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Section 29

AUSTRALIA 670314

Patents Act 1990

PATENT REQUEST: STANDARD PATENT/PATENT OF ADDITION

We, being the person(s) identified below as the Applicant, request the grant of a patent to the person identified below as the Nominated Person, for an invention described in the accompanying standard complete specification.

Full application details follow.

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[54] Invention Title: A VAPOR RECOVERY FUEL DISPENSER

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BASIC CONVENTION APPLICATION(S) DETAILS

[31] Application Number	[33] Country	Country Code	[32] Date of Application
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Drawing number recommended to accompany the abstract ....

GILBARCO INC.
By our Patent Attorneys
WATERMARK PATENT & TRADEMARK ATTORNEYS

.... 22 May 1995.

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AUSTRALIA

Patents Act 1990

NOTICE OF ENTITLEMENT

We, GILBARCO INC, of 7300 W Friendly Avenue, Greensboro NC 27420, UNITED STATES OF AMERICA, being the applicant in respect of Application No. 47335/93 state the following:-

The Person nominated for the grant of the patent has entitlement from the actual inventors as the inventors are employees of the nominated person and the invention was made in the course of their normal duties.

The person nominated for the grant of the patent has entitlement from the applicants of the basic applications listed on the patent request form as the applicants are employees of the nominated person and the invention was made in the course of their normal duties.

The basic application listed on the request form is the first application made in a Convention country in respect of the invention.

By our Patent Attorneys,
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5 December 1995

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A VAPOR RECOVERY FUEL DISPENSER

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(56) Prior Art Documents
US 5038838
US 5040577
AU 51667/93 B67D 5/37 5/378

(57) Claim

1. A vapor recovery fuel dispenser comprising:

a fuel pump driven by a first motor for pumping fuel from a reservoir along a delivery line to an outlet;

a vapor pump driven by a second motor for returning fuel vapors from proximate the fuel outlet along a vapor return line to a repository; and

control means for receiving electrical signals relating to the operation of the dispenser and controlling the dispensing of fuel and recovery of fuel vapor in dependence on the received signals characterised in that the control means comprises means for disabling the recovery of vapor in response to detecting an error condition within the ~~dispenser.~~ component parts of the dispenser.

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AUSTRALIA

Patents Act 1990

ORIGINAL
COMPLETE SPECIFICATION
STANDARD PATENT

Application Number:
Lodged:

Invention Title: A VAPOR RECOVERY FUEL DISPENSER

The following statement is a full description of this invention, including the best method of performing it known to US :-

A VAPOR RECOVERY FUEL DISPENSER

The present invention relates to improvements in vapor recovery fuel dispensers, particularly those with positively driven vapor pumps.

The primary purpose of using a vapor recovery fuel dispenser is to retrieve or recover the vapors which would otherwise be emitted to the atmosphere during a fueling operation, particularly for motor vehicles.

The traditional vapor recovery apparatus is known as the "balance" system, in which a sheath or boot encircles the liquid fueling nozzle and connects with tubing back to the fuel reservoir. As the liquid enters the tank, the vapor is forced into the sheath and back toward the fuel reservoir where the vapors can be stored or recondensed.

Balance systems have numerous drawbacks, including cumbersomeness, difficulty of use, ineffectiveness when seals are poorly made, and slowed fueling rates.

To improve on the balance systems, Gilbarco, Inc., assignee of the present invention, patented an improved vapor recovery system for fuel dispensers, U.S. Patent 5,040,577, the content of which is herein incorporated by way of reference. This patent discloses vapoı recovery apparatus in which a vapor pump is introduced in the vapor return line, driven by a motor. The fuel pump includes a pulser, conventionally used for generating pulses indicative of the amount of fuel being pumped. A microprocessor translates the pulses indicative of the flow rate into a desired vapor pump operating rate. This permits the vapor to be pumped at a rate correlated with the fuel flow rate so that, as the fuel is pumped faster, vapor is also pumped faster, and vice versa. This also enables the relative rates of the two pumps to be adjusted, for example to take into account temperature variations between the fuel being delivered and the vapor returned.

Although offering significant advantages over prior systems, it has been realised that in the system disclosed in US Patent 5,040,577, because the vapor recovery pump is not mechanically linked to the fuel pump of the dispenser, it is possible that in the event of a malfunction in the dispenser, the vapor return system may be operative while no fuel is being dispensed. If this situation is sustained for any period of time then the vapor/air mixture in the storage tank, to which the vapor is returned, becomes diluted and can become potentially explosive.

According to a first aspect of the present invention there is provided a vapor recovery fuel dispenser comprising:

a fuel pump driven by a first motor for pumping fuel from a reservoir along a delivery line to an outlet;

a vapor pump driven by a second motor for returning fuel vapors from proximate the fuel outlet along a vapor return line to a repository; and

control means for receiving signals relating to the operation of the dispenser and controlling the dispensing of fuel and recovery of fuel vapor in dependence thereon, characterised in that the control means comprises means for disabling the recovery of vapor in response to detecting an error condition within the dispenser.

A dispenser in accordance with the first aspect of the invention prevents excess air being drawn in if a fault develops in the dispenser.

Preferably the control means: is operably interposed between the fuel pump and the vapor pump; monitors when both pumps are operating; and disables operation of the vapor pump when the operation of fuel pump is not detected. This prevents vapor being recovered whilst the fuel pump is inactive.

In a dispenser employing a plurality of fuel pumps it is advantageous that the control means monitors the plurality of fuel pumps, fuel pump operation being detected if operation of any one of the fuel pumps is detected.

Preferably the control means combines signals from the plurality of fuel pumps in exclusive OR gates to derive a single signal indicative of operation of any of the fuel pumps and compares the single signal indicative of operation of the vapor pump and the single signal indicative of operation of the fuel pumps and disables operation of the dispenser if the two signals disagree for a period of time in excess of a threshold. This prevents a "run-away" vapor pump diluting the vapor air mixture in a storage tank, and also disable the dispenser if normal operation of the dispenser is externally interfered with causing the signals to disagree.

Advantageously the vapor pump motor is responsive to a signal to operate the vapor pump and the control means monitors when the vapor pump motor is operating and disables operation of the vapor pump motor when vapor pump motor operation is detected while the vapor pump is not signalled to operate.

Preferably the control means monitors the electrical current to the vapor pump motor, and disables operation of that pump when the monitored current indicates an error condition. Such a condition may arise when fuel is entrained in the vapor recovery flow line, either due to a gradual build up, or due to the overfilling of a vehicle tank. Such a condition if undetected could result in an insufficient quantity of vapor being returned, and could also damage the pump.

In addition, or as an alternative, to disabling vapor recovery by disabling the vapor recovery pump, a valve in the vapor recovery line can be used to disable vapor recovery and preferably the control means monitors when the vapor pump is operating and outputs a signal to open the valve when operation is detected, and to close the valve when operation is not detected. The incorporation of such a valve also prevents the escape of vapor due to back pressure in the system when the vapor recovery pump is inactive.

Advantageously the dispenser further comprises means for generating a pump-enable signal to operate the dispenser, the pump-enable signal being applied to the control means which disables vapor recovery when the pump-enable signal is deactivated.

Preferably the dispenser comprises a first sensor that generates a first pulse train representative of the flow rate of the fuel pump and a second sensor that generates a second pulse train representative of the flow rate of said vapor pump, wherein the control means is operably interposed between the fuel pump and the vapor pump and controls the speed of the vapor pump to return substantially all fuel vapors proximate said outlet with substantially no excess air in response to evaluations of the pulse trains. The pulse trains can advantageously be used to control the rate of flow of vapor relative to the rate of flow of fuel to enable the dispenser to perform its normal operation as well as enabling the control means to detect a malfunction.

According to a second aspect of the invention there is provided a method of recovering fuel vapor in a vapor recovery fuel dispenser comprising

pumping fuel with a fuel pump from a fuel reservoir along a fuel delivery line to an outlet,

pumping fuel vapors from proximate the outlet along a vapor return line to a vapor repository with a pump that is not mechanically actuated by the fuel pump, and

disabling the recovery of vapor in response to detecting an error condition within the dispenser.

One embodiment of the present invention will now be described by way of example only with reference to the drawings of which:

Figure 1 schematically illustrates the components of a dispenser in accordance with the present invention; and

Figures 2 to 7 illustrate circuitry embodied in the dispenser of Figure 1.

Referring to Figure 1 a fuel dispenser 10, preferably a petrol dispenser, is connected to a multiplicity of turbine pumps 8 in fuel storage tanks 12, 14, 16 through pipes 18, 20, 22, respectively. The pipes draw fuel from the tanks and the respective liquid flow rates are measured in meters 24, 26, 28. The fuel from the pipes is mixed in mixing manifold 30. The mixing manifold has downstream of it a pipe 32 which outlets to a hose 34, terminating in a controllable dispensing nozzle 38. The nozzle 38 is provided with a vapor return line which connects with a vapor return hose 36 in the hose 34, preferably concentrically within it. The vapor return line 36 connects with a vapor line 40 extending to a vapor pump 44. An electrically operated solenoid valve 42 is provided in line 40 to close off the vapor line when not in use.

Various other tank, pump and meter arrangements can also be used. In particular, the invention is useful for dispensers in which the output of each meter is passed to a separate hose, without any mixing. In such a case, the signals output on lines 56 will be exclusive; i.e. there will be a signal indicative of fuel flow only on one of the lines at a time. Dispensers of this type are sold by Gilbarco, Inc. under the MPD designation.

A conventional handle 64 is mounted in the outside wall of the dispenser 10, on which the nozzle 38 can rest when not in use. As is conventional, the handle 64 is pivotally mounted, so it can be lifted after the nozzle is removed, to activate a switch, and the activation of the switch is signalled along line 62 to a transaction computer 66.

Controller 50 is provided with electrical connections 56 with the meters 24, 26, 28 so that signals indicative of the fuel flow rate can be transmitted from the meters to the controller 50. Preferably the meters 24, 26, 28 are pulsers, such as are commonly used in gasoline dispensers made by Gilbarco, Inc. The pulsers emit a pulse for every 4.5 ml of fuel passed by the pump. Thus, as the fuel is being pumped, a pulse train is delivered on the respective lines of the connections 56, with the pulse train frequencies corresponding to the fuel flow rate. The fuel pumps may, of course, be located in the dispenser 10, or elsewhere, and may have the metering devices integral with them.

Controller 50 also has a connection 41 to the valve 42 to open or close that valve, as desired. Controller 50 also has connections 58, 60 to the transaction computer 66 which controls the overall operation of the dispenser 10, in conventional fashion. Line 58 transmits signals from the transaction computer 66 to the controller

50 indicating that pumping is desired, and line 60 transmits signals from the controller 50 to disable pumping, when the controller 50 has ascertained that pumping should be disabled. This will be discussed in more detail later.

The vapor pump 44 is preferably a positive displacement pump, such as the Blackmer Model VRG3/4. It is driven by a motor 46, preferably a brushless three-phase DC motor. The brushless DC motor 46 includes three hall effect sensors, one for each phase of the three-phase motor. These are used in conventional motor drive electronics in the controller 50 to apply appropriately phased power to the three phase motor 46. The hall effect signals are a form of feedback and indicate the angular displacement of the motor. Rates of change of angular displacement signalled by the hall effect sensors by a pulse frequency are sent over lines 52 to the controller 50. That is, the lines 52 provide a tachometer reading of the rate of rotation of the motor 46. The motor drive electronics portion of the controller 50 outputs three-phase power over lines 54 to the motor to drive the motor as desired. Of course, if desired, the motor can be separately driven with a separately denominated motor drive which takes its instructions from the controller 50.

The vapor of the vapor pump 44 is transmitted along line 48 back to a storage vessel. The returning vacuum can be transmitted via a manifold system to the plurality of tanks 12, 14, 16 or, as shown more simply in Figure 1, to one tank.

The controller 50 plays a number of important roles which will be described below in more detail. However, to generalize, the flow rate of the fuel being pumped through the lines 18, 20, 22 as controlled by the transaction computer 66, via a connection not shown, is transmitted to the controller 50 over lines 56. The controller 50 evaluates the pulse trains 56 and output signals over lines 54 to the motor 46 to drive the vapor pump 44 at a rate correlated with the fuel pumping rate. Thus, generally the faster the liquid is pumped out, the faster the vapor is retrieved.

However, the controller 50 also includes circuitry to compare whether fuel is passing the meters 24, 26, 28 with whether the motor 46 is being driven. In the event that the motor 46 is running, and therefore pumping vapor back to the tank 16, when fuel is not passing, the controller can disable the motor 46 to prevent the air from being pumped into the tanks 12, 14, 16. Similarly, the controller 50 can combine the flow rates of the three meters 24, 26, 28, whose output is mixed, to get an overall fuel flow rate to output a proper vapor pump flow rate to the motor 46. Further, the controller 50 ascertains when the fuel is passing the meters 24, 26, 28 (or in an alternative embodiment, when the motor 46 is being driven) and passes a signal on line 41 to open the valve 42. Further, the controller 50 includes circuitry which monitors the current drawn by the motor 46. When the current is drawn at a rate which is uncharacteristic of normal vapor pumping, it can determine an error condition, such as fuel clogging the vapor return line and disable the vapor pump. The circuitry of the controller 50 which enables these functions to be carried out will now be described.

Referring now to Figure 2, there is shown a circuit useful for monitoring the status of fuel delivery and the status of the vapor recovery. If the status of these two devices, which are represented by Boolean logic levels or terms, do not agree with predetermined standards, it is deduced that an error condition exists in the vapor recovery system.

This functionality may be implemented by a variety of software or hardware embodiments. The embodiment shown in Figure 2 includes the input of the fuel pump delivery pulse signal on lines 56, entering as a pulse train, from the meters 24, 26, 28, thereby indicating the presence of dispensing of fuel. A fourth signal is also shown in Figure 2, corresponding to a possible other dispensing position or other fuel to be added to the blend. These signals are combined by exclusive OR gates U1, U2, U3, such that the dispensing of any fuel product by any source becomes noticed by transitions at the output of U3.

Likewise, the presence of vapor pump rotation is detected by combining tachometer feedback on lines 52 (or any detection of rotation) from the hall effect sensors (or other pickup device) by exclusive OR gates U4, U5 such that the rotation becomes noticed by the transitions at the output of U5. Chip U6 then converts both pulse trains (fuel delivery and motor rotation) into separate and stable logic levels by functioning as a retriggerable one-shot. The two terms are then compared by exclusive OR gate U7. If they are in disagreement for a predetermined period of time (allowing for mechanical system lags), the output of comparator U8 goes to a logic low level, thereby disabling the system. The disabling system is the output on line 60 to the transaction computer.

This circuit will detect a vapor recovery system failure or the detection of tampering or halting of fuel dispensing, which might result in vapors escaping into the environment. It also detects a "runaway" vapor recovery system which would introduce air into the fuel storage tank if the vapor pump were operating with no fuel being dispensed. This could result in an explosive condition in the fuel storage tank if left unchecked.

The circuit depicted in Figure 3 monitors the status of the vapor pump motor's enabling (run or halt) signal and monitors the actual state of the motor (running or halted). If the motor is determined to be running while the system has requested a halted condition, measures are then taken to disable the motor by destroying the motor feedback to the motor drive portion of the controller. This function may be implemented by a variety of software or hardware embodiments.

In the preferred embodiment, the three-phase brushless DC motor 46 has the hall effect transducers described above. These tachometer/feedback terms proceed to the motor controller 51 to serve as rotational feedback terms for the controller 51. The presence of motor rotation is derived by monitoring and combining the motor tachometer/feedback terms by exclusive OR gates U8, U9 to produce a pulse train as the shaft of the motor rotates. The output of U9 proceeds to the clock input of counter

31, so that counter 31 is incremented for each pulse received. Likewise, the motor enable control inputs, ENABLE.MOTOR, is dually connected to the input of motor controller 51 and the reset line of counter 31. Thus, when the controller 51 is enabled, the counter 31 is held in a reset condition. Conversely, when the motor controller 51 is disabled, the counter is not held in a reset condition, and left free to increment.

Consequently, if rotational pulses are detected during a halted or disabled state, the counter 31 increments until a chosen tap (Q12 in this example) becomes true (logic high in this example), turning on transistors Q1, Q2, Q3 which ground the motor feedback signals, thereby destroying feedback to the motor controller 51 and preventing continued power to the motor. The inherent delay presented by the counter 31 allows for inertia overspin by the motor, thereby preventing false tripping caused by expected motor characteristics. An additional signal, ERROR.CONDITION, may also be derived to signal system difficulty, resulting in termination of the fuel dispenser's operation. This circuit detects a run-away vapor recovery system which would be introducing air into the fuel storage tank if the pump was operating with no fuel being dispensed, which could result in an explosive condition in the fuel storage tank if left unchecked.

The circuit shown in Figure 4 monitors to ascertain if fuel is accidentally introduced into the vapor recovery system. The presence of the fuel would indicate either an attempt to "top off" a vehicle fuel tank during refueling or a poor nozzle placement, causing a splash-back condition at the vehicle's fuel tank filler neck. This condition is determined by excessive motor current as the vapor pump attempts to pump the fuel, an uncompressible medium.

While the particular function can be implemented by various embodiments, in the embodiment depicted in Figure 4, the vapor pump motor current is measured by the voltage drop across resistor R0. This relatively small amplitude and potentially noisy (in differential- and common- mode) voltage is then filtered by R1, R3, C1 to remove high-frequency differential-mode noise and then subsequently fed into an instrumentation style differential-mode amplifier made up of amplifier 71, amplifier 72, and resistors R5, R6, R7, R8 through impedance matching resistors R2, R4. The differential-mode amplifier serves to amplify the signal to usable levels while also removing common-mode noise. The resultant voltage, available at the output of amplifier 72 is further clamped to positive-only values by resistor R9 and diode CR1. The resultant signal is then presented to comparator 61 to be compared to a set threshold, as provided by potentiometer R10. R10's threshold is set to be representative of a motor current produced when fuel is passing through the vapor pump. If the actual motor current passes this set threshold, the output of comparator 61 goes high, thereby charging capacitor C2. After a finite delay to discriminate against motor start-up transients, the voltage across C2 becomes greater than the voltage set by divider resistors R14, R15 such that comparator 82's output, FLUID.DETECT, goes high, indicating fuel present in the vapor recovery system. The FLUID.DETECT signal is passed on line 60 to the transaction computer 66 to disable operation. Additionally, a locked-rotor condition caused by ice, motor or pump failure will cause the motor current to be in excess of that caused during vapor pumping, likewise causing FLUID.DETECT to become true. Therefore, the signal FLUID.DETECT may be used to detect either condition, and ultimately to terminate the operation of the fuel dispenser.

This circuit provides three major benefits: 1) detection of splash-back which results in "purchased fuel" being returned back to the station owner and not the consumer; 2) detection of "topping off", which is illegal in California; and 3) detection of a locked-rotor condition which represents another system malfunction. Detection prevents or terminates the dispensing of fuel since no vapor collection is possible.

Referring now to Figure 5, a circuit is depicted for opening the solenoid valve 42 when vapor pumping is to be implemented. Various other hardware and software embodiments may be employed. In the Figure 5 embodiment, vapor pump rotation is detected by combining the tachometer feedback signals 52 from the hall effect sensors of motor 46 in exclusive OR gates U10, U11. Thus, rotation becomes noticed by transitions at the output of exclusive OR gate U11. One shot 102 then converts the pulse train into a stable logic level signal by functioning as a retriggerable one shot whose period is greater than the typical minimum pulse width produced by the motor feedback signals during operation. This signal, the output of one shot 102 is then used to gate the vapor solenoid valve by outputting the signal on line 41.

It should be noted that alternately (or in conjunction) the presence or detection of fuel flow (i.e., the signals on line 56) may be substituted for (or logically combined with) the presence or detection of vapor pump motor rotation. This substitution (or combination) is possible because in a working system, vapor pump motor rotation will be a function of fuel flow.

During periods of motor rotation where the vapor pump is actively moving vapors from the nozzle to the vapor return lines, the signal output on line 41 is true, and the vapor solenoid valve 42 may be opened with assured direction of flow. During periods of no motor rotation, that signal becomes false, closing the valve and preventing the escape of vapors via system back pressure.

The system eliminates the escape of vapors into the atmosphere during idle dispensing periods and eliminates the need for a check valve in the vapor return line or dispensing nozzle. Also, since the valve is not located in the nozzle, which is subject to accident, breakage and abuse, the cost of replacement of the nozzle is lessened by locating the valve in the dispenser.

The circuit shown in Figure 6 may be used for determining and controlling the vapor pump motor speed to correlate with the fuel flow being pumped, where multiple fuel sources are used and the fuels are blended. The invention may be implemented by a variety of software or hardware embodiments.

In this embodiment, fuel flow is derived by inputting a pulse train whose frequency is a function of fuel flow, and converting these pulses to a voltage whose amplitude is directly proportional to the pulse train's frequency. Separate, but exclusively occurring pulse trains may enter along lines 56 from the fuel pumps. If blending is desired, preconditioning to assure that the pulse trains are not in quadrature is necessary. Various circuits to achieve this will be apparent to those of ordinary skill in the art. Otherwise, the signals to U12 and U13 should come from meters which do not operate simultaneously.

These pulse trains are digitally combined by exclusive OR gates U12, U13 such that any pulse transition from any of the aforementioned inputs results in a pulse transition at the output of exclusive OR gate E13. These transitions are then inputted to F/V (frequency to voltage) converter 91, such that for zero transitions (frequency = zero), a nominal potential of 0 volts is present at its output. Likewise, for a given non-zero frequency of transitions at its input, F/V converter 91 outputs a voltage as a function of (e.g. linearly proportional) the input frequency, supply voltage VDD, and components C21 and R22. Components R21, R23, C22, C23, C24 further serve to remove artifacts from the conversion process and to tailor the response resulting from variations of input frequency.

An additional pulse train source may be inputted simultaneously or separately for a different meter at the lower level input 56'. This pulse train is similarly converted to a voltage in F/V converter 92 with identical resistors and capacitors to those used above. The output of F/V converter 92 is mathematically summed with the output of

F/V converter 91 via inverting amplifier 96, gain-setting resistors R17, R18, R19, compensation capacitor R31 and current drains comprising Q4, Q5, R30, R31, R32, R33, R34. The resulting output of inverting amplifier 96 represents the sum of the fuel flows from the two possible simultaneous input sources, allowing the use of fuel blending dispensers which simultaneously meter two separate grades of fuel. The use of the F/V converters permits addition of the signals, without concern of digital signals obscuring one another by being out of, or in, phase.

Note that if the signals on lines 56 are quiescent, but the signal of line 56' is not, the output of the inverting amplifier 96 will represent only that flow, allowing a fourth metering device to be interfaced to the vapor control system, thereby supporting four-product dispenser applications.

The sum flow term from the output of the inverting amplifier 96 is then fed to the input of inverting amplifier 95, where slope and offset operations are performed. These two operations provide for assignment of a first-order relationship between fuel flow and motor velocity, or specifically the equation: $V = M(m + B)$, where V is the vapor motor velocity, m is the rate of fuel flow, B is a constant offset term, and M is a constant multiplier term. In this example, M is adjustable via potentiometer R36, and B is adjustable via potentiometer R38.

Also, in this embodiment, provision is made to insert additional circuitry between the output of the inverting amplifier 95 and the subsequent integration stage such that additional terms corresponding to pressure and temperature may be introduced, for example, temperature compensation as disclosed in Australian Patent No. 648188. ~~copending application Serial No. 824,702, filed January 21, 1992 and assigned to the assignee of the present invention~~. The entire disclosure of that patent ~~application~~ is hereby incorporated by reference.

Separately, instantaneous motor velocity derived from the motor tachometer (such as taken from U11 shown in Figure 5) is inputted to F/V converter 93 as a pulse train whose frequency is proportional to velocity. F/V converter 93 is likewise configured as F/V converters 91 and 92 with the exception of the omission of response tailoring components, as the subsequent inverting input of the integrating stage serves as an artifact and response filter. F/V converter 93 then outputs a voltage whose amplitude is linearly proportional to motor velocity.

The two major terms, fuel flow and vapor pump motor velocity, are now fed into integrating amplifier 97, with flow being a positive term (driving term) and velocity being a negative term (feedback term). The difference between these two terms is then integrated over time, with the output of integrating amplifier 97 now incorporating an error term which is used to correct for perturbations and motor speed if the instantaneous speed differs from that given by the previously stated equation: $V = M(m + B)$.

Furthermore, integrating amplifier 97 provides complex (pole and zero) compensation for the motor/pump assembly, effectively compensating for inertial mass and mass induced-delays such that effective step and ramp response to changes in fuel flow is maintained at all times and under all flow rate slewing and pump loading conditions. This network is comprised of resistors R43, R44, R45 and capacitors C33, C34.

Additionally, analog switch 98 is included to assure that integration begins at time = 0, initial system start-up. This prevents continuous integration and the subsequent accumulation of error should the system be disabled and unable to respond to the integrator's output. The omission of this function would either result in either an abrupt short-term burst of motor rotation at system start-up for a positive integration accumulation, or a lag in initial motor start-up for a negative integration accumulation.

Finally, since integrator 97's output is capable of slewing both positive or negative, a clamp network comprised of R41, R42, CR2, CR3, CR4, CR5, C35, C36 is provided at the integrator's output. This limits excursions to a range compatible with the motor drive electronics.

Since the vapor pumping rate is correlated with the aggregate fuel flow rate, the vapor pump can operate to return substantially all of the vapor proximate the nozzle 38 with substantially no excess air.

Referring now to Figure 7, a circuit diagram in a simplified block form illustrates the various sub-systems of Figures 2-5 combined together. Having described each of the sub-circuits independently, it is believed that those of ordinary skill in the art will readily understand the functioning of the bulk of the circuit depicted in Figure 7. However, the circuit shown in Figure 7 also includes an Error Status Latch 104, which latches an error signal out to AND gate 106 to disable the motor drive electronics whenever any of the error conditions are noticed in NOR gate 108. The latch is reset by a clearing input form the signals 56 when the fuel pump is next restarted. If the error is cleared, operation may resume. If not, the error will be detected and again disable the dispenser.

While the invention has been disclosed with respect to a particularly preferred analog embodiment, the scope of the invention is defined by the claims of this specification, and those of ordinary skill in the art will appreciate that the functionalities obtained can be obtained through numerous other systems, electrical, mechanical and hardware, including a digital implementation, whilst still in accordance with the present invention.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A vapor recovery fuel dispenser comprising:

a fuel pump driven by a first motor for pumping fuel from a reservoir along a delivery line to an outlet;

a vapor pump driven by a second motor for returning fuel vapors from proximate the fuel outlet along a vapor return line to a repository; and

control means for receiving electrical signals relating to the operation of the dispenser and controlling the dispensing of fuel and recovery of fuel vapor in dependence on the received signals characterised in that the control means comprises means for disabling the recovery of vapor in response to detecting an error condition within the ~~dispenser~~ component parts of the dispenser.

2. A dispenser as claimed in claim 1 wherein the control means is operably interposed between the fuel pump and the vapor pump; monitors when both pumps are operating; and disables operation of the vapor pump when operation of the fuel pump is not detected.

3. A dispenser as claimed in claim 2 wherein the control means monitors a plurality of fuel pumps within the dispenser, fuel pump operation being detected if operation of any one of the fuel pumps is detected.

4. A dispenser as claimed in claim 3 wherein the control means combines signals

from the plurality of fuel pumps in exclusive OR gates to derive a single signal indicative of operation of any of the fuel pumps and compares the single signal indicative of operation of the vapor pump and the single signal indicative of operation of the fuel pumps.

5. A dispenser as claimed in claim 4 wherein the con l means disables operation of the dispenser if the two signals disagree for a period of time in excess of a threshold.

6. A dispenser as claimed in claim 2, 3, 4 or 5 wherein the control means permits continued operation of the vapor pump for a short period after fuel pumping cessation is detected to allow for mechanical inertia.

7. A dispenser as claimed in any preceding claim wherein the vapor pump motor is responsive to a signal to operate the vapor pump and wherein the control means monitors when the vapor pump motor is operating and disables operation of the vapor pump motor when motor operation is detected while the vapor pump is not signalled to operate.

8. A dispenser as claimed in claim 7 wherein the control means permits continued operation of the vapor pump motor for a short period after detection of cessation of the signal to operate to allow for mechanical inertia.

9. A dispenser as claimed in any preceding claim wherein the control means receives a signal indicative of operation of the vapor pump motor, which signal is a pulse train, and the control means counts pulses in the pulse train during periods when the signal to operate the vapor pump is absent and disables operation of the motor when a threshold number of pulses is counted.

10. A dispenser as claimed in any preceding claim wherein the control means monitors the electrical current to the vapor pump motor, and disables operation of the vapor pump when the monitored current indicates an error condition.

11. A dispenser as claimed in claim 10 wherein the motor current is detected by a drop in voltage across a resistive element in series with a motor winding.

12. a fuel dispenser as claimed in claim 11 wherein the control means includes a filter to filter the voltage across the resistive element to remove noise.

13. A dispenser as claimed in claim 12 wherein the control means includes a potentiometer between a voltage source and a comparator, the filtered voltage is applied to the comparator and the control means disables operation of the vapor pump motor if the filtered voltage exceeds a voltage set by a setting of the potentiometer.

14. A dispenser as claimed in any one of claims 10 to 13 wherein the control means permits continued operation of the vapor pump motor during short periods of high current but disables operation when current exceeds a threshold level for a

threshold period of time.

15. A dispenser as claimed in any preceding claim further comprising a valve in the vapor return line, wherein the control means monitors when the vapor pump is operating and outputs a signal to open the valve when operation is detected, and to close the valve when operation is not detected.

16. A dispenser as claimed in any preceding claim further comprising a valve in the vapor return line, wherein the control means monitors when the fuel pump is operating and outputs a signal to close the valve when fuel pump operation is not detected.

17. A dispenser as claimed in claim 16 wherein the control means monitors a plurality of fuel pumps within the dispenser, fuel pump operation being detected if operation of any one of the fuel pumps is detected.

18. A dispenser as claimed in claim 17 wherein the control means combines signals from the fuel pumps in exclusive OR gates to derive a single signal indicative of operation of any of the fuel pumps.

19. A dispenser as claimed in any preceding claim further comprising means for generating a pump-enable signal to operate the dispenser, the pump-enable signal being applied to the control means which disables vapor recovery when the pump-enable signal is deactivated.

20. A dispenser as claimed in any preceding claim further comprising a first sensor that generates a first pulse train representative of the flow rate of the fuel pump and a second sensor that generates a second pulse train representative of the flow rate of the vapor pump, wherein the control means is operably interposed between the fuel pump and the vapor pump and controls the speed of the vapor pump to return substantially all fuel vapors proximate said outlet with substantially no excess air in response to evaluations of the pulse trains.

21. A dispenser as claimed in any preceding claim wherein the control means monitors a motor of a pump and detects operation of the motor from a signal from a tachometer of the motor.

22. A dispenser as claimed in claim 21 wherein the motor is a three phase brushless DC motor and each phase has a tachometer in the form of a hall effect sensor monitored by the control means.

23. A dispenser as claimed in claim 22 wherein the control means combines signals from the hall effect sensors in exclusive OR gates to derive a single signal indicative of operation of the motor.

24. A dispenser as claimed in any preceding claim wherein a signal indicative of

operation of a fuel pump motor is a pulse train and the control means converts pulses in the pulse train to a logic level one state of which corresponds to vapor recovery being disabled.

25. A dispenser as claimed in any preceding claim wherein the control means is operably interposed between the fuel pump and the vapor pump for controlling the speed of the vapor pump to return substantially all fuel vapors proximate the outlet with substantially no excess air.

26. A fuel dispenser substantially as hereinbefore described with reference to, and as illustrated in, the accompanying drawings.

DATED this 5th day of December, 1995.

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ABSTRACT

A VAPOR RECOVERY FUEL DISPENSER

A fuel dispenser comprises a fuel delivery pump (8), a separate vapor recovery pump (44) and control means (50) responsive to signals from sensors for identifying an error condition and preventing further vapor recovery which could result in an air rich explosive mixture in the vapor recovery system including an associated fuel storage tank.

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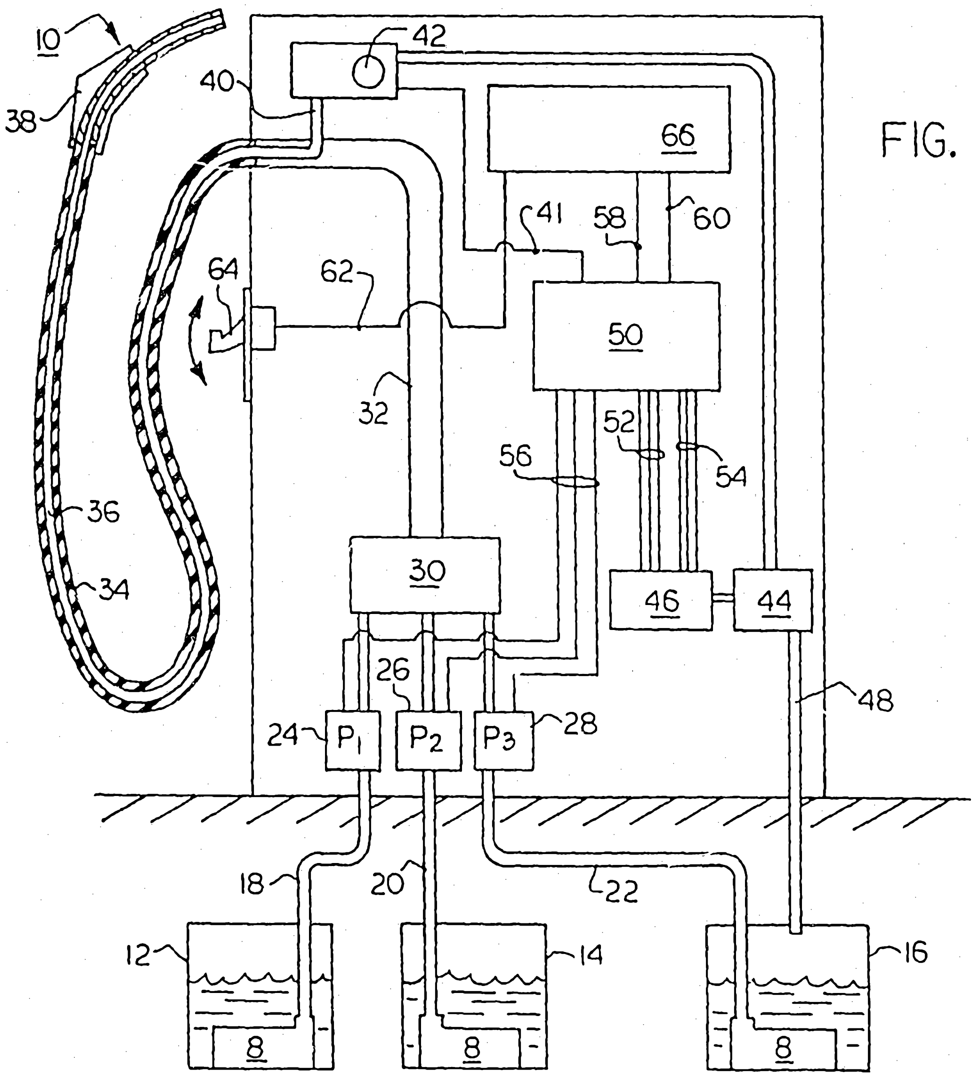


FIG. 1

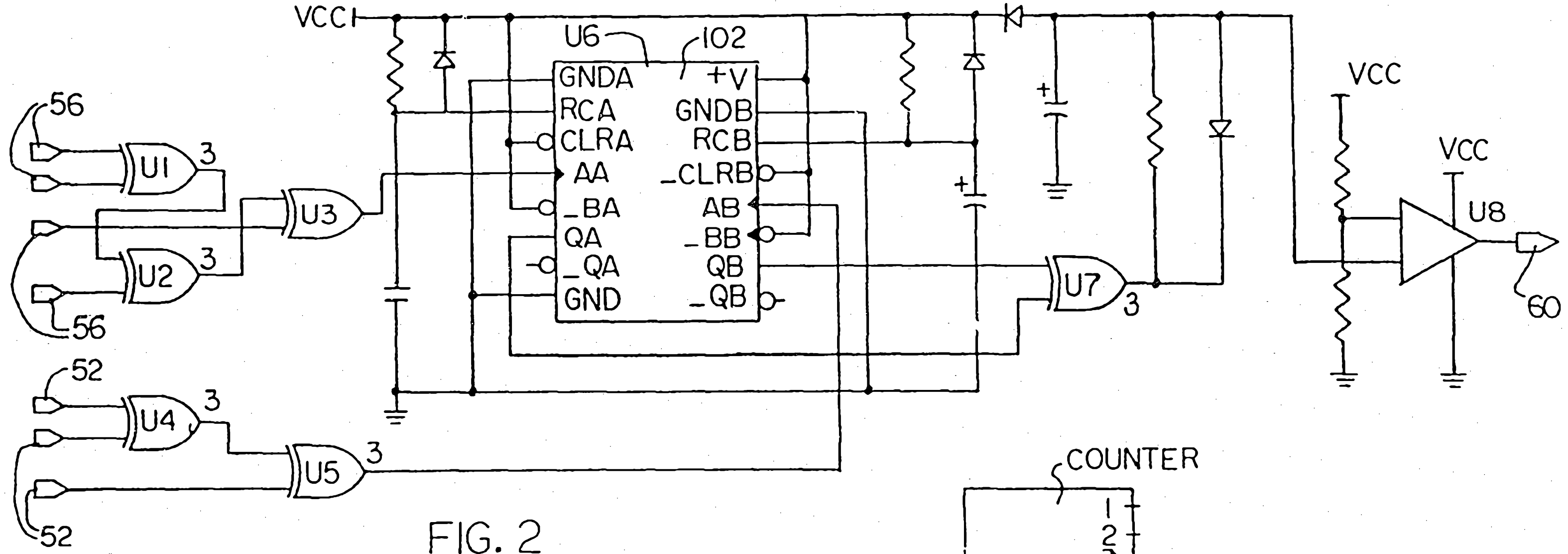

VCC1
U6
102
GNDA
RCA
CLRA
AA
_BA
QA
_QA
GND
+V
GNDB
RCB
_CLRB
AB
_BB
QB
_QB
56
U1
U2
U3
3
52
U4
U5
U7
VCC
U8
60

FIG. 2

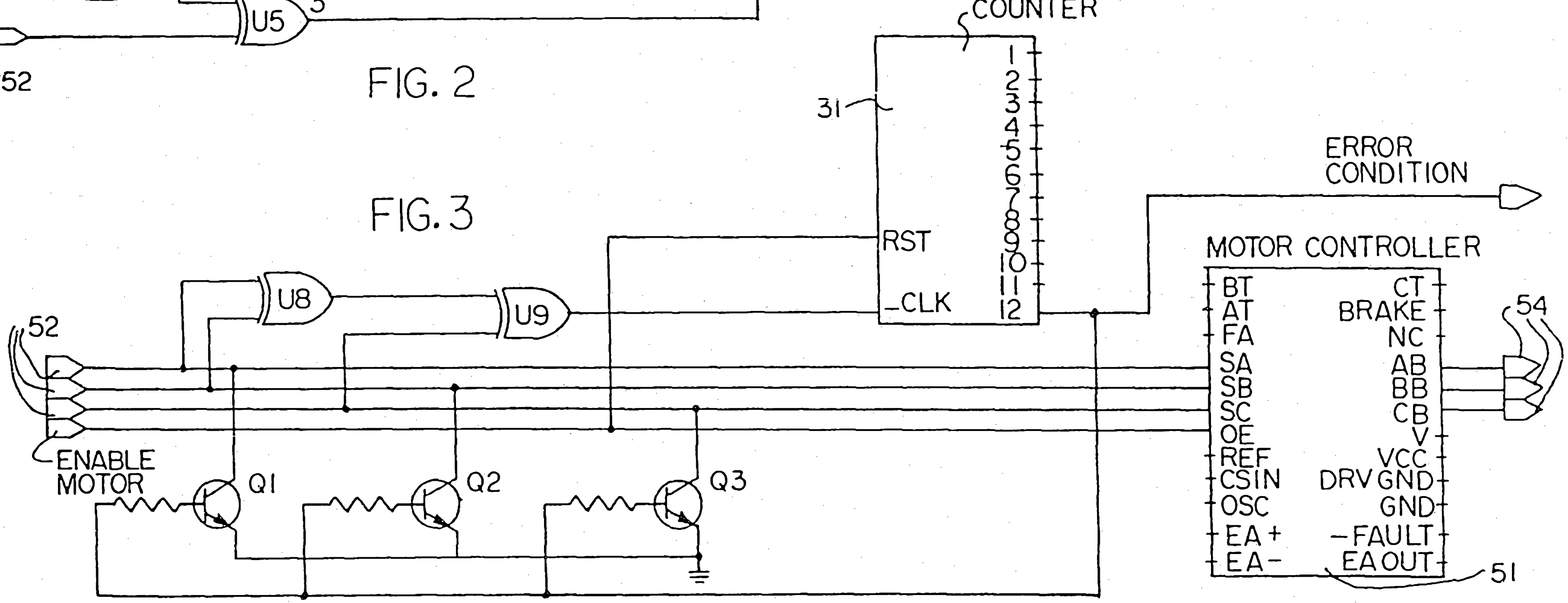

COUNTER
31
1
2
3
4
5
6
7
8
9
10
11
12
RST
_CLK
ERROR CONDITION
MOTOR CONTROLLER
BT
AT
FA
SA
SB
SC
OE
REF
CSIN
OSC
EA+
EA−
CT
BRAKE
NC
AB
BB
CB
V
VCC
DRV GND
GND
−FAULT
EA OUT
51
54
52
U8
U9
ENABLE MOTOR
Q1
Q2
Q3

FIG. 3

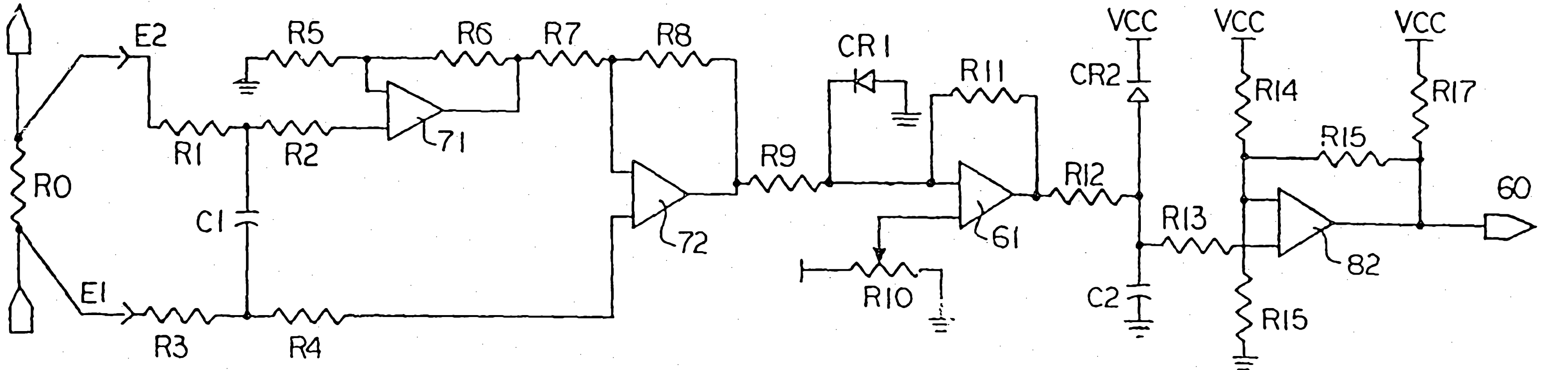

E2
R5
R6
R7
R8
CR1
R11
VCC
CR2
VCC
R14
VCC
R17
R15
R0
R1
R2
71
R9
R12
R13
60
C1
72
61
82
R10
C2
E1
R3
R4
R15

FIG. 4

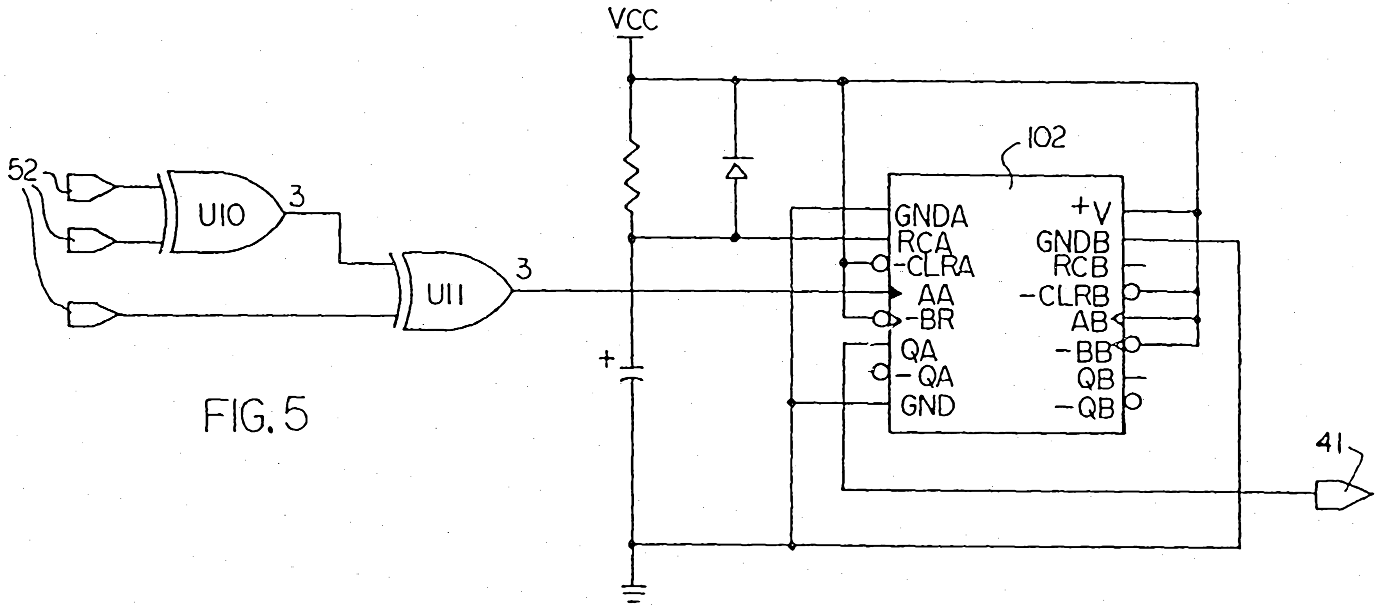
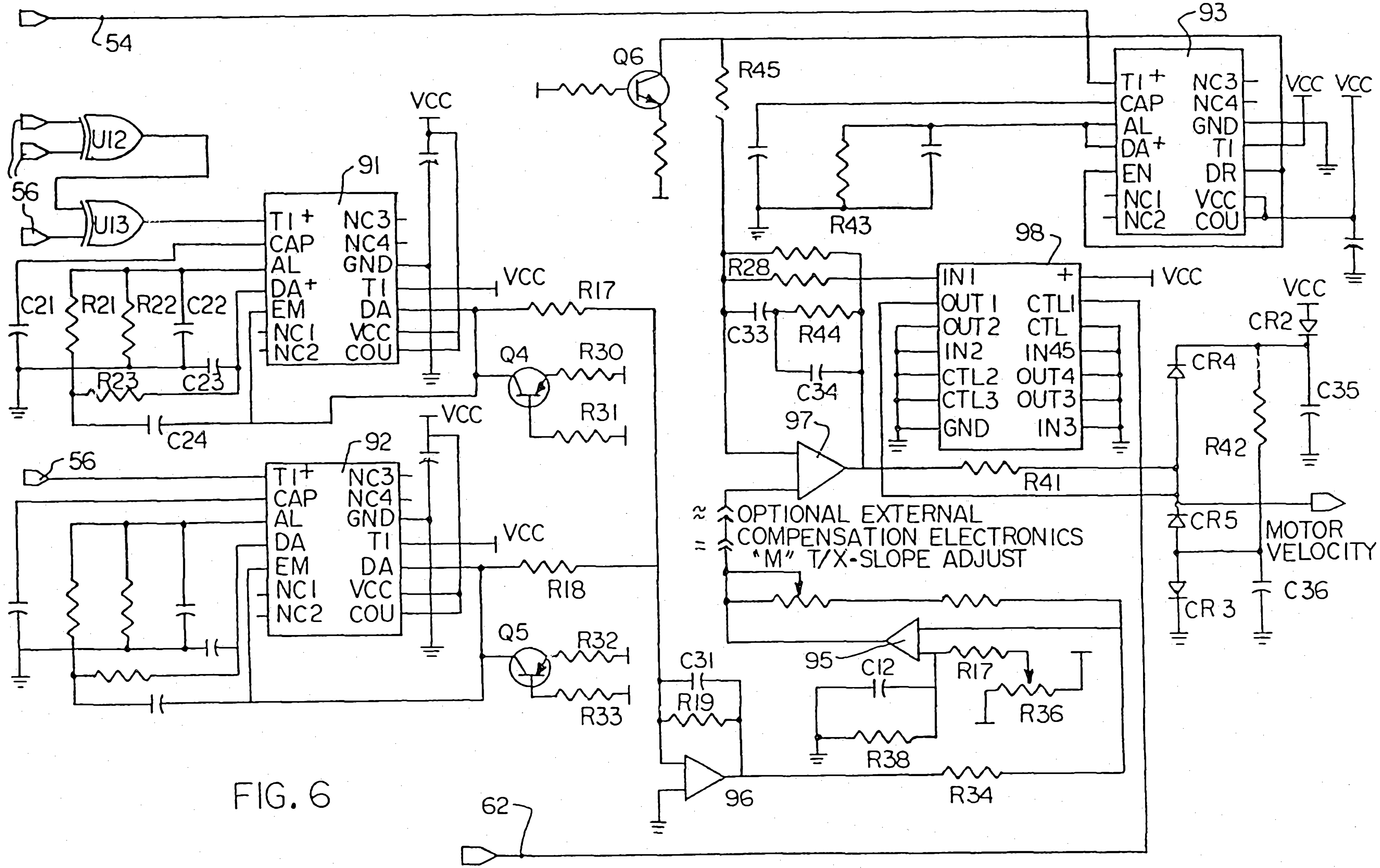

VCC
102
52
U10
3
U11
3
GNDA
RCA
-CLRA
AA
-BR
QA
-QA
GND
+V
GNDB
RCB
-CLRB
AB
-BB
QB
-QB
+
41

FIG. 5



54
56
U12
U13
91
92
93
98
97
95
96
62
Q4
Q5
Q6
VCC
TI+
CAP
AL
DA+
EM
NC1
NC2
NC3
NC4
GND
TI
DA
VCC
COU
EN
DR
C21
R21
R22
C22
R23
C23
C24
R17
R18
R30
R31
R32
R33
R45
R43
R28
C33
R44
C34
IN1
OUT1
OUT2
IN2
CTL2
CTL3
CTL1
CTL
IN45
OUT4
OUT3
IN3
R41
CR2
CR3
CR4
CR5
C35
R42
C36
MOTOR VELOCITY
OPTIONAL EXTERNAL COMPENSATION ELECTRONICS
"M" T/X-SLOPE ADJUST
C31
R19
C12
R17
R36
R38
R34

FIG. 6

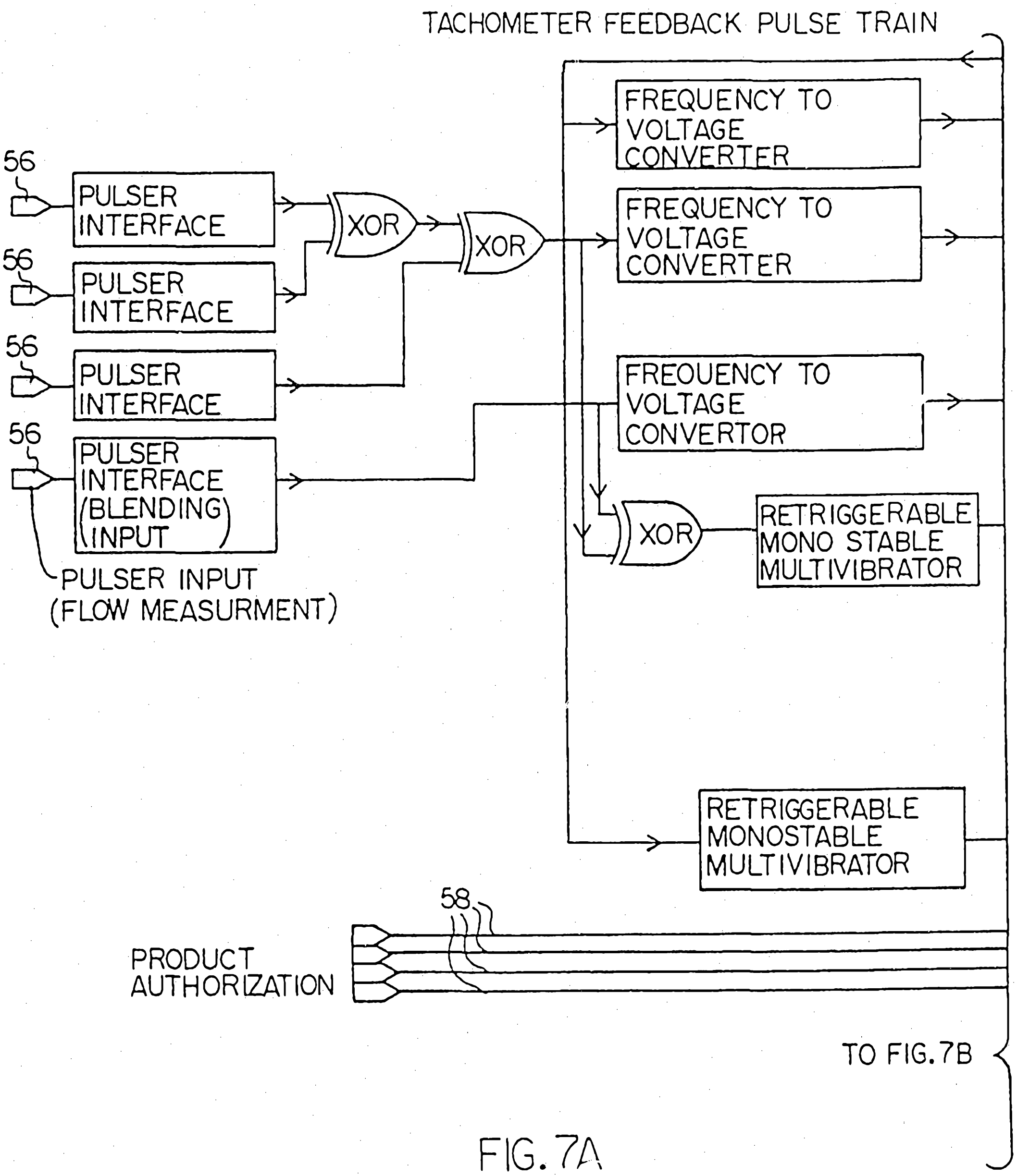

TACHOMETER FEEDBACK PULSE TRAIN
56
PULSER INTERFACE
56
PULSER INTERFACE
56
PULSER INTERFACE
56
PULSER INTERFACE (BLENDING INPUT)
PULSER INPUT (FLOW MEASURMENT)
XOR
XOR
FREQUENCY TO VOLTAGE CONVERTER
FREQUENCY TO VOLTAGE CONVERTER
FREOUENCY TO VOLTAGE CONVERTOR
XOR
RETRIGGERABLE MONO STABLE MULTIVIBRATOR
RETRIGGERABLE MONOSTABLE MULTIVIBRATOR
58
PRODUCT AUTHORIZATION
TO FIG.7B

FIG. 7A

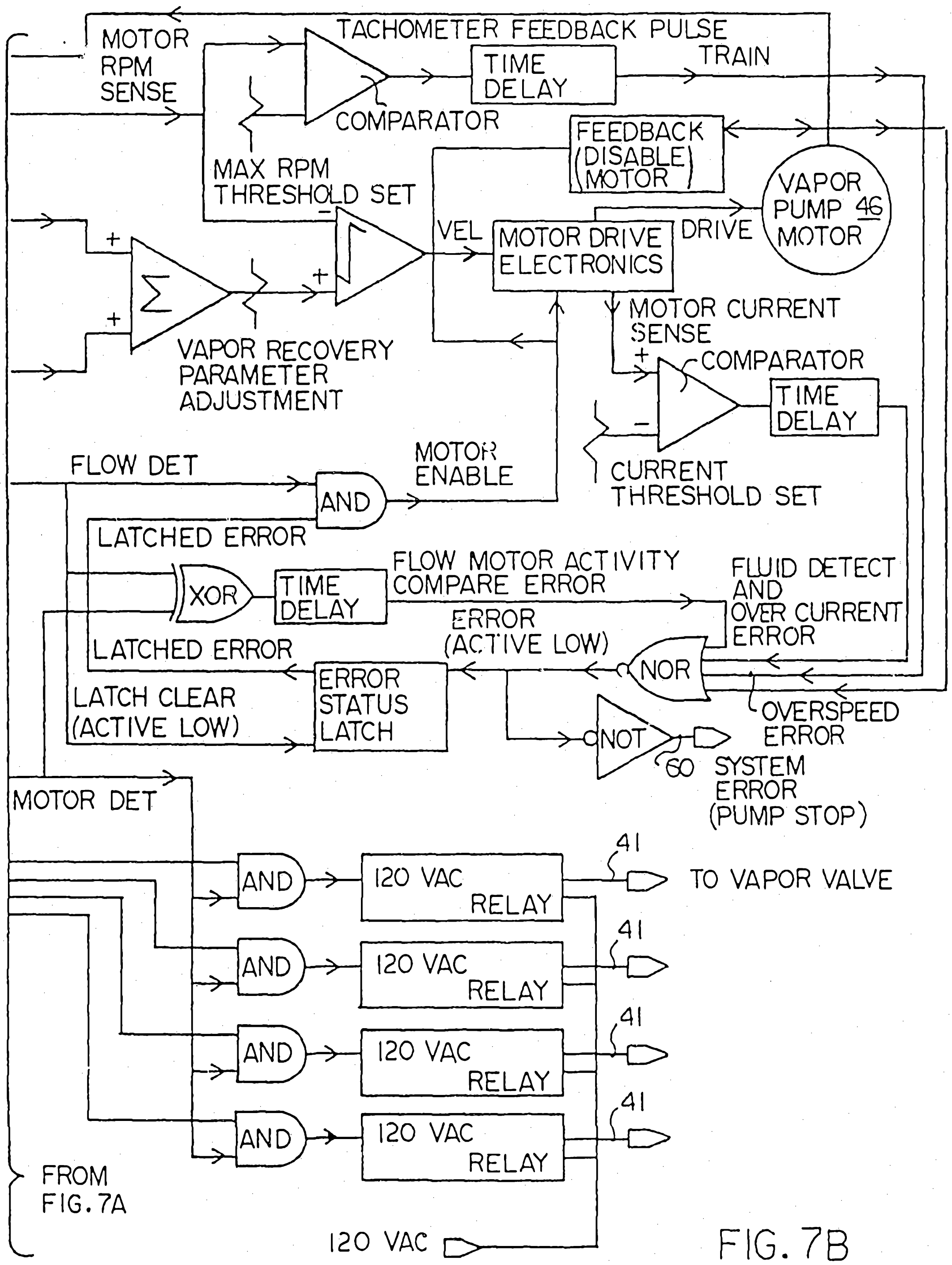

TACHOMETER FEEDBACK PULSE
TRAIN
MOTOR
RPM
SENSE
TIME
DELAY
COMPARATOR
MAX RPM
THRESHOLD SET
FEEDBACK
(DISABLE)
MOTOR
VAPOR
PUMP 46
MOTOR
VEL
MOTOR DRIVE
ELECTRONICS
DRIVE
Σ
VAPOR RECOVERY
PARAMETER
ADJUSTMENT
MOTOR CURRENT
SENSE
COMPARATOR
TIME
DELAY
CURRENT
THRESHOLD SET
FLOW DET
AND
MOTOR
ENABLE
LATCHED ERROR
FLOW MOTOR ACTIVITY
COMPARE ERROR
XOR
TIME
DELAY
FLUID DETECT
AND
OVER CURRENT
ERROR
ERROR
(ACTIVE LOW)
LATCHED ERROR
NOR
ERROR
STATUS
LATCH
LATCH CLEAR
(ACTIVE LOW)
OVERSPEED
ERROR
NOT
60
SYSTEM
ERROR
(PUMP STOP)
MOTOR DET
AND
120 VAC
RELAY
41
TO VAPOR VALVE
AND
120 VAC
RELAY
41
AND
120 VAC
RELAY
41
AND
120 VAC
RELAY
41
FROM
FIG. 7A
120 VAC

FIG. 7B