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(54) Title: PRESSURE MEASURING DEVICE

(57) Abstract

A pressure measuring system that is more accurate than the pressure sensor/transducer incorporated into the system. The system includes a pressure switch and a pressure sensor or transducer, each of which is operative to sense the pressure in a vessel, fluid line, or the like. The pressure switch has a preselected set point, such that when the pressure being sensed crosses the set point, the switch is triggered. Circuitry monitors the sensor and switch and when the switch is triggered the circuitry determines the error, if any, in the reading from the sensor, and corrects future readings from the sensor based upon the value of the calculated error.

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PRESSURE MEASURING DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority pursuant to 35 U.S.C. 119 based upon U.S. Provisional Patent Application Serial No. 60/095,419 filed August 5, 1998, the entire disclosure of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention generally relates to the field of pressure measuring devices. More specifically, the invention is directed to a pressure measuring system that provides relatively accurate readings while incorporating relatively inexpensive sensing components.

DESCRIPTION OF THE RELATED ART

A number of mechanical and electro-mechanical systems incorporate pressure transducers or sensors to measure or detect a desired pressure in a vessel, conduit, or other fluid-containing member. Sensing the pressure in such a member is a good indication of the status of the system, and can be used to detect dangerous pressure levels so that remedial measures can be taken to prevent the components of the system from being damaged by high pressure levels. In many systems, the sensed pressure is used for comparison with a preselected set point and, if the sensed pressure varies from the set point, some correcting device is actuated to eliminate the difference between the desired and actual values.

Because a very accurate pressure measurement is typically desired, such systems normally incorporate one or more relatively expensive high-precision pressure transducers. Many such systems require several pressure transducers in order to sense pressures at different locations within the system. Thus, the cost of such systems rises considerably, because a large number of the high-precision transducers are needed.

In an effort to alleviate some of the high costs associated with high-precision pressure transducers, others have proposed systems that include multiple low-precision pressure transducers and one or more high-precision transducers, with the high-precision transducer or transducers being used to periodically calibrate the readings from the less precise pressure transducers. One such device is disclosed in U.S. Patent Number 4,339,943 to Hedrick. While such a system may do away with the need for multiple high-precision pressure transducers, the system still requires at least one such transducer.

Still others have proposed complex monitoring systems for intermittently testing one or more relatively imprecise pressure transducers. A form of such a device is disclosed in U.S. Patent Number 4,817,022 to Jornod et al. While such a system may alleviate the need for a high-precision pressure transducer, the complex monitoring system is itself quite expensive, and thus does not address the problem of providing a pressure measuring device that is relatively inexpensive and also quite accurate.

Others have employed strain gauge devices for determining pressure levels in fluid-containing members. In contrast to high-precision pressure transducers, strain gauge pressure measuring devices are quite inexpensive and for that reason they are desirable; however, strain gauges are relatively limited in terms of both the range and accuracy they provide. Thus, strain gauges do not address the need for a relatively inexpensive and relatively precise pressure measuring device.

Accordingly, it will be apparent that there continues to be a need for a system that takes relatively precise pressure readings, while at the same time is cost-efficient. The present invention addresses these needs and others.

SUMMARY OF THE INVENTION

One object of the present invention is to use a relatively imprecise and inexpensive pressure transducer in connection with a pressure switch in order to achieve relatively accurate pressure readings.

According to one aspect of the invention, a relatively inexpensive pressure transducer or sensor is incorporated in a pressure-measuring system, the system also includes a pressure switch with a preselected pressure set point. The pressure transducer or sensor repeatedly senses the pressure in a fluid-containing vessel or other member, and the pressure sensed by the transducer is preferably displayed to a user or output for other use. When the pressure in the vessel crosses the pressure set point, the pressure switch is triggered. The reading from the pressure transducer at the time the switch is triggered is determined and, if that reading from the transducer does not match the pressure set point, an error correction is calculated and future readings from the transducer are adjusted based upon the error correction.

The pressure measuring system in one illustrative embodiment comprises: a pressure transducer in communication with a fluid-containing member to sense the pressure in the member and generate a pressure signal corresponding to the pressure sensed by the transducer; a pressure switch in communication with the member, the pressure switch having a preselected set pressure point and being operative to trigger when the pressure in the member crosses the set point; and circuitry electrically connected to the pressure sensor and to the pressure switch, the circuitry being responsive to triggering of the pressure switch to determine the pressure sensed by the pressure transducer and to calibrate signals from the pressure transducer.

BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of the invention discussed in the above summary of the invention will be more clearly understood when taken together with the following detailed description of preferred embodiments which will be understood as being illustrative only, and the accompanying drawings reflecting aspects of those embodiments, in which:

FIG. 1 is a block diagram of a pressure measuring system comprising one illustrative embodiment of the present invention;

FIG. 2 is a schematic diagram showing another embodiment of a pressure measuring system connected to a fluid-containing member for measuring the pressure in the member;

FIG. 3 is a flow chart depicting the operational flow of the system of FIG. 1; and

FIG. 4 is a block diagram of another illustrative embodiment of the pressure measuring system of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the following detailed description, like reference numerals will be used to refer to like or corresponding elements in the different figures of the drawings. Referring now to the drawings, and particularly to FIG. 1, there is shown a pressure measuring system 10 depicting one illustrative embodiment of the present invention. The pressure measuring system comprises a pressure sensor or transducer 12, a pressure switch 14, and a controller 16 electrically connected to the pressure transducer and to the pressure switch. The pressure measuring system is operative to sense the pressure within a fluid-containing member 18 and, if appropriate, to automatically correct the sensed values to obtain a more precise value than that sensed by the pressure transducer. The system is operative to sense pressures in members containing either gases or liquids.

The pressure measuring system 10 in one illustrative embodiment comprises the pressure transducer 12. The pressure transducer is connected to a fluid-containing member 18 for fluid communication with the member, for example, through a conduit 20 (FIG. 2). The pressure transducer includes an inlet, for example in the form of a threaded nipple (not shown), to threadedly engage a complementarily formed, internally threaded outlet port of the conduit (not shown). The pressure transducer is operative to sense the pressure in the conduit, and thus the pressure in the fluid-containing member. The pressure transducer can take many different forms which are well known to those of ordinary skill in the art, such as a piezoresistive or a metallic strain gauge that incorporates a sensing diaphragm, a quartz pressure transducer, a capacitive pressure sensor, an inductive pressure sensor, or the like. The strain gauge-type transducers incorporate a strain gauge, which is a resistive element whose resistance changes with the amount of strain (or pressure) placed on it.

The pressure transducer 12 incorporated in the system 10 of the present invention is further operative to generate an electrical output signal that is proportional to the sensed pressure. The output may be either a voltage or a current, with the voltage or current level output by the transducer being proportional to the sensed pressure. It will be apparent that the signal from the pressure transducer can be either a digital or analog signal.

It will be understood that the pressure measuring system 10 may incorporate either a pressure sensor or a pressure transducer, so long as the device includes an electronic output for generating an electronic signal, in the form of either a voltage or a current, having a value corresponding to the pressure sensed in the member. Thus, the two terms, sensor and transducer, are used herein interchangeably.

The pressure measuring system 10 further includes the pressure switch 14, which can also take many different forms which are well known to those of ordinary skill in the art, such as a membrane-type or diaphragm-operated pressure switch, one that incorporates sliding or pivoting actuating members, and the like. The pressure switch is preferably adjustable and set at the factory with a preselected pressure set point at which it will be actuated. As with the pressure transducer 12, the pressure switch 14 includes an inlet, such as a threaded port, to engage a complementary outlet in the conduit 20 to establish fluid communication between the pressure switch and fluid-containing member 18. Thus, the pressure transducer 12 and pressure switch 14 are each connected to the same conduit 20 and sense the same pressure in that conduit.

In the case of the diaphragm-type pressure switch, the switch is normally open, with the pressure, when it exceeds the preselected set point for that pressure switch, operating across the deflectable diaphragm to establish electrical communication across plural electrical contacts to close the switch and generate an electrical output signal. Conversely, if the pressure in conduit 20 subsequently drops below the set point for the switch, the diaphragm will return to its normal position and the electrical contacts will no longer be in contact with each other, and the switch will return to its normal, untriggered state, such that its output goes low. The electrical signal generated by the pressure switch can be either a digital or analog signal.

The actuating member of the pressure switch 14 is typically spring biased toward the open position, with the pressure in the conduit 20 serving to overcome the force from the spring to drive the actuating member to the closed position to trigger the switch. The biasing force applied by the spring is preferably adjustable, such as with an adjustment screw, so that the pressure set point may be changed for the pressure switch.

Referring to Fig. 1, the pressure measuring system 10 further includes the controller 16. The controller comprises circuitry, for example a microprocessor, that is electrically connected to the pressure switch 14 and to the pressure transducer 12. In one embodiment, the controller is connected to the switch and transducer through respective amplifiers 22 (FIG. 2) for receipt of electrical signals from the switch and transducer. Some transducers output signals having a value on the order of millivolts, and thus the amplifier is incorporated in certain embodiments and is operative to amplify the low level output from the transducer to a high level output, on the order of several volts. Some other transducers output signals that do not require amplification. In addition, because many pressure switches do not require amplifiers, the switch 14 is shown in Fig. 1 connected directly to the controller for direct communication with the controller. In some embodiments, the particular switch used may require the use of an amplifier (FIG. 2). Thus, it will be apparent to those of ordinary skill in the art that the amplifiers are optional and depend upon the particular types of switches and transducers used by the system 10.

The controller 16 is programmed to process the electrical signals from the switch 14 and transducer 12 and output a value corresponding to the pressure within the member 18, as described in greater detail below in connection with Fig. 3. The controller 16 is also programmed to take readings from the transducer at a selected sampling rate, which is dependent on the frequency characteristics of the pressure waveform being monitored. For example, if the pressure waveform is varying rapidly (corresponding to a high frequency), the sampling rate is preferably also high. In addition, the accuracy of the system is dependent on the ability to read the pressure transducer 12 quickly. Thus, the sampling rate is preferably made relatively high to ensure better accuracy of the system. The controller may include an analog-to-digital converter (not shown) to convert analog signals from the pressure transducer and pressure switch into digital signals.

The controller 16 is also electrically connected to a memory 24 that stores characteristic information for the transducer 12 and switch 14, and which is accessed by the controller. The memory may be in the form of a look-up table or the like. For example, the memory may store corresponding pressure values for particular electrical signal values received from the transducer, as described in greater detail below. In addition, the system may perform two-point interpolations to interpolate between the two closest points stored in the look-up table in cases where the electrical signal value received by the controller falls between two entries in the look-up table.

Referring now to Fig. 3, the operation of the pressure measuring system 10, and in particular that of the controller 16, will be described. Initially, the system 10 is actuated at step 30, for example by delivering a suitable supply of power to the pressure transducer 12, pressure switch 14, and controller 16. At step 32, the controller receives an amplified electrical signal from the pressure transducer, and processes the signal to determine the pressure within the member 18. The controller preferably receives the signal, determines the value of the signal (in volts or amps), and accesses the memory 24 to determine the corresponding pressure value. For example, an amplified signal from the transducer with a voltage of 3 volts may correspond to a pressure of 5 psi in the member, whereas a voltage of 5 volts may correspond to a pressure of 8 psi, and so on, and those values may be associated in the look-up table of memory 24. Next, at step 34, the controller determines whether the pressure switch 14 has been triggered, for example by checking whether the signal line from the pressure switch 14 has gone from low (or off) to high (or on). If not, operation flows to step 36, and the controller outputs an uncorrected pressure reading, for example to a display 26, or to another device for further processing. Operation then flows back to step 32, and the process is repeated.

The process described above will continue, with the output generated by the controller 16 corresponding to the uncorrected reading from the transducer, until the switch 14 is triggered. Once the switch is triggered, the controller sets a trigger flag in memory to true, and operation flows to step 38 rather than to step 36. The controller then adjusts the reading from the pressure transducer based on an error correction. The error correction is calculated as follows:

$$p_{error} = p_2 - p_1$$

where p_2 is the measured pressure transducer reading at the time the switch 14 is triggered, and p_1 is the pressure set point for the pressure switch. The controller stores the value p_{error} (which can be positive or negative) in memory 24, and outputs the corrected pressure value at step 40. In the instance where the switch has just been triggered, the pressure value output by the controller is the pressure set point for the pressure switch. Operation then proceeds back to step 32. Once the trigger flag has been set to true, the readings from the pressure transducer will be corrected using the above described error correction, according to the following equation:

$$p_{output} = p_2 - p_{error}$$

For example, assume the pressure set point is 10 psi, and that when the switch is triggered, the reading from the pressure transducer is 11 psi. The value of p_{error} is thus 1 psi. If the next reading from the pressure transducer has a value of 13 psi, then the controller corrects the value and outputs a pressure value of 12 psi (13 psi - 1 psi). If, on the other hand, when the switch is triggered, the reading from the pressure transducer is only 9 psi, then the value of p_{error} is -1, such that if the next reading from the transducer has a value of 13 psi, the controller outputs a value of 14 psi. Thus, the controller corrects for values that are either too high or too low.

If the pressure switch 14 is triggered again, for example when the pressure in the member 18 changes from a value above to a value below the pressure set point, the controller 16 is signaled due to the line from the pressure switch going low, and the controller preferably determines a new correction factor using the above-mentioned error correction equation.

It will be apparent that the pressure measuring system 10 of the present invention may include virtually any type of pressure transducer or sensor 12. Where cost is a concern, for example where a large number of pressure transducers are required to monitor an extensive network of fluid conduits or members, relatively inexpensive pressure transducers, such as strain gauge transducers, may be employed. Each transducer may have an associated pressure switch, with the look-up table in the memory 24 serving to associate the transducer and switch pairs, such that when a particular pressure switch is triggered, an error correction for the associated pressure transducer is calculated, and future readings from that transducer are corrected based upon the error correction. The controller is programmed to calculate individual error corrections for each transducer, and to store each error correction in the memory for future access.

Referring to Fig. 4, a second illustrative embodiment of the pressure measuring system 100 is shown. The system includes a pressure transducer 102, multiple pressure switches 104, and a controller 106. The pressure switches preferably each have a different pressure set point, and each is electrically connected to the controller via a separate line 108, 110, and 112. Thus, this system provides a multi-point calibration, and produces accurate pressure readings throughout a range of pressures. When one of the pressure switches is triggered, the controller is signaled via one of the lines 108, 110, or 112, and thus the controller knows which of the pressure switches was triggered. The controller then accesses the memory, for example the look-up table, and determines the set point for that particular pressure switch. The controller then performs the necessary error correction using the above-described equation to determine p_{error}, and stores the value of p_{error} in memory 24. The subsequent readings from the pressure transducer are then corrected by subtracting (or adding) p_{error} to the reading. If another one of the pressure switches is subsequently triggered, the controller determines the set point for that switch, calculates a new p_{error} based upon the new set point, and corrects subsequent readings from the pressure transducer based upon the new value of p_{error} and stores the new value of p_{error} in memory along with the first value of p_{error}.

After calculating the new value of p_{error}, if the pressure changes and is closer to the set point of the first switch than that of the second switch, the system preferably uses the correction factor for the first switch switch, i.e. the first value of p_{error}. For example, if the first switch triggers at 10 psi, and the second switch triggers at 20 psi, and the pressure in the member 18 has previously risen from a value below 10 psi to a value above 20 psi (such that both of the switches have been triggered), then when the sensed pressure drops back below, for example, 15 psi, the controller is programmed to use the correction factor for the first switch to correct the readings from the pressure transducer. If the sensed pressure rises above 15 psi again, the controller then uses the correction factor for the second switch to correct the readings from the pressure transducer. Thus, it will be apparent that the system 100 provides a more accurate output through a range of pressures, especially in cases when the error is non-linear. Such a system provides a technique for "zeroing" the pressure transducer at multiple non-zero values.

It will be apparent that the pressure measuring system 100 may also include more than one pressure transducer, with each having a particular range in which it is relatively accurate, and that the system may include multiple pressure switches that are used to adjust the readings from the respective transducers. The controller is preferably programmed to select readings from only one of the transducers, based upon the approximate pressure value within the member 18. For example, if a first one of the transducers has a range from 0 to 10 psi, and a second transducer has a range from 0 to 20 psi, the controller will select the readings from the first transducer when each transducer provides a reading of about 5 psi. The multiple transducers and switches are preferably connected to the single controller 16, with the controller selecting between the various transducers and monitoring each of the pressure switches.

From the foregoing, it will be apparent that the pressure measuring system 10 of the present invention provides relatively accurate pressure readings while using a relatively low-precision pressure transducer.

While the invention has been particularly shown and described with reference to preferred embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

CLAIMS:

1. A pressure measuring system for measuring the pressure in a member, comprising:

a pressure transducer in communication with the member, the transducer being operative to sense the pressure in the member and generate an electrical signal corresponding to the pressure sensed by the transducer;

a pressure switch in communication with the member, the pressure switch having a preselected set pressure point and operative to trigger and generate an electrical trigger signal when the pressure in the member crosses the set point; and

circuitry electrically connected to the pressure sensor and to the pressure switch, the circuitry being responsive to triggering of the pressure switch to calculate a correction factor for adjusting additional signals from the pressure transducer.

2. The system of claim 1 wherein the pressure transducer comprises a strain-gauge sensor.

3. The system of claim 1 wherein the circuitry comprises a processor.

4. The system of claim 1, further including at least two pressure switches, the pressure switches each having unique, preselected set points, and wherein:

the circuitry is connected to each of the at least two pressure switches.

5. The system of claim 3 wherein the processor is programmed to detect triggering of the pressure switch, calculate the difference between the preselected set pressure point of the pressure switch and the signal being received from the pressure transducer to create a correction factor, and to adjust additional signals from the pressure transducer based upon the correction factor.

6. A pressure measuring system for measuring the pressure in a member, comprising:

a pressure transducer in communication with the member to sense the pressure in the member and generate an electrical pressure signal corresponding to the pressure sensed by the transducer;

a plurality of pressure switches, each of which is in communication with the member, the pressure switches each having unique preselected pressure set points and being operative to trigger when the pressure in the member crosses a respective one of the set points; and

circuitry electrically connected to the pressure sensor and to the respective pressure switches, the circuitry being responsive to triggering of one of the pressure switches to determine the pressure sensed by the pressure transducer and the pressure set point of the triggered switch, and to calculate a correction factor based upon the difference between the pressure set point for the triggered pressure switch and the pressure sensed by the pressure transducer, the circuitry being operative to adjust additional electrical pressure signals from the pressure transducer based upon the correction factor.

7. The system of claim 6 wherein the pressure transducer comprises a strain-gauge sensor.

8. The system of claim 6 wherein the circuitry comprises a processor.

9. The system of claim 8 wherein the processor is programmed to detect triggering of one of the pressure switches, access a memory to determine a pressure set point of the triggered pressure switch, calculate the difference between the pressure set point of the pressure switch and the signal being received from the pressure transducer to create a correction factor, and to correct additional signals from the pressure transducer based upon the correction factor.

10. A method of measuring the pressure in a member, comprising:

sensing a pressure level in the member using a pressure sensor;

detecting whether a pressure switch connected to the member is triggered, the pressure switch having a preselected pressure set point;

if the pressure switch is triggered, calculating a difference between the pressure sensed by the pressure sensor, at approximately the time the pressure switch is triggered, and the pressure set point of the pressure switch;

receiving additional readings from the pressure sensor; and

correcting the additional readings from the pressure sensor using the calculated difference.

11. The method of claim 10 further including displaying the calibrated readings.

12. The method of claim 10, wherein the step of detecting comprises detecting whether one of multiple pressure switches is triggered, and wherein the step of calculating comprises calculating the difference based upon the pressure set point for the triggered pressure switch.

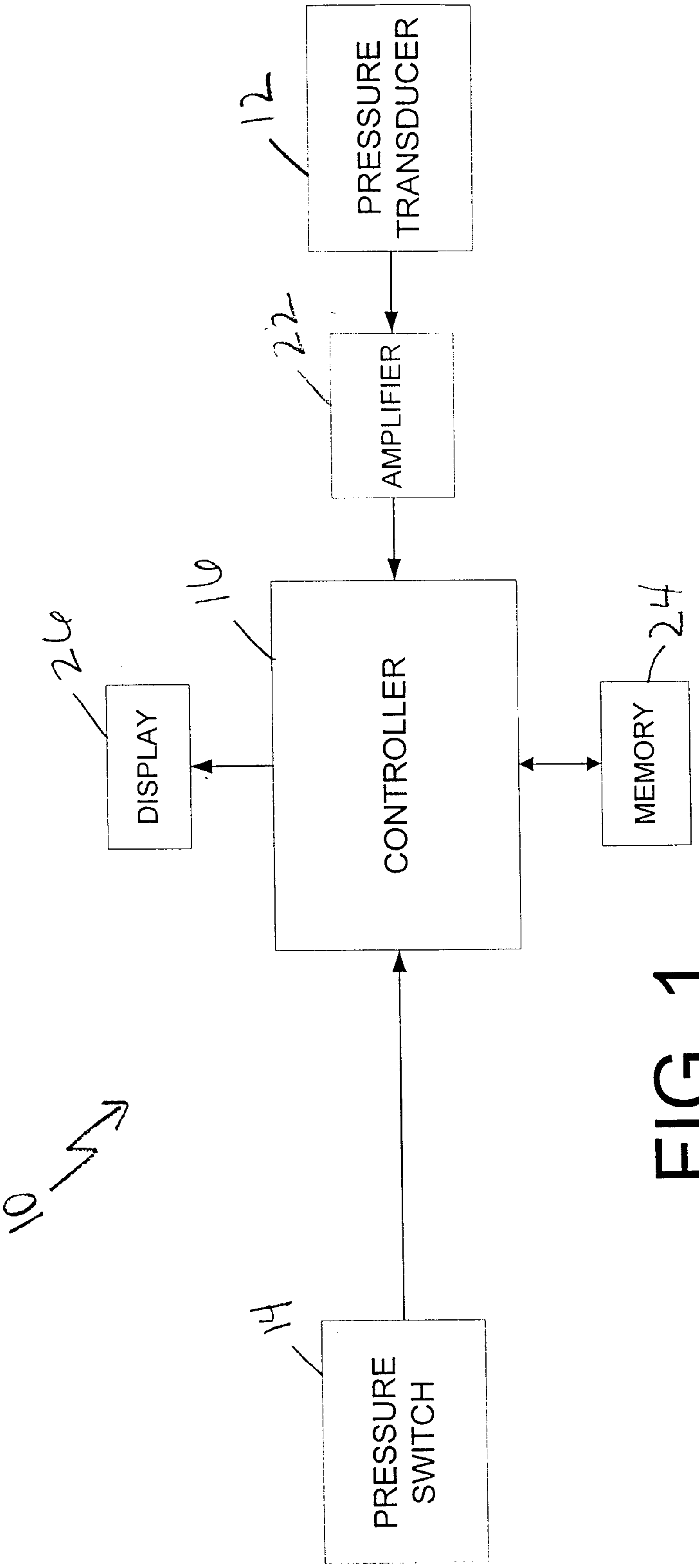
PRESSURE TRANSDUCER
12
AMPLIFIER
22
CONTROLLER
16
DISPLAY
26
MEMORY
24
PRESSURE SWITCH
14
10

FIG. 1

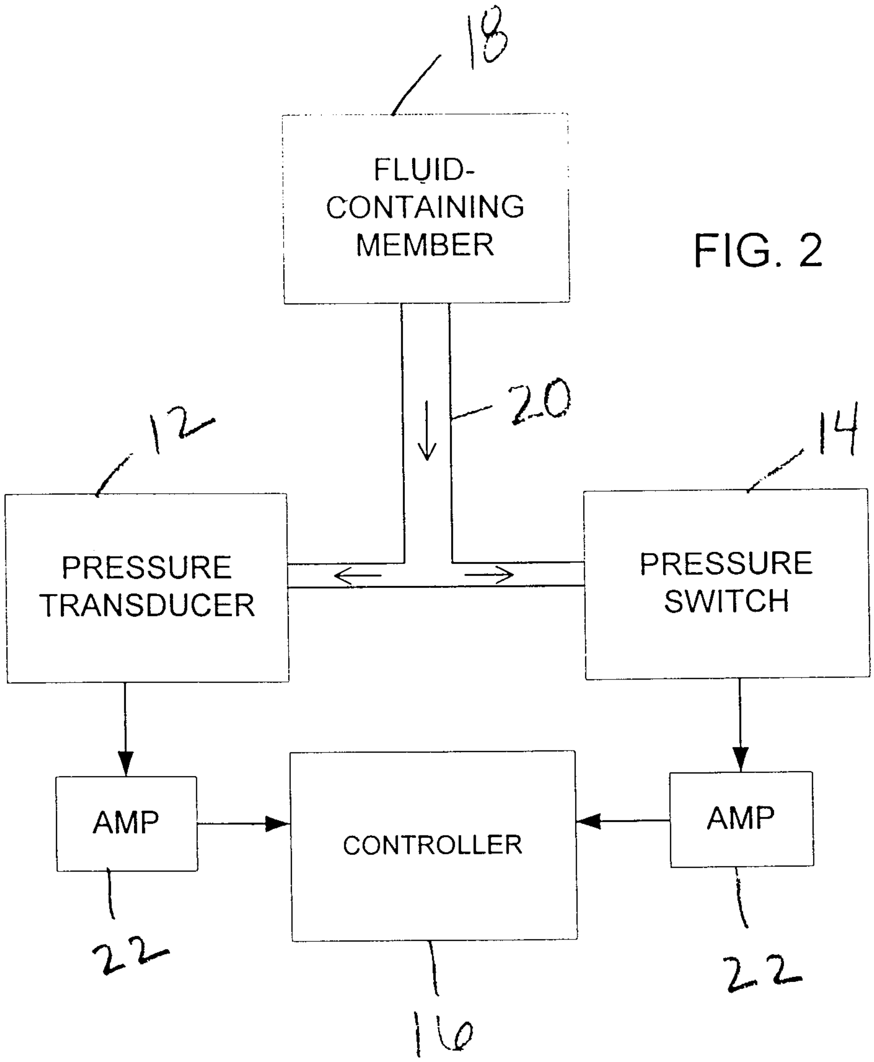
18
FLUID-
CONTAINING
MEMBER
20
12
PRESSURE
TRANSDUCER
14
PRESSURE
SWITCH
AMP
CONTROLLER
AMP
22
16
22

FIG. 2

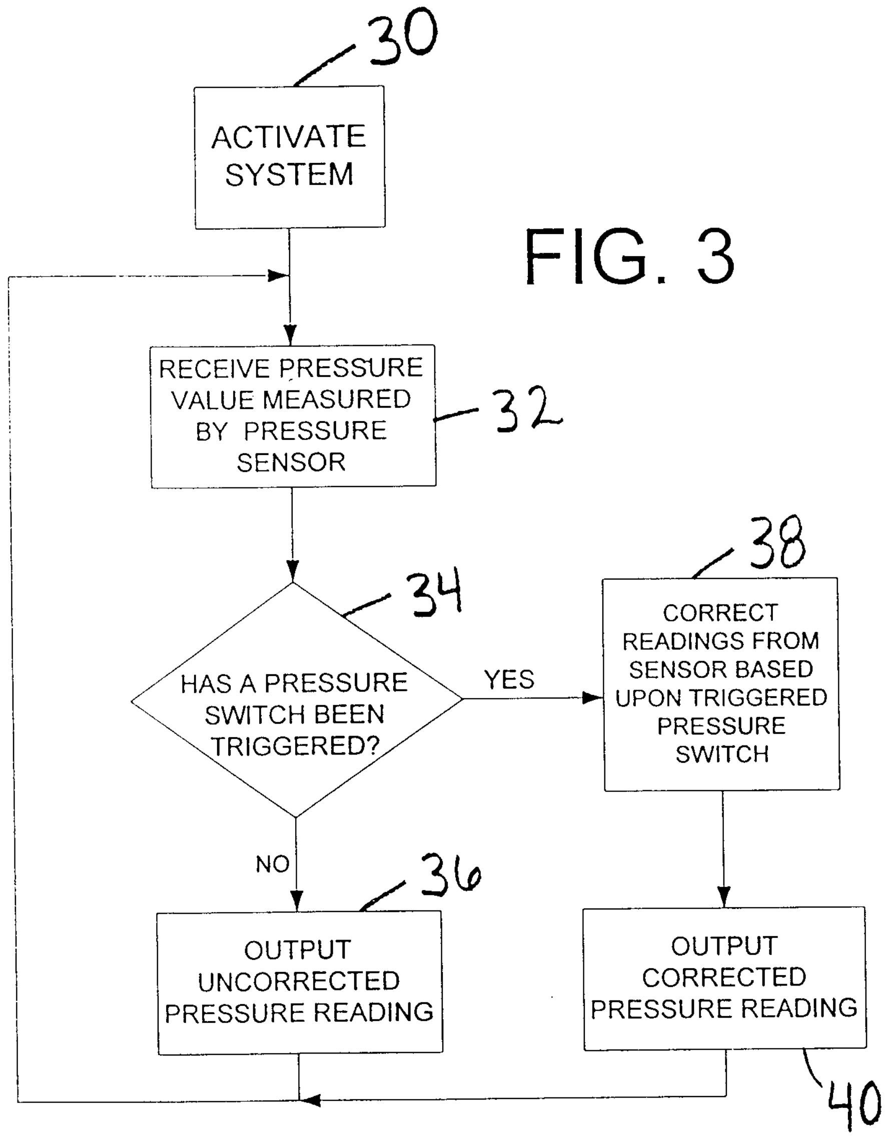
30
ACTIVATE SYSTEM
RECEIVE PRESSURE VALUE MEASURED BY PRESSURE SENSOR
32
34
HAS A PRESSURE SWITCH BEEN TRIGGERED?
YES
NO
38
CORRECT READINGS FROM SENSOR BASED UPON TRIGGERED PRESSURE SWITCH
36
OUTPUT UNCORRECTED PRESSURE READING
OUTPUT CORRECTED PRESSURE READING
40

FIG. 3

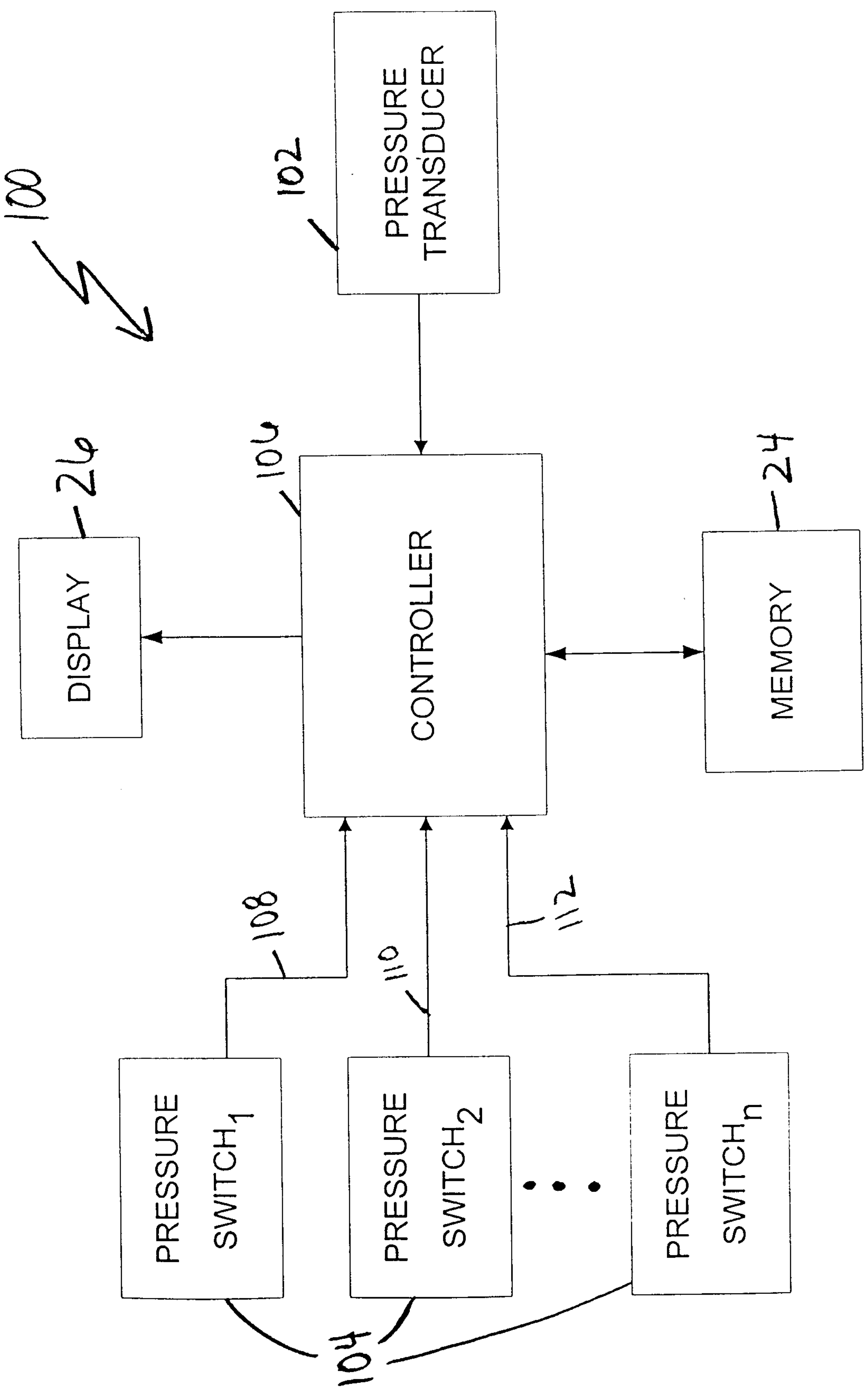
100
PRESSURE TRANSDUCER
102
DISPLAY
26
CONTROLLER
106
MEMORY
24
108
110
112
PRESSURE SWITCH$_1$
PRESSURE SWITCH$_2$
PRESSURE SWITCH$_n$
104

FIG. 4