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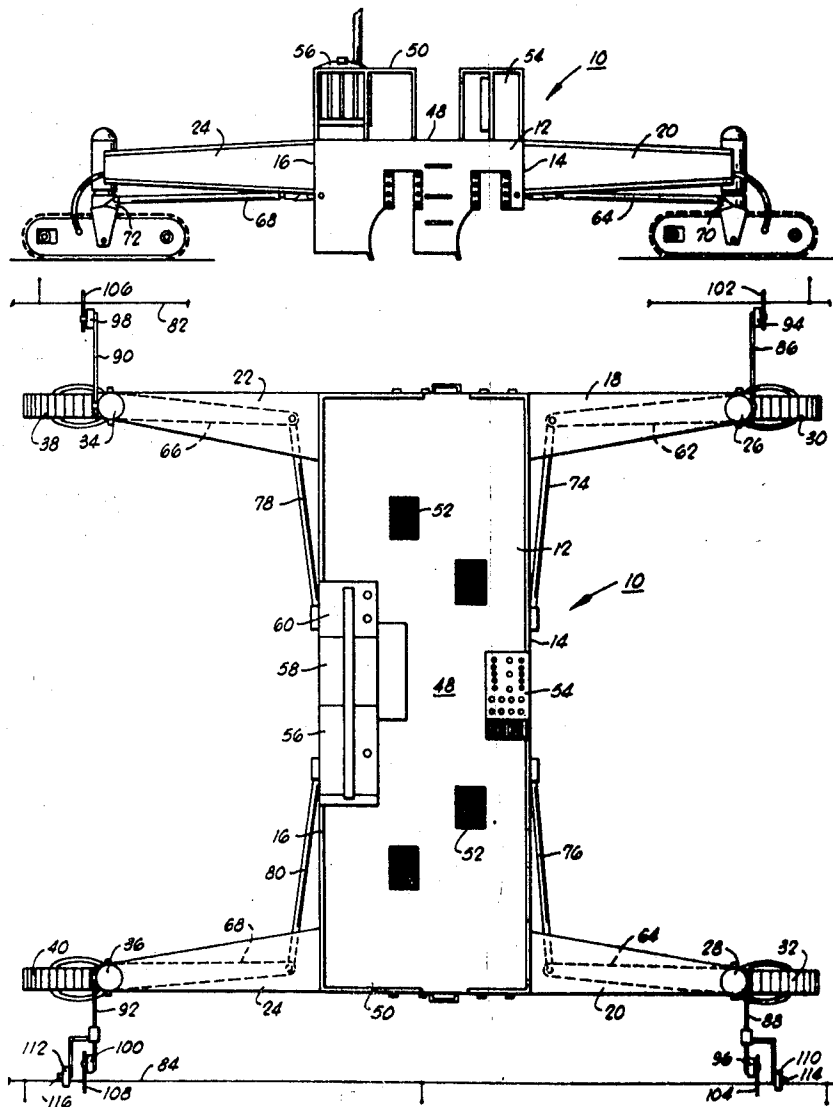
[54] **CONTROL SYSTEMS FOR ROAD CONSTRUCTION MACHINERY**
25 Claims, 17 Drawing Figs.

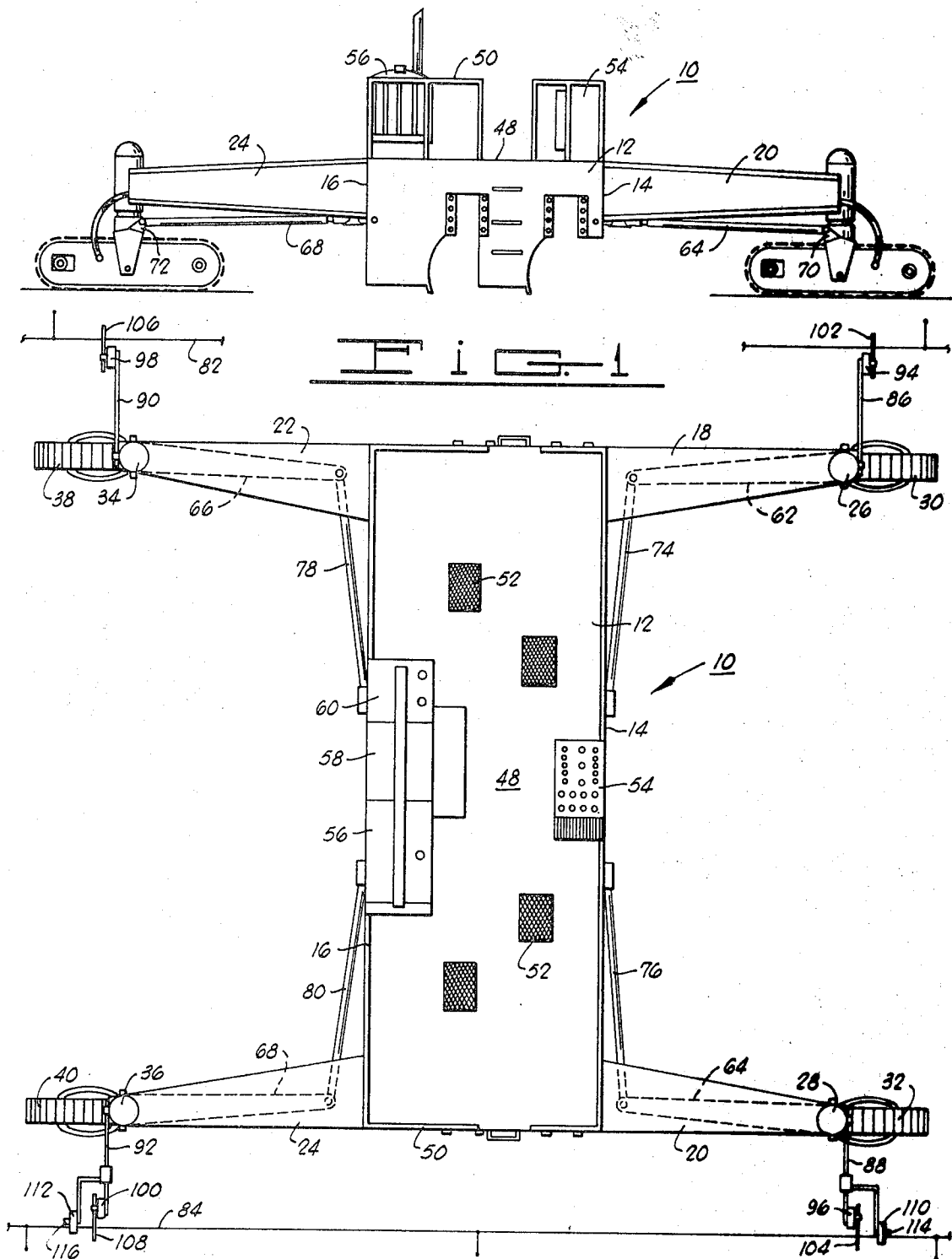
[52] U.S. Cl. **94/46,**
37/108

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

[50] Field of Search **94/46;**
37/108

ABSTRACT: Method and apparatus for controlling road construction machinery such that operating elements are accurately controlled to condition a roadway surface to a predetermined level along a preset path, such apparatus utilizing control sensing mechanism which serves to adjust the height and/or crown profile of a surface relative to a reference level in coaction with leveling and steering adjustment as continually fed into the mobile supporting elements of the machinery. The continual adjustment control may be effected with respect to any of several selected reference levels to control the relative height of various operating elements such as strike-off, auger assemblies, screeds and various other of the surface-forming instrumentalities.





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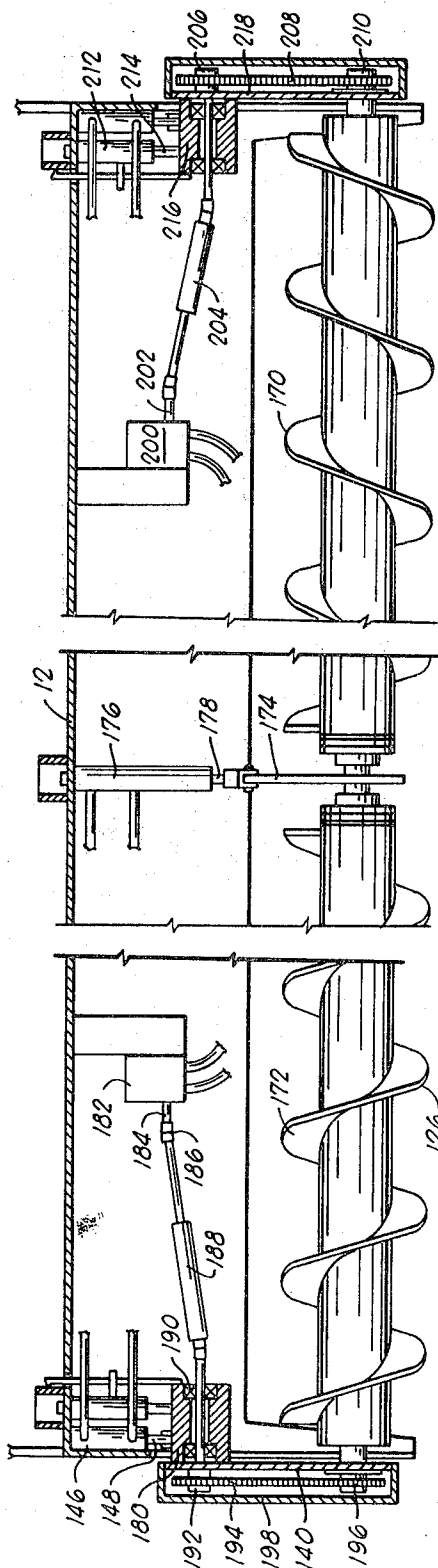


Fig. 1

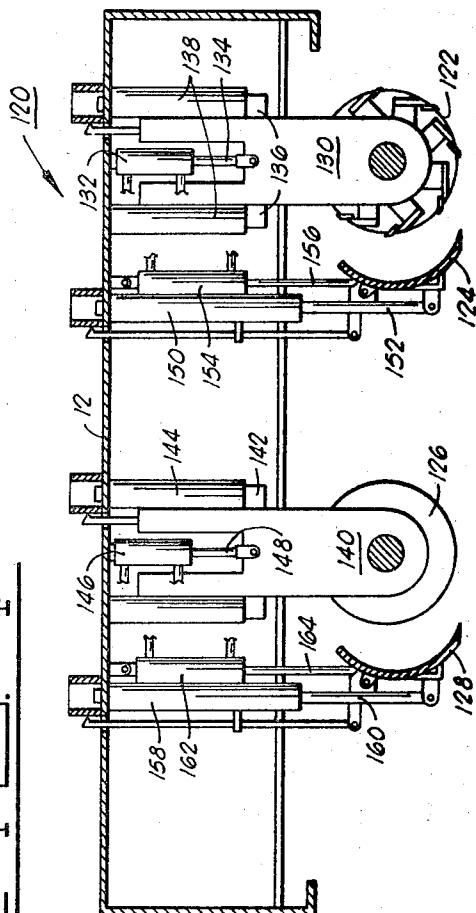


Fig. 2

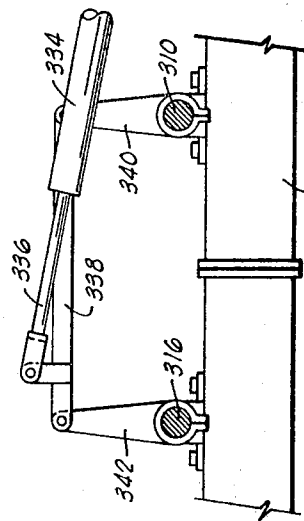


Fig. 3

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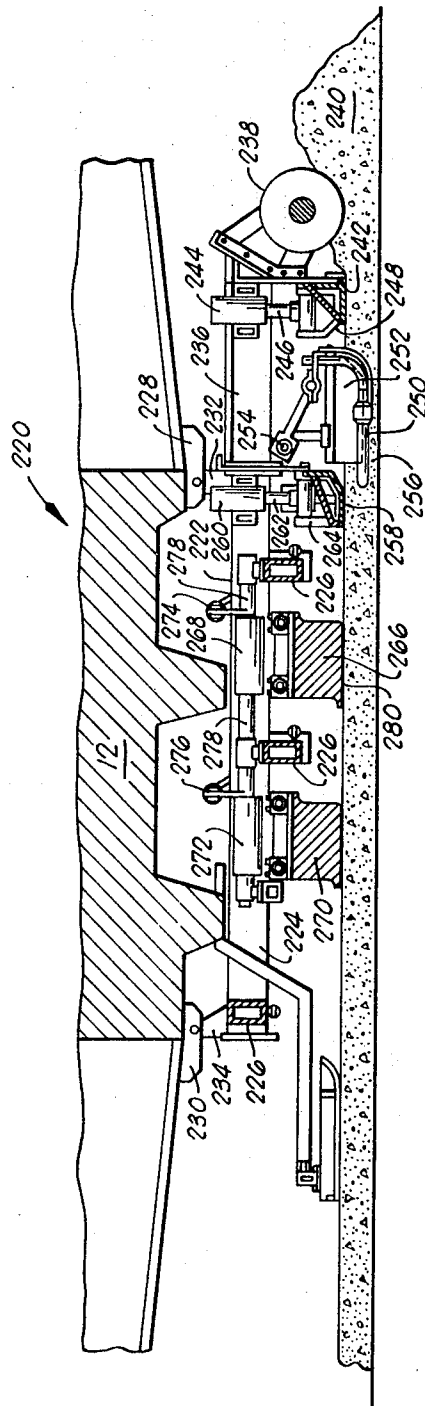
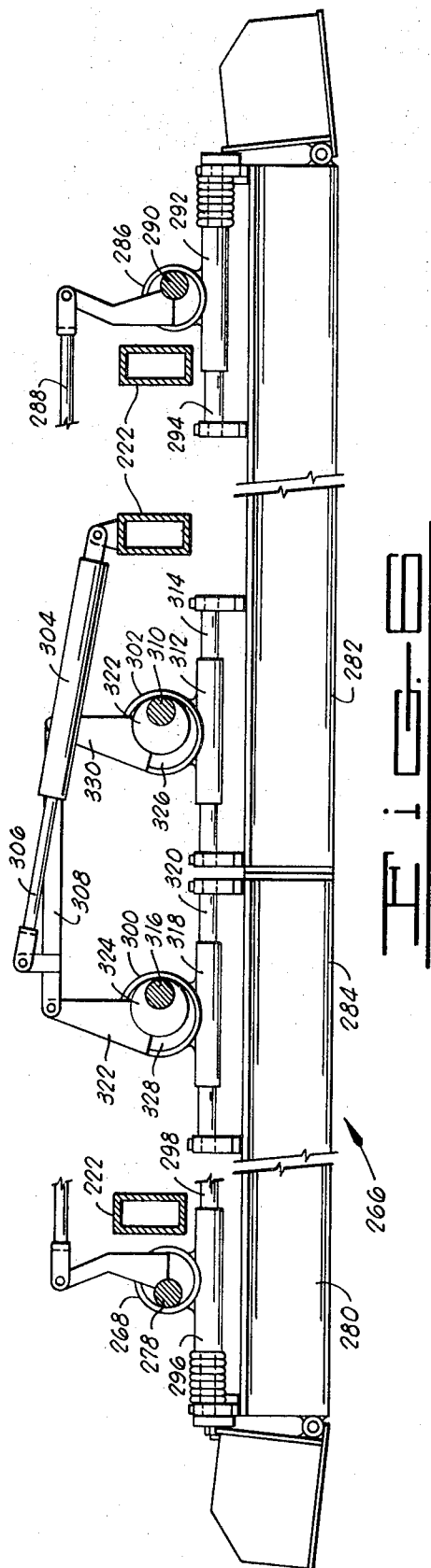
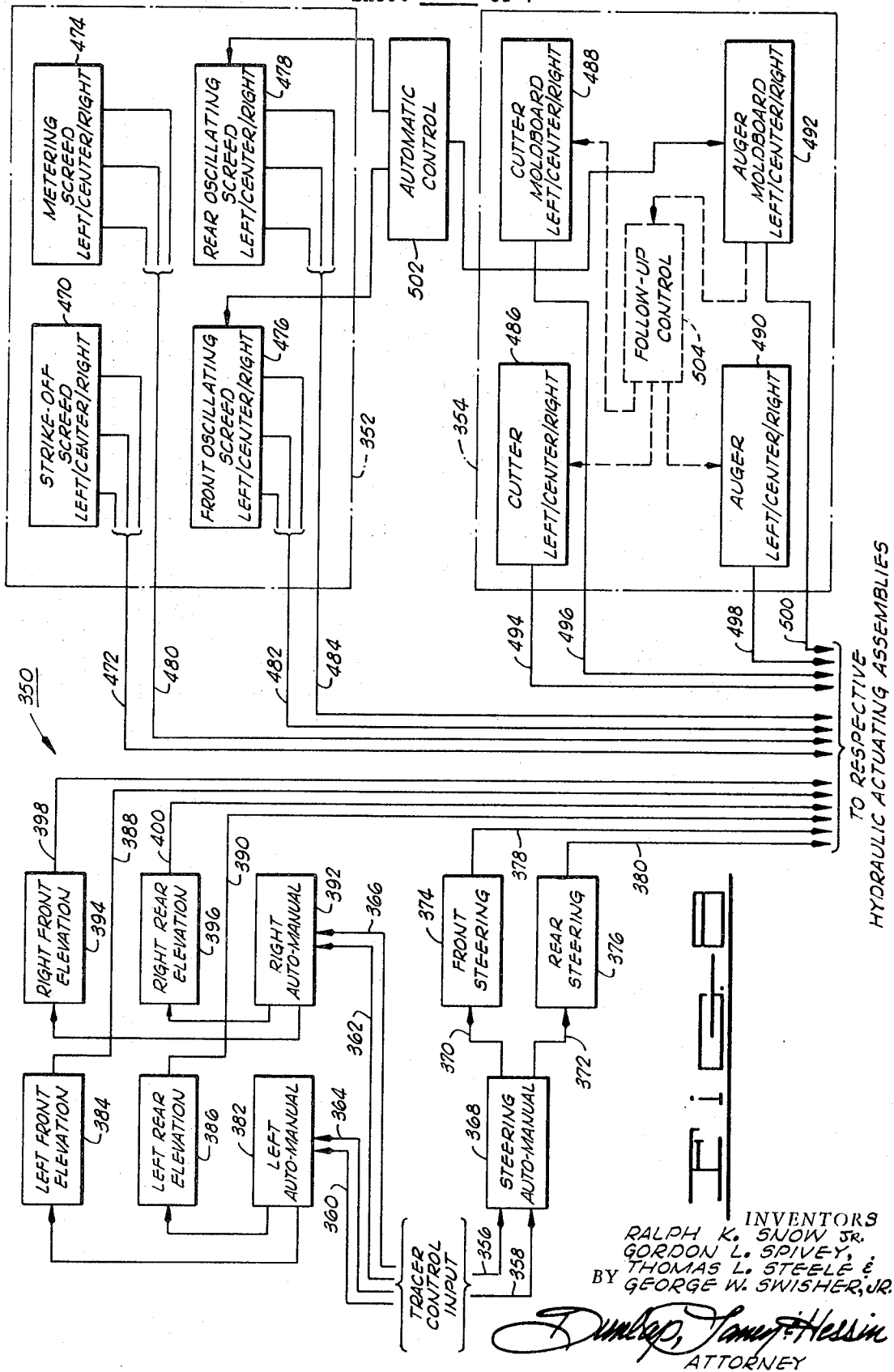


FIG. 3

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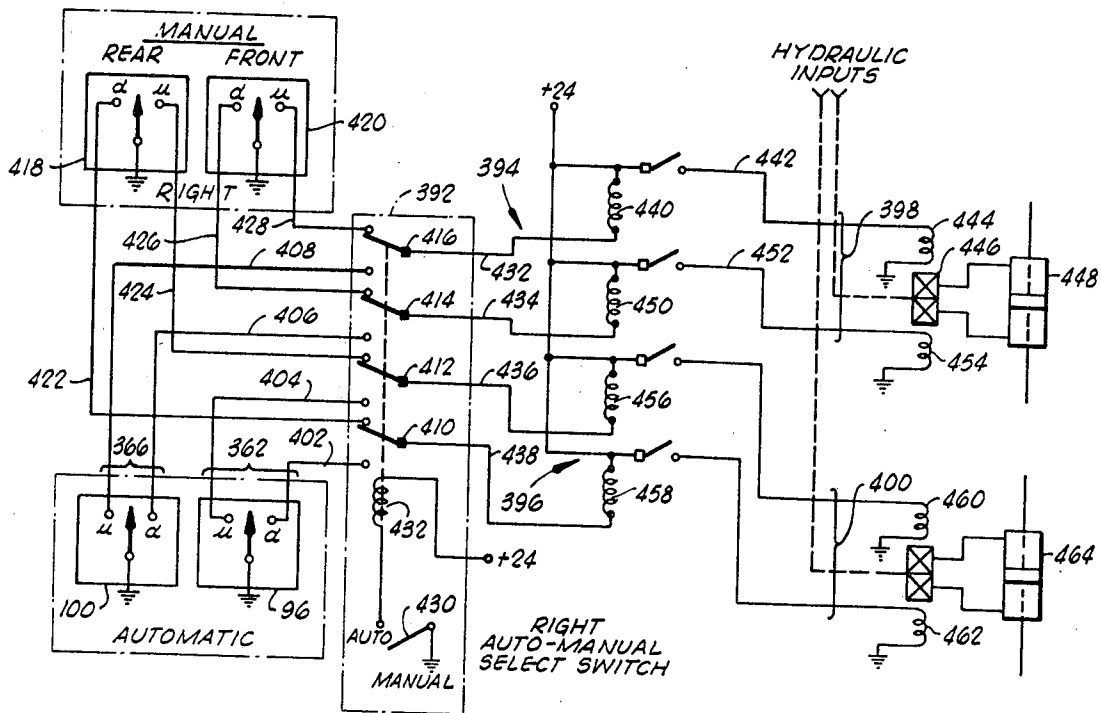


Fig. 9

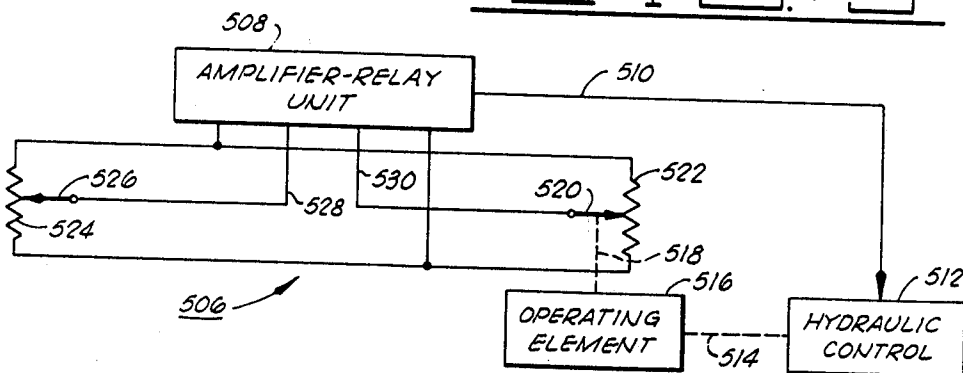


Fig. 10

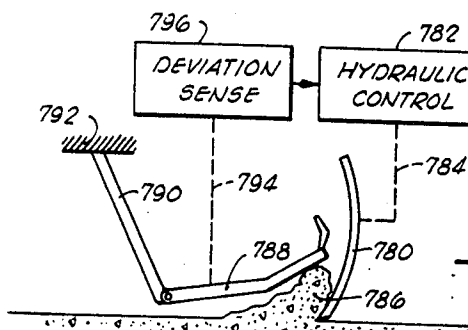


Fig. 17

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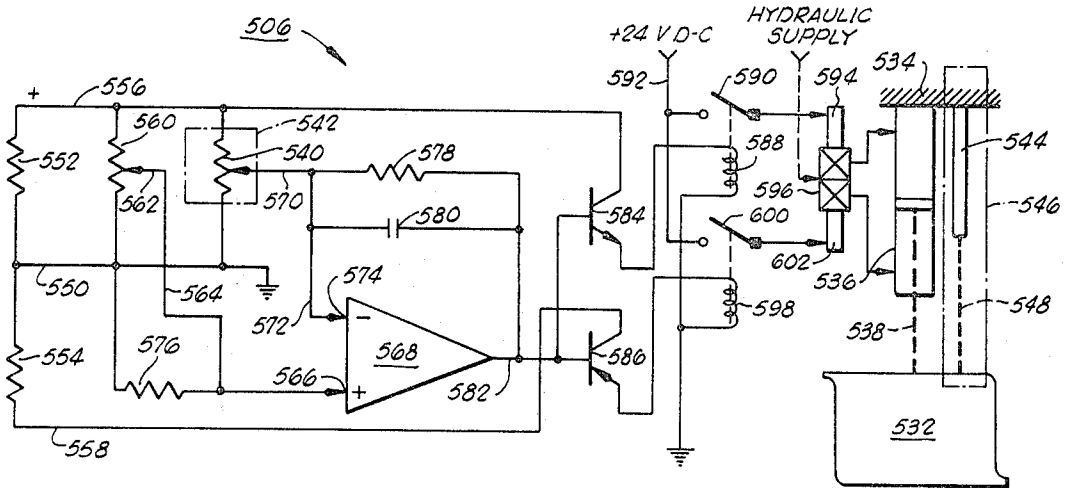


Fig. 11

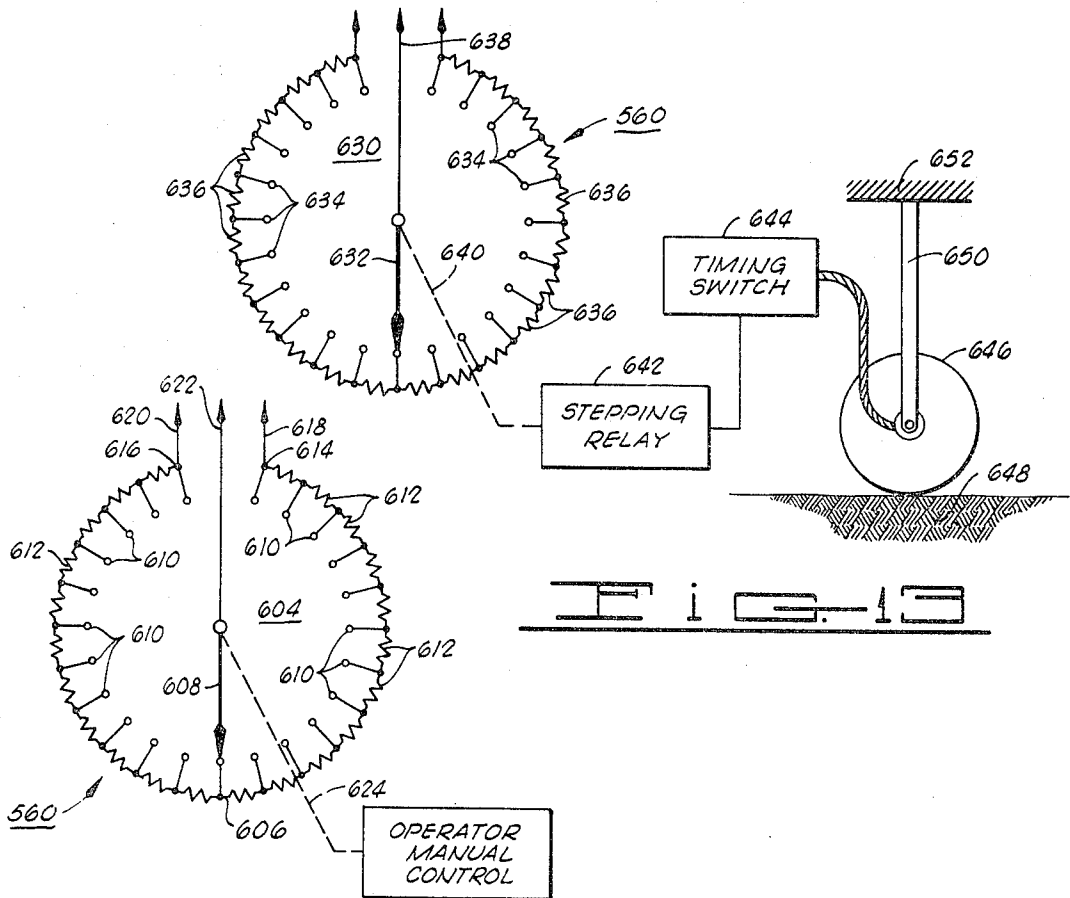
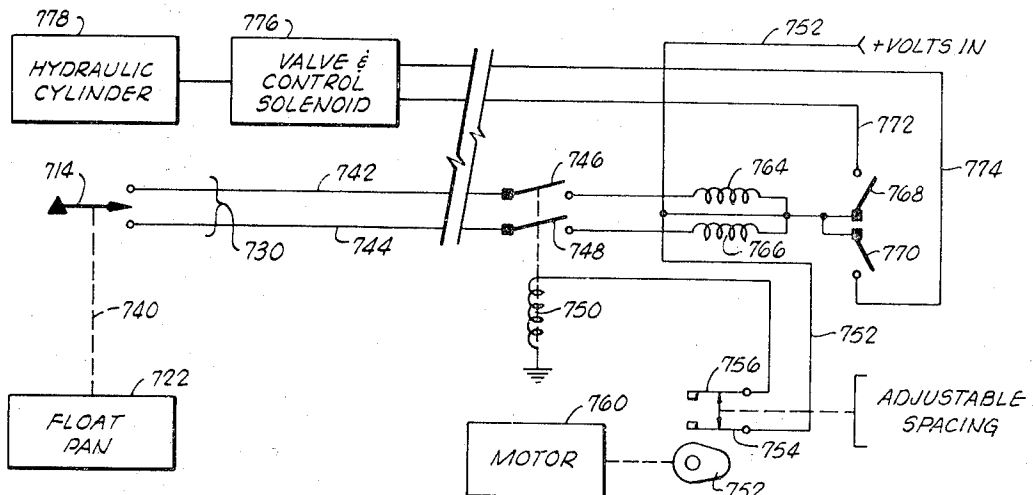
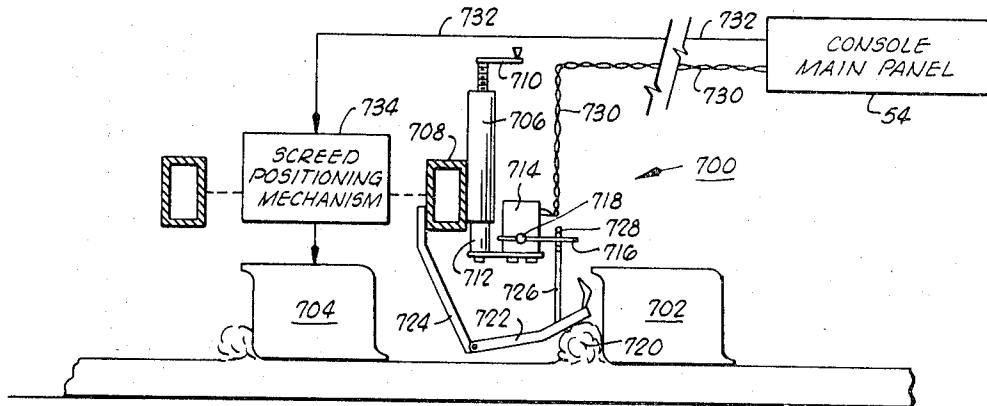
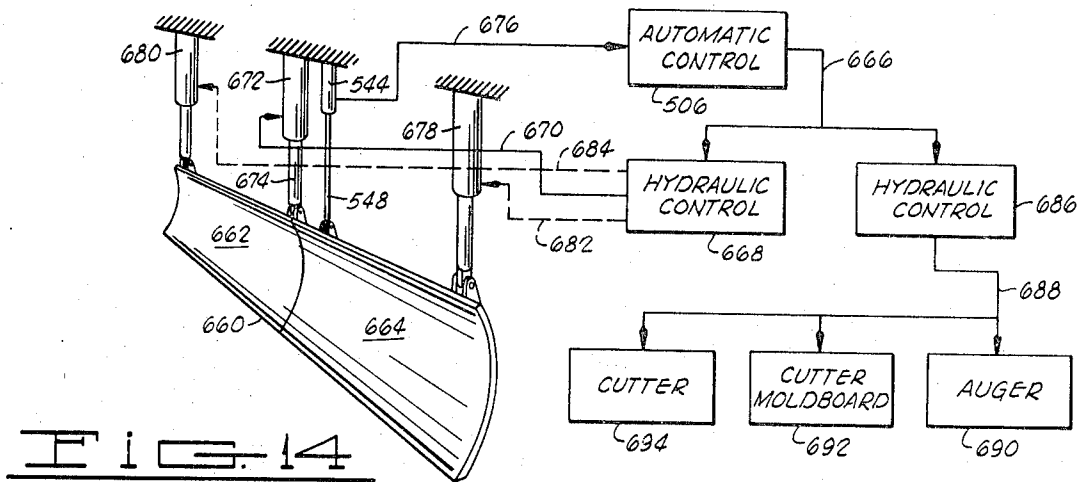


Fig. 12

Fig. 13

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CONTROL SYSTEMS FOR ROAD CONSTRUCTION MACHINERY

CROSS-REFERENCE TO RELATED APPLICATIONS

The present invention is particularly related to the subject matter of the copending U.S. Pat. application, Ser. No. 446,239, now U.S. Pat. No. 3,423,859, entitled "Road Construction Methods and Apparatus" filed on Apr. 7, 1965 in the name of George W. Swisher et al. and assigned to the present assignee, as well as to the subject matter of the copending U.S. Pat. application, Ser. No. 710,256 entitled "Slip-Form Paving Apparatus" filed on Mar. 4, 1968 in the name of George W. Swisher et al. and assigned to the present assignee.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates generally to control of roadway construction apparatus and, more particularly, but not by way of limitation, it relates to improved control systems for enabling completely automatic control of such machinery.

2. Description of the Prior Art

The prior art includes various forms of paving and grading machinery, both self-propelled and otherwise moved, which function to perform the various road building operations along a right-of-way. The control of such prior devices has generally been exercised through manual control by an attending operator, such manual control requiring continual and exacting attention to the various control functions, the operation being rendered extremely dependent upon an operator's skill and attentiveness. Some relief from criticality has been afforded the operating personnel by development of the basic string-line guidance systems which utilize a reference line for control of steering and grade level along a right-of-way. Still further improvement of such prior art guidance methods is enabled by overcoming various problems as to consistency of operation and exactness of control.

SUMMARY OF THE INVENTION

The present invention contemplates automatic control systems for use with roadway grading and paving equipment of the self-powered type. In a more limited aspect, the invention contemplates apparatus for providing complete automation of the guidance and leveling functions of the construction machine, as well as automatic variation with respect to the desired roadway surface level of individual operating elements. The apparatus affords automatic control of steering of both front and rear mobile assemblies while the construction machine vertical level is automatically adjustable to a reference level at each one of the four corners. Further, the automated control extends to apparatus for automatically varying the crown profile of the roadway surface either by manual control or as a function of distance; and this similar automation technique may be applied to further control the vertical level of entire surface finishing elements.

The invention further includes a method of automating the control of operating elements of a roadway construction machine by sensing the head or excess material buildup at a selected point on the roadway surface to derive a control indication for feedback to control certain other combinations of the operating elements. The method may be utilized to control various operating elements of machinery, such as slip-form paving apparatus or grading apparatus, such that it functions to condition either paving material or other subgrade material, respectively, to a desired surface consistency and level.

Therefore, it is an object of the present invention to provide automatic control apparatus for enabling completely automatic control of heavy road building machinery.

It is also an object of the invention to provide apparatus for sensing the head or excess buildup of roadway material adjacent operating elements to effect corrective control of selected other operating elements.

It is still another object of the present invention to provide automating control apparatus which can be employed with

various forms of construction machinery, e.g. slip-form paving equipment or cutting and grading equipment.

It is still another object of the present invention to provide self-propelled road construction machinery which can be automatically steered and leveled with respect to a reference level while various operating elements are further automatically controlled to regulate the finished roadway profile.

Finally, it is an object of the present invention to provide completely automated road building machinery which relieves the operator from responsibility for certain ordinary functions so that he may apply himself more intently to the actual roadway surface formation.

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 illustrates a particular form of self-propelled road construction machinery which is adaptable to support various construction finishing elements;

FIG. 2 is a top view of the road construction machine of FIG. 1;

FIG. 3 is a side view of a particular form of finishing element, cutting and grading equipment, which can be utilized with the road construction machine of FIG. 1;

FIG. 4 is a front view of a material distributing auger which is employed in the cutting and grading equipment of FIG. 3;

FIG. 5 is a side view of major components of a slip-form paving assembly which may also be utilized with the road construction machine of FIG. 1;

FIG. 6 is a front view of an oscillating extrusion screed as utilized in the slip-form paving assembly of FIG. 5;

FIG. 7 is a front view of additional support mechanism of the oscillating extrusion screed of FIG. 6;

FIG. 8 is a block diagram of a control system for use with the road construction machine of FIG. 1 when supporting either the cutter-grader assembly of FIG. 3 or the slip-form paving assembly of FIG. 5;

FIG. 9 is a schematic diagram of a control unit of the type which is embodied in the control system of FIG. 8;

FIG. 10 is a block diagram of one form of automatic control unit which serves to adjust an operating element in response to a sensed value;

FIG. 11 is a schematic diagram of the automatic control unit of FIG. 10 as employed with an oscillating extrusion screed in such as the slip-form paver assembly of FIG. 5;

FIG. 12 is a partial schematic diagram of one form of sense control unit for use with the control unit of FIG. 11;

FIG. 13 is a partial schematic diagram of an alternative form of sense control unit for use with the control unit of FIG. 11;

FIG. 14 is a block diagram of an automatic control unit similar to that of FIG. 11 when employed with a moldboard element such as in the cutter-grader assembly of FIG. 3;

FIG. 15 is a schematic block diagram showing the application of head or excess material correction control as employed with oscillating extrusion screeds such as those in slip-form paver assembly of FIG. 5;

FIG. 16 is a partial schematic diagram of a control circuit as employed in the automatic head correction control of FIG. 15; and

FIG. 17 is an alternative usage of the automatic head correction as employed for moldboard control in a cutter-grader assembly.

DESCRIPTION OF THE INVENTION

FIGS. 1 and 2 are directed to the mobile road construction machine 10 which is particular subject matter of the aforementioned related U.S. Pat. applications, Ser. Nos. 446,239 (now U.S. Pat. No. 3,423,859) and 710,256. The mobile machine 10 is a form of road construction machinery which is capable of carrying either cutter-grader devices or slip-form

paving devices in operative relationship to the earth's surface along a prescribed path. The machine 10 is capable of automatic guidance as well as automatic level control while performing either the grading or paving functions.

The machine 10 consists of a central frame 12 having a front side 14 and a rear side 16. A pair of spaced track support members 18 and 20 extend forwardly from the front side 14 of frame 12. Similarly, a pair of rear track support members 22 and 24 extend rearwardly from rear side 16 of frame 12. The forward track support members 18 and 20 are suitably connected to respective support posts 26 and 28 which carry respective endless track assemblies 30 and 32. Each of support posts 26 and 28 is individually hydraulically adjustable as to vertical height in the manner previously disclosed in U.S. Pat. application Ser. No. 446,239. In similar manner, the respective rear track support members 22 and 24 extend out into affixture to support posts 34 and 36 which are pivotally secure to respective endless track assemblies 38 and 40. The support posts 34 and 36 also comprise a hydraulic cylinder arrangement such that they too are independently variable in length (vertically) to provide adjustment of the height and level of central frame 12 with respect to the roadbed or such other reference line.

The central frame 12 consists of an operating platform 48 surrounded by safety rail 50 and including a plurality of optimally placed observation gratings 52. Also located in accessible relationship on platform 48 is a control console 54, a main power engine 56, suitable power conversion apparatus 58 and such as a hydraulic reservoir 60. The machine 10 may utilize a large hydraulic power system of conventional design since it is preferable that the majority of individually powered components about the machine 10 and respective cutter-grader or slip-form paver assemblies (to be described) will utilize hydraulic power. It should be understood however, that various other forms of power, *i.e.* pneumatic, electrical, etc., may be utilized as certain specific advantages become apparent to the skilled artisan.

The steering of machine 10 is carried out hydraulically and in synchronous relationship. Thus, a respective steering arm 62, 64, 66 and 68 is rigidly secured to each of the respective track assemblies 30, 32, 38 and 40. For example, FIG. 1 shows the right assemblies with steering arm 64 and 68 pivotally connected to respective bifurcated pivot members 70 and 72 which are again pivotally attached to the right front track 32 and the right rear track 40, respectively. Hydraulic control exercised at console 54 then selectively displaces push rods 74, 76, 78 and 80 to guide their respective track assemblies 30, 32, 38 and 40. Actually, a double acting hydraulic cylinder (not shown) is centrally connected to effect reciprocal movement of forward push rod 74 and 76 while a rear cylinder (not shown) effects concerted movement of push rods 78 and 80.

In a manner well known in the art, and as discussed in the aforementioned Pat. applications, the respective string lines 82 and 84, left and right respectively, provide a reference for which the hydraulic steering and level controls may be controlled to follow automatically. The sensing arms 86, 88, 90 and 92 serve to support sensing apparatus outboard from machine 10 in contacting proximity to each of string lines 82 and 94. The assignment of sensing functions, *i.e.* either level or steering, to particular corners of machine 10 will vary with particular applications; however, an often used application finds six individual sensing applications utilized to automatically control level and steering. Four control sensors 94, 96, 98 and 100 extend respective sensor arms 102, 104, 106 and 108 into sensing contact with their respective string lines 82 or 84. The sensing arms 102—108 are disposed generally horizontally so that they each give an indication of level displacement for each corner of machine 10.

Similarly, an additional pair of control sensors 110 and 112 extend respective sensor arms 114 and 116 into generally vertical disposition to sense sideways movement of machine 10 relative to string line 84 thereby to obtain guidance control. The guidance sensors 110 and 112 may be placed on either

side of machine 10, this depending upon certain operational factors which are readily apparent to the skilled operator. A suitable form of control sensor such as the sensors 94—100, 110 and 112 is the particular subject matter of a copending U.S. Pat. application, Ser. No. 683,256 entitled "Line Tracer Control Device" filed on Nov. 15, 1967, now U.S. Pat. No. 3,514,630, in the name of Steele et al. and assigned to the present assignee.

FIG. 3 depicts the disposition of operating elements in cutter-grader assembly 120 of the type which may be carried in working or operative relationship by mobile machine 10. The cutter grader 120 consists of four vertically adjustable operating elements, a cutter 122, a cutter moldboard 124, an auger 126, and an auger moldboard 128 which are movably supported from main frame 12 of machine 10. The operating elements may be readily disassembled from machine 10, and each is vertically adjustable during operation. Thus, and to describe structure on one side only, the cutter 122 is rotatably suspended from a support plate 130 which is slidable up and down in response to positioning of a double acting hydraulic cylinder 132 and connecting rod 134. The support plate 130 is maintained in vertical position by slide guides such as guide plates 136 welded to support plates 130 and each is slidable within a respective slide way 138 which is welded or otherwise secured to frame 12. The auger 126 is similarly suspended in vertically adjustable manner by a support plate 140, slide plate 142, and slide guides 144 with vertical adjustment being effected by double-acting hydraulic cylinder 146 through connecting rod 148.

The cutter moldboard 124 and auger moldboard 128 are each suspended in similar manner such that each is individually adjustable as to height. Thus, cutter moldboard 124 is suspended by a cylindrical guide 150 and a guide rod 152 while vertical disposition is adjusted by means of a double-acting hydraulic cylinder 154 and connecting rod 156. Similarly, the auger moldboard 128 is supported by means of a cylindrical guide member 158 and guide rod 160 with vertical positioning provided by double-acting hydraulic cylinder 162 and connecting rod 164. More particular description of the structure may be had with reference to the aforementioned Pat. application Ser. No. 446,239.

FIG. 4 illustrates suspension structure for auger 126; however, the other operating elements, *viz.* cutter 122 and moldboards 124 and 128, would be similarly supported. Thus, auger 126 is actually made up of two end-to-end aligned auger elements, a right auger element 170 and a left auger element 172. Each of the auger elements 170 and 172 is rotationally connected at the center to a hanger plate 174 which is independently vertically adjustable by means of a double-acting hydraulic cylinder 176 and connecting rod 178. Thus, the adjustable center connection allows for crown adjustment separate from other variations to the surface profile. The left auger section 172 is then supported by support plate 130, as described in FIG. 3, support plate 130 being rigidly secured to a block 180 which provides connection to the height adjusting hydraulic cylinder 146 and connecting rod 148. A continuously variable drive to auger section 172 is provided from a hydraulic motor 182 which provides variable rotational output via shaft 184, universal joint 186 and telescoping shaft 188 for application through bearings 190 in block 180 to a drive sprocket 192. Sprocket 192 then drives chain 194 over gear 196 to impart rotational motion to the auger section 172. It is preferable that the drive chain 194 be completely encased in oil as insured by case cover 198.

The opposite side auger section 170 receives similar variable speed drive in either direction from a hydraulic motor 200 suitably mounted to main frame 12. Rotational output from hydraulic motor 200 is supplied via output shaft 202 and a telescoping shaft 204, necessary flexible joints being provided, for application to a drive sprocket 206, drive chain 208 and drive gear 210 which applies rotational output directly to auger section 170. The various support and adjustable suspension members controlling left auger 170 are the same as those

previously described with respect to right auger section 172. Thus, elevation of the outer edge of auger section 170 is adjusted by variation of hydraulic cylinder 212 and connecting rod 214 to position block 216, and, therefore, a support plate 218 at a selected vertical disposition.

FIG. 5 depicts a slip-form paver assembly 220 which is also adapted to be carried in operative relationship beneath the mobile machine 10. The slip-form paver assembly 220 is quickly interchangeable with the cutter-grader assembly 120 for performance of whatever the desired road building operation. The slip-form paver assembly in conjunction with carriage equipment is disclosed more particularly in the aforementioned U.S. Pat. application Ser. No. 710,256 such that only general description is necessitated herein.

The slip-form paver assembly 220 is primarily supported by a main frame 222 consisting of a rectangular array of steel beams such as longitudinal beams 224 and transverse beams 226. The slip-form paver assembly 220 is carried beneath the main frame 12 of the mobile machine 10 and it is connected by means of forward connecting plates 228 and rear connecting plate 230 which are pin connected to respective forward hanger straps 232 and rear hanger straps 234 which extend upward from frame 222. A front frame 236 is rigidly secured to the forward edge of frame 222 to provide support for additional paving material conditioning elements. Thus, forward frame 236 supports a distributing element or an auger 238 across the work space for the purpose of distributing rough-strown paving material 240. The auger 238 may be controlled at variable speeds in either direction of rotation by means of hydrostatic drive equipment not specifically shown.

Immediately behind the auger 238, a strike-off 242 is supported in vertically adjustable relationship. Thus, the strike-off 242 is suspended by a plurality of double-acting hydraulic cylinders 244 and connecting rods 246 acting through connecting shoes 248 to position the front edge of strike-off 242. Also supported from front frame 236 are a plurality of transversely arrayed internal vibrators 250 and intersticed baffle plates 252. The internal vibrators 250 and baffle plates 252 are secured to a shaft 254 which can be rotated by hydraulic means (not specifically shown) through about a 90° turn to lift vibrators 250 and baffle plates 252 up out of the leveled paving material 256.

The level paving material 256 is then operated upon or conditioned by the succeeding operating elements as carried by main frame 222. Thus, a metering screed 258 is vertically controlled by plural hydraulic cylinders 260, connecting rods 262 and connecting shoes 264 for positioning to a preset level to provide desired volumetric disposition of paving material 256. Thereafter, oscillating extrusion screeding is effected to further condition paving material 256 to its final profile. First oscillating screed 266 is maintained in extruding contact with the upper surface of paving material 256 by means of eccentric assembly 268, while oscillating extrusion screed 270 is held in similar extruding contact by means of an eccentric assembly 272. Each of the eccentric assemblies 268 and 272 is independently controllable by means of respective hydraulic cylinders 274 and 276 to change its vertical disposition relative to a shaft 278 which is held in rigid position relative to frame 222.

Extrusion screed vertical adjustment and the necessary components are shown to be better advantage in FIGS. 6 and 7, front views of the forward oscillating extrusion screed 266. The extrusion screed 266 in one form is formed as a hollow steel column having a flat sole plate 280 and it is formed in two sections, a left screed section 282 and a right screed section 284. The left and right screed sections 282 and 284 are connected at the center in such manner that a flexure can take place to allow for crowning of the pavement slab. Thus, in the case of the use of tubular columns, the natural flexibility of the columns will allow a central bending for crowning purposes, but if more rigid or solid materials are employed it may be necessary to provide a hinge connection at the center point.

A left side eccentric assembly 286, like the right side eccentric assembly 268, is hydraulically actuatable through a connecting rod 288 to raise or lower the left side of screed 266. Thus, eccentric assembly 286 is made to rotate about a supporting shaft 290 which is held rigid with respect to frame 222 such that the slidable support columns 292 are brought to a different level. The slidable support columns 292 are reciprocable on slide shafts 294 which are securely bracketed to support the left side of extrusion screed 266. The similar adjustment is effected by the right side eccentric assembly 268 as it is rotated by hydraulic means (not shown) with respect to shaft 278 to raise or lower a slidable support column 296 as it rides on slide shaft 298. In operation, the respective left and right eccentric assemblies 286 and 268 are set only occasionally as a particular paving job progresses.

A pair of center eccentric assemblies 300 and 302 find much more utility as they can be simultaneously adjusted by means of a double-acting hydraulic cylinder 304, connecting rod 306 and tie bar 308 to effect concerted vertical adjustment of the center portion of extrusion screed 266. The eccentric assembly 302 is adjustable with respect to a shaft 310 to adjust the vertical height of slidable support sleeve 312 riding on slide shafts 314 which support the central portion of left screed section 282. Similarly, the right eccentric assembly 300 is rotatable with respect to shaft 316 to effect the same vertical level adjustment of slidable support sleeves 318, slide shafts 320 and the interior portion of right screed section 284.

Each of the forward oscillating extrusion screed 266 and the rear extrusion screed 270 are individually adjustable as to their vertical disposition by means of eccentric assemblies such as 300 and 302 of FIG. 6. However, a further adjustment is provided to vary the central height of both of front and rear extrusion screeds 266 and 270 simultaneously. This adjustment becomes particularly attractive for varying the crown profile of the paving slab. Thus, each of shafts 310 and 316 include respective cams 322 and 324 which rotate within respective lobe assemblies 326 and 328. The lobes 326 and 328 are rigidly secured for rotation with levers 330 and 332 to effect vertical height adjustment of the center of only the front extrusion screed 266; however, the respective shafts 310 and 316 can be further rotated, thus rotating respective cams 322 and 324, to provide additional eccentric movement and therefore height adjustment. This height adjustment will be effected the same amount for both the forward and rear extrusion screeds 266 and 270.

The linkage of FIG. 7 provides mechanism whereby shafts 310 and 316 can be rotated to change position of their respective cam lobes 322 and 324. This effect is gained through operation of a double-acting hydraulic cylinder 334 and a connecting rod 336 which effects lateral movement of tie bar 338 to rotate respective levers 340 and 342 in unison. More particular explanation as to structure and interaction of the components is set forth in the aforementioned U.S. Pat. application Ser. No. 710,256.

Referring now to FIG. 8, one form of control system 350 is adaptable to include, alternately, either a slip-form control 352 or a cutter-grader control 354 such that automated control of the major functions of each can be performed in conjunction with control of mobile machine 10. Thus, tracer control inputs such as shown in FIG. 2 may be utilized: Steering sense inputs from control sensors 110 and 112 may be applied in on respective leads 356 and 358 while level sense inputs from respective control sensors 94, 96, 98 and 100 are applied in on respective leads 360, 362, 364, and 366.

The steering sense inputs on leads 356 and 358 are applied to a steering manual select switch 368 which may be located in the operating console 54 and which serves to place drive control on either the sense inputs on leads 358 and 356 or on control panel switches (not specifically shown) under control of the operator. In either event, the respective outputs are applied on leads 370 and 372 for application to the respective front steering control 374 and rear steering control 376. The outputs from front steering 374 and rear steering 376 are then

controlled by leads 378 and 380 for application to control their respective hydraulic assemblies to effect the desired steering actuation.

The level sense inputs would be similarly applied such that the left side front and rear level sense inputs on leads 360 and 364 would be selected in an automatic-manual selector switch 382 with the selected energization being applied to the left front elevation 384 and left rear elevation 386 to apply actuating output on leads 388 and 390 for application to their respective hydraulic actuating assemblies. Similarly, the right side front and rear level sense inputs on leads 362 and 366 would be applied to right automatic-manual selector switch 392 with selected outputs being applied to energize the right front elevation 394 and right rear elevation 396 to provide actuating outputs on leads 398 and 400 to the respective hydraulic actuating assemblies.

The actual structure for such paired control assembly is shown in schematic form in FIG. 9 which illustrates, for example, the circuitry applicable to the system controlling the right side front and rear elevation. Thus, automatic sensing is provided by control sensors 96 and 100 which may provide a ground indication on respective leads 402, 404, 406 and 408 to normally open contacts of four ganged relay actuated switches 410, 412, 414 and 416 of the automatic-manual select switch 392. Manual control from respective manual rear switch 418 and manual front switch 420 situated at the operator's console 54 are applied via respective leads 422, 424, 426 and 428 to the remaining normally closed contacts of the relay switch sections 410-416 of selector switch 392. Automatic selection is effected by closure of a front panel switch 430 which energizes relay coil 432 to actuate the selector relay 392. In either event, control output may be present on leads 432 and 434 to right front elevation control 394 as well as on leads 436 and 438 to the right rear elevation control 396.

An input on lead 432 will energize a power relay 440 to provide energizing output voltage on lead 442 to the solenoid coil 444 of four-way control valve 446 such that a hydraulic cylinder 448 is operated in a first direction. Similarly, an output on lead 434 will energize a relay 450 which provides energizing output on leads 452 to relay coil 454, this tending to energize hydraulic cylinder 448 in the opposite direction. The similar actuation takes place with respect to the right side rear elevation components as controlled by power relays 456 and 458 controlling respective solenoid valve relays 460 and 462 to provide double-acting energization of the right rear elevation hydraulic cylinder 464.

Each of the other paired control functions may be constituted of the similar types of switching and power relay circuitry to effect the desired hydraulic response. That is, the left side automatic-manual selection of front and rear elevation would be similarly constituted, and the automatic-manual selection of front and rear steering may utilize the same circuitry. Also, the same basic control systems can be utilized to control various hydraulic actuations in the slip-form paver control system 352 and the cutter-grader control 354.

Referring again to FIG. 8, the operator's front panel control of the slip-form paver control system 352 requires a plurality of hydraulic control circuits including a strike-off screed control 470 which is capable of effecting individual control of left side, center and right side screed level via a line 472. Also, the front panel control includes leading screed control 474, front oscillating screed control 476 and rear oscillating screed control 478 all of which are capable of rendering tertiary actuation as to the respective left side, center and right side hydraulic positioning mechanisms. The respective cables 480, 482, and 484 conduct energizing voltage to the respective hydraulic actuating assemblies.

The cutter-grader control system 354 includes a similar type of control arrangement as effected by switch actuation at the front panel of the operator's control console 54. Individual control of the cutter, cutter moldboard, auger, and auger moldboard are effected by respective switch assemblies 486,

488, 490 and 492, and each of these is tertiary in nature to provide for left side, center and right side individual controls. The control outputs for each of switch assemblies 486-492 are provided on respective cables 494, 496, 498 and 500 which lead to the positions of their respective hydraulic actuating assemblies.

An automatic control 502, to be disclosed in greater detail below, may be employed with either the slip-form control assembly 352 or the cutter-grader control assembly 354. It has been found to be particularly desirable to utilize automatic control 502 for regulation of front oscillating screed 476 and/or rear oscillating screed 478. Also, automatic control 502 of similar nature may be utilized for controlling operating elements such as the auger moldboard 492 of the cutter-grader assembly 120. In addition, an automatic followup control 504 (shown in dash lines) may be employed to effect additional following control as will be further described below.

FIG. 10 shows one form of automatic control unit 506 which may be employed as the automatic control 502 of FIG. 8. The control unit 506 consists of an amplifier-relay unit 508 which is energized to provide an output on lead 510 for actuation of a hydraulic control 512. Hydraulic control 512 may be any one of the various controls employed to regulate an operating element of a construction machine, but in any event, the operating element 516 provides a continual mechanical indication of its instantaneous position with respect to a known reference level. The mechanical motion indicated by dash line 518 is applied to position a wiper 520 of a sensing potentiometer 522. Potentiometer 522 is connected in parallel with a control potentiometer 524 such that a control wiper 526 and sensing potentiometer wiper 520 provide a differential reading which is applied for input to the amplifier-relay unit 508 via leads 528 and 530. The control potentiometer 524 and sensing potentiometer 522 are connected in a bridge circuit across the upper and lower energization extremes of the unit 508.

FIG. 11 shows a form of automatic control unit 506, in greater detail as it is employed with a slip-form paver control system to effect periodic changes in the vertical position of an oscillating extrusion screed 532. Actually, the circuit is connected to effect crowning control such that the center portion of oscillating extrusion screed 532 would be varied relative to the slip-form frame 534 by means of the double-acting hydraulic cylinder 536 and connection 538. In the circuitry of automatic control unit 506, the potentiometer 540 shown in dash lines 542 is actually the frame-connected potentiometer 544 which is shown in dash lines 546 as being connected by a mechanical linkage 548 to the oscillating extrusion screed 532.

The circuitry of unit 506 consists of a ground lead 550 which is connected through respective resistors 552 and 554 to a positive voltage lead 556 and a negative voltage lead 558, respectively. A control potentiometer 560 is connected between positive lead 556 and ground lead 550 and the control wiper 562 provides control output on lead 564 to a positive input 566 of a differential amplifier 568. The sensing potentiometer 540 is bridge connected in parallel with control potentiometer 560 between positive voltage supply lead 556 and ground lead 550 to provide a sense output via wiper 570 and lead 572 for application to the negative input 574 of amplifier 568. The amplifier 568 may be a standard form of differential amplifier but one form which has proved to be extremely accurate and reliable is an operational amplifier of the module type, Model No. PF85A11 commercially available from Philbrick Researches of Boston, Mass.

A very high value of resistance 576 provides decoupling between positive input 566 and ground while similar feedback and a.c. decoupling is provided by a resistance 578 and capacitor 580 connected between output 582 of amplifier 568 and the negative input 574. The output 582 of amplifier 568 is then applied in parallel to each of the bases in an npn-type transistor 584 and a pnp-type transistor 586 which serve to sense the plurality of the sensing amplifier output to effect the

desired control function. Thus, a positive going output on lead 582 will cause pnp transistor 584 to conduct with current flowing to actuate a relay coil 588 to close relay contacts 590 such that energizing voltage from input 592 is applied to solenoid 594 of the four-way solenoid valve 596. Such actuation of solenoid valve 596 then applies hydraulic power to actuate the hydraulic cylinder 536 to displace extrusion screed 532 in a first direction.

In the event that the signal output from amplifier 568 on lead 582 is negative going, the pnp transistor 586 is caused to conduct to energize relay coil 598 to close relay contact 600 and actuate the remaining solenoid 602 of solenoid valve 596. This actuation then causes hydraulic cylinder 536 to function in its opposite manner and to control extrusion screed 532 to move in the opposite direction. Of course, as previously described, any movement of oscillating extrusion screed 532 is reflected through linkage 548 to be read as a sense output from potentiometer 544 secured to frame 534. The potentiometer 544 (the same as the schematically illustrated potentiometer 540) may be selected in accordance with the desired accuracy of response; however, one type which has given particularly good performance is a precision resistor known in the art as the Bourns Model 180 Linear Motion Potentiometer.

FIG. 12 illustrates one form of potentiometer-type resistance which can be employed as the control potentiometer 560 of FIG. 11. Such a potentiometer 604 may be constructed from a switch 606 having a detent controlled wiper arm 608 which is selectively positionable on any of a plurality of contacts 610. A plurality of low value resistors 612, of approximately equal resistance (if a linear resistance change is desired) are tied between each adjacent pair of the contacts 610 to provide a serial resistance extending from a first contact 614 around to a second contact 616. Respective output leads 618 and 620 can then be connected into a control circuit and wiper output lead 622 will conduct a variable or voltage-divided output in accordance with the setting of wiper arm 608.

This type of potentiometer 604 is utilized in such as the control circuit 506 when employed for controlling the crowning variation of extrusion screeds in a slip-form paving apparatus as shown in FIG. 11. Thus, the potentiometer 604 may be mounted at the main panel of the operator's console 54 (FIG. 1) so that the operator can control (as indicated by dash line 624) the wiper 608 at a rate determined by the speed of the paving apparatus. Such operation will be specifically described below in the operation section. While the potentiometer 604 is described in terms of a basic detent switch with a plurality of serially connected resistors, it should be understood that various other types of continuous resistance element with segmenting wiper contact can be employed to provide a voltage divided output for control purposes.

FIG. 13 shows another form of control potentiometer 560, which includes a potentiometer 630 having an output wiper element 632 adapted to contact successive ones of a plurality of contacts 634 each separated by a fixed resistance 636. The potentiometer 630 provides the same type of control output on lead 638 but in this case the wiper 632 is mechanically rotated as a direct function of the movement of the slip-form paver (or grader) apparatus along the right-of-way. Thus, in one form, wiper 632 may be rotated by a mechanical linkage 640 which is rotated by a suitable form of stepping relay 642. The stepping relay 642 may be periodically energized by a suitable form of timing switch 644 which is actuated periodically in response to rotation of a tachometer wheel 646 in contact with roadway or earth 648 as supported by a support arm 650 rigidly secured to frame portion 652. It is contemplated that timing switch 644 should be of such construction that its period is adjustable independently of variations in the speed of tachometer wheel 646. This provides for automatic crowning control of a paving slab around a roadway turn at any desired rate of bend to meet the roadway specification. In one form then it may be desirable to transmit rotation from tachometer wheel 646 via such as a flexible cable 654 through an adjusta-

ble gear arrangement (not specifically shown) for actuation of timing switch 644.

FIG. 14 shows a similar form of automatic control 506 as it may be employed for control of a moldboard 660. This usage is also primarily intended for an automatic crowning control as the moldboard 660, actually right and left moldboards 662 and 664, serves to gradually diminish crown through the first half of a turn and to gradually build up the crown again through the second half of a turn. Thus, automatic control 506 utilizing either the operator's control potentiometer 606 (FIG. 12) or the automatic tachometer wheel potentiometer 630 (FIG. 13) operates to provide an output signal via lead 666 to hydraulic control 668. The hydraulic control 668 acting along line 670 adjusts the double-acting hydraulic cylinder 672 and connecting rod 674 to vary the vertical level of the center or crown portion of moldboard 660. This also causes a variation through mechanical linkage 548 to change the resistance reading in the precision linear motion potentiometer 54 such that an error or voltage is reflected along lead 676 for input to automatic control 506 to provide a nulling input which indicates correct positioning.

In some operations, it may be desirable to utilize hydraulic control 668 to vary also the outer hydraulic cylinders 678 and 680 to alter the vertical level of one or the other ends of moldboard 660. The possibility of this connection is indicated by dashlines 682 and 684 respectively. Also, certain operations benefit from the utilization of a control output on lead 666 to control other operating elements of the same road construction machinery. Thus, as shown in FIG. 14, the output control signal 666 may also be applied to a hydraulic control 686 which provides a hydraulic actuation via lines 688 to adjust one or more of the preceding operating elements, the auger 690, the cutter moldboard 692, and the cutter 694.

Another form of automatic control system is shown in FIG. 15. This mechanism provides control of the head or excess material buildup in front of certain of the operating elements. Such automatic control may be utilized with either the slip-form paving apparatus (FIG. 5) or the cutter-grader apparatus (FIG. 3). The use of such automatic control enables increased precision of material handling, either paving material or base material, and its benefits can become particularly apparent when used to monitor head buildup at outward extremities of the operating elements, those areas which are not readily open to the operator's surveillance through one of the observation gratings 52.

In FIG. 15, an automatic control 700 is utilized to control head buildup in front of oscillating extrusion screeds 702 and 704 of a slip-form paving apparatus. An adjustable support arm 706 is rigidly secured to a frame member 708 of a slip-form paver apparatus. The support member 706 can be adjusted by rotation of screw crank 710 to raise or lower a tube 712 which supports a control sensor 714 at a preselected level. The control sensor 714 may be the similar type of two-position switch mechanism as previously disclosed, the switch being actuated by rotary movement in the vertical plane of a sensor arm 716 acting through an input shaft 718. A paving material head 720, as built up in front of rear oscillating extrusion screed 702, is sensed by a float pan 722 which is pivotally attached to support arm 724 extending in rigid connection from frame member 708. A rod 726 having an actuating eye 728 is secured to the upper surface of float pin 722 to extend upward such that actuating eye 728 surrounds the sensor 716. Thus, crank 710 can be manipulated to set the level of control sensor 714 and sensor arm 716 such that float pin 722 will null at a desired height of head 720. The null position will serve to maintain head 720 at that height during the period when no active control measures need be effected.

Variation of head 720, and therefore float pan 722, will cause actuation of control sensor 714 to provide a control input via leads 730. The control input on leads 730 may then be applied to apparatus at the console 54 to generate a control output on a lead 732 to vary a screed positioning mechanism 734 such that forward screed 704 is raised up or down in com-

pensation such that head 720 is maintained at the desired height or amount of buildup where nulling of sensor 714 occurs. Here again, the type of control may be varied. For example head 720 formed before rear oscillating extrusion screed 702 may be sensed and control output applied directly to adjust the vertical level of extrusion screed 702; however, it may be decided to employ such control output to control vertical disposition of forward screed 704 (as shown) or as a combination control of both of screeds 702 and 704.

The control circuitry of FIG. 16 may be utilized with the head control system 700 of FIG. 15 as follows: The float pan 722 is caused to vary in vertical disposition by the head 720 to vary the linkage 740, i.e. rod 726, sensing arm 716 etc., to close control sensor 714 and to energize one or the other of leads 730, either lead 742 or lead 744. The leads 742 and 744 connect to the operator's console 54 whereupon they are applied to respective relay switch contacts (normally open) 746 and 748 which may be actuated by energization of relay coil 750. The relay coil 750 is periodically energized by d-c voltage from lead 752 through switch contacts 754 and 756 as closed by a cam 758 driven at a preset rotation by a motor 760. Such delayed or intermittent correction control enables gradual correction of the head buildup without resulting in any paving or surface voids due to over compensating. The spacing between contacts 754 and 756 are preferably made adjustable and it is contemplated that variously shaped additional cams may be substituted for cam 758 to derive a proper compensation rate in controlling the operating elements to correct the head buildup without over compensating.

If a control output or system ground is present on either of control leads 742 and 744, and if relay 750 is actuated closed by proper orientation of cam 758, one or the other of relay coils 762 or 764 will be energized to close its respective relay contact 768 or 770. An output is then conducted on one or the other of leads 772 or 774 for conduction back down to the proximity of the operating element for application to a valve control solenoid 776. The valve control solenoid 776 then actuates hydraulic cylinder 778 in a prescribed manner to effect proper positioning of a surfacing element such as an extrusion screed, a cutter auger, a moldboard or others of the related operating elements.

FIG. 17 shows the similar automatic control of head buildup as employed with a moldboard 780. The moldboard 780 may be vertically positionable by means of a hydraulic control 782 and a support linkage 784. A head of buildup base material or such 786 may be sensed by a float pin 788 suspended by support arm 790 from frame portion 792. Variations in position of float pan 788 are transmitted via a linkage 794 to a deviation sense mechanism 796 which may be similar to that circuitry of FIG. 16. A correction signal or solenoid actuation is then applied to control hydraulic control 782 in accordance with any deviation to make appropriate adjustment in vertical height of moldboard 780. Here again, error sensed in head 786 may be used to control vertical adjustment of moldboard 780, or it may be used to control others of the coating operating elements.

OPERATION

In operation, various combinations and portions of the control circuitry, both automatic and manual, may be called upon for performance of various roadbuilding functions. The various control functions in basic application can be employed to control operation of the mobile assembly 10 with either the cutter-grader assembly 120 or the slip-form paver assembly 220. In either case, the control functions can be utilized with but slight variation to derive proper feed back information for application to corrective control apparatus as will be described below.

When cutter-grader assembly 120 is operated, the mobile assembly 10 is automatically guided by following such as string line 84 by the outboard rigged control sensors 110 and 112. The steering sensors can be located on either side de-

pending upon the operation. Similarly, level control is effected by control sensing of sensors 94, 96, 98 and 100 in each of the four corners of the mobile assembly 10. Automatic control is also effected here with the respective control sensors energizing their proper hydraulic actuating assemblies to continually correct for variations from the desired grade level as sensed from the left string line 82 and/or right string line 84.

As shown in FIG. 8, with automatic control of level and steering, the operator has full control as to adjustment of the cutter, cutter moldboard, auger and auger moldboard as effected through cutter-grader control 354. Each of the cutter switch 486, cutter moldboard switch 488, auger switch 490 and auger moldboard switch 492 provides actuation for each side and center of their respective elements. Thus, the operator can raise and lower each of the left, right or center portions of the operating element individually and incrementally so that he can continually balance out the respective level settings to effect proper grading and removal of excess material.

When the cutter-grading operation comes to a turn, it may be desirable to vary the crown of the grade cut uniformly about the turn. Conventionally, this would be the gradual removal of crown through the first half of a turn with subsequent rebuilding of crown through the second half of the turn. This control may be effected automatically by circuitry similar to that of FIG. 11 when connected as shown in FIG. 14. Flags may be marked at uniform distances along the string line (lines 82 and 84) about the curve such that the operator need only rotate wiper arm 608 of control potentiometer 604 (FIG. 12) one increment or step at each flag position. This unbalances the bridge input to operational amplifier 568 such that differential output causes conduction of one or the other of transistors 584 or 586 to provide the proper automatic control output to effect corrective positioning of the then, element. As shown in FIG. 14, the appropriate output on leads 666 to hydraulic control 668 would provide actuation via lead 670 to cylinder 672 to incrementally position the center of moldboard 660.

The alternative form of FIG. 13 can also be employed, this tending to eliminate the necessity for marking flags along the curve string line. The tachometer wheel 646 being of known diameter allows for adjustment of timing switch 644 so that an output signal may be provided after travel of a preset distance. This output from timing switch 644 then actuates stepping relay 642 and wiper arm 632 to effect incremental variation of control potentiometer 630. Here again then, the bridge input to operation amplifier 568 is unbalanced such that it will provide a differential output which will drive hydraulic control 668 and hydraulic cylinder 672 to a null position.

It may also be desirable to sense the head buildup before an operating element for the purpose of effecting corrective control. Thus, as shown in FIG. 17, a moldboard 780 (e.g. auger moldboard 128 of cutter-grader assembly 120) may have the head 686 sensed for the purpose of correcting either the level of moldboards 780 or the level of previous operating elements which adjustments will also vary the head buildup as to all rearward elements. The head buildup with respect to cutter-grader operation in grade cutting or subgrading operations can be extremely important due to the fact that the operator cannot always see all portions of the operating elements to maintain proper manual control. Thus, the furthest outboard reaches of each of moldboard 128, auger 126, cutter moldboard 124, and cutter 122 may be difficult to observe and automatic deviation sensing as set forth in FIG. 17 may be employed as required.

In the slip-form paving operation, the slip-form paving assembly 220 utilizes the automatic control functions in similar manner. Automatic control as shown in FIG. 11 is employed for crowning control to vary the profile of the pavement surface. Once again, the operator may effect manual control by means of control potentiometer 604 (FIG. 12), or a tachometer wheel 646 and control potentiometer 630 (FIG. 13) may be utilized to provide corrective input to the circuitry of FIG.

11. In each case, the control potentiometer 604 or 630 provides periodic, uniform unbalance of the bridge input to operational amplifier 568 such that it will conduct to effect correction of the hydraulic mechanism until the bridge circuit is once again balanced, i.e. the null position is achieved.

More specifically, a command input or uniform resistance change is effected as control potentiometer 560 (potentiometers 604 or 630 of FIGS. 12 and 13) to effect predetermined conduction of operational amplifier 568 such that it energizes one or the other of transistors 584 and 586 controlling the relays 588 and 598, respectively. The relay energization then effects actuation of valve 596 and hydraulic cylinder 536 to bring screed member 532 to a new position. At this new position, potentiometer 544 (same as bridge potentiometer 540) will be brought to a null position where the bridge input is again balanced. Such correction and nulling sequence is periodically effected a number of times as the slip-form paver assembly proceeds around a roadway curve, and through the second half of the curve the exact opposite should take place. That is, control potentiometer 560 should intermittently progress in the opposite direction and this will function to incrementally raise the center of screed member 532 to gradually rebuild the crown of the paving surface.

Head buildup is also sensed in the slip-form paving operation as shown in FIG. 15. The entire paving operation can be placed under control of the head sensing apparatus 700. For example, head 720 prior to the second extrusion screed 702 can be sensed by floating pan 722 to control actuation of sensor switch 714. Any excess or diminution of head 720 will be signalled by a switch closure present on lead 730 to console main panel 54 whereupon control circuitry, as shown in FIG. 16, generates the appropriate output on lead 732 to control screed position mechanism 734 such that it displaces the front extrusion screed 704. If desired, the control actuation from control main panel 54 can be applied to one or more of the previous operating elements such as primary feed meter 242 or secondary meter 258 or any combination of such elements.

The foregoing discloses novel automatic control systems for use with road building machinery of the heavy, multi-lane finishing type. The invention includes novel control methods and apparatus which serve to regulate various operational functions of the machinery to enable far more complete automation of this form of apparatus than has ever been available heretofore. This increased automation capability enables faster operation of the various cutting-grading and paving functions with greater accuracy and improved versatility as to application.

Changes may be made in the combination and arrangement of elements 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 as defined in the following claims.

We claim:

1. In a mobile roadway construction machine which supports plural, vertically adjustable operating elements in contact with a roadway surface, automated control apparatus comprising:

a voltage source;

first and second potentiometer means forming a bridge circuit by having respective ends connected together and across said voltage source and having said respective potentiometer wiper arms connected to provide electrical control outputs, said first potentiometer means being manually adjustable;

linkage means rigidly secured between said operating element and the wiper arm of said second potentiometer such that its resistance is varied in proportion to vertical movement of said operating element;

control circuit means receiving said electrical control outputs and being energized in response thereto to generate an actuation output;

positioning support means which is vertically adjustable and rigidly secured to said machine to support said operating element in contact with said roadway at a preset level; and

actuation means energized by said actuation output to adjust said positioning support means such that the level of said operating element is changed until cessation of derivation of said electrical control output by said input means.

2. Automatic control apparatus as set forth in claim 1 wherein said control circuit means comprises:

differential amplifier means providing a first polarity output in response to raising of the level of said operating element and providing a second polarity output in response to lowering of the level of the operating element;

first transistor means conductive in response to said first polarity signal to energize said actuation means; and second transistor means conductive in response to input of said second polarity signal to energize said actuation means.

3. Automatic control apparatus as set forth in claim 1 wherein said control circuit means comprises:

differential amplifier means providing a first polarity output in response to raising the level of said operating element and providing a second polarity output in response to lowering of the level of the operating element;

first transistor means conducted in response of said first polarity signal to energize said actuation means; and second transistor means conductive and response to input of said second polarity signal to energize said actuation means.

4. Automatic control apparatus as set forth in claim 2 wherein said actuation means comprises:

valve means including first and second solenoid means each energizable to place said valve means in respective first and second actuating positions to control said positioning support means to lengthen and shorten respectively; and

first and second power relay means each responsive to respective first and second outputs from said first and second transistors to control respective ones of said first and second control solenoids.

5. Automatic control apparatus as set forth in claim 1 which is further characterized in that: said follower potentiometer is a linear resistance potentiometer having a wiper arm which is rigidly connected for movement with said operating element.

6. Automatic control apparatus as set forth in claim 1 wherein said control circuit means comprises:

relay means conducting said electrical control signal when energized;

a source of relay energization power;

switch means which is normally open and connected to apply said energizing power to said relay means; and

motor driven cam means for contacting said normally open switch to effect a predetermined amount of switch closure per revolution to generate a pulsed actuation output.

7. Automatic control apparatus as set forth in claim 1 which is further characterized in that: said operating element which is connected to said positioning support means is an oscillating extrusion screed of a slip-form paver assembly.

8. Automatic control apparatus as set forth in claim 1 which is further characterized in that: said operating element which is attached to said positioning support means is a moldboard of a cutter-grader assembly.

9. Automatic control apparatus as set forth in claim 3 which is further characterized in that: said operating element which is connected to said positioning support means is an oscillating extrusion screed of a slip-form paver assembly.

10. Automatic control apparatus as set forth in claim 3 which is further characterized in that: said operating element which is attached to said positioning support means is a moldboard of a cutter-grader assembly.

11. In a mobile roadway construction machine which supports plural, vertical adjustable operating elements in contact with a roadway surface, automated control apparatus:

float pan means pivotally supported from said machine immediately in front of an operating element to move vertically in accordance with excess material head build up in front of said operating element;

control sensor means supported by said machine to be actuated by said float pan to provide a first output signal in response to upward movement of the float pan and a second output signal in response to downward movement of the pan;

control circuit means receiving said first and second electrical control signals and being energized in response thereto to generate an actuation output;

positioning support means which is vertically adjustable and rigidly secured to said machine to support said operating element in contact with said roadway at a preset level; and

actuation means energized by said actuation output to adjust said positioning support means such that the level of said operating element is changed until cessation of derivation of said electrical control signal by said input means.

12. Automatic control apparatus as set forth in claim 11 wherein said control circuit means comprises:

relay means conducting said electrical control signal when energized;

a source of relay energization power;

switch means which is normally open and connected to apply said energizing power to said relay means; and motor driven cam means for contacting said normally open switch to effect a predetermined amount of switch closure per revolution to generate a pulsed actuation output.

13. Automatic control apparatus as set forth in claim 11 wherein said actuation means comprises:

valve means including first and second solenoid means each energizable to place said valve means in respective first and second actuating positions to control said positioning support means to lengthen and shorten respectively; and first and second power relay means each responsive to respective first and second outputs from said first and second transistors to control respective ones of said first and second control solenoids.

14. Automatic control apparatus as set forth in claim 11 which is further characterized in that: said operating element which is connected to said positioning support means in an oscillating extrusion screed of a slip-form paver assembly.

15. Automatic control apparatus as set forth in claim 11 which is further characterized in that: said operating element which is attached to said positioning support means is a moldboard of a cutter-grader assembly.

16. In a roadway construction machine of the type which is propelled by oppositely disposed pairs of front and rear mobile elements each attached to an adjustable length support post which is affixed to the machine, the machine carrying a surface-forming operating element transverse to and in operating contact with the roadway, and the machine including a power source and operating controls, the control system comprising:

first control sensor means tracking the motion of said machine relative to said roadway and actuable in response to variations thereof to produce a characteristic steering output signal;

steering control means operatively connected to said mobile elements and energized by said steering output signal to turn said mobile elements in a given direction;

second control sensor means tracking the horizontal attitude of said machine relative to said roadway and actuable in response to variations thereof to produce a characteristic level output signal;

level control means operatively connected to each of said support posts and energized by said level output signal to adjust the length of said support posts to level said machine;

third control sensor means tracking the position of said operating element relative to said roadway and actuable

in response to variations thereof to produce a characteristic operating element control signal; and

operating element control means affixed to said machine and adjustably supporting said operating element at a selected position relative to said roadway and being energizable by said operating element control signal to adjust said position.

17. In a roadway construction machine, the control system as set forth in claim 16 wherein said operating element control means comprises:

support means which is adjustable in length and connected between said machine and said operating element;

positioning means energized by said power source and actuable to adjust the length of said support means; and

actuating means energized by a characteristic operating element control signal to actuate said positioning means to effect particular adjustment.

18. In a roadway construction machine, the control system as set forth in claim 17 wherein said actuating means comprises:

first relay means actuated in response to a first characteristic operating element control signal to actuate said positioning means to move said operating element in a first direction; and

second relay means actuated in response to a second characteristic operating element control signal to actuate said positioning means to move said operating element in the opposite direction.

19. In a roadway construction machine, the control system of claim 18 which is further characterized to include:

manual override means interconnected between the input from said third control sensor means and said first and second relay means to disconnect said first and second characteristic operating element control signal inputs; and

manual switch means for effecting selective actuation of said first and second relay means.

20. A control system as set forth in claim 16 wherein said roadway construction machine is a slip-form paver assembly and said operating element is an extrusion screed member.

21. A control system as set forth in claim 16 wherein said roadway construction machine is a cutter-grader assembly and said operating element is a vertically adjustable moldboard element.

22. In a roadway construction machine, the control system as set forth in claim 16 wherein said operating element control means comprises:

support means which is vertically adjustable and affixed between said machine and said operating element at a central lateral position of said operating element;

positioning means for effecting adjustment of said support means at said central position; and

actuation means energizable in response to operating element control signals to control said positioning means such that it varies the height of said operating element central portion relative to the ends.

23. In a roadway construction machine, the control system of claim 22 wherein said third control sensor means comprises:

control potentiometer means providing a first voltage output proportional to the desired height of said operating element central portion;

follower potentiometer means affixed for adjustment in response to vertical movement of said operating element central portion to provide a second voltage output proportional to the actual height of said central portion;

means for detecting any voltage difference between said first and second voltage outputs to produce a respective first or second operating element control signal in accordance with said first voltage output being greater or less than said second voltage output.

24. In a roadway construction machine, the control system of claim 23 which is further characterized to include: manual

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means for incrementally varying said control potentiometer means and selecting the first voltage output indicative of desired height of said operating element central portion.

25. In a roadway construction machine, the control system of claim 23 which is further characterized to include:

tachometer wheel means suspended from said machine into contact with said roadway to generate an actuation out-

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put after each traverse of a predetermined distance along the roadway; and

periodic actuation means energized by said actuation output to incrementally vary said control potentiometer to a next successive resistance setting.

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