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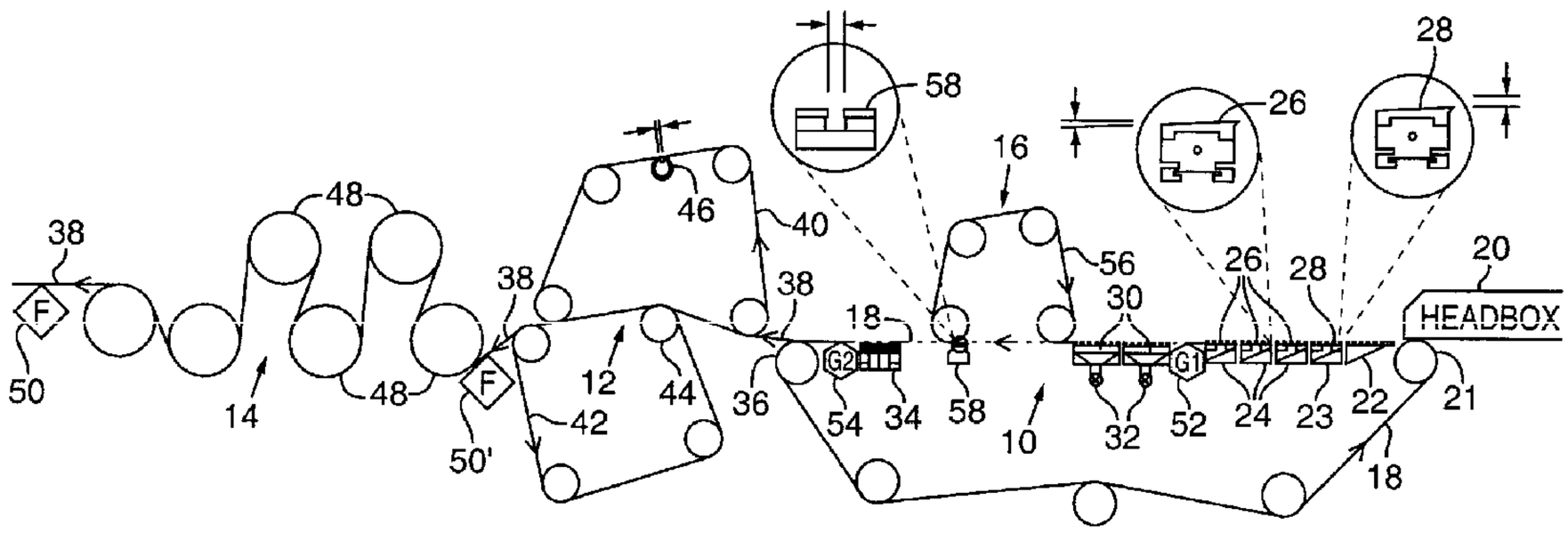
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(54) **APPAREIL DE FABRICATION DU PAPIER AVEC ELEMENTS DE DESHYDRATATION VARIABLES AJUSTES PAR COMMANDE INFORMATIQUE EN REPONSE AUX CAPTEURS DE CARACTERISTIQUES DES FEUILLES DE PAPIER**

(54) **PAPERMAKING MACHINE WITH VARIABLE DEWATERING ELEMENTS ADJUSTED BY COMPUTER CONTROL SYSTEM IN RESPONSE TO SENSORS OF PAPER SHEET CHARACTERISTICS**



(57) An automatic control system for a papermaking machine having a plurality of variable dewatering devices with moveable elements which engage the conveyor carrying the paper stock and are adjusted by electrical operating devices, such as servo motors or solenoid valves, to vary their water removal rate in response to control signals produced by a computer controller. A plurality of sensors are spaced along the path of the paper sheet downstream from the variable dewatering devices to sense the paper sheet characteristics including light transparency and mass, and to apply sensor output signals corresponding thereto to the computer controller. The servo motors have their shafts coupled to adjustment devices for cam mechanisms which adjust the moveable elements of the variable dewatering elements. The variable dewatering elements include a variable angle foil, a variable height blade, a variable width slot Uhle box, and a variable width pickup device, whose moveable elements are adjusted to change their water removal rates. Shaft position encoders on the servo motors or other operating devices produce feedback position signal which are applied to inputs of the computer controller to indicate when the moveable elements reach their desired adjustment positions.

PAPERMAKING MACHINE WITH VARIABLE DEWATERING ELEMENTS ADJUSTED BY COMPUTER CONTROL SYSTEM IN RESPONSE TO SENSORS OF PAPER SHEET CHARACTERISTICS

ABSTRACT OF THE DISCLOSURE

An automatic control system for a papermaking machine having a plurality of variable dewatering devices with moveable elements which engage the conveyor carrying the paper stock and are adjusted by electrical operating devices, such as servo motors or solenoid valves, to vary their water removal rate in response to control signals produced by a computer controller. A plurality of sensors are spaced along the path of the paper sheet downstream from the variable dewatering devices to sense the paper sheet characteristics including light transparency and mass, and to apply sensor output signals corresponding thereto to the computer controller. The servo motors have their shafts coupled to adjustment devices for cam mechanisms which adjust the moveable elements of the variable dewatering elements. The variable dewatering elements include a variable angle foil, a variable height blade, a variable width slot Uhle box, and a variable width pickup device, whose moveable elements are adjusted to change their water removal rates. Shaft position encoders on the servo motors or other operating devices produce feedback position signal which are applied to inputs of the computer controller to indicate when the moveable elements reach their desired adjustment positions.

PAPERMAKING MACHINE WITH VARIABLE DEWATERING ELEMENTS ADJUSTED BY COMPUTER CONTROL SYSTEM IN RESPONSE TO SENSORS OF PAPER SHEET CHARACTERISTICS

FIELD OF THE INVENTION

The present invention relates generally to papermaking machines having automatic control systems, and in particular to control systems and methods of operating papermaking machines with variable dewatering elements which are adjusted by the control system in response to output signals of sensors of paper sheet characteristics spaced along the path of the paper sheet downstream from the dewatering elements to make a paper sheet of improved characteristics.

BACKGROUND OF THE INVENTION

It has previously been proposed in U.S. Patent No. 3,936,665 of Donoghue, issued February 3, 1976, to provide an automatic computer operated control system for a papermaking machine including a plurality of sensors spaced laterally across the width of the paper sheet to provide a more uniform width characteristic in the paper sheet by adjusting the paper stock valve in the head box of such papermaking machine. U.S. Patent No. 5,300, 193 of Rule et al., issued April 5, 1994, discloses a method for controlling the paper machine stock pond consistency at the top forming roll by adjusting the vacuum pressure of a suction box in response to control signals produced by a sensor of the mass flow rate of the stock pond positioned between the forming roll and the suction box. However, unlike the present invention, this automatic control system does not employ a computer control system for adjusting a plurality of variable dewatering devices having moveable elements which engage the conveyor for the paper sheet to vary their water removal rate in response to sensors of the paper sheet characteristics spaced longitudinally along the path of the paper sheet at positions downstream from the dewatering elements.

U.S. Patent No. 4,443,298 of Thorp, issued April 17, 1984, shows a papermaking machine having hydrofoil blades and an automatic control for adjusting the width of the slot between adjacent hydrofoil blades to control the turbulence of the paper stock liquid adjacent the head box. Light sensors including light emitters which transmit light beams across the width of the paper stock to light detectors on the other side of the paper stock are used to sense the turbulence of the paper stock produced by the hydrofoil blades. The present computer control system adjusts dewatering elements to vary their water removal rate in response to the paper sheet sensor output signals in order to produce a paper sheet of improved characteristics. Unlike the present invention, this patent does not show an automatic control system for a papermaking machine including a plurality of paper sheet characteristic sensors which are spaced along the path of the paper sheet downstream from the dewatering elements. Instead, this patent is concerned with controlling the intensity or force of the turbulence of the paper stock or furnish prior to formation of the paper sheet by adjusting the position of the hydrofoil blades immediately adjacent the head box.

U.S. Patent No. 5,421,961 of Miller, issued June 6, 1995, shows a computer control system for adjusting the position of a forming board to a parallel position adjacent the output of the head box of a papermaking machine. The control system senses the position of the forming board with a transducer which detects the movement of a magnet attached to the forming board. Thus, unlike the control system of the present invention, this patent does not employ sensors spaced along the path of the paper sheet to sense the characteristics of the paper sheet and apply output signals to cause the control system to produce control signals which adjust dewatering elements in the papermaking machine for controlling the water removal rate and thereby changing the paper sheet characteristic being sensed.

U.S. Patent No. 4,278,497 of Mellen, issued July 14, 1981, U.S. Patent No. 4,280,869 of Eckert, issued July 28, 1981, and U.S. Patent No. 5,169,500 of Mejdell, issued December 8, 1992 all show paper sheet

dewatering elements which are adjusted to vary the width between adjacent blades which contact the underside of the conveyor carrying the paper sheet or to adjust the angle of a foil contacting the underside of the conveyor to control the water removal rate of the dewatering element. However, these dewatering elements are not automatically controlled by control systems including sensors which sense the paper sheet characteristics being measured, but instead are controlled by sensors which sense the vacuum produced in a suction box having the adjustable dewatering device mounted thereon or by manual adjustment of the foil angle.

SUMMARY OF THE INVENTION

It is therefore one object of the present invention to provide an improved automatic control system and method of operating a papermaking machine in which a plurality of dewatering elements are adjusted in response to the output signals of sensors spaced longitudinally along the path of the paper sheet downstream from the dewatering elements for sensing the paper sheet characteristics and thereby control the water removal rate of the dewatering elements in order to provide a paper sheet of improved characteristics.

Another object of the present invention is to provide such an control system and method in which the dewatering devices have moveable elements which engage the surface of the conveyor carrying the paper stock to control the water removal rate which are adjusted by electrical operating devices in response to control signals in a fast and accurate manner.

A further object of the invention is to provide such a control system and method in which the dewatering devices each have at least one moveable blade which is moved by its associated operating device in response to the control signal for automatic adjustment of the water removal rate of such dewatering device.

An additional object of the present invention is to provide such a control system in which the dewatering device includes a moveable blade which

is adjusted in height relative to the conveyor of the paper sheet or adjusted to change the width of the slot between adjacent blades by its operating device in response to a control signal produced by the control system.

Still another object of the invention is to provide such a control system in which the dewatering device includes a foil blade whose foil angle relative to the conveyor is adjusted by an electrical operating device in response to a control signal produced by the control system.

A still further object of the present invention is to provide such an improved control system in which the operating devices each produce a position signal which corresponds to the position of the moveable element it is adjusting for more accurate control.

Other objects and advantages of the present invention will be apparent from the following detailed description of a preferred embodiment thereof and from the attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic view of a papermaking machine showing the location of variable dewatering devices and paper sheet characteristic sensors which are operated by the control system of the present invention;

Fig. 2 is a block diagram of the control system of the present invention;

Figs. 3A and 3B show the flow chart of a computer program which can be employed to operate a computer control system of Fig. 2;

Fig. 4 is a side elevation view of an adjustable angle foil dewatering device which can be employed in the papermaking machine of Fig. 1 and its foil angle adjusted by the computer control system of Fig. 2; and

Fig. 5 is a vertical section view taken along the line 5-5 of Fig. 4.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

As shown in Fig. 1, a papermaking machine includes a forming section 10 where the paper sheet is formed from a liquid slurry of paper pulp and water known as paper stock, a press section 12 where additional water is removed from the paper sheet by pressing it against a felt sheet which acts as a blotter to absorb moisture, and a dryer section 14 where the paper sheet is dried and finished. In addition, the forming section 10 may be provided with a top surface finishing section 16 where a special finish is provided on the top surface of the paper sheet. The forming section 10 includes a porous conveyor belt 18 in the form of a woven screen or "wire" which may be made of stainless steel, bronze, or other suitable metal, or of a woven fabric of synthetic plastic such as polyester. A liquid slurry of paper pulp and water referred to as "paper stock" is supplied from the output of a head box 20 onto the upper surface of the conveyor wire 18 driven over a breast roll 21 which transports it across the surface of a forming board 22 and a dewatering table 23. The paper sheet is formed on such forming board and dewatering table in a conventional manner and such paper sheet is then conveyed across the surface of a plurality of gravity boxes 24 having variable angle foils 26 provided on their upper surface. In addition, the gravity boxes of dewatering table 23 may be provided with variable height turbo blades 28 which provide turbulence to the paper stock during formation of the paper sheet and are adjusted in height relative to the bottom surface of the conveyor wire. Both the variable angle foils 26 and the variable height blades 28 are dewatering devices which remove water from the paper sheet as it is formed and conveyed across these elements. The variable angle foils 26 each engage the bottom surface of the conveyor at a small foil angle on the range of about zero to four degrees, which produces a vacuum below the conveyor belt that sucks water from the paper sheet. Adjustment of this foil angle controls the water removal rate of the foil and such removed water then drains through the gravity boxes 24 and is disposed of. The variable height blade 28 is spaced from blades on either side which are at different heights relative to the conveyor 18 in order to provide

an undulation and turbulence of the paper stock to form the paper sheet and to assist in removing water therefrom.

Next the paper sheet passes from the variable angle foils 26 across the upper surface of suction boxes 30 which have fixed blades that engage the conveyor wire and are spaced apart by slots to allow water to drain from the paper sheet as it is conveyed across the suction boxes 30. The vacuum of the suction boxes 30 may be changed to vary their water removal rate by adjusting vacuum control valves 32 on such suction boxes. The conveyor transports the paper sheet over a final suction box 34 and around a suction couch roll 36 at the output of conveyor 18 from which the paper sheet 38 is transferred into the press section 12.

A conveyor felt 40 of an endless sheet of water absorbing blotter type woven felt material engages the upper surface of the paper sheet 38. The paper sheet is pressed between conveyor felt 40 and a press conveyor wire 42 of the same type material as conveyor wire 18, when the paper passes over a press roll 44. The water absorbed in the felt sheet 40 is removed by a Uhle tube vacuum box 46 which includes a pair of spaced blade elements that engage the felt and are separated by a variable slot which is adjusted by movement of one of the blades for controlling the water removal rate of such Uhle box. The paper sheet 38 is transferred from the press section 12 into the dryer section 14 where it is conveyed about dryer rolls 48 which are heated internally with steam to dry the paper sheet by evaporation due to thermal contact with such rolls. As a result, the dried paper sheet 38 is transmitted from the output of the dryer section across a transparency sensor 50 which includes a laser light source and photo detector on opposite sides of the sheet for testing the light transparency characteristic of the paper sheet. It should be noted that the transparency sensor 50 may be located alternatively at the output of the press section 12 at position 50′ instead of at the output of the dryer section.

In addition, a plurality of mass sensors 52 and 54 may be provided beneath the conveyor 18 in the forming section 10 in order to determine the mass

or density of the paper sheet as it is conveyed along such conveyor. The first mass sensor 52 may be positioned between the foil gravity boxes 24 and the suction boxes 30 while the second mass sensor 54 is positioned between the final suction box 34 and the couch roll 36 at the output of the forming section. These mass sensors may be gamma gauges which employ radioactive sources and detectors to measure the mass or density of the paper sheet as it passes over such sensors. The mass sensors 52 and 54 thereby determine the amount of water remaining in the sheet at the position where the sensors are located which is spaced along the conveyor downstream from the dewatering elements 26, 28, and 30 that are adjusted to control the water removal rate.

When a top surface finishing section 16 is employed on the forming section 10, a special finish conveyor 56 is provided which is urged into contact with the upper surface of the paper sheet 38 to press it against the sheet conveyor 18 in order to provide such upper surface with a desired finish. A variable slot pickup device 58 may be provided on the conveyor 18 adjacent the output of the finishing section 16 in order to force the paper sheet 38 to remain on the conveyor 18 and not be picked up by the finish conveyor 56. The variable slot pickup device 58 has a pair of blade members separated by a slot whose width may be varied by moving one of the blade members in response to control signals produced by the computer control system of Fig. 2 in a manner hereafter described.

The dewatering devices including the adjustable angle foils 26, the variable height turbo blades 28, the suction boxes 30, the variable slot Uhle box 46, and the variable slot pickup device 58 each have a moveable element which is adjusted by electrical operating devices such as electric motors in response to control signals produced by the computer control system of Fig. 2 to vary their water removal rates. In addition, the vacuum valves 32 of the suction boxes 30 may also be adjusted by an electrical operating device such as a solenoid valve actuator which is controlled by the control signals of the computer to vary the vacuum within such suction boxes.

As shown in Fig. 2, the automatic control system of the present invention includes a computer controller 60 having at least three inputs connected to the outputs of sensors 50, 52, and 54 for sensing different characteristics of the paper sheet at positions spaced along the path of such sheet downstream from the dewatering devices. Thus, transparency sensor 50 senses the paper sheet's light transparency and produces a corresponding sensor output signal which is applied to an input of the computer controller. Also, mass sensors 52 and 54 sense the paper sheet mass which indicates the amount of water relative to the amount of paper fiber remaining in the sheet at the point where the sensor is located and apply corresponding sensor output signals to the controller. The computer controller sends control signals from its outputs to a plurality of electrical operating devices for adjusting a moveable element in each of the dewatering devices. The operating devices include a drive motor 62 for adjusting the angle of the variable angle foil 26 in a manner hereafter described with respect to Figs. 4 and 5. Thus, the computer controller 60 applies a first control signal at output 63 through a servo amplifier 64 to the drive motor 62 which may be a servo motor having a shaft position encoder which produces a position output signal corresponding to the rotational position of the shaft at output 66 which is transmitted as a feedback signal back to the computer controller. As a result, the computer determines when the foil angle reaches the proper angle by detecting the rotational position of the motor shaft and stops further movement of the motor shaft such as by terminating the control signal 63 applied to motor 62. The adjustment of the foil angle by the servo motor 62 is accomplished by the cam actuator mechanism shown in Figs. 4 and 5 as hereafter discussed.

In a similar manner, the adjustable height turbo blade 28 is controlled by a second servo drive motor 68 in response to a control signal 72 supplied by the computer controller 60 through a servo amplifier 70 to such motor. The servo motor 68 is also provided with a shaft position encoder that produces a feedback position signal 74 which is transmitted to the computer

controller to indicate the rotational position of the motor shaft which corresponds to the height of the blade 28. The servo motor 68 adjusts the height of the blade 28 by means of any suitable cam mechanism in a similar manner to the cam adjustment of the foil angle of the foil 26 as shown in Figs. 4 and 5.

A third servo drive motor 76 is used for varying the width of the slot of the Uhle box 46 by adjustment of a moveable Uhle blade in response to a control signal 78 transmitted from the computer controller 60 through a servo amplifier 80 to the drive motor. The servo drive motor 76 also has a shaft position encoder which produces a feedback position signal 82 that is fed back to the computer controller to indicate the width of the variable slot of the Uhle box. Thus, the Uhle box includes at least one moveable Uhle blade separated by a slot from another blade both of which engage the felt conveyor 40. The moveable blade is adjusted by a suitable cam actuator to vary the slot width by the operation of the drive motor 76 in a similar manner to the cam actuated variable angle foil 26.

The variable slot pickup device 58 is also provided with a moveable blade separated by a slot from a second blade which both engage the underside of the conveyor 18. The moveable blade member is adjusted to vary the slot width by a fourth servo drive motor 84 in response to a control signal 86 produced by computer controller 60 and transmitted through servo amplifier 88 to such drive motor. In addition, the drive motor 84 employs a shaft position encoder which produces a feedback position signal 90 which is transmitted back to the computer controller to indicate when the desired width of the slot of the pickup device is reached. The drive motor 84 moves the adjustable blade of the variable slot pickup device by means of a suitable cam mechanism similar to that used by the Uhle box 46 and the variable angle foil 26 as described above.

An electrically operated servo drive device 92, which may be a solenoid or drive motor, is employed to adjust each of the vacuum control valves 32 of the suction boxes 30 in order to change the vacuum in such boxes and thereby control their dewatering rates. The electrical operating device 92 is

actuated by a control signal 94 supplied by the computer controller 60 through a servo amplifier 96 to the operating device 92. The operating device 92 transmits a feedback position signal 98 to the computer controller 60 which corresponds to the position of the valve.

As shown in Figs. 4 and 5, the variable angle foils 26 each include a plurality of rigid foil segments 100 of a suitable hard wear-resistant ceramic material such as aluminum oxide, which are fixedly mounted on the top of a support base member 102 of fiberglass reinforced plastic material which extends across the conveyor 18. The support base 102 is provided with a dovetail projection 104 on the top surface thereof which extends into a dovetail slot 106 in the bottom of each of the ceramic segments 100 and is bonded thereto by a thermo-setting bonding material 108, such as epoxy resin. The foil support base 102 is attached to a separate mounting member 110 of fiberglass reinforced plastic having a plurality of downward sloping cam slots 112 and 114 formed in the opposite sides of a top portion thereof. The cam slots 112 and 114 are engaged by cam follower members 116 and 118, respectively, which are attached to the support base 102 by mounting bolts 120 and 122 extending through the front side and the rear side of the support base as shown in Fig. 5. The mounting member 110 is provided with a T-shaped slot 124 in its bottom portion for mounting on a T-bar of stainless steel or fiberglass reinforced plastic fixed to the frame of the papermaking machine and extending across the width of the paper sheet conveyor 18. Two resilient seals 125 of rubber may be provided between the base member 102 and the mounting member 110 to protect the cam mechanism from corrosive liquid. This construction is described in U.S. Patent No. 5,169,500 of Mejdell issued December 8, 1992.

As shown in Fig. 4, an actuating screw 126 is attached at its inner end to an end cap member 127 which is fixed by bolts 129 to the support base 102 in order to move such support base longitudinally along the mounting member 110 by rotation of such screw. This causes the cam followers 112 and 114 to slide along the cam slots 116 and 118, respectively, to adjust the foil

angle formed between the top surface 136 of the foil 26 and the bottom of the conveyor 18. Thus, the actuating screw 126 extends through threaded stop collars 128 and 130 on opposite sides of a fixed support bracket 132 which is fixedly attached to the side of the bottom portion of mounting member 110 so that the support base 102 is moved by the screw relative to the mounting member. The outer end 134 of the adjusting screw is mechanically coupled to the drive shaft of the drive motor 62 for rotation by such motor.

It should be noted that the cam slot 112 on the front side of the mounting member 110 is of a different slope than the cam slot 114 on the back side of such mounting member as is clearly shown in Fig. 4. As a result of this, the foil member 20 pivots about the mounting member 110 to change the foil angle between the upper surface 136 of the foil and the paper sheet conveyor in contact therewith, without changing the height of the front edge 138 of the foil relative to the conveyor. A foil angle indicator scale 130 is provided on the support for the bracket 132 and an angle pointer 142 is provided by the end of the foil base member 102. As shown by scale 130 the foil angle may be adjusted in the range of zero degrees to four degrees and in Fig. 4 is set at two degrees.

The height of the adjustable turbo blade 28 on the forming table 23 may be changed relative to the conveyor 18 while maintaining the upper surface of such blade parallel to such conveyor by using a similar cam arrangement to that of Figs. 4 and 5 except that the cam slots 112 and 114 would then have the same slopes. As a result, the height of the adjustable blade is changed uniformly along such blade relative to the other blades on opposite sides thereof. This adjusts the turbulence of the paper stock flowing over the forming table and varies the water removed from the paper sheet formed on the forming table 23.

It should be noted that for adjusting the width of the slot between blades of the pickup device 58 and the slot between the blades of the Uhle box 46, the cam actuating means would be provided on a horizontal surface rather than a vertical surface of the support for such blade. One suitable cam mechanism is shown in

U.S. Patent No. 4,278,497 of Mellen issued July 14, 1998 or in U.S. Patent No. 4,280,869 of Eckerdt issued July 26, 1981.

A computer program flow chart for the computer controller 60 of Fig. 2 is shown in Figs. 3A and 3B. As shown in Fig. 3A, the flow chart of a computer program for the computer controller 60 of Fig. 2 includes a program start step 144 and a program initialization step 146 which causes a data gathering step 148 to be initiated for gathering input data from a plurality of input signal sources including paper sheet characteristics sensor inputs 150, dewatering devices settings input 152, a historical dewatering devices data source 154, and a data input 156 from other devices and control systems such as the chemical content of the paper stock employed in the head box of the papermaking machine as well as filler and fiber content of the stock. The input data from sources 150, 152, 154, and 156 are all applied to the data gathering input step 148 and are also applied to a closed loop algorithm step 158 containing a suitable algorithm for optimizing paper sheet quality. The data gathering input step 148 has one of its outputs connected to a statistical display 160 for the operator and a papermaking machine history and run-time reporting step 162 as well as a historic dewatering device and sensor data storage step 164.

The other output of the closed loop algorithm step 158 is transmitted to an optimum settings of dewatering devices step 166 which stores the optimum settings of the dewatering devices including the foil angles, blade heights, slot widths, and suction box vacuum pressure inputs supplied by step 152 when the optimum paper sheet quality has been achieved as determined by the step 158. In addition, a second output of the step 158 is supplied to an automatic or semi-automatic mode decision step 168 which determines whether the papermaking machine is operated in a fully automatic mode or a semi-automatic mode. In the semi-automatic mode the output of step 168 goes to a semi-automatic/calibration routine 170 in which the target settings of the dewatering devices are entered by the operator rather than by the computer.

This semi-automatic/calibration routine 170 is shown in greater detail in the sub-routine flow chart of Fig. 3B as hereafter described.

When the automatic mode is selected, the output of the mode selection step 168 is supplied to a step 172 for moving the optimum settings of the dewatering devices stored in step 166 to the target settings step 174 which stores the target settings of such dewatering devices. In addition, step 172 produces an output which initiates a closed loop setting algorithm step 176 which applies the target settings of the dewatering devices obtained in step 174, to the actual devices in step 180 through control signal outputs 178 to adjust the dewatering devices in step 180 to the target settings of dewatering devices by moving a moveable element of each of such devices to adjust the foil angle, blade height, slot width, and suction box vacuum of such devices. The position of the moveable element of each of the dewatering devices is transmitted as device position signals 182 from the dewatering device adjustment step 180 to the close loop setting algorithm step 176 to indicate the position that the moveable element of the dewatering device has been adjusted to. When this target setting adjustment is complete, the close loop step 176 applies an output to a program exit decision step 184 which decides whether to exit the program by sending a "yes" command to the program end step 186 or sending a "no" signal back to the input data gathering step 148 which causes the program to continue.

As shown in Fig. 3B, the semi-automatic/calibration routine 170 includes a semi-automatic/calibration routine start step 188 which is actuated by the output of the mode decision step 168 of Fig. 3A. The calibration routine start step 188 applies an output to a decision step 190 for deciding whether or not to make individual adjustment of one or more dewatering devices. Thus, step 190 produces a "yes" output when an adjustment is to be made which is supplied to step 192 causing the operator to make the adjustment to the command position for one or more dewatering devices. The output of step 192 transmits the adjusted setting of the dewatering device to a target setting of dewatering device storage step 194 which stores the target settings selected by the operator.

When the output of the dewatering device adjustment step 190 is "no" it applies an input to a save current setting as recipe decision step 196 which causes the current or present setting of the dewatering devices to be saved as a recipe by applying a "yes" output in a save setting step 198 which produces a setting output which is applied to a recipe for dewatering settings step 200 for saving as an operator-defined recipe the current settings of the dewatering devices. When the output of the save step 196 is "no" is actuates a load existing setting recipe step 202.

The load existing setting recipe decision step 202 has a "yes" output which actuates an operator selects step 204 in which the operator selects a pre-defined setting recipe for each of the dewatering devices and stores it as a target setting of the dewatering device in step 206. The target settings of step 206 are obtained from the recipes for dewatering device settings stored in 200. At the "no" output of the load existing setting recipe decision step 202, a move optimum target setting decision step 208 is actuated which provides a "yes" output to the optimum settings move step 210 in which the optimum settings of the dewatering devices of step 166 on the flow chart of Fig. 3A are moved to the target settings step 174 determined by the automatic mode flow chart of Fig. 3A. After this, the move optimum settings step 210 produces an output which actuates a semi-automatic/calibration routine stop step 212. Similarly, the "no" output of the move optimum settings to target settings decision step 208 actuates the calibration routine stop step 212. This completes the computer program flow chart of Fig. 3B.

It will be obvious to those having ordinary skill in the art that many changes may be made in the above described detailed description of a preferred embodiment thereof. Therefore, the scope of the present invention should only be determined by the following claims.

We claim:

1. A control system for a papermaking machine to make paper sheet of improved characteristics, comprising:
a plurality of dewatering devices for removing water from paper stock material conveyed on a conveyor across at least some of said dewatering devices, said dewatering devices being spaced along the path of the conveyor and having movable elements which engage the surface of the conveyor on the opposite side from the paper stock and may be moved to adjust the water removal rate;
a plurality of electrical operating devices for adjusting said movable elements;
a plurality of sensors positioned downstream from their dewatering devices for sensing different characteristics of the paper sheet as it is conveyed past said sensors and for producing corresponding sensor output signals; and
a controller to control the electrical operating devices for adjusting the movable elements in said dewatering devices in accordance with said sensor output signals to change the sensed characteristics of said paper sheet to desired characteristics.

2. A control system in accordance with claim 1 in which the dewatering devices each include blades which engage the conveyor and have at least one movable blade which is moved by its operating device in response to said controller.

3. A control system in accordance with claim 2 in which the movable blade is a foil blade whose foil angle to the conveyor is adjusted by the controller.

4. A control system in accordance with claim 2 in which the movable blade is separated by a slot from another blade and the width of the slot is adjusted by the controller.

5. A control system in accordance with claim 2 in which the movable blade is adjusted in height relative to the conveyor by the controller.

6. A control system in accordance with claim 1 in which the operating devices each produce a position signal corresponding to the position of the moveable element it is adjusting and apply said position signal to said controller.

7. A control system in accordance with claim 4 in which the movable blade is on a variable slot pickup box for maintaining the paper sheet on the conveyor as it travels past a top surface forming wire and the movable blade is adjusted to vary the width of the slot of said pickup box.

8. A control system in accordance with claim 4 in which the movable blade is on a variable slot Uhle box for removing water from a conveyor felt in the press section of the papermaking machine and the movable blade is adjusted to vary the width of the slot.

9. A control system in accordance with claim 1 in which the controller is an automatic controller that includes a computer which produces control signals in response to the sensor output signals and applies said control signals to said operating devices.

10. A control system for a papermaking machine to make paper sheet of improved characteristics, comprising:
a plurality of dewatering devices for removing water from paper stock material conveyed on a conveyor across at least some of said dewatering devices, said dewatering devices being spaced along the path of the conveyor and having movable elements which engage the surface of the conveyor on the opposite side from the paper stock and may be moved to adjust their water removable rate;

a plurality of electrical operating devices for adjusting said movable elements;
a plurality of sensors positioned along the path of the paper sheet and downstream from their dewatering elements for sensing different characteristics

of the paper sheet as it is conveyed past said sensors and for producing corresponding sensor output signals; and

an electrical controller connected between the outputs of said sensors and the inputs of said operating devices for producing control signals which are applied to the said operating devices to adjust said movable elements to change the sensed characteristics of said paper sheet to desired characteristics.

11. A control system in accordance with claim 10 in which the dewatering devices each includes wear resistant bearing elements which engage the conveyor and have at least one movable bearing element which is moved by its operating device in response to the control signal of said controller, and the operating device produces a position signal corresponding to the adjusted position of said moveable bearing element which is transmitted to the controller.

12. A control system in accordance with claim 11 in which the movable bearing element is a foil blade whose foil angle to the conveyor is adjusted by the controller transmitting the control signal to an electrical motor which acts as the operating device.

13. A control system in accordance with claim 11 in which the movable bearing element is separated by a slot from another bearing element and the width of the slot is adjusted by the controller.

14. A control system in accordance with claim 11 in which the movable bearing element is adjusted in height relative to the conveyor by the controller.

15. A control system in accordance with claim 10 in which the operating devices each produce a position signal corresponding to the position of the moveable element it is adjusting and apply said position signal to said controller.

16. A control system in accordance with claim 10 in which the electrical controller includes a computer which automatically controls the operation of the papermaking machine.

17. A method of operating a papermaking machine to make paper sheet of improved characteristics, comprising the steps of:
conveying paper stock material on a conveyor across a plurality of dewatering devices spaced along the path of the conveyor to remove water from the stock material to form a paper sheet, said dewatering devices having moveable elements which engage the surface of the conveyor on the opposite side from paper stock;
sensing different characteristics of the paper sheet by a plurality of sensors positioned along the path of the sheet and downstream from their dewatering devices to produce sensor output signals;
transmitting said sensor signals to an electrical controller to produce corresponding control signals; and
transmitting said control signals to electrical operating devices which adjust moveable elements in said dewatering devices to change their water removal rate in response to said control signal to change the sensed characteristics of said paper sheet.

18. A method in accordance with claim 17 in which the controller is a computer.

19. A method in accordance with claim 17 in which the sensors include a sensor which senses the light transparency of the paper sheet and at least one sensor which senses the mass of the paper sheet.

20. A method in accordance with claim 17 in which the movable elements of the dewatering devices are adjusted by electrical motors in response to said control

signals, said motors having shaft position encoders which produce position signals corresponding to rotational position of the motor shaft and the position of the moveable element, and said position signals being fed back to the electrical controller.

Smart & Biggar
Ottawa, Canada
Patent Agents

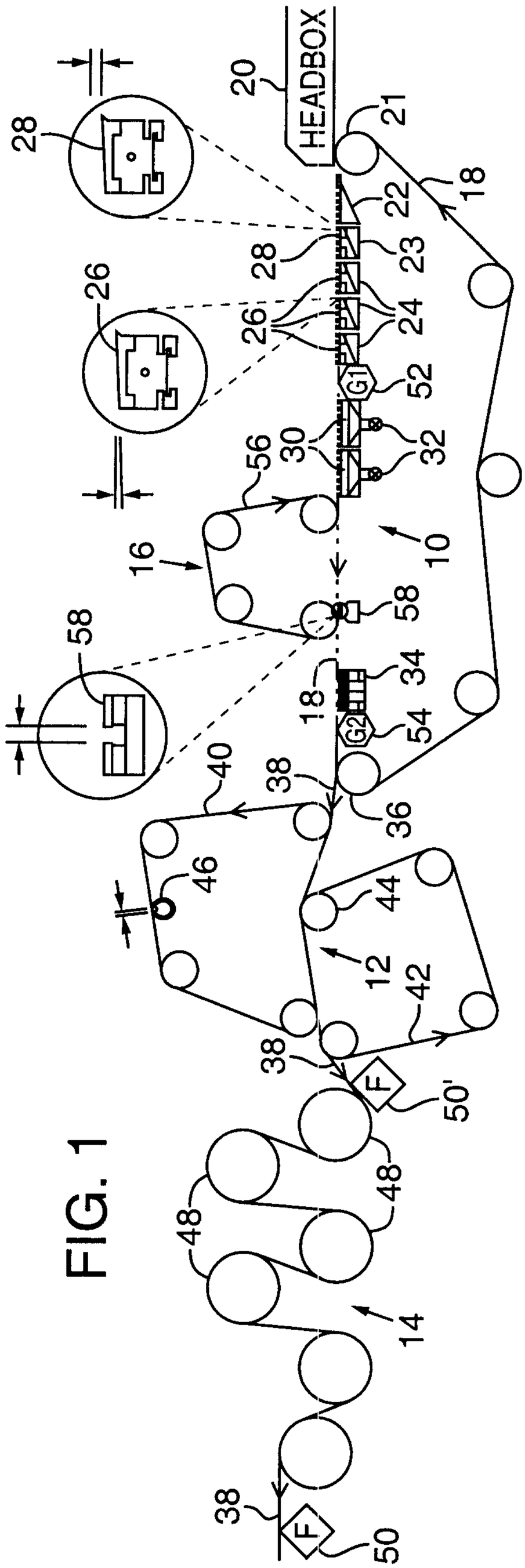

HEADBOX
20
21
22
18
28
23
26
24
G1
52
56
30
32
16
10
58
58
34
18
G2
54
40
38
36
46
44
12
42
38
F
50'
8
48
48
14
38
F
50

FIG. 1

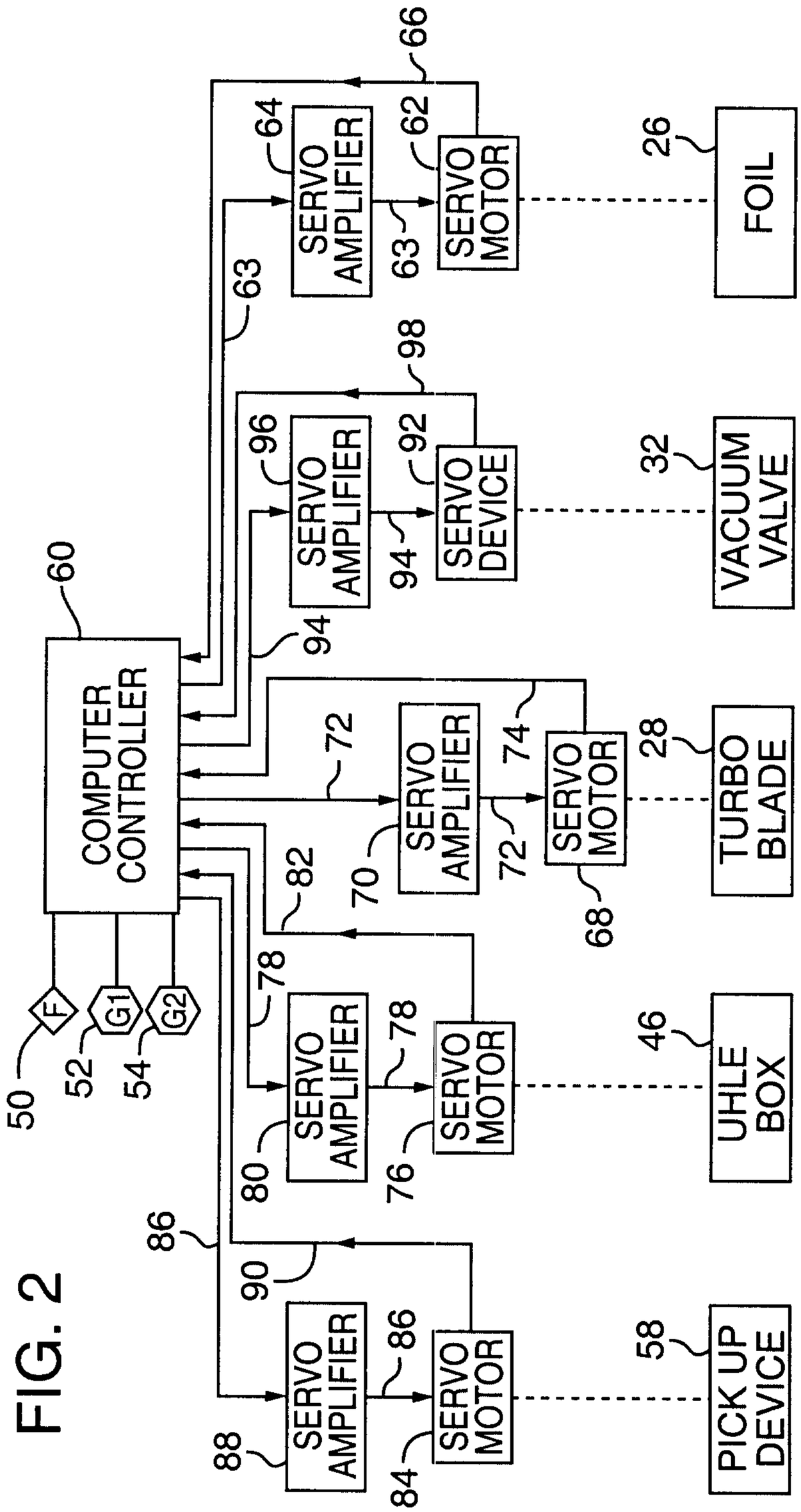
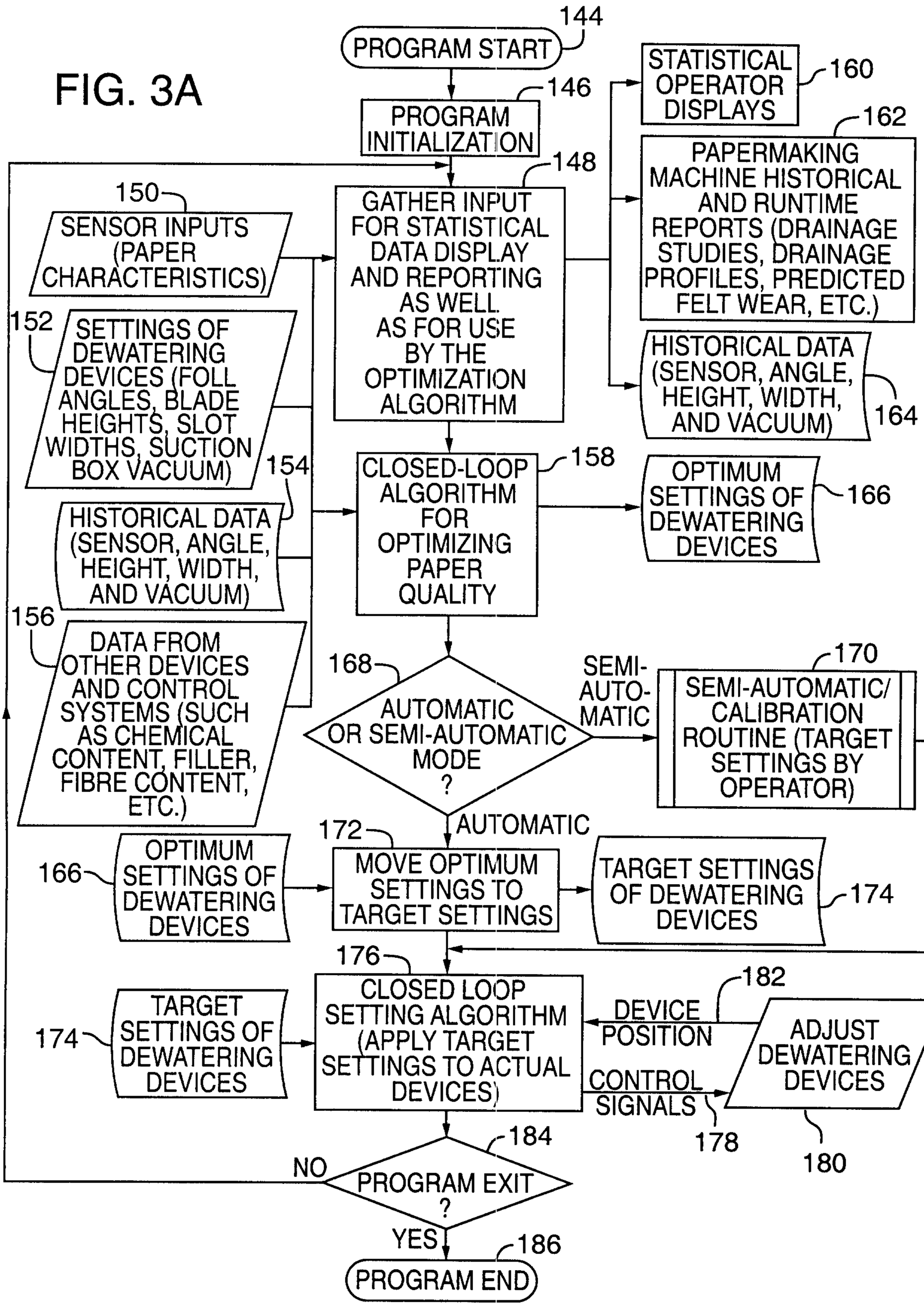

COMPUTER CONTROLLER
F
G1
G2
50
52
54
60
66
64
SERVO AMPLIFIER
62
SERVO MOTOR
63
26
FOIL
98
96
SERVO AMPLIFIER
92
SERVO DEVICE
94
32
VACUUM VALVE
72
SERVO AMPLIFIER
74
SERVO MOTOR
70
72
68
28
TURBO BLADE
82
78
SERVO AMPLIFIER
78
SERVO MOTOR
80
76
46
UHLE BOX
86
90
SERVO AMPLIFIER
86
SERVO MOTOR
88
84
58
PICK UP DEVICE

FIG. 2

FIG. 3A


144
PROGRAM START
146
PROGRAM INITIALIZATION
148
GATHER INPUT FOR STATISTICAL DATA DISPLAY AND REPORTING AS WELL AS FOR USE BY THE OPTIMIZATION ALGORITHM
150
SENSOR INPUTS (PAPER CHARACTERISTICS)
152
SETTINGS OF DEWATERING DEVICES (FOLL ANGLES, BLADE HEIGHTS, SLOT WIDTHS, SUCTION BOX VACUUM)
154
HISTORICAL DATA (SENSOR, ANGLE, HEIGHT, WIDTH, AND VACUUM)
156
DATA FROM OTHER DEVICES AND CONTROL SYSTEMS (SUCH AS CHEMICAL CONTENT, FILLER, FIBRE CONTENT, ETC.)
158
CLOSED-LOOP ALGORITHM FOR OPTIMIZING PAPER QUALITY
160
STATISTICAL OPERATOR DISPLAYS
162
PAPERMAKING MACHINE HISTORICAL AND RUNTIME REPORTS (DRAINAGE STUDIES, DRAINAGE PROFILES, PREDICTED FELT WEAR, ETC.)
164
HISTORICAL DATA (SENSOR, ANGLE, HEIGHT, WIDTH, AND VACUUM)
166
OPTIMUM SETTINGS OF DEWATERING DEVICES
168
AUTOMATIC OR SEMI-AUTOMATIC MODE ?
SEMI-AUTO-MATIC
170
SEMI-AUTOMATIC/ CALIBRATION ROUTINE (TARGET SETTINGS BY OPERATOR)
AUTOMATIC
172
MOVE OPTIMUM SETTINGS TO TARGET SETTINGS
174
TARGET SETTINGS OF DEWATERING DEVICES
176
CLOSED LOOP SETTING ALGORITHM (APPLY TARGET SETTINGS TO ACTUAL DEVICES)
174
TARGET SETTINGS OF DEWATERING DEVICES
182
DEVICE POSITION
CONTROL SIGNALS
178
ADJUST DEWATERING DEVICES
180
184
PROGRAM EXIT ?
NO
YES
186
PROGRAM END

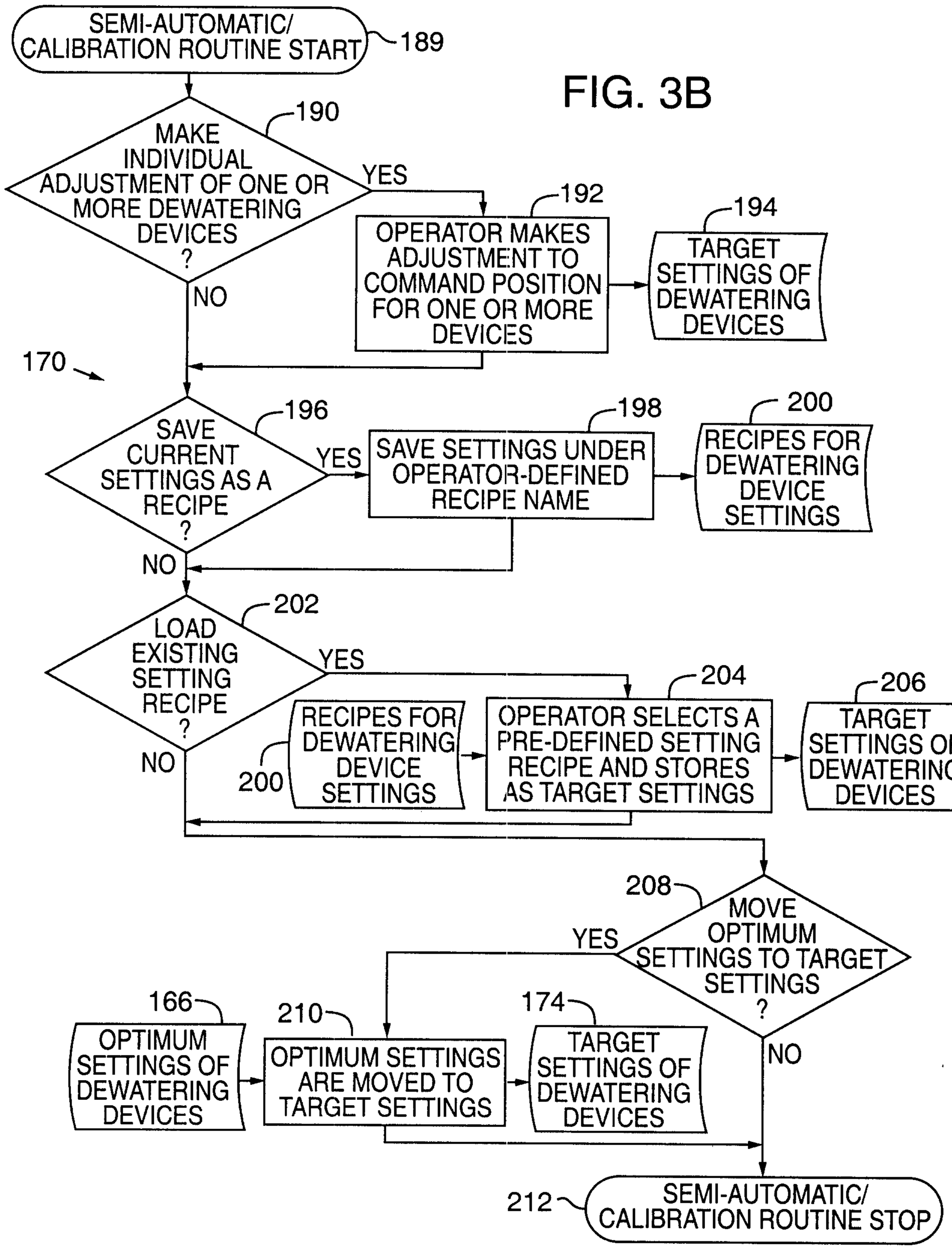

SEMI-AUTOMATIC/ CALIBRATION ROUTINE START
189
MAKE INDIVIDUAL ADJUSTMENT OF ONE OR MORE DEWATERING DEVICES ?
190
YES
NO
OPERATOR MAKES ADJUSTMENT TO COMMAND POSITION FOR ONE OR MORE DEVICES
192
TARGET SETTINGS OF DEWATERING DEVICES
194
170
SAVE CURRENT SETTINGS AS A RECIPE ?
196
YES
NO
SAVE SETTINGS UNDER OPERATOR-DEFINED RECIPE NAME
198
RECIPES FOR DEWATERING DEVICE SETTINGS
200
LOAD EXISTING SETTING RECIPE ?
202
YES
NO
RECIPES FOR DEWATERING DEVICE SETTINGS
200
OPERATOR SELECTS A PRE-DEFINED SETTING RECIPE AND STORES AS TARGET SETTINGS
204
TARGET SETTINGS OF DEWATERING DEVICES
206
MOVE OPTIMUM SETTINGS TO TARGET SETTINGS ?
208
YES
NO
OPTIMUM SETTINGS OF DEWATERING DEVICES
166
OPTIMUM SETTINGS ARE MOVED TO TARGET SETTINGS
210
TARGET SETTINGS OF DEWATERING DEVICES
174
SEMI-AUTOMATIC/ CALIBRATION ROUTINE STOP
212

FIG. 3B

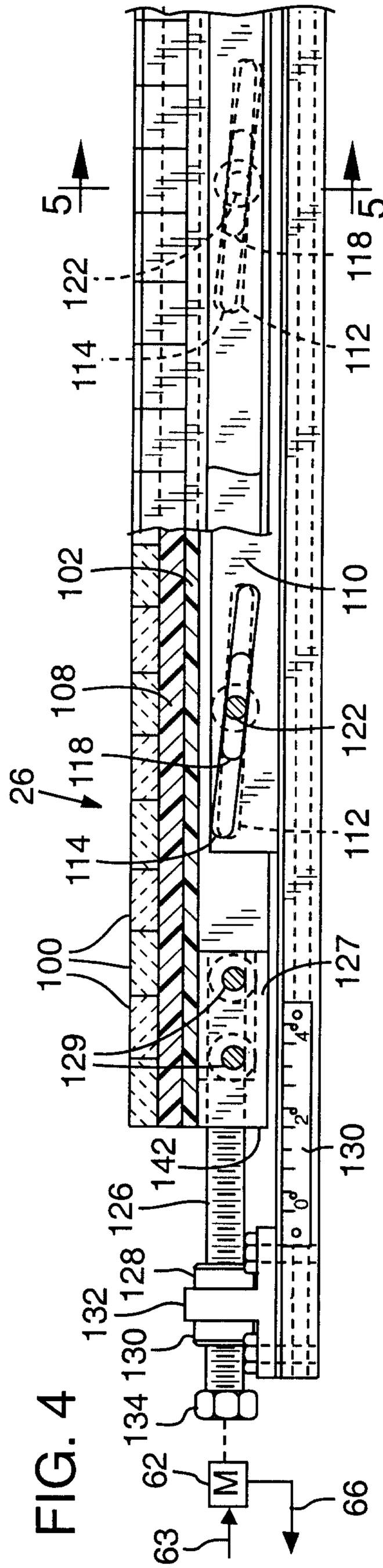

5
122
114
102
108
26
118
114
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142
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118
112

FIG. 4

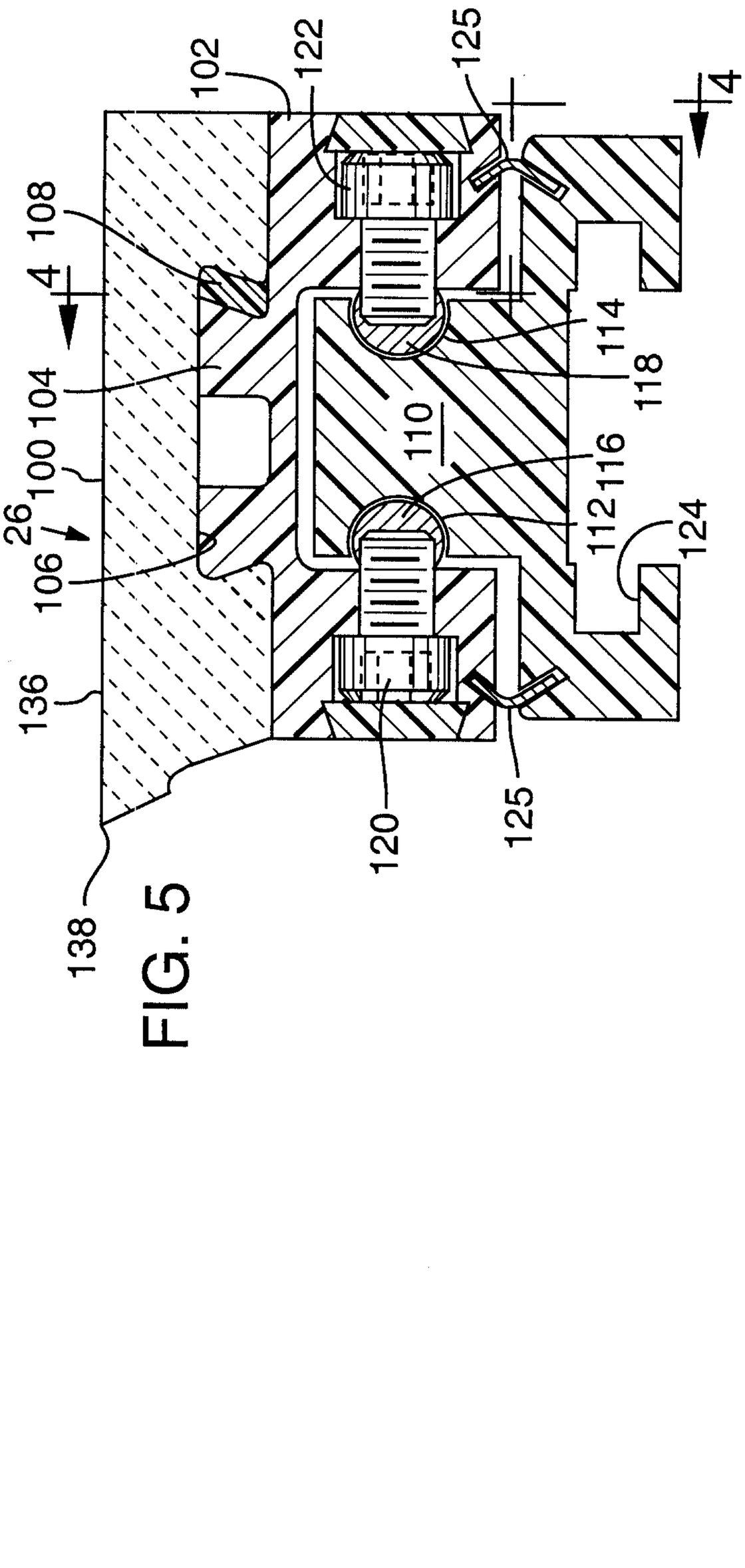

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125
4
108
4
104
100
106
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136
138
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114
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112
116
124
120
125

FIG. 5