FLUKE®

HART® Transmitter Calibration

Application Note

Introduction

In today's process plants, most new field instruments are *smart* digital instruments. *Smart* implies a microprocessor-based instrument with extra functionality and digital compensation, supporting multiple sensor types or multiple variables. These instruments generally offer better accuracy, long-term stability, and reliability than conventional analog instruments.

The most common class of smart instruments incorporates the HART protocol, with more than five million HART instruments in use in 100,000 plants worldwide. HART, an acronym for Highway Addressable Remote Transducer, is an industry standard that defines the communications protocol between smart field devices and a control system that employs traditional 4-20 mA wiring.

Two capabilities are required to properly service HART instruments: precision analog source and measure capability and digital communication capability. Until recently, this required two separate tools, a calibrator and a communicator. Today, the capabilities of those two tools are available in a single HART Documenting Process Calibrator that can help you quickly and effectively service HART instruments.

HART® COMMUNICATION PROTOCOL

HART calibration is required!

A common misconception is that the accuracy and stability of HART instruments eliminate the need for calibration. Another misconception is that calibration can be accomplished by re-ranging field instruments using only a HART communicator. Still another misconception is that the control system can remotely calibrate smart instruments. *These are not true.* All instruments drift. Re-ranging with just a communicator is not calibration. A precision calibrator or standard is required. Regular performance verification with a calibrator traceable to national standards is necessary due to:

1. Shifts in performance of electronic instruments over time, due to exposure of the electronics and the primary sensing element to temperature, humidity, pollutants, vibration, and other field environmental factors.
2. Regulations governing occupational safety, consumer safety, and environmental protection.
3. Quality programs such as ISO 9000 standards for all instruments that impact product quality.
4. Commercial requirements such as weights, measures, and custody transfer.

Regular calibration is also prudent since performance checks will often uncover problems not directly caused by the instrumentation, such as solidified or congealed pressure lines, installation of an incorrect thermocouple type, or other errors and faults.

A calibration procedure consists of a verification (As Found) test, adjustment to within acceptable tolerance if necessary, and a final verification (As Left) test if an adjustment has been made. Data from the calibration are collected and used to complete a report of calibration, documenting instrument performance over time.

All instruments, even HART instruments, must be calibrated on a regular, preventive maintenance schedule. The calibration interval should be set short enough to insure that an instrument never drifts out of tolerance, yet long enough to avoid unnecessary calibrations. Alternatively, the interval may be determined by critical process requirements, e.g., calibration before each batch.

How are HART instruments *properly* calibrated?

To calibrate a HART instrument consistent with its application, it is very helpful to understand the functional structure of a typical HART transmitter. The article in Appendix A, by Kenneth L. Holladay of Southwest Research Institute, describes a typical HART instrument and defines both proper and improper calibration practices. Originally published in *Intech*, May 1996, it is reprinted with permission of the author.

Note: If you are unfamiliar with HART calibration or need a review, this is an excellent point to stop and read the article in Appendix A. It covers the basics of HART instrumentation and addresses issues critical to instrument maintenance.

HART instruments consist of three distinct sections (see Figure 1). Proper HART calibration may involve either or both sensor trim and output trim. Adjusting range values (LRV and URV) without a calibrator is not calibration. Performing an output trim while ignoring the input section is not proper calibration. *Adjusting range values with a calibrator may be a practical calibration alternative for instruments operated in 4-20 mA analog mode, provided that the PV and PVAO are not used for process control.*

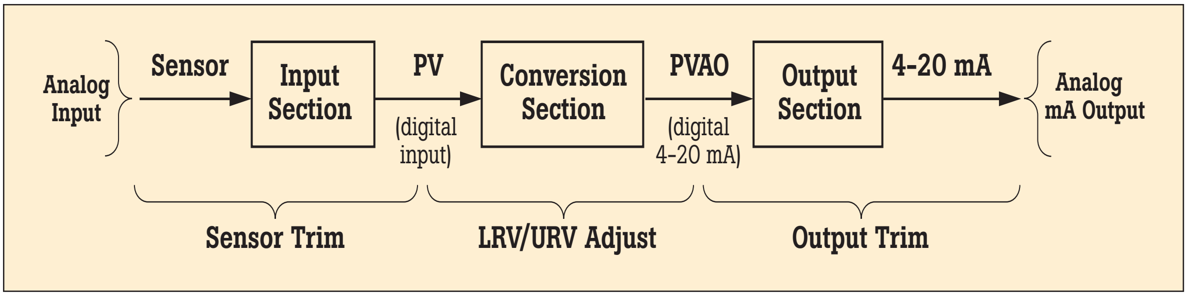

Figure 1.

Figure 2.

New tool speeds calibration

Today, instrument maintenance is moving out of the shop and into the field. This reduces process interruptions and avoids the time and expense of returning instruments to the shop. Portable communicators and calibrators are often used together to complete field calibrations. However, the desire to carry less equipment and to perform maintenance in the field has created a need for a new class of calibration tool.

The new 754 Documenting Process Calibrator from Fluke is the first powerful yet easy-to-use tool for field calibration of HART instrumentation. Pressing a single key enters the HART mode and displays the essential HART information in the Active Device Screen, shown in Figure 2. Additional HART functionality is accessed with only a few more keystrokes, per the menu tree in Figure 3.

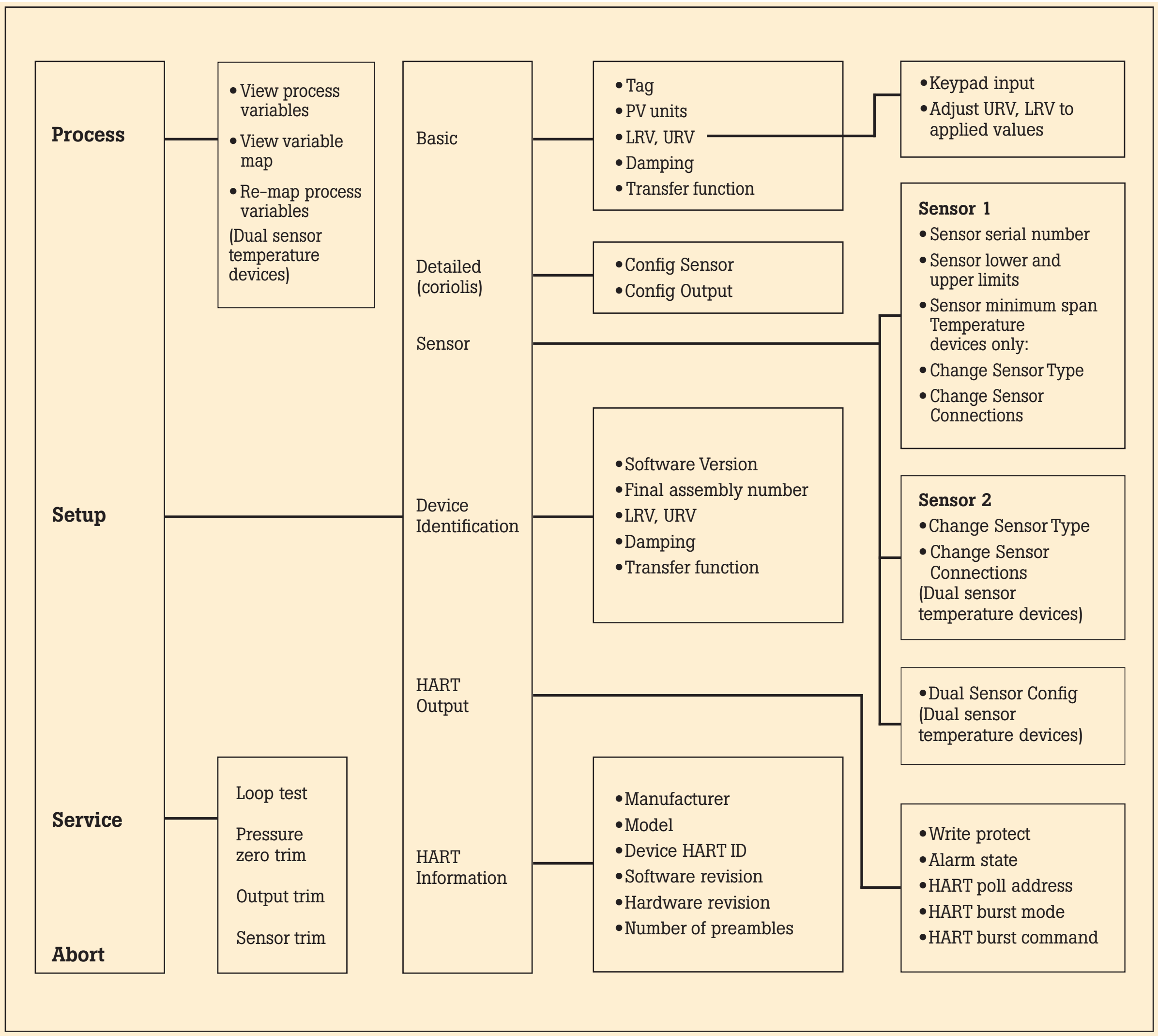

Figure 3.

No communicator is required!

The 754 requires no external box or communicator for everyday HART calibration and maintenance. It supports many popular models of HART transmitters, with more device-specific command support than any other HART field calibrator.

- Interrogate HART devices to determine type, manufacturer, model, tag-ID, PV, and PVAO
- Perform automated HART sensor trim and output trim for selected devices
- Adjust ranging, damping, and other basic process–configuration settings
- Read and write HART tag and message fields to re-label smart transmitters
- Clone additional transmitters with basic HART configuration data

Versatile HART protocol support

With 64 MB of memory, the 754 supports a substantial set of HART instructions:

- **Universal commands —** provide functions that are implemented in **all field devices**, for example, read manufacturer and device type, read primary variable (PV), or read current output and percent of span
- **Common practice commands —** provide functions that are common to **many but not all field devices**, for example read multiple variables, set damping time, or perform loop test
- **Device-specific commands —** provide functions that are **unique to a particular field device**, for example sensor trim. The 754 Version supports these devices:

HART operating modes supported

- For **Point to Point operation**, the most commonly used mode, connects the 754 to a single HART device in a 4-20 mA loop.
- In **Multi-Drop** mode, several HART instruments can be bussed together. The 754 searches for each, identifies addresses in use, and allows you to select the instrument for calibration and related operations.
- In **Burst Mode**, the HART instrument transmits bursts of data without waiting to be interrogated by a master unit. The 754 can take transmitters out of burst mode during test or calibration, then later restore them to burst mode.

Is there still a role for the communicator?

Commissioning a HART instrument or modifying HART variables not supported by the 754 requires the use of a communicator. The 754 is designed to perform the vast majority of day-to-day operations you normally perform with a separate communicator. The HART capability of the 754 is comparable to that of the model 475 HART communicator, with the exception of the DD interpreter. While the DD interpreter enables a common communicator to read command set libraries from any HART supplier, it offers capabilities far beyond those generally required for daily HART instrument maintenance.

HART calibration applications

The following examples demonstrate how the 754 makes HART calibration an efficient operation. The 754 enables easy hookup using its HART cable, fast access to the most important HART data, automatic branching to appropriate adjustment choices, automatic completion of test templates, and automatic *fetch*ing and *send*ing of analog readings during trim.

Manufacturer	Pressure Instruments	Temperature Instruments	Coriolis Instruments
ABB/Kent-Taylor	600T	658T[1]	
ABB/ Hartmann & Braun	Contrans P,[1] AS 800 Series		
Endress & Hauser	CERABAR S, CERABAR M, DELTABAR S	TMT 122[1], TMT 182[1], TMT 162[1]	
Foxboro Eckardt		TI/RTT20[1]	
Foxboro/Invensys	I/A Pressure		
Fuji	FCX FCXAZ	FRC	
Honeywell	ST3000	STT25T[1], STT25H[1]	
Micro Motion			2000 2000 IS 9701 9712 9739
Moore Products		344[1]	
Rosemount	1151 2088 3001C 3051, 3051S	3044C 644 3144 3244, 3144P	
Siemens	SITRANS P DS SITRANS P ES		
SMAR	LD301	TT301[1]	
Viatran	I/A Pressure		
Wika	UNITRANS	T32H[1]	
Yokogawa	EJA	YTA 110, 310 and 320	

Table 1.

[1]Sensor Trim not supported

Example 1

Calibration of a Rosemount 3051 HART Pressure Transmitter

Basic connections

This example assumes that the transmitter is isolated from the process and is not electrically connected to a loop power supply. Make basic connections to the 3051 per the diagram in Figure 4. A separate 250 ohm resistor is not necessary because the 754 incorporates a resistor in series with the loop supply through its mA jacks. The 3051 in this example is configured for psi units.

Procedure

1. Power on the Fluke 754 Calibrator. Press the red HART key followed by the **Loop Power** softkey and the 754 will display the basic HART information for the 3051 (Figure 5).

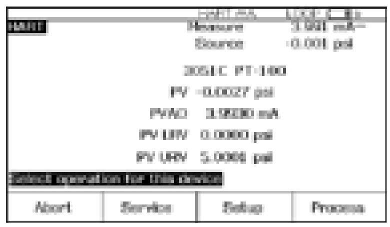

Figure 5.

2. Press the HART key again and you are prompted to select the 754 configuration (Figure 6). Selecting **MEAS mA, SOURCE psi** will configure the calibrator to measure the analog mA output and the pressure being applied simultaneously to the transmitter input and the pressure module. (Selecting **MEAS PV, SOURCE psi** will configure the 754 to evaluate the digital PV output from the transmitter.) Press ENTER to select.

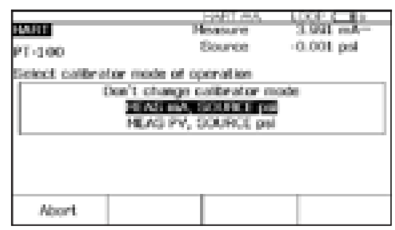

Figure 6.

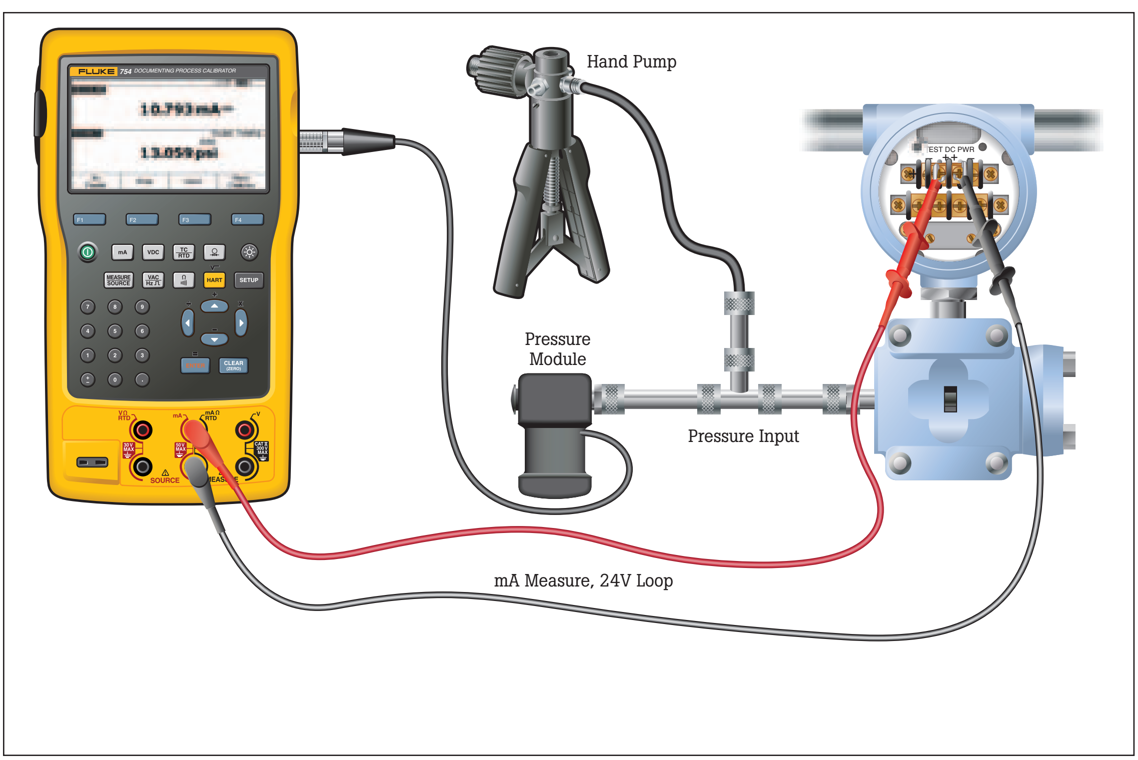

Figure 4

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3. Vent the pressure line and press CLEAR (ZERO) to zero the pressure module. Press the **As Found** softkey, and then press ENTER to select **Instrument** for a linear transmitter calibration. (If the 3051 is configured for square root output, select **√ Instrument**.) Notice that the calibration template is automatically completed with the exception of Tolerance. Fill in the appropriate test tolerance and press **Done**.
4. Press the **Manual Test** softkey to begin calibration. Apply the input pressures as instructed in the SOURCE screen. Press the **Accept Point** softkey when the correct pressure is applied for each point. When the test is complete, the error summary table is displayed (Figure 7). Test errors exceeding the tolerance are highlighted. When done viewing the table, press the **Done** softkey. Press **Done** again to accept, or ENTER to change the tag, serial number or ID fields.

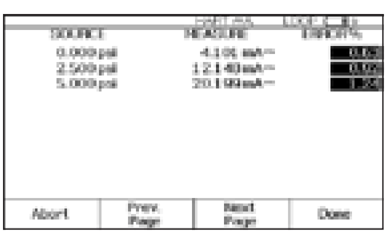

Figure 7.

5. If the As Found test failed (i.e., there were highlighted errors in the error summary table), adjustment is necessary. Press the **Adjust** softkey. Select **Sensor Trim** and press ENTER. (Do not select **Pressure Zero Trim**. It is the same as trimming the lower sensor point at zero, which is useful for pressure transmitters that do not offer Sensor Trim.) The 754 screen should look like Figure 8.

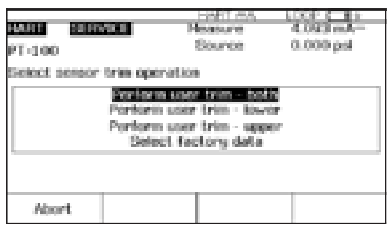

Figure 8.

6. Select **Perform user trim – both** and press ENTER. Zero the pressure module (vented to atmosphere) by pressing CLEAR (ZERO). Press the **Continue** softkey and you are prompted for the Lower Trim value. For best results, apply the LRV pressure and press **Fetch** to load the value being measured by the pressure module. Press **Trim**. Then press **Continue** to move to the Upper Trim. As before, apply the URV pressure, press **Fetch**, and press **Trim**. If the 3051 is used with the digital PV output, skip to step 8 and perform the As Left test. If the 4-20 mA analog output is used in the process, continue on to step 7.
7. Select **Output Trim** and press ENTER. The value of the primary variable (PVAO) is in the upper right corner of the display. This is normally a 4 mA signal. The mA value, as constantly measured by the Fluke 754, is in the center of the display. Press the **Fetch** softkey to load the measured mA value. Press **Send** to *send* the value to the 3051 to trim the output section for the 4 mA value. Press **Continue** for the 20 mA trim and repeat this step.
8. After completing Output Trim, press the **Done** softkey and proceed with the As Left verification test. Press the **As Left** softkey. Press **Done** and then press **Manual Test**. Apply the requested pressures and press **Accept Point** when the readings are stable. On completion an error summary table is displayed. If none of the errors are highlighted (Figure 9), the 3051 passes the calibration test. If errors are highlighted, the test has failed and further adjustment is required. Return to step 5 for adjustment of the 3051.

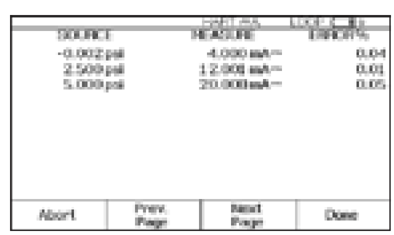

Figure 9.

Example 2

Calibration of a Rosemount 3144 HART Temperature Transmitter

Basic connections

This example assumes that the transmitter is isolated from the process and is not electrically connected to a loop power supply. Make basic connections to the 3144 per the diagram in Figure 10. A separate 250 ohm resistor is not necessary because the 754 incorporates a resistor in series with the loop supply through its mA jacks. The 3144 in this example is configured for a type K thermocouple sensor with a span of 0 °C to 300 °C.

Procedure

1. Power on the Fluke 754 Calibrator. Press the red HART key followed by the **Loop Power** softkey. Press ENTER to bypass the warning screens and the 754 will display the basic HART information for the 3144 (Figure 11).

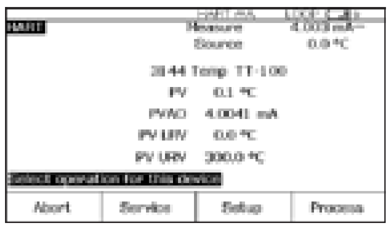

Figure 11.

2. Press the HART key again and you are prompted to select the 754 configuration (Figure 12). Selecting **MEAS mA, SOURCE T/C typ K** configures the calibrator to measure the analog mA output of the transmitter and source the correct temperature stimulus at the 3144 input. (Selecting **MEAS PV, SOURCE T/C typ K** will configure the 754 to evaluate the digital PV output from the transmitter.) Press ENTER to select.

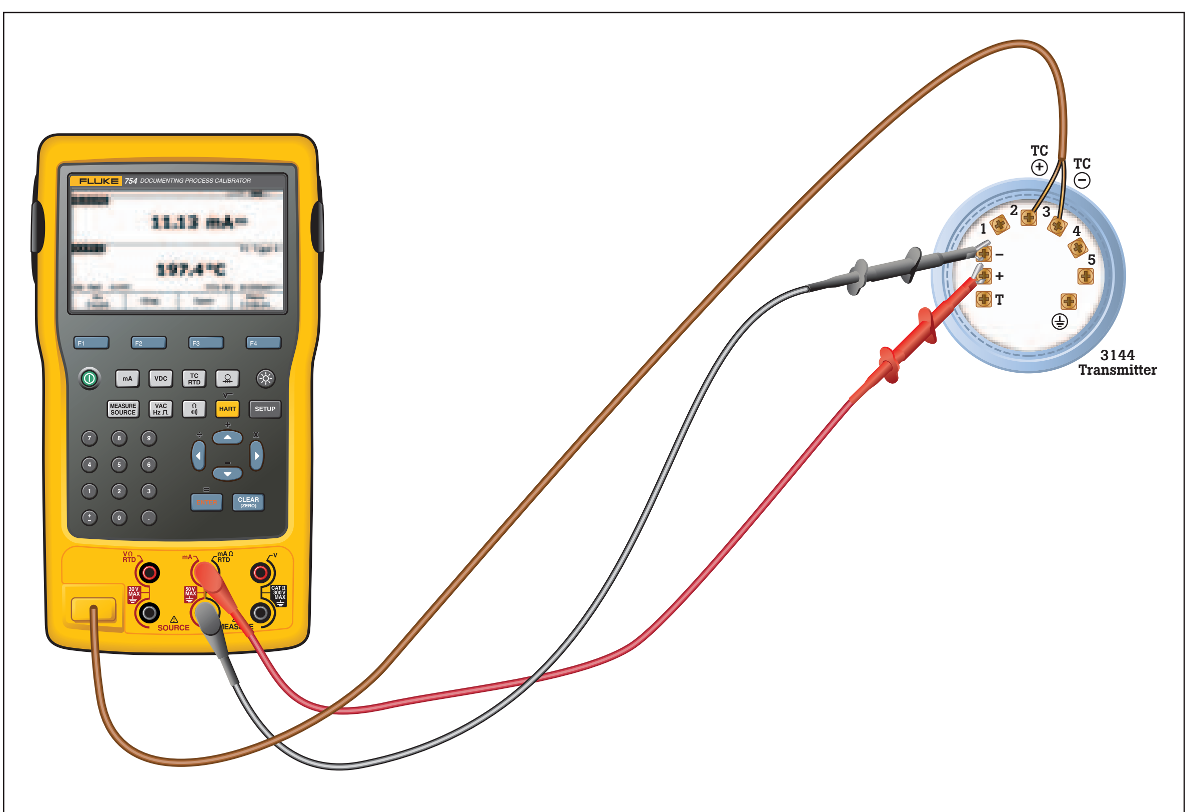

Figure 10.

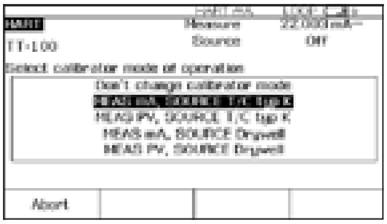

Figure 12.

3. Press the **As Found** softkey, and then press ENTER to select **Instrument** for a linear transmitter calibration. Notice that the calibration template is automatically completed with the exception of the Tolerance. Fill in the appropriate test tolerance and press the **Done** softkey.
4. Press the **Auto Test** softkey to begin calibration. Once the test is complete, an error summary table is displayed (Figure 13). Test errors exceeding the tolerance are highlighted. When done viewing the table, press the **Done** softkey. Press **Done** again to accept, or ENTER to change the tag, serial number or ID fields.

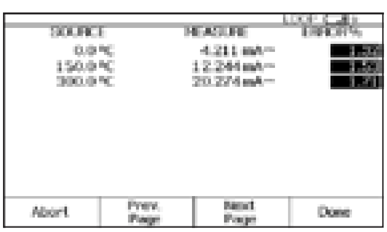

Figure 13.

5. If the As Found test failed (i.e., there were highlighted errors in the error summary table), adjustment is necessary. Press the **Adjust** softkey. Select **Sensor Trim** and press ENTER. Select **Perform user trim – both** and press ENTER. The 754 screen should look like Figure 14.

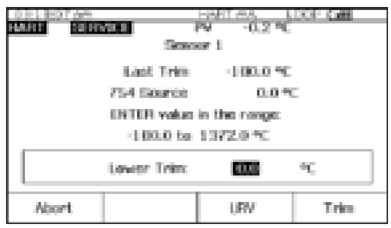

Figure 14.

6. For best results, press **LRV** to apply the LRV for the Lower Trim value. Press **Trim** and then **Continue** to move to the Upper Trim. Press **URV**, press **Trim**, and then press **Done**. If the 3144 is used with the digital PV output, skip to step 8 and perform the As Left test. If the analog 4–20 mA output is used in the process, continue on to step 7.
7. Select **Output Trim** and press ENTER. The value of the primary variable (PVAO) is in the upper right corner of the display. (Figure 5). This is normally a 4 mA signal. The mA value, as constantly measured by the Fluke 754, is in the center of the display. Press the **Fetch** softkey to load the measured mA value. Press **Send** to *send* the value to the 3144 to trim the output section for the 4 mA value. Press **Continue** for the 20 mA trim and repeat this step.

Figure 15.

8. After completing Output Trim, press the **Done** softkey and proceed with the As Left verification test. Press the **As Left** softkey. Press **Done** and then press **Auto Test**. On completion, an error summary table is displayed. If errors are highlighted, the test has failed and further adjustment is required. Return to step 5 for adjustment of the 3144.

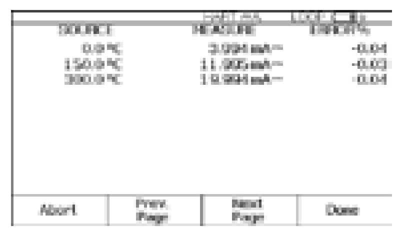

Figure 16.

Example 3

Calibration of HART instruments using universal commands

The 754 supports a majority of the installed workload of HART transmitters—*see Table 1*—by supporting sensor trim, which employs device-specific commands that are unique to a particular instrument. So how can you calibrate instruments that are not supported by the 754?

The short answer is that the 754 supports a substantial set of the *universal* HART commands and the *common practice* HART commands. The 754 can communicate with virtually any HART instrument and, in most cases, can complete a calibration procedure (except for sensor trim for unsupported instruments).

This example applies to instruments used in analog mode (4-20 mA). If the instrument is operated in digital mode, i.e., *its PV is the output variable that is used for control*, a calibration of the Input Section is all that is needed. Adjustment will require a Sensor Trim, (see Figure 17) which means that for instruments not supported by the 754 you will need to use ***both*** a 754 (to perform the As Found and As Left tests and record the results) and a communicator (to perform sensor trim).

For instruments used in analog mode, i.e., *where the 4-20 mA analog output is used for control*, the 754 can be used for calibration. After performing an As Found and determining that adjustment is required, this example first performs an Output Trim to bring the instrument within tolerance. Failing that, the example performs an adjustment to the Lower and Upper Range Values (LRV and URV) to compensate for input section error.

Note: Appendix A explains that these adjustments do not constitute a proper HART calibration. While this is true, these adjustments are a practical calibration alternative for instruments operated in 4-20 mA analog mode if error corrections are not large

How to determine digital or analog?

The transmitter is in digital mode if its HART Poll Address is set between 1 to 15. An address of 0 (zero) sets it to 4-20 mA analog output mode. The 754 will automatically connect to a device at address 0; if a device is not found at 0 the 754 will begin polling addresses 1 to 15. The 754 also displays a non-zero address with the basic HART information.

Basic connections

This example assumes that the transmitter is isolated from the process and is not electrically connected to a loop power supply. Make basic connections to the transmitter per the diagram in Figure 18. A separate 250 ohm resistor is not necessary because the 754 incorporates a resistor in series with the 24 V loop supply through its mA jacks. This example assumes a type K thermocouple transmitter with an input range of 0 °C to 100 °C, 4-20 mA output, and a 0.25 % test tolerance.

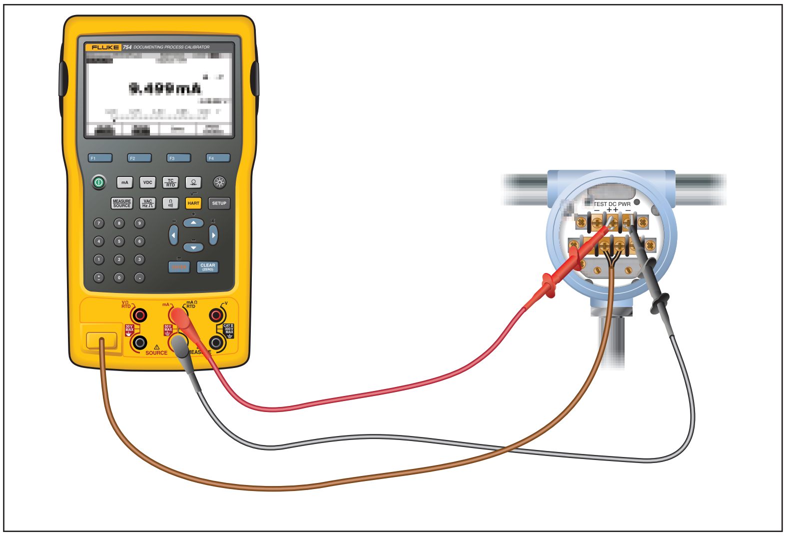

Figure 18.

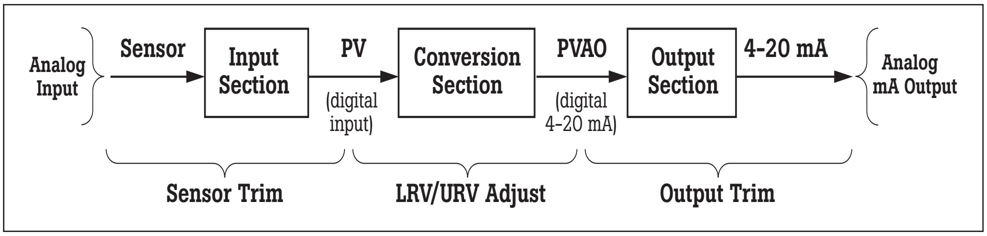

Figure 17.

Procedure

1. Power on the Fluke 754 Calibrator. Press the HART key and the **Loop Power** softkey (if loop power is not already supplied). Press ENTER until any device warnings are cleared and the basic HART information is displayed (Figure 19).

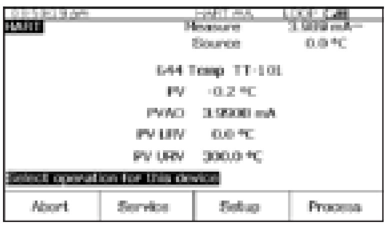

Figure 19.

2. Press the HART key again and you are prompted to select the 754 configuration (Figure 20). Move the cursor to **MEAS mA, SOURCE T/C typ K** (or measure mA if source configuration is not offered), and press ENTER. (If you were verifying the digital PV instead of the mA output, i.e., the transmitter has a non-zero HART poll address, you would select **MEAS PV, SOURCE T/C typ K** (or measure PV if source configuration is not offered) instead.)

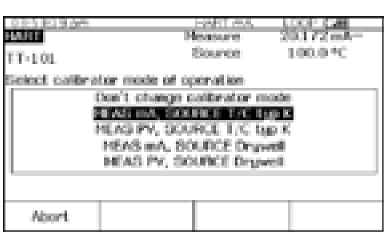

Figure 20.

3. If source was not configured in the previous step press the Measure/Source button and configure the source for a type K thermocouple. Press Measure/Source until you are at the dual screen. Press the **As Found** softkey and press ENTER to select **Instrument** calibration. Move the cursor to **Tolerance** and ENTER the appropriate test tolerance (0.25 % in this example). Verify that the **0 % Source Value** and **100 % Source Value** are the proper, ***nominal*** operating values for the transmitter (0.0 °C and 100.0 °C in this example, Figure 21). If the Lower (0 %) and Upper (100 %) Range Values (LRV and URV) have been previously modified for calibration purposes, you will need to ENTER the nominal values. For example, if a previous calibration modified the URV to 100.2 °C, you need to manually ENTER the nominal value of 100.0 °C for the **100 % Value**. Entering nominal zero and span values ensures that errors are calculated correctly.

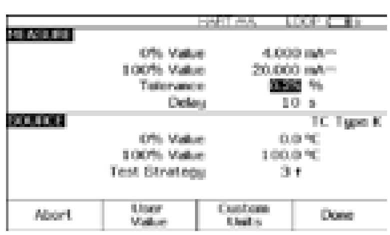

Figure 21.

4. Press **Done** and then press **Auto Test**. Once the test is complete, an error summary table is displayed (Figure 22). Test errors exceeding the tolerance are highlighted. If the test passed, i.e., if no errors are highlighted, adjustment is not required.

Figure 22.

If errors are highlighted, adjustment is necessary by performing an Output Trim. Press **Done** to leave the results screen, edit the tag, serial number or ID fields as necessary, and press **Done** again.

5. Press the **Adjust** softkey, select **Output Trim** and press ENTER. The value of the primary variable (PVAO) is in the upper right corner of the display (Figure 23). This is normally a 4 mA signal. The real-time mA value as measured by the Fluke 754, is in the center of the display. Press the **Fetch** softkey to load the measured mA value. Press the **Send** softkey to *send* the value to the transmitter to trim the output section for the 4 mA value. Press **Continue** for the 20 mA adjustment and repeat this step.

Figure 23.

6. Now perform an As Left test. Press **As Left**, press **Done**, and then press **Auto Test**. On completion the error summary table is displayed. If errors are highlighted, the test has failed and further adjustment is required.

Note: If the failure error is large, sensor trim adjustment with a communicator may be necessary. Often, however, adjustment can be accomplished with a 754 by modifying the LRV (Lower Range Value) and URV (Upper Range Value) to compensate for Input Section error.

7. In the case of a pressure transmitter that has on-board Zero and Span adjustment buttons, calibration is easy. Simply apply a calibrated source at the LRV and URV values and press the respective Zero and Span buttons on the transmitter. Then verify the condition of the transmitter by completing an As Left test as in step 6. Many HART transmitters do not have physical adjustments and need either a communicator *or a Fluke 754* to adjust the LRV and URV values. For those cases, proceed to step 8.

8. The error summary table (displayed from step 6) provides the data necessary to make LRV and URV changes. Write down the LRV and URV values (in this example 0 and 100 degrees C). Return the 754 to the normal Measure/Source screen displaying the **As Left** softkey by pressing the **Done** softkey 3 times.

9. Press the MEASURE/SOURCE button (2) times and input the LRV value (0 degrees C this example) using the 754 keypad and press ENTER.

10. Press HART and then press the **Setup** softkey. Select **Basic** from the menu and press ENTER to display the basic setup parameters shown in Figure 24. Move the cursor to **Lower Range Value** and press ENTER. Move the cursor to Apply Values and press ENTER. Press ENTER to select 4 mA. Press the Continue softkey, then press "any key" then press the Set softkey. Press "any key", the Done and abort Softkeys until you exit to the source screen. Using the 754 keypad, type in the URV (100 degrees C in this example) value recorded in step 8 and press ENTER.

11. Repeat step (10) but select 20 mA after Selecting "Apply Values" instead of 4 mA.

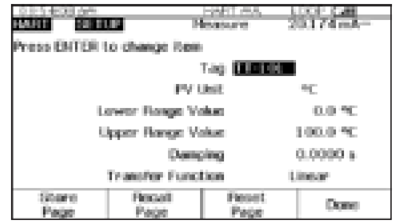

Figure 24.

12. Now press **Done** and then press **Abort** 3 times. Perform a new As Found test by pressing **As Found**. (Remember to make sure that the original, nominal zero and span values are shown as the **0 % Value** and **100 % Value**.) Press **Done** and then press **Auto Test**. On completion, the error summary table is displayed. If errors are highlighted, the test has failed—repeat the adjustment or trim sensor section with a communicator.

Note: If you encounter any difficulty with any of these examples, you may call 1-800-44-FLUKE for assistance (1-800-443-5853).

Appendix A

Calibrating HART Transmitters

By Kenneth L. Holladay, P.E.

Calibrating a conventional instrument

For a conventional 4-20 mA instrument, a multiple point test that stimulates the input and measures the output is sufficient to characterize the overall accuracy of the transmitter. The normal calibration adjustment involves setting only the zero value and the span value, since there is effectively only one adjustable operation between the input and output as illustrated below.

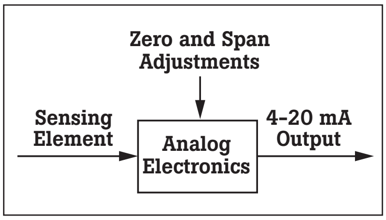

Figure A1. Conventional Transmitter Block Diagram.

This procedure is often referred to as a Zero and Span Calibration. If the relationship between the input and output range of the instrument is not linear, then you must know the transfer function before you can calculate expected outputs for each input value. Without knowing the expected output values, you cannot calculate the performance errors.

Calibrating a HART instrument

For a HART instrument, a multiple point test between input and output does not provide an accurate representation of the transmitter's operation. Just like a conventional transmitter, the measurement process begins with a technology that converts a physical quantity into an electrical signal. However, the similarity ends there. Instead of a purely mechanical or electrical path between the input and the resulting 4-20 mA output signal, a HART transmitter has a microprocessor that manipulates the input data. As shown in Figure A2, there are typically three calculation sections involved, and each of these sections may be individually tested and adjusted.

Just prior to the first box, the instrument's microprocessor measures some electrical property that is affected by the process variable of interest. The measured value may be millivolts, capacitance, reluctance, inductance, frequency, or some other property. However, before it can be used by the microprocessor, it must be transformed to a digital count by an analog to digital (A/D) converter.

In the first box, the microprocessor must rely upon some form of equation or table to relate the raw count value of the electrical measurement to the actual property (PV) of interest such as temperature, pressure, or flow. The principle form of this table is usually established by the manufacturer, but most HART instruments include commands to perform field adjustments. This is often referred to as a sensor trim. The output of the first box is a digital representation of the process variable. When you read the process variable using a communicator, this is the value that you see.

The second box is strictly a mathematical conversion from the process variable to the equivalent milliamp representation. The range values of the instrument (related to the zero and span values) are used in conjunction with the transfer function to calculate this value. Although a linear transfer function is the most common, pressure transmitters often have a square root option. Other special instruments may implement common mathematical transformations or user defined break point tables. The output of the second block is a digital representation of the desired instrument output. When you read the loop current using a communicator, this is the value that you see. Many HART instruments support a command which puts the instrument into a fixed output test mode. This overrides the normal output of the second block and substitutes a specified output value.

The third box is the output section where the calculated output value is converted to a count value that can be loaded into a digital to analog converter. This produces the actual analog electrical signal. Once again the microprocessor must rely on some internal calibration factors to get the output correct. Adjusting these factors is often referred to as a current loop trim or 4-20 mA trim.

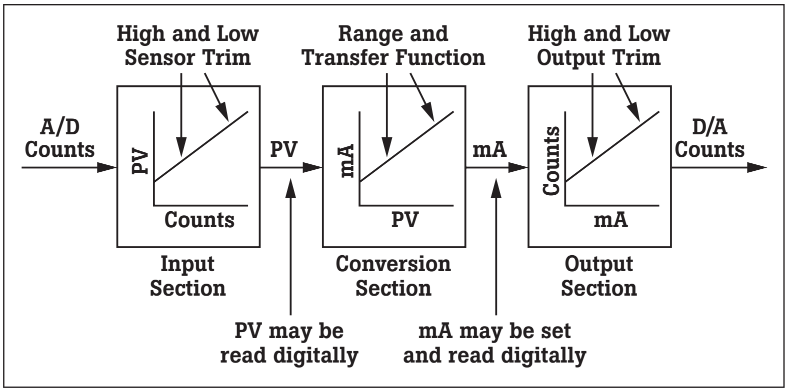

Figure A2. HART Transmitter Block Diagram.

HART calibration requirements

Based on this analysis, you can see why a proper calibration procedure for a HART instrument is significantly different than for a conventional instrument. The specific calibration requirements depend upon the application.

If the application uses the digital representation of the process variable for monitoring or control, then the sensor input section must be explicitly tested and adjusted. Note that this reading is completely independent of the milliamp output, and has nothing to do with the zero or span settings. The PV as read via HART communication continues to be accurate even when it is outside the assigned output range. For example, a range 2 Rosemount 3051c has sensor limits of -250 to +250 inches of water. If you set the range to 0 to 100 inches of water, and then apply a pressure of 150 inches of water, the analog output will saturate at just above 20 milliamps. However, a communicator can still read the correct pressure.

If the current loop output is not used (that is the transmitter is used as a digital only device), then the input section calibration is all that is required. If the application uses the milliamp output, then the output section must be explicitly tested and calibrated. Note that this calibration is independent of the input section, and again, has nothing to do with the zero and span settings.

Calibrating the input section

The same basic multiple point test and adjust technique is employed, but with a new definition for output. To run a test, use a calibrator to measure the applied input, but read the associated output (PV) with a communicator. Error calculations are simpler since there is always a linear relationship between the input and output, and both are recorded in the same engineering units. In general, the desired accuracy for this test will be the manufacturer's accuracy specification.

If the test does not pass, then follow the manufacturer's recommended procedure for trimming the input section. This may be called a sensor trim and typically involves one or two trim points. Pressure transmitters also often have a zero trim, where the input calculation is adjusted to read exactly zero (not low range). Do not confuse a trim with any form of re-ranging or any procedure that involves using zero and span buttons.

Calibrating the output section

Again, the same basic multiple point test and adjust technique is employed, but with a new definition for input. To run a test, use a communicator to put the transmitter into a fixed current output mode. The input value for the test is the mA value that you instruct the transmitter to produce. The output value is obtained using a calibrator to measure the resulting current. This test also implies a linear relationship between the input and output, and both are recorded in the same engineering units (milliamps). The desired accuracy for this test should also reflect the manufacturer's accuracy specification.

If the test does not pass, then follow the manufacturer's recommended procedure for trimming the output section. This may be called a 4-20 mA trim, a current loop trim, or a D/A trim. The trim procedure should require two trim points close to or just outside of 4 and 20 mA. Do not confuse this with any form of re-ranging or any procedure that involves using zero and span buttons.

Testing overall performance

After calibrating both the Input and Output sections, a HART transmitter should operate correctly. The middle block in Figure A2 only involves computations. That is why you can change the range, units, and transfer function without necessarily affecting the calibration. Notice also that even if the instrument has an unusual transfer function, it only operates in the conversion of the input value to a milliamp output value, and therefore is not involved in the testing or calibration of either the input or output sections.

If there is a desire to validate the overall performance of a HART transmitter, run a Zero and Span test just like a conventional instrument. As you will see in a moment, however, passing this test does not necessarily indicate that the transmitter is operating correctly.

Effect of damping on test performance

Many HART instruments support a parameter called damping. If this is not set to zero, it can have an adverse effect on tests and adjustments. Damping induces a delay between a change in the instrument input and the detection of that change in the digital value for the instrument input reading and the corresponding instrument output value. This damping induced delay may exceed the settling time used in the test or calibration. The settling time is the amount of time the test or calibration waits between setting the input and reading the resulting output. It is advisable to adjust the instrument's damping value to zero prior to performing tests or adjustments. After calibration, be sure to return the damping constant to its required value.

Operations that are NOT proper calibrations

Digital range change

There is a common misconception that changing the range of a HART instrument by using a communicator somehow calibrates the instrument. Remember that a true calibration requires a reference standard, usually in the form of one or more pieces of calibration equipment to provide an input and measure the resulting output. Therefore, since a range change does not reference any external calibration standards, it is really a configuration change, not a calibration. Notice that in the HART transmitter block diagram (Figure 2), changing the range only affects the second block. It has no effect on the digital process variable as read by a communicator.

Zero and span adjustment

Using only the zero and span adjustments to calibrate a HART transmitter (the standard practice associated with conventional transmitters) often corrupts the internal digital readings. You may not have noticed this if you never use a communicator to read the range or digital process data. As shown in Figure 2, there is more than one output to consider. The digital PV and milliamp values read by a communicator are also outputs, just like the analog current loop.

Consider what happens when using the external zero and span buttons to adjust a HART instrument. Suppose that an instrument technician installs and tests a differential pressure transmitter that was set at the factory for a range of 0 to 100 inches of water. Testing the transmitter reveals that it now has a 1 inch of water zero shift. Thus with both ports vented (zero), its output is 4.16 mA instead of 4.00 mA, and when applying 100 inches of water, the output is 20.16 mA instead of 20.00 mA. To fix this he vents both ports and presses the zero button on the transmitter. The output goes to 4.00 mA, so it appears that the adjustment was successful.

However, if he now checks the transmitter with a communicator, he will find that the range is 1 to 101 inches of water, and the PV is 1 inch of water instead of 0. The zero and span buttons changed the range (the second block). This is the only action that the instrument can take under these conditions since it does not know the actual value of the reference input. Only by using a digital command which conveys the reference value can the instrument make the appropriate internal adjustments.

The proper way to correct a zero shift condition is to use a zero trim. This adjusts the instrument input block so that the digital PV agrees with the calibration standard. If you intend to use the digital process values for trending, statistical calculations, or maintenance tracking, then you should disable the external zero and span buttons and avoid using them entirely.

Loop current adjustment

Another observed practice among instrument technicians is to use a hand-held communicator to adjust the current loop so that an accurate input to the instrument agrees with some display device on the loop. If you are using a Rosemount model communicator, this is a "current loop trim using other scale." Refer again to the zero drift example just before pressing the zero button. Suppose there is also a digital indicator in the loop that displays 0.0 at 4 mA, and 100.0 at 20 mA. During testing, it read 1.0 with both ports vented, and it read 101.0 with 100 inches of water applied. Using the communicator, the technician performs a current loop trim so that the display reads correctly at 0 and 100, essentially correcting the output to be 4 and 20 mA respectively.

While this also appears to be successful, there is a fundamental problem with this procedure. To begin with, the communicator will show that the PV still reads 1 and 101 inches of water at the test points, and the digital reading of the mA output still reads 4.16 and 20.16 mA, even though the actual output is 4 and 20 mA. The calibration problem in the input section has been hidden by introducing a compensating error in the output section, so that neither of the digital readings agrees with the calibration standards.

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Fluke-700BCW	Bar Code Wand
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Fluke-700TC2	TC Mini-Plug Kit, JKTERS
Fluke-700TLK	Process Test lead kit
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