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(54) Title: SENSOR ASSEMBLY FOR HYGENIC MATERIAL PROCESSING SYSTEMS

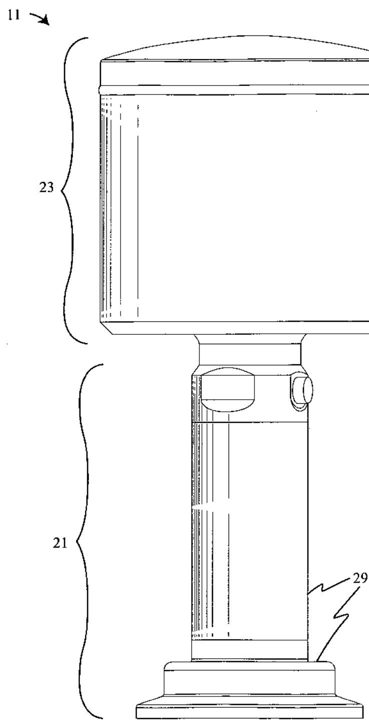

Figure 1

(57) Abstract: A sensor assembly (11) includes a replaceable sensor module (21) and an assembly housing (23). The assembly housing (23) contains an assembly housing processor (25) and an electrical connector (61) connected to the processor. The replaceable sensor module (21) has an enclosure (29) adapted to be mounted in a position to sense a process variable, a process variable transducer (31) positioned in said enclosure so as to be exposed to the process variable, and a non-volatile memory (33) having stored therein specific profiling data for the sensor module. The assembly housing processor (25) has data representing a desired sensor assembly output characteristic, and is responsive to receipt of specific profiling data and to the data representing the desired sensor assembly output characteristic to calibrate the sensor assembly (11) to provide the desired sensor assembly output characteristic when connected to the sensor module (21) having the specified profiling data. Radial and axial seals (53) & (51) are provided for the openings in the assembly housing (23). Measurement of loop current (I_L) in a two-wire loop current communication system for the sensor assembly (1 1) and detection of sensor aging are also included.

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SENSOR ASSEMBLY FOR HYGENIC MATERIAL PROCESSING SYSTEMS

Technical Field.

This invention relates to sensor assemblies for use in automated process control systems, and particularly to such sensor assemblies with improved reliability and functionality for use in hygienic material processing systems.

Background Art.

Automated process control systems are conventionally used in various industries, such as biotechnology, beverage, dairy, food, and pharmaceutical manufacturing. These systems rely upon the measurement of process parameters (pressure, temperature, flow rate, fluid level, etc.) which are sensed by sensor assemblies. These sensor assemblies not only sense the particular process parameter desired at that particular point in the process, but also transmit the sensed values of the parameter to the automated process control system for appropriate action by the control system. That is, the sensor assemblies typically have both a sensing function and a communications function. Prior art sensor assemblies are conventionally single integrated units (i.e., includes the sensor function and the communications/signal processing in a single physical housing). With conventional prior art sensor assemblies, the entire assembly must be replaced when the sensing portion fails.

The housing for conventional sensor assemblies vary widely depending upon various factors, including (1) type of process connection, (2) parameter range for operation, (3) signal output (e.g., 4-20ma, digital or field bus), and (4) orientation of installation. Although it is possible to keep a complete inventory of the sensor assemblies needed to keep the process line functioning, that can be an expensive proposition which some industries typically forgo. For example, the dairy facilities frequently do not stock a complete inventory of sensor assemblies. If the proper sensor assembly is not available, for whatever reason, when an installed assembly fails, production must be shut down until the proper sensor assembly is obtained and installed. This can be an expensive inconvenience for companies located near sources of replacement sensor assemblies. It can become an even more serious inconvenience when the plant is located in remote areas or in emerging countries with limited infrastructure.

One possible solution is to replace only the sensing portion of the assembly, since that is the portion that typically fails. That would drastically reduce the inventory that would be required to maintain full production. But this presents a problem: how to calibrate the sensor assembly in the field. As noted above, the sensor assembly includes both a sensing function and a communication function. Calibration of the sensor assembly involves ensuring not only that the sensing portion is supplying signals at the desired levels for the particular process parameter value being measured, but also that the communication part of the sensor assembly properly recognizes the output of the sensing portion and accurately communications the proper value of the proper parameter to the automated process control system. Such calibration in the field can be difficult. Since field calibration is not a common occurrence, it is prone to error if attempted by a local technician who typically lacks the needed expertise and can be a cause of further delay and expense if done by a specialist, who typically must travel to the processing facility to effect the replacement.

In many industries, e.g., dairy or brewing, sensor assemblies are subjected to high levels of humidity and moisture in general. This operating environment can also be true for tropical locales, even for typically "dry" material processing systems. The electronics in sensor assemblies can be extremely sensitive to unwanted moisture. Unwanted moisture can enter existing sensor assemblies (and potentially damage the electronics) not only in high humidity conditions, but also when the housing for the assembly is dented or otherwise damaged in such a way as to interfere with any moisture seals which are built into the sensor assembly. Existing sensor assemblies typically have visual displays incorporated into the assembly for displaying to a user the value of the particular parameter being measured. These displays are typically seen through a transparent cover. In high humidity conditions, this cover can accumulate moisture, thereby obscuring the view of the visual display in conventional sensor assemblies. The transparent enclosure, of course, must also be attached to the sensor assembly housing in such a way as to prevent the passage of moisture to the interior of the housing, but this goal is not always satisfactorily achieved with existing sensor assemblies. Frequently it is not possible for the person installing the transparent cover to determine whether the cover has been properly installed on the sensor assembly housing or to determine whether a moisture-tight seal has been achieved.

Summary of the Invention.

Among the various objects and features of the present invention may be noted the provision of an improved sensor assembly which provides for easy sensor replacement.

Another object is the provision of a sensor assembly with an auto-calibrated output.

A third object is the provision of such a sensor assembly which simplifies inventory and supply chain problems.

A fourth object is the provision of such a sensor assembly which is less complex to install, use and maintain.

A fifth object is the provision of such a sensor assembly which is particularly suited for hygienic processing environments such as food, dairy, brewery and pharma.

A sixth object is the provision of such a sensor assembly which reduces the risk of moisture ingression due to physical damage to sensor assembly sealing surfaces.

A seventh object is the provision of such a sensor assembly which minimizes the risk of moisture or other contamination accumulating on the transparent cover of the assembly.

An eighth object is the provision of such a sensor assembly which provides a positive indication such as a tactile or a visual indication when the seals between the transparent cover and the housing are properly seated.

A ninth object is the provision of such a sensor assembly which provides redundant sealing against moisture ingression with two different failure modes.

Other objects and features will be in part apparent and in part pointed out herein.

In a first aspect of the present invention, a sensor assembly for use in an automated process control system includes a replaceable sensor module, an assembly housing containing an assembly housing processor and an electrical connector connected to the processor and accessible by the automated process control system. The replaceable sensor module includes an enclosure adapted to be mounted in a position to sense a process variable, a process variable transducer positioned in the enclosure so as to be exposed to the process variable, and a non-volatile memory having stored therein specific profiling data for the sensor module. The assembly housing processor in the assembly housing has data representing a desired sensor assembly output characteristic, and is responsive to receipt of the specific profiling data and to the data representing the desired sensor assembly output characteristic to calibrate the sensor assembly to provide the desired sensor assembly output characteristic when connected to the sensor module having the specified profiling data.

In a second aspect of the present invention, a sensor assembly includes a replaceable sensor module containing at least one transducer and at least one electronic circuit connected to the transducer, and an assembly housing containing at least an assembly housing processor and an electrical connector connected to the processor. The assembly housing has a cover secured thereto, and also has an opening for accepting a plug body through which passes at least one electrical connector. The assembly housing has at least two paths for migration of moisture from the exterior of the assembly housing to the interior of the assembly housing. At least one axial seal is positioned along a first of the moisture migration paths to resist the passage of moisture from the exterior of the assembly housing to the interior of the assembly housing. At least one radial seal is also positioned along the first moisture migration path to resist the passage of moisture from the exterior of the assembly housing to the interior of the assembly housing.

In a third aspect of the present invention a method of operating a sensor assembly in a hygienic material processing system includes sensing a process variable using at least one transducer and at least one electronic circuit connected to the transducer, periodically automatically testing an electrical characteristic of the transducer, the testing occurring at a time other than when the process variable is being sensed, providing at least one threshold for the value of said electrical characteristic, and indicating when the electrical characteristic has gone over the threshold.

In a fourth aspect of the present invention, a sensor assembly for use in an automated process control for a hygienic material processing system includes a two-wire current loop communications link communicating sensor data to the automated process control. The current in the loop corresponds to the measured value of the process variable. Feedback from the current loop is used to control the magnitude of the current and to generate a display of the loop current for the user.

Brief Description of the Drawings

Fig. 1 is a front elevation of the sensor assembly of the present invention;

Fig. 1A is an exploded view of the sensor assembly of Fig. 1;

Fig. 1B is an exploded view like Fig. 1A with parts broken away for clarity;

Fig. 2 is a diagrammatic view illustrating the use of the sensor assembly of the present invention;

Fig. 3 is a block-diagram illustrating various electronic components contained in the sensor assembly of Fig. 1;

Fig. 3A is a schematic illustrating the transmitting/current measuring portion of the present invention;

Fig. 4 illustrates the data structure of profiling data stored in the sensor assembly, and more particularly in the sensor module portion of the sensor assembly;

Fig. 5 is an exploded view with parts broken away of the mechanical connection of one portion of the sensor assembly to the main housing of the assembly;

Fig. 5A is an exploded view like Fig. 5 with additional parts broken away for clarity, illustrating an axial and radial sealing feature of the present invention;

Fig. 6 is an exploded view of the sensor assembly with parts broken away to illustrate additional axial and radial sealing features of the present invention.

Similar reference characters indicate similar parts throughout the several views of the drawings.

Best Modes for Carrying Out the Invention

Turning to the drawings, a sensor assembly 11 of the present invention is shown in Fig. 1. A partially exploded view is shown if Fig. 1A. Assembly 11 is designed for use in the automated process control for a hygienic material processing system 13 as illustrated in Fig. 2. In Fig. 2, assembly 11 is shown mounted in a position to sense the value of a process parameter (such as pressure of a fluid F) flowing in a pipe P. Assembly 11 communicates the value of the parameter via any standard communication protocol to a process controller 15 having a number of inputs and outputs 17 to control the process in a conventional manner. The present invention is not limited to any particular process control system, and is instead directed to assembly 11 for use in any such system. The process parameter is described herein as being the pressure of the liquid or other flowable material being processed, but could also be the level and/or the flow rate of the liquid and flowable material.

Turning back to Figs. 1 and 1A, sensor assembly 11 includes a replaceable sensor module 21 and an assembly housing 23. Assembly housing 23 contains (see Fig. 3) an assembly housing processor (micro-controller) 25 and a loop transmitter and power supply circuit 27 connected to the assembly housing processor 25 and accessible by automated process control system 13. Two wire transmitter systems are well-known in process control systems. The transmitter and power supply 27 is connected to the loop (indicated by LOOP+ and LOOP- in the lower right-hand corner of Fig. 3) and is powered by the loop current flowing through the current loop. In fact, all the electronics of sensor assembly 11 are ultimately powered by the current from the current loop. The magnitude of the loop current is varied by loop transmitter and power supply 27 as a function of the magnitude of the process parameter variable being measured. Thus, the loop current is held at essentially a constant current value corresponding to the value of the parameter being measured, while at the same time all the needs of the circuitry in sensor assembly 11 are being supplied from the same current. This latter load is, of course variable, so the present invention requires monitoring of the loop current to ensure that it stays at the constant current value representing the measured parameter value despite the changing amount of current needed by the electronics in sensor assembly 11.

Turning to Fig. 3A, loop transmitter and power supply 27 is shown in more detail, as including a power supply portion 27A and a negative feedback control circuit portion 27B. Power supply portion 27A supplies regulated power at a desired level to the rest of the circuitry of sensor assembly 11. For example, to supply regulated power at 3.3V, power supply portion 27A may include an output voltage regulator such as the type sold under the trade designation LTC3632 and a linear regulator such as the type sold under the trade designation TPS77033. Of course, any number of different such components could be used, and the particular type of components making up power supply portion 27A is not considered to be part of the present invention.

The loop current I_L flows between the terminals of the loop, labeled Loop+ and Loop- as indicated in Fig. 3A. The magnitude of that current is governed by NPN transistor U2, which may preferably be that sold under the trade designation BCP55. The collector of transistor U2 is connected to current loop terminal Loop+, while the emitter is connected through a feedback resistor R9 to the other loop terminal Loop-. The voltage drop across resistor R9 is supplied to a conventional feedback control circuit which constitutes the transmitter portion 27A of the circuitry. This feedback control circuit uses the voltage drop across resistor R9, which is a direct measure of the current flowing in the loop and an input representing the value of measured process variable, and supplies a corresponding signal to the base of transistor U2 (Fig. 3A) The feedback control circuit is conventional in construction. For example, it can preferably be configured using an amplifier sold under the trade designation OPA4379. The precise details of such feedback circuits and their use in transmitting data over two-wire current loops are well-known and are not considered to be part of the present invention.

The feedback signal is preferably also supplied to an internal current meter 27C of the present invention. More specifically, the feedback signal is measured using an analog-to-digital converter (ADC). Such an ADC may be present in many available ASIC chips. For example, the ASIC chip sold under the trade designation ZMD31050 has a built-in ADC which is suitable for this task. The ASIC (or alternatively, micro-controller 25) uses this converted digital value to compute the actual loop current. More specifically, the processor in the ASIC or the micro-controller itself uses an equation to compute the actual current value corresponding to the measured value of the feedback signal. A first order linear equation has been found to adequate for this task, although higher order equations could also be used. The current loop value, after it is calculated is then displayed on a suitable display such as display 28. The 4x7-CHAR LED display shown in Fig. 3 may be used for display 28, or other suitable display may be provided.

Turning back to Fig. 1, replaceable sensor module 21 includes an enclosure or housing 29 (Fig. 1) adapted to be mounted in a position to sense the process variable. A process variable transducer 31 is positioned in enclosure 29 so as to be exposed to the process variable. A non-volatile memory 33 (shown as an EEPROM) is also disposed in sensor module 21 and has stored therein specific profiling data for the sensor module. More specifically (see Fig. 4), EEPROM 33 has stored therein the pressure-temperature characteristics for that particular sensor module 21. That is, the contents of EEPROM 33 vary from sensor module to sensor module as a function of the particular transducer 31 contained in the sensor module. As shown in Fig. 4, the profiling data preferably includes data taken at three different gain levels (Low, Mid, and High) at multiple different points across its range.

Turning back to Fig. 3, it is preferred that sensor module 21 include its own processor 37 (which in Fig. 3 is an ASIC chip) which is connected to pressure transducer 31 and to EEPROM 33. ASIC 37 includes and analog-to-digital converter (ADC) to convert the output of the process parameter transducer 31 to digital values. It is these ADC values which constitute the recorded profiling data indicated in Fig. 4. As a result, it should be noted that the profiling data stored is a function not only of the particular transducer in the sensor module, but also of the particular ASIC chip.

As shown in Fig. 3, transducer 31 (not shown) using a bridge 39 to sense the process parameter (in this example, pressure). That transducer includes a strain gage mounted on a diaphragm, which is described below. In addition, a temperature transducer 41 is included in transducer 31 for supplying temperature information to ASIC 37. It should be understood that the present invention is not limited to the use of any particular type of sensor for sensing the desired process parameter. Although at present ASIC 37 is contemplated as being a CMOS integrated circuit chip sold under the trade designation ZMD31050, it should also be understood that any ASIC capable of performing these functions could be used. This particular chip is useful since it has the ability to test the lumped resistance of the bridge 39 under programmed control. This chip is designed to electrically short across the bridge (which effectively cancels the load on the sensor) and measure the lumped resistance (common mode voltage) of the bridge. ASIC 37 is programmed to measure this electrical characteristic of the transducer periodically between actual process readings. In addition, high (upper) and low (lower) thresholds are set in ASIC 37 so that measurements outside the thresholds are identified. This state can be indicated either electrically, visually, or both. This feature allows drift of the sensor due to age, adverse conditions, etc. to be detected so that the system can be recalibrated.

Note that EEPROM 33 is connected to both ASIC 37 and the housing processor 25. Specifically, sensor module 21 is connected to micro-controller 25 by an i2c communication bus (although the particular communications protocol is not a feature of this invention). The profiling information from the EEPROM is supplied to ASIC 37 so that the digital output of ASIC 37 to housing processor 25 preferably provides fully calibrated digital sensor readings. The information is also supplied to the housing processor. Housing processor 25 is responsive to this information to generate a calibration curve (by way of example, a third order calibration curve) which it supplies to ASIC 37. Housing processor 25 is also responsive to this information and to its own data representing the desired sensor assembly output characteristics for that particular sensor assembly to provide the desired sensor assembly output characteristic when connected to the sensor module having the specified profiling data. In this way, sensor module 21 can be used with any number of different assembly housing 23 to provide the correct output for that particular sensor assembly at that particular location. This significantly reduces the necessary inventory of sensor modules.

Turning back to Fig. 1A it can be seen that sensor module 21 includes a screw thread 41a by which the sensor module 21 is secured to a mating surface in assembly housing 23 to secure the sensor module and the assembly housing into a single unitary structure. It is preferred that the sensor module and the assembly housing be capable of being secured together by hand, without the use of hand tools. Alternatively, the sensor module 21 may be secured to assembly housing 23 by corresponding bayonet-connector type structures, which are well known in the art. In the later case, mechanical connection of the sensor module to the assembly housing automatically provides the required electrical connection therebetween. Bayonet-type electrical connectors are well known.

Other connectors such as push-pull electrical connectors such as those sold by LEMO S.A. may also be used to provide simultaneous electrical and mechanical connection.

As shown in Fig. 1A, sensor assembly 11 includes a transparent cover 45 with screw threads 47 which together with mating threads 49 on the interior of assembly housing 23 permit the cover to be attached to the assembly housing. The attachment of cover 45 to assembly housing 23 potential creates a path for migration of moisture from the exterior of the assembly housing to the interior of assembly housing 23. For this reason, an o-ring 51 is disposed on cover 45 and a second o-ring 53 is disposed in assembly housing 23. (In Fig. 1B, various parts have been removed to more clearly show the o-rings.) When cover 45 is properly screwed onto assembly housing 23, both o-ring 51 and o-ring 53 provide moisture-resistant seals between the cover and the assembly housing. Note as well that attaching cover 45 to assembly housing 23 causes o-ring 51 to be axially compressed, while that same action causes o-ring 53 to be radially compressed. Each of these seals, therefore, provides an independent seal, with different modes of failure, thereby maximizing the possibility of preventing moisture from entering the interior of assembly housing 23. O-ring 51 is positioned such that when the cover is properly sealed to assembly housing 23 that fact can be visually verified. It is also preferred that both o-rings provide a suitable tactile sensation when cover 45 is properly sealed to assembly housing 23.

Also shown in Figs. 1A and 1B are a threaded plug 57 for attachment to a corresponding threaded sleeve 59 (Fig. 1A only) of assembly housing 23. The electrical connector 61 for making connection between the micro-controller 25 and the process controller 15 extends through plug 57. Threaded sleeve 59 potentially creates a second path for migration of moisture into the assembly. As can be seen in Fig. 5 and 5A, a pair of o-rings 63 and 65 are disposed between plug 57 and mating sleeve 59 to provide axial and radial seals to prevent such a migration of moisture into the assembly.

The connection between sensor module 21 and assembly housing 23 also provides a potential path for moisture migration into the assembly housing. A pair of o-rings 71, 73 (Figs. 1A, 1B, and 6) are disposed in such a manner as to provide axial and radial seals such as described above in connection with the other two migration paths.

Also shown in Figs. 1A and 1B is a block 77 which includes the various electronic components contained within assembly housing 23. Securing cover 45, plug 57, and sensor module 21 to the assembly housing 23 as described above provides a redundant, moisture resistant seal for the entire assembly housing. Note that many of the seals are coaxial. However, the seals formed by o-rings 71 and 73, while coaxial to each other, are positioned transversely relative to the position of the seals formed by the other o-rings. The seals formed by sensor module o-rings 61 form seals which are adjacent each other. This is also true of o-rings 71 and 73. The o-rings 51 and 53 which form the seals for cover 45 are more widely spaced apart, but they still provide both axial and radial sealing.

In view of the above, it will be seen that the various objects and features of the present invention are achieved and other advantageous results obtained. Nothing in this description should be construed in a limiting sense.

Claims:

1. A sensor assembly for use in an automated process control for a hygienic material processing system comprising:

a replaceable sensor module;

an assembly housing containing an assembly housing processor and an electrical connector connected to the processor and accessible by said automated process control system;

said replaceable sensor module including an enclosure adapted to be mounted in a position to sense a process variable, a process variable transducer positioned in said enclosure so as to be exposed to the process material being processed, and a non-volatile memory having stored therein specific profiling data for the sensor module;

said assembly housing processor in said assembly housing having data representing a desired sensor assembly output characteristic, said processor being responsive to receipt of said specific profiling data and to the data representing the desired sensor assembly output characteristic to calibrate the sensor assembly to provide the desired sensor assembly output characteristic when connected to the sensor module having the specified profiling data.

2. The sensor assembly as set forth in claim 1 wherein the assembly housing includes a first mating surface adapted to receive the sensor module and the sensor module includes a second mating surface adapted to mate with the first mating surface of the assembly housing to attach the sensor module to the assembly housing to form a unitary structure.

3. The sensor assembly as set forth in claim 2 wherein the mating structures are threaded.

4. The sensor assembly as set forth in claim 2 wherein the mating structures include electrical connections such that attachment of the sensor module to the assembly housing provides both mechanical and electrical connection.

5. The sensor assembly as set forth in claim 2 wherein the sensor module includes an electrical connector to provide electrical contact between said sensor module electrical connector and the processor in the assembly housing.

6. The sensor assembly as set forth in claim 2 wherein the sensor module may be attached to the assembly housing by hand.

7. The sensor assembly as set forth in claim 1 wherein the process variable is selected from the group comprising pressure of the material, temperature of the material, level of the material and flow rate of the material.

8. The sensor assembly as set forth in claim 1 wherein said profiling data stored in said sensor module non-volatile memory includes data taken at at least two gain levels.

9. The sensor assembly as set forth in claim 1 wherein said profiling data stored in said sensor module non-volatile memory includes pressure-temperature characteristics for said sensor module.

10. The sensor assembly as set forth in claim 1 wherein said processor in said assembly housing uses the profiling data stored in the sensor module and the data representing the desired sensor assembly output to generate a calibration curve for the sensor assembly.

11. The sensor assembly as set forth in claim 10 wherein the coefficients of the calibration curve are supplied to the sensor module by the processor in said assembly housing.

12. The sensor assembly as set forth in claim 10 wherein the calibration curve is at least a second order polynomial.

13. The sensor assembly as set forth in claim 1 wherein the desired sensor assembly output characteristic includes a desired sensor assembly output range, said processor having data representing said desired range, said processor using said sensor module profiling data and said data representing a desired sensor assembly output characteristic to provide a sensor output signal corresponding to the desired process variable range and to the particular sensor module being used.

14. The sensor assembly as set forth in claim 1 wherein the sensor module includes a module processor responsive to said process variable transducer, said profiling data, and to data from the assembly housing processor to supply calibrated process variable data to the assembly housing processor.

15. The sensor assembly as set forth in claim 14 wherein the module processor is connected to at least one temperature transducer in addition to being connected to the process variable transducer.

16. The sensor assembly as set forth in claim 1 wherein the sensor module includes a temperature transducer in addition to the process variable transducer.

17. A sensor assembly for hygienic material processing systems comprising:

a replaceable sensor module containing at least one transducer and at least one electronic circuit connected to said transducer;

an assembly housing containing at least an assembly housing processor and an electrical connector connected to the processor, said assembly housing having a cover secured thereto, said assembly housing also including an opening for accepting a plug body through which passes at least one electrical connector, said assembly housing having at least two paths for migration of moisture from the exterior of the assembly housing to the interior of the assembly housing;

at least one axial seal positioned along a first of said migration paths to resist the passage of moisture from the exterior of the assembly housing to the interior of the assembly housing; and

at least one radial seal positioned along said first migration path to resist the passage of moisture from the exterior of the assembly housing to the interior of the assembly housing.

18. The sensor assembly as set forth in claim 17 wherein said first migration path is between the sensor module and said assembly housing.

19. The sensor assembly as set forth in claim 17 wherein said first migration path is between said cover and said assembly housing.

20. The sensor assembly as set forth in claim 17 wherein said first migration path is between said plug body and said assembly housing.

21. The sensor assembly as set forth in claim 17 wherein said first migration path is between the sensor module and said assembly housing and a second of said migration paths is between the plug and the sensor housing, each of said paths having an axial seal and a radial seal to resist the passage of moisture from the exterior of the assembly housing to the interior of the assembly housing.

22. The sensor assembly as set forth in claim 21 further including a third migration path between the cover and the assembly housing, further including an axial seal and a radial seal along the third migration path to resist the passage of moisture from the exterior of the assembly housing to the interior of the assembly housing.

23. The sensor assembly as set forth in claim 17 wherein at least one seal provides a visual indication to a user when said seal is properly seated.

24. The sensor assembly as set forth in claim 17 wherein at least one seal provides a tactile indication to a user when said seal is properly seated.

25. The sensor assembly as set forth in claim 17 wherein the axial seal has a first failure mode and the radial seal has a second, independent failure mode.

26. The sensor assembly as set forth in claim 17 wherein said at least one axial seal and said at least one radial seal are of generally annular configuration and are generally coaxially located relative to each other.

27. The sensor assembly as set forth in claim 26 wherein said at least one axial seal and said at least one radial seal are disposed adjacent each other.

28. The sensor assembly as set forth in claim 26 wherein one of said seals is disposed axially in-board the other of said seals.

29. The sensor assembly as set forth in claim 17 wherein said assembly housing has at least three paths for migration of moisture from the exterior of the assembly housing to the interior of the assembly housing, further including axial seals along each of said three migration paths and radial seals along each of said three migration paths.

30. The sensor assembly as set forth in claim 29 wherein the axial and radial seals along a first of said migration paths is generally transverse to the axial and radial seals along at least one of said other migration paths.

31. In a sensor assembly for use in an automated process control for a hygienic material processing system, said sensor assembly measuring a process variable magnitude and supplying information concerning the process variable magnitude to the automated process control, the improvement comprising:

a two-wire communications link adapted to be connected to the automated process control so as to communicate information from the sensor assembly to the automated process control by a current loop, said current loop also providing power to the sensor assembly;

a control circuit responsive to a level of a parameter indicative of the process variable to be sensed to control the amount of current flowing through the current loop to be at a level corresponding to the level of the parameter;

said control circuit including a feedback input representing said amount of current flowing through the current loop, said feedback input further being connected to a current meter circuit, said current meter circuit being responsive to the feedback input to determine and display indicia representative of the process variable.

32. The sensor assembly improvement as set forth in claim 31 wherein the current meter circuit includes an analog-to-digital converter which in response to the feedback input generates a corresponding digital signal.

33. The sensor assembly improvement as set forth in claim 32 wherein the current meter circuit further includes a processor responsive to the digital signal to calculate the amount of current flowing through the current loop.

34. A method of operating a sensor assembly in a hygienic material processing system comprising:

sensing a process variable using at least one transducer and at least one electronic circuit connected to said transducer;

periodically automatically testing an electrical characteristic of said transducer, said testing occurring at a time other than when the process variable is being sensed;

providing at least one threshold for the value of said electrical characteristic;

indicating when the electrical characteristic has gone over said threshold.

35. The method as set forth in claim 34 wherein lower and upper thresholds are provided, and the indicating step includes indicating that the electrical characteristic has gone below the lower threshold and indicating that the electrical characteristic has gone above the upper threshold.

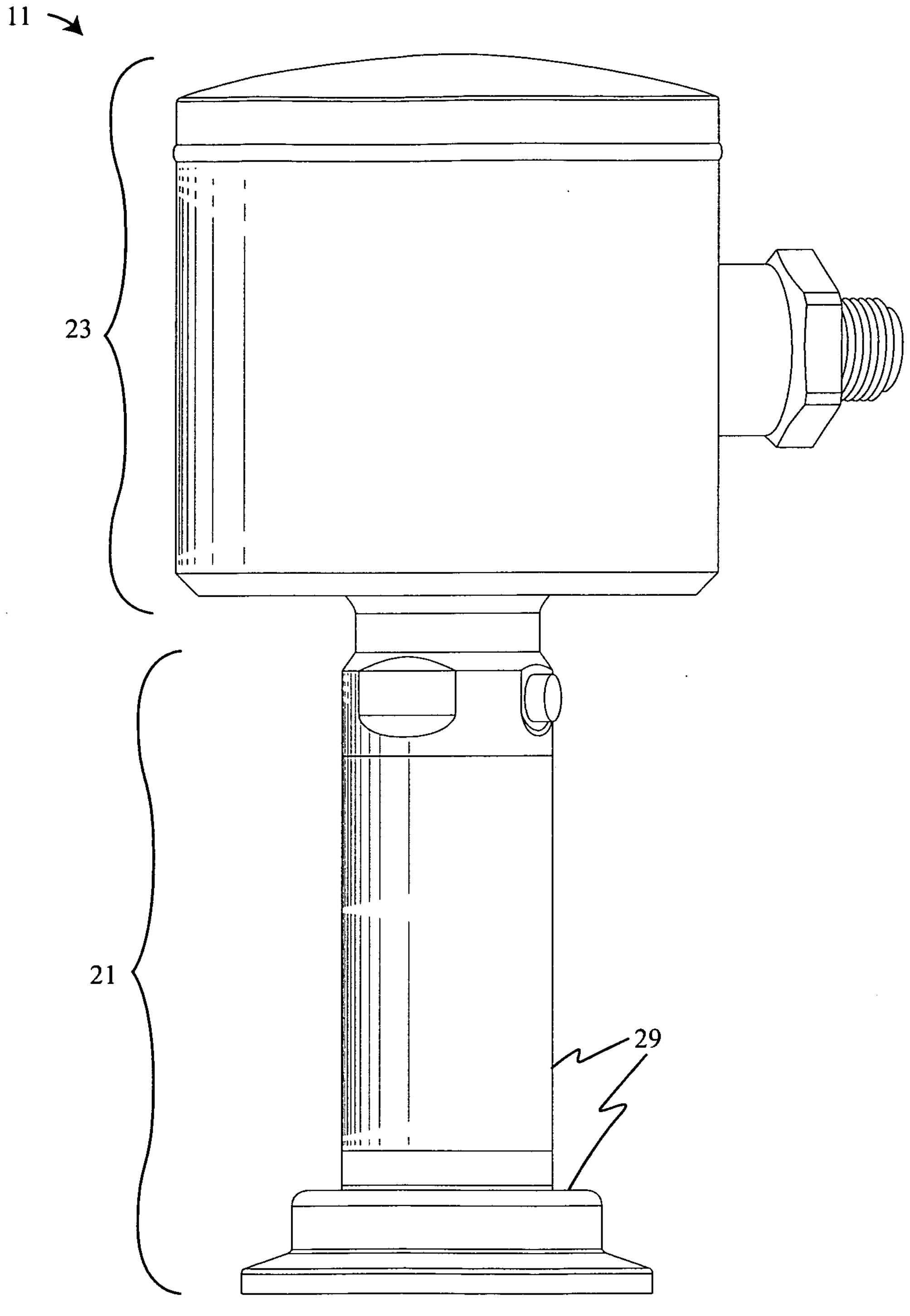


Figure 1

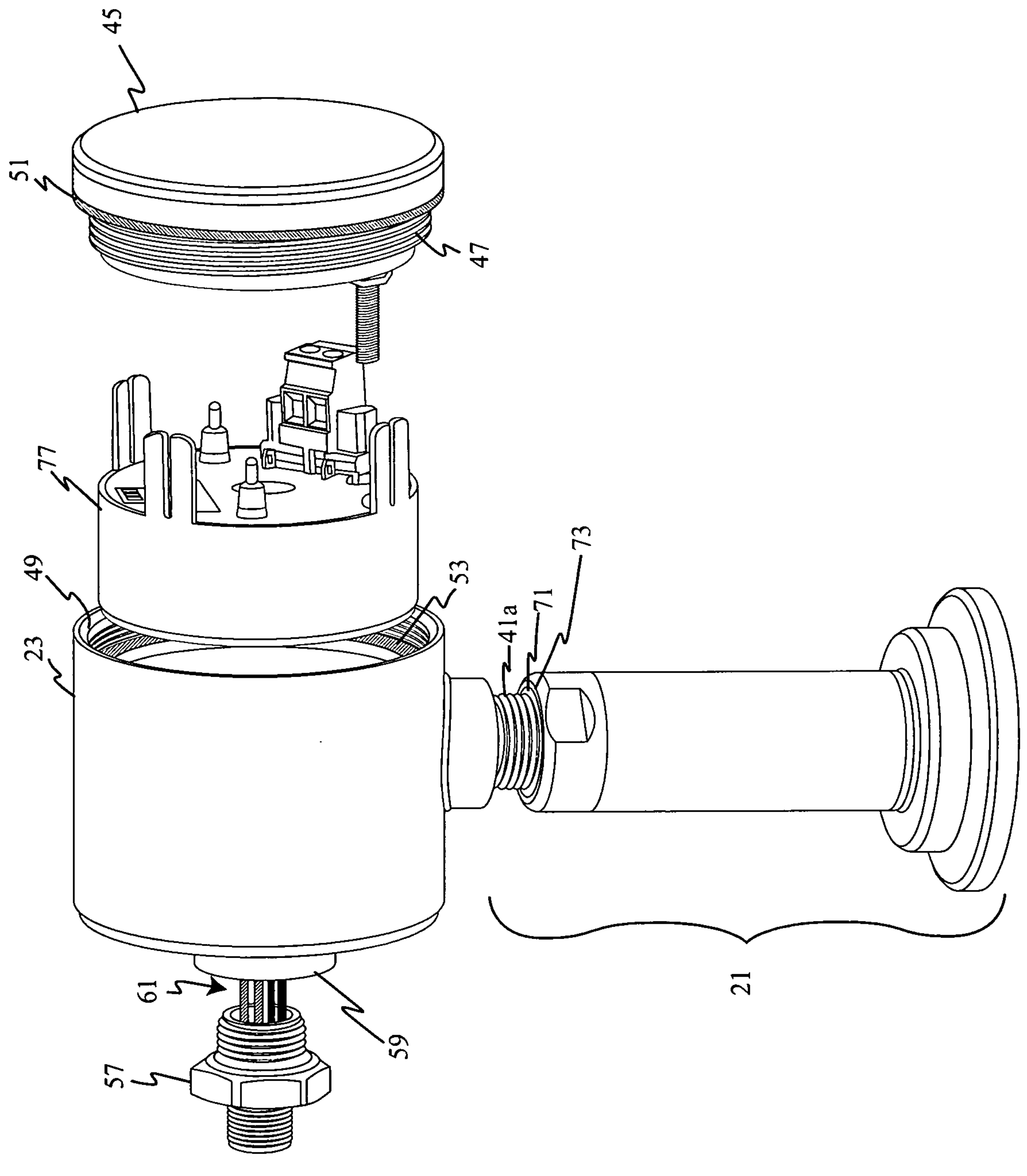


Figure 1A

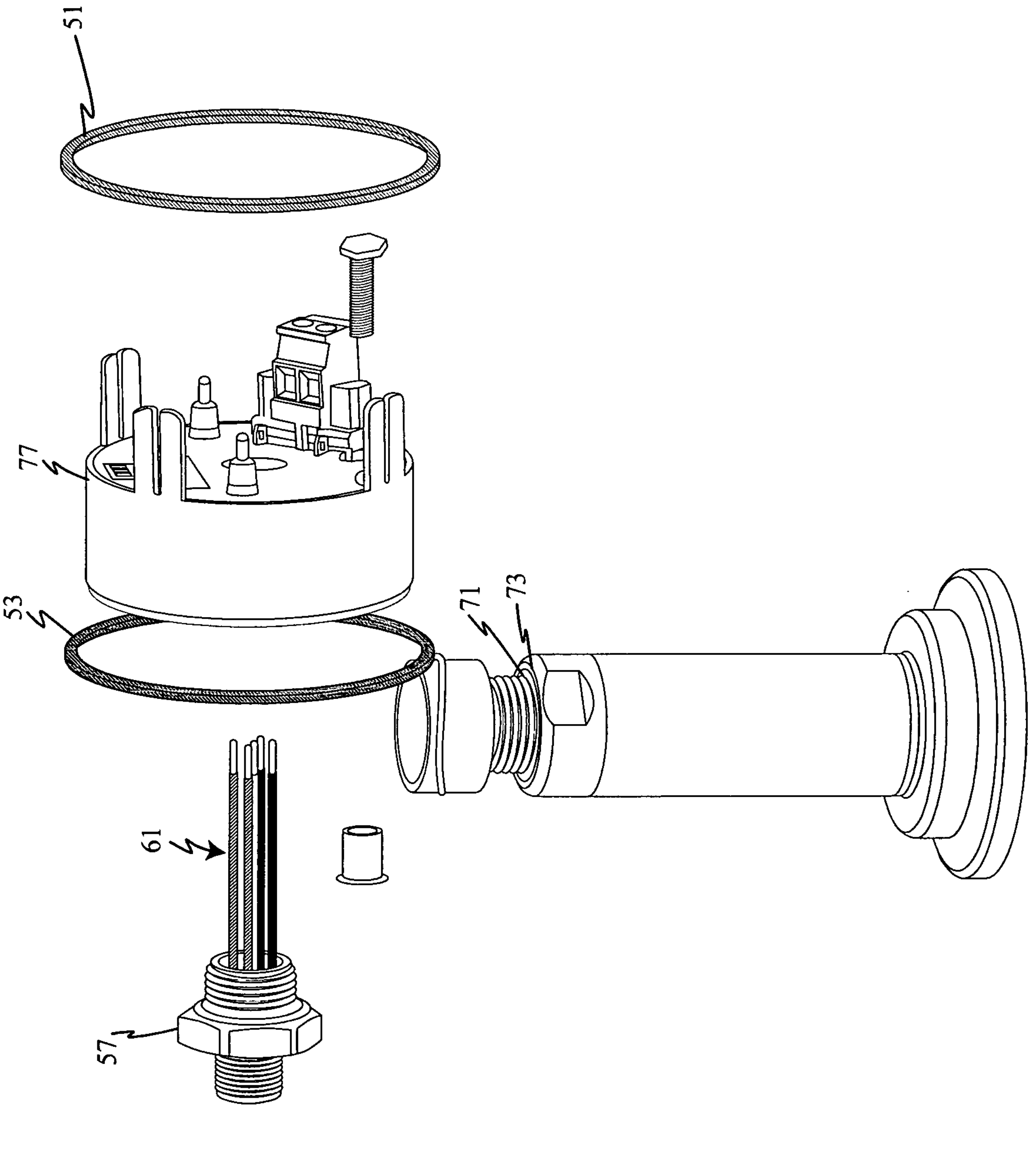


Figure 1B

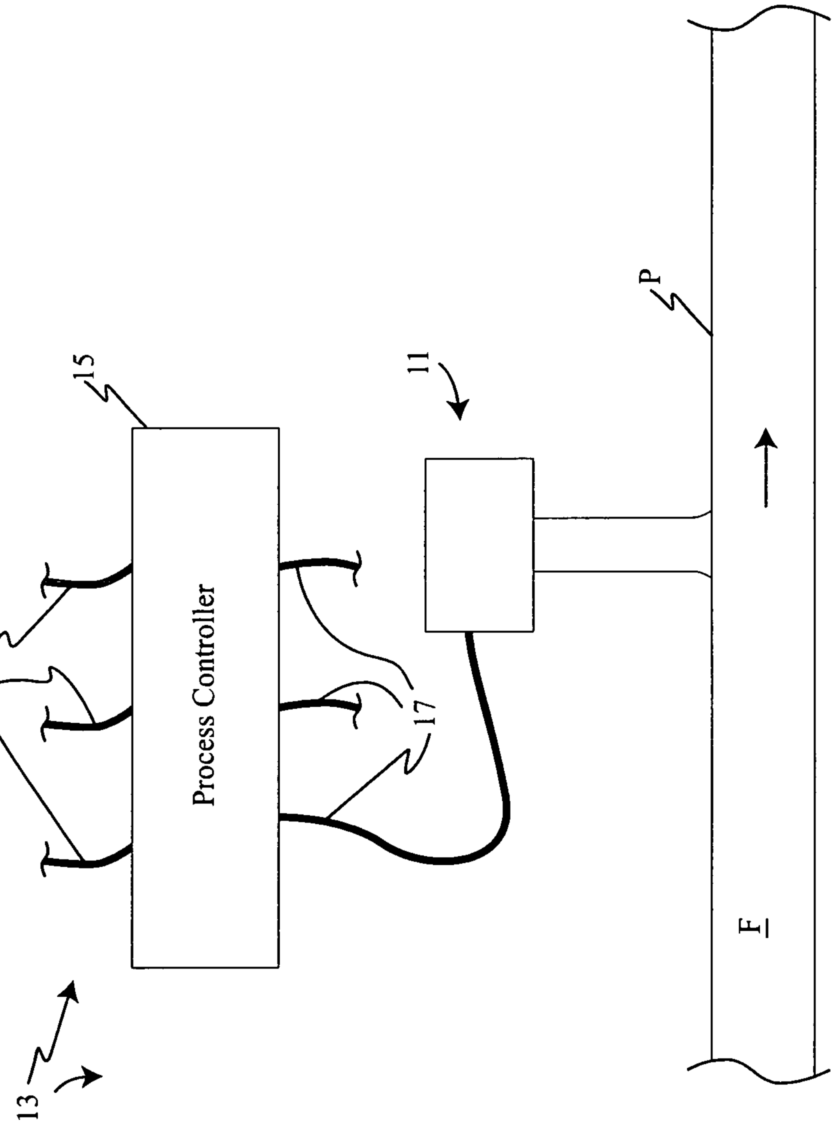


Figure 2

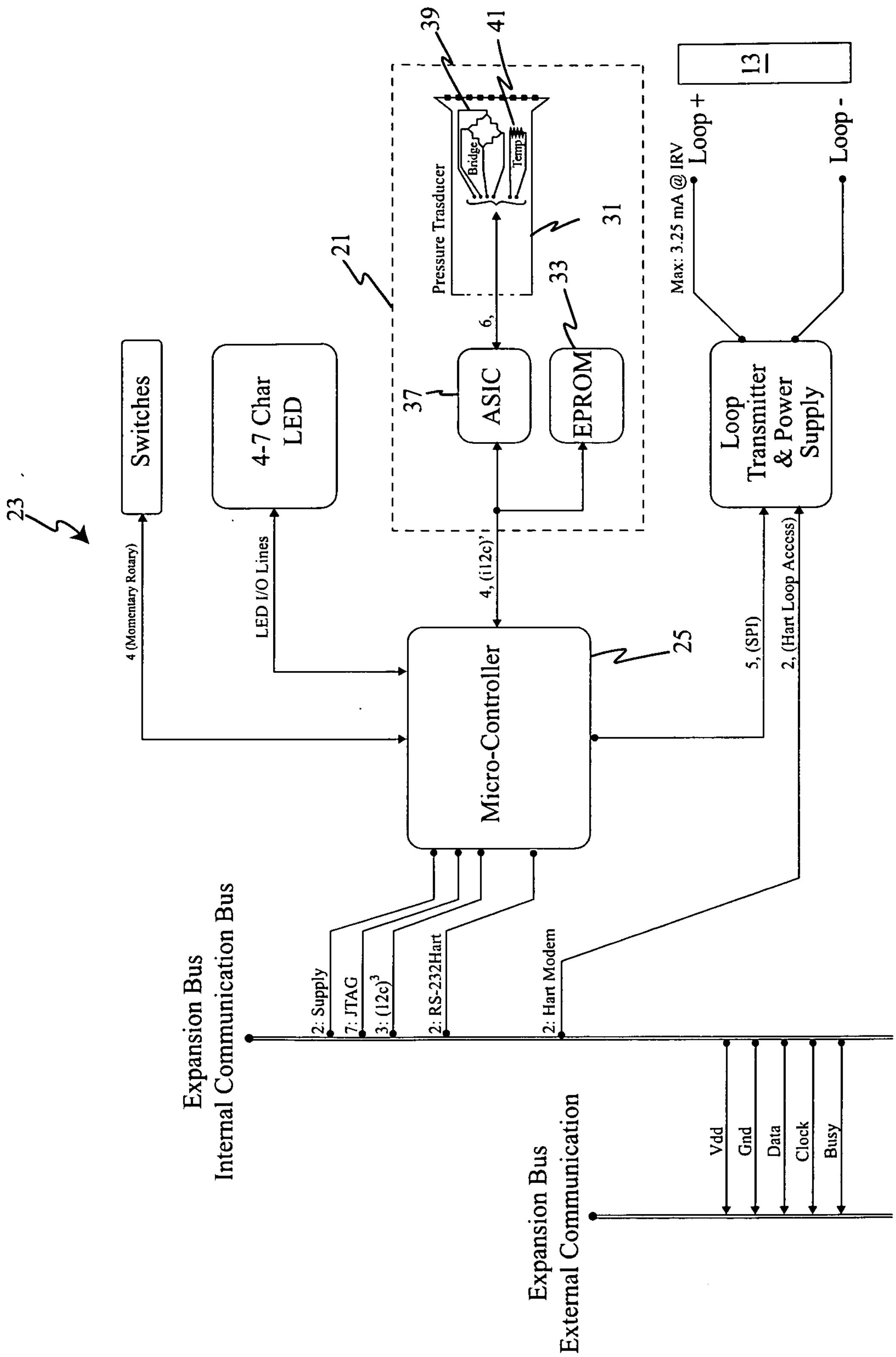

23
Switches
4 (Momentary Rotary)
4-7 Char LED
LED I/O Lines
21
39
41
Pressure Trasducer
Bridge
Temp
31
6,
ASIC
37
EPROM
33
4, (i12c)'
Micro-Controller
25
Loop Transmitter & Power Supply
5, (SPI)
2, (Hart Loop Access)
Max: 3.25 mA @ IRV
Loop +
Loop -
13
Expansion Bus
Internal Communication Bus
2: Supply
7: JTAG
3: (12c)3
2: RS-232Hart
2: Hart Modem
Vdd
Gnd
Data
Clock
Busy
Expansion Bus
External Communication

Figure 3

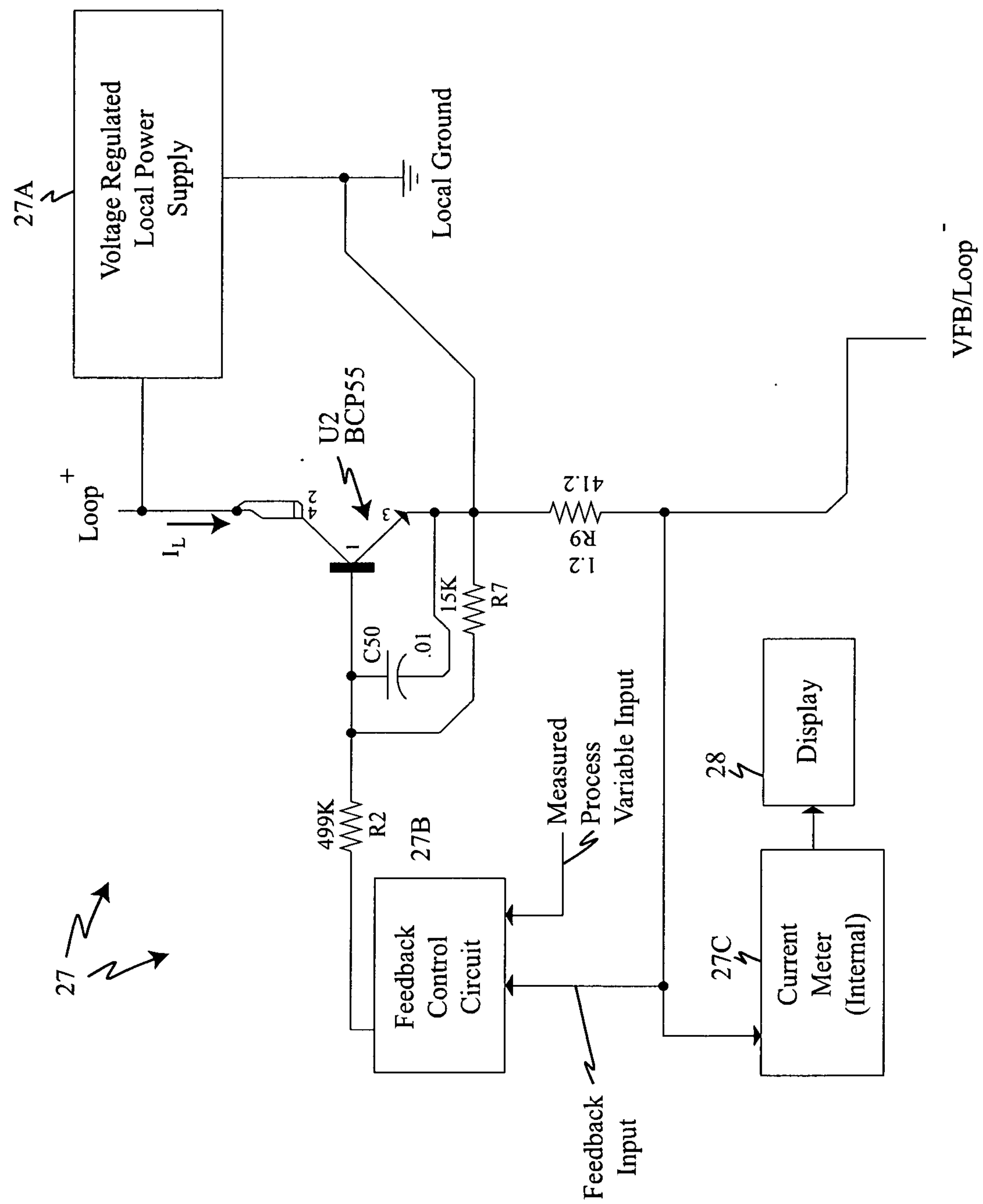
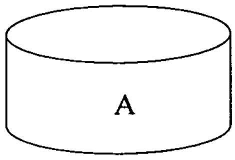

27A
Voltage Regulated
Local Power
Supply
Local Ground
VFB/Loop
-
Loop
+
I_L
U2
BCP55
2
4
1
3
41.2
R9
1.2
15K
R7
C50
.01
499K
R2
27B
Measured
Process
Variable Input
28
Display
27
Feedback
Control
Circuit
27C
Current
Meter
(Internal)
Feedback
Input

Figure 3A



Profiling
Data Structure
SAB EEPROM

Cal Pt. Index 1Byte	Cal Pt. % 1Byte	ADC Counts Low Gain 2 Bytes	ADC Counts Mid Gain 2 Bytes	ADC Counts High Gain 2 Bytes
0	0			
1	4			
2	7			
3	10			
4	15			
5	20			
6	30			
7	40			X
8	50			X
9	60		X	X
10	70		X	X
11	80		X	X
12	90		X	X
13	100		X	X

Figure 4

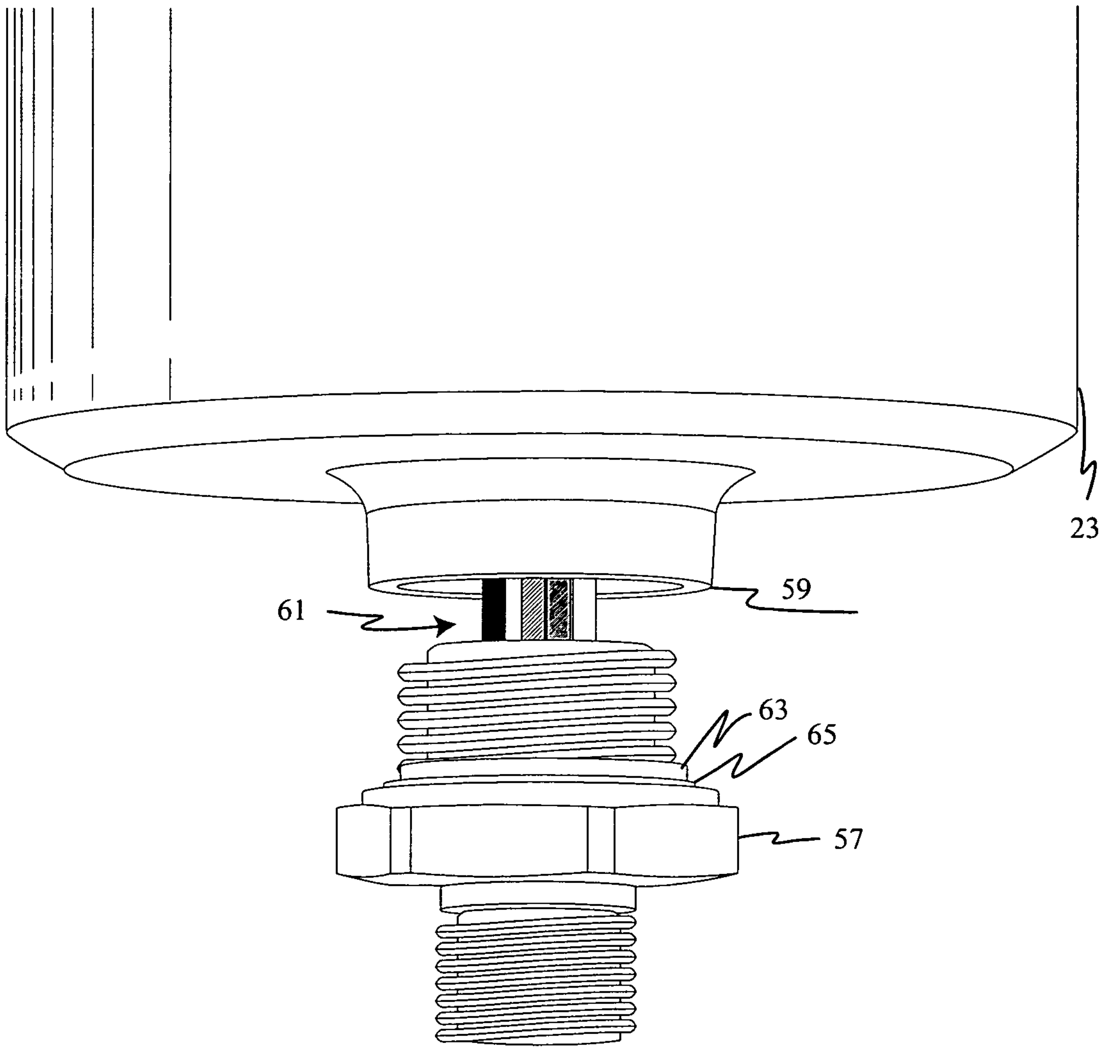


Figure 5

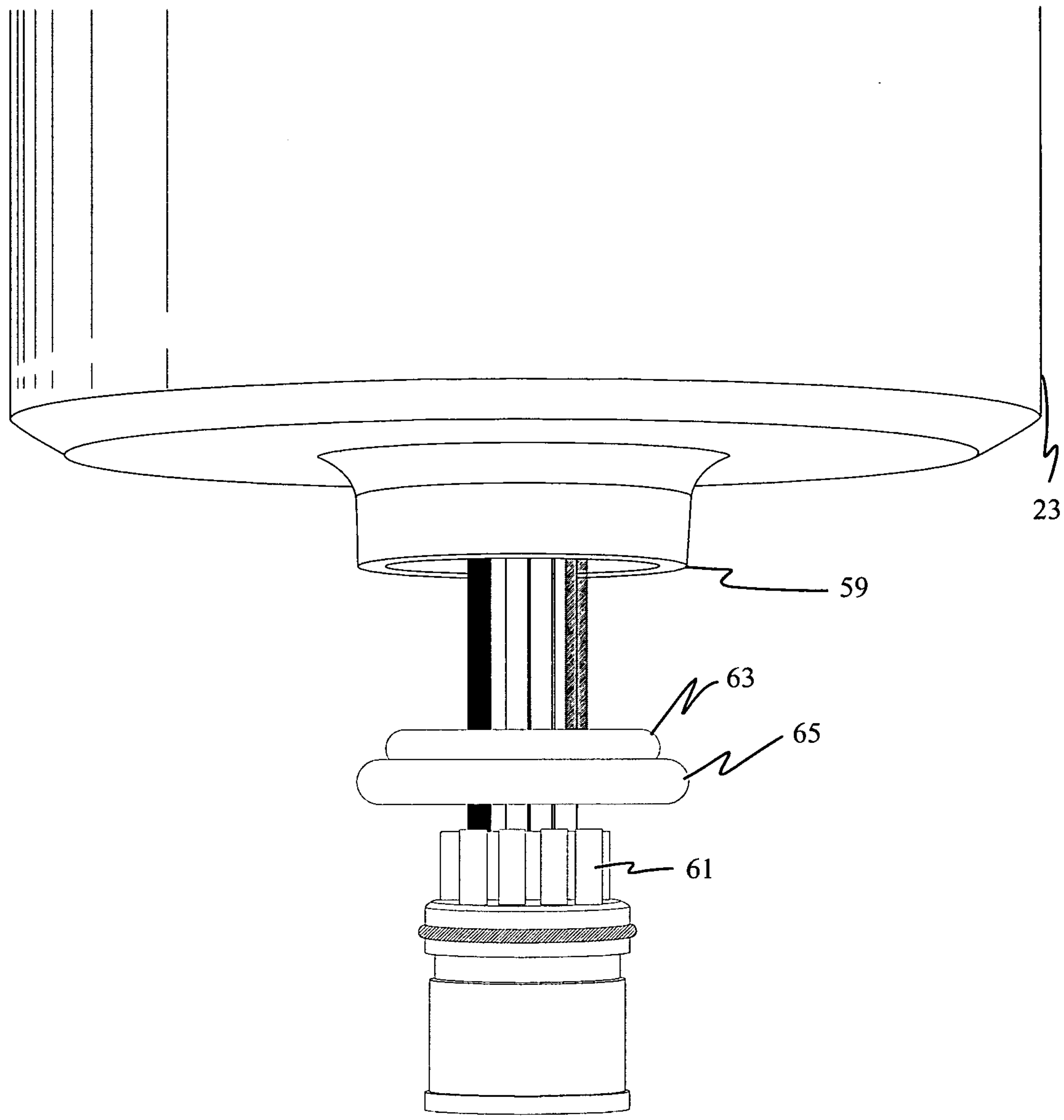


Figure 5A

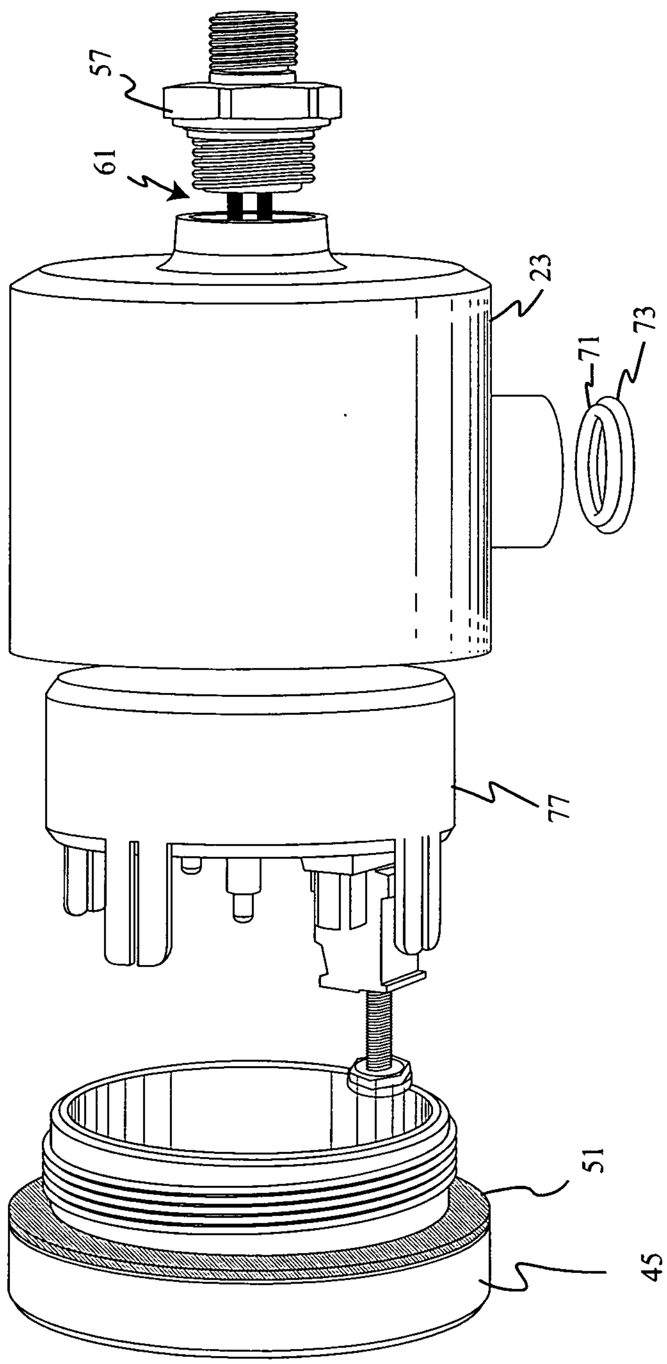


Figure 6