

[54] VEHICULAR MATERIAL SPREADER CONTROL APPARATUS

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 [51] Int. Cl. A01c 19/20
 [58] Field of Search 222/23, 52, 178, 63, 76, 334; 239/677

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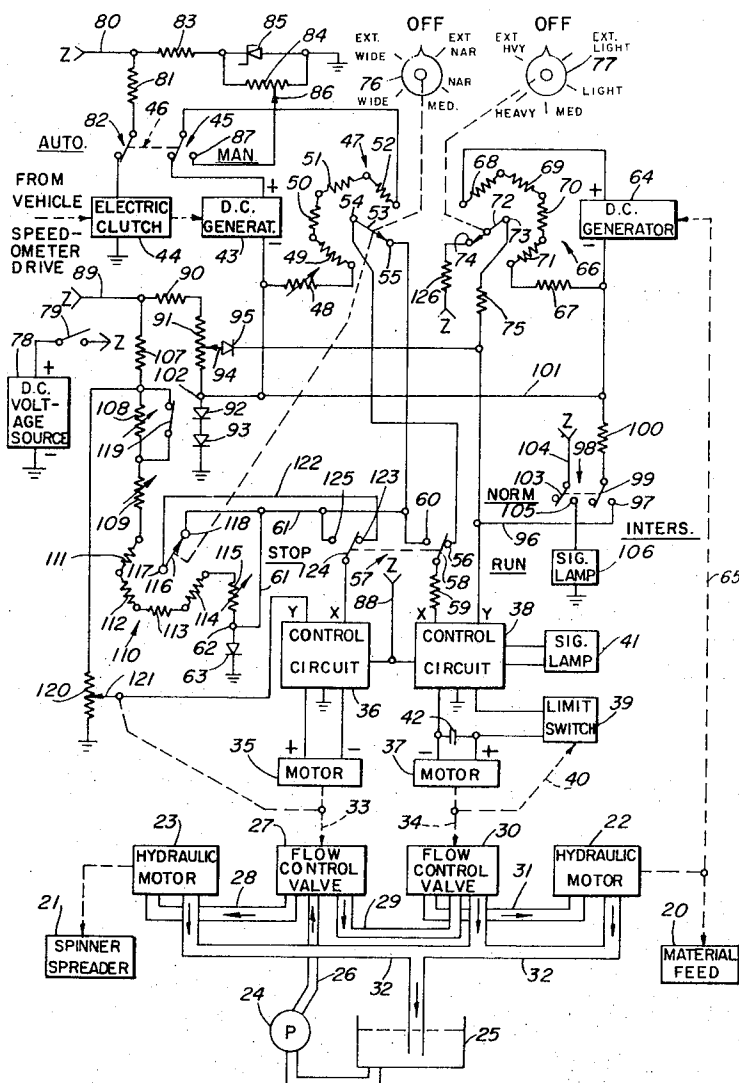
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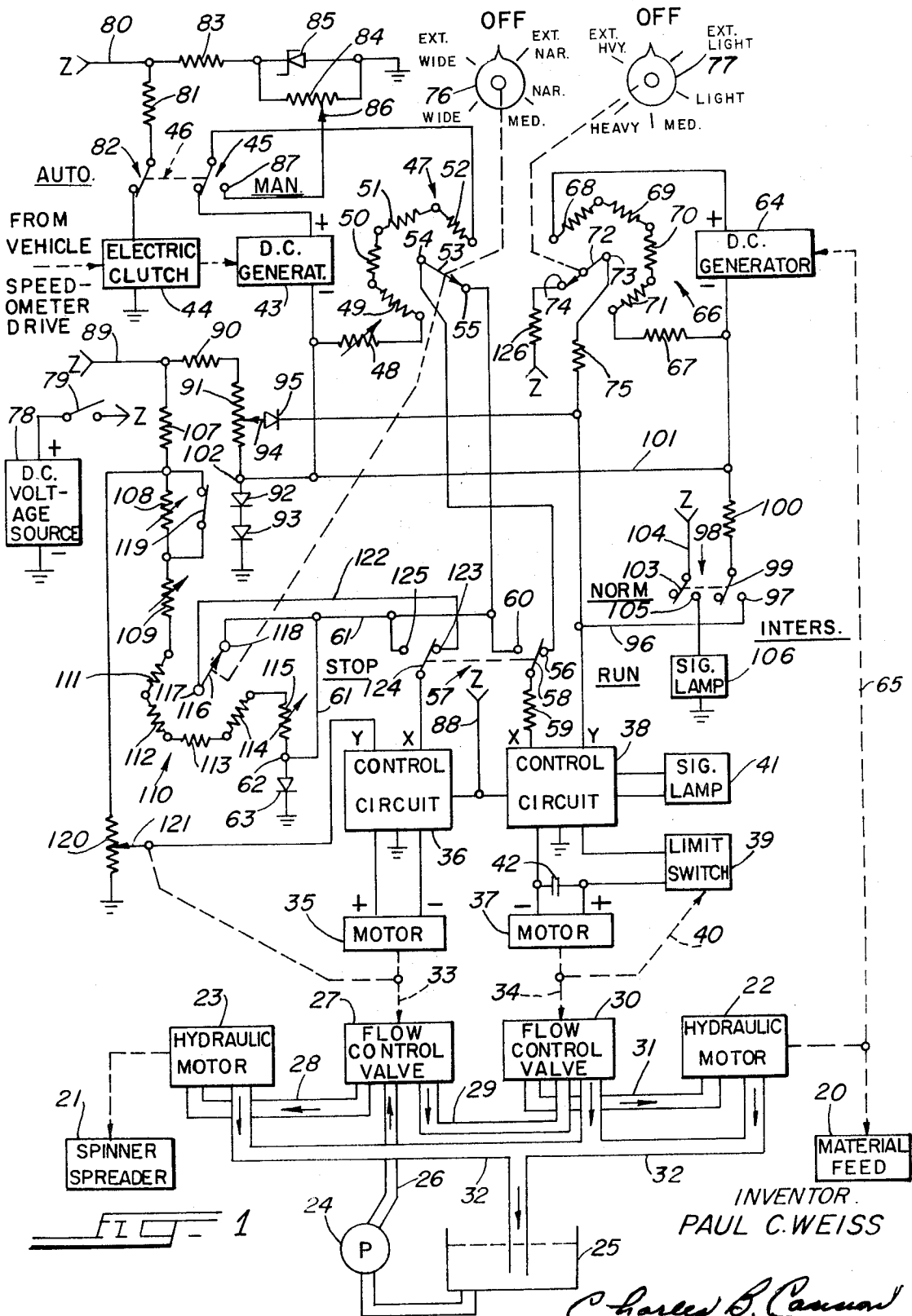
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[57] ABSTRACT

The system for spreading the particulate material is interconnected with the dispensing system to automatically adjust the dispensing rate concomitantly with any adjustment in width of spread to maintain constant the spreading density. In one embodiment the speed control circuit for the spinner motor is interconnected with the speed regulating circuit for the dispenser motor. In another embodiment the feeding mechanism for dispensing and the spinner are driven by the same prime mover and the dispensing rate is further controlled by a speed regulated hopper gate. In a further embodiment the speed control circuit for the spinner motor is interconnected with a hopper gate while the feeding mechanism is independently controlled. Several forms of compensation are provided for various non-linearities in the systems and for the various materials handled.

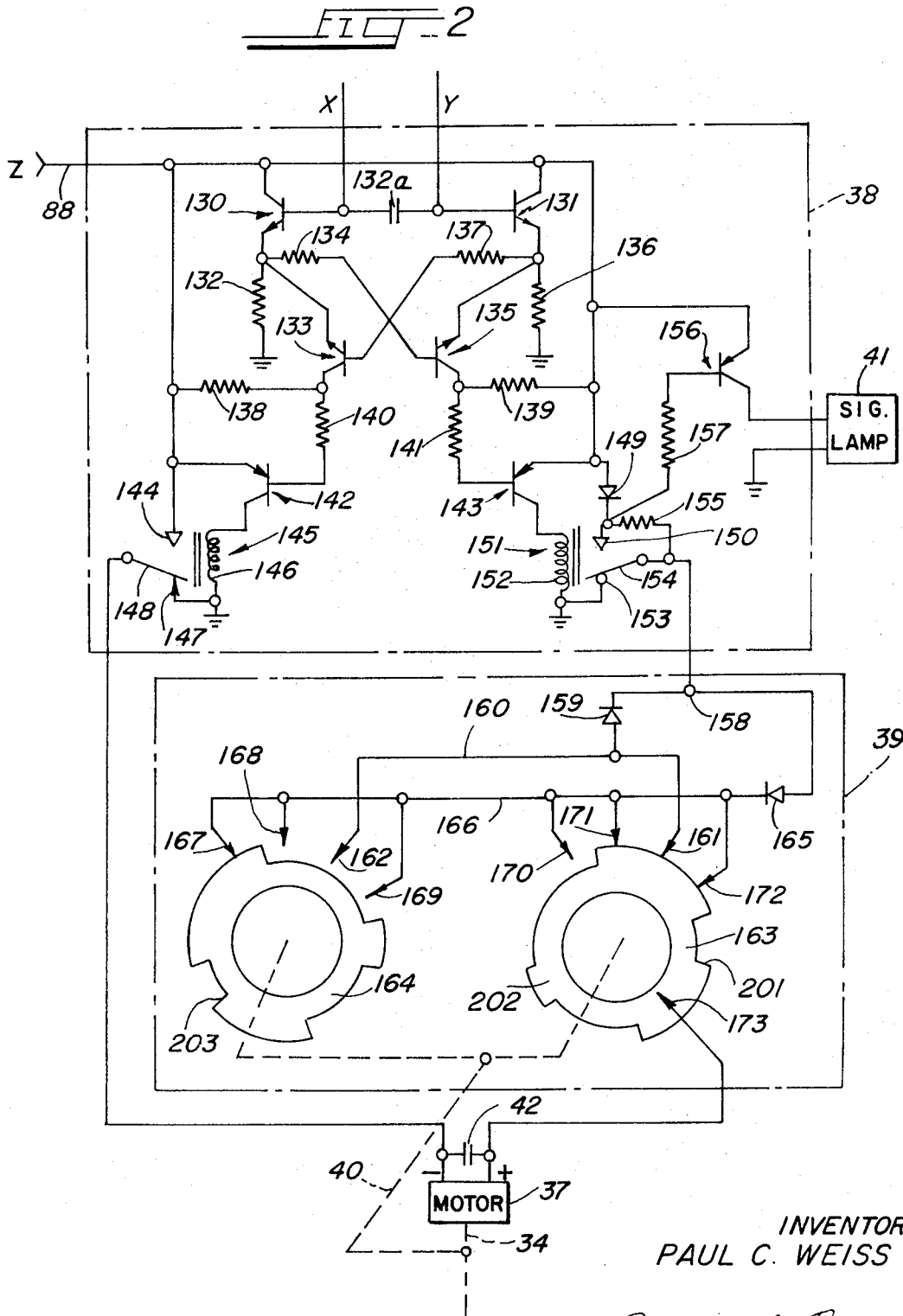
17 Claims, 14 Drawing Figures





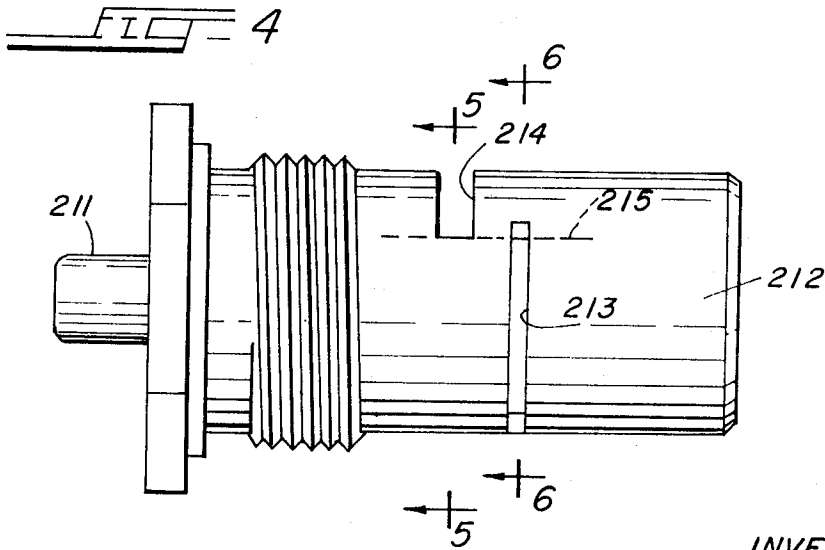
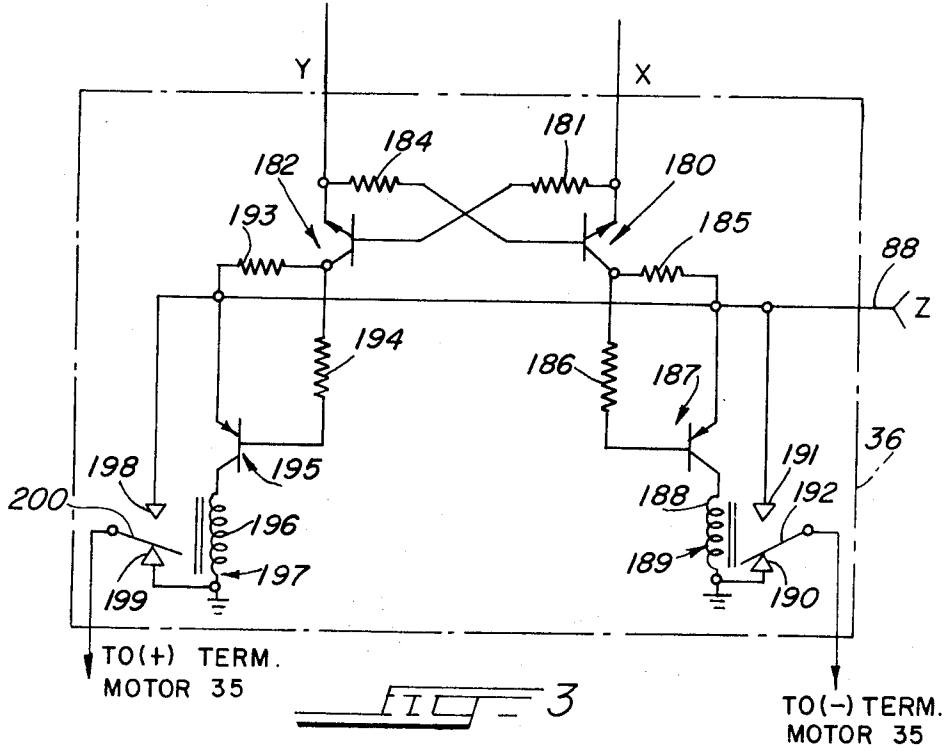
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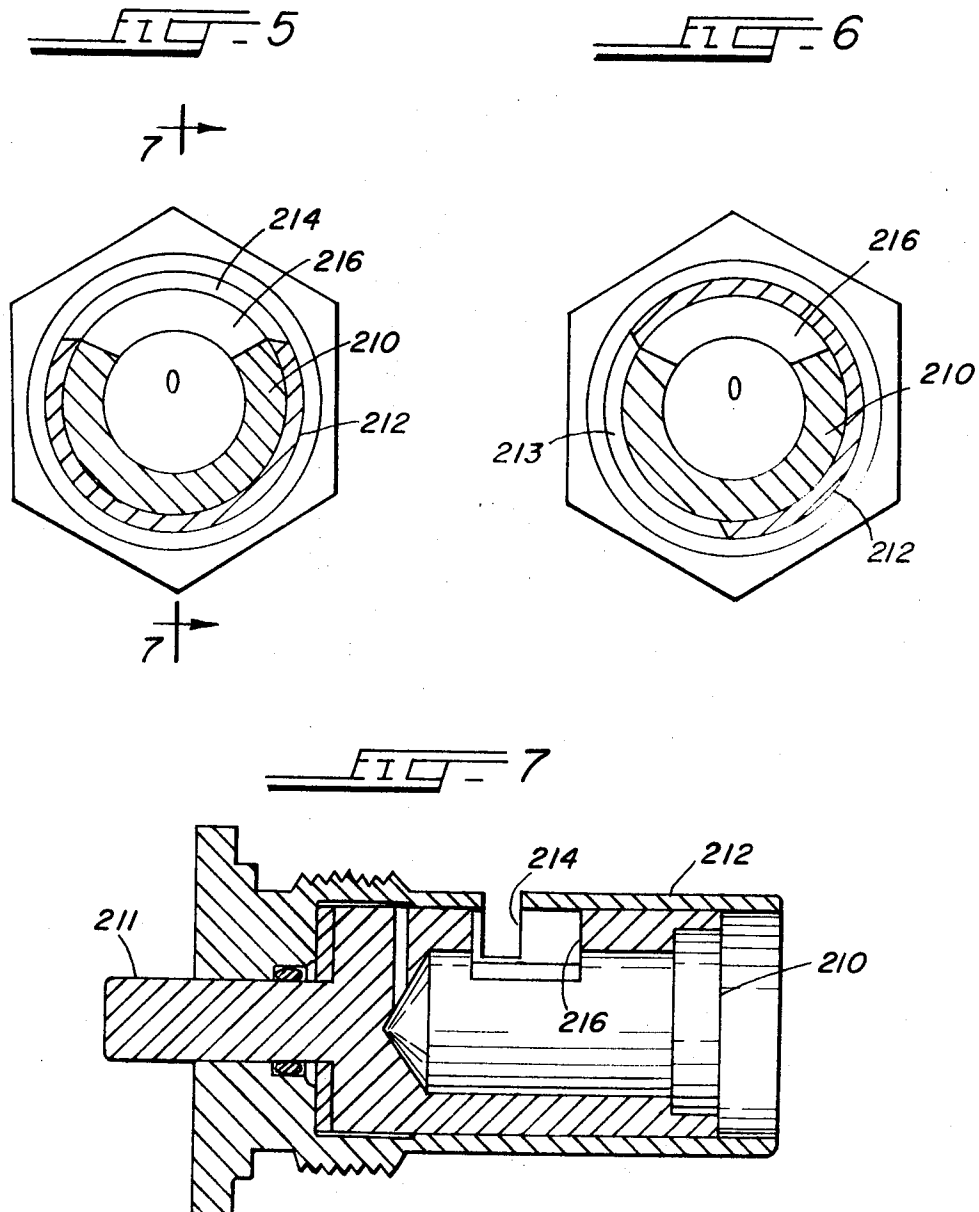
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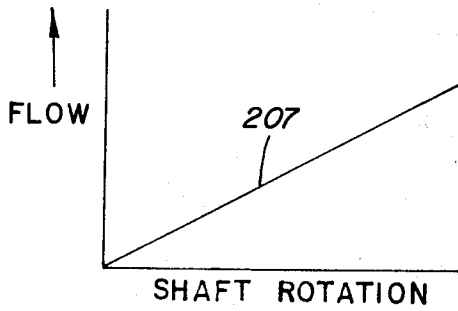


FIG. 8

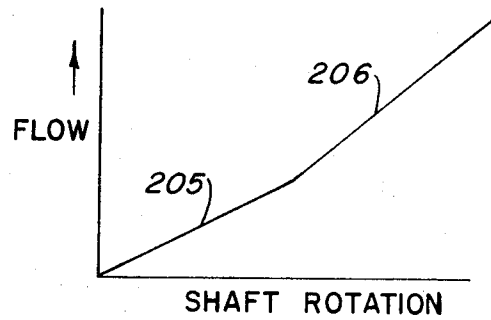


FIG. 9

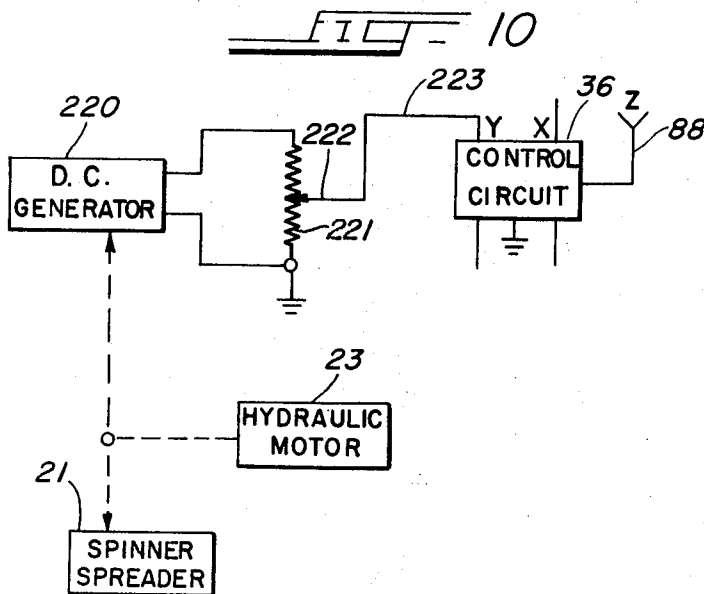
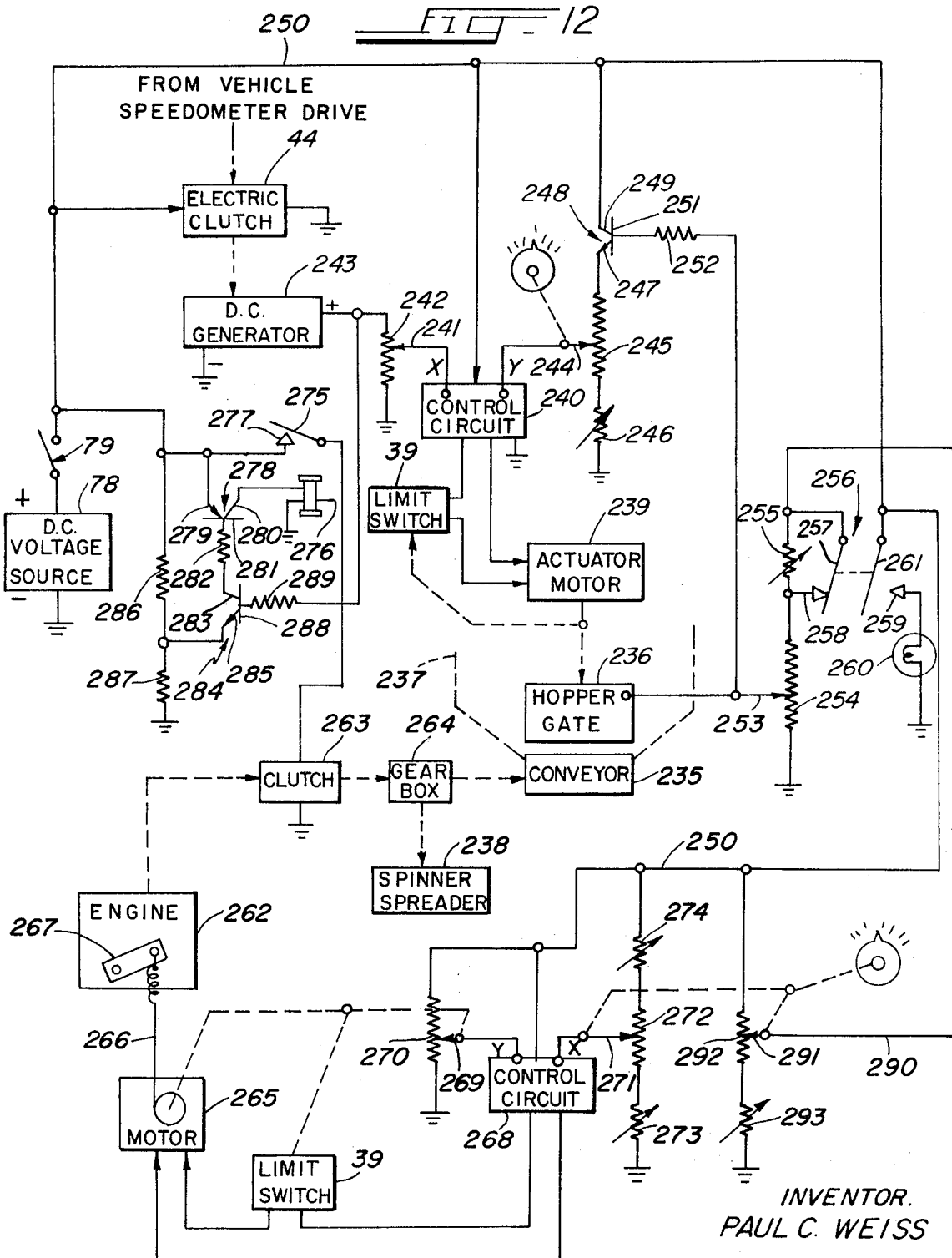


FIG. 10

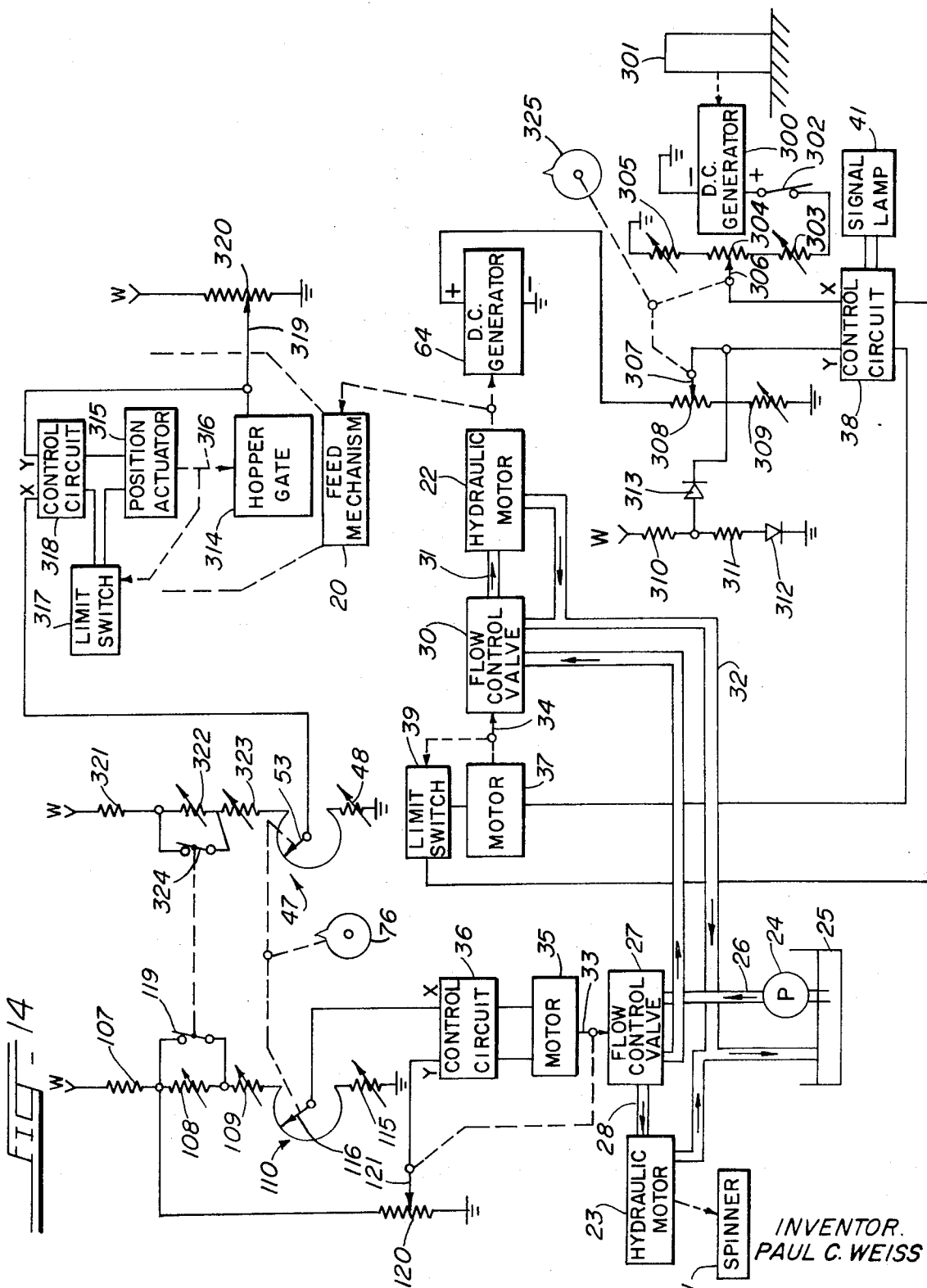
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VEHICULAR MATERIAL SPREADER CONTROL APPARATUS

The present invention relates to apparatus for controlling the operation of a vehicular material spreader. More particularly, it relates to the apparatus for controlling the material dispensing and spreading mechanisms of such a spreader.

Vehicular material spreaders find extensive use in agriculture and highway maintenance. Whether it is fertilizer for agricultural purposes or particulate ice control material on the highway, there is a need, for various reasons, for maintaining constant and uniform the density of application of the material being spread. Heretofore, various attempts have been made to regulate the distribution of material as a function of ground speed. Assuming that the width of distribution can be maintained constant both the quantity distributed per unit distance traveled and the density distribution can be maintained reasonably constant. However, it often becomes necessary to vary the width of spread as the vehicle is traveling. In prior equipment, it has been left to the judgment of the operator to adjust the rate of distribution to allow for any changes in the width of spread. In practice, this does not prove satisfactory.

Therefore, it is an object of the present invention to provide automatic equipment for changing the dispensing rate when the adjustment of the spreading width is altered by the operator.

A further object of the present invention is to provide a system wherein the width of spread can be adjusted and selected independent of any change in selected density of distribution and vice versa.

Another object of the invention is to provide means for conveniently changing the calibration of the spreading width selector for correlation with different materials to be spread and with different characteristics of the spreading mechanism.

Another object of the invention is to provide means for quickly changing the calibration of the rate selector to compensate for the effectiveness of the materials being spread.

It is also an object of the present invention to provide means for indicating to the operator when he is attempting to operate his vehicle beyond the capacity or capability of the mechanism. Other objects will be readily apparent to those skilled in the art.

In accordance with one aspect of the invention, there is provided apparatus for controlling the operation of a vehicular material spreader having means for dispensing material from a reservoir at a controllable rate and means for spreading the dispensed material over a controllable area, the apparatus comprising in combination: first control means for regulating the operation of the dispensing means for causing material to be dispensed at a rate which varies as a function of the ground speed of the vehicular spreader, adjustable second control means for regulating the operation of the spreading means to determine the area covered thereby, and means for automatically changing the dispensing rate when the adjustment of the second control means is altered to maintain constant the density of material spread per unit area independent of change in the area covered.

In accordance with another aspect of the invention, there is provided apparatus for controlling the operation of a vehicular material spreader having a driven material feeder and an adjustable gate for dispensing material from a reservoir at a controllable rate, and a motor driven spinner for spreading the dispensed material over a controllable areas, which apparatus comprises in combination: first control means including an actuator means for regulating the position of the gate to maintain a desired opening from the reservoir which is controlled thereby, adjustable second control means for controlling the operating speed of the spinner motor to spread the dispensed material over a desired area, means for adjusting the second control means to select the area covered by the spinner, and means for automatically changing the rate at which material is dispensed concomitantly with adjustment of the second control means to alter the rate in a direction and magnitude to maintain constant the density of material spread per unit area

independent of change in the area covered by the spinner, the last mentioned means including means for controlling the first control means as a function of the adjustment of the means for adjusting the second control means.

In accordance with a still further aspect of the invention, there is provided apparatus for controlling the speed of operation of a device as a function of a controlling input signal which comprises in combination: a rotary hydraulic motor for driving the device; means for supplying fluid under pressure to the hydraulic motor for energizing the same; a pressure compensated flow control valve interconnecting the fluid supply means with the hydraulic motor for controlling its speed of operation; a signal producing means responsive to operation of the hydraulic motor for generating a first electric signal having a parameter proportional to the speed of rotation of the motor; second signal producing means for producing a second electric signal; and an adjustable control circuit coupling the first and the second signal producing means operatively to the valve for adjusting the valve in response to the signals in a manner controlling the speed of the motor tending to maintain the two signals in a predetermined relationship, the valve having a non-linear characteristic such that its response rate is lower during a first portion of its range of adjustment to prevent overcorrection at low speeds of the motor and to allow for slippage therein.

The invention will be better understood after reading the following detailed description of the presently preferred embodiments thereof with reference to the appended drawings in which:

FIG. 1 is a schematic diagram of a control system embodying the present invention;

FIG. 2 is a schematic diagram showing a detail of the circuit of FIG. 1;

FIG. 3 is a schematic diagram showing a further detail of the circuit of FIG. 1;

FIG. 4 is an elevational view of a variable orifice assembly employed in the flow control valves of FIG. 1;

FIG. 5 is a transverse sectional view taken along the line 5—5 in FIG. 4;

FIG. 6 is a transverse sectional view taken along the line 6—6 in FIG. 4.

FIG. 7 is a longitudinal sectional view taken along the line 7—7 in FIG. 5;

FIG. 8 is a curve showing the flow control characteristic of the variable orifice of FIG. 4 as employed in the flow control valve for the spinner spreader of FIG. 1;

FIG. 9 is a curve showing the flow control characteristic of the variable orifice of FIG. 4 as employed in the flow control valve for the material feed mechanism of FIG. 1;

FIG. 10 is a schematic diagram showing a modification of the system of FIG. 1;

FIG. 11 is a schematic diagram showing a still further modification of the system of FIG. 1;

FIG. 12 is a schematic diagram showing a different embodiment of the invention;

FIG. 13 is a schematic diagram showing a modification of the system of FIG. 12; and

FIG. 14 is a schematic diagram showing a still further embodiment of the invention.

Throughout the figures of the drawings, the same reference numerals are used to designate the same or similar parts.

For convenience, the invention will be described as applied to a vehicle for distributing salt or the like for control of ice along a highway. Such vehicles generally have a reservoir in the form of a body or hopper for holding the material to be spread. A conveyor or screw (auger) feed mechanism is employed to advance the material from the reservoir to an outlet point where it is spread by means of a spinner or similar device. An adjustable gate is generally also provided at the outlet point for further controlling the feed of material from the reservoir to the spreader.

Referring now to FIG. 1, there is shown a control system for a vehicle having a material feed, designated generally by the

reference numeral 20, of the type which determines the rate of feed by its speed of operation. Examples of this type of feed mechanism are the conveyor or screw type structures. Also shown, is a spinner spreader 21 of conventional construction.

A pair of rotary hydraulic motors 22 and 23 are provided, respectively, for driving the material feed 20 and spinner spreader 21. A pump 24 supplies hydraulic fluid under pressure from a reservoir 25 over inlet pipe 26 to a first flow control valve 27. The valve 27 is of the bypass type having a controlled outlet supplying motor 23 over conduit 28 and a bypass outlet supplying a conduit 29 leading to the inlet of a second flow control valve 30. The valve 30 is of similar construction to the valve 27 having a controlled outlet which supplies motor 22 over conduit 31 and a bypass outlet leading to the return conduit 32 terminating in the reservoir 25. Each of the motors 22 and 23 is provided with a return connection to the conduit 32, as shown. The details of construction of the flow control valves 27 and 30 will be described more fully hereinafter. It should be sufficient at this point to note that the valves are arranged to control the rate of flow of fluid to the respective motors as a function of the positioning of corresponding input shafts 33 and 34, respectively.

Adjustment of the flow control valve 27 is effected by a direct current motor 35 operatively connected to shaft 33. Motor 35 is controlled by a control circuit 36 having two input circuits or channels designated X and Y. The control circuit is in the form of a differential amplifier responding to differences in potential at the inputs X and Y for controlling the motor 35. If the potential or voltage applied to the input X exceeds the voltage applied to the input Y, the motor 35 will be caused to rotate in one direction. If the relationship of the voltages applied to the inputs X and Y is reversed, then the motor 35 will be driven in the opposite direction. The motor will continue to be driven until the voltages at the inputs X and Y become substantially equal. The details of construction of control circuit 36 will be described more fully hereinafter.

In somewhat similar fashion a direct current motor 37 is coupled operatively to shaft 434 for controlling valve 30. A control circuit 38 has an output coupled to the input terminals of motor 37 through a limit switch 39. A mechanical interconnection between the shaft 34 and limit switch 39 is indicated by the numeral 40. For a purpose which will appear hereinafter, a signal lamp 41 is shown connected to the control circuit 38. The details of construction of control circuit 38 in conjunction with lamp 41 and limit switch 39 will be described more fully below. As shown, a capacitor 42 is connected across the input terminals to the motor 37.

In order to control the operation of the hydraulic motor 22 and the material feed 20 as a function of ground speed, there is provided a D.C. generator 43 coupled through the electric clutch 44 to the speedometer drive or speedometer cable of the vehicle. The output from generator 43 is connected through the normally closed contacts of a section 45 of a double-pole double-throw switch 46 to a voltage divider consisting of the series arrangement of a potentiometer 47 and an adjustable resistor 48. As shown, the potentiometer 47 consists of four resistors 49, 50, 51 and 52 connected in series between adjacent fixed contacts of a rotary multi-position switch. The wiper or slider for the potentiometer is provided by the switch armature 53 having an output terminal 54. In addition, an auxiliary fixed contact 55 is provided for engagement by the slider 53 when it is out of engagement with the resistance elements of the potentiometer.

The slider 53 of potentiometer 47 is connected through terminal 54 to one fixed contact 56 of a double-pole double-throw switch 57. An armature 58 of switch 57 is connected through a resistor 59 to the X input of control circuit 38. During normal operation of the system, the armature 58 will engage contact 56, as shown. For a purpose to be described below the switch 57 is also provided with a fixed contact 60 connected through a bus 61 to a junction point 62 which is, in turn, connected through a substantially constant voltage diode 63 to ground.

A feedback function for the control circuit 38 is provided by a second D.C. generator 64 driven by the hydraulic motor 22 over the coupling 65. The output from generator 64 is connected over a separate voltage divider consisting of potentiometer 66 in series with resistor 67. Potentiometer 66, like potentiometer 47, has four resistors 68, 69, 70 and 71, connected between fixed contacts of a multi-position switch having an armature 72, an output terminal 73, and an auxiliary fixed contact 74. The armature or wiper 72 of potentiometer 66 is connected through terminal 73 and a resistor 75 to the Y input of control circuit 38. As shown, manual control knobs, which may be conveniently located on the dashboard of the vehicle, are provided, the knob 76 being coupled to the slider 53 while the knob 77 is coupled to the slider 72.

On the drawing, various designated positions are indicated for the respective knobs 76 and 77. Each position corresponds to a stationary contact associated with the corresponding potentiometers 47 and 66. In the illustration, both knobs are indicated in the OFF position and their associated sliders are on the auxiliary contacts 55 and 74, respectively. It is assumed that as each knob is indexed, for example, in a clockwise direction, the associated slider is also advanced clockwise and vice versa.

Voltage to operate the control circuit described to this point is provided by a D.C. voltage source 78. The output from source 78 is connected through a master ON-OFF switch 79 to a point designated by the letter Z. It is to be understood that all points on the drawing designated by this letter are interconnected. Thus, when switch 79 is closed, voltage is applied over a first path 80, first through a resistor 81 and the normally closed contacts of the section 82 of switch 46 to one side of the electric clutch 44. The clutch 44 is also provided with a connection to ground. The path 80 also supplies voltage through a voltage divider, consisting of a resistor 83 connected in series with the parallel arrangement of a potentiometer 84 and a zener diode 85, to ground. The potentiometer 84 is provided with a slider 86 which is connected to fixed contact 87 of switch section 45.

The point Z is also connected over a path 88 to both control circuits 36 and 38 which, in turn, are provided with corresponding ground connections. A still further path, 89, supplies power to a network of voltage dividers. One voltage divider connected between the path 89 and ground includes a resistor 90 in series with a potentiometer 91 and two constant voltage diodes 92 and 93. The potentiometer 91 has a slider 94 which is connected through a diode 95 in the anode-to-cathode direction to the junction between resistor 75 and the Y input of circuit 38. This latter junction is also connected over a lead 96 to a fixed terminal 97 of a double-pole single-throw switch 98.

An armature 99 of switch 98 is connected through a resistor 100 to a bus 101 which interconnects the negative terminals of the generators 43 and 64 with the junction 102 between the potentiometer 91 and diode 92. The second armature 103 of switch 98 is connected over a path 104 to the voltage point Z. Another fixed contact 105 of the switch 98 is connected through a signal lamp 106 to ground.

The path 89 is also connected to ground through a series arrangement consisting of a fixed resistor 107, a first adjustable resistor 108, a second adjustable resistor 109, a potentiometer 110 consisting of the four series connected resistors 111, 112, 113, and 114, another adjustable resistor 115 and the diode 63. The resistors 111, 112, 113 and 114 are connected in sequence between fixed contacts of a multi-position switch having an armature 116 connected to an output terminal 117 which armature functions as a slider. There is also provided an auxiliary fixed contact 118 which is engaged by the slider 116 when it is out of engagement with the resistances of the potentiometer. A normally closed switch 119 is connected in shunt to the adjustable resistor 108.

Finally, a potentiometer 120 has its resistance element connected between ground and the junction between resistors 107 and 108. The wiper 121 of potentiometer 120 is mechani-

cally interconnected with the shaft 33 driven by motor 35 and is electrically connected to the Y input of control circuit 36. The slider 116 of potentiometer 110 is connected through terminal 117 and a lead 122 to a fixed contact 123 of the switch 57. An armature 124 of switch 57 is connected to the X input of control circuit 36. Another fixed contact 125 of the switch 57 is connected to the bus 61.

One further voltage connection is provided from the point Z through a resistor 126 to the contact 74 associated with slider 72. As shown, the sliders 53 and 116 of potentiometers 47 and 110 are mechanically ganged or interconnected for conjoint rotation under the manipulation of control knob 76.

Before proceeding with a discussion of the operation of the circuit of FIG. 1, reference should be had to FIG. 2 for the details of the control circuit 38 and limit switch 39. The X and Y inputs of the circuit 38 are connected, respectively, to the corresponding base electrodes of N-P-N transistors 130 and 131, respectively. A condenser 132a is connected in parallel with the inputs. As shown, the collector electrodes of transistors 130 and 131 are connected to the path 88 which leads to the voltage source point Z. The emitter electrode of transistor 130 is connected to ground through a resistor 132 and to the emitter electrode of another N-P-N transistor 133. It is also connected through a resistor 134 to the base electrode of an N-P-N transistor 135. In similar manner, the emitter electrode of transistor 131 is connected to ground through a resistor 136 and to the base electrode of transistor 133 through a resistor 137. It is also connected to the emitter electrode of transistor 135, as shown. The collector electrodes of transistors 133 and 135 are connected, respectively, by way of resistors 138 and 139 to the voltage supply path 88. The aforesaid collector electrodes are also connected through respective resistors 140 and 141 to corresponding base electrodes of P-N-P transistors 142 and 143. The emitter electrode of transistor 142 is connected both to the voltage path 88 and to a fixed contact 144 of a relay 145 having a solenoid 146 and a second fixed contact 147, the latter being connected to ground. The armature 148 of the relay 145 is connected to the negative terminal of the motor 37. Solenoid 146 is connected between ground and the collector electrode of transistor 142.

Transistor 143 has its emitter electrode connected to the voltage path 88 and through a diode 149 in the anode-to-cathode direction to a first fixed contact 150 of a relay 151 having a solenoid 152, a second fixed contact 153, and an armature 154. A resistor 155 is connected between the fixed contact 150 and the armature 154. The contact 153 is connected to ground and the solenoid 152 is connected between ground and the collector electrode of transistor 143.

A lamp control circuit is provided consisting of a further P-N-P transistor 156 having its emitter electrode connected to the voltage path 88, its collector electrode connected to one side of the signal lamp 41, the other side of which is connected to ground, and its base electrode connected through a resistor 157 to the fixed contact 150 of relay 151.

Relay armature 154 is also connected to a junction 158 within the limit switch 39. The junction 158 is connected over one path to the cathode of a diode 159, the anode of which is connected to a lead 160 interconnecting fixed contacts 161 and 162 on opposite sides of a wafer switch having a rotatable element provided with two rotary contact members 163 and 164. The members 163 and 164 are rotate in unison under the control of the connection 40 driven by the shaft 34.

A further connection exists from junction 158 to the anode of a second diode 165 having its cathode connected to a bus 166 which interconnects the fixed contacts 167, 168, 169, 170, 171, and 172. Finally a stationary contact 173 is provided which engages switch member 163 and is connected to the positive terminal of the motor 37. The spacing between adjacent contacts 167, 168, 162 and 169, as well as between contacts 170, 171, 161, and 172, is 30° of arc with contacts 167 and 170 occupying the same angular position and so on with corresponding pairs of the others.

In FIG. 3, to which attention is now directed, there is shown the control circuit 36. The X input of the circuit is connected to the emitter electrode of a first N-P-N transistor 180 and also through a resistor 181 to the base electrode of a second N-P-N transistor 182. The emitter electrode of the latter transistor is connected to its Y input and through a resistor 184 to the base electrode of transistor 180. The collector electrode of transistor 180 is connected through a resistor 185 to the voltage path 88 and through a resistor 186 to the base electrode of a P-N-P transistor 187. The emitter electrode of transistor 187 is connected to the voltage path 88 while its collector electrode is connected to ground through the solenoid 188 of a relay 189 having fixed contacts 190 and 191. The fixed contact 190 is connected to ground while the contact 191 is connected to the positive path 88. An armature 192 is connected to the negative terminal of the motor 35.

The collector electrode of transistor 182 is similarly connected through a resistor 193 to the positive path 88 and through a resistor 194 to the base electrode of a P-N-P transistor 195. The emitter electrode transistor 195 is connected to the path 88 while its collector electrode is connected to ground through the solenoid 196 of a relay 197 having fixed contacts 198 and 199 as well as an armature 200. The fixed contact 198 is connected to the path 88 while the contact 199 is connected to ground. The armature 200 is connected to the positive terminal of motor 35.

Returning now to FIG. 1, it should be noted that the switch 46 provides selection between AUTO. (for automatic) and MAN. (for manual) operation with automatic operation representing the normal condition. Switch 57 has associated with it a RUN and STOP function. The functions associated with the switch 98 are NORM. (for normal) and INTERS. (for intersection). The control knobs 76 and 77 are associated with the functions indicated therewith on the drawings.

Assuming that the various switches in FIG. 1 are in the positions shown therein when the main switch 79 is closed, the electric clutch 44 will be energized through a circuit traceable from point Z through path 80, resistor 81, closed switch section 82 to the clutch 44 and back to ground. This interengages the generator 43 with the speedometer drive of the vehicle and, if the vehicle is moving, will result in a voltage at the output terminals of generator 43. However, the X input of control circuit 36 is connected through armature 124 of switch 57 and contact 123 thereof to slider 116 of potentiometer 110 which engages the contact 118 which, in turn, is joined to the junction 62 between resistor 115 and diode 63. The diode is poled such that a nominal voltage of about 0.7 volts positive exists at the junction 62 due to current passing through it. This voltage is related to the minimum voltage obtainable from the potentiometer 120 when its slider 121 approaches its grounded end such that the motor 35 is rotated until flow control valve 27 is shut off. Thus, spinner spreader 21 will be at a standstill.

Similarly, the 0.7 volts appearing at junction 62 is applied through contact 55, slider 53, closed armature 58 and resistor 59 to the X input of control circuit 38. The Y input of circuit 38 is connected to the cathode of diode 95 whose anode is connected to the wiper 94 of potentiometer 91. This potentiometer is in a closed circuit connected to the voltage source and, therefore, applies a positive voltage to the Y input. Since two diodes, 92 and 93, are connected in series between the junction 102 and ground, the voltage appearing at such junction is about 1.3 volts. Therefore, the minimum voltage obtainable from the slider of potentiometer 91 is in excess of 1.3 volts. Thus, it will be seen that the voltage on the Y input of circuit 38 is more positive than the voltage at the X input. Hence, the relay 145 in circuit 38 (see FIG. 2) will be energized connecting the positive terminal of the voltage source to the negative terminal of the motor 37. The relay 151 will be deenergized with its armature 154 connected to ground through contact 153. This will complete a circuit for the motor 37 through the limit switch 39 so long as such switch provides a closed path. The direction or polarity of the current is such as to rotate motor 37 in a direction to close valve 30.

Rotation will continue until the limit switch 39 opens the circuit to motor 37. This corresponds to the shut-off position of valve 30. A counter clockwise rotation of the limit switch through 60° will locate the gap 201 in contact member 163 opposite the fixed contact 161. Thus, it can be shown that the circuit through diode 159 is interrupted. Although a circuit exists through diode 165 it is poled the wrong way to pass current when positive voltage is applied to the negative terminal of motor 37. Hence, the motor will be deenergized.

A further shut-off circuit for circuit 38 is provided by the connection of the positive terminal of the voltage source through resistor 126, contact 74, slider 72, and resistor 75 to the Y input of circuit 38. Thus, if the width control knob 76 is rotated away from the OFF position to cause both sliders 53 and 116 to engage contacts associated with the resistance elements of the corresponding potentiometers 47 and 110, the voltage applied to the Y input of circuit 38 through the slider 72 will still maintain the flow control valve 30 shut and the material feed 20 inoperative.

If, conversely, knob 76 is in the OFF position while knob 77 is rotated away from the OFF position, the material feed 20 will still be inoperative due to the bias applied to the Y input of control circuit 38 from the slider 94 of potentiometer 91. This arrangement insures that the material feed 20 will not operate when the spinner spreader 21 is inoperative.

Whenever knob 76 is rotated away from its OFF position some voltage greater than 0.7 volts will be applied from the potentiometer 110 through a readily traceable circuit to the X input of control circuit 36. This assumes that switch 57 is in its RUN position. The arrangement is such that for any voltage applied to the X input of circuit 36 from the potentiometer 110, the motor 35 will be rotated to open flow control valve 27 to cause operation of hydraulic motor 23 and spinner spreader 21. The valve 27 will open under the rotation of shaft 33 until the slider 121 of potentiometer 120 is positioned at a point whereat the voltage applied to the Y input of circuit 36 substantially matches the voltage appearing at the input thereof.

It has been found that the transistors employed in the differential amplifier input stages of control circuits 36 and 38 have a threshold of operation rendering them insensitive to very low voltage inputs. To overcome such threshold level, there is applied a fixed bias of equal magnitude to both input terminals X and Y. Such bias is provided for control circuit 38 by the connection of junction 102 via conductor 101 to the negative terminals of the generators 43 and 64. That is, the small voltage drop appearing across the two diodes 92 and 93 will be applied to both inputs of the circuit 38. With respect to circuit 36, the minimum voltage applied to the inputs thereof is determined by the voltage at the junction between resistor 114 of the potentiometer 110 and adjustable resistor 115. This voltage is the minimum voltage that can be applied to the control circuit 36 for all positions of the wiper 116 other than its OFF position.

With the selector 76 adjusted such that the spinner spreader 21 is operating, the D.C. generator 43 will be in communication with the X input of control circuit 38 through a readily traceable circuit. Assume that the knob 77 has also been rotated to select some rate of application of the medium to be distributed. The slider 72 will engage some portion of potentiometer 66 corresponding to the selected quantity. This removes the high positive voltage appearing at contact 74. However, there is still a low voltage applied to the Y input of circuit 38 from the potentiometer 91. This keeps flow control valve 30 closed and the material feed 20 inoperative until the speed of the vehicle exceeds some predetermined minimum value whereat the generator 43 develops a voltage such that the voltage appearing at the X input of circuit 38 exceeds the voltage appearing at its Y input. When this occurs the relay 151 in control circuit 38 will be actuated while relay 145 will be deenergized. Positive voltage will now be applied to the junction 158 within the limit switch 39.

As previously mentioned, a closed circuit exists through diode 165 and the contact of the limit switch. Thus, voltage will be applied to the motor 37 with a polarity such that it rotates shaft 34 to open valve 30. Once valve 30 opens, the hydraulic motor 22 will be energized imparting motion to both the material feed mechanism 20 and the generator 64. The voltage appearing at the terminals of generator 64 will increase with increased speed of operation of the hydraulic motor 22 until the voltage applied therefrom to the Y input of control circuit 38 matches the voltage appearing at its X input. Under these conditions, the voltage at the Y input will exceed the voltage at the wiper 94 of potentiometer 91 such that current no longer flows through the diode 95.

As the vehicle speeds up along the roadway the voltage from generator 43 will increase causing the control circuit 38 to respond with increased speed of operation of motor 22 and increased voltage output from generator 64 until balanced conditions prevail. Thus, the quantity of material discharged is increased as the speed of the vehicle increases. That is, generator 43 will be driven at a speed proportional to the ground speed of the vehicle. This will apply through slider 53 of potentiometer 47, a potential proportional to the round speed to the X input of the control circuit 38. The circuit 38 compares this potential with the potential received from slider 72 indicative of the speed of operation of the hydraulic motor 22 and material feed 20. If a discrepancy exists, the control circuit, through motor 37, adjusts the flow control valve 30 to bring the speed of motor 22 into desired relation to ground speed. The spinner spreader 21 operates at a speed determined by the settings of the variable resistors 109 and 115 and the potentiometer 110. In a typical installation for spreading salt on a roadway, the resistor 109 is generally adjusted so that the maximum width of spread with the control 76 set at EXTRA WIDE is equivalent to four lanes. The resistor 115 is generally set for one lane width when the control 76 is positioned at EXTRA NARROW.

The operator selects the rate of application of material by the knob 77. Moving the knob so as to position the slider 72 toward the negative terminal of generator 64 will increase the rate of distribution while adjusting the slider in the opposite direction will decrease the rate of distribution. With the knob 76, the operator selects the width of distribution or area to be covered by the spinner spreader 21. Manipulation of knob 76 simultaneously adjusts both potentiometer 47 and potentiometer 110. As previously mentioned, the speed of spinner 21 is determined by the setting of potentiometer 110. Moving the slider 116 to contacts nearer the adjustable resistor 109 will increase the speed of the spinner and widen the spreading path. The converse applies when the slider 116 is moved toward the resistor 115. The arrangement of potentiometers 110 and 47 is such that as potentiometer 110 is adjusted to widen the path covered by the spinner, the potentiometer 47 will be adjusted so as to cause increased delivery from the material feed 20. The converse will apply when knob 76 is manipulated to adjust the potentiometers so as to call for a narrower path of spread.

The adjustable resistor 48 controls the minimum density of material obtainable and is selected in order to properly proportion the range of adjustment afforded by potentiometer 47 to the range of adjustment afforded by the width control potentiometer 110. The value of the resistor 48 should be selected to satisfy the following equation:

$$R_{48} = \frac{R_{47}}{\frac{W_{\max.}}{W_{\min.}} - 1} \quad (1)$$

where: R_{48} is the required resistance of resistor 48; R_{47} is the total resistance of the four resistors of potentiometer 47; and $W_{\max.}$ and $W_{\min.}$ represent the maximum and minimum widths, respectively, to be covered by the spreader measured in any consistent units.

The resistor 67 is employed to adjust the ratio between the maximum and minimum quantities deliverable by the material feed 20. For example, if it is desired that the ratio between the heaviest and lightest rate of application should be of the order of 3:1, the value of resistor 67 should be selected so that when added to the total resistance of potentiometer 66 the sum is three times the value of resistor 67.

In the foregoing description it has been assumed that the width of spread is a linear function of the speed of the spreader. However, in practice this is not the case. Due to various factors the speed of rotation of a spinner type spreader must increase a greater amount at higher absolute speeds than at lower absolute speeds for the same change in spreading width. Variable resistor 48 when adjusted in accordance with equation (1) tends to partially compensate for the above mentioned non-linearity. Further compensation can be obtained by profiling the resistance element of potentiometer 110 such that its electrical characteristic is suitably non-linear. The selection of the actual contour of the characteristic of potentiometer 110, or its equivalent, can best be made by trial and error.

With the system shown in FIG. 1, the switch 79 serves as a master power switch for the control circuits 36 and 38. However the power source for the hydraulic motors 22 and 23 is driven from a prime mover independent of the source 78. Therefore, the switch 57 serves as a RUN-STOP control to close both of the flow control valves 27 and 30 when it is desired to stop the dispensing and spreading mechanism without regard to the status of the vehicle. That is, when switch 57 is manipulated to connect the armatures 58 and 124 to contacts 60 and 125, respectively, a suitable low potential is applied to each of the X inputs of the control circuits 36 and 38. The control circuits are arranged such that when the particular input terminals are so connected, as previously described, the motors operate to close the respective flow control valves.

In snow or ice control operations it is often desirable to increase the rate of distribution of the material when passing through intersections or when proceeding uphill. In order to effect this without altering the normal adjustments of the width and rate controls, there is provided the switch 98, as previously described. When this switch is manipulated to cause contacts 97 and 105 to be engaged, the signal lamp 106 is ignited to signal this position while the resistor 100 is connected to function with resistor 75 as a voltage divider reducing the voltage applied to the Y input of circuit 38. If resistors 75 and 100 are of equal value the signal applied to the Y input of circuit 38 will be reduced by 50 percent causing the output of the material feed 20 to be doubled. By suitably proportioning the ratio between resistors 100 and 75, the extent of the increase can be suitably selected.

It is also quite common in snow and ice control to use a variety of control materials. For example, under certain conditions, sand may be used while under other conditions salt. In order to enable the same equipment to handle either salt or sand or other materials having different spreading characteristics, there is provided the switch 19 and adjustable resistor 108. Opening the switch 119 causes insertion of the resistor 108 in series with the potentiometer 110. This drops the voltage available from potentiometer 110 and reduces the entire range of speeds available from the spinner spreader 21. Thus, when sand, requiring a higher spinner speed for a given width distribution, is being handled, the switch 119 would be closed. When salt, requiring a lower spinner speed for the same width distribution, is being handled, the switch 119 would be opened. By providing this selectable arrangement, the calibration of the width control 76 can be arranged to be equally valid when spreading sand or salt. Obviously, the equipment can be calibrated for any two different materials, and with a suitable number interchangeable resistors can be used with a like number of different materials.

Occasionally, it is necessary to operate the equipment manually such as when a speedometer cable fails or the clutch

44 fails or perhaps the generator 43 fails. For this purpose there is provided an auxiliary voltage source available at slider 86 of potentiometer 84 which is connected to the potentiometer 47 in place of generator 43 when the switch 46 is manipulated to the MAN. position. At the same time, the clutch 44 is deenergized by opening switch section 82. The slider 86 may be preset to provide proper operation at a predetermined ground speed, for example, 24 miles per hour.

For proper operation, the potentiometer 91 should be adjusted so that with the vehicle stopped in the automatic position, the relay 145 in control circuit 38 will just trip to shut off flow through the valve 30. In practice, this prevents discharge of material until some minimum speed of the vehicle is attained such as three to 4 miles per hour.

The capacitor 42 located across the terminals of motor 37 is provided for prolonging the life of the contacts in the relays 145 and 151. Such protection is not needed for the control circuit 36 which operates the spinner spreader since circuit 36 normally operates infrequently.

The signal lamp 41 is provided to indicate when the capacity of the material feed 20 is exceeded. That is, it indicates when the flow control valve 30 is fully open and the controller is calling for an increase. This condition can develop when the pump 24 is being driven at too slow a speed to supply oil to drive the motors 22 and 23. It can also occur when the operator drives his vehicle too fast.

Referring to FIG. 2, it will be seen that when relay 151 is deenergized armature 154 is grounded through contact 153. This causes current to flow through diode 149 and resistor 155 developing a negative bias on the base of transistor 156 relative to its emitter. In such case, the transistor 156 is conductive and the signal lamp 41 is illuminated. If the relay 151 is energized calling for rotation of motor 37 in a direction to open valve 30, the current supplying the motor must pass through the diode 149. The drop in voltage across diode 149 is sufficient to bias transistor 156 into its conductive state causing lamp 41 to be illuminated. However, if, while relay 151 is energized, the limit switch 39 reaches an open circuit condition interrupting current flow through diode 149, the potential at the base electrode of transistor 156 will approach the potential of its emitter causing it to become non-conductive and causing the lamp 41 to become extinguished. This signifies that the system is incapable of meeting the demand for one of the reasons previously mentioned.

Referring further to the limit switch 39, it was noted previously that one limiting condition involved counter clockwise rotation through 60°. It can be shown that the second limiting condition occurs when the rotating contacts 163 and 164 advance clockwise through an angle of 150°. This will bring the portion 202 of the switch element 163 into engagement with the fixed contact 161 while the contacts 170, 171 and 172 will be disengaged. At the same time, the gap 203 in the rotatable contact 164 will come opposite the fixed contact 162. In this position, no path will exist for current to flow through diode 165 from junction 158 to the positive terminal of the motor 37. However, a path will exist for current to flow in the opposite direction from the positive terminal of the motor 37 through contact 173, section 202 of contact 163, fixed contact 161, and diode 159 to the junction 158.

It will thus be seen that the limit switch provides a convenient means for restricting the flow of current in one direction when one limiting condition is attained and restricting it in the other direction when the opposite limiting condition is attained. The full range of adjustment of the limit switch as shown in FIG. 2 is 210°. By altering the interconnections between junction 158 and the various fixed contacts 161, 162, 167, 168, 169, 170, 171 and 172 it is possible to select limiting ranges between 60° and 300° in 30° intervals.

Typical values that have been found satisfactory for the various resistors and potentiometers in the system of FIG. 1 are tabulated below wherein an asterisk after the value for a resistor indicates that the element is variable; $K = \times 10^3$; all resistance values are in ohms; and all capacitance values are in microfarads.

RESISTORS

No.	Value	No.	Value	No.	Value
48	2.5 K*	90	2.7 K	137	4.7 K
49	680	100	4.7 K	138	10 K
50	820	107	100	139	10 K
51	1.5 K	108	2.5 K*	140	8.2 K
52	1.5 K	109	2.5 K*	141	8.2 K
59	2.7 K	111	560	155	1.5 K
67	1.2 K	112	470	157	68
68	1.5 K	113	390	181	4.7 K
69	820	114	330	184	4.7 K
70	820	115	1 K*	185	10 K
71	390	126	1.2 K	186	8.2 K
75	4.7 K	132	2.7 K	193	10 K
81	270	134	4.7 K	194	8.2 K
83	2.2 K	136	2.7 K		

CAPACITORS

42 8
132a 5

POTENTIOMETERS

84 5 K
91 250
120 2 K

TRANSISTORS

No.	Type	No.	Type
130	2N 1304	156	2N 555
131	2N 1304	180	2N 1302
133	2N 1302	182	2N 1302
135	2N 1302	187	2N 1303
142	2N 1303	195	2N 1303
143	2N 1303		

In the preceding description of the operation of the system of FIG. 1 mention was made of the non-linear characteristic of the spinner spreader 21 and of the means employed to compensate therefor. Other non-linearities are present in a hydraulically powered system which, if not compensated for, would give rise to error in the operation of a constant density system. Thus, it has been found that in the closed loop system driving the material feed 20, the hydraulic motor 22 is characterized by slippage, particularly at low speeds. The characteristics of the system are also such that unless suitable compensation is introduced at low speeds, overcorrection or hunting will ensue. In order to avoid this difficulty, the operation of flow control valve 30 is made non-linear. That is, its response rate is made to be lower during a first portion of its range of adjustment than during a second portion. This is illustrated graphically in FIG. 9 with the section of the curve 205 representing the first portion and 206 and a latter portion of its range. On the other hand a linear characteristic such as shown by the curve 207 in FIG. 8 is satisfactory and desirable for the flow control valve 27 which regulates the hydraulic motor 23 driving the spinner spreader 21.

While various flow control valves may be used, it is believed that superior results are obtained by combining the valves 27 and 30 of FIG. 1 within a common housing. The construction may be closely similar to the valve arrangement described in U.S. Pat. No. 3,429,232 issued Feb. 25, 1969, entitled "Remote Control Electric Actuating Device." In particular, reference is had to the valve illustrated in FIG. 2 of said patent. However, some slight modification of the foresaid valve structure must be effected in order to adapt it for the control required in the system of the present FIG. 1.

As described in said patent, the valve sections are adjusted by an assembly of interfitted sleeves wherein the inner sleeve is provided with a series of circumferentially spaced independent apertures of graduated size which can be sequentially brought into registration with apertures in the outer sleeve member. As each inner aperture is brought into registration with the outer sleeve apertures, a stepped change in fluid flow is obtained. It should be apparent, however, that the system described in the present application requires a continuously variable control rather than a stepped control. In order to afford this characteristic, the interfitted sleeve arrangements in the aforesaid patent structure must be replaced by the valving structure shown in FIGS. 4 to 7 of the present application to which attention is now directed.

An adjustable orifice assembly is shown in FIGS. 4 to 7 for providing the non-linear characteristic shown in FIG. 9. A first or inner sleeve member 210 having a shaft extension 211 for manipulation thereof is telescopically interfitted with a sliding fit for relative rotation within a second or outer sleeve member 212. The outer member 212 is provided with a plurality of separate slotted apertures 213 and 214 lying in separate parallel planes normal to the axis of the member 212 with each of said slots located at a different angular position around the circumference of said member. As best seen in FIG. 4, the adjacent ends of the slots 213 and 214 on the inner surface of the sleeve member 212 lie on a common element of the cylindrical sleeve represented by the broken line 215.

The inner sleeve 210 is provided with a slotted aperture 216 of lesser circumferential extent than the aggregate circumferential extent of the slots 213 and 214 on the sleeve 212. The slot 216 lies in a plane normal to the axis of the sleeve 210 and has an axial width and location such as to cover at least the same axial zone covered in the aggregate by the slots 213 and 214. Thus, as the sleeve 210 is rotated counter clockwise as viewed in FIGS. 5 and 6 relative to the sleeve 212, the orifice opening will vary from fully opened to closed. If the axial width of the slot 214 in the member 212 is more than twice the axial width of the slot 213, then the characteristic of the valve will take the form shown in FIG. 9. If the slot 214 has exactly twice the axial extent of the slot 213, the response will be linear as shown in FIG. 8. A suitable characteristic has been obtained for use in the control of the material feed structure with the slot 214 having an axial width approximately 2.7 times the width of the slot 213.

In the embodiment shown in FIG. 1, the feedback from motor 35 to the Y input of control circuit 36 is by way of a mechanical connection from the shaft 33 of control motor 35 to the slider 121 of potentiometer 120. Alternatively, a feedback arrangement of the type shown in FIG. 10 may be employed. Here, the connection from control motor 35 to slider 121 is eliminated and a further D.C. generator 220 is provided driven by hydraulic motor 23. The electrical output of generator 220 is applied to a potentiometer 221 having its slider 222 connected over a conductor 223 to the Y input of control circuit 36. Thus, a signal is fed to the Y input of circuit 36 which is proportional to the speed of the spinner 21. This will be matched by the control circuit 36 against the signal obtained from potentiometer 110 representative of the desired speed. In all other respects, the system of FIG. 1 can remain the same.

As previously mentioned, the usual rotary hydraulic motor is characterized by slippage and this is usually substantial. However, where a close tolerance constant displacement hydraulic motor is available, the system of FIG. 1 may be modified and simplified by replacing the D.C. generator 64 with the circuit shown in the outline box 225 of FIG. 11. Instead of the connection 65 from the hydraulic motor 22 to the generator 64 a mechanical connection 226, as seen in FIG. 11, is provided between the shaft 34 of motor 37 and a slider 227 of a potentiometer 228. One end of the resistance element of the potentiometer 228, at 229, is connected to the positive potential point Z while the opposite end of the resistance element is connected to the junction with resistor 67. The point 229 is also connected to the collector electrode of an N-P-N transistor 230 whose base electrode is connected through a resistor 231 to the slider 227 of potentiometer 228. The emitter electrode of the transistor 230 is connected to the end of resistor 68.

The flow control valve 30 should now be provided with a control orifice characteristic that is linear, as shown in FIG. 8, rather than the non-linear function of FIG. 9. Thus, the speed of the hydraulic motor 22 will be directly related to the angular position of the shaft 34. This angular position is translated by the feedback connection 226 of FIG. 11 to a voltage appearing at the positive and negative output terminals of the circuit 225 which is proportional to the speed of motor 22. The transistor 230 functions as a voltage-to-current converter in known manner.

In a typical construction of the circuit of FIG. 11, the potentiometer 228 may have a value of 2,000 ohms, the resistor 231 may have a value of 5,600 ohms, while a type 2N 1304 transistor may be employed for the transistor 230.

Turning now to FIG. 12, there is shown a somewhat different control arrangement. In this embodiment there is a driven conveyor 235 and an adjustable gate 236 for dispensing material from a reservoir shown in phantom outline at 237. A motor driven spinner is shown at 238. A first control means is provided in the form of an actuator means or motor 239 for regulating the position of the gate 236 to maintain an opening from the reservoir 237 in a desired proportional relation relative to the ground speed of the vehicular spreader. Actuator motor 239 is controlled by a control circuit 240, which may be similar to the control circuit 36 described with reference to FIG. 3, cooperating with a limit switch 39 as described with reference to FIG. 2. The X input for control circuit 240 is obtained from a connection to the slider 241 of a potentiometer 242 having its resistance element connected between ground and the positive terminal of a D.C. generator 243 driven through an electric clutch 44 from the speedometer drive or speedometer cable of the vehicle. As shown, the negative terminal of generator 243 is connected to ground.

The Y input for control circuit 240 is obtained from a connection to slider 244 of a potentiometer 245. The potentiometer 245 is connected at one end through an adjustable resistor 246 to ground. At its other end, the potentiometer 245 is connected to the emitter electrode 247 of a transistor 248 whose collector electrode 249 is connected to the source of positive voltage 78 by way of switch 79 and bus 250. The base electrode 251 of transistor 248 is connected through a resistor 252 to the slider 253 of a further potentiometer 254. The slider 253 is mechanically coupled to the gate 236 for concurrent operation. If desired, the slider could be coupled to the actuator mechanism for the gate so long as its position is indicative of the relative position of the gate. One end of potentiometer 254 is connected to ground while the other end is connected through an adjustable resistor 255 to a variable source of positive voltage described in further detail below. Shunted across the resistor 255 is a circuit controlled by double-pole double-throw switch 256 having one armature 257 connected to one end of resistor 255 and a fixed contact 258 connected to the other end thereof. Another fixed contact of switch 256 is the contact 259 connected through a signal lamp 260 to ground. The second armature, 261, of the switch 256 is connected to the voltage source 78, as shown.

A suitable internal combustion engine 262 is coupled in driving relation through a clutch 263 and a gear box 264 to both the spinner 238 and the conveyor 235. Speed of the engine 262 is regulated by means of a small servo motor 265 coupled over link 266 to an adjustable governor arm 267 on the engine. The motor 265 is controlled by a limit switch 39 and a control circuit 268, similar to the circuit 240. The Y input for circuit 268 is connected to a slider 269 of potentiometer 270 having its resistance element connected between ground and the positive source of voltage 78, as shown. The X input for circuit 268 is derived from a connection to slider 271 of potentiometer 272 connected at one end through an adjustable resistor 273 to ground and at its other end through adjustable resistor 274 to the bus 250 and the positive source of voltage. As shown, a feedback connection is provided from the control motor 265 to the slider 269. Thus, for any adjustment of the slider 271 of potentiometer 272, motor 265 will operate to reposition the slider 269 of potentiometer 270 until the voltages at terminals X and Y are substantially equal. This arrangement provides a control means for controlling the operating speed of the engine or motor 262 which drives the spinner 238 and the conveyor 235.

With this type of system where an auxiliary engine 262 is provided, it is desirable to provide some arrangement for disengaging the conveyor from the engine drive. Such would be desired when the vehicle stops, the engine 262 is still running, and distribution of material is to be interrupted. This facility is

provided by means of the control for clutch 263. As shown, the clutch is controlled electrically having a grounded terminal and a terminal connected to an armature 275 under the control of a relay solenoid 276. When solenoid 276 is energized, the armature 275 is drawn into engagement with fixed contact 277 to complete an electric circuit to the positive source of voltage 78 via switch 79. Energy for solenoid 276 is obtained from the positive source of voltage through a transistor 278. The emitter 279 of the transistor 278 is connected to the positive source of voltage while the collector electrode 280 is connected to the solenoid. The transistor 278 has a base electrode 281 connected through a resistor 282 to the collector electrode 283 of a control transistor 284. The transistor 284 has an emitter electrode 285 connected to the junction between resistors 286 and 287 which are connected in series between the source of positive voltage and ground. The transistor 284 also has a base electrode 288 connected through a resistor 289 to the positive terminal of generator 243.

The arrangement is such that when the output of generator 243 is below a predetermined minimum value both transistors 278 and 284 are non-conductive and relay solenoid 276 is deenergized. When the voltage from generator 243 exceeds the preset value determined by the junction between resistors 286 and 287, the transistor 284 conducts causing conduction of transistor 278 and energization of solenoid 276. Preferably, the control circuit is arranged for energization of the solenoid and engagement of clutch 263 when the vehicle speed reaches $2\frac{1}{2}$ to 3 miles per hour.

Returning now to the connection of the second end of resistor 255, it will be seen that it is joined by lead 290 to the slider 291 of another potentiometer 292. The latter has its resistance element connected at one end to the voltage supply bus 250 and at its other end through an adjustable resistor 293 to ground. As shown, a mechanical connection joins slider 291 to the slider 271 of potentiometer 272 for conjoint operation.

In the embodiment of FIG. 12, the operator controls the quantity of material distributed by adjusting potentiometer 245. The width of the spread is adjusted by the operator by manipulating potentiometer 272. Variable resistors 246, 273, 274, and 293, with potentiometer 242, provide means for adjusting the various ranges of the system.

The non-linear response of a spinner type spreader was discussed in connection with the description of FIG. 1. In the embodiment of FIG. 12, the situation is further complicated by the fact that the conveyor 235 is driven in tandem with the spreader 238 by the same prime mover. The delivery of the conveyor, being linear with speed, compensation must be introduced through the control of the hopper gate. This is the purpose of the variable voltage supply for resistor 255 and potentiometer 254 obtained from potentiometer 292. The manner of selecting values for the various resistance components will be described below. As with the embodiment of FIG. 1, provision is made in the system of FIG. 12 for altering the density of distribution a predetermined amount when, for example, the vehicle crosses an intersection requiring such greater density. This means takes the form of switch 256 which, when actuated to disengage contact 258 and engage contact 259, ignites the signal lamp 260 and lowers the voltage on slider 253. For example, if resistor 255 has the same value as the potentiometer 254, then inserting resistor 255 in series with potentiometer 254 will cause the hopper gate 236 to be opened twice as far and to double the output from the reservoir 237.

Typical values for the resistors and potentiometers are set forth below:

		ohms
Potentiometer	242	5,000
Potentiometer	245	5,000
Resistor	246	2,000 variable
Resistor	252	5,600
Potentiometer	254	2,000
Resistor	255	2,500 variable
Potentiometer	270	2,000

Potentiometer	272	2,000
Resistor	273	1,000 variable
Resistor	274	2,000 variable
Resistor	282	5,600
Resistor	286	2,700
Resistor	287	82
Resistor	289	5,600
Potentiometer	292	500
Resistor	293	20,000 variable
Transistor	278	(2N1303 or 2N555) choice depends on solenoid 276,
Transistor	284	2N1302
Transistor	248	2N1302

Assume, for purpose of discussion, that switch 256 is in the position shown in the drawing such that resistor 255 is bypassed. Assume also that the speed of engine 262 is a linear function of the position of slider 271 with the relationship between speed and width of spread being as set forth in the following tabulation:

R.P.M.	900	1500	2100	2700	3300
Width (Feet)	12	19	25	30	34

It should be understood that the slowest speed is obtained with slider 271 at the end of potentiometer 272 which is joined to resistor 273, and the fastest speed is obtained with the slider 271 at the opposite end of the potentiometer. Therefore, for a speed of 2,100 R.P.M., the slider 271 should be at the center of its associated resistance element. Also assume a ground speed signal from generator 243 and a setting of slider 244 on potentiometer 245 such that a voltage signal of 7.25 volts is required at slider 253 to satisfy the controller, the voltage from source 78 being 14.5 volts. Also assume that 7.25 volts on slider 253 represent 50 percent opening of hopper gate 236.

With potentiometer 272 adjusted for maximum engine speed of 3,300 R.P.M., width of spread will be 34 ft. and the gate will be open 50 percent. This follows from the fact that slider 291 will be at the upper end of potentiometer 292 applying full 14.5 volts to potentiometer 254. The density per unit area, with constant vehicle speed and fixed setting of potentiometer 245, will be a direct function of gate opening and conveyor speed and an inverse function of width of spread. For constant density per unit area the magnitude of the following expression must remain constant:

$$\frac{\text{gate opening} \times \text{conveyor speed}}{\text{width of spread}} \quad (2)$$

Substituting the values assumed above in expression (2) yields:

$$\frac{50\% \times 3300}{34} = 48.7$$

In order to obtain the same magnitude for expression (2) when the minimum width of spread is selected, i.e., 12 feet at 900 R.P.M., the gate opening must be 65 percent. This is found from solving the equation:

$$\frac{\text{gate opening percent} \times 900}{12} = 48.7$$

But if the gate is open 65 percent, the slider 253 is also at the 65 percent point on potentiometer 254. However, with all other conditions remaining constant, as assumed, the voltage on slider 253 must remain at 7.25 volts. It will be realized that this can be obtained by dropping the voltage across potentiometer 254 to 11.15 volts. Remembering that for minimum width of spread slider 291, being ganged to slider 271, is at the low voltage end of potentiometer 292, it can be shown that resistor 293 should be adjusted to a value of 9,920 ohms to provide 11.15 volts at slider 291.

For medium or intermediate width of spread, i.e., 25 feet at 2,100 R.P.M., the slider 291 would be centered on potentiometer 292. With resistor 293 set at a value of 9,920 ohms, it can be shown that the voltage on slider 291 is 12.63 volts.

Under this condition, the slider 253 and therefore the hopper gate opening must be at 57.5 percent to maintain a voltage of 7.25 volts on slider 253. Substituting these values in expression (2) yields:

$$\frac{57.5\% \times 2100}{25} = 48.3$$

which is close enough for practical purposes to the value of 48.7 at the extreme width conditions.

In the above example it was assumed that the speed of the spreader varied as a linear function of the manipulation of slider 271. This assumption was made for simplicity in explaining the underlying concept of the compensation for non-linearity in the operation of the spreading mechanism. In practice it is preferred to contour or profile the potentiometer 272 so that the change in width of spread is a linear function of the position of slider 271. Obviously, the potentiometer 272 could be replaced by a step function component, e.g., a multi-position switch with associated scaled resistors as in the embodiment of FIG. 1.

It will be seen that the system of FIG. 12 provides an arrangement wherein means for automatically changing the operating speed of the conveyor 235 comprises a drive train consisting of clutch 263 and gear box 264 for the conveyor which is powered by the spinner motor or engine 262, whereby change in speed of the spinner motor simultaneously alters the speed of both the spinner and the conveyor. Independently, the gate control operating in response to voltage from the generator 243 adjusts the opening controlled by gate 236 as a function of the ground speed of the vehicle, compensating for spreading non-linearity. The limit switches 39 are provided to restrict the maximum and minimum positions of the gate 236 as well as of the governor arm 267. A manual switch (not shown) may also be provided to override the circuit for controlling solenoid 276 so that the clutch 263 may be engaged when the vehicle is at a standstill.

In the embodiment shown in FIG. 12, the feedback from motor 265 to the Y input of the control circuit 268 is by way of a mechanical connection from the shaft of motor 265 to the slider 269 of potentiometer 270. This may be replaced by an electrical feedback arrangement as shown in FIG. 13. Here the connection from control motor 265 to slider 269 along with potentiometer 270 is eliminated. In its stead a further D.C. generator 294 is provided driven by engine 262. The electrical output of generator 294 is applied to a potentiometer 295 having its slider 296 connected to the Y input of circuit 268. Thus, a signal is fed to the Y input of circuit 268 which is proportional to the speed of the engine 262 and, therefore, of the spinner 238. This will be matched by the control circuit 268 against the signal obtained from potentiometer 272 representative of the desired speed. In all other respects, the system of FIG. 12 can remain the same.

In the circuit described with reference to FIG. 12, the ground speed is employed to control the position of the hopper gate while the spreader width adjustment is interconnected with the material feed mechanism. In the system of FIG. 1, the spreader width adjustment is also interconnected with the control of the feed mechanism; however, the ground speed is employed to regulate the speed of the material feed rather than the position of a gate. It is also possible to achieve a compensated system by employing the ground speed to control the operation of the material feed mechanism while the spreader width control is arranged to control the position of a hopper gate. Such a system is illustrated in FIG. 14 to which attention is now directed.

Since many of the components in the system of FIG. 14 may be substantially identical with components employed in the system of FIG. 1, they are designated by the same reference numerals. Thus, it will be seen that both the feed mechanism 20 and the spinner 21 are driven by rotary hydraulic motors under the control of flow control valves in a manner identical to that described with reference to FIG. 1. Furthermore, the arrangement for regulating the flow control valve 27 which

determines the spinner speed may be substantially identical to the FIG. 1 system.

In order to provide ground speed control, a D.C. generator 300 is interconnected with a ground wheel 301. The interconnection with the ground wheel is intended to be symbolic and may be effected by connection with the speedometer drive of a vehicle or the drive train thereof or the like. The negative terminal of the generator 300 is connected to ground while the positive terminal is connected through a RUN-STOP switch 302 to a voltage divider consisting of an adjustable resistor 303, a potentiometer 304, and another adjustable resistor 305. The resistor 305 has its free end connected to ground, as shown. The potentiometer 304 has a slider 306 electrically connected to the X input of the control circuit 38. The slider 306 is mechanically joined to a slider 307 of a potentiometer 308. The potentiometer 308 is connected in series with an adjustable resistor 309 between ground and the positive terminal of D.C. generator 64. An electrical connection is provided between the slider 307 and the Y input of control circuit 38. Another voltage divider in the form of a resistor 310 in series with a resistor 311 and a diode 312 is connected between ground and a source of positive potential designated by the letter W. The potential W may be obtained through a master switch (not shown) from the available battery voltage on the vehicle, preferably between 12 and 14½ volts. The junction between resistors 310 and 311 is connected through a diode 313 to the slider 307.

Associated with the feed mechanism 20 is a hopper gate 314 whose position is determined by a position actuator 315 mechanically coupled thereto by the symbolic connection 316. A limit switch 317, mechanically coupled to the connection 316, is inserted in series with the position actuator 315 across the output of the control circuit 318. The Y input for the control circuit 318 is provided by a connection to the slider 319 of a potentiometer 320 connected between ground and the potential source W. The slider 319 is mechanically joined to the hopper gate 314 such that its position is controlled by the position of the gate. The X input of the control circuit 318 is obtained by a connection to the slider 53 of potentiometer 47 which may be of the same construction as the like numbered potentiometer in FIG. 1. Voltage is applied to the potentiometer 47 over the series circuit consisting of fixed resistor 321, adjustable resistor 322, and another adjustable resistor 323. A switch 324 is connected in shunt with the adjustable resistor 322 and is mechanically ganged with the switch 119 such that both switches are opened and closed simultaneously.

The operation of the spinner control circuit in FIG. 14 is substantially the same as the operation of the similarly identified components in FIG. 1. The network consisting of resistors 310 and 311 and diodes 312 and 313 provides an inhibiting voltage to prevent operation of the feed mechanism 20 until the vehicle exceeds a minimum speed in a manner similar to the functioning of the voltage provided at slider 94 in FIG. 1. It can be appreciated that the switch 302 in FIG. 14 performs the function of STOP and RUN since when the switch is opened zero voltage is applied to the X input of control circuit 38 which is then caused by the voltage received through diode 313 to actuate motor 37 in a direction to close flow control valve 30 halting operation of motor 22 and feed mechanism 20. In this embodiment the operator selects the quantity of material by manipulating the control knob 325 which effects adjustment of the potentiometers 304 and 308. The arrangement is such that as slider 306 is positioned toward the grounded side of potentiometer 304 the slider 307 is positioned toward the high potential side of potentiometer 308, and vice versa. This represents a reciprocal interconnection similar to that disclosed in application Ser. No. 689,503, filed Dec. 11, 1967, now U.S. Pat. No. 3,511,411 granted May 12, 1970 and entitled "Apparatus for Controlling Planting and Material Spraying and Spreading Device." It will, therefore, be seen that for any given position of the control knob 325 the feed mechanism 20 will be operated in a certain speed rela-

tionship relative to ground speed for distributing a selected quantity of material.

It should also be apparent from the various preceding descriptions that as potentiometer 47 is adjusted the position actuator 315 will be energized to adjust the hopper gate 314 until the feedback voltage from the slider 319 of potentiometer 320 causes the voltages at the input of control circuit 318 to be in balance. It should also be observed that through the interconnection of potentiometer 47 with potentiometer 110, the hopper gate 314 is opened and closed in response to change in selected speed for the spinner 21. As the spinner speed is increased, the hopper gate will be opened and vice versa. As the hopper gate opens, increased material flow will result. The arrangement is such that this compensates for the increase in width due to increased spinner coverage. The density of distribution of the material is maintained constant.

As with the embodiment of FIG. 1, the embodiment of FIG. 14 has provision for switching from distribution of salt to distribution of sand and vice versa. This means take the form of switch 119. However, there is also another factor that may be taken into account and compensated for. This is the effectiveness of the particular material employed. That is, it is well known that salt is more effective for controlling ice than sand. Therefore, when salt is used the rate of distribution may be reduced over that required with sand because of such difference in effectiveness. Such reduction can be accomplished by means of the resistor 322 and switch 324.

With switches 119 and 324 closed, as shown in FIG. 14, the voltage on potentiometers 110 and 47 will be less than when such switches are open. Therefore, the speed range of spinner 21 will be less and the opening of hopper gate 314 will be less. Such are the conditions which are preferable for distributing salt. When sand is to be distributed the switches 119 and 324 are closed raising the voltages applied to potentiometers 47 and 110 and both increasing the range of spinner speed and the range of opening of the hopper gate 314. Adjustment of resistors 108 and 322 can adapt the system to various material.

From the foregoing description of several embodiments of the invention it should be apparent that various combinations of control can be employed for achieving similar results. It might be noted that the adjustment for effectiveness of the materials being dispensed can also be incorporated in the system of FIG. 1. This could take the form of a resistor inserted between the positive terminal of generator 43 and resistor 52 with a shorting switch thereacross. Such switch would be ganged with the switch 119 so that the switchover of the system for effectiveness is accomplished automatically at the same time that the system is switched over from one material to the other insofar as spreading characteristic is concerned.

For simplicity the circuits as described with reference to FIGS. 12, 13 and 14 have all represented the X and Y inputs to the various motor or actuator control circuits as being referenced directly to ground potential. However, depending upon the input stages of the particular control circuit it may be necessary, as will be readily understood, to provide a biased "ground" as represented by the junction 102 in FIG. 1.

While the invention has been described with reference to ice control vehicles, it should also be evident to those skilled in the art that it can be applied to material spreaders of sundry nature including those used for spreading particulate fertilizer or herbicides. Numerous other changes may be made in the invention as will occur to those skilled in the art without departing from the true spirit of the invention as defined in the appended claims.

What is claimed is:

1. Apparatus for controlling the operation of a vehicular material spreader having means for dispensing material from a reservoir at a controllable rate and means for spreading the dispensed material over a controllable area, said apparatus comprising in combination: first control means for regulating the operation of the dispensing means for causing material to

be dispensed at a rate which varies as a function of the ground speed of the vehicular spreader, adjustable second control means for regulating the operation of the spreading means to determine the area covered thereby, and means for automatically changing said dispensing rate when the adjustment of said second control means is altered to maintain constant the density of material spread per unit area independent of change in the area covered, said first control means comprising a control channel having an output for supplying a control signal to the dispensing means to determine the rate of operation thereof, feedback means for supply to a first input to said control channel a feedback signal indicative of the rate of operation of said dispensing means, and means for supplying to a second input to said control channel a reference signal proportional to the ground speed of the vehicular spreader, said control channel being arranged to provide said control signal as a function of the difference between said reference signal and said feedback signal; said second control means including adjustable means for altering the adjustment thereof; and said means for automatically changing the dispensing rate comprising means interrelating said adjustable means with said means for supplying a reference signal to vary the proportional relationship between said reference signal and said ground speed in a direction to maintain said constant spreading density.

2. Apparatus according to claim 1, wherein said control channel is responsive to electrical input signals; said feedback means including means for providing an electrical feedback signal whose voltage is proportional to the rate of feed of said dispensing means; said means for supplying a reference signal including an adjustable voltage divider having an output and an input, said output being coupled to said second input to the control channel for providing said reference signal thereto, and means for supplying a voltage to said input of the voltage divider which is proportional to said ground speed; and said interrelating means including means for adjusting said voltage divider to change the relationship between the voltage at its input and the reference signal at its output.

3. Apparatus according to claim 2, wherein said second control means is responsive to an electrical signal, and said adjustable means therefor includes a second adjustable voltage divider for adjusting a voltage signal applied to said second control means, and said means for adjusting said first voltage divider is coupled for conjoint operation to means for adjusting said second voltage divider.

4. Apparatus according to claim 3, wherein said second voltage divider has a non-linear characteristic for compensating for non-linearity in the operation of the spreading means.

5. Apparatus according to claim 1, wherein said first control means comprises a control channel responsive to electrical input signals and having an output for supplying a control signal to the dispensing means to determine the rate of operation thereof, and means for providing said electrical input signals in proportion to the ground speed of the vehicular spreader; and wherein said second control means includes adjustable means for altering the adjustment thereof; and wherein said means for automatically changing the dispensing rate comprises means interrelating said adjustable means with said means for providing said electrical input signals to vary the proportional relationship between said input signals and said ground speed in a direction to maintain said constant spreading density.

6. Apparatus according to claim 1, wherein means are coupled to said first control means for inhibiting operation of the dispensing means until the ground speed of said vehicular spreader exceeds a predetermined minimum value.

7. Apparatus according to claim 1, wherein first means are coupled to said first control means for supplying a regulating signal thereto, said first means being selectably adjustable to select a desired application density, and second means are coupled to said first control means selectably actuatable for altering said application density without changing the adjustment of said first means.

8. Apparatus according to claim 1, wherein a signal device is provided, and means interconnect said signal device with said first control means for providing an indication when the ground speed of said spreader exceeds the dispensing capability of said dispensing means.

9. Apparatus for controlling the operation of a vehicular material spreader having a driven material feeder and an adjustable gate for dispensing material from a reservoir at a controllable rate, and a motor driven spinner for spreading the dispensed material over a controllable area, said apparatus comprising in combination: first control means including an actuator means for regulating the position of the gate to maintain an opening from the reservoir which is controlled thereby in a desired functional relation relative to the ground speed of the vehicular spreader, second control means for controlling the operating speed of the spinner motor to spread the dispensed material over a desired area, means for adjusting said second control means to select the areas covered by the spinner, means for automatically changing the rate at which material is dispensed concomitantly with adjustment of said control means to alter said rate in a direction and magnitude to maintain constant the density of material spread per unit area independent of change in the area covered by the spinner, said means for automatically changing the rate at which material is dispensed comprising a drive train for the feeder which is powered by the spinner motor whereby change in speed of the spinner motor simultaneously alters the speed of both the spinner and the feeder, the said spinner motor being an auxiliary internal combustion engine, and means for automatically preventing operation of the feeder until the vehicular spreader exceeds a predetermined minimum ground speed.

10. Apparatus according to claim 9, wherein said additional means comprises a clutch mechanism between said spinner motor and said feeder, said clutch mechanism being normally disengaged, and means coupled to said clutch mechanism and responsive to the ground speed of said vehicular spreader for automatically engaging said clutch mechanism when said minimum ground speed is exceeded.

11. Apparatus according to claim 9, wherein said means for automatically changing the rate at which material is dispensed includes means for compensating for non-linearity in the operation of the spinner.

12. Apparatus according to claim 11, wherein said means for compensating for non-linearity comprises means interconnecting said first control means with said means for adjusting said second control means for additionally regulating the position of said gate as a function of selected spinner speed in a direction and magnitude related to said non-linearity to compensate therefor.

13. Apparatus for controlling the operation of a vehicular material spreader having means for feeding material from a reservoir at a controllable rate, said apparatus comprising in combination: a hydraulic motor for driving said feeding means, a flow control valve for controlling the flow of hydraulic fluid to said motor, an electrically operable position actuator for adjusting said valve, a control circuit for supplying operating current to said position actuator, a limit switch connected in series with an input of said actuator across an output of said control circuit, said switch being coupled mechanically to said actuator for opening the circuit thereto when said actuator reaches a predetermined limiting position, a signal lamp, means coupling said signal lamp to said output of the control circuit, and means for supplying signals to an input of said control circuit proportional to the error between the actual operating speed of said motor and a speed bearing a given functional relationship to the ground speed of the vehicular spreader, said signals being of a character tending to cause adjustment of said valve in a direction tending to reduce said error to zero, said means coupling said signal lamp to said output being responsive to opening of said limit switch only when said error is calling for an adjustment beyond the limiting position for changing the operating condition of said lamp.

14. Apparatus according to claim 13, wherein said control circuit has two output terminals and means for connecting both of said terminals to ground potential when no error signal is applied to the input of said control circuit, and alternatively connecting one output terminal or the other to a source of electrical energy of given polarity while the other terminal remains grounded when an error signal is present depending upon the direction of the error; and wherein said means coupling said signal lamp is connected to one of said output terminals for energizing said lamp so long as said one output terminal is connected to ground either directly within said control circuit or through a closed circuit including said position actuator.

15. Apparatus for controlling the operation of a vehicular material spreader having means for feeding material from a reservoir at a controllable rate and spinner means for spreading the material supplied by the feeding means over a controllable area, said apparatus comprising in combination: first and second rotary hydraulic motors for driving respectively said spinner means and said feeding means, first and second pressure compensated flow control valve arrangements each with an adjustable orifice control means for controlling the flow of hydraulic fluid respectively to said first and second motors, means for supplying hydraulic fluid under pressure to said two control valve arrangements, first and second electrically operable position actuators coupled respectively to the corresponding orifice control means of said first and second valve arrangements for independently adjusting the orifice therein, first and second control circuits coupled respectively to said first and second position actuators for supplying operating current thereto, first signal producing means responsive to operation of said second hydraulic motor for generating a first electric signal having a parameter proportional to the speed of

rotation of said second motor, second signal producing means for producing a second electric signal having a parameter proportional to the ground speed of said vehicular spreader, means coupling said first and second signals to said second control circuit for adjusting said second valve arrangement in a manner tending to maintain said parameters of said two signals in a predetermined ratio, adjustable signal producing means coupled to said first control circuit for applying a control signal thereto for adjusting said first valve arrangement to determine the operating speed of said spinner means, means interconnecting said adjustable signal producing means with one of said first and second signal producing means for simultaneously changing said predetermined ratio upon change in adjustment of said adjustable signal producing means, said simultaneous change being in a direction tending to maintain constant the density at which material is spread independent of change in speed of said spinner means, and compensating means for compensating for differences between the response characteristics of the overall apparatus for feeding material and the overall apparatus for spreading the material.

16. Apparatus according to claim 15, wherein said compensating means comprises an adjustable orifice control means for said first valve arrangement having a linear response characteristic, in combination with an adjustable orifice control means for said second valve arrangement having a non-linear response which varies at a low rate for low flow rates and at a higher rate for high flow rates.

17. Apparatus according to claim 15, wherein said compensating means comprises a non-linear potentiometer in said adjustable signal producing means having its slider positioned by said interconnecting means for compensating for non-linearity in the operation of said spinner means.

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