United States Patent

Snow

[15] 3,637,026

[45] Jan. 25, 1972

[54] CROSS SLOPE CONTROL OF MOBILE MACHINERY

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[73] Assignee: **CMI Corp.**, Oklahoma City, Okla.

[22] Filed: **Oct. 6, 1969**

[21] Appl. No.: **864,122**

[52] **U.S. Cl.**.....**172/4.5**, 172/669, 94/46 AC

[51] **Int. Cl.**.....**E02f 3/76**, E01c 19/48

[58] **Field of Search**.....37/105; 172/4.5; 94/46

[56] **References Cited**

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3,126,653	3/1964	Bourgeous	172/2 X
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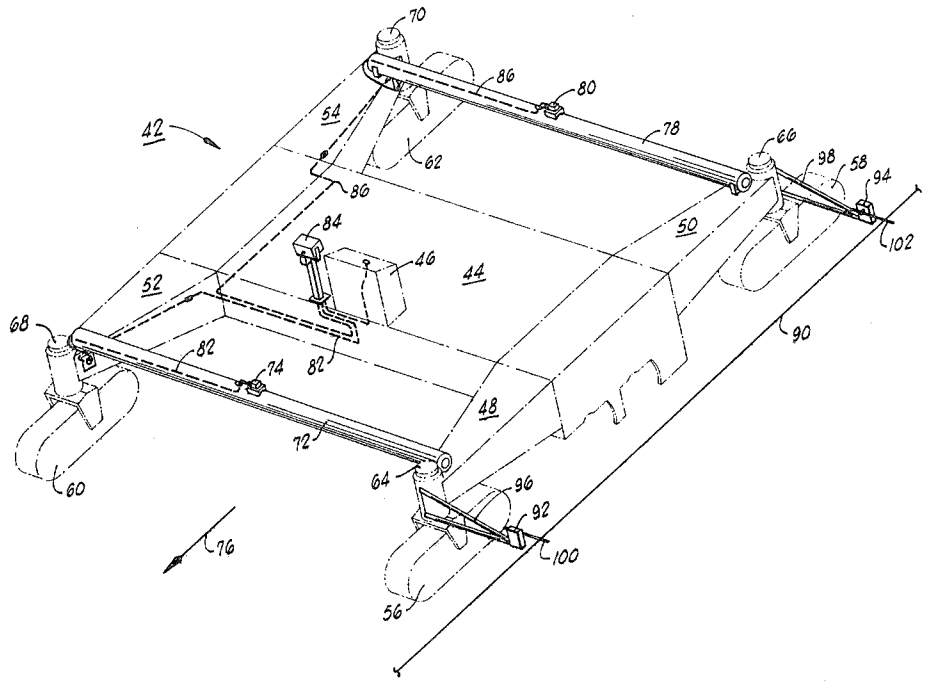
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[57] **ABSTRACT**

Apparatus for controlling the cross slope of mobile machinery relative to an external reference such as a string line. The apparatus consisting of accelerometer assemblies affixed at selected transverse midpoints of the machinery to provide a continual electrical output proportional to the cross slope angle of the machinery, whereupon this continual output is compared to a reference voltage selected in accordance with the desired cross slope angle to provide a further control output for use in keeping or repositioning the tilt angle of the machinery so that it is continually maintained at a desired cross slope angle. Such cross slope control assembly works in conjunction with machinery elevation control mechanisms responsive to a string line or other external reference such that cross slope is maintained with respect to an established level.

6 Claims, 4 Drawing Figures



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SHEET 1 OF 3

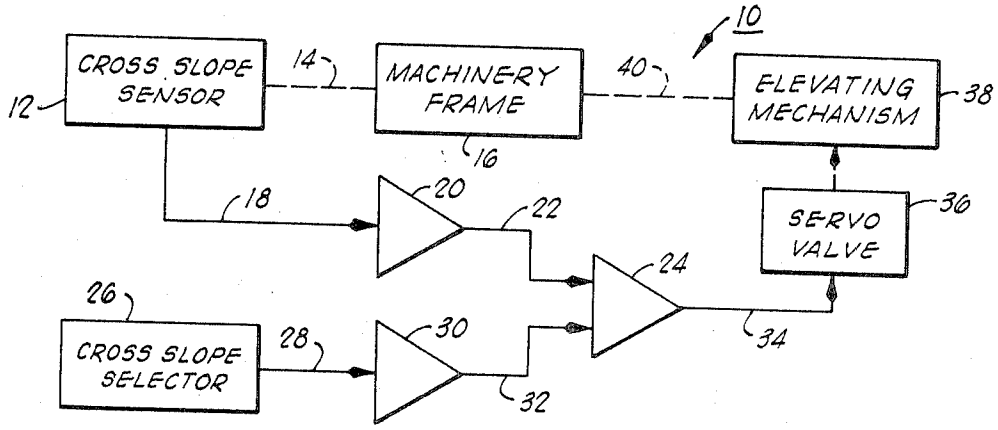


Fig. 1

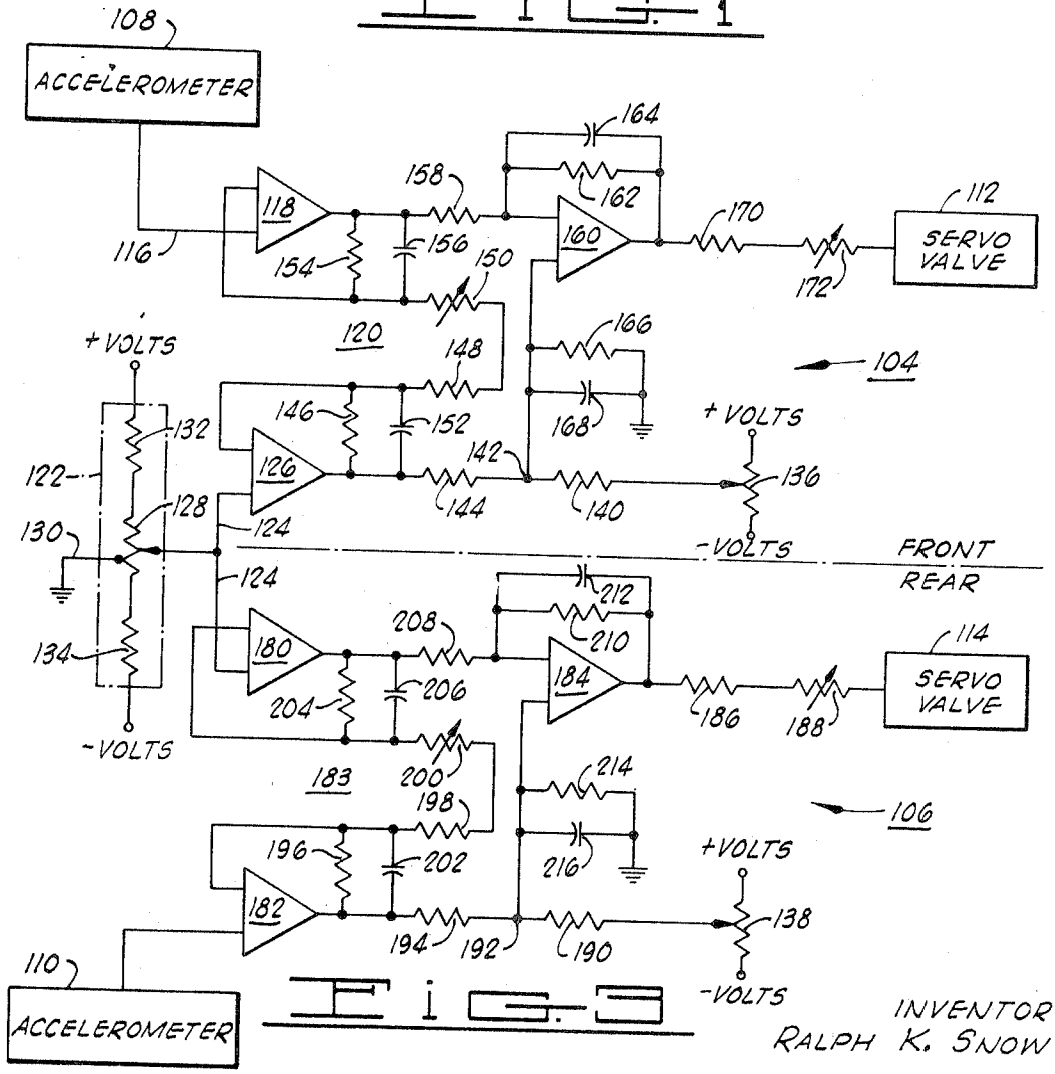


Fig. 3

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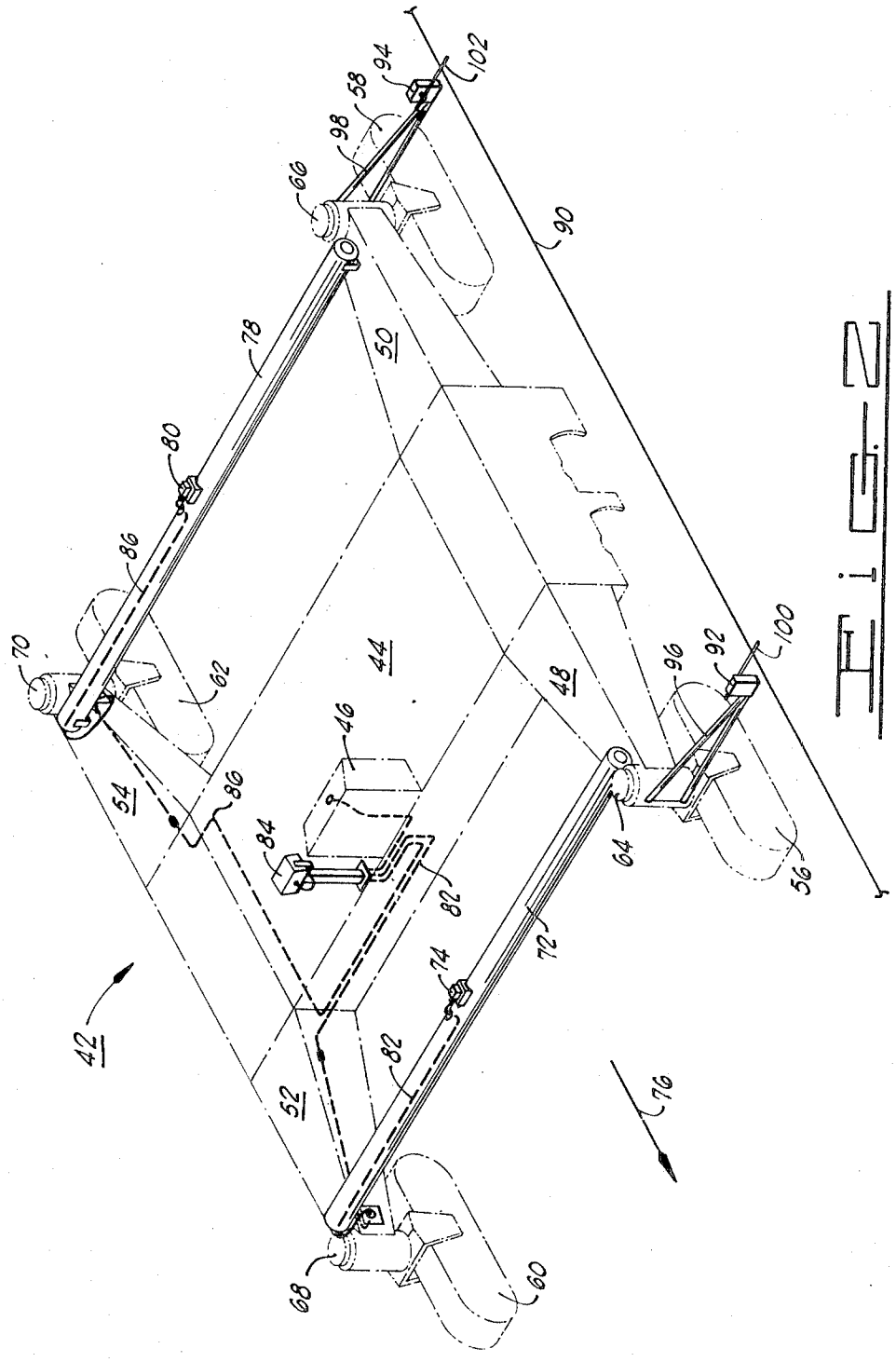


Fig. 2

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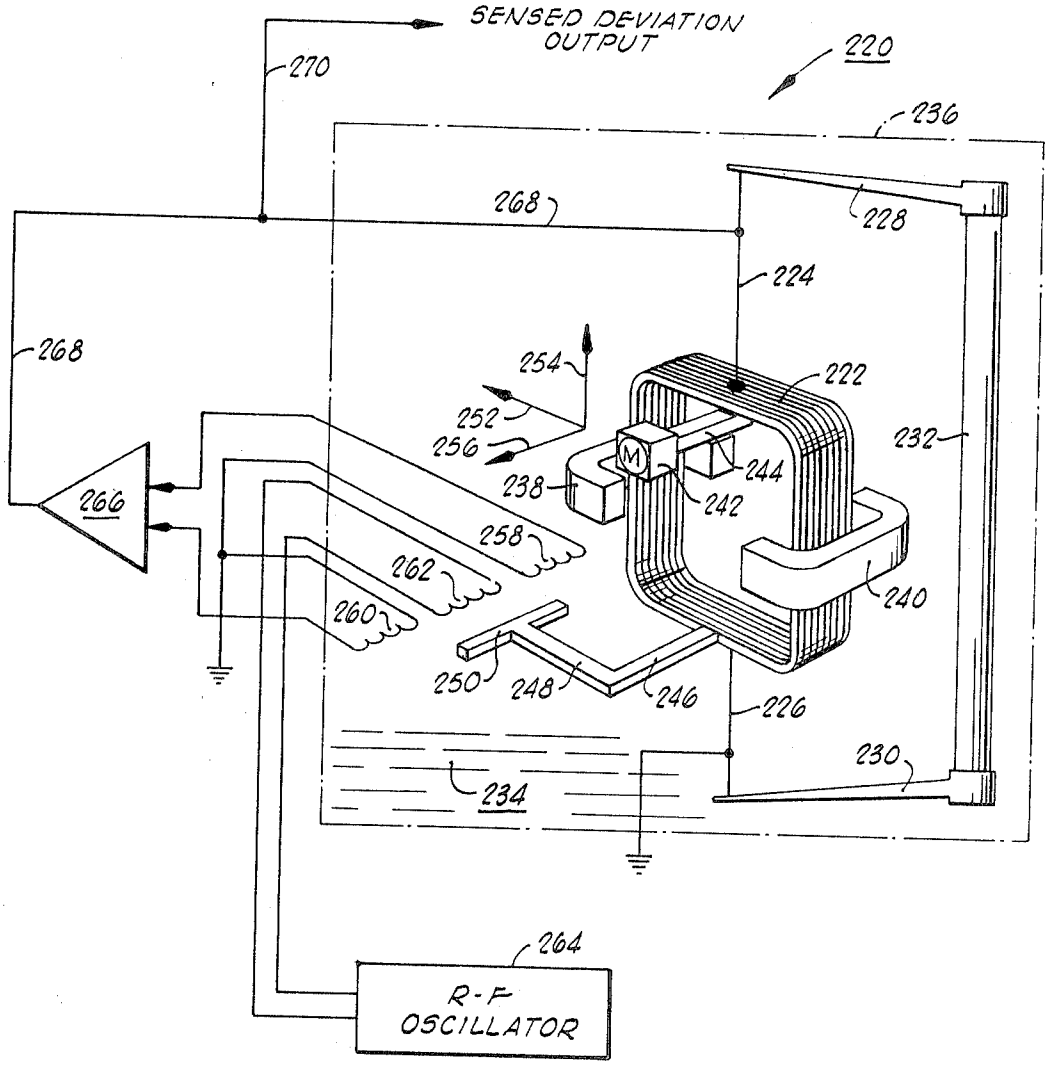


Fig. 4

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CROSS SLOPE CONTROL OF MOBILE MACHINERY

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates generally to mobile machinery control systems and, more particularly, but not by way of limitation, it relates to improved automatic control apparatus for continually regulating the cross slope of road construction machinery.

2. Description of the Prior Art

The prior art includes various types of transverse angle control mechanism for use in such as heavy mobile machinery. Such prior art systems and mechanisms have generally been characterized by an on-off system rather than a continuous type of control which would be capable of enabling smooth adjustment of very large equipment with minimal hunting and adverse effects. Many forms of prior art device merely provide a pendulum-type of switch transversely oriented to provide on-off actuation in response to deviation of the machinery from a preset transverse level. Still other forms utilize a continuous tracking output such as a slide wire assembly affixed to the machinery and providing a gravitationally varied output. Such systems are limited to a relatively coarse control capability due to inherent properties as to structure and operation. Still other forms of sensor device such as bubble switches, mercury flow switches etc., have been employed with some success in various attempts at effecting transverse slope control for diverse applications.

SUMMARY OF THE INVENTION

The present invention contemplates cross slope control apparatus for use with mobile machinery to enable control such that the machinery is maintained at a predetermined elevational level and transverse angle relative to a work path. In a more limited aspect, the invention consists of an accelerometer providing a reference output indicative of cross slope for comparison with a selected reference voltage indicative of desired cross slope whereupon a comparison output voltage is then applied to cross slope correcting mechanisms of the machinery, e.g., hydraulic elevation adjusting means, whereby the proper cross slope is achieved. The machinery may also be simultaneously reactive to an external reference level such that the cross slope adjusting mechanism operates in superposition to an elevational level maintaining structure.

Therefore, it is an object of the present invention to provide an extremely sensitive device for maintaining the transverse tilt of a construction machine relative to a work path.

It is also an object of the present invention to provide cross slope control means which is capable of highly accurate, continuous control of machinery, either free-running or as controlled relative to an external elevation reference.

It is still further an object of the present invention to provide a cross slope control apparatus which is highly reliable and extremely accurate through adverse conditions.

Finally, it is an object of the invention to provide apparatus capable of sensing fine variations in cross slope relative to a predetermined elevational level, which apparatus provides proportional indication and is independent of any form of sliding electrical contact.

Other objects and advantages of the invention will be evident from the following detailed description when read in conjunction with the accompanying drawings which illustrate the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of cross slope control apparatus constructed in accordance with the present invention;

FIG. 2 is a perspective view illustrating one form of mobile machinery having slope control apparatus affixed thereon;

FIG. 3 is a schematic diagram of cross slope control circuitry as utilized in an application such as that of FIG. 2; and

FIG. 4 is a schematic diagram of one form of accelerometer which may be utilized in the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The block diagram of FIG. 1 depicts one form of cross slope apparatus **10** consisting of both control circuitry and mechanical feed back connection. A cross slope sensor **12** may be rigidly affixed to the machinery to be controlled, and cross slope sensor **12** should be affixed, as by dash line **14**, to machinery frame **16** such that it is aligned transversely across the machine and work path. The cross slope sensor **12** then provides an electrical signal output via lead **18** which is proportional in magnitude and direction to the cross slope of machinery frame **16**.

The reference voltage on lead **18** is then applied to a conditioning amplifier **20** whose output **22** is then applied to one input of a differential amplifier **24**. A cross slope selector **26**, viz a suitable control selector disposed at the operating station, provides a voltage output on lead **28** which is representative of the desired cross slope angle. The voltage on the lead **28** is then applied through a conditioning amplifier **30** to generate an output on lead **32** for input to differential amplifier **24**. Differential amplifier **24** then generates a control voltage indicative of the differential inputs and such voltage is applied via lead **34** to a servo valve **36** which, in turn, adjusts the cross slope angle of machinery frame **16** by means of elevating mechanism **38** and a mechanical linkage **40**.

The conditioning amplifiers **20** and **30** may be a standard type of low drift amplifier having high impedance and providing isolation and stabilization to the differential inputs of differential amplifier **24**. The servo valve **36** is merely one form of well-known mechanism for controlling the application of hydraulic pressure to hydraulic elevational elements or mechanism **38** to adjust the level of machinery frame **16**, as will be further described below. Such control mechanisms are fully taught in various of prior applications and patents, e.g., U.S. Pat. No. 3,423,859 entitled "Road Construction Method and Apparatusq" issued Jan. 28, 1969 in the name of Swisher, et al. and assigned to the present assignees. It should be understood that the correcting system may also be utilized with other than hydraulic power mechanisms.

A machinery frame **42**, as shown in FIG. 2, is similar to that employed in automatic grading machinery as disclosed in the aforementioned U.S. Pat. No. 3,423,859. The machinery frame **42** consists of a center bridge portion **44** which supports an operating console **46**, and a bridge portion **44** is supported by quadrature-arrayed support legs **48**, **50**, **52** and **54** each supported on respective mobile track assemblies **56**, **58**, **60** and **62**. Each of the respective mobile assemblies **56—62** are pivotally supported beneath elevation assemblies **64**, **66**, **68** and **70** which are hydraulic piston assemblies, each individually adjustable to heighten or lower the respective support legs **48—54** relative to its respective mobile assembly **56**, **58**, **60** and **62**.

A front sensor support beam **72** having a sensor assembly **74** firmly affixed thereon is mounted transversely across machinery frame **42**, a work path being indicated by arrow **76**, with opposite ends of sensor support **72** being secured to respective support legs **48** or **52**. Similarly, a rear sensor support beam **78** is secured transversely between rear support legs **50** and **54** to carry a sensor assembly **80** positioned generally along the centerline of the machinery frame **42**.

Sensor **74** is then connected via a multiwire electric cable **82** to a circuit box **84**, while rear sensing assembly **80** is connected dash lines. through an electric cable **86** to the circuit box **84**. Operator control of cross slope selection (as will be further described) is effected by the operator at control box **84**, and cables **82** and **86** are also connected for operation of servo valves within respective support legs **52** and **54** to control elevating assemblies **68** and **70**, respectively. Such hydraulic control of support leg elevating assemblies is fully disclosed in the aforementioned U.S. Pat. No. 3,423,859.

The elevational level of machinery frame **42** may be maintained with respect to an external reference sr string line **90** as a pair of control sensors, forward control sensor **92** and rearward control sensor **94**, are supported outboard by respective

frame support arms **96** and **98**, each rigidly affixed to respective frame support legs **45** and **50**. The control sensor boxes **92** and **94** then extend sensor rods **100** and **102** outward for contact with stringline **90**. Such sensor control practice is also fully disclosed in the aforementioned U.S. Pat. No. 3,423,859. However, it should be understood that elevational level may be maintained by any of several external references, such as ground skis in contact with a pregraded surface or adjacent paving slab, laser equipment, etc.

The schematic diagram of FIG. **3** represents a forward sensing circuit **104** and a rear sensing circuit **106** as may be employed with road construction machinery as shown in FIG. **2**. Thus, respective forward and rear accelerometers **108** and **110** provide inputs to the respective sensing circuits **104** and **106**, the outputs of which are employed to control respective front servo valve **112** and rear servo valve **114**. Each of the accelerometers **108** and **110** may be a pendulous-type accelerometer such as that of FIG. **4**, to be further described below. A suitable commercial form of accelerometer is such as the Model LSXVG 39–.5 which is available from Schavitz Engineering Company of Pennshawken, N.J. This type of accelerometer is highly sensitive and capable of producing a very linear output from zero through plus or minus several volts in proportion to angular movement from zero to plus or minus as much as 30°. The servo valves **112** and **114** may be any of many types depending upon size requirements, and one constructed form of the invention has utilized a Moog servo valve [five gallons, Type 76–102] to good advantage for control and regulation of the hydraulic elevating assemblies.

An output from the front accelerometer **108** is applied via lead **116** to a differential input of a differential amplifier **118**, a part of a differential network **120** which compares sensor output on lead **116** with a reference voltage input. The reference voltage is obtained from a slope voltage source **122** via a lead **124** to differential input of a differential amplifier **126**. The reference voltage is obtained from a slope control potentiometer **128** having respective ends connected to dropping resistors **132** and **134** which, in turn are connected to the regulated plus and minus voltage supplies respectively.

It has been found that a 24 volt regulated DC supply may be utilized with center-grounded output to provide plus 12 volts and minus 12 volts availability. These same plus and minus 12 volt supply voltages are applied to respective front calibration potentiometer **136** and rear calibration potentiometer **138**. It should be understood, however that the matter of supply voltage is relative and that any of various conventional power supplies and voltage standards may be employed.

The differential amplifiers **118** and **126** are conditioning amplifiers characterized by low drift, high impedance and very low output power such that they afford isolation and stabilization as between their respective accelerometer assemblies and input to the power amplifying stages to follow. The amplifiers **118** and **126** may be such as module-type differential amplifiers No. PF 85AU available from Philbrick/Nexus Research of Dedham, Massachusetts.

A voltage is obtained from a calibration potentiometer **136** for conduction through a resistor **140** to a terminal point **142**. The calibration voltage is applied to the output of amplifier **126**, as developed across a resistor **144**, and it serves to adjust and compensate for relative differences in output as between amplifiers **118** and **126**. A parallel-connected resistor **146** and capacitor **152** are connected across amplifier **126** to provide sensitivity adjustment and, similarly, a resistor **154** and capacitor **156** provide the similar function across the amplifier **118**. A resistor **148** and potentiometer **150** enable gain control of amplifiers **118** and **126** in concert.

The differential amplifier **160** is a power amplifier and it may be such as a module amplifier of the Philbrick-Nexus Type SQ 210. A second differential input to differential amplifier **160** is derived from terminal point **142** and differential amplifier **126**. Stabilizing regeneration as between the output of differential amplifier **160** and the accelerometer voltage input is provided by a parallel-connected resistor **162** and capacitor **164**. The reference differential input to differential amplifier **160** is regeneratively filtered in similar manner by means of a resistor **166** and capacitor **168** connected to ground. The output from differential amplifier **160** is then applied through a series-connected resistor **170** and current adjusting potentiometer **172** to control the servo valve **112**.

The rear sensing circuit **106** is similarly constituted with the reference input from slope control potentiometer **128** and position input from rear accelerometer **110** being applied to differential inputs of respective conditioning amplifiers **180** and **182** of a differential network **183** for stabilization with a calibrated comparison voltage from calibration potentiometer **138**. The output from amplifiers **180** and **812** are then amplified for further differential input to respective inputs of a differential power amplifier **184** with subsequent output of any control voltage through a resistor **186** and current adjusting potentiometer **188** to control the rear servo valve **114**.

A comparison voltage for application to one input of each of differential amplifier **180** and **182** is derived with the aid of calibration potentiometer **138** which applies compensating voltage through the resistor **190** to a terminal point **192**. This potential is applied to the output of amplifier **182** as developed across a resistor **194** to adjust the output voltage. Potential application through the resistor **198** and gain potentiometer **200** places an adjusted input on the comparison differential input of differential amplifier **180**. The remainder of the circuitry is similar to that for the front differential network **120**, i.e., a capacitor **202** and resistor **196** are connected in parallel with amplifier **182** for sensitivity control and a parallel-connected resistor **204** and capacitor **206** are similarly connected between the output and comparison differential input of differential amplifier **180**. The output from amplifier **180** is applied through a resistor **208** to one differential input of power amplifier **184**, with sensitivity adjustment of amplifier **184** made by means of a parallel-connected resistor **210** and capacitor **212**. And the remaining differential input of power amplifier **184** receives signal from terminal point **192**, the output of differential amplifier **182**, with decoupling being effected by means of a resistor **214** and capacitor **216** to ground.

It should be mentioned that in the interest of maximum stability, the ground circuit as indicated in FIG. **3** should be isolated, i.e., separate from the electrical system or frame ground of the machinery. Thus, the common or ground connection for the positive and negative 12 volt regulated power supply outputs may be connected by separate lead to ground connection **130** of the slope control potentiometer **128**, as well as to the respective return connections of resistors, **166** and **214**. The slope control potentiometer **128** is preferably a precision-type of potentiometer and it is located on the control box **84** (FIG. **2**) at the operating position so that the operator can select or dial in his desired cross slope angle after which the front and rear cross slope assemblies **104** and **106** will carry out the tracking function. That is, when the system is properly calibrated, the accelerometers **108** and **110** will be transversely positioned to seek a null relative to that voltage value which has been dialed in at slope control potentiometer **128**.

FIG. **4** represents a pendulous-type accelerometer **220** such as may be employed for accelerometers **108** and **110** (FIG. **3**). The accelerometer **220** consists of a torque coil **222** which is suspended by means of thin wire filaments or bands **224** and **226** connected to respective spring members **228** and **230**. The spring members are then affixed to a suitable insulative support **232**, and the whole assembly is preferably enclosed within a damping chamber **236** filled with a light silicone **234** oil, as outlined generally by dash lines.

The torque coil is maintained in a neutral position by means of a pair of oppositely polarized permanent magnets **238** and **240**, each of which allows relatively large gap with respect to torque coil **222**. A mass **242** is suspended on a horizontal bar **244** which is affixed to extend outward from the top center of torque coil **222**. Similarly, a lower bar **246** extends outward from the lower center of torque coil **222**, but lower brace **246**

supports a lateral brace 248 carrying a reactance member 250 which will be further described below. Thus, referring to the three different planes of arrows 252, 254 and 256, the lateral or transverse arrow 252 represents the sensitive axis of the accelerometer 220, while the vertical arrow represents the general disposition of coil support bands 224 and 226, and horizontal arrow 256 indicates the third dimension wherein braces 244 and 246 extend.

Position variation of torque coil 222 is sensed by a pair of series-connected sensing coils 258 and 260 which are arranged in equal physical disposition to an R–F coil 262 with energy coupling being varied in accordance with the positioning of reactive mass 250, i.e., through rotation of torque coil 222 and lower brace 246. R–F input energy to coil 262 is derived from a suitable R–F oscillator 264 of well-known type, and output energy from sensor coils 258 and 260 is applied in series opposition to respective inputs of an amplifier 266. The differential output of amplifier 266 is then applied via lead 268 back to band 224 which is in conductive connection to torque coil 222 and lower band 226 to the ground or common connection. The sensed deviation output is then available on an output lead 270, i.e., such as lead 116 of FIG. 3.

The accelerometer 220 is installed for operation in such manner that the sensitive axis extends transversely across the machinery with which it is utilized. Preadjustment and positioning of magnets 238 and 240 will then assure that torque coil 222 is transversely aligned so that sensing coils 258 and 260 receive equal coupling of R–F energy from R–F coil 262 through the reactive member 250. This then enables a null output from amplifier 266 such that no corrective current flow appears on lead 268 for feedback to torque coil 222, and no output signal voltage is apparent on output lead 270. Thus error movement of the machinery in the plane 252–254 causes rotation of the torque coil 222 and therefore the reactive member 250 in the plane 252–256 to generate a corrective voltage through varying energy coupling as between R–F coil 262 and the sensing coils 250 and 260.

The accelerometer type of sensor is desirable in comparison to slide wire, mercury switch, gyroscope and other types due to certain inherent characteristics. That is, the accelerometer will be capable of operation with no resistance to machine longitudinal motion and, in addition, such devices offer improved linearity with no noise and no wearing parts disadvantages. It should be understood too that other types of accelerometer, such as the spring-mass, piezoelectric, and strain gauge types, may also be employed in various applications.

While the invention has been specifically described with respect to front and rear sensing assemblies working on such as an automatic grading machine, as shown in FIG. 2, the cross slope teachings may be employed on many different types of mobile machine utilizing either single or plural sensing units. Thus, it is also contemplated that a single sensing circuit as outlined generally in FIG. 1 may be employed with such as motor-grader machinery carrying a center-mounted workpiece. Such cross slope control may be effected through servo adjustment or either a central tool-carrying frame or by direct position control of the workpiece. It is also contemplated that the cross slope control may be utilized with paving and asphalting apparatus of various types.

OPERATION

The sensing circuits 104 and 106 must first be balanced and calibrated to provide proper tracking as between the slope control assembly 122 and the respective front and rear accelerometers 108 and 110. Thus, with the machinery frame cross slope held level, the slope control potentiometer 128 can be set at its zero position, i.e., at ground or common potential, and any mechanical adjustment to zero the accelerometers of sensors 108 and 110 can also be carried out. Then, each of the front and rear differential circuits 120 and 182 is balanced to provide proper differential output in relation to its respective servo valve 112 or 114.

With regard to the front sensing circuit 104, calibration potentiometer 136 is adjusted to its zero or midpoint where the potential at terminal point 142 is the same as that applied to the opposite differential input of differential amplifier 160, and a null point is achieved with no output to servo valve 112. The balance potentiometer 150 is also adjusted to provide the proper balance so that no output is apparent from either of differential amplifiers 118 and 126 at the zero position. The similar calibration and balancing adjustments are made to the rear sensing circuit 106 in the same manner, and the equipment is then ready for service operation.

The operator then dials in a desired cross slope through slope control potentiometer 128 in the form of a plus or minus potential which is applied to respective differential inputs of forward and rear differential amplifiers 126 and 180. This then developes respective forward and rear error signals at the outputs of differential amplifiers 126 and 180, which error signals are further applied to respective inputs of differential power amplifiers 160 and 184. The amplified error signals from differential amplifiers 160 and 184 are then applied to drive their respective servo valves 112 and 114 until the respective forward and rear accelerometers 108 and 110 come to the desired angular position wherein a proper nulling input voltage is developed. That is, in the case of front sensing circuitry 104, accelerometer 108 develop an output voltage on lead 116 which is in proportion to its cross slope angular deviation, which output is applied with a comparison voltage to differential amplifier 118 to develop a first error voltage for input to power amplifier 160. Power amplifier 160 will develop an error output to actuate the servo valve 112 until the difference output from differential amplifier 118 is equal to that differential output from differential amplifier 126, the control input.

The rear control circuitry 106 follows in the same manner such that differential amplifier 182 will produce an error output for input to power amplifier 184, and the differential power amplifier 184 will continue to maintain certain actuation of servo valve 114 until the differential inputs become equal. Operation of both the front and rear control circuits 104 and 106 from a single-slope control potentiometer 128 insures that the forward and rear parts of the machinery frame 42 will be controlled in concerted manner.

Referring also to FIG. 2, one side of the machinery frame 42 may be held to a predetermined elevational level by reference to an external position or mark, e.g., by utilization of the control boxes 92 and 94 extending respective control sensor rods 100 and 102 into contact with a stringline 90. This then provides elevation level control at support legs 48 and 50 of machinery frame 42, while additional control by the operator at control box 84 maintains the remainder of machinery frame 42 at whatever the proper attitude relative to stringline 90. Thus, the operator may dial in angles which are either positive or negative from 0° relative to the elevation level as established by the stringline 90.

The foregoing discloses novel cross slope control mechanism for use with road construction machinery wherein highly accurate and reliable cross slope angle is maintained as the machinery progresses along the work path. The mechanism has a further advantage of being easily accessible for control by the operator with instantaneous response to changes in control input as the desired cross slope angle can be directly dialed for control input. The apparatus of the present invention is characterized by relatively low cost and high reliability due to isolation from vibration and environmental hazards. the use of precision accelerometers as sensing elements enables an extremely great precision of cross slope setting and control.

Changes may be made in the combination and arrangements as heretofore set forth in the specification and shown in the drawings; it being understood that changes may be made in the embodiments disclosed without departing from the spirit and scope of the invention.

What is claimed is:

1. Apparatus for controlling cross slope of mobile machinery along a work path relative to an external reference, comprising:

elevation control means affixed to one side of said mobile machinery to maintain said mobile machinery at a predetermined level to said external reference;

servo accelerometer means affixed at a transverse midpoint of said machinery, and including pendular means including a torque coil and a reactive member which is normally disposed in a quiescent position adjacent said torque coil and moveable in response to movement of the machinery transverse to the work path to move said reactive member proportionately, and circuit means including a source of oscillatory electrical energy disposed adjacent said reactive member and having its magnitude controlled in proportion to the positioning of said reactive member thereby to generate a continuous electrical sense output indicative of the amount of displacement of said pendular means from its quiescent position;

selector means providing an electrical control output in proportion to a desired cross slope angle of said machinery;

control circuitry for comparing said sense output and said control output to generate an electrical error output; and

elevation adjusting means disposed on said mobile machinery and energized by said error output to actuate said elevation control means to reposition said machinery to the selected cross slope angle.

2. Apparatus as set forth in claim 1 wherein said selector means comprises:

reference voltage means;

potentiometer means connected across said reference voltage means to provide a positive or negative proportional voltage output in response to selection of a desired cross slope angle of the machinery.

3. Apparatus as set forth in claim 1 wherein said control circuitry comprises:

differential amplifier means having first and second differential inputs and receiving said sense output at a first differential input and said control output at a second differential input to generate an electrical error output in the form of a difference signal.

4. Apparatus as set forth in claim 1 which is further characterized to include:

second accelerometer means affixed to the transverse midpoint of said machinery and disposed at an appreciable longitudinal distance from said first accelerometer means to provide a continuous electrical second sense output in proportion to the cross slope angle of said machinery to said work path; and

second control circuitry for comparing said second sense output and said control output to generate a second electrical error output; and

second elevation adjusting means disposed on said mobile machinery and energized by said second error output to actuate said elevation control means to reposition said machinery at the selected cross slope angle.

5. Apparatus as set forth in claim 4 wherein said second accelerometer means comprises:

pendular means including a reactive member which is normally disposed in quiescent position and movable in response to movement of the machinery transverse to the work path to move said reactive member proportionately;

circuit means including a source of oscillatory electrical energy disposed adjacent said reactive member and having its magnitude controlled in proportion to positioning of said reactive member to generate an output indicative of the amount of displacement of said pendular means from its quiescent position.

6. Apparatus for controlling cross slope of mobile machinery along a work path relative to an external reference, comprising:

first and second elevation control means affixed to one side of said mobile machinery at generally forward and rearward positions, respectively, to maintain said mobile machinery at a predetermined level and attitude relative to said external reference;

first and second accelerometer means affixed at a transverse midpoint of said machinery at said generally forward and rearward positions, respectively, to provide first and second continuous electrical outputs which are proportional to the cross slope angle of said machinery to said work path at each of the generally forward and rearward positions;

selector means providing first and second electrical control outputs in proportion to the desired cross slope angle of said machinery at respective forward and rearward positions;

first and second control circuits for comparing said respective first and second sense outputs and said first and second control outputs and thereby to generate the first and second electrical error outputs; and

first and second elevation adjusting means disposed on said mobile machinery at generally forward and rearward positions and energized by respective first and second error outputs to actuate said first and second elevation control means thereby to reposition said respective forward and rearward parts of the machinery to the selected cross slope angles.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,637,026 Dated January 25, 1972

Inventor(s) Ralph K. Snow

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

Column 2, line 64 the words "dash lines" should be omitted.

Column 3, line 1 the word "frame" should be omitted.

Column 3, line 35 the word "slope" should be --reference--

Column 4, line 13 the number "812" should be --182--

Column 4, line 22 the word "the" should be omitted.

Column 4, line 25 the word "the" should be omitted.

Signed and sealed this 22nd day of August 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents