Maintenance and Calibration of
HART Field Instrumentation

Richard Pirret, P.E.
Fluke Corporation
Everett, Washington

Abstract

The field instrumentation in process plants is beginning to come under more sophisticated metrological discipline. Most new field instruments are now *smart* digital instruments. One popular digital protocol is the HART (Highway Automated Remote Transducer) protocol, which shares characteristics of both analog and digital control systems.

To properly service these instruments, precision analog source / measure capability and digital communication are both required. Historically, this operation has required two separate tools, a calibrator and a communicator. Today, these capabilities are available in a single HART Documenting Process Calibrator that can help technicians quickly and effectively service a HART instrument workload.

Process environment demands productivity

Intense competition in the Process Industries demands maximum output at minimum cost. That productivity push extends into the maintenance department. At the same time, regulations and quality standards are demanding more rigorous calibration plus extensive documentation. Yet maintenance expenses are slashed to the minimum. Most plants have responded by replacing analog instrumentation with *smart* instruments. *Smart* is process jargon that describes any microprocessor-based field device. The microprocessor offers extra functionality, such as multiple sensor types, multiple measurement variables (e.g. flow rate and volume), digital compensation, and temperature compensation. These smart instruments generally offer better accuracy, long-term stability, and reliability than conventional analog instruments. Manufacturers of field instruments have accelerated the changeover by offering smart transmitters at prices approaching those of analog units. The majority of installed instruments are now digital instruments. Most of these instruments use the HART protocol.

What is the HART protocol?

HART stands for Highway Addressable Remote Transducer. The HART protocol uses 1200 baud Frequency Shift Keying (FSK) based on the Bell 202 standard [1] to superimpose digital information on the conventional 4-20 mA analog signal. Maintained by an independent organization, the HART Communication Foundation, the HART protocol is an industry standard developed to define the communications protocol between intelligent field devices and a control system.

HART [2] is the most widely used digital communication protocol in the process industries, with over five million HART field instruments installed in over 100,000 plants worldwide. HART:
- Is supported by all of the major vendors of process field instruments
- Preserves present control strategies by allowing traditional 4-20 mA signals to co-exist with digital communication on existing two-wire loops
- Is compatible with traditional analog devices
- Provides important information for installation and maintenance, such as Tag-IDs, measured values, range and span data, product information and diagnostics
- Can support cabling savings through use of multidrop networks
- Reduces operation costs, through improved management and utilization of *smart* instrument networks

Calibration is still required
Some instrument shops have come to believe that the accuracy and stability of HART instruments, plus the presence of instrument diagnostics, have eliminated the need for calibration. Others believe that calibration can be accomplished by re-ranging field instruments using only a HART communicator, either in the field or from the control room. However, regular performance verifications with a suitable reference standard, are necessary because:
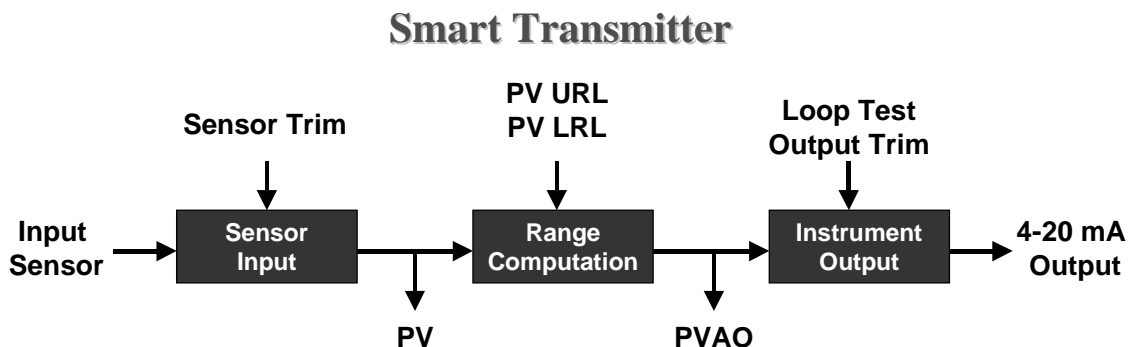- Regulations governing occupational safety, environmental protection, and consumer safety often require evidence of traceable calibration for process instrumentation.
- Quality programs, such as ISO 9000, dictate periodic calibration to recognized standards for all instruments that impact product quality.
- Whenever weights, measures, and custody transfer are involved, periodic calibration is required.
- Even with very long stated calibration intervals, the performance of instruments will change over time. This shift may be caused by long-term shifts in the transmitter electronics, or by exposure of the transmitter and the primary sensing element to temperature, humidity, environmental pollutants and vibration.
- Regular performance checks will often uncover problems not directly caused by the instrumentation, such as solidified or congealed pressure lines, or pressure lines that have become filled with condensate.
- Other errors, for example installation of a wrong thermocouple type, are often uncovered through periodic calibration.

How are HART instruments calibrated?
Calibration of an analog transmitter is fairly straightforward. Following an As-Found test, the zero and span adjustments may be used to set the correct relationship between the input signal and the 4 – 20 mA output. An As-Left test completes the calibration.

Analog Transmitter

Zero   Span

Input Sensor → Analog Electronics → 4-20 mA Output
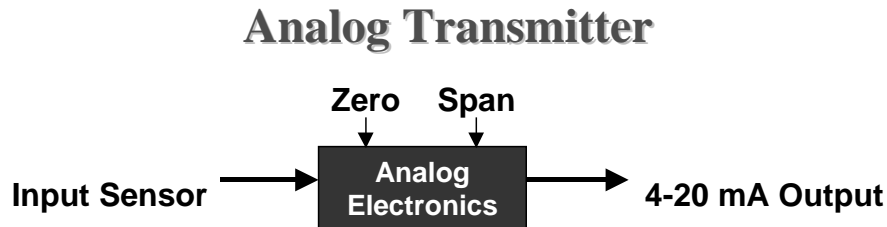
 A HART instrument is more complex, having three distinct stages. The sensor input stage sets the relationship between an input sensor and the PV, or primary variable. The PV is denominated in engineering units, for example, psi or ^{o}F. The Sensor Input stage is adjusted by digitally trimming using Sensor Trim.   The second stage is a computational stage, establishing the relationship between PV (Primary Variable) and PVAO (Primary Variable Analog Output). Range is scaled by assigning the PV Upper Range Limit and Lower Range Limit values. The PVAO is a digital value of the 4-20 mA output signal. The final stage, the Instrument Output, is set digitally with Output Trim. Performing these trims and entering the URV and LRV has typically been performed using a HART configurator or communicator, such as the Fisher-Rosemount 268 or 275. A separate calibrator was required to provide the precision analog source and measure functions.

Smart Transmitter

PV URL
PV LRL

Sensor Trim

Loop Test
Output Trim

Input Sensor → Sensor Input → Range Computation → Instrument Output → 4-20 mA Output

PV   PVAO

The calibration approach for a HART instrument will depend on how the transmitter outputs are used. If only the 4-20 mA analog signal is used, it may be treated much as an analog transmitter. Using the manual zero and span buttons on the transmitter, or by digitally setting the PV LRV and PV URV, the correct relationship between input sensor and 4-20 mA analog output are set. However, in this scenario, the Sensor Input stage has not been properly adjusted. If one were to use a communicator to read the digital value PV, it will most likely be incorrect, even though the 4-20 mA output will be correct.

If any of the digital signals will be used by the control system, then a more rigorous approach is required. If the PV will be used, then the input stage must be correctly set using Sensor Trim. Then the PV LRV and PV URV should be digitally assigned, and never changed using the manual zero and span buttons. Finally, the Output Trim is used to correctly set the relationship between the PVAO and the 4-20 mA analog output. Holladay [3] provides an excellent discussion on the proper calibration of HART devices.

New tools speed calibration

It is desirable to complete required calibrations as quickly and efficiently as possible. In the past, maintenance of smart instrumentation was often done in the shop. A benchtop calibrator was used for analog reference signals, and a HART communicator or configurator provided the digital communication. Today, most instrument maintenance is moving to the field. This reduces process interruption and avoids the time and expense of removing the instrument to the shop. Portable communicators and calibrators are often used together to complete these field calibrations. However, the desire to carry as little equipment as possible and to speed calibrations has created a need for a new class of calibration tool. Today, the HART Documenting Process Calibrator combines calibration capabilities and essential HART communication functions in one compact, easy-to-use tool. With such a tool, one can quickly address a workload of both HART and conventional instrumentation. One such tool is shown at left.

Documenting Process Calibrator with HART communication
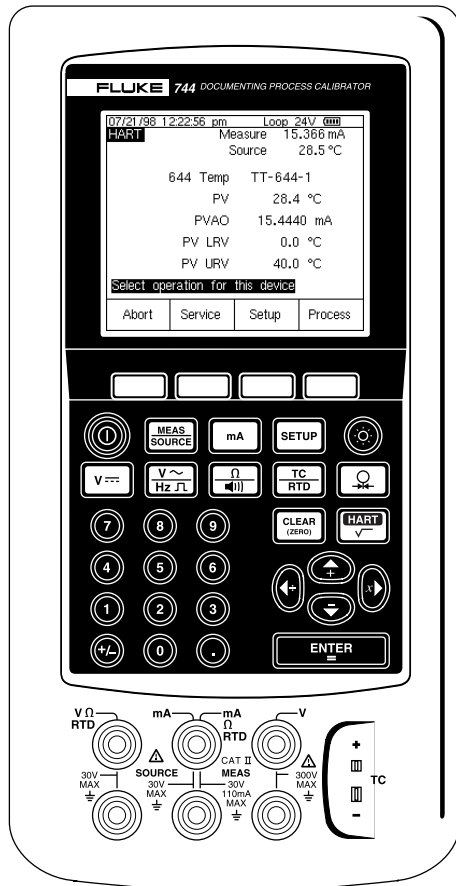
Essential HART information is visible at a glance in the Active Device Screen, shown in Figure 1.
- Model number and Tag ID
- PV (Primary Variable)
- PVAO (digital representation of the Analog Output)
- PV LRV (Primary Variable Lower Range Value)
- PV URV (Primary Variable Upper Range Value)

Also shown are the present values of the analog source and measure functions.


Figure 1, Active Device Screen

Via the Service, Setup and Process softkeys, the Active Device Screen serves as a portal to the entire HART feature set, as shown in the function tree below:
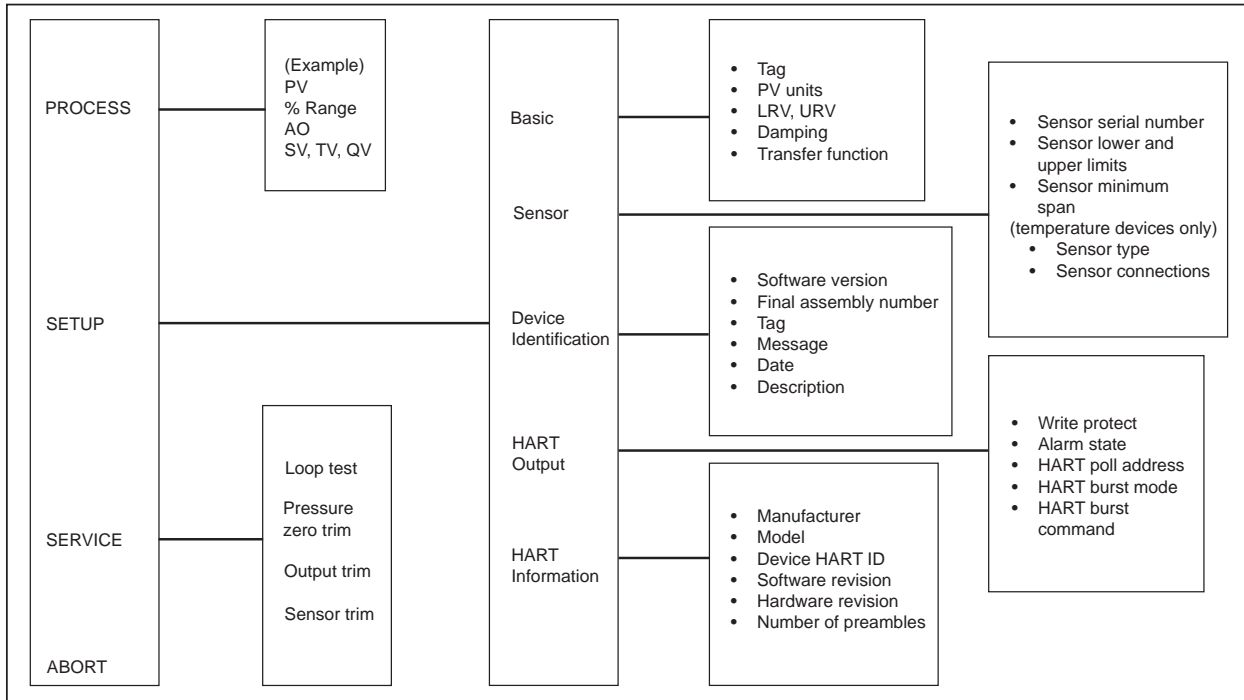
## Saving calibration time with an integrated HART calibrator

The following examples demonstrate how a HART Documenting Process Calibrator can shorten calibration times to help reduce maintenance costs.

1. **Easy hookup:** Today, both a calibrator and communicator are required, so hooking up the test takes longer. With the new integrated HART calibrator, hook-up is much simpler. Simply connect the source and measure leads as you would for an analog transmitter. Then,
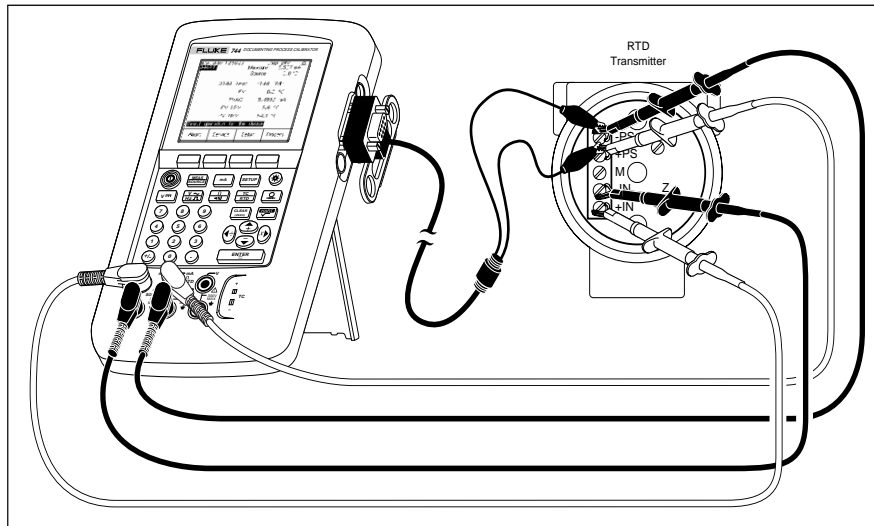
using the provided HART cable, connect the serial port to instrument power input or the HART terminals.

2. Fast acquisition of transmitter characteristics: With today's communicators, initialization and self-test can take 1-2 minutes. With an integrated HART calibrator, simply press the "HART" key. Any connected devices are automatically identified, typically within 10 seconds. If more than one device is found (multi-drop configuration), simply select one of the found devices to see the active device screen, Figure 1, above.
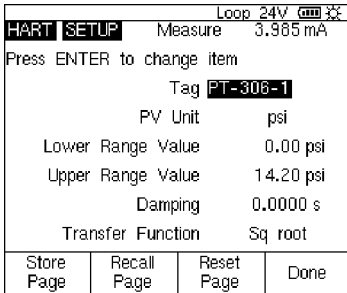

3.   Easy HART changes: Rather than calling up and then changing individual functions, the HART calibrator uses simple, shallow menus to quickly reach and edit key HART values. From the Active Device Screen, changes are quick and easy. For example, selecting Setup and Basic positions you to easily edit HART variables such as Tag ID, PV units, Upper and Lower Range Values.

4. Automatic selection of analog mode source / measure setting: With a calibrator / communicator pair, calibrator functions must be selected and entered by hand. With the integrated calibrator, from the active device screen simply press the "HART" key to go to the analog mode. All appropriate source / measure combination will be displayed, based upon the active HART device. Simply pick an entry from the list.
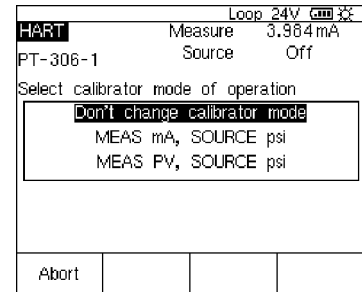

5. Automatic filling-in of test templates: With conventional calibrators, test limits would be entered by hand. Then, tests would be manually executed. With the HART calibrator, test procedure templates are automatically completed. Measure and source limits are automatically filled-in, again based on the presently connected HART device. Then, automated As-found procedures are readily started.
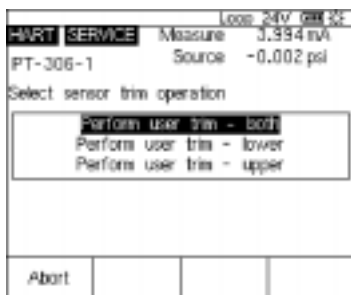

6.   Automatic branching to adjustment choices: Once the "As-Found" test is completed, an Adjust softkey becomes available. Press "Adjust". The HART SERVICE screen automatically appears with appropriate selections for the connected HART device. Simply choose from the list to automatically configure the calibrator to execute the desired trim.

7.   Automatic entry of analog readings: While performing digital trims per observed analog measurements, no user entry of analog readings is required. Readings may be captured with the Fetch softkey. Correct digital trim is then accomplished simply by using the Send key to apply the fetched reading..
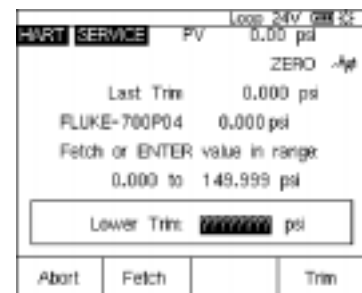
Guidelines for selection:
A technician's typical HART workload is roughly 70% troubleshooting and maintenance, 20% commissioning, and 10% calibration. In selecting a HART-capable calibrator, one should look for a tool that can not only calibrate but can extend to most of the daily troubleshooting and maintenance tasks.

Calibrate 10%   Maintain 70%

Commission 20%
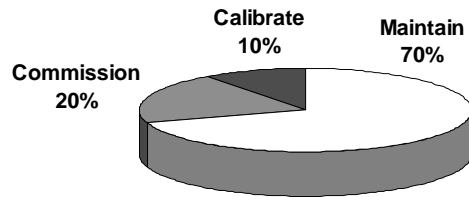
In general, that means insuring the tool can quickly interrogate and read virtually all HART devices at the Universal command level. Specifically, one should look for these capabilities:
- All of the necessary analog source / measure functions
- Fast and easy HART communication, with no programming knowledge required
- Loop power supply, including automatic insertion of 250 Ohm resistor whenever loop power is enabled
- Full compliance with the Data Link Layer of the HART protocol, addressing multiple masters, burst mode, and multi-drop configurations.
- Extensive implementation of Universal, Common-practice, and Device-specific commands
- A broad selection of supported devices from a variety of manufacturers, e.g. ABB, Endress + Hauser, Honeywell, Moore, Rosemount, Siemens, SMAR, and Yokogawa.

Conclusion
Using one tool that integrates both calibration and HART communication capabilities can greatly simplify and shorten the process of calibrating a HART field device. This streamlining converts directly to increased technician productivity and reduced maintenance costs.

References
1. Bell System Technical Reference, PUB 41212, Data Sets 202S and 202T Interface Specification, July 1976

2. HART Field Communication Protocol, An introduction for users and manufacturers, HART Communication Foundation, 9390 Research Blvd, Suite I-350, Austin, TX 78759-6540, or visit www.hartcomm.org

3. Holladay, Kenneth L., Southwest Research Institute, Calibrating HART Transmitters, HART Book 8, July 1998

Richard Pirret is a member of the Process Tools Group at Fluke Corporation in Everett, Washington. He has been with Fluke for 19 years in various development and business positions.