. A contact 76 connected to the wire 30 extends through the wall of the tube at its lowest point, and is immersed in the fluid 75. The upper ends of the resistance element 73, 74 pass through the closed ends of the tube, and are connected to the lines 21 and 22 respectively.

When the unit 70 is tilted, the fluid flows from the higher leg of the V-shaped passageway down into the lower leg thereof. As the fluid in the lower leg rises in that passageway, the length of exposed resistance element is shortened, which reduces the resistance in that leg of the bridge circuit. At the same time, the fluid draining from the upper leg exposes a longer length of resistance element, which produces increased resistance. The unbalanced bridge condition causes current to flow through the meter 31 and amplifier 32, to operate the motor and restore the unit 70 to its original position.

While we have shown four illustrative forms of tilt-responsive unit in the drawings, it will be understood that other forms will function satisfactorily, and are included within the scope of the claims. We also wish to make clear that other forms of circuit than the Wheatstone bridge can be embodied in the invention, and that the essence of the invention resides in the use of a tilt-responsive unit mounted on the movable member, or, more generally, movable by virtue of movement of the movable member, and embodying a resistance element that is shorted to an associated conductor by a contact medium that moves along the length of the resistance element as the unit is tilted. The current flow produced by the shift in position of the contact medium along the length of the resistance element is used to deflect an angle-indicating meter, or is amplified to operate a motor that restores the tilted member to its original position, or both.

The advantageous feature of the invention is that current flow in the circuit is proportional to the angular deflection of the movable member from its preset position, which means that meter deflection is proportional, and motor speed can be made proportional.

It is also contemplated that the invention could be used with alternating current instead of direct current, in which case the battery 23 would be replaced by an A.C. generator. With alternating current, inductance or capacitance can be used in the circuit in place of resistance, as is well understood in the art, and the resistance elements of the tilt-responsive unit would be replaced by suitable inductors or capacitors. Accordingly, the term "impedance" when used in the claims, means resistance in a direct current system, or reactance in an alternating current system.

We claim:

1. An automatic control system for setting and holding the blade of an earthworking machine at any selected angle of inclination within a predetermined range of inclinations extending on both sides of zero, said system comprising, in combination with the blade, a first resistance element, a first contact element relatively movable in electrical contact along the length of said first resistance element through a definite range of movement, means whereby said first contact element is moved from a medial point on said first resistance element toward opposite ends thereof in response to opposite inclinations of the blade, a second resistance element, a second contact element relatively movable in electrical contact along the length of said second resistance element through a definite range of movement, first circuit means including a source of electrical energy and connecting said resistance elements in parallel relation to each other and to said source in a closed circuit, second circuit means interconnecting said two contact elements, said resistance, said contact elements and said two circuit means forming a bridge circuit, said range of movement of the second contact element being sufficient to provide a balanced condition of the bridge substantially throughout said range of movement of the first contact element, indicator means driven with the movement of the second contact element and indicating the position thereof in terms of the blade inclination that corresponds to a balanced condition of the bridge, manually operable means for moving the second contact element and the indicator means to preset the blade inclination desired, and power means actuated in opposite directions by current flow in opposite directions in the said second circuit means for maintaining said bridge balanced by moving the blade to, and holding it at, the angle of inclination selected.

2. An automatic control system for setting and holding the blade of an earthworking machine at any selected angle of inclination within a predetermined range of inclinations extending on both sides of zero, said system comprising, in combination with the blade, a first resistance element, a first contact element relatively movable in electrical contact along the length of said resistance element through a definite range of movement, means whereby said contact element is moved from a medial point on said resistance element toward opposite ends of the latter in response to opposite inclinations of the blade, a second resistance element, a second contact element relatively movable in electrical contact along the length of said second resistance element through a definite range of movement, first circuit means connecting said resistance elements in parallel relation to each other and to said source in a closed circuit, second circuit means interconnecting said two contact elements, one of said circuit means including a source of electrical energy, said resistance, said contact elements and said two circuit means forming a bridge circuit, said range of movement of the second contact element being sufficient to provide a null condition of the bridge substantially throughout said range of movement of the first contact element, indicator means driven with the movement of the second contact element and indicating the position thereof in terms of the blade inclination that corresponds to null condition of the bridge, manually operable means for moving the second contact element
and the indicator means to vary the blade inclination that corresponds to null condition of the bridge, manually operable bridge-balancing means actuable independently of the movement of said contacts to balance the bridge when the blade has zero inclination and the indicator means indicates zero inclination, and power means, actuated in opposite directions by current flow in opposite directions in the circuit means other than said one circuit means, acting to move the blade to and hold it in the position of inclination that balances the bridge.

References Cited in the file of this patent

UNITED STATES PATENTS

1,342,594 Parkin ---------------- June 8, 1920

1,506,192 Meijer ---------------- Aug. 26, 1924
2,023,748 Shipley ---------------- Dec. 10, 1935
2,256,833 McDonald ---------------- Sept. 23, 1941
2,412,263 Hartig ---------------- Dec. 10, 1946
2,455,394 Webber ---------------- Dec. 7, 1948
2,456,619 Curry et al. ------------- Dec. 21, 1948
2,478,956 Webber ---------------- Aug. 16, 1949
2,656,290 Bell ------------------- Apr. 28, 1953

FOREIGN PATENTS

135,332 Switzerland ---------------- Nov. 1, 1929