United States Patent

Martenson et al.

[15] **3,691,916**

[45] **Sept. 19, 1972**

[54] **PROPORTIONAL SCREED CONTROL FOR A FINISHER**

[72] Inventors: **Earl D. Martenson,** North Aurora; **Ray E. Ingham,** Wheaton, both of Ill.

[73] Assignee: **Barber-Greene Company,** North Aurora, Ill.

[22] Filed: **Dec. 30, 1970**

[21] Appl. No.: **102,647**

[52] **U.S. Cl.** ..... **94/46 AC**

[51] **Int. Cl.** **E01c 19/48**

[58] **Field of Search** ..... 94/45, 46, 46 AC

[56] **References Cited**

UNITED STATES PATENTS

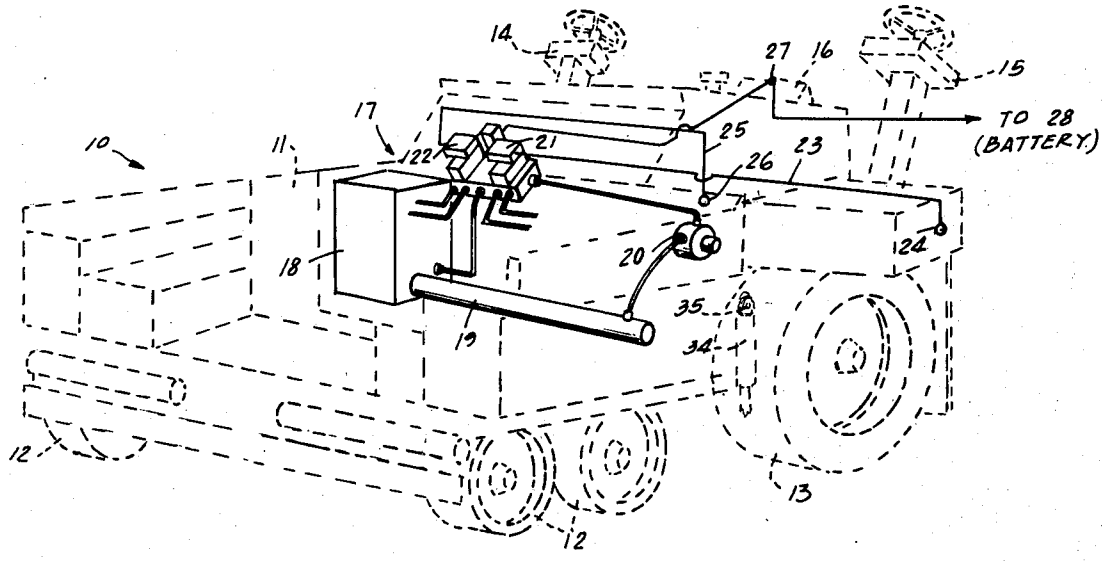
3,285,148	11/1966	Munyon	94/46 AC
3,181,441	5/1965	Flom	94/46 AC
3,158,945	12/1964	Curlett	94/45 R X
3,414,327	12/1968	Austin	299/1
3,543,654	12/1970	Long	94/46 AC
3,453,939	7/1969	Pollitz	94/46 R

Primary Examiner—Jacob L. Nackenoff
Attorney—McDougall, Hersh & Scott

[57] **ABSTRACT**

A finishing machine, or paver, employs a proportional control system for controlling the disposition of a floating screed with respect to both grade and slope of the supporting surface. The apparatus for controlling grade includes a device for sensing grade with respect to a reference and an amplifier and switch unit for operating a grade control actuator in response to the sensed changes in grade. The slope control apparatus is generally the same as the grade control apparatus and further includes a variable remote set point unit for establishing a reference indicative of the desired slope.

11 Claims, 8 Drawing Figures



PATENTED SEP 19 1972

3,691,916

SHEET 1 OF 3

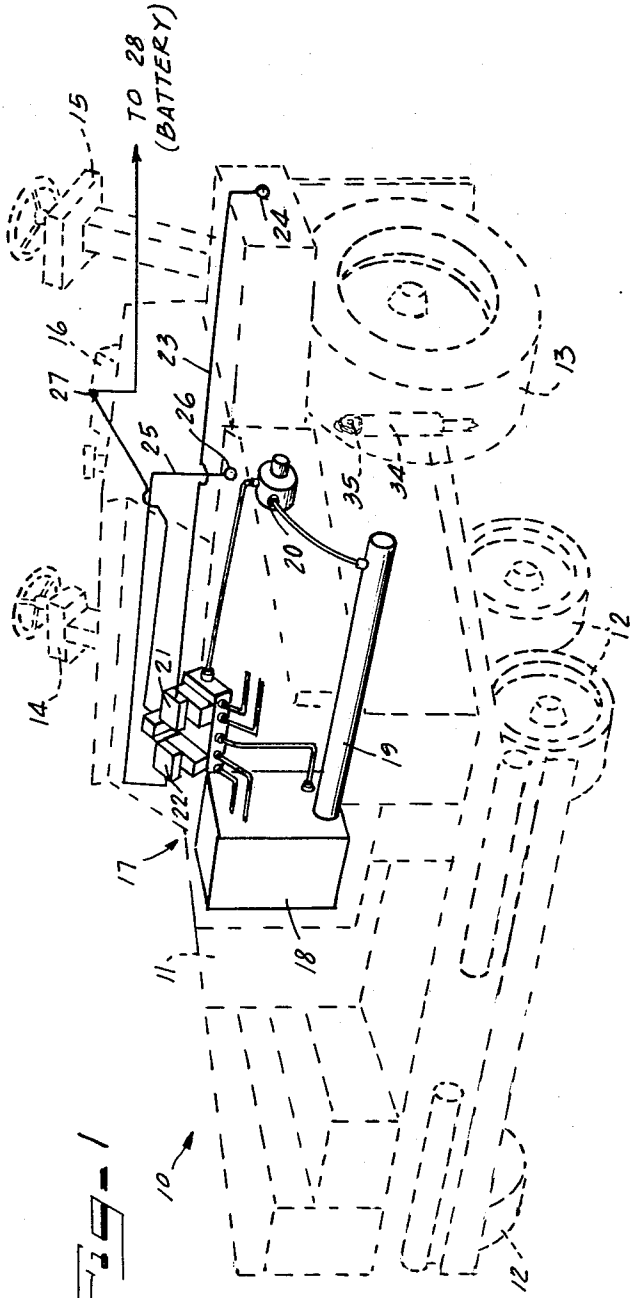


FIG-1

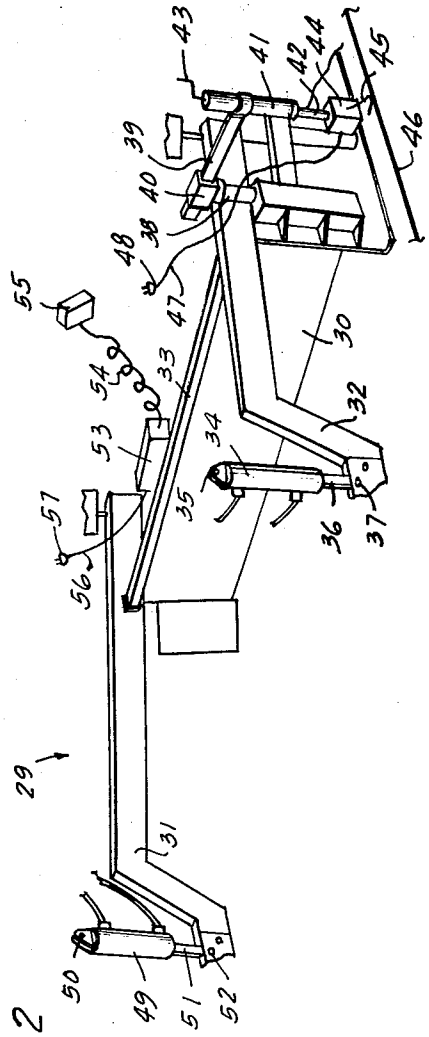


FIG-2

INVENTORS
EARL D. MARTENSON
RAY E. INGHAM

BY Hill, Sherman, Meroni, Gross & Simpson ATTORNEYS

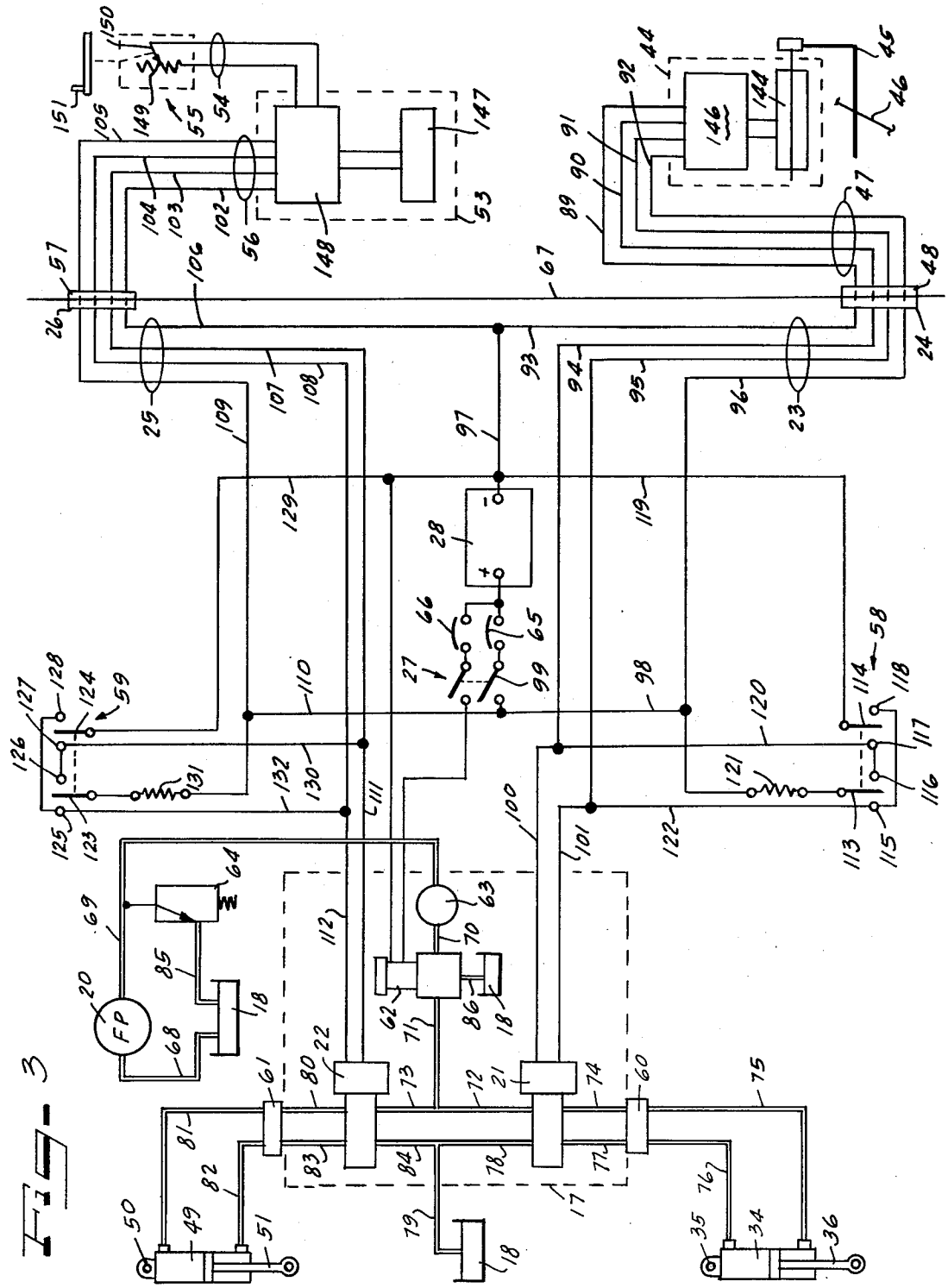


FIG. 3

INVENTORS
EARL D. MARTENSON
RAY E. INGHAM

BY Hill Sherman, Meroni, Gross & Simpson ATTORNEYS

Fig. 4

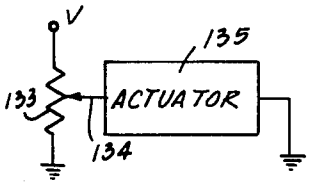


Fig. 5

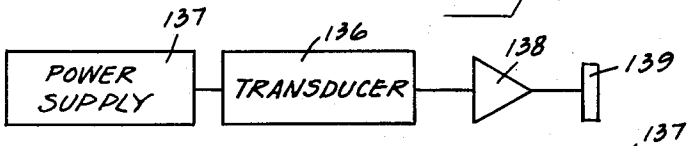


Fig. 6

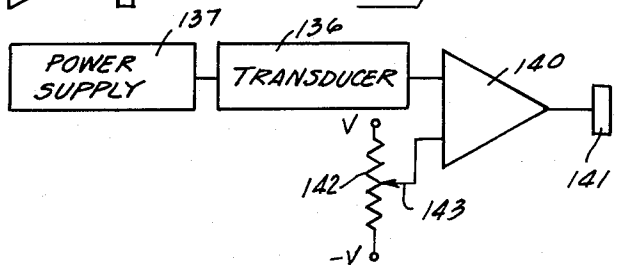
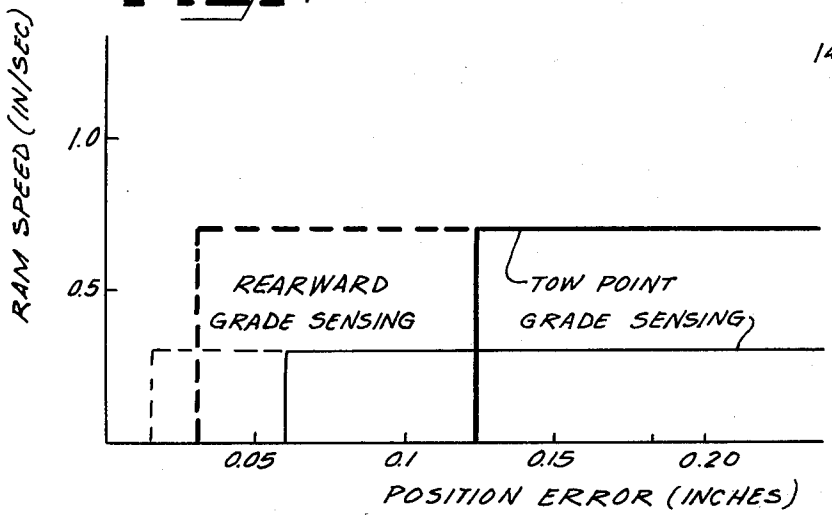


Fig. 7



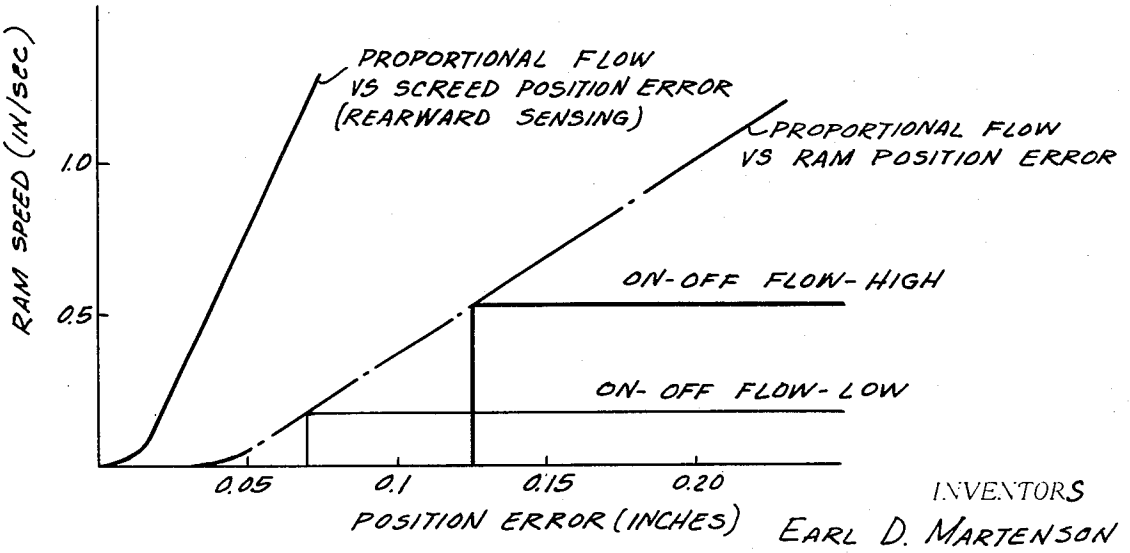


Fig. 8

INVENTORS
EARL D. MARTENSON
RAY E. INGHAM

BY Hill, Sherman, Meroni, Gross & Simpson ATTORNEYS

PROPORTIONAL SCREED CONTROL FOR A FINISHER

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to paving machines, and is primarily concerned with proportional control apparatus for controlling the positioning of a floating screed with respect to both the desired grade and slope of the surface being finished.

2. Description of the Prior Art

Heretofore, bituminous pavers have utilized solenoid valve control systems, generally referred to as on-off constant speed control systems, which provided a choice of only three flow conditions; stop; a set flow rate in a first direction; and a set flow rate in the opposite direction. This type of system would produce incremental motions of the tow point of perhaps an eighth of an inch per energizing cycle.

The specifications for a finished mat are becoming more and more stringent and tolerances accordingly tightened so that the present trend is toward automatic control in order to provide constant conditions and consistent product through the control of system variables in a proportional manner. It is therefore highly desirable and a primary object of the present invention to provide a paver which employs proportional control techniques for the automatic control of screed position whereby the grade and slope of the finished surface is extremely accurate.

SUMMARY OF THE INVENTION

According to the invention, a paver is provided which employs proportional grade and slope control. The proportional control is a high resolution control wherein rearward sensing of grade and slope is utilized without the sacrifice of response to tractor variations. In the proportional control system, proportional valves respond very quickly, for example within a few milliseconds, and provide an essentially variable flow rate of varying magnitude corresponding to the amount of correction required, and as the magnitude of the sensed error decreases, the flow rate correspondingly decreases. In addition, continuous sensing and response of the proportional system allows for a complete "floating " control of the tow point, even when the sensing point is established well rearward toward the screed.

In contrast to the above-described on-off constant speed systems, the proportional flow control system, including proportional flow control valves, offers an infinite number of controlled flow rates instead of three possible condition. This infinite number of controlled conditions provides a high resolution system which produces a near perfect positioning of the tow point, and the entire screed assembly is effectively dissociated from the vertical movement of the tractor unit. The desired position may, however, be easily changed as the screed encounters unavoidable variations such as variations in travel speed and/or variations in material ahead of a strike-off location. In the system according to the present invention, the tow point will undergo very small corrections and the screed itself will be controlled much closer through the utilization sensing.

The grade control apparatus of the present invention includes a device for providing an electrical signal which is indicative of the difference between a grade reference and the instantaneous sensed grade. This signal is amplified and utilized to drive a grade control cylinder which repositions the leveling arm of the screed. The sensing device includes a positionable and operatively movable grid or shoe for traveling a predetermined grade reference. Movement of the machine relative to the reference effects a generation of the grade control signal.

The slope control apparatus of the present invention is quite similar to the grade control apparatus, but further includes a variable set point device whereby an operator may establish a desired reference slope, variations from which reference slope will effect generation of a slope control signal. The slope control signal is amplified and utilized for driving a cylinder to position a second leveling arm of the screed at the desired slope. The grade and slope controls can be applied to either side of the machine, that is, the grade reference can be sensed on either side of the machine and the opposite side is then slaved via the slope control.

The grade and slope control apparatus each include a null meter for visual monitoring of the grade and slope conditions upon initial set up, prior to a finishing operation, during the paving process, and for maintenance and trouble shooting of the apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of the invention, its organization, construction and operation will be best understood from the following detailed description of an exemplary embodiment thereof, taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a pictorial representation of a portion of the electric and hydraulic circuit for a paving machine, shown in phantom, constructed in accordance with the principles of the present invention;

FIG. 2 is a fragmentary view of the forward end of a screed, particularly illustrating a pair of leveling arms and a corresponding pair of controlled cylinders along with the grade and slope sensing devices of the present invention;

FIG. 3 is an electrical and hydraulic and schematic diagram of the proportional grade/slope control system according to the present invention;

FIG. 4 is a block diagram of a typical control technique;

FIG. 5 is a schematic block diagram relating to the grade control apparatus of the present invention;

FIG. 6 is a schematic block diagram of the slope control apparatus of the present invention;

FIG. 7 is a graphical illustration of the comparison of tow point vs. rearward sensing for a floated screed paver; and

FIG. 8 is a graphical illustration of a comparison of correction speed vs. position error for a floated screed paver.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

GENERAL DESCRIPTION

A tractor unit for a paver is generally illustrated in FIG. 1 at 10 and includes a body 11 carried on a plu-

rality of wheels, wheels 12 and 13 being indicated in the drawing. The tractor includes a pair of operator stations 14 and 15 and a control console 16 therebetween. A hydraulic manifold 17 is provided on the tractor 10 and generally comprises a hydraulic reservoir 18, a manifold suction member 19, a pump 20 and proportional servo valves 21 and 22. The pump 20 is driven by the power unit (not shown) of the paver.

The servo valve 21 is connected by way of an electrical cable 23 to a plug 24 for electrical connection to grade control apparatus. Likewise, the servo valve 22 is connected by way of a cable 25 to a plug 26 for connection to slope control apparatus. These components will be referred to in greater detail hereinbelow.

FIG. 2 illustrates a screed assembly 29 including a screed 30 connected between a pair of arms 31 and 32. A cross beam 33 is also connected between the arms 31 and 32.

A hydraulic cylinder 34 has an upper end 35 for connection to the tractor 10 and a movable member 36 which is connected to the arm 32 at a point 37 immediately behind the left hand tow point (not shown). In and out movement of the movable member 36 therefore causes arcuate movement of the arm 32 about the tow point.

In order to initiate a corrective positioning of the arm 32 about the tow point, the paver is provided with grade control apparatus. A standard 38 has an arm 39 connected thereto by way of a connecting device 40 which may be adapted to permit movement of the arm 39 therein and/or movement of the arm 39 arcuately about the standard 38. A vertical adjuster 41 is connected to the end of the arm 39 and includes an inwardly and outwardly movable member 42 whose position is adjusted by means of crank 43. A grade sensing device 44 is carried by the end of the movable member 42 to position a grid or shoe 45 with respect to a reference 46. The reference 46 may be any of several well known devices such as a stringline. The grid 45 is pivotally movable within the grade sensing device 44 to effect a translation of movements of the screed with respect to the reference 46 into signals for controlling the displacement of the movable member 36 of the hydraulic cylinder 34.

A second hydraulic cylinder 49 has an upper end 50 for attachment to the tractor 10 and a movable member 51 attached to the arm 31 at a point 52 immediately behind the right end tow point (not shown). In order to control the slope of the screed 30, a slope sensing device 53 is shock mounted on the cross beam 33 and includes a pendulum type transducer for generating slope control signals for controlling the movement of the movable member 51 of the hydraulic cylinder 49. The slope sensing device 53 has associated therewith and connected thereto by way of a cable 54 a remote set point unit 55 by which an operator can remotely set a desired reference angle for the screed 30, i.e. the tow point elevation.

The grade sensing unit 44 has a cable 47 with a plug 48 for connection to the plug 24 in FIG. 1. Similarily, the slope sensing device 53 has a cable 56 with a plug 57 for connection to the plug 26 in FIG. 1.

FIG. 3 illustrates, in schematic form, the relationships between the hydraulic and electrical circuits, which relationships will be explained in detail and become readily apparent below. However, it should be noted that the electrical plugs 25, 57 and 24, 48 may be mounted or adapted to accommodate one another by affixation at the rear plate 67 of the tractor frame, as symbolically illustrated in FIG.3.

HYDRAULIC CIRCUIT

Referring primarily to FIG. 3, it can be seen that in addition to the aforementioned hydraulic components, the hydraulic circuit of the invention also includes a pair of pilot controlled check valves 60 and 61, a solenoid dump valve (normally open) 62, a hydraulic oil filter 63 and a relief valve 64. The fixed displacement pump, as mentioned above, is driven by the power unit of the tractor and provides hydraulic fluid to the proportional servo valves 21 and 22 over a fluid path including the reservoir 18, a conduit 68, the pump 20, a conduit 69, the oil filter 63, a conduit 70, the dump valve 62, a conduit 71, a conduit 72 to the valve 21 and a conduit 73 to the valve 22. Although FIG. 3 shows three separate reservoir 18, in actual practice only one such reservoir need be used.

The proportional servo valve 21 is further connected in fluid circuit with the reservoir 18 by way of a path including a conduit 74, the check valve 60, a conduit 75, the cylinder 34, a conduit 76, the check valve 60, a conduit 77, the valve 21 again, a conduit 78, and a conduit 79. Likewise, the proportional servo valve 22 is also includes circuit with the reservoir 18 over a path including a conduit 80, the check valve 61, a conduit 81, the hydraulic cylinder 49, a conduit 82, the check valve 61 again, a conduit 83, the proportional servo valve 22 again, a conduit 84 and the conduit 79.

The relief valve extends a fluid path between the conduits 69 and at the reservoir 18 by way of a conduit 85; and the dump valve is connected in fluid communication with the reservoir 18 by way of a conduit 86. At this time it should be mentioned that each servo valve 21,22 is of the type having an actuating member which will move in one direction or the other depending on the polarity of the signal and which will move a distance in either direction directly proportional to the amount of movement of the sensing grid 45.

ELECTRICAL CIRCUIT

The apparatus of the present invention is provided with an electrical circuit which includes, in addition to the aforementioned electrical components. a left hand jog switch 58, a right hand jog switch 59, a grade control circuit breaker 65, a dump valve circuit breaker 66, and an on-off switch 27.

The cable 47 includes a plurality of conductors 89–92. The grade cable 23 includes a plurality off corresponding conductors 93–96. The grade sensing device is connected to the negative terminal of the battery 28 by way of the conductor 89, the plugs 48 and 24, the conductor 93 and a conductor 97, and to the positive terminal of the battery 28 by way of the conductor 92, the plugs 48 and 24, the conductor 96, a conductor 98, a switch contact 99 of the on-off switch 27 and the grade control circuit breaker 65. These electrical connections provide a power source for the grade sensing device 44 as will be understood from the description of operation below.

The conductors **90** and **91** constitute output conductors for the grade sensing device **44** and extend an electrical control signal to the proportional servo valve **21** over a path including the conductor **90**, the plugs **48** and **24**, the conductor **94**, a conductor **100**, the valve **21**, a conductor **101**, a conductor **95**, the plugs **24** and **48** and the conductor **91**.

The cable **56** from the slope sensing device **53** comprises a plurality of electrical conductors **102–105**, and the cable **25** comprises a corresponding plurality of conductors **106–109**. The slope sensing device is connected to the negative terminal of the battery **28** by way of the conductor **102**, plugs **57** and **26**, the conductor **106**, conductor **97**, and to the positive terminal of the battery **28** by way of the conductor **105**, plugs **57** and **26**, the conductor **109** the conductor **110**, the switch contact **99** and the circuit breaker **65**. These connections provide a source of power for the slope sensing device as will also be understood from the description below.

The conductors **103** and **104** for providing control signals to the proportional servo valve **22** over a path which includes the conductor **103**, the plugs **57** and **26**, the conductor **107**, a conductor **111**, the valve **22**, a conductor **112**, the conductor **108**, the plugs **26** and **57**, and the conductor **104**.

The jog switch **58** includes a pair of movable contacts **113** and **114** which are movable between respective fixed contacts **115**, **116** and **117**, **118**. When the jog switch **58** is manipulated to place the contacts **113** and **115** in engagement and the contacts **114** and **117** in engagement, the negative terminal of the battery **28** is extended to the conductor **100** by way of a conductor **119**, the contacts **114**, and a conductor **120**, and the positive terminal of the battery **28** is extended to the conductor **101** by way of circuit breaker **65**, the switch contact **99**, the conductor **98**, a dropping resistor **121**, the contacts **113** and **115**, and the conductor **122**. It is evident that a manipulation of the jog switch **58** to the opposite condition wherein contacts **113** and **116** engage and wherein the contacts **114** and **118** engage, the opposite potential is applied across the conductors **100**, **101** and thereby across the proportional servo valve **21**. The same ability to reverse the polarity with respect to the conductors of the valve **22** is similarly provided by way of jog switch **59** and its associated electrical components **123–132**.

Referring for a moment to FIGS. **4**, **5** and **6**, the techniques employed in the present invention are schematically illustrated. In FIG. **4**, for example, a variable resistor is connected between a fixed potential V and ground. The variable resistor **133** has a movable tap **134**. An actuator device **135** is disposed between the affixed potential V and ground by way of the movable tap **134**. Movement of the tap **134** along the resistor **133** provides a variable current flow through the actuator device, and if the actuator device operates proportionally with respect to the amount of current flowing therethrough, a proportional control system is established.

In FIG. **5**, the foregoing techniques are carried further wherein a transducer **136** is provided with operating power from a power supply **137** and is effective to provide at its output electrical control signals in response to, for example, mechanical movements. The output signal of the transducer is amplified at an amplifier **138** and utilized to drive a proportional control device **139**. This is, in general, the technique utilized in the grade control feature of the present invention.

In FIG. **6**, the foregoing technique is taken at a step further wherein the output of the transducer is applied through a driving amplifier **140** for operating a proportional control device **141**. Here, however, a variable reference is provided by means of, for example, a variable voltage divider circuit **142**, **143** which is connected between a fixed supply voltage V and a voltage -V. This, in general, is the technique employed for the slope control feature of the present invention.

GRADE CONTROL

The grade control apparatus of the present invention operates as follows. As the paver is moved along the surface to be paved and adjacent a reference **46** which establishes the desired grade, vertical movements of the screed are detected by the corresponding arcuate movements of the grid **45**. The grid **45** forms a part of a transducer **144** within the grid control device **44**. As was the case in FIG. **5**, the transducer is provided with a supply of electrical energy, here via an amplifier **146** of the grade sensing device **44**, and operates to produce output signals which are indicative of the magnitude and direction of movement of the grid **45**. The transducer **144** may take various forms including a variable resistance or a variable inductor.

The output signals of the transducer **144** are amplified by the amplifier **146** and presented by way of the aforementioned electrical circuit (elements **90**, **91**, **94**, **95**, **100** and **101**) to the proportional servo valve **21**. The servo valve **21** operates in response to the signal from the amplifier **146**, both in magnitude and in direction, to increase or decrease flow communication therethrough with the hydraulic cylinder **34**. The hydraulic cylinder **44** operates in accordance with the fluid supplied thereto by way of the servo valve **21** and by way of its movable member **36** moves the arm **32** to compensate for the sensed position of the screed **30** with respect to the reference **46**. Inasmuch as the vertical movement of the screed **30** may be continuous, the response of the cylinder **34** is also continuous and provides a compensating inverse direct proportional relation to the vertical movement of the screed.

In order to prepare the finisher for a particular grade with respect to the reference **46**, it may be necessary to initiate movement of the screed without utilizing the operational mode of proportional control. Therefore, the jog switch **58** is provided to extend positive and negative signals to the servo valve **21**, as previously discussed, in order to move the screed up or down.

SLOPE CONTROL

The slope control feature of the present invention is quite similar to the grade control techniques and operates as follows. First assuming that a desired slope reference has been established, the slope sensing device **53** includes a transducer **147** for detecting changes of the slope transversely of the screed. This transducer **147** is preferably of the pendulum type which utilizes a change of inductance to provide a variable output signal in accordance with the direction and magnitude of the slope being sensed. The output signal

is provided to anamplifier **148** which amplifies and presents the signal over conductors **103, 104, 107, 108, 111** and **112** to the proportional servo valve **22**. Operation of the proportional servo valve **22** is the same with respect to this signal as the operation of the servo valve **21** with respect to the grade control signal; therefore, further explanation of the hydraulic circuit in this respect is unnecessary. It should be pointed out, however, that the response of the hydraulic cylinder **49** is such so as to compensate for the changes in slope of the screed **30** by correspondingly moving the arm **31** in a direction opposite to the sensed change of slope. Attention is invited that inasmuch as the slope may also be a continuously changing factor, the slope control signal will also be a continuously changing signal and effect corresponding continuous compensating changes in the position of the arm **31** that is, the elevation of the tow point continuously changes as required.

The slope sensing device **53** is provided with a remote set point unit **55** and connected thereto by way of a flexible cable **54**. The set point unit **55** includes a variable resistor **149** having a movable tap **150** which is manually controlled by a hand operated dial **151** to change the desired angle of the screed transversely of the machine by establishing a selectable reference. Just as the grade control apparatus functioned with respect to the reference **46**, the slope control apparatus functions with respect to a slope reference established by the remote set point unit.

While we have described our invention by reference to certain specific illustrative embodiments, many changes and modifications may be made in the invention by those skilled in the art without departing from the spirit and scope thereof, and it is to be understood that we intend to include within the patent warranted hereon all such changes and modifications as may reasonably and properly be included within the scope of our contribution to the art.

What we claim is:

1. A paver comprising: a tractor; a screed having a pair of spaced-apart arms pivotally connected to said tractor for towing; a pump; a pair of fluid-operated cylinders operatively connected between said tractor and respective arms of said screed; a pair of proportional servo valves connected in fluid circuit with respective fluid-operated cylinders and said pump; and proportional control means electrically connected to said servo valves for controlling the position thereof comprising a grade control device electrically connected to one of said servo valves and including means for sensing the position of the screed with respect to a desired grade reference and means for producing a grade correction signal for the associated servo valve in accordance with the sensed position, and a slope control device connected to the other of said servo valves and including means for sensing the slope of the screed with respect to a desired slope and means for producing a slope correction signal for the associated servo valve in accordance with the sensed slope of the screed.

2. The paver according to claim **1**, comprising means mounting said grade control device at the screed and outboard thereof for accurate sensing of screed movement.

3. The paver according to claim **1**, wherein said grade sensing means includes a movable member for continuously contacting the reference and said means for producing a grade correction signal includes a transducer coupled to said movable member.

4. The paver according to claim **1**, wherein said means for producing a grade correction signal comprises an amplifier for amplifying the grade correction signal.

5. The paver according to claim **1**, wherein said grade sensing means comprises a movable member for continuously contacting the grade reference and means mounting said grade control device at the screed and outboard thereof including adjusting means for adjusting the elevations of said grade control device.

6. A paver according to claim **1**, comprising means mounting said slope control means on said screed.

7. A paver according to claim **1**, wherein said slope control device includes a movable member and said means for producing a slope correction signal includes a transducer coupled to said movable member.

8. A paver according to claim **1**, wherein said means for producing a slope correction signal includes an amplifier for amplifying said slope correction signal.

9. A paver according to claim **1**, wherein said means for producing a slope correction signal includes an amplifier, and a reference set point unit for establishing a slope reference for said amplifier.

10. A paver according to claim **9**, wherein said set point unit is a remote unit having a flexible cable connected to said slope control device.

11. A paver comprising: self-propelled means; a screed towed by said self-propelled means including a pair of spaced-apart arms movably connected to said self-propelled means; a pair of fluid-operated cylinders each connected to said self-propelled means and to respective arms adjacent the movable connections; a pump; a pair of proportional servo valves connected in respective fluid circuits with said pump and said fluid-operated cylinders and operable to permit fluid flow in response to the direction of controlling electrical signals and in proportional response to the magnitude of said electrical signals; grade control means for controlling one of said fluid-operated cylinders including grade sensing means for sensing the position of said screed with respect to a reference grade and means electrically connected to one of said servo valves for producing a grade control signal indicative of the difference and direction between the sensed position and a reference grade; and slope control means for controlling the other of said servo valves including means for sensing the slope of said screed with respect to a reference slope, and means electrically connected to the other of said servo valves for producing a slope control signal indicative of the magnitude and direction of deviation between the sensed slope and the reference slope.

* * * * *