United States Patent [19]

Teach

[11] **3,873,226**

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[54] **LASER BEAM CONTROL SYSTEM FOR ROAD PAVING MACHINES**

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[73] Assignee: **Laserplane Corporation,** Dayton, Ohio

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[52] **U.S. Cl.** **404/84,** 73/510, 73/490

[51] **Int. Cl.** **E01c 19/00**

[58] **Field of Search** 404/84, 83; 325/320; 178/66; 73/510

[56] **References Cited**

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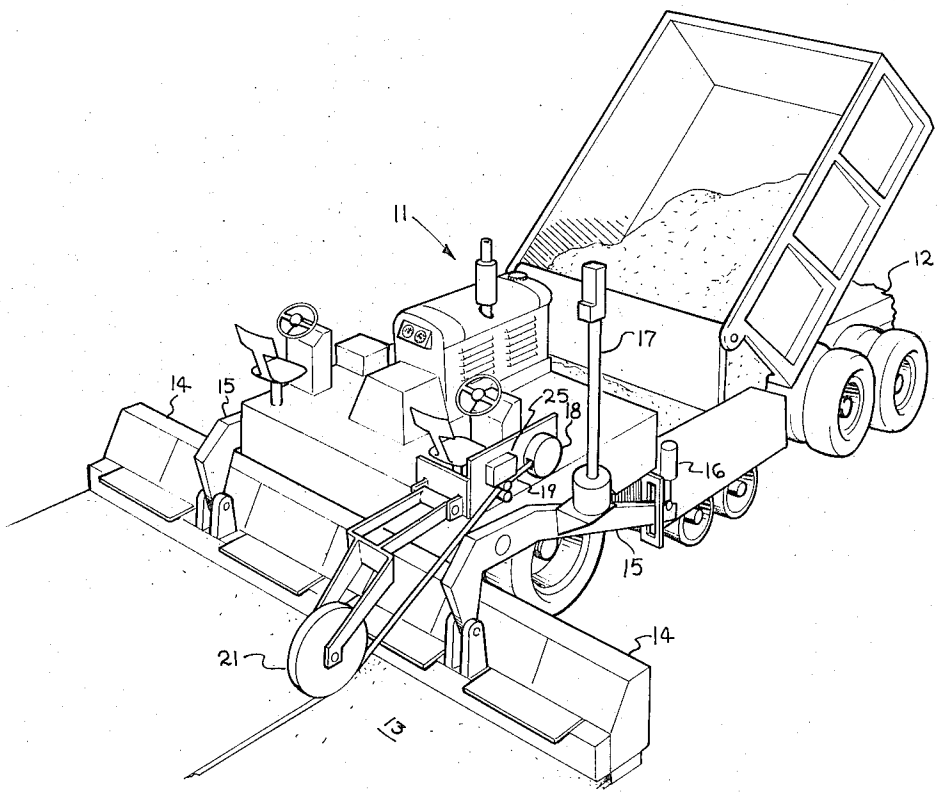
Primary Examiner—Nile C. Byers, Jr.
Attorney, Agent, or Firm—W. A. Schaich

[57] **ABSTRACT**

Apparatus for controlling the elevation of the pavement distributor head of a mobile road paving machine in predetermined relationship to a fixed horizontal plane, as set by a laser beam which is periodically swept across such plane, such apparatus comprising a tape dispensing device carried by the machine to dispense a tape of indefinite length therefrom at zero velocity relative to the surface being paved, and a tape reader for detecting indicia on the tape at predetermined intervals to increase or decrease the predetermined relationship between the pavement dispensing head and the fixed plane, to thereby increase or decrease the elevation of the paved surface at predetermined intervals.

8 Claims, 4 Drawing Figures



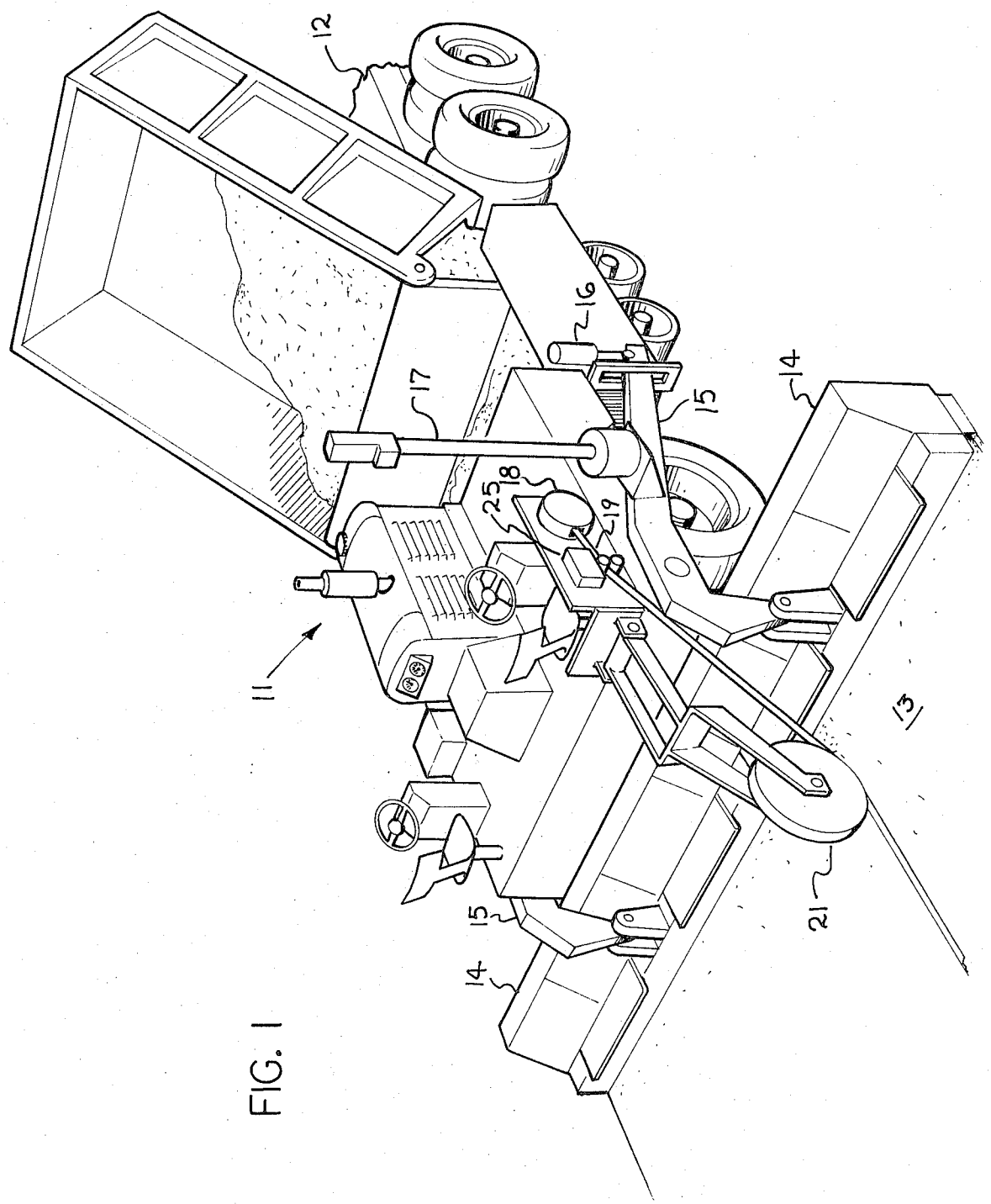


FIG. 1

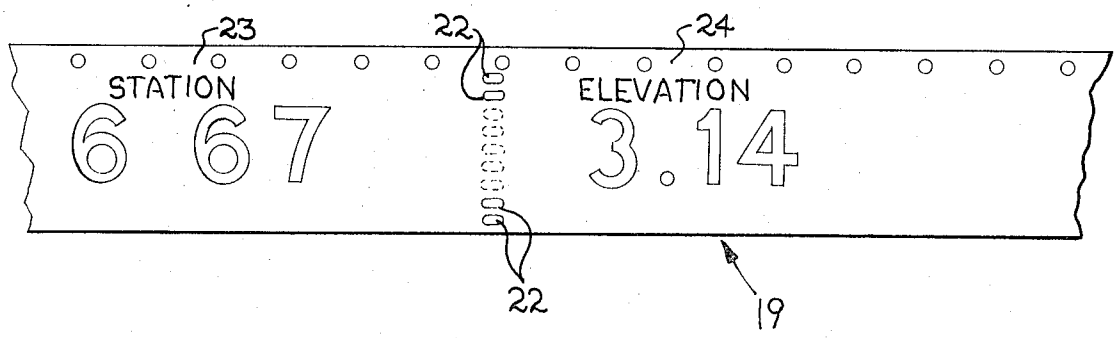


FIG. 2

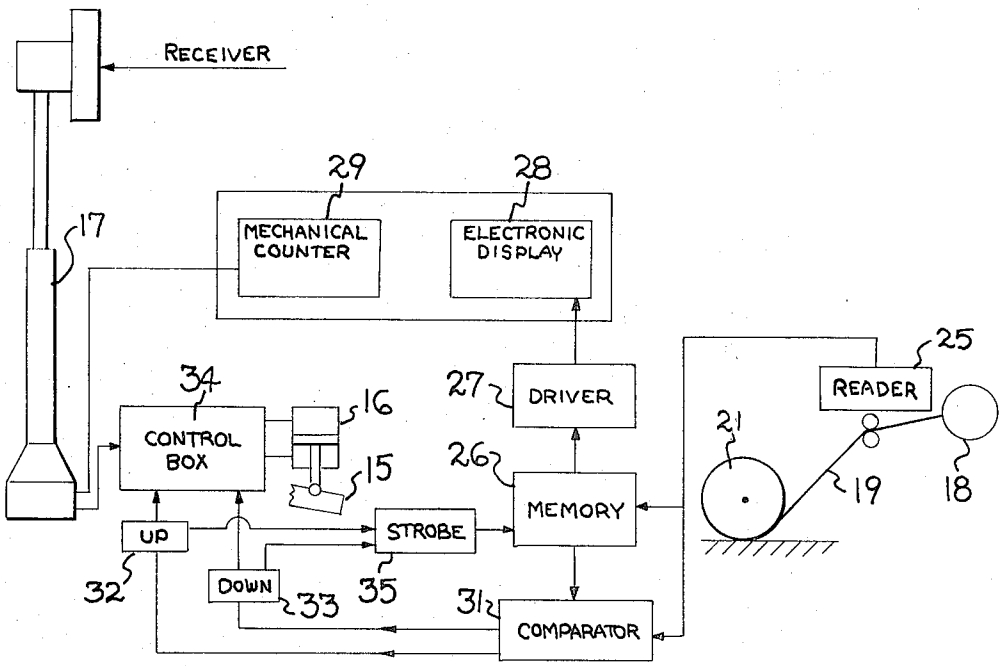


FIG. 3

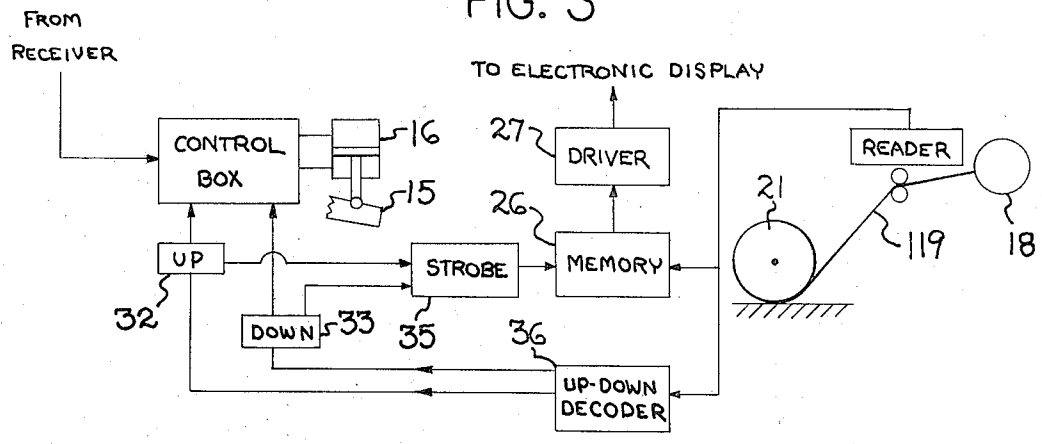


FIG. 4

LASER BEAM CONTROL SYSTEM FOR ROAD PAVING MACHINES

GENERAL BACKGROUND OF THE INVENTION

In U.S. Pat. No. 3,588,349 to Robert H. Studebaker there is described apparatus for maintaining a predetermined vertical relationship between the elevation of the working tool of an earth working machine and a fixed horizontal elevation. As described in the aforesaid Studebaker patent, such apparatus comprises a laser beam generating device remote from the machine to periodically project a laser beam along a multitude of paths lying in a horizontal plane, and a servo system, including a laser beam receiver carried by the machine, for sensing the height of the laser beam plane and for raising or lowering the elevation of the earth engaging tool to maintain a predetermined difference between the tool and the laser beam. To change the predetermined relationship between the laser plane and the tool of the earth working machine along the path of travel of the machine according to the teachings of the aforesaid Studebaker patent, however, for example to increase or decrease the elevation of a road at predetermined locations, and to thereby establish grade breaks or vertical curves, it was necessary to manually locate each of such predetermined locations by conventional surveying techniques and to manually re-set the servo system of the machine as it reached each such location. This, of course, involved considerable work and expense, especially in regard to road paving machines where grade specifications are normally considerably more narrow than in the case of earth grading machines, and this requirement thereby has heretofore substantially impeded the application of the laser plane control system to road paving systems.

In accordance with the present invention, however, it has been found that the laser plane elevation control system of the aforesaid Studebaker patent can be successfully and economically applied to road paving machines, and without the need to establish, by manual surveying techniques, the elevation of a very great number of locations very closely spaced to one another along the length of the road being paved in order to generate grade breaks or vertical curves within acceptable standards. In accordance with the present invention, any earth working machine, particularly a road paving machine, may be provided with a coil or reel of tape which is unwound onto the earth surface being worked as the machine moves along its intended path of travel. This tape is provided with periodically spaced indicia which indicates the distance travelled by the machine. The machine is provided with a servo system that includes a tape reader for reading the indicia on the tape and for changing the predetermined distance between the laser plane and the elevation of the earth working tool, such as the pavement distributor of a paving machine, which is then being established by the laser beam control system.

Accordingly, it is an object of the present invention to provide an improved elevation control system for an earth working machine. More particularly, it is an object of the present invention to provide an improved laser beam actuated control system for accurately controlling the elevation of the earth working tool of an earth working machine as a variable function of the distance traversed by the machine from a known location as it moves along its intended path of travel, and it is

an even more particular object of the present invention to provide a road paving machine with such an improved laser beam actuated control system for controlling the elevation of the vertically adjustable pavement distributor thereof.

For a further understanding of the present invention and the objects thereof, attention is directed to the following portion of the specification, to the drawing and to the appended claims.

DESCRIPTION OF THE DRAWING

FIG. 1 is a perspective view of a self-propelled type of bituminous paving machine incorporating a control system in accordance with the present invention;

FIG. 2 is a fragmentary plan view of a typical portion of the tape being dispensed by the paving machine of FIG. 1;

FIG. 3 is a schematic view of the control system of the paving machine; and

FIG. 4 is a schematic view of a control which is an alternate to that shown in FIG. 3.

DETAILED DESCRIPTION OF THE INVENTION

As is shown in FIG. 1, the control system of the present invention may be applied to a bituminous paving machine, shown generally at **11**. For purposes of illustration, paving machine **11** may be considered to be of the self-powered type manufactured by the Construction Equipment Division of Blaw-Knox Company under the designation PF–220, except as is otherwise hereinafter specifically described. Paving machine **11** is shown as receiving a fresh load of bituminous paving material in a hopper portion at its front end from a conventional dump truck **12**, shown fragmentarily. A thin laterally extending layer of bituminous paving material **13** is applied to the road bed by one or more generally laterally extending pavement distributors, shown as two distributors **14** each of which may be considered to extend at a slight angle as it extends from the center of the road toward the edge, in order to properly crown the road for the drainage of water therefrom.

Since the bed of the road being paved is generally not graded to elevation specifications as stringent as those to which the road must be paved, variations in grading are overcome by making the vertical elevation of distributors **14** adjustable, relative to the road bed, to apply paving material thereto in varying depth as the paving machine moves along its intended path of travel. Vertical adjustability of distributors **14** is accomplished by mounting each at the load end of a first class lever arm **15**, the other or force end of which is connected to the end of the cylinder rod of an hydraulic cylinder **16**. Hydraulic fluid is controllably admitted under pressure to either the rod end or the open end of the piston to raise or lower the force end of arms **15** and to thereby lower or raise the load end thereof.

As is explained in the aforesaid Studebaker U.S. Pat. No. 3,588,249, and also in U.S. Pat. No. 3,494,426 to Robert H. Studebaker, the control of hydraulic fluid to and from hydraulic cylinder **16** to maintain distributors **14** at a predetermined elevation may be controlled by a control system which senses the elevation of a plane along which a laser beam is periodically projected. To that end, machine **11** is provided with a vertically extending laser beam receiving device **17** which may be of the type described in the aforesaid U.S. Pat. No. 3,494,426, or the type described in my copending pa-

tent application Ser. No. 358,881, filed on May 10, 1973, and which is attached to lever arm **15** as shown.

Typically, a laser beam receiving device of such a type is capable of adjustment in elevation, relative to the elevation of one or both of the pavement distributors, in increments of 0.01 feet over a total range of adjustment of 5 feet, there thereby being 500 different predetermined relationships between the elevations of the laser beam receiver and the controlled pavement distributor which can be selected by the operator. This fact can be used to advantage to accurately and automatically control the grade of the paved surface at a non-horizontal angle or at a variable angle, that is at an angle which is not parallel to the plane along which the laser beam is projected or which periodically changes from the angle of such plane, by providing means to automatically select a different one of the 500 of such predetermined relationships as the machine travels to each of a plurality of different locations along its longitudinal path of travel from a known starting location. These different locations can be accurately determined, without the need to manually locate each by conventional surveying techniques, by providing machine **11** with a tape dispenser **18** to dispense a tape **19,** on which each of the locations is pre-identified by detectable indicia and by dispensing the tape at zero velocity relative to the paved surface, as the paving machine moves along its path of travel. Tape **19** is preferably of a weather-resistant, relatively non-stretchable material such as Mylar, and it is fed at zero velocity relative to the paved surface over distributor **14** to be applied to the paved surface **13** by a floating press down wheel **21** which is attached to paving machine **11.**

As is shown in FIG. **2,** the longitudinal location on the tape at which it is desired to select one of the 500 predetermined relationships to be controlled by the laser beam actuated control system can be indicated by the binary coded placement of punched holes **22,** it being necessary to have nine positions at each longitudinal position along the tape, extending in lateral rows thereacross, where such holes can be placed or omitted to select from 500 possible predetermined locations. The tape may also be advantageously provided with visually detectable station and elevation identification data, **23** and **24** respectively, to permit inspectors to verify the elevation or grade of the road after the paving machine has passed thereover.

To determine the distance that paving machine **11** has travelled from a known starting point by the binary coded placement of punched holes **22** thereon, paving machine **11** is provided with a tape reader **25** of conventional character. At the start of the paving operation, the tape **19** is pulled through reader **25** and is positioned properly on the ground at the start point. The tape reader will then sense the first location which is indicated on the tape **19** and will deliver this information, in binary code, to a memory circuit **26.** The memory circuit **26,** in turn, activates a driver **27** which is operatively connected to an electronic display panel **28.** In the meanwhile the position of the vertically adjustable laser beam receiver **17** is mechanically sensed and is indicated on a mechanical counter **29,** preferably mounted closely adjacent electronic display **28** at the operator's station so that equivalent readings on the two devices can be quickly verified.

As the paving machine **11** moves along its intended path of travel it will reach the first point where it is desired to effect an elevation change, changes usually being made in increments of 0.01 feet, for the type of laser beam receivers heretofore described. At this point the new instructions on the tape **19** are read by reader **25,** and this information is simultaneously passed to memory circuit **26** and to a comparator circuit **31.** The comparator circuit will sense that this position is greater or less than that indicated by the information stored in the memory circuit, and will then feed a signal to the "up" circuit **32,** or to the "down" circuit **33,** which will instruct the control box **34** to raise or lower, respectively, the laser beam receiver **17** by one increment. At the same time up circuit **32** or down circuit **33,** as the case may be, will cause a strobe **35** to erase the information stored in memory circuit **26** and will replace it with information as to the new elevation. Mechanical counter **29** and electronic display **28** must now each indicate the new elevation.

To generate a linear grade break by the utilization of the aforesaid control system, for example one of 1 foot per 100 feet, it will be necessary to raise or lower the mast **17** by one increment of 0.01 feet for each foot of forward travel, and to generate a grade break of 2 feet per 100 feet, it will be necessary to raise or lower the mast by one increment of 0.01 feet for each 0.5 feet of forward travel. Vertical curves can also be generated by the utilization of the control system by maintaining uneven spacing between the points on the tape where the rows of punched holes are located.

As is shown in FIG. **4,** some simplification in the control circuitry may be achieved with the use of a tape **119** having eleven positions for the location of punched holes, rather than the nine positions on tape **19.** The first nine of such positions provide the display through the memory and driver circuits **26** and **27,** as heretofore described. The next two positions provide the elevation change information to an up-down decoder circuit **36** which determines any required change and appropriately instructs the up circuit **32** or down circuit **33.** Up circuit **32** or down circuit **33,** as the case may be, in turn will to cause strobe **35** to strobe memory circuit **26** cause it to remember the new elevation rather than the previous elevation.

It is to be pointed out that the forward advance of a self-propelled type of paving machine of the type described herein, for the purpose of the practice of the present invention, can be measured by a ground contacting fifth wheel rather than by the tape dispensing arrangement described above. However, it is felt, with the present state of the art of such devices, that the use thereof would involve some chance of error arising from slippage of the wheel relative to the ground.

The best mode known to me to carry out this invention has been described above in terms sufficiently full, clear, concise and exact so as to enable any person skilled in the art to make and use the same. It is to be understood, however, that it is within my contemplation that certain modifications of the above described mode of practicing the invention can be made by a skilled artisan without departing from the scope of the invention, and it is therefore desired to limit the invention only in accordance with the appended claims.

I claim:

1. Apparatus for controlling the vertical height of a vertically adjustable working tool of a mobile earthworking machine, said apparatus comprising, in combination:

means for sensing the elevation of a laser beam periodically moving in a pre-determined substantially horizontal plane;

control means responsive to said laser beam for maintaining a pre-determined vertical relationship between said plane and the vertical height of said tool; and

adjustment means for changing said pre-determined relationship at pre-determined locations along the intended path of travel of the said machine, said adjustment means comprising:

1. means on the machine for dispensing an indicia bearing tape measuring the distance traveled by said machine as said machine moves along its path of travel, and
2. reader means responsive to said indicia and operatively associated with said control means for changing said predetermined relationship as a function of the distance traveled by said machine.

2. Apparatus according to claim **1** wherein said mobile earth-working machine is a paving machine and wherein said working tool is the pavement distributor portion thereof.

3. Apparatus according to claim **1** wherein said indicia on said tape comprises binary coded punched holes and wherein said reader means comprises a reader for reading binary coded information.

4. The method for controlling the vertical height of a vertically adjustable working tool of a mobile earth-working machine comprising the steps:

1. sensing the elevation of a pre-determined substantially horizontal plane;
2. controlling the height of the adjustable tool in a pre-determined relationship to said substantially horizontal plane;
3. accurately measuring the distance traveled by said earth-working machine as it moves along its path of travel by dispensing a tape therefrom at a pre-determined rate relative to its velocity of travel, said tape bearing detectable indicia along its length; and
4. changing the pre-determined relationship between the height of said adjustable tool and said substantially horizontal plane in response to the indicia carried by said tape.

5. The method according to claim **4** wherein the tape is dispensed at zero velocity relative to the ground traversed by said machine.

6. The method according to claim **4** wherein said mobile earth working machine is a road paving machine and wherein said working tool is the pavement distributor portion thereof.

7. The method of controlling the effective height of an earth-working tool carried by a mobile vehicle and vertically adjustable relative thereto comprising:

1. moving the vehicle along a known path from a known reference point;
2. dispensing a tape from a dispensing reel on said vehicle at zero velocity relative to the ground traversed by the vehicle, whereby the length of tape dispensed measures the linear movement of the vehicle from said reference point;
3. providing indicia on said tape corresponding to desired elevations of said earth-working tool at points along the vehicle path; and
4. reading said indicia as said tape is dispensed and adjusting the height of said tool in response to said reading.

8. Apparatus for controlling the working height of an earth-working tool carried by a mobile vehicle and vertically adjustable relative thereto by power means comprising:

1. a flexible tape bearing indicia corresponding to desired elevations of said earth-working tool at points spaced from a reference point;
2. a dispenser for said tape mounted on said vehicle and constructed and arranged to dispense tape as said vehicle moves from said reference point at zero velocity relative to the ground traversed;
3. electronic means for reading said indicia as said tape is dispensed; and
4. means for controlling said power means in response to the reading of said indicia, thereby adjusting the working height of said earth-working tool as the vehicle moves from said reference point.

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