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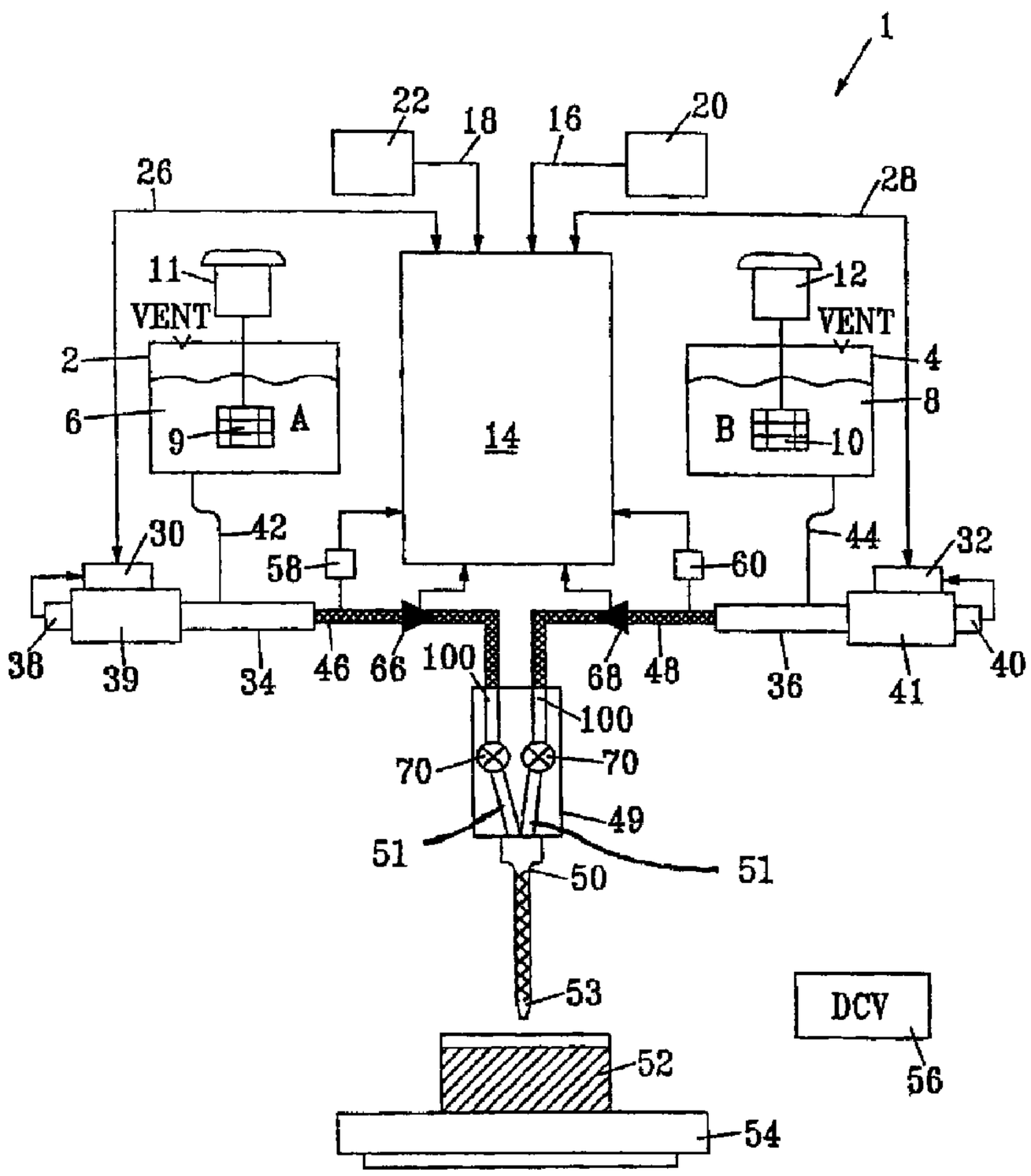

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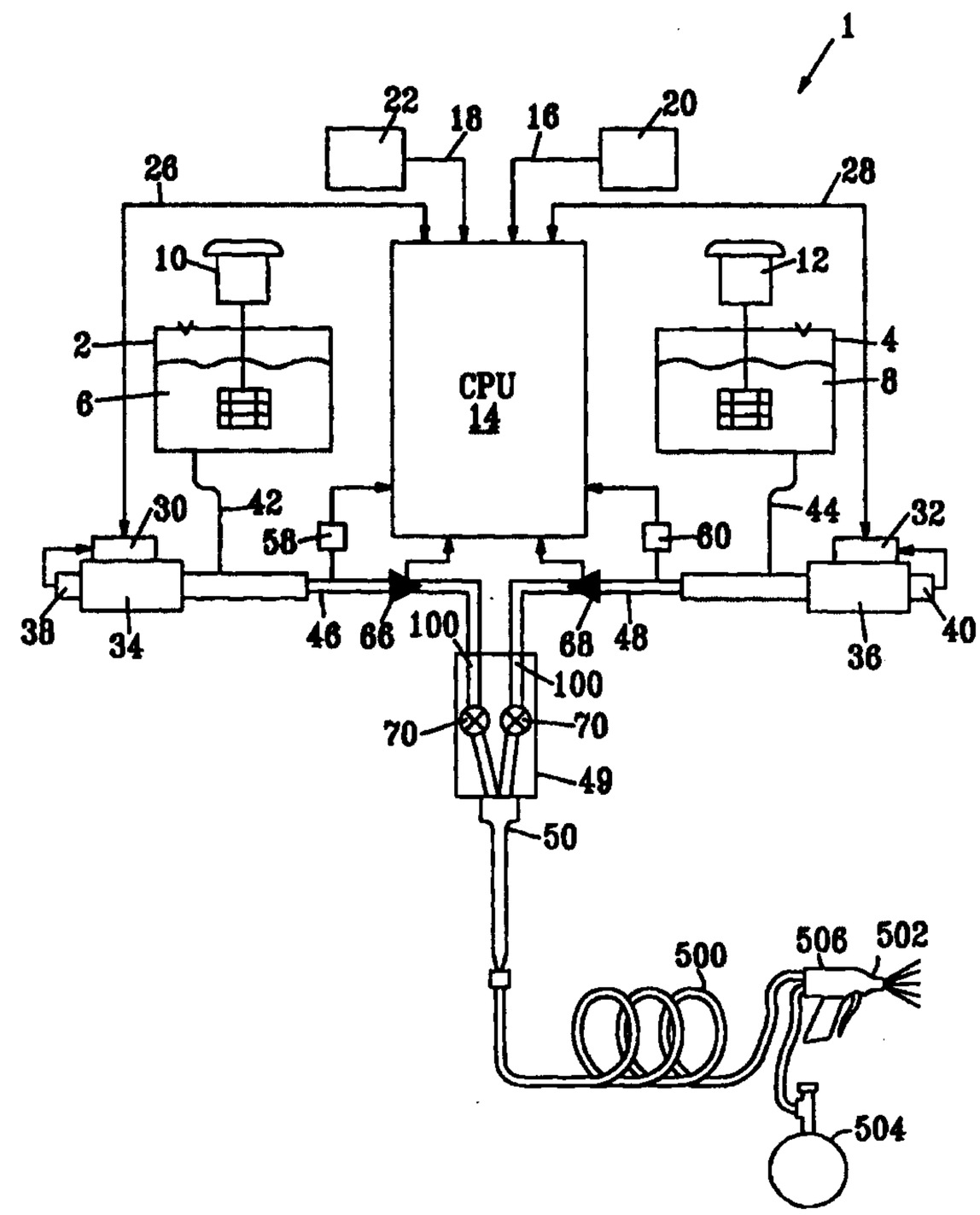
(54) Title: METHOD AND APPARATUS FOR DISPENSING LIQUIDS AND SOLIDS

(57) Abstract

A system (Fig. 16) for metering and dispensing component liquids and solids has a microprocessor–based control system and progressive cavity pumps which provide accurate control of component ratios, shot sizes, flow rates and dispense durations. The system has feedback components (58, 66, 60, 68) for controlling the pressure, flow rates, fluid levels and amounts of fluids dispensed. The pressure in the flow system is used to control the pumps (34, 36) rather than a valved nozzle (49). The system may be used as a sprayer with compressed air added. Back and forth movement of the pump provides compensation for pressure changes. A mold charging system uses pressure to control the pumps which are cycled on and off to avoid overpressurizing the mold. The rate of pressure increase is used to control the rate of flow from the pumps as the mold approaches completion of the charge to avoid overpressurizing the mold.



DESCRIPTION

METHOD AND APPARATUS FOR DISPENSING LIQUIDS AND SOLIDS

BACKGROUND OF THE INVENTION

The field of the present invention is devices that meter and dispense singular and plural component liquids and solids and methods of dispensing same.

Systems for mixing and dispensing singular and multi-component materials are well known in the art. An almost infinite variety of substances may be dispensed. Many materials are packaged through dispensing in a fluid or semifluid state. Paint is sprayed, molds are pressure charged with materials, and electronic devices are potted. A variety of means for distributing such materials are available. Where plural components are involved, such systems typically include pumping mechanisms for pumping and metering separate materials in a prescribed ratio to a mixing device that thoroughly mixes these materials together. The mixed composition then flows out of a dispensing nozzle directly to the surface or point of application where the composition is desired.

When a curable composition is desired, two or more suitable materials are mixed to interact with each other to create a flowable, curable composition which will set or harden to a non-flowable state. The time required for a curable composition to harden is referred to as the "cure" time and often is a short period of time. Such resulting curable compositions have been used, for instance, as adhesives, sealants and potting materials in a wide variety of industrial applications and for the creation of useful objects.

SUMMARY OF THE INVENTION

Embodiments of the present invention are directed to dispensing systems employing progressive cavity pumps and controlled motor operation.

In a first separate aspect of the present invention, a dispensing system includes a plurality of progressive cavity pumps with a manifold assembly extending from the pumps to an outlet. A valve assembly, a pressure sensor

and a mixer are associated with the manifold assembly. A controller controls the motors of the dispensing system responsive to pressure input and pressure input as a function of time from the pressure sensor.

In a second separate aspect of the present invention, the dispensing system of the foregoing separate aspect includes a valve and trigger associated with a nozzle at the outlet. A source of compressed air may also be controlled by the valve. With these features, the system can be employed as a highly accurate paint sprayer.

In a third separate aspect of the present invention, the dispensing system of the first aspect further contemplates start and stop modes as well as a low flow mold when pressure increases above a predetermined rate. Operation using such modes can be advantageously applied to charging of molds.

In a fourth separate aspect of the present invention, the dispensing system of the first aspect further contemplates a stop mode, an end of cycle mode and an oscillation mode. The oscillation mode can be employed to insure proper conditioning of the system for instantaneous startup with preestablished pressures.

In a fifth separate aspect of the present invention, the dispensing system of the first aspect further contemplates flow rates proportional to the differential pressure between actual pressure and target pressure. A PID loop may be employed. Such a system is advantageous for a substantially constant pressure output.

In a sixth separate aspect of the present invention, the dispensing system of the first separate aspect further contemplates motor torque control to establish a virtual stall mode to the dispensing system.

In a seventh separate aspect of the present invention, a method for dispensing a mixture of materials from progressive cavity pumps through a valve controlled manifold assembly includes repeated sampling of pressure between one of the pumps and the outlet of the manifold assembly, starting the motor and stopping the motor based upon preselected pressures and driving the motors at preselected proportional speeds responsive to pressures sensed by the pressure sensor as a function of time.

In a eighth separate aspect of the present invention, the method of the seventh aspect further contemplates an opening and closing of the valve assembly independently of the sample pressure. This method is applicable for the use in spray painting and like functions.

In a ninth separate aspect of the present invention, the method of the seventh aspect further contemplates a cycling of the progressive cavity pumps with the valve controlled manifold assembly closed. The cycling maintains the system in preparation for subsequent instantaneous dispensing.

In a tenth separate aspect of the present invention, the method of the seventh aspect further contemplates a speed reduction with a rate of pressure increase of the mixed pump materials exceeding a preselected amount. This aspect provides advantageous operation for charging molds and the like.

In an eleventh separate aspect of the present invention, the method of the seventh separate aspect further contemplates further control of the progressive cavity pump through speed adjustment as a function of the differential pressure between actual pressure and preset target pressure. A system tending toward constant pressure flow can result.

In a twelfth separate aspect of the present invention, the method of the seventh aspect further contemplates a sensing of torque and limiting torque as a means to provide a virtual stall response to the method of dispensing a mixture of materials.

In a thirteenth separate aspect of the present invention, various combinations of the foregoing aspects are contemplated to provide system advantage.

According to another aspect of the present invention, there is provided a dispensing system comprising a plurality of progressive cavity pumps; a manifold assembly including an outlet and being in flow communication between the plurality of progressive cavity pumps and the outlet; a valve assembly in the manifold assembly controlling flow communication between the plurality of progressive cavity pumps and the outlet; a plurality of motors, each motor being coupled to a respective one of the plurality of progressive cavity pumps; a mixer in the manifold assembly to mix the outputs of the plurality of progressive cavity pumps; a controller in signal communication with a pressure sensor and with the plurality of motors, the controller being responsive to pressure input from the pressure sensor to control the motors based on the pressure sensed by the pressure sensor and on the pressure sensed by the pressure sensor as a function of time.

According to another aspect of the present invention, there is provided a method for dispensing a mixture of materials from progressive cavity pumps driven by motors, respectively, through a valve controlled manifold assembly to an outlet, comprising repeatedly sampling pressure between one of the pumps and the outlet; starting the motors when the sampled pressure approaches or falls below a preselected low pressure; stopping the motors when the sampled pressure approaches or rises above a preselected high pressure; and driving the motors at preselected proportional speeds responsive to the pressure sensed by a pressure sensor as a function of time.

Accordingly, it is an object of the present invention to provide improved systems and methods for accurately dispensing flowable material. Other and further objects and advantages will appear hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a preferred embodiment of a dispensing system which dispenses a single or plural component fluid.

FIG. 2 is a cross-sectional diagram of a dispense head.

FIG. 3 is a cutaway view of a partial pump stator assembly having a

single helix rotor within the double helix bore.

FIG. 4 is an electrical block diagram of a preferred embodiment of a motor controller.

FIG. 5 is a diagram showing how FIGs. 6-9 connect to create a software flowchart for controlling aspects of the dispensing system.

FIGs. 6-9 are software flowcharts for controlling aspects of the dispensing system.

FIG. 10 is a software flowchart that describes the RS232 and DIP switch software for the motor controller.

FIG. 11 is a software flowchart that describes the RS232 data flow in the motor controller.

FIG. 12 is a software flowchart that describes the motor controller timer interrupt software.

FIG. 13 is a block diagram of a dispensing system useful with a spray gun.

FIG. 14 is a software flow chart that describes motor control of the device of FIG. 13.

FIG. 15 is a software flowchart of an oscillation routine for maintaining material in a progressive cavity pump.

FIG. 16 is a block diagram of a dispensing system for pressure charging a mold.

FIG. 17 is a software flowchart for the device of FIG. 16.

FIG. 18 is a flow chart of a constant pressure system.

FIG. 19 is a flow chart of a calibration routine.

FIG. 20 is a flow chart of a virtual stall system.

FIG. 21 is a front view of a dispense head assembly.

FIG. 22 is a side view of a high flow manifold.

FIG. 23 is a cross section of the manifold of FIG. 22.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 illustrates a block diagram of a previously employed dispensing system forming a basis for the present system. The dispensing system 1 dispenses a single or plural component fluid. In FIG. 1, the dispensing

system 1 has a plurality of vats 2, 4, each of which holds a fluid 6, 8 that is a constituent material of the desired final product. Agitators 9, 10 stir the fluids 6, 8 in order to maintain the fluids as homogeneously as possible. The dispensing system 1 has a master control unit 14 which may be a CPU, microprocessor, microcontroller, arithmetic logic unit, ASIC, field programmable gate array, or other logic control circuit. The master control unit 14 receives data and commands via data interconnects 16, 18 from a user input device 20 and/or a programming input device 22. The user input device 20 may be a keypad, buttons, switches, barcode reader, or other input device.

Depending on the input, the master control unit 14 controls various aspects of the dispensing system 1. For example, the master control unit 14 has lines 26, 28 for transmitting commands and receiving data from pump controllers 30, 32 which in turn direct and manage pumps 34, 36. The control unit 14 calculates desired pump parameters, such as acceleration, speed and duration, based on data entered through aforementioned user input devices and from data resident in the software and hardware of the control unit.

Primary items of information stored in the resident software are the dispense volume of each pump rotation, and the ratio between motor rotation and pump rotation. The software then calculates the number of motor rotations to deliver the desired quantity of material, including velocity or rotational speed. If one revolution of the pump outputs a known volume of a fluid, the control unit 14 calculates the tick count to control the number of revolutions and partial revolutions the pump makes and thus, direct the quantity of the fluid to be dispensed. The desired pump parameters are then downloaded to the pump controllers 30, 32, via the data lines 26, 28 and stored.

A signal to begin a cycle is sent simultaneously to each pump controller 30, 32 by the control unit 14, both pumps 34, 36 activate under their respective programs. The pump controllers 30, 32 then count the ticks received from absolute position encoders 38, 40 over time to manage the rotational speed or acceleration of the pumps 34, 36. The absolute position encoders 38, 40 are coupled mechanically to the shafts of the motors 39, 41

and may operate optically, mechanically, electrically or magnetically. The encoders 38, 40 count tick marks to detect the position of the shafts as they rotate. The encoders 38, 40 send pulses (i.e., a number of ticks over time) representing the shaft position information to the pump controllers 30, 32. As later described in FIG. 4, the pulses enter a control circuit 190 (within the motor controllers 180) and are used by the control circuit 190 to control power drivers 200 and the motors 39, 41. Thus, the pulses from the encoders are used by the motor controllers to adjust or fine tune the operation of the motors 39, 41. The pump controllers 30, 32 may send status and other information including encoder information to the master control unit 14. Thus, the motors 39, 41 and in turn the pumps 34, 36 are controlled by a pump control system including the master control unit 14, the pump controllers 30, 32 and the encoders 38, 40.

If a revolution of the pump outputs a known volume of a fluid, the pump control system, either the master control unit 14 or the motor controller depending on which device is to have feedback control in a particular design, can use the encoder tick measurement of the number of revolutions and partial revolutions made by the pump and thus, calculate the expected volume of the fluid dispensed. The master control unit 14 may count the ticks from the encoders 38, 40 over time to determine the rotational speed or acceleration of the pumps 34, 36. Thus, the pump control system, including the encoders 38, 40, measure pump displacement and rate to act as pump movement sensors.

The action of the pumps 34, 36 draws fluids 6, 8 into the pumps through vat fluid lines 42, 44. The fluids 6, 8 pass into the pump fluid lines 46, 48 and into a dispense head 49 having a separate chamber 51 for each pump fluid line 46, 48. From the dispense head 49, the fluids pass into a static mixer tube 50. The static mixer tube 50 has internal projections that mix the fluids 6, 8 together and dispense an end product 52 through the output nozzle 53 of the static mixer tube 50. The end product 52 may be dispensed onto a scale 54 which weighs the end product. The dispensing system 1 receives DC power from a DC power supply 56.

Thus, the dispensing system as shown in FIG. 1 is a two-channel

system, where each channel handles the dispensing of one fluid. The first channel (channel A) includes the vat 2, vat fluid line 42, pump 34, pump controller 30, encoder 38, pump fluid line 46 and dispense head 49. The second channel (channel B) comprises the vat 4, vat fluid line 44, pump 36, pump controller 32, encoder 40, pump fluid line 48 and dispense head 49. The dispensing system may also be modified to include additional channels and include additional vats, agitators, pumps, fluid lines and other components as desired to dispense three or more component mixtures or dispense multiple mixtures through separate dispense heads at the same or remote locations.

Pressure transducers 58, 60 send feedback information about the pressure in the pump fluid lines 46, 48 to the master control unit 14 so that the master control unit 14 can monitor the pressure in the pump fluid lines 46, 48 from the output of the pumps 34, 36 to the dispense head 49. The ability to maintain a constant pressure from the output of each pump 34, 36 to the dispense head 49 helps assure that the fluid is compressed uniformly and constantly so that an accurate amount of fluid is dispensed. Additionally, if there is a blockage or malfunction, the pressure transducer will signal a preset overpressure situation, and the system will shut down. Similarly, flow meters 66, 68 measure the flow rates within the pump fluid lines 46, 48 and transmit flow rate information to the master control unit 14, thereby allowing the master control unit 14 to monitor the fluid flow rates. Should the flow rates differ from calibration data, the system can be shut down and an error reported.

The dispense system can also use information from the pump controllers 30, 32 and the flow meters 66, 68 and other feedback sensors to check the pump and plumbing for leaks and trapped air. Appropriate error messages may be issued to the user to insure optimum performance. The dispense system may change the delivered material composition, from shot-to-shot or during the time the material is being dispensed, in order, for example, to adjust material pre-cure and post cure characteristics such as the viscosity, color and thixotropic factors of the material.

The dispense head 49 has positive cutoff valves 70 which are symbolically shown in FIG. 1. The positive cutoff valves 70 are controlled by

the master control unit 14 and serve to cut off the flow of fluids in the dispense head 49 whenever appropriate (i.e., when the dispense cycle is completed). The control lines between the master control unit 14 and the positive cutoff valves 70 are not shown in FIG. 1.

The agitators 9, 10 in the vats 2, 4 are driven by agitator motors 11, 12. The agitators 9, 10 are illustrated as stir paddles but may be any type of agitator well known in the art. The agitators 9, 10 run at a constant desired speed. However, as the level of the fluid in a vat 2,4 falls, less current is required to drive the agitator at the same speed. The master control unit 14 can detect the reduced current flow and determine the amount of fluid remaining in the vat. Alternately, the system can be made to maintain a constant current instead of constant motor speed. An additional encoder and motor controller similar to those previously described are coupled to each agitator motor so that the motor controller (and master control unit 14) can receive rotational position information from the agitator motors. Accordingly, the master control unit 14 can determine the rotational speed of each agitator to determine the level of fluid remaining in the vat. As the fluid level in the vat falls and as the current flow to the agitator motor is kept constant, the rotational speed of the agitator motor increases. The master control unit 14 can measure the rotational speed of the agitator motor to determine the level of fluid remaining in the vat. The master control unit 14 can also decrease the current to the agitator motor when the master control unit 14 detects that the motor speed has increased. Each vat 2, 4 may have a float connected to a normally closed switch. When the fluid level falls below a certain level, the float falls and triggers the switch to open.

FIG. 2 is a cross-sectional diagram of a dispense head 49. The dispense head 49 is a combination manifold/on-off valve that controls the flow of fluids. The dispense head 49 includes a bellows assembly 80 as a seal. The bellows assembly 80 includes a bellows 82. A valve rod 88 is inserted into a center hole of the bellows 82. The bellows 82 slides freely along the length of the valve rod 88. The valve rod 88 is also inserted into an aperture of a rod seal ring 90. The rod seal ring 90 is not affixed to the valve rod 88 and is also free to slide back and forth along the length of the valve rod 88.

A seat/rod seal 94 slides over and around an end of the valve rod 88 and abuts the raised lip 92 of the valve rod 88. A retaining screw 96 enters the opening of the seat/rod seal 94 and screws into mating threads 98 of the valve rod 88. The retaining screw 96 holds the seat/rod seal 94 in place.

Each bellows assembly 80 is shown as mounted in a separate chamber 51 within the dispense head 49. The dispense head 49 has two inlets 100. The inlets 100 receive fluids 6, 8 from the pump fluid lines 46, 48, and go perpendicularly into the illustration of FIG. 2.

A pneumatic valve actuator includes an air cylinder 101 having a piston 102 which moves freely within the air cylinder 101. Screws 103 pass through passages in the free piston 102 and engage the mating screw threads 99 of the valve rods 88 to attach the valve rods 88 to the air cylinder 101. Each air chamber 104 of the air cylinder 101 has at least one air port (not shown) that allows air to be pumped into or out of the chamber. As shown in FIG. 2, the piston 102 is in its rightmost position (i.e., in a position furthest away from the valve nose 106). The piston 102 has an O-ring groove 108 for holding a dynamic O-ring which acts as an air seal between chambers of the air cylinder 101.

When air is selectively pumped into the chambers 104 such that the air pressure in the rightmost chamber sufficiently exceeds the air pressure in the leftmost chamber, the piston 102 travels leftward towards the valve nose 106. This leftward motion of the piston 102 pushes the valve rod 88 leftward and expands the bellows 82. When the piston 102 extends the valve rods 88 leftward, the seat/rod seal 94 compresses into the tapered bore of the valve seat 110, thereby closing off the flow of fluids in the dispense head 49. The rod seal ring 90 is held in place within a cavity of the dispense head 49 and has an O-ring groove 112 for holding a static O-ring. The static O-ring acts as a fluid seal to prevent fluid in the dispense head 49 from leaking around the rod seal ring 90. Instead of a pneumatic actuator such as the air cylinder, the system may utilize an electronic actuator such as a solenoid to move the valve rods 88. The system may also use any other actuator well known in the art.

FIG. 3 illustrates a progressive cavity pump stator 130 and a rotor 134.

The stator 130 may be made of PTFE or other suitably deformable, durable, yet highly chemically resistant and abrasion resistant material. Such materials may be filled with wear resistant material such as graphite, glass or molybdenum disulfide. The stator 130 has a concentric double helix bore 132 running through its center. A first helix thread and a second helix thread wind down the length of the bore 132, are opposed to each other by 180 degrees and cross each other every 180 degrees.

The rotor or screw 134 having a single helix thread is inserted through the double helix bore 132. The interaction of the single helix rotor 134 and the double helix bore 132 creates the pumping action.

The single helix thread of the rotor 134 engages portions of the double helix threads of the bore 132 to create sealing lines 136. Fluid may be carried between a pair of sealing lines 136. As the rotor 134 turns within the double helix bore 132, the sealing lines 136 move down the length of the bore, thereby transporting the fluid and creating a progressive cavity pump. The desired total number of turns in the double helix threads of the bore of the stator 130 depends on the desired pump characteristics.

Because the pump is a constant displacement pump, the pressure of the system rises or falls to a steady state depending on the viscosity and flow rate of the material being pumped, and the dynamic back pressure of the system through which the fluid is dispensed. As this pressure is different for each output requirement, it is imperative that the pressure be maintained between cycles to insure accurate shot-to-shot dispense reproducibility.

FIG. 4 is an electrical block diagram of a preferred embodiment of the motor controller 180. The motor controller 180 may be used to drive any motor described herein. The motor 182 is a permanent magnet DC brush or brushless motor and in particular, a 48 volt 1/2 horsepower motor. The motor 182 is mechanically connected to an encoder 186. The encoder detects the absolute position of the motor shaft and sends this position information 188 to the control circuit 190. The control circuit 190 can use the position information to determine the rotational speed or acceleration of the motor. The control circuit 190 sends various control signals 192 and "ready" control signals 194 to a multiplexor 196. The ready signals 194 allow the control circuit 190 to

turn off any specific power driver 200 if the power driver suffers a non-catastrophic failure. Signals from the multiplexor 196 pass to various power drivers 200. A DC-to-DC converter 212 converts a 48 volt power supply to 5 volts which runs various electronics in the system and also sends 48 volts to the power drivers 200. The power drivers 200 are semiconductor devices that use low level inputs (i.e., signals from the multiplexor 196) to control relatively high current level outputs (i.e., lines 220, 222) to control the motor 182.

Three of the input signals are the brake control signal 202, direction control signal 204 and the pulse width modulation (PWM) control signal 206. The brake control signal 202 causes the power drivers 200 to short the lines 220, 222 going to the motor 182 which uses back electromotive force (emf) to dynamically brake or stop the motor 182 as quickly as possible. The direction control signal 204 tells the power drivers 200 whether to reverse the direction of the motor 182. The pulse width modulation control signal 206 carries a train of pulses and the power drivers 200 count the number of pulses over time. As the number of pulses per unit time increases, the power drivers 200 output increasingly higher voltages up to a maximum of 48 volts to speed up the motor 182 accordingly. As the number of pulses per unit time falls, the power drivers 200 reduce the output voltage to slow down the motor 182.

The power drivers 200 have current feedback lines 224 that return current flow information to the control circuit 190. The control circuit 190 uses the current flow information to see how hard the motor 182 must work to maintain a given speed. This information can be used to derive the torque.

The control circuit 190 may receive information, analog or digital, from devices connected to the monitor port 228. For example, a temperature sensor may be connected to the monitor port 228 to provide temperature data to the control circuit 190. A RS232 control port 230 facilitates communication between the control circuit 190 and the master control unit 14 for motor information and commands. The RS232 control port 230 allows the system to monitor the motor controller 180 for such information as the desired motor speed, actual motor speed, desired number of total motor revolutions, actual number of total motor revolutions, and current flow to each of the power drivers 200. A DIP switch 232 may optionally be used to manually set the

speed of the agitators which would otherwise be adjustable by the control circuit 190. The DIP switch settings are sent over lines 234 to the control circuit 190.

Thus, the dispense system has various communication abilities. The dispense system may be attached to an outside telephone line, allowing service personnel at a remote location to monitor the system's performance and diagnose any malfunctions. A bar code reader may be attached to the dispense system where the system uses the bar code reader to identify a part, automatically configures itself to dispense according to a known program, and displays an image of the part so the user can verify that the program is the correct program for the displayed part. The system also may monitor material utilization, store in memory the total material used, and communicate with a manufacturing network to provide material use information to an external computer system.

Thus, the dispensing systems described herein have various types of feedback components. For example, the feedback components may include motor controllers, pressure transducers, flow meters, current detectors and any other components that obtain information about a device (such as a pump, motor, agitator, fluid line) and use (or let a control device use) the information to control the device. The feedback components allow the dispensing system to dispense, meter and mix more accurately.

While the pumps 34, 36 output the same volume of fluid per pump revolution, regardless of the density of the fluid, the dispensing system may require calibration prior to production runs. Prior art dispensing systems required the user to experiment by altering the velocity or time duration of the pump.

The dispensing system of the present invention employs a calibration process which separately calibrates each channel (channel A, channel B, channel C, etc.) of the system. Prior to the calibration run, the user replaces the static mixer tube 50 with a calibration nozzle (not shown). The calibration nozzle does not mix the fluids from the two channels into one output nozzle, but instead has multiple output nozzles, one for each channel. The user then weighs a first container on the scale 54 and zeroes the scale. The first

container is placed under one of the output nozzles. The user presses a foot pedal to begin the dispense cycle. The master control unit 14 instructs the pump 34, 36 of each channel to output a certain volume of fluid. Actually, the pumps dispense at a rate equal to 35% of the maximum rated motor speed so as to better "weight" the accuracy of small shot sizes. The fluid from channel A is dispensed into the first container. The user weighs the first container on the scale 54 and inputs the weight in grams into the keypad. Based upon the number of revolutions made by the pump and the weight of fluid dispensed, the master control unit 14 can compare the expected weight of the fluid dispensed with the actual weight dispensed. The master control unit 14 computes a number that represents the number of encoder ticks per gram for channel A. This calibration process is independent of the pump type, gear ratio, encoder resolution, motor horsepower and the like. All of these variables are taken into account in the single computed number. The process is repeated with a second container for channel B.

Advantageously, the effects of temperature, varying pressure, transient imbalance phenomena and other variables on the actual volume of fluid dispensed are eliminated. Such a system also permits the user to dispense accurately by weight or by volume. Additionally, the systems can be calibrated for differing fluids, dispense amounts, flow rates, ratios and the like. This calibration system is quick and easy to execute.

The dispensing system is easily programmable by a user to control or change the flow rate, ratio, quantity and/or other dispensing criteria in any manner. FIG. 5 illustrates how the software flowcharts shown in FIGs. 6-9 fit together. The software flowchart of FIGs. 6-9 controls the overall aspects of the dispensing system. First, in block 300, the system initializes various hardware components such as communication ports, serial ports and other circuits. In block 302, the system loads a machine data file that contains information specific to the system such as the pump types and ratios of the gear boxes. In block 304, the system checks to see if the user enabled the pressure relief switch (i.e., an emergency stop switch). If enabled, the system will shut down the system, interrupt any dispense cycle, stop the pump motors 34, 36 and open the dispense head 49 (Step 306) to relieve the

overpressure condition. Otherwise, the system checks the fluid levels in the vats 2, 4 (Step 308). If empty or low, an Empty flag is set (Step 310). If not empty, the system reads the pressure in the pump fluid lines 46, 48 as provided by the pressure transducers 58, 60 (Step 312). If the detected pressure exceeds a preset pressure limit, the system finds overpressure (Step 314), stops the pump motors, and lights LEDs to warn the user (Step 316). When the pressure is within normal operating conditions, the user can dispense in either a timed dispense mode or a continuous run mode. The system checks if the user entered a time duration for the dispense cycle (timed dispense mode) in Step 318. If YES, the system waits for the user to depress the foot pedal (Step 320) and in response, the system starts the dispense cycle and the system retrieves the desired time, calculates the stop time, opens the dispense head and starts the pump motors (Step 322). If the system was in a timed run mode and the time has expired (Step 324), the system will stop the pump motors 39, 41 and close the dispense head (Step 326).

If the user selected the continuous run mode instead of the timed run, the system waits for the user to depress the foot pedal (Steps 328, 332) which causes the system to open the dispense head and start the pump motors (Steps 330, 334). At Step 336, the system checks to see if any user inputs were made on the LCD display panel. At any time other than a dispense cycle, the user may enter the set parameters routine via the data entry keyboard 20 or 22.

The user's depression of the Ratio key (Step 338) allows the user to enter the desired ratios for each constituent fluid (Step 340). If the desired ratios do not total 100%, the system will require the user to re-input desired ratios (Step 342). When correct ratios are entered, the system computes the new quantities of fluids desired and recalculates the correct pump speeds to use (Step 344).

If the user depresses the Time key (Step 346), the user may input the desired run time (Step 348). The system then computes the correct pump speeds for this desired run time (Step 350).

If the user depresses the Quantity key (Step 352), the user may input

the desired total quantity of the end product in grams (Step 354). Based upon the desired weight of the end product, the system calculates new quantities and pump speeds (Step 356).

If the user depresses the Calibrate key (Step 358), the user can start the calibration process. In the calibration process, the user places a container under the output nozzle of channel A (Step 360). The user starts the dispense cycle by depressing the foot pedal (Step 362), which causes the dispense head to open and the pump motors to start (Step 364). At Step 366, the system checks to see if the dispense cycle is completed. If YES, the pump motors are stopped and the dispense head closed (Step 368). The user takes the container with the dispensed fluid from channel A, weighs it on the scale 54, and enters the weight in grams on the keypad (Step 370). The system takes the weight information and computes the number of encoder ticks per gram (Step 372). Alternately, the system could calculate the density of the fluid as grams/cc. The calibrated number of ticks per gram for channel A is saved in the machine data file (Step 374). This calibration procedure is repeated for each fluid (Step 376).

If the user depresses the Program key (Step 378), the user may select a program (Step 380) previously stored in the machine data file. This selected program which may contain the user's most commonly used ratios or quantities is loaded into the system (Step 382).

If the user wants to save a program into the machine data file, the user depresses the Store key (Step 384) and saves the program under an identifying program number (Step 386). This new program is stored by the system in the machine data file (Step 388).

Turning to FIG. 10, the software flowchart for controlling the motor controller 180 over the RS232 port 230 and DIP switch 232 is shown. As previously indicated, the motor controller can control the speed, direction and on/off of the motor. Starting at Step 400, the system checks to see if information was received over the RS232 port or the DIP switch. If the information came from the DIP switch, the DIP switch settings are read (Step 402). If information was received over the RS232 port, the system retrieves the last buffered values for the speed, direction and desired number of

encoder ticks (Step 404) for the motor controller. At Step 406, the system compares the new values with the old values. If the new values are different, the new values are saved and used by the power drivers 200 to control the motor (Step 408).

The software flowchart of FIG. 11 illustrates how the master control unit 14 of the system controls and queries the motor controller 180. The master control unit 14 uses the RS232 port 230 either to set new values into the motor controller or to query the motor controller for these values. If the master control unit 14 wants to set new values into the motor controller, the master control unit sends a command to the motor controller that is not prefaced by the "?" character (Step 420). The master control unit 14 can set the desired velocity of the motor (Step 422) with a "V" command (Step 424), the encoder ticks (Step 426) with an "E" command (Step 428), or the direction of the motor (Step 430) with a "D" command (Step 432). The master control unit 14 can instruct the motor controller to start the motor (Step 434) with a "GO" command (Step 436) or to stop the motor (Step 438) with a "STOP" command (Step 440).

If the master control unit 14 wants to query the motor controller for the velocity of the motor (Step 444), the master control unit 14 sends a "V" command prefaced by a "?" (Step 446) which causes the motor controller to output the velocity information onto the RS232 line (Step 448). Similarly, the master control unit 14 can obtain the encoder ticks read (Step 450) with an "E" command (Step 452), the direction of the motor (Step 454) with a "D" command (Step 456), or the current flow to the motor (Step 458) with a "C" command (Step 460). Erroneous commands are indicated by Steps 442 and 462.

The motor controller 180 uses a timer interrupt scheme to ensure that the motor is accurately controlled. FIG. 12 shows the software flowchart for this timer interrupt. A timer is set to the Timeout period (Step 480) which may be approximately 6 milliseconds. When this timer expires (Step 482), the motor controller reads the number of encoder ticks read during the 6 millisecond period (Step 484) and updates the total number of ticks read thus far with this number (Step 486). The motor controller then compares the total

number of ticks read against the desired number of ticks to be read (Step 488). If the numbers match, the motor controller directs that the motor should be braked and stopped (Step 490). If the numbers do not match yet, the motor controller compares the number of ticks read during the 6 milliseconds with the desired number of ticks to be read during the 6 milliseconds and determines whether the actual motor speed is too slow or too fast (Step 492). If the actual speed is too slow or too fast, the motor controller adjusts the speed (Step 494).

Following are various systems providing specific categories of function and usage built upon the foregoing system, a spray system, a system for retaining material in a progressive cavity pump, a dispensing system for pressured charging of molds and a high flow rate system. Various control schemes are employed to facilitate operation in such uses.

FIG. 13 and FIG. 14 illustrate a system which may be employed for spraying paint or the like. The system is particularly useful where mixing is to occur between two elements of the material sprayed. Structurally the device is much like that disclosed above. The reference numbers are taken from the preceding embodiments and reflect common equipment. Associated with the static mixer tube 50 is a dispensing conduit 500. The dispensing conduit 500 is resilient in the ranges of pressures encountered with the pumps 34 and 36. The resilient quality of the dispensing conduit 500 can operate as an accumulator to lessen pressure spikes and generally cause the control system to be less sensitive.

A nozzle 502 is associated with the distal end of the dispensing conduit 500. The nozzle 502 may include the introduction of a source of compressed air 504 such that the dispensed liquid and pressurized air form an appropriate spray for painting or other uses. Without the air, liquid deposition through a different nozzle 502 is equally possible.

A valve 506, which may include a trigger, controls the flow to the nozzle 502. When compressed air is also supplied, the valve 506 would control the source of compressed air 504 as well.

The valve 506 is not associated with the controllers 30 and 32 for the pumps 34 and 36. As progressive cavity pumps are employed, it is

impractical to control the system by stalling the pumps. Consequently, some mechanism is required to control the pumps 34 and 36 when the valve 506 is closed. Only in this way is overpressure within the system and potential damage to the pumps themselves avoided. Direct electrical control from the valve 506 to the pump controllers 30 and 32 is normally inappropriate because the variety of uses of such systems may include highly flammable materials in a vaporized state.

Control can be provided by one or more pressure sensors used to provide input to the controllers 30 and 32 to control the pumps 34 and 36. Pressure transducers 58 and 60 provide the appropriate input. When the valve 506 is closed, the pressure transducers 58 and 60 recognize an increase in pressure. When the valve 506 is opened, a decrease in pressure is recognized. The master control unit 14 is employed to cause the controllers 30 and 32 to properly respond to the changes in pressure determined by the transducers 58 and 60.

Looking to the software flow chart of FIG. 14, the control logic responsive to the transducers 58 and 60 and controlling the controllers 30 and 32 is presented. With the system initialized, the pressures from one or both of the transducers 58 and 60 are read in an A/D input (Step 510). An increment run timer (Step 512) keeps track of incremental time. The pressure from one or both of the transducers 58 and 60 is compared with a preselected high set point (Step 514) when the pumps are dispensing. If the pressure is greater than the high set point and the pumps are dispensing, dispensing is terminated and an increment run time is initiated with the stalled counter set to one (Step 516). When the pressure is either above the high set point but the pumps are not dispensing or the pressure is below the high set point regardless of whether or not the pumps are dispensing, the pressure is compared with a preselected low pressure set point (Step 518). If the pressure is lower than the low set point, a start dispensing signal is given (Step 520) and the stalled counter is reset to zero. If the pressure is greater than the low set point, nothing changes. Consequently, if the pumps are dispensing, they will continue to dispense. If the pumps are not dispensing, the stalled counter will continue to accumulate.

With the foregoing software logic flow, a system such as illustrated in FIG. 13 may be activated once the dispensing conduit 500 has been put in place. The valve 506 is opened and the controllers 30 and 32, recognizing a pressure below the low set point (Step 518) starts the dispensing (Step 520). Once the dispensing conduit 500 is charged, the nozzle 502 may be closed. With the valve 506 closed, the pumps 34 and 36 continue to build pressure until the pressure approaches, reaches or exceeds the high set point (Step 514) where dispensing is stopped (Step 516). When the system is to be used, air is provided to the valve 506 and the liquid mixture is up to pressure. As the valve 506 is opened, a spray is dispensed from the nozzle and the pressure within the system begins to fall. When the pressure approaches, reaches or falls below the low set point (Step 518), the controllers 30 and 32 are energized to activate the pumps 34 and 36. The pumps 34 and 36 run until pressure again climbs above the high set point (Step 514). The increment run timer (Step 512) may be used to determine the length of time since flow was experienced within the system, the time since the last initialization. Depending on the material, a preselected time may be chosen to provide a warning before the substance being dispensed hardens up, cures or may otherwise become mechanically coalesced. A signal generator may be hooked with the increment run timer to provide the appropriate warning signal.

As previously discussed with prior embodiments, the motors 39 and 41 are controlled to operate at the same time and at different flow amounts such that an appropriate ratio is created and always dispensed. With the pressure activated control, the motors are designed to start up and shut down together and to run at a established proportion. This insures consistent mixtures regardless of the timing and operating of the valve 506.

A system is contemplated for maintaining constant conditions in a mixture of materials in a progressive cavity pump while the outlet is closed. The system contemplates periodic motion which can prevent the settling or mechanical coalescing of materials and inhibit the formation of a set in the flexible stator material. These conditions could otherwise increase the power needed to start the rotation of the pump. The pump rotor is rotated in one

direction a partial turn and then rotated in the other direction a partial turn. The second rotation is controlled to create the appropriate static pressure within the device. In the example routine of FIG. 15, the pumps are first rotated backward and then forward. The opposite sequence is also applicable.

Looking at the software flow chart of FIG. 15, a routine is entered with the pump or pumps in the nondispensing mode. A clock within the controller 14 keeps time (Step 522). The time is periodically read (Step 524) for either specific times from initiation of the routine or intervals from the last cycle. When it is time to initiate the cycle, the pumps rotate backward one-sixteenth of a turn (Step 526). Next the pumps are rotated forward a partial turn which is nominally one-sixteenth of a turn (Step 528) but for the determinations made below. Once the cycle of backward and forward revolutions is complete, the pressure prior to the cycle is compared to the pressure after the cycle. If the new pressure is greater than the prior pressure before the cycle (Step 530), the forward rotation of the pump is decreased by one-sixty-fourth of a turn (Step 532). If on the other hand, the pressure is less than the pressure prior to the cycle (Step 534), then the forward rotation is increased by one-sixty-fourth of a turn (Step 536). It is, of course, the succeeding cycle which is affected by Steps 532 and 536. Through the change to the forward rotation, appropriate pressure levels can be maintained while agitation is provided to the materials within the pump cavities. In no case will the pressure be allowed to increase beyond the higher set point limit.

Alternatively, a feedback system may be employed to maintain constant conditions with such periodic oscillation cycles. In the use of a backwards and forwards scheme, the limit on the forward motion may be through a pressure transducer 58, 60 with the forward movement terminating when a preset pressure is achieved through a partial forward rotation.

As dispensing systems are dependent on pressure integrity for accuracy, it is of value to constantly monitor the system for leaks. In normal dispense modes, the system will run at a characteristic pressure in each channel, depending on viscosity and flow rate which does not account for leakage. A dispense system using progressive cavity pumps can maintain

proper pressure by the method of oscillation described when not dispensing. It also can detect leaks by determining how much the pump must move past the starting point to maintain pressure over a series of such oscillations. If the oscillation backwards and then forwards at a set pressure includes continued advancement, either incrementally or continuously, to a new radial location, then there is a leak in the system, either at the pump stator/rotor interface or at some other location. This self diagnosis can be detected by the controller and reported to the user interface for action by the user. Either a large forward displacement or a large accumulation of incremental displacements is sensed and a signal is generated when the forward displacement exceeds a preset amount.

The dispensing system may be configured for use in charging a mold. Reference is made to FIG. 16. Molds come in a great variety of types, configurations and sizes. The mold cavities are made from a great variety of materials and by a great variety of techniques. Some molds are relatively fragile in the sense that it is possible to damage the mold through the application of excessive pressure in charging. Further, often viscous materials are used as the charging material. Pressure is required to charge the molds with such materials to run such an operation on an economically viable basis. Therefore, it is advantageous to provide a system capable of rapidly charging a mold without exceeding stringent pressure requirements.

A dispensing system is illustrated as including the base mechanisms as previously disclosed. A charging conduit 550 is directed from the static mixer tube 50 to a mold 552. The charging conduit 550 is in pressure flow communication between the static mixture tube 50 and the mold 552. Relief exists within the mold 552 for displacement of the air from the cavity as the charge is introduced.

In charging a mold with viscous material, pressure can build up at the charging port before the mold is filled. Such pressure can exceed the mold strength in fragile molds. Consequently, maximum pressure can be reached with more charging to be accomplished. However, the pressure will drop as the material flows into the extremities of the mold. As this occurs, charging can be resumed. As the mold begins to approach a full charge, the charging

pressure ramps up more quickly. The remaining areas to be filled are smaller proportionally to the flow rate of the charge. Further, such areas are typically at the extremities of the mold, well displaced from the charge port.

To maximize charging rate, an interactive system may be used. Two charging pressures may be preselected. The first is the maximum charge pressure with which the mold is to be burdened. The second is a preselected lower pressure where charging may be resumed to good effect. A first charge may be introduced to the mold until the upper pressure limit is reached. The charging is then terminated until the charging pressure drops below the lower predetermined pressure. At this time, charging is resumed. Cycling on and off occurs until a predetermined rate of increase in pressure is sensed. Once the predetermined pressure rate is reached, the flow rate of the charge is reduced. The reduced rate prevents rupture of the mold and excessive cycling of the dispensing system. By having multiple charging rates selected by the rate of pressure increase during charging, a higher lower pressure may be empirically determined to minimize charging time. A higher initial charging rate can also be used. The system may also sense when the charge is complete through a lack of pressure reduction at the mold port.

In accomplishing the foregoing, a pressure sensor is to be in communication with the pressure flow to the mold. The pressure transducers 58 and 60 may be employed. Where greater sensitivity is required, the pressure may be sensed at or near the charging port at the mold 552. The motors 39 and 41 are controlled by the controller 14 based upon the input of the pressure sensors. Looking at FIG. 17, the pressures are first read and provided to the master control unit 14 by A/D inputs (Step 554). A timer (Step 556) is provided to measure incremental run times as controlled by the system. The pressure is compared to a high set point (Step 558). If the pressure is greater than the high set point and if the system is charging, the controller enters a STOP mode and a command to stop charging is given (Step 560). The stalled counter is also set at 1 (Step 561).

If either the pressure has not risen so high as the high set point or the device is not charging, the pressure is compared with the preselected low set point (Step 562). If the pressure is found to be below the low set point, the

controller enters a START mode and a command is given to start dispensing (Step 564). The stalled counter is initialized to 0 (Step 565). When the pressure is higher than the set point (Step 558), the stalled counter is set to 1 (Step 561) so that the increment run timer begins to track the time that there is no dispensing.

During the time that there is no dispensing, the pressure drops within the mold. The pressure is periodically checked to determine when further charging should occur. When the pressure is greater or equal to the low set point and there is no dispensing (Step 566), the stalled counter is compared with the preselected total time, Timeout, for determining a full mold (Step 568). If the mold is full, i.e., the pressure did not drop to the low set point within the preselected allotted time, the stalled counter surpasses the allotted time, the counter enters an END OF CYCLE mode and the cycle is terminated (Step 570). The stalled counter is set to 0 (Step 570). If the preselected Timeout is not surpassed, an increment is added (Step 572) to the increment run timer. This continues until the pressure drops below the low set point and dispensing is reinitiated or the Timeout period is exceeded. With the dispensing initiated (Step 564), the pressure rises above the low set point. Before it reaches the high set point, the stalled counter is incremented (Step 574) with each cycle.

A pressure rise rate greater than a preselected amount indicates the mold is getting full. The lack of pressure drop indicates that the mold is full. With the pressure between the high set point and the low set point and the pumps dispensing a charge, the stalled counter is compared with the time differential of pressure as a percentage of the total amount of time used to check whether the mold is full, Timeout (Step 576). If pressure is rising above a certain rate, the controller switches to a LOW FLOW mode and flow rate is reduced (Step 578). Until the charging is complete, the system will now charge at the lower rate. Accordingly, charging is cycled on and off as pressure rises and falls within the charging port to the mold. When the mold is almost full, the rate of pressure increase exceeds a preselected value and the rate of charging is slowed. Finally, when the pressure fails to drop during the nondispensing mold, indicating that the mold is full, the charging cycle is

terminated. Total dispense quantity as the mold is filled can be monitored and the pressure controlled or profiled on a pre-determined basis to fill the mold as efficiently as possible. Such factors as material setting time, air evacuation, and void filling may be taken into account, as well as pressure.

In certain applications, such as low pressure painting, mold filling and other pressure maintenance applications, high pressures can be undesirable to disastrous. Progressive cavity pumps typically provide positive displacement with a high mechanical advantage that can create extremely high pressures. As the rate of pressure increase gets higher, the possibility for overshooting becomes correspondingly higher and, for example, low pressure molds can be damaged. Consequently, in applications requiring close pressure control, more sophisticated system controls are appropriate.

It is often desirable to maintain a given material delivery pressure rather than a specific flow rate. This may be beneficial for the application or simply as a means to avoid overpressure. This is true of paint spray applications as well as mold filling applications. In a typical mold filling application, material is delivered with a constant maximum available pressure throughout the cycle. When the mold is empty, a rather high flow rate is possible without exceeding this maximum pressure. As the mold fills, the maximum flow rate decreases as the back pressure of the material filling the mold increases as explained above.

A feedback loop may be employed through the pump control system to control the flow rate to a mold as a function of the pressure differential to maximize flow rate, minimize charging time, and maintain a given delivery pressure. The pressure differential is the difference between the desired pressure and the actual pressure. The loop is a straightforward PID (proportional, integral, derivative) loop. The pressure differential is used as the error term to determine the proper flow rate to maintain pressure. This loop is illustrated in FIG. 18 and the mechanism in FIGs. 13 or 16.

The pressure (Pa) is sampled (Step 580). The sampling occurs at the pump outlet which may be any point between the pump and the ultimate point of discharge. Appropriate factors responding to empirical observations based on the position of the pressure sensor can be incorporated. The pressure

differential (dP) is then computed (Step 581) by comparing the preselected target pressure (Pd) previously input into the system with the actual pressure (Pa), $dP_S = (Pd\text{-}Pa_S)$. The subscript s denotes successive samples.

The flow rate (Q), actually the rate at which the motor or motors are to be driven, is then calculated as a function of the differential pressure (Step 582). This is accomplished using the PID gains where:

G_p is the proportional gain,

G_i is the integral gain,

G_d is the derivative gain.

The flow (Q) is then calculated as follows:

$$Q = G_p \cdot dP_S + G_i \cdot (dP_S + dP_{S-1}) + G_d \cdot (dP_S - dP_{S-1}).$$

This calculation generates a flow rate (Q) which is then employed to set the controllers to establish pump speed (Step 583). Pump speed is achieved by pulse width modulation (PWM) through an amplifier to regulate motor torque. Feedback through an encoder provides speed control over the controller regulating torque.

The pump control system may provide virtual stall to the system. An attribute of many pumping systems which employ pressurized air for driving the pump provide a mode of operation where the pump is controlled by an output valve. The air pressure is not turned off during nonuse. Rather, a stall condition is established by back pressure in the pump outlet. When that back pressure rises to a level that the air pressure forces and the fluid pressure forces are equal, the pump stalls. The pump then remains in that condition until further demand is placed at the outlet by opening the valve. The pump then reinitiates operation until again stalled. This operation may not necessarily result in complete stoppage. Where viscous flow or greatly throttled flow is experienced, the back pressure can approach the complete stall point but allow slow continuing pump operation. This stall attribute of, for example, air driven pumps is advantageous in many applications.

A virtual stall pressure can be created for a progressive cavity pump which is otherwise able to deliver material at extremely high pressures. Motor torque is used as the sensed input. The motor controller(s) 30, 32 controlling

the motor(s) 39, 41 uses a micro controller to send torque commands to a pulse width modulation (PWM) amplifier that drives the motor(s) 39,41. An optical encoder(s) 38, 40 is associated with the motor(s) 39, 41 to sense motor position. Signals are sent back to the micro controller(s) of the motor controller(s) 30, 32. With this system, the micro controller(s) is able to control torque at any given speed.

To provide a virtual stall pressure to the pump(s) 34, 36 by measuring torque and speed, a table or curves establishing the relationships between torque and pressure at different speeds is used. A calibration scheme is employed to establish these relationships. The controller(s) 30, 32 is programmed to run the pump(s) 34, 36 at an appropriate operative velocity. With this velocity obtained, the output pressure of the pump(s) 34, 36 is adjusted. The torque is then read by the micro controller(s) at a number of pressure set points. To maintain a constant speed, the imposition of higher pressures creates greater torque demands on the motor. Effectively, a family of curves of torque vs. pressure are generated with each curve representing a different pump speed. Given a pump speed and the torque required to maintain that speed, output pressure may be determined from the table or curves. This calibration procedure is illustrated in FIG. 19 where a pump velocity is set (Step 584), a valve is positioned on the outlet from the pump to set operating pressure (Step 585) and the resulting torque is sensed (Step 586). From the foregoing, a torque profile is established (Step 587) to set maximum torque limits at specific speeds to act as a virtual stall pressure downloaded to the controller (Step 588).

Turning to the operation of the virtual stall system as illustrated in FIG. 20, speed is to be the constant until a stall condition is approached. The actual speed is compared with the target speed (Step 589). A PID algorithm is used to compute a torque command to a PWM amplifier (Step 590). This torque command is compared with the calibrated pressure based on the pump speed (Step 591). If the pressure would exceed the limit, the torque command is set at the limit (Step 592). If not, the torque command is unchanged and implemented (Step 593). The rate of torque change may also be used at Step 590 to assist in avoiding overpressure.

A final embodiment has been developed to provide a high flow rate of dispensing. In providing the higher rate, the dispense head 49 of the first embodiment is not employed. Rather, the devices of FIGs. 21 through 23 are substituted between the motors 39 and 41 and the static mixer tube 50. The static mixer tube 50 may also be reconfigured to accommodate the higher flow. The pump fluid lines 46 and 48 enter a housing 600. Ball valves 602 and 604 are positioned in the material inlets 46 and 48, respectively. The ball valves 602 and 604 include crank arms 606 and 608. These crank arms are coupled with a clevis 610. The clevis 610 is coupled with a pneumatic piston 612 which can move the clevis 610 in either direction. With movement of the clevis 610, the crank arms 606 and 608 pivot about the ball valves 602 and 604 to open and close same.

A releasably coupled manifold 613 receives the pump fluid lines 46 and 48 past the ball valves 602 and 604. The manifold 613 includes passages 614 and 616 through a block 618. The passage 614 is coupled with a tube 620 while the passage 616 is coupled with a tube 622. The tubes 620 and 622 are illustrated to be of substantially different diameter, contemplating the use of mixtures of paints with pigments and resins with accelerators, for example. The tube 620 is shown to extend to a concentric discharge within the tube 622. The use of a concentric discharge avoids the difficulty of having a high percentage of the smaller volume introduced remain unmixed at the wall of the larger tube. A poppet valve 624 is spring biased to the closed position such that only pressure within the tube 620 will allow communication between the tube 620 and 622. A mixer 50 may be appropriately employed downstream of the manifold 613. The mixer would be coupled in pressure communication with the tube 622.

While the invention is susceptible to various modifications and alternative forms, specific examples thereof have been shown by way of example in the drawings and are herein described in detail. It should be understood, however, that is not intended to limit the invention to the particular forms disclosed, but on the contrary, the invention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the following claims.

50418-2

CLAIMS:

1. A dispensing system comprising

a plurality of progressive cavity pumps;

a manifold assembly including an outlet and being in flow communication between the plurality of progressive cavity pumps and the outlet;

a valve assembly in the manifold assembly controlling flow communication between the plurality of progressive cavity pumps and the outlet;

a plurality of motors, each motor being coupled to a respective one of the plurality of progressive cavity pumps;

a mixer in the manifold assembly to mix the outputs of the plurality of progressive cavity pumps;

a controller in signal communication with a pressure sensor and with the plurality of motors, the controller being responsive to pressure input from a pressure sensor to control the motors based on the pressure sensed by the pressure sensor and on the pressure sensed by the pressure sensor as a function of time.

2. The dispensing system of claim 1, the manifold assembly including a conduit between the mixer and the outlet being resilient in the operating range of the progressive cavity pumps.

3. The dispensing system of claim 1, the outlet including a nozzle, the valve assembly including a valve and an actuating trigger controlling the valve and being adjacent the nozzle.

4. The dispensing system of claim 3 further comprising a source of compressed air in communication with the nozzle and controlled by the valve.

5. The dispensing system of claim 1, the motors being set to drive at preselected speed ratios by the controller.

6. The dispensing system of claim 1, the pressure sensor being in communication with the manifold assembly between the mixer and the outlet.

7. The dispensing system of claim 1, the controller having repetitive pressure sampling with the motors on or off, the controller having a motor START mode with the pressure at the pressure sensor below a preselected lower pressure and a motor STOP mode with the pressure at the pressure sensor above a preselected upper pressure.

8. The dispensing system of claim 7, the controller having a motor LOW FLOW mode with an increase in pressure above a preselected rate.

9. The dispensing system of claim 7, the controller having a timer and an END OF CYCLE mode activated at a preselected time beyond a last STOP mode.

10. The dispensing system of claim 9, the controller having a time OSCILLATION mode following the STOP mode, the OSCILLATION mode being with at least one of the progressive cavity pumps periodically cycling portions of a revolution backward and forward.

11. The dispensing system of claim 1, the controller including a preset target pressure, pump speed being controlled as a function of the differential pressure between actual pressure at the pressure sensor and the preset target pressure.

12. The dispensing system of claim 11, the controller further including a proportional integral derivative loop, pump output flow being controlled through the proportional integral derivative loop as a function of the differential pressure between actual pressure at the pressure sensor and the preset target pressure.

13. The dispensing system of claim 11, the controller further including a pulse width modulation amplifier in electrical communication with at least one of the motors, pump output flow being controlled through the pulse width modulation amplifier.

14. The dispensing system of claim 1, the controller including a torque control to at least one of the motors, a motion sensor on the at least one of the motors, a memory of motor torque versus pump output pressures for a plurality of motor speeds and a preset maximum pump output pressure, motor torque being limited by the controller at below the preset maximum pump output pressure as determined from the memory.

15. The dispensing system of claim 14, the motion sensor on the at least one of the motors being an encoder.

16. The dispensing system of claim 14, the torque control being a pulse width modulation amplifier.

17. A method for dispensing a mixture of materials from progressive cavity pumps driven by motors, respectively, through a valve-controlled manifold assembly to an outlet, comprising

repeatedly sampling pressure between one of the pumps and the outlet;

starting the motors when the sampled pressure approaches or falls below a preselected low pressure;

stopping the motors when the sampled pressure approaches or rises above a preselected high pressure; and

driving the motors at preselected proportional speeds responsive to the pressure sensed by a pressure sensor as a function of time.

18. The method of claim 17, further comprising

opening the valve-controlled manifold assembly independently of the sampled pressure; and

closing the valve-controlled manifold assembly independently of the sampled pressure.

19. The method of claim 17 further comprising periodically cycling the progressive cavity pumps with the valve-controlled manifold assembly closed, including rotating the progressive cavity pumps a partial turn in a first direction and rotating the progressive cavity pumps a partial turn in a second direction opposite to the first direction.

20. The method of claim 19 further comprising repeatedly measuring the sampled pressure with the valve-controlled manifold assembly closed, the first direction being backwards, the rotation of the progressive cavity pumps in the second direction being until a preselected pressure is reached.

21. The method of claim 20 further comprising

sensing the amount of forward rotation;

generating a signal when a forward displacement exceeds a preset amount.

22. The method of claim 17 further comprising seriatim periodically cycling the progressive cavity pumps with the valve-controlled manifold assembly closed, each cycle including measuring the sampled pressure a first time, rotating the progressive cavity pumps a partial turn in a first direction, rotating the progressive cavity pumps a partial turn in a second direction opposite to the first direction, measuring the sampled pressure a second time and comparing the second measurement of the sampled pressure with the first measurement of the sampled pressure, the rotation of the progressive cavity pumps said partial turn in the second direction including changing the amount of rotation in the second direction if the sampled pressure after rotation is different from the sampled pressure before rotation in a just prior cycle.

23. The method of claim 17 further comprising

driving the pumps;

mixing the pumped materials;

reducing the driving speed of the pumps when a rate of pressure increase of the mixed pump materials exceeds a preselected amount.

24. The method of claim 17 further comprising

controlling the speed of the progressive cavity pumps;

repeatedly sensing pressure of the output of the pumps;

storing a target pressure;

adjusting speed of the progressive cavity pumps as a function of the differential pressure between actual pressure of the pressure sensor and a preset target pressure.

25. The method of claim 24, the function being

$$Q = G_p \cdot dP_s + G_j \cdot (dP_s + dP_{s-1}) + G_d \cdot (dP_s - dP_{s-1})$$

where Q is flow rate of the pumps, G_p is the proportional gain, G_j is the integral gain, G_d is the derivative gain and dP_s is the differential between the target pressure and the actual pressure with the subscript s denoting successive pressure samples.

26. The method of claim 17 further comprising

inputting a preset pump speed to at least one of the pumps;

repeatedly sensing speed of the at least one pump;

repeatedly sensing torque driving the at least one pump;

comparing the sensed torque with a preset maximum value for the speed sensed;

limiting torque to the preset maximum value for the speed sensed;

calculating and establishing torque for the preset speed if below the preset maximum value.

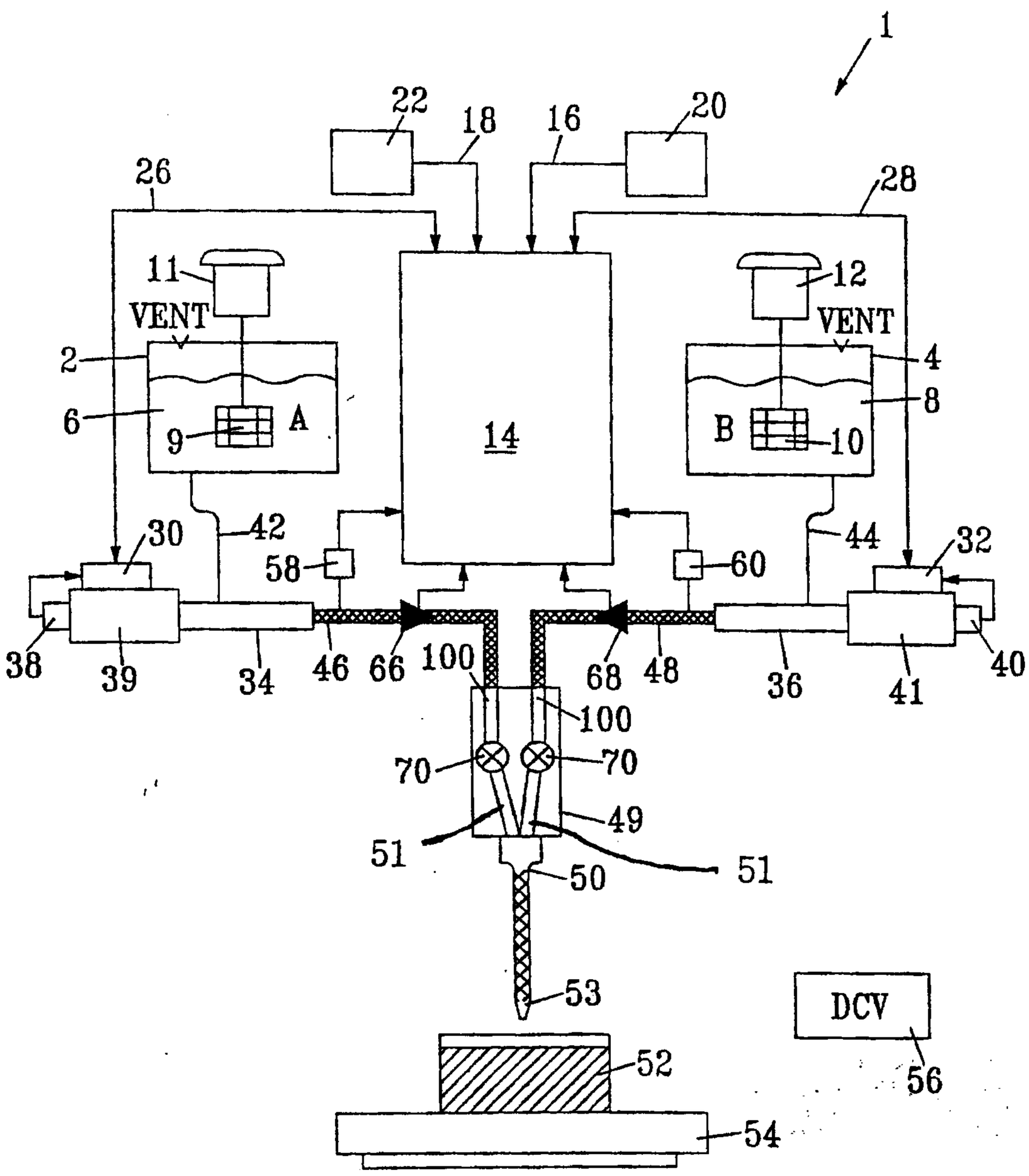
27. The method of claim 26 further comprising establishing preset maximum torque values for a range of pump speeds including for each speed running the at least

one pump at the speed, increasing the pump output pressure, sensing the resulting torque required and storing the torque versus pressure relationship for the speed.

SMART & BIGGAR

OTTAWA, CANADA

PATENT AGENTS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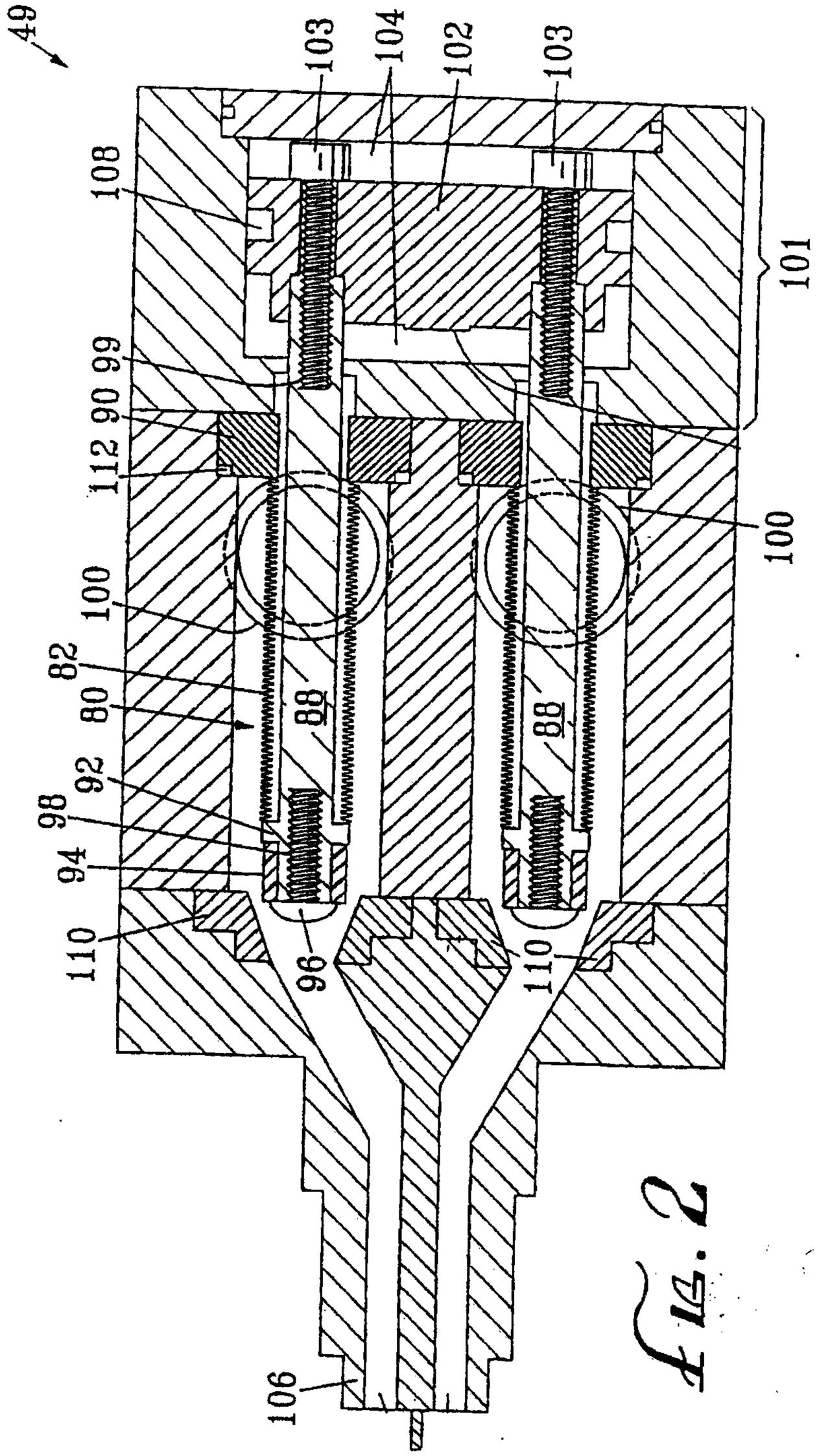
53
DCV
52
56
54

FIG. 1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103
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110
106

Fig. 2

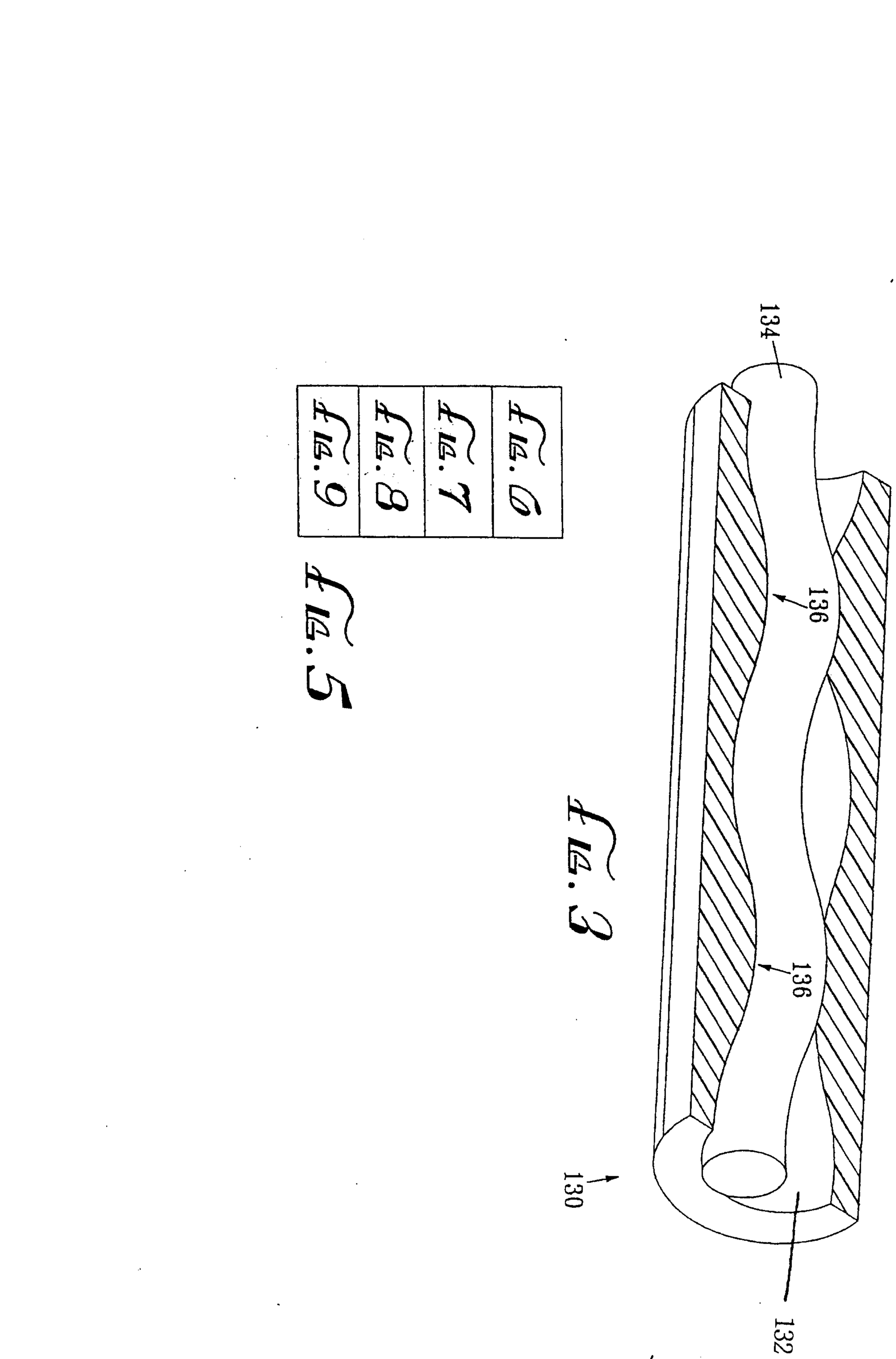

FIG. 3

FIG. 6	
FIG. 7	
FIG. 8	
FIG. 9	

FIG. 5

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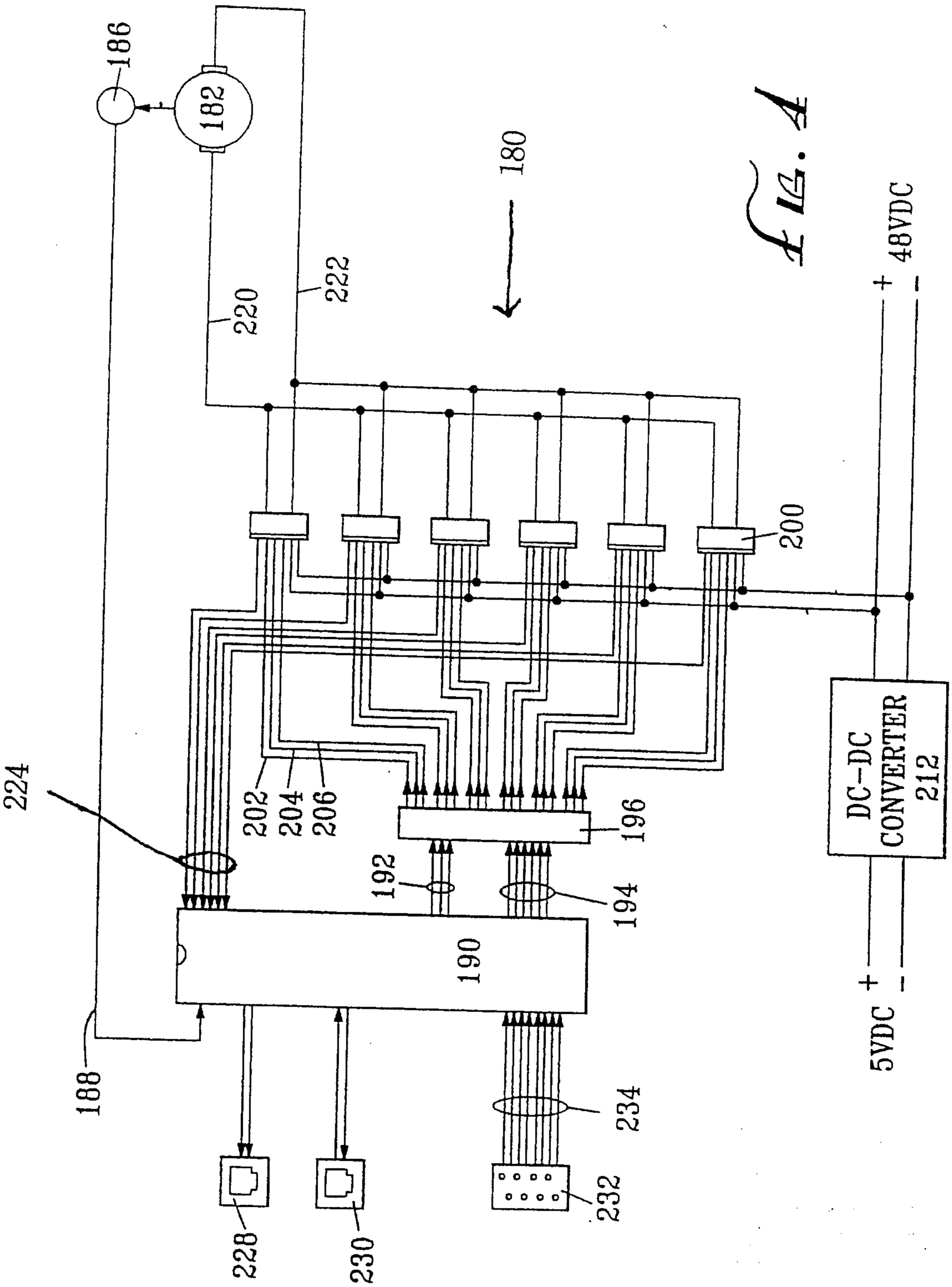

186
182
180
220
222
224
202
204
206
196
192
194
200
190
188
234
232
228
230
DC-DC CONVERTER 212
+ 48VDC
−
+ 5VDC
−

FIG. 4

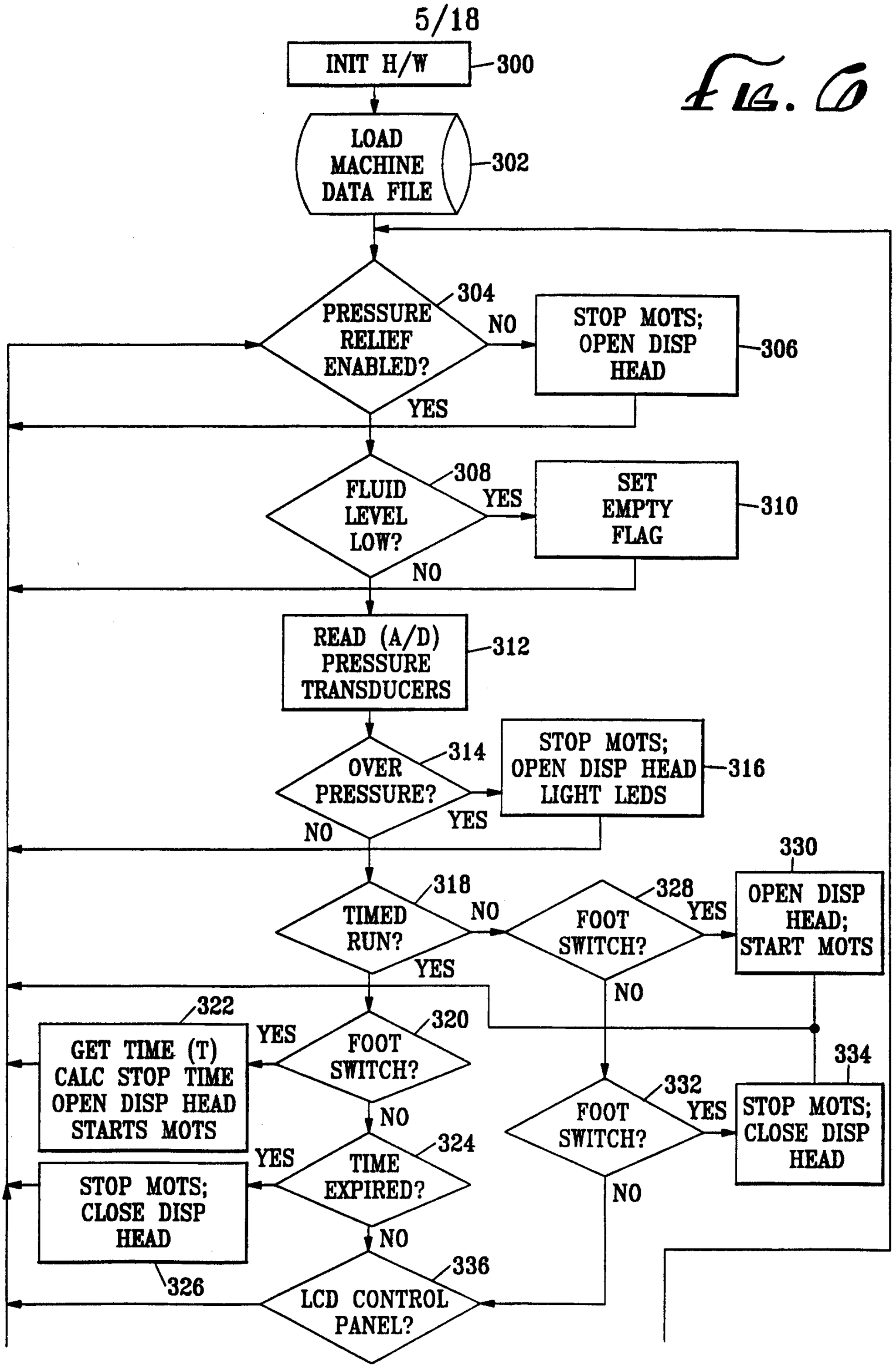

INIT H/W
300
LOAD MACHINE DATA FILE
302
PRESSURE RELIEF ENABLED?
304
NO
STOP MOTS; OPEN DISP HEAD
306
YES
FLUID LEVEL LOW?
308
YES
SET EMPTY FLAG
310
NO
READ (A/D) PRESSURE TRANSDUCERS
312
OVER PRESSURE?
314
YES
STOP MOTS; OPEN DISP HEAD LIGHT LEDS
316
NO
TIMED RUN?
318
NO
FOOT SWITCH?
328
YES
OPEN DISP HEAD; START MOTS
330
YES
GET TIME (T) CALC STOP TIME OPEN DISP HEAD STARTS MOTS
322
FOOT SWITCH?
320
NO
FOOT SWITCH?
332
YES
STOP MOTS; CLOSE DISP HEAD
334
NO
TIME EXPIRED?
324
YES
STOP MOTS; CLOSE DISP HEAD
326
NO
LCD CONTROL PANEL?
336

FIG. 6

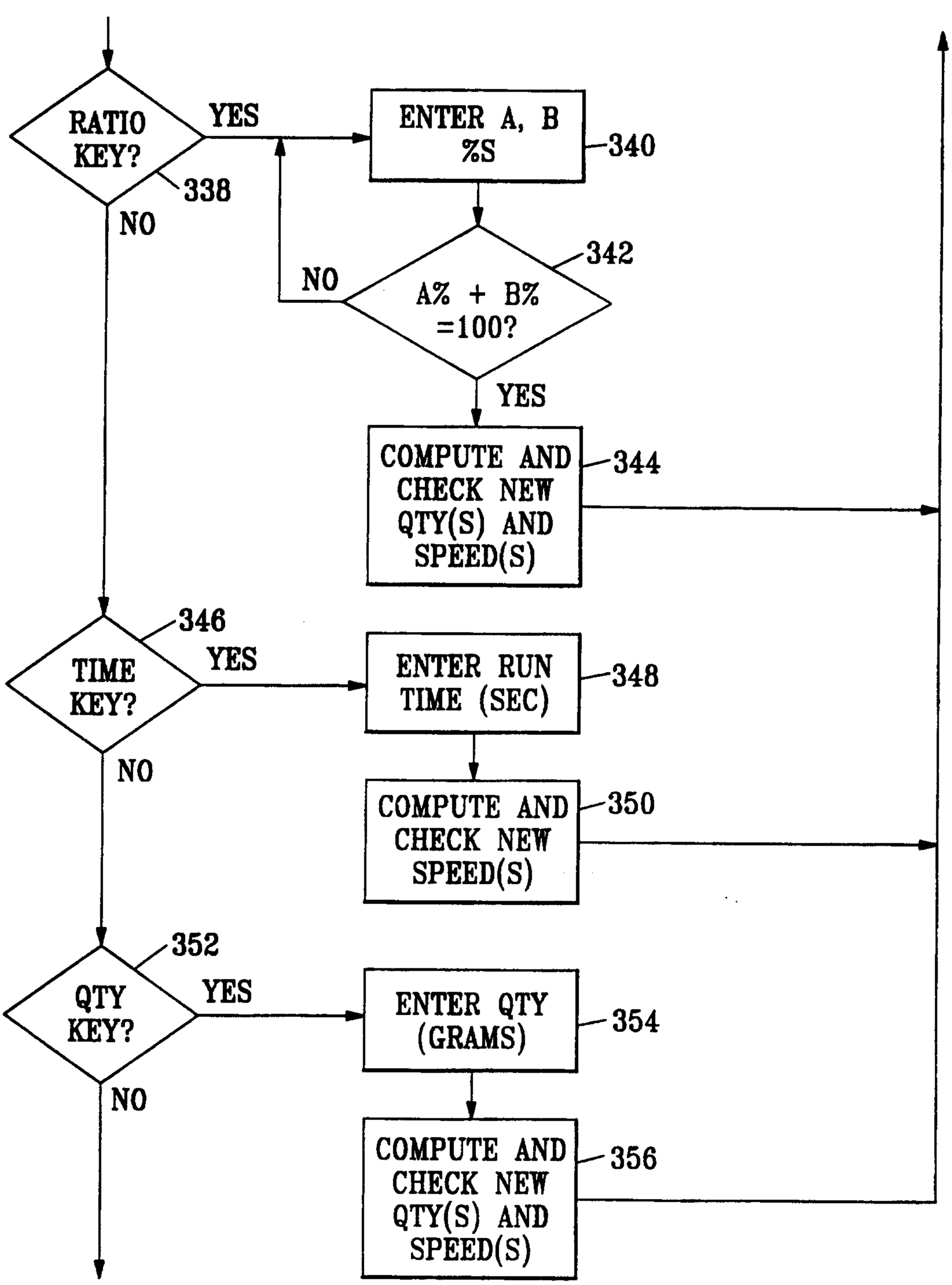

RATIO KEY?
YES
NO
338
ENTER A, B %S
340
A% + B% =100?
342
NO
YES
COMPUTE AND CHECK NEW QTY(S) AND SPEED(S)
344
TIME KEY?
346
YES
NO
ENTER RUN TIME (SEC)
348
COMPUTE AND CHECK NEW SPEED(S)
350
QTY KEY?
352
YES
NO
ENTER QTY (GRAMS)
354
COMPUTE AND CHECK NEW QTY(S) AND SPEED(S)
356

FIG. 7

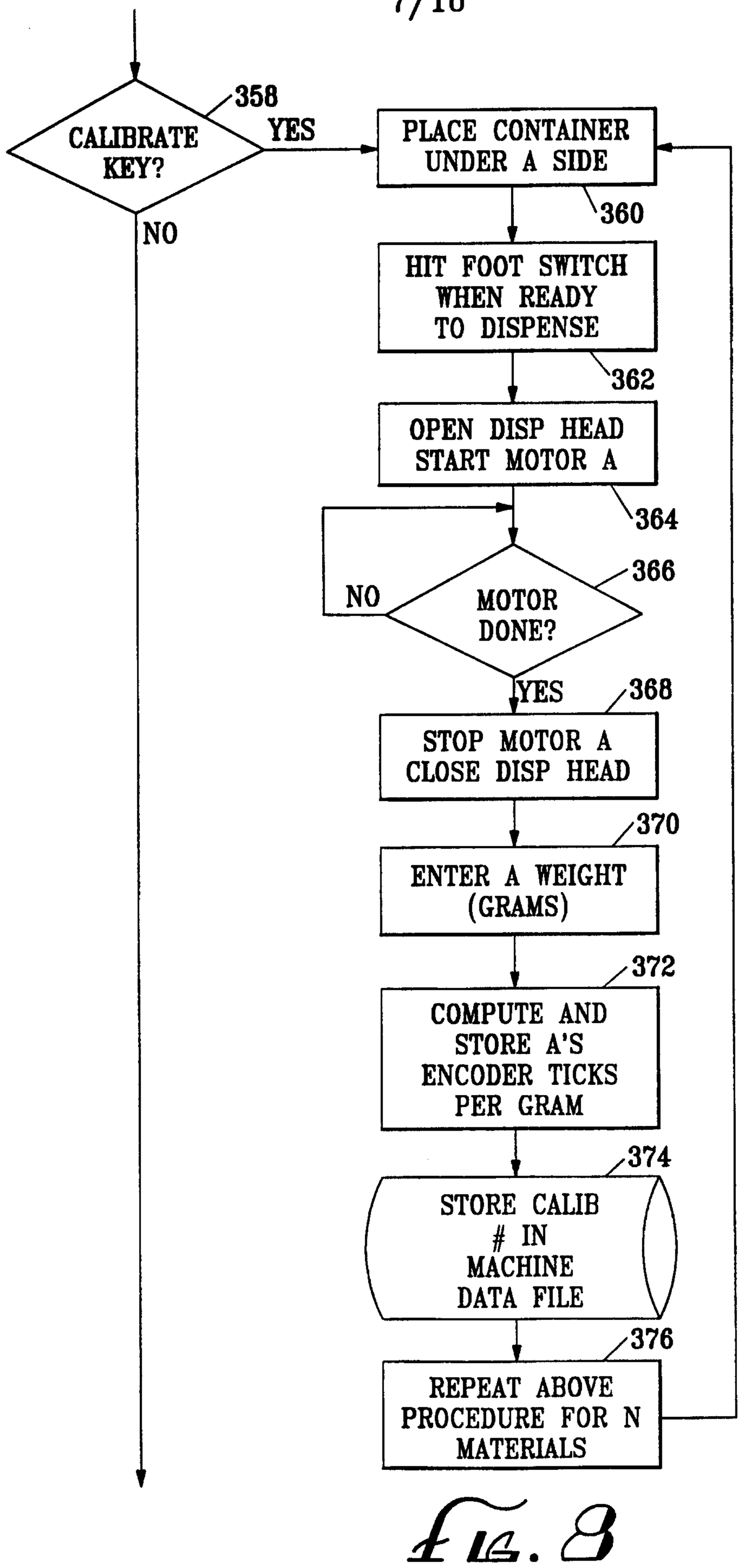

CALIBRATE KEY?
358
YES
NO
PLACE CONTAINER UNDER A SIDE
360
HIT FOOT SWITCH WHEN READY TO DISPENSE
362
OPEN DISP HEAD START MOTOR A
364
MOTOR DONE?
366
NO
YES
368
STOP MOTOR A CLOSE DISP HEAD
370
ENTER A WEIGHT (GRAMS)
372
COMPUTE AND STORE A'S ENCODER TICKS PER GRAM
374
STORE CALIB # IN MACHINE DATA FILE
376
REPEAT ABOVE PROCEDURE FOR N MATERIALS

FIG. 8

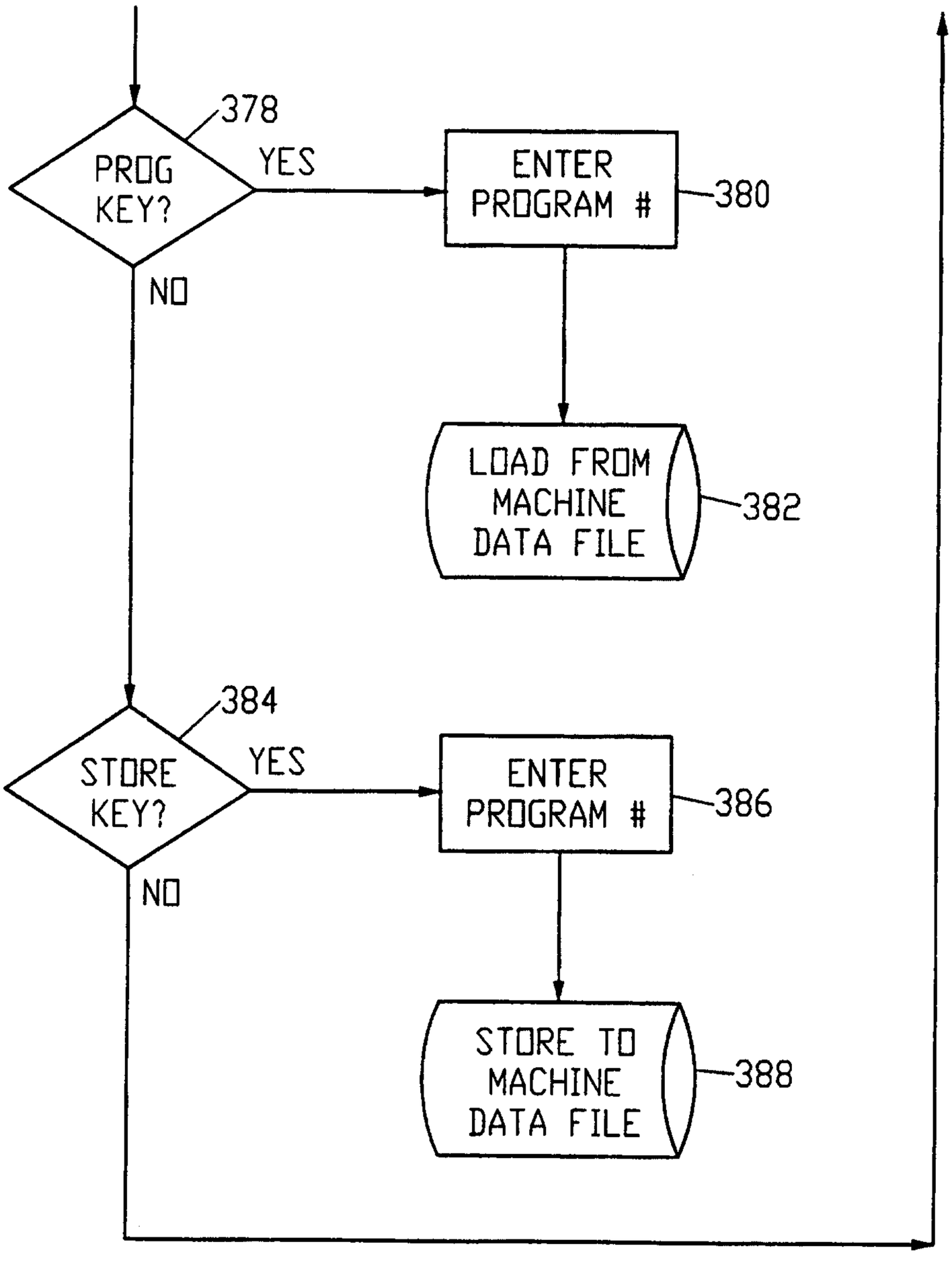

PROG KEY?
378
YES
NO
ENTER PROGRAM #
380
LOAD FROM MACHINE DATA FILE
382
STORE KEY?
384
YES
NO
ENTER PROGRAM #
386
STORE TO MACHINE DATA FILE
388

FIG. 9

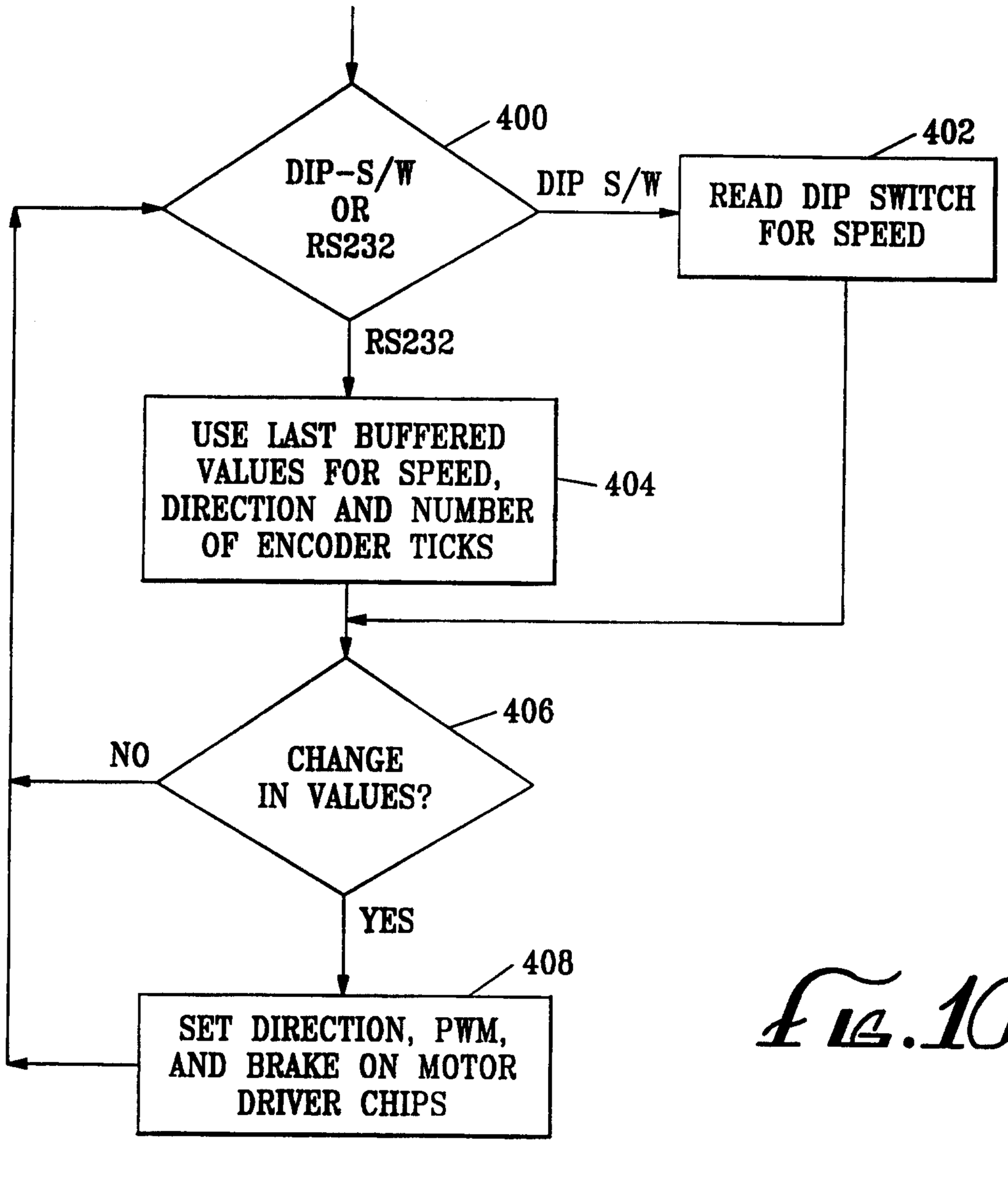

400
DIP-S/W
OR
RS232
DIP S/W
402
READ DIP SWITCH
FOR SPEED
RS232
USE LAST BUFFERED
VALUES FOR SPEED,
DIRECTION AND NUMBER
OF ENCODER TICKS
404
406
NO
CHANGE
IN VALUES?
YES
408
SET DIRECTION, PWM,
AND BRAKE ON MOTOR
DRIVER CHIPS

FIG. 10

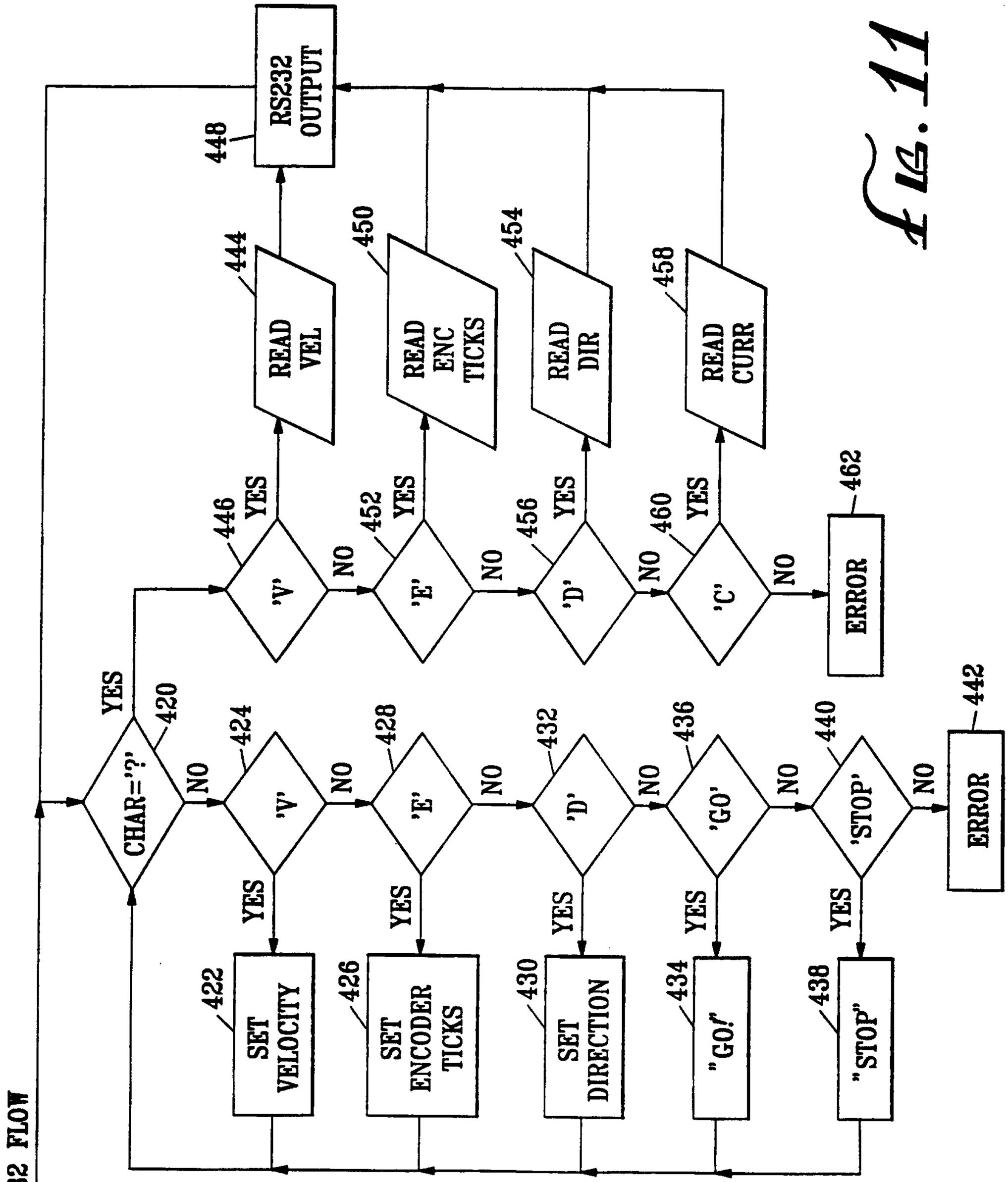

RS232 FLOW
CHAR='?'
YES
NO
420
'V'
424
'E'
428
'D'
432
'GO'
436
'STOP'
440
ERROR
442
SET VELOCITY
422
SET ENCODER TICKS
426
SET DIRECTION
430
"GO!"
434
"STOP"
438
'V'
446
'E'
452
'D'
456
'C'
460
ERROR
READ VEL
444
READ ENC TICKS
450
READ DIR
454
READ CURR
458
RS232 OUTPUT
448

Fig. 11

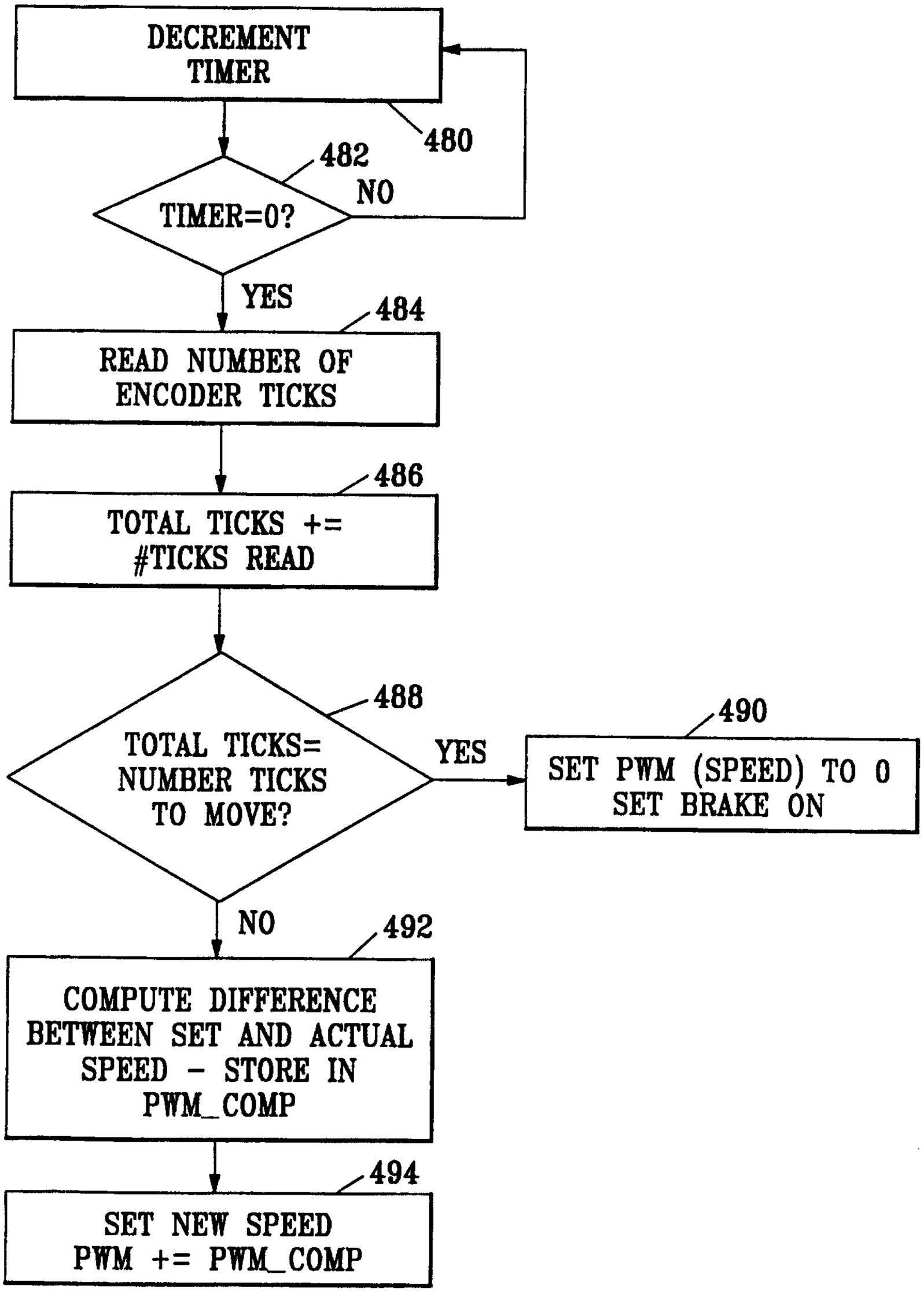
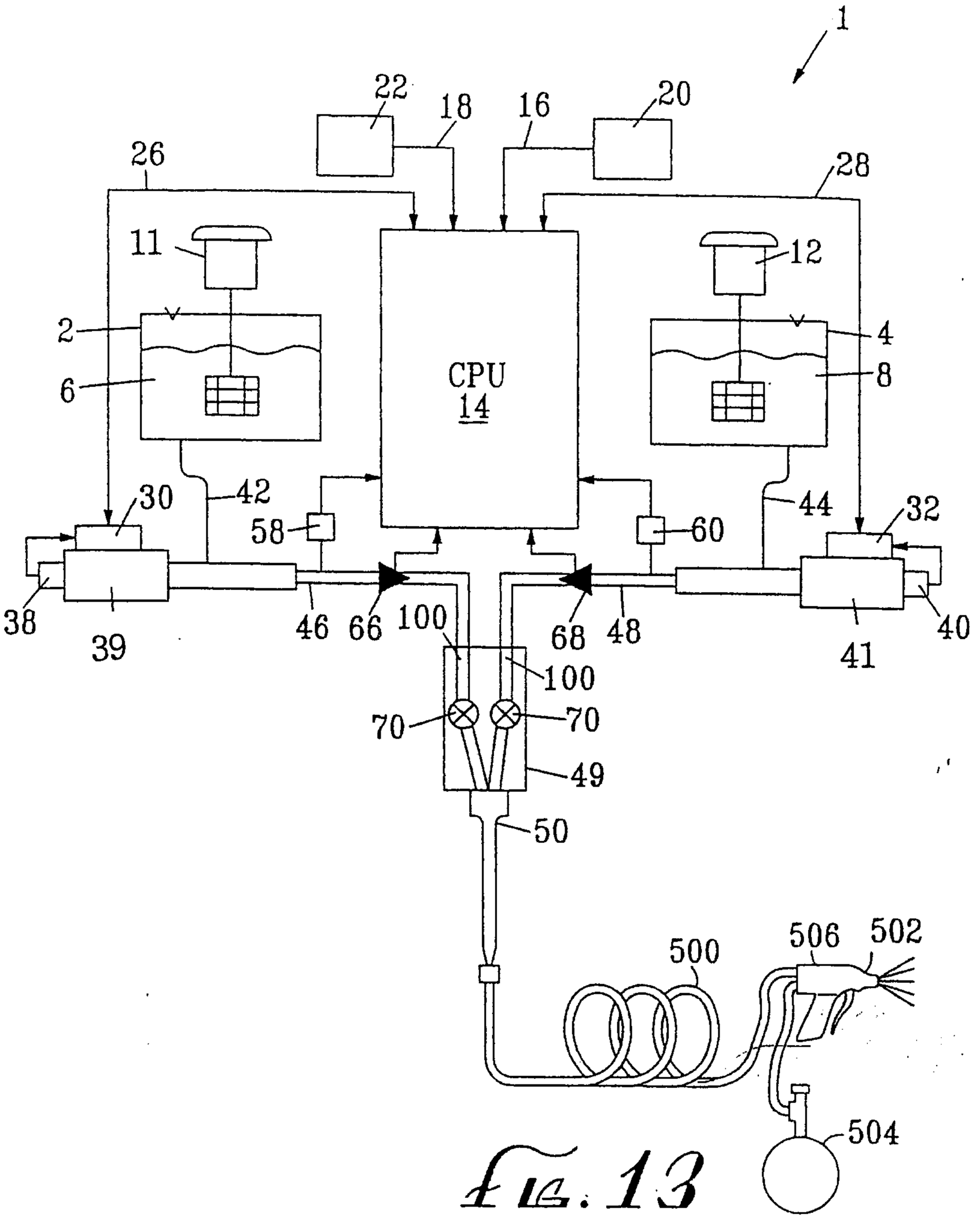

DECREMENT TIMER
480
482
TIMER=0?
NO
YES
484
READ NUMBER OF ENCODER TICKS
486
TOTAL TICKS += #TICKS READ
488
TOTAL TICKS= NUMBER TICKS TO MOVE?
YES
490
SET PWM (SPEED) TO 0
SET BRAKE ON
NO
492
COMPUTE DIFFERENCE BETWEEN SET AND ACTUAL SPEED - STORE IN PWM_COMP
494
SET NEW SPEED
PWM += PWM_COMP

FIG. 12


1
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CPU
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30
42
44
32
58
60
38
39
46
66
100
68
48
41
40
100
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70
49
50
500
506
502
504

Fig. 13

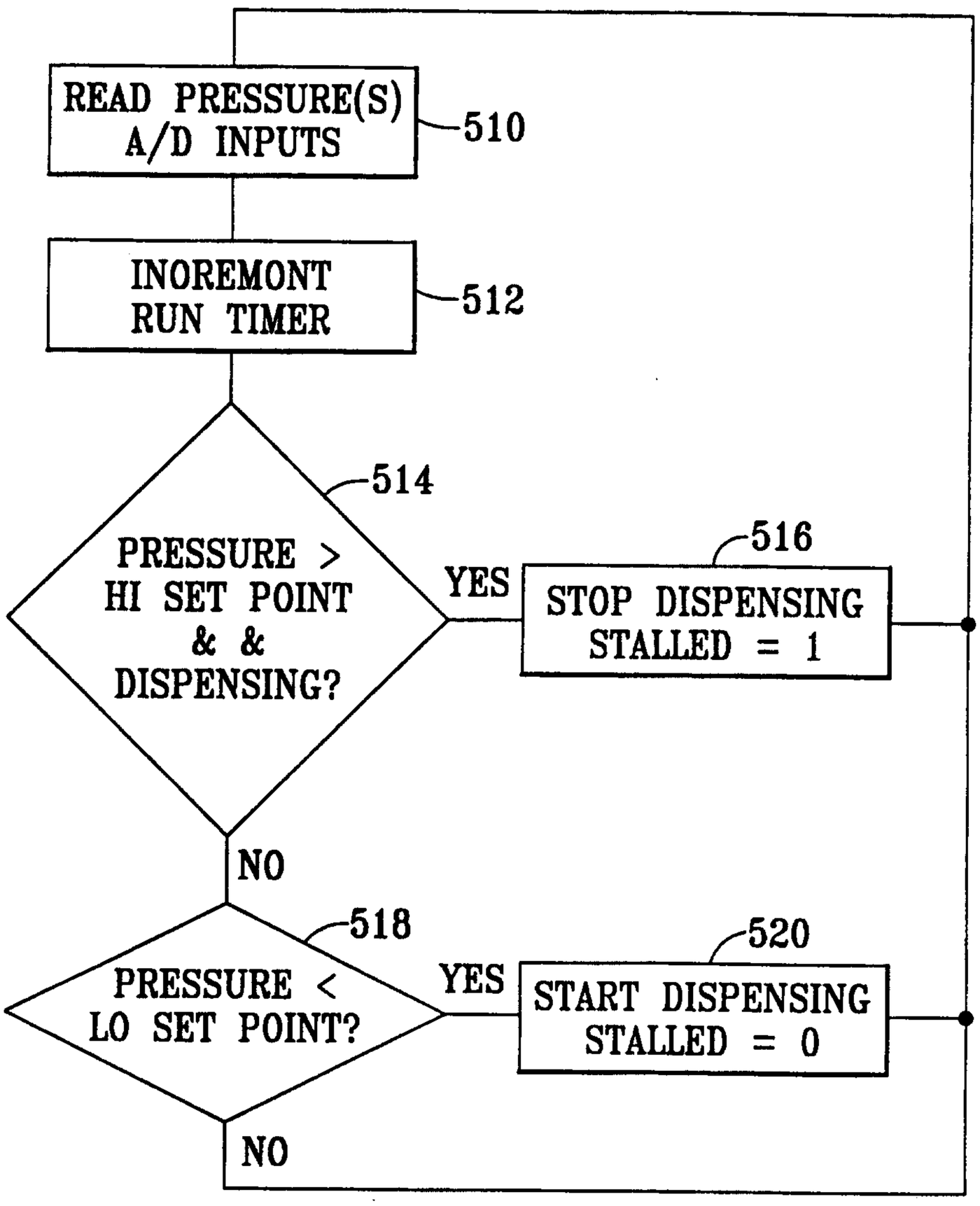

READ PRESSURE(S)
A/D INPUTS
510
INOREMONT
RUN TIMER
512
514
PRESSURE >
HI SET POINT
& &
DISPENSING?
YES
516
STOP DISPENSING
STALLED = 1
NO
518
PRESSURE <
LO SET POINT?
YES
520
START DISPENSING
STALLED = 0
NO

FIG. 14

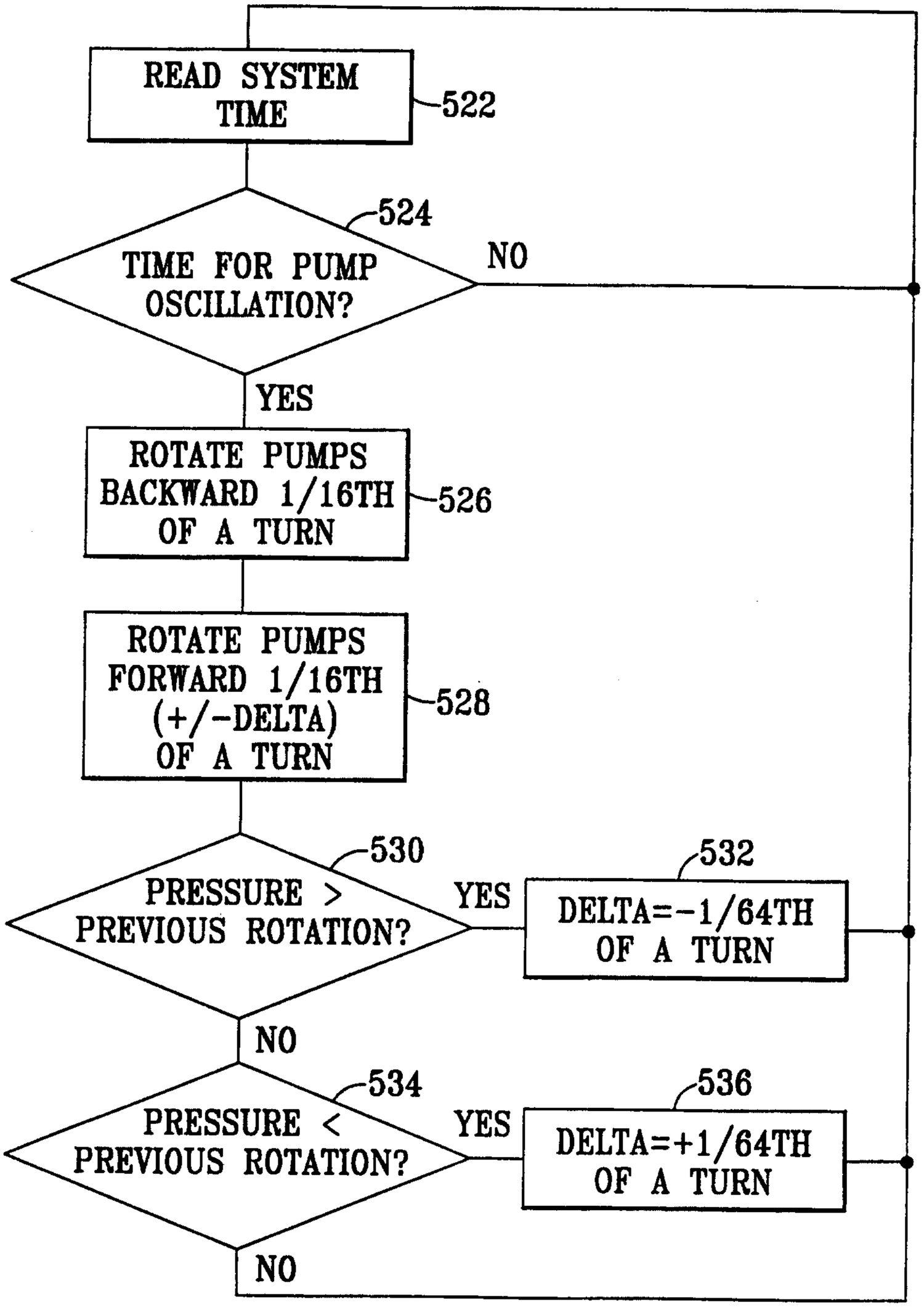
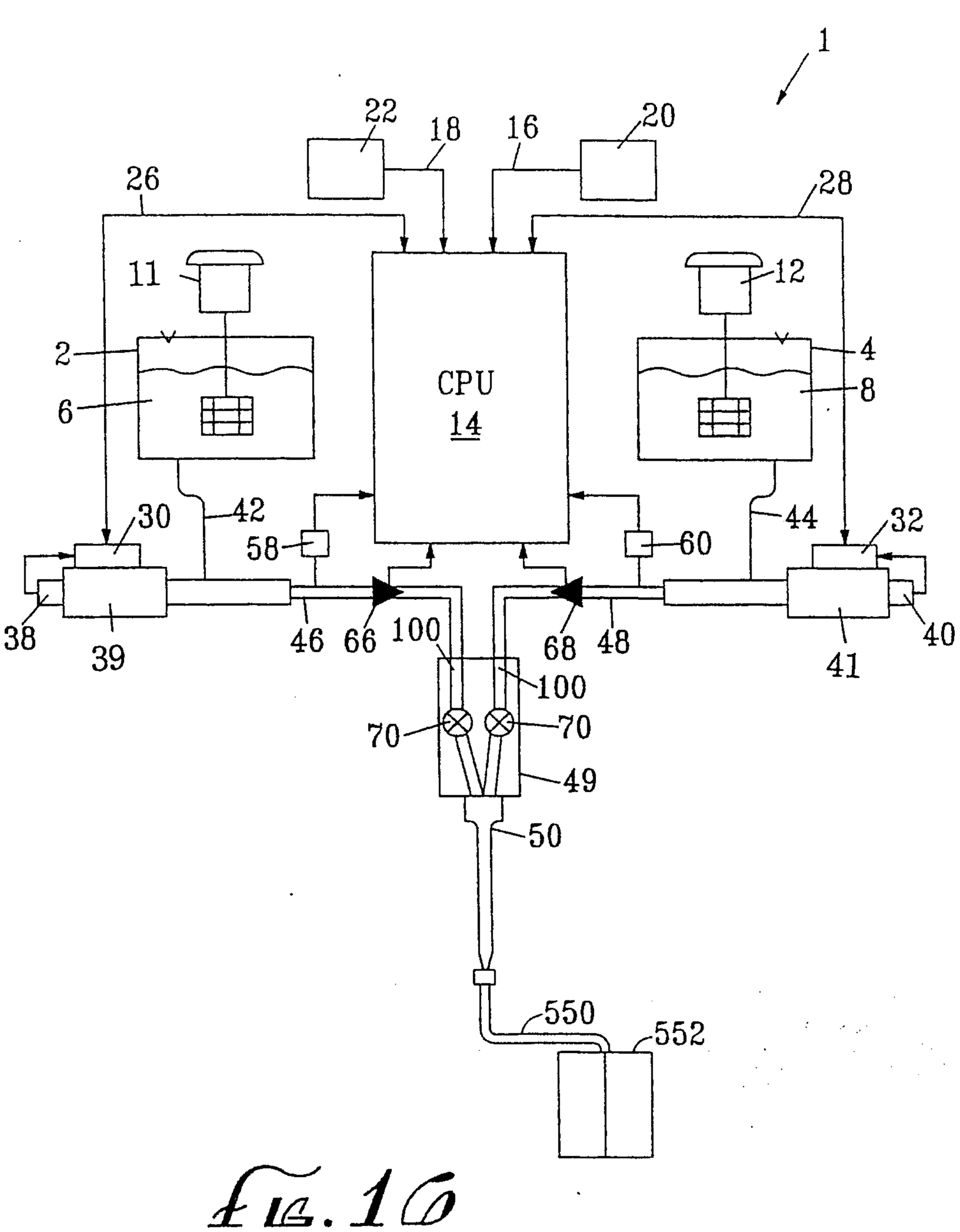

READ SYSTEM TIME
522
524
TIME FOR PUMP OSCILLATION?
NO
YES
ROTATE PUMPS BACKWARD 1/16TH OF A TURN
526
ROTATE PUMPS FORWARD 1/16TH (+/-DELTA) OF A TURN
528
530
PRESSURE > PREVIOUS ROTATION?
YES
532
DELTA=-1/64TH OF A TURN
NO
534
PRESSURE < PREVIOUS ROTATION?
YES
536
DELTA=+1/64TH OF A TURN
NO

FIG. 15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100
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100
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70
49
50
550
552

Fig. 16

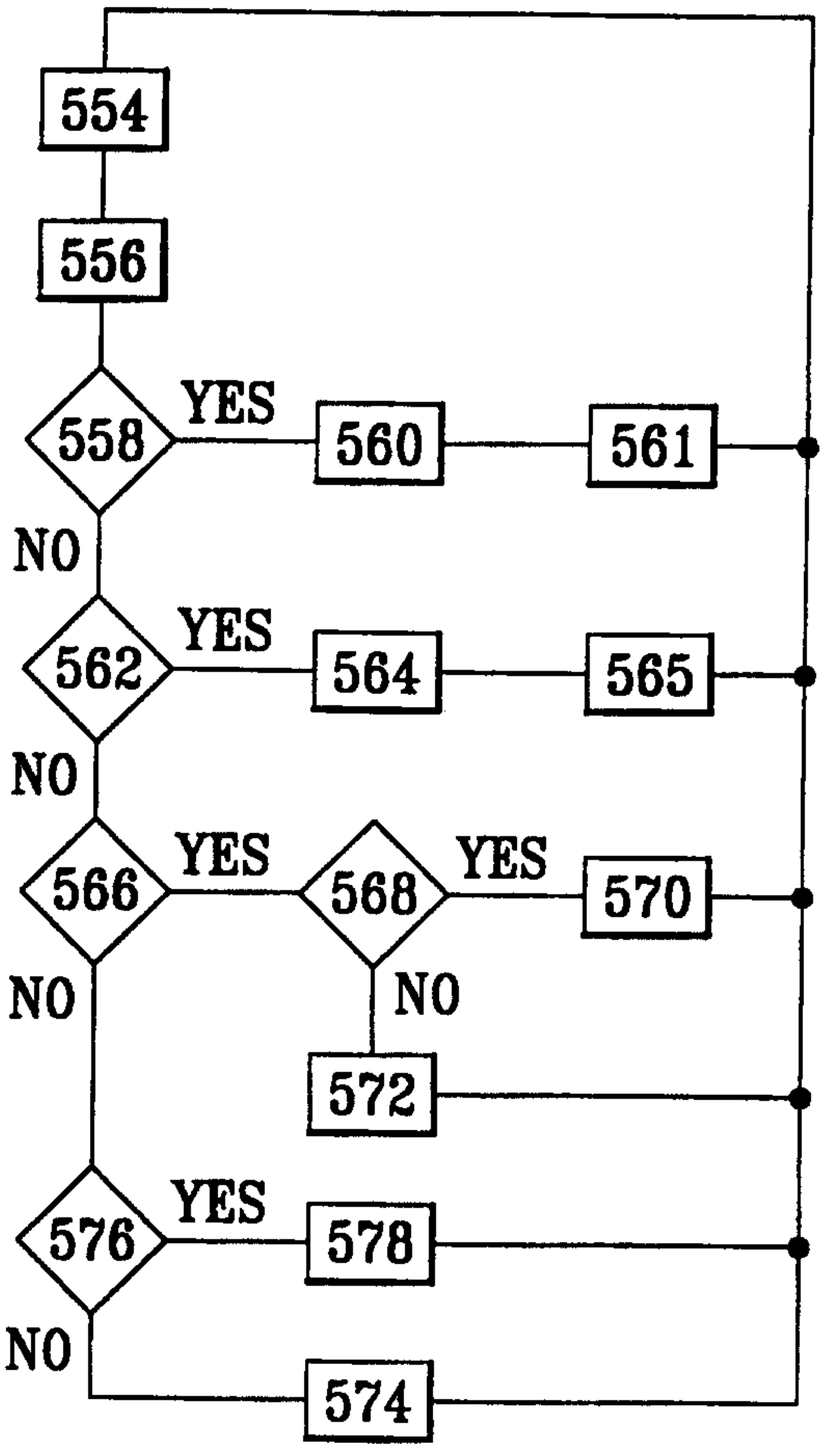

554
556
558
YES
560
561
NO
562
YES
564
565
NO
566
YES
568
YES
570
NO
NO
572
576
YES
578
NO
574

FIG. 17

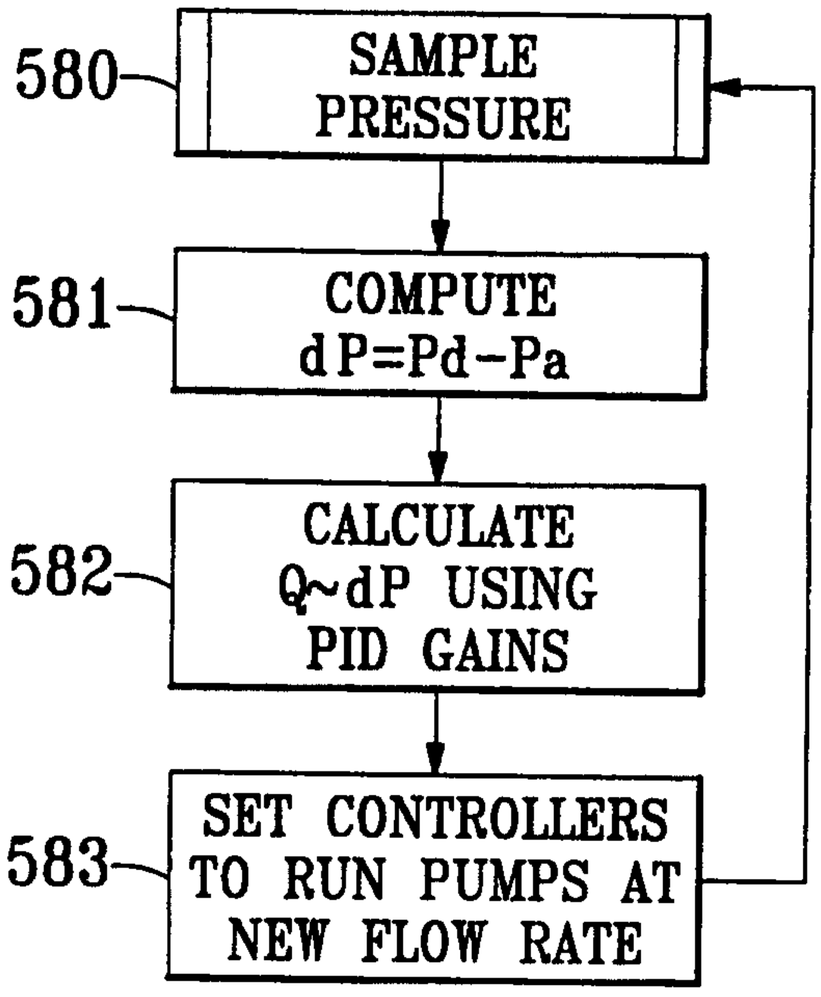

580
SAMPLE PRESSURE
581
COMPUTE dP=Pd-Pa
582
CALCULATE Q~dP USING PID GAINS
583
SET CONTROLLERS TO RUN PUMPS AT NEW FLOW RATE

FIG. 18

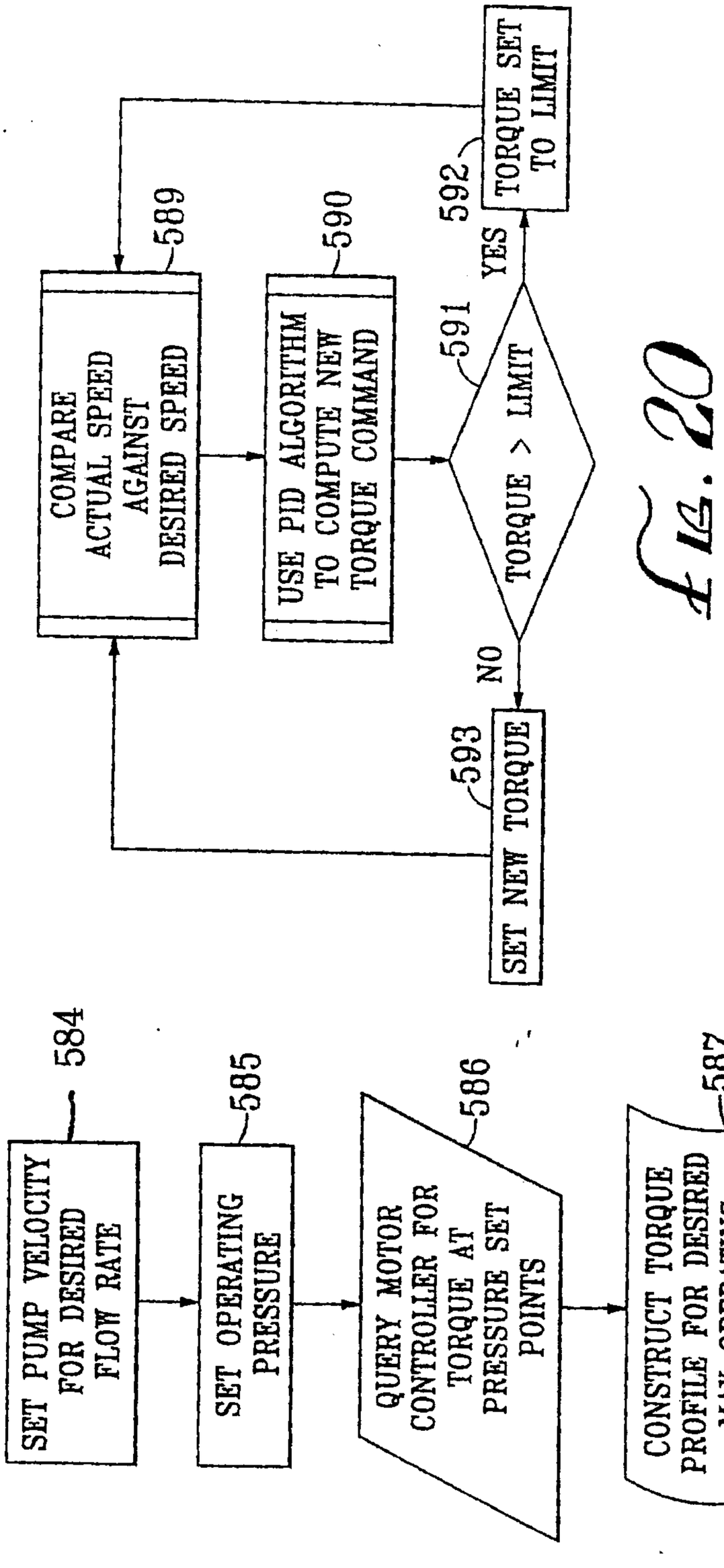

SET PUMP VELOCITY FOR DESIRED FLOW RATE
584
SET OPERATING PRESSURE
585
QUERY MOTOR CONTROLLER FOR TORQUE AT PRESSURE SET POINTS
586
CONSTRUCT TORQUE PROFILE FOR DESIRED MAX OPERATING PRESSURE
587
DOWNLOAD TORQUE PROFILE TO CONTROLLER
588
COMPARE ACTUAL SPEED AGAINST DESIRED SPEED
589
USE PID ALGORITHM TO COMPUTE NEW TORQUE COMMAND
590
TORQUE > LIMIT
591
YES
NO
TORQUE SET TO LIMIT
592
SET NEW TORQUE
593

Fig. 19

Fig. 20

FIG. 21

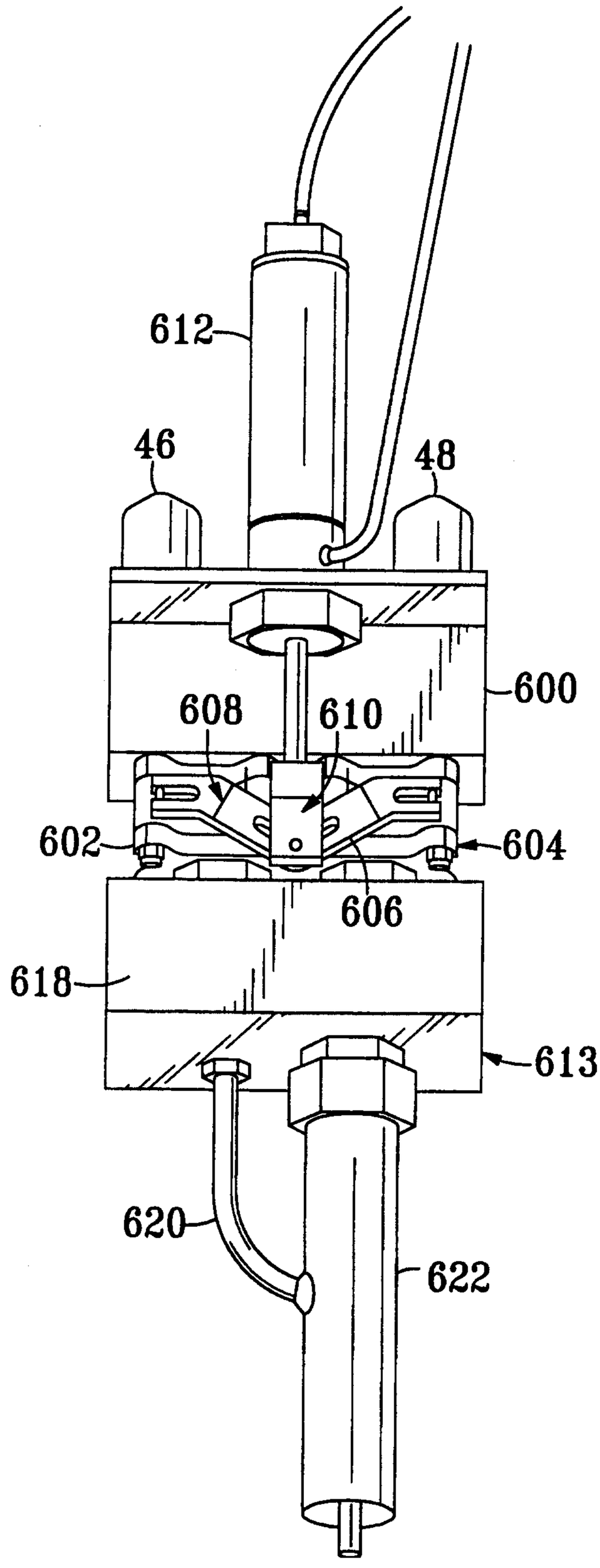


FIG. 22

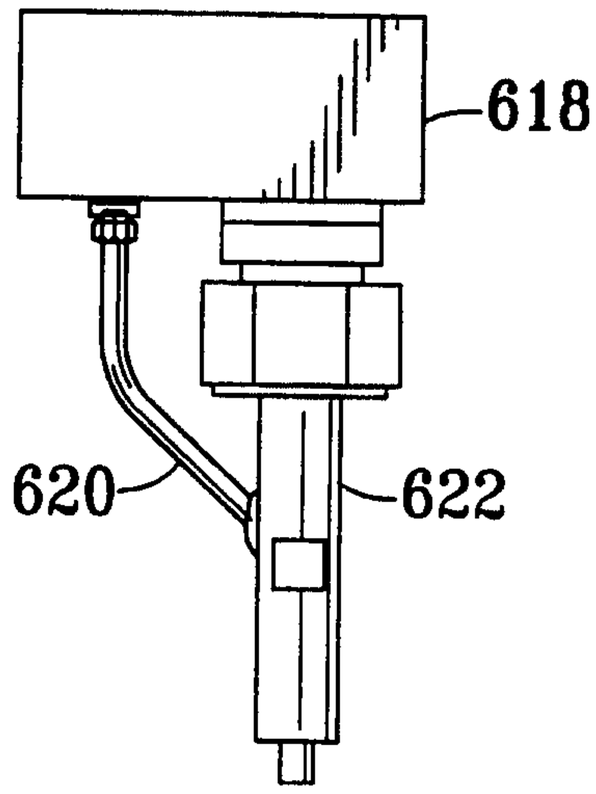
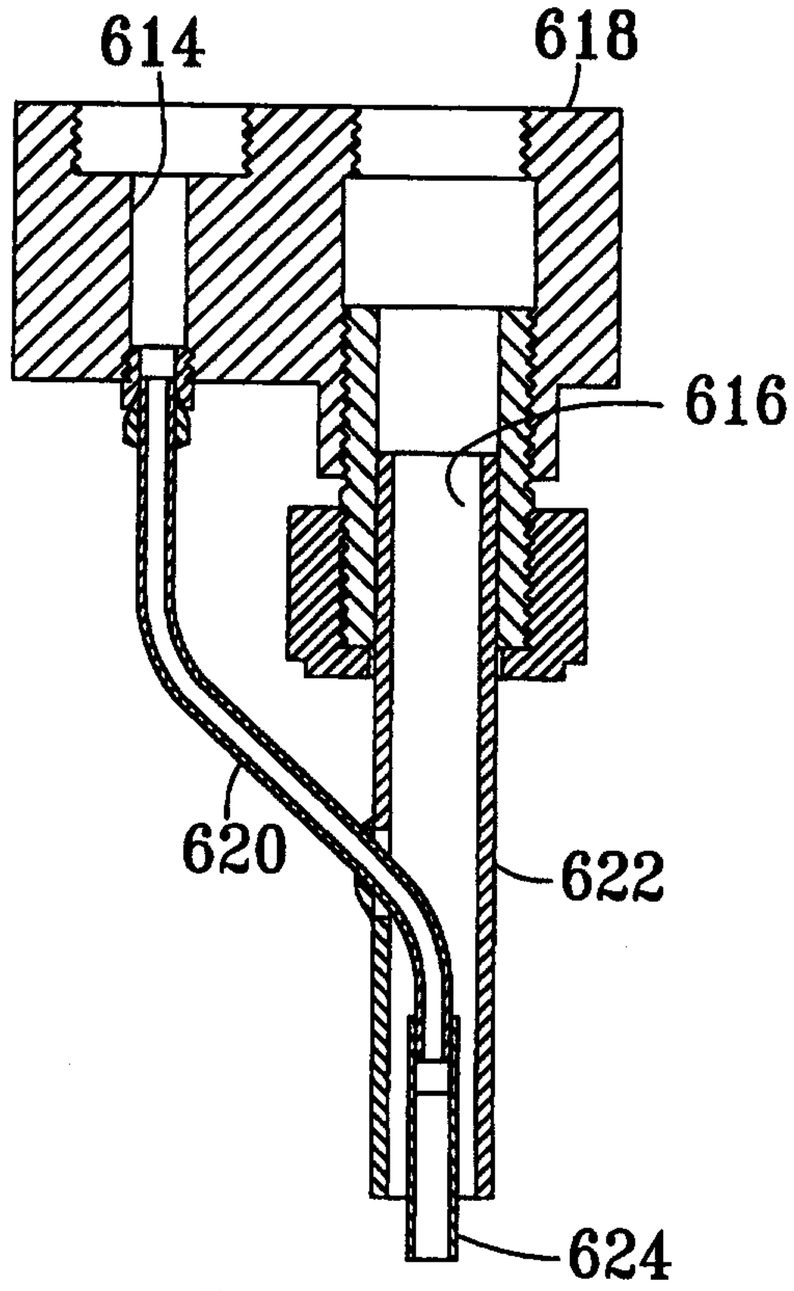
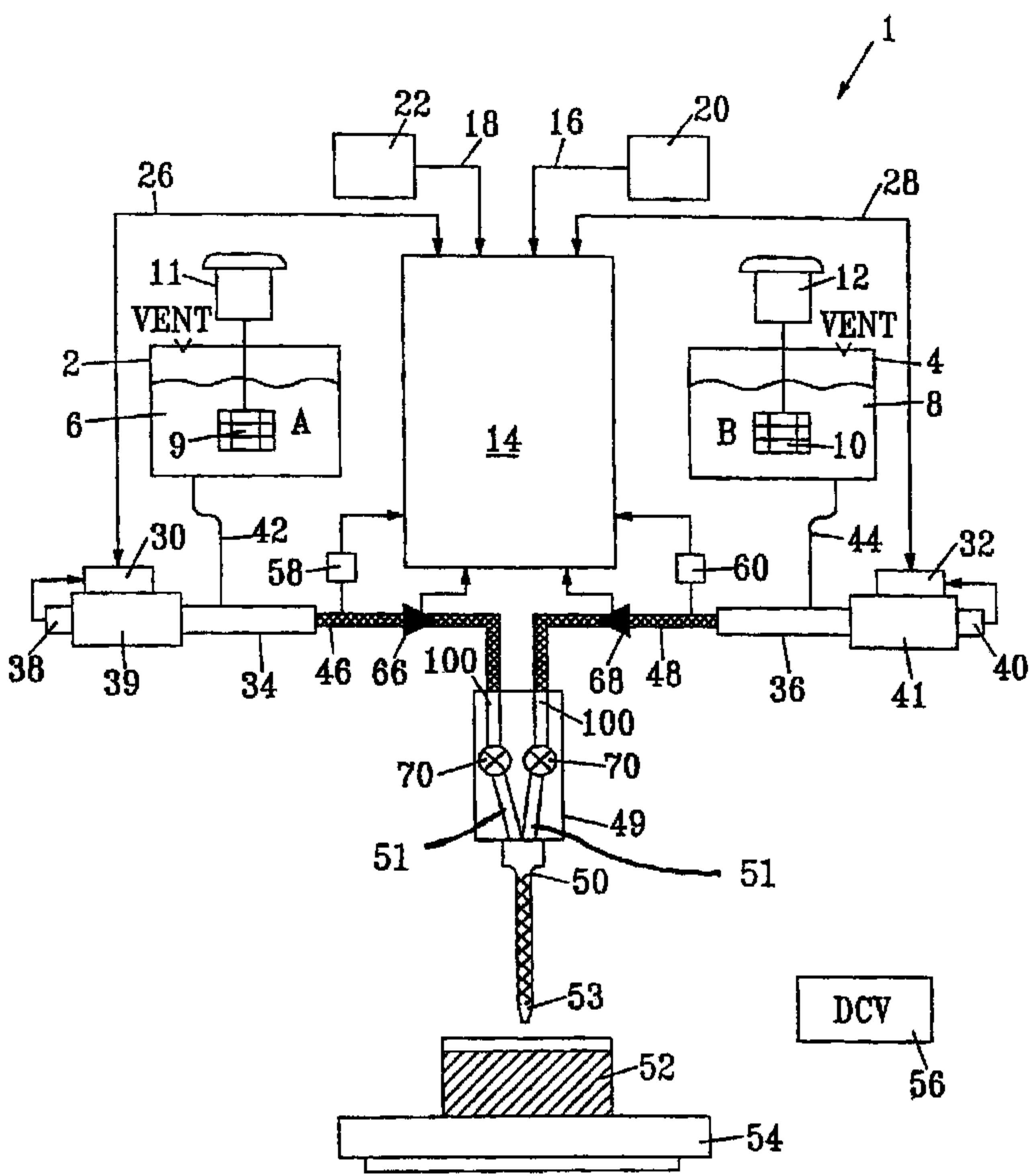


FIG. 23

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