

Improving Plant Safety & Availability through Advanced Measurement Diagnostics

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ABSTRACT

To increase plant safety and availability, users have traditionally attempted to improve measurement accuracy and repeatability, use transmitters with better robustness, and employ installation “best practices”. Unfortunately, many users are finding that while upgrading an older measurement to state-of-the-art can yield dramatic improvements, further upgrades will yield diminishing returns. The next round of safety and availability improvements will instead come from diagnostics in the field devices. In their most basic form, these diagnostics, when combined with open digital protocols and Asset Management software, will allow users to reduce time to repair by speeding trouble-shooting. “Advanced” diagnostics, some of which are available today, will go beyond alarming transmitter failures to actually **predict** impending failures in the complete measurement system. This will significantly reduce unscheduled shutdowns, and also reduce the risk of onscale failure.

Traditional Approaches to Improving Safety & Availability

Instrumentation engineers seeking to improve safety and availability have traditionally used a combination of three approaches:

- Improve measurement accuracy and repeatability
- Use more robust transmitters
- Employ “best practices” in installation and maintenance

Accurate and repeatable measurements improve safety by minimizing undetected failures, and improve availability by minimizing false trips. Consider the example of a reactor which must shut down at a pressure of 1000 psig. A pressure measurement with a repeatability of +/-20 psig could conceivably allow the reactor to operate as high as 1020 psig – potential safety risk – or might prematurely shut the reactor down at 980 psig, reducing availability. Improving measurement repeatability from +/-20 psig to +/-5 psig will minimize both of these risks. Alternatively, some users will choose to account for the measurement uncertainty by operating with a safety limit of 980 psig – improving measurement repeatability allows the user to reduce this safety margin, and improve process **efficiency** with no penalty in either safety or availability.

Using robust transmitters which fail less frequently will directly improve plant availability. For example, a plant with 400 transmitters each with an MTBF of 100 years can expect about 4 transmitter failures each year. Upgrading to higher quality transmitters with an MTBF of 400 years will reduce this to 1 failure each year.

Many measurement failures can be attributed to poor installation or maintenance practices. For example, using very long impulse lines in a differential-pressure flowmeter installation will increase the likelihood of impulse line plugging and freezing – reducing availability – with higher fugitive emissions – reducing safety. Using shorter impulse lines or converting to direct-mount will improve both safety and availability – and should actually cost less.

Most users have spent the past few decades continuously improving their measurements using the approaches outlined above. However, users are finding that while upgrading an older measurement to current state-of-the-art can yield dramatic improvements, further upgrades will yield **diminishing returns**. In the example above, while the improvement from +/- 20 psig to +/- 5 psig may have yielded significant benefits, it should be clear that future improvements – even to perfection – will return no more than one-third of the benefits of the previous upgrade. Similar comments apply to improvements in transmitter robustness and installation “best practices”.

If the traditional approaches to improving process safety and availability yield diminishing returns, where will the next generation of improvements come from?

Diagnostics – The Next Frontier

Diagnostics embedded in the field devices promise to provide significant improvements in process safety and availability by:

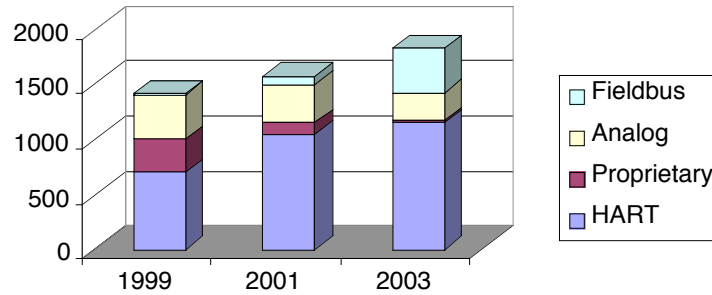
- Speeding trouble-shooting.
- Detecting onscale failures.
- Reducing unscheduled shutdowns by allowing the user to predict – and prevent – failures in advance.

The Enablers – Open Digital Protocols and Asset Management Software

Diagnostics in field devices are of limited utility unless the user can economically and conveniently access diagnostics alerts and information. For example, how useful is an “RTD failure detection” diagnostic if the user must climb a ladder to the top of a column to check the status of an RTD? How much more useful if that diagnostic information could be easily accessed in the maintenance shop?

Digital protocols allow a field device to transmit additional information – including diagnostics – on the same pair of wires that carry the process variable. This minimizes incremental cost. While *proprietary* digital protocols have existed for years, these continue to be abandoned by users and suppliers in favor of *open* protocols (Figure 1).

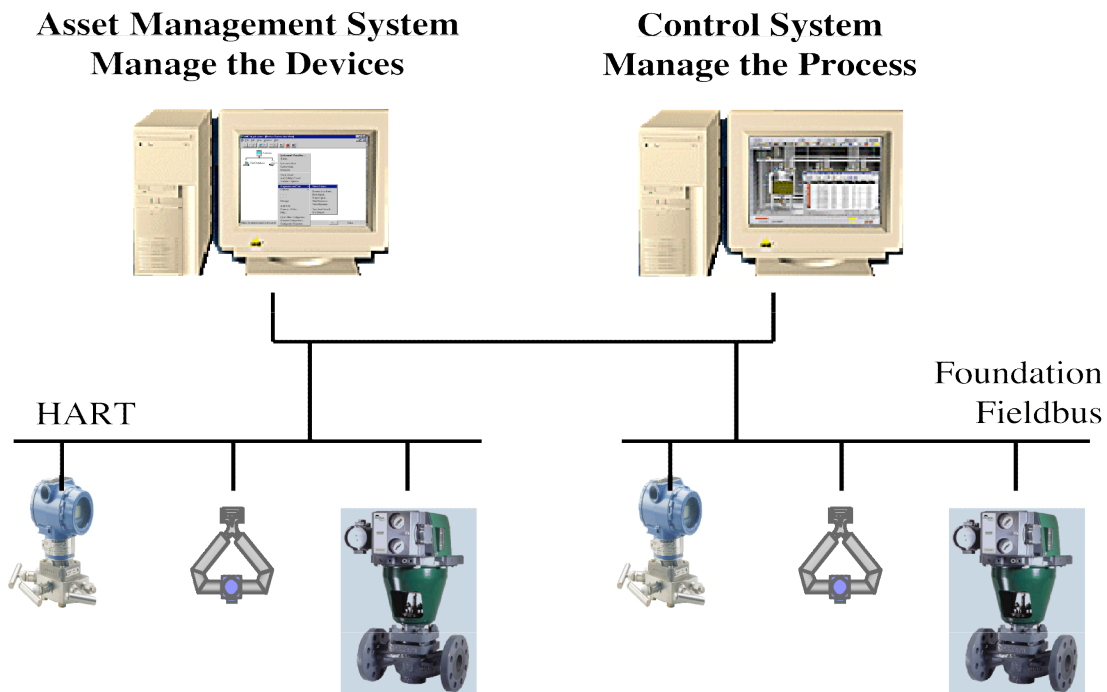
Figure 1 – Global Pressure Transmitter Shipments (by protocol) – (thousands)



Source: 1999 Pressure Transmitter Worldwide Outlook Study
 © ARC Advisory Group, Dedham, MA USA

Given the large installed base of HART, and the lack of a single open standard, even in the long term it seems likely that any Asset Management system will need to connect to multiple open standards, including HART, Foundation™ fieldbus and other open “fieldbuses”. However, by using only open protocols the user can connect devices from multiple suppliers to a single Asset Management system, consolidating all diagnostic information, as shown in Figure 2. This not only minimizes capital, installation and training costs, but also simplifies maintenance and streamlines regulatory compliance.

Figure 2 – Asset Management System

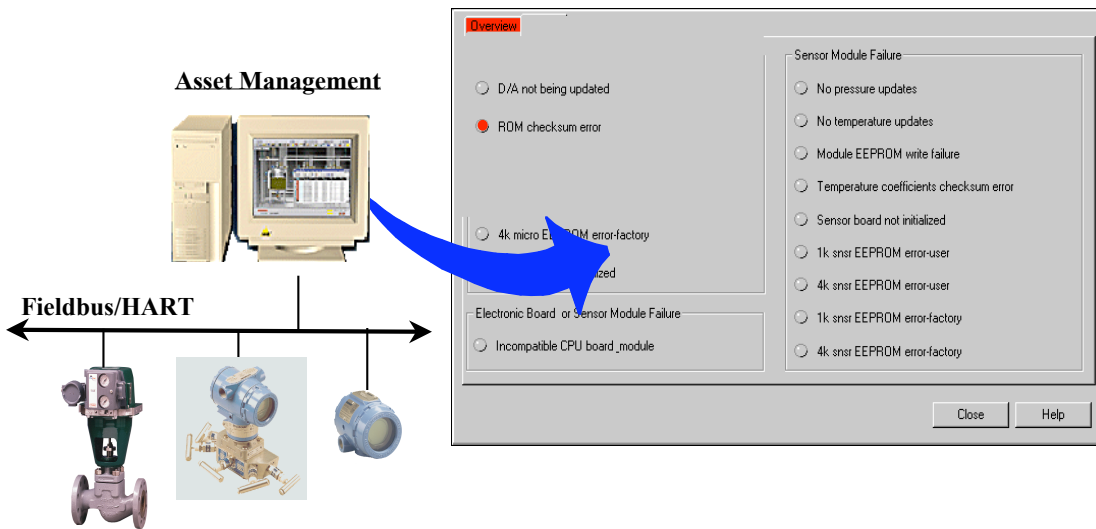


How Can Diagnostics Reduce Time to Repair?

Most instrumentation-related failures are “repair by replacement”. However, operators typically do not page maintenance with “the RTD in the 12th tray of the column has failed”; instead, the operator will usually call and say “something’s wrong with the column temperature control.” To reduce repair time in a repair by replacement system, the user must speed trouble-shooting – “how long does it take to isolate a problem to a *specific* component of a *specific* transmitter?”

Modern smart transmitters can include extensive diagnostic capabilities that allow the user to quickly isolate the source of any problem. The screen capture below shows a failed pressure transmitter electronics board (“ROM Checksum Error”).

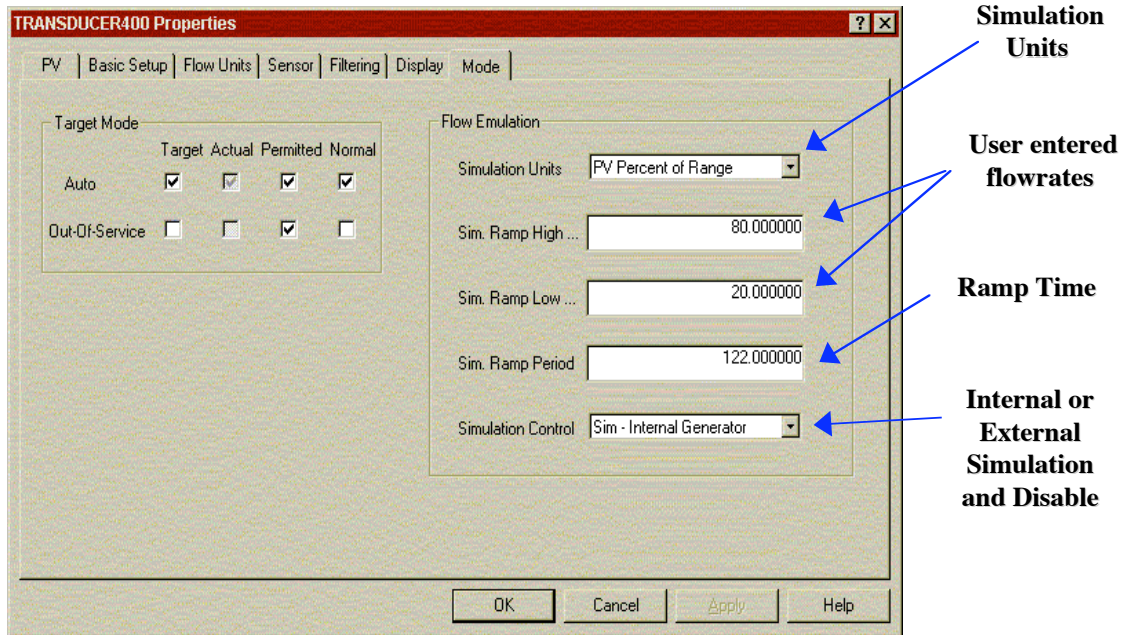
Figure 3 – Device Diagnostics to Speed Trouble-shooting



The relevant information for the maintenance technician is the Recommended Action. For the failed pressure transmitter shown above, this is “Replace Electronics”. While the more detailed diagnostic message shown, which traces the failure to a specific component, may offer no incremental information, repeated failures of the same type may suggest a more detailed investigation in co-operation with the supplier – for example, “*why* have 3 transmitters in this application failed with ‘ROM Checksum Error’?”

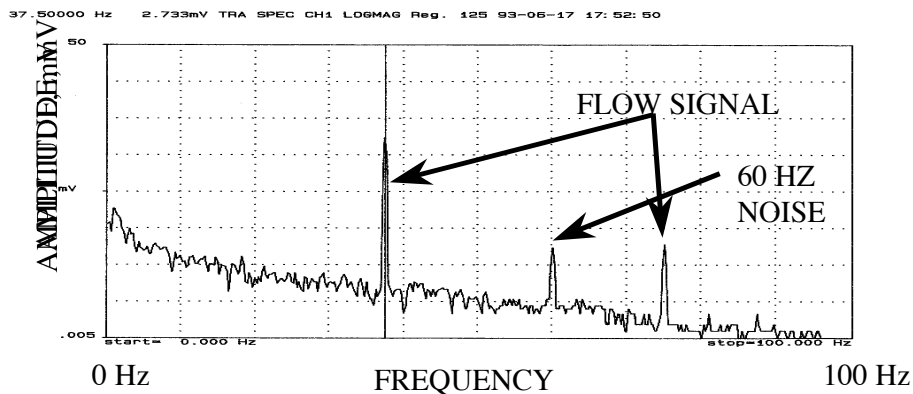
In addition to detecting failures, modern smart transmitters allow the user to easily diagnose application, configuration or installation errors. For example, the screen below allows the user to simulate a flow signal and test both the electronics and the configuration of the vortex meter. While older vortex meters allow a fixed flow simulation to be done with board jumpers, newer smart devices allow a user-selected simulation to be done much more easily, either as shown from the Asset Management software or from a connected handheld configurator.

Figure 4 – Diagnosing Application or Configuration Errors



Successful flow simulation in a vortex meter rules out transmitter or configuration problems, and helps to isolate an application error. Both vortex and magnetic flowmeters obtain reliable flow readings – maximum signal to noise - by maximizing the signal and minimizing the noise. However, in many applications the noise itself can contain useful diagnostic information. For example, the screen below shows an extra spike at 60 Hz – this spike probably indicates a grounding problem. Again, this diagnostic speeds isolation of this common installation problem.

Figure 5 – Diagnosis of Grounding Problem with Magnetic Flowmeter



Therefore, device diagnostics can minimize repair time by speeding trouble-shooting – identifying device failures and isolating application and installation errors.

What is Predictive Maintenance?

Most plants operate with a combination of reactive and preventive maintenance:

- Reactive: fix it when it breaks
- Preventive: check it periodically in an attempt to prevent it from breaking
- Predictive: fix it just before it breaks

To illustrate the value of predictive maintenance, consider the “nail in tire” analogy. A nail in a car tire will, if undetected, eventually cause a blowout, potentially leading to an expensive or even fatal accident. Fixing the car after the accident – *reactive* maintenance – can be very expensive. *Preventive* maintenance requires the user to inspect the tires before every trip to check for an embedded nail. This is very time consuming, as most inspections will not reveal a nail. Also, these inspections will not prevent the accident if the nail pierces the tire after the car leaves the driveway. What’s needed is *predictive* maintenance – ignore the tire until and unless it alerts you that it has a nail in it. This approach minimizes both maintenance labor and the risk of accidents.

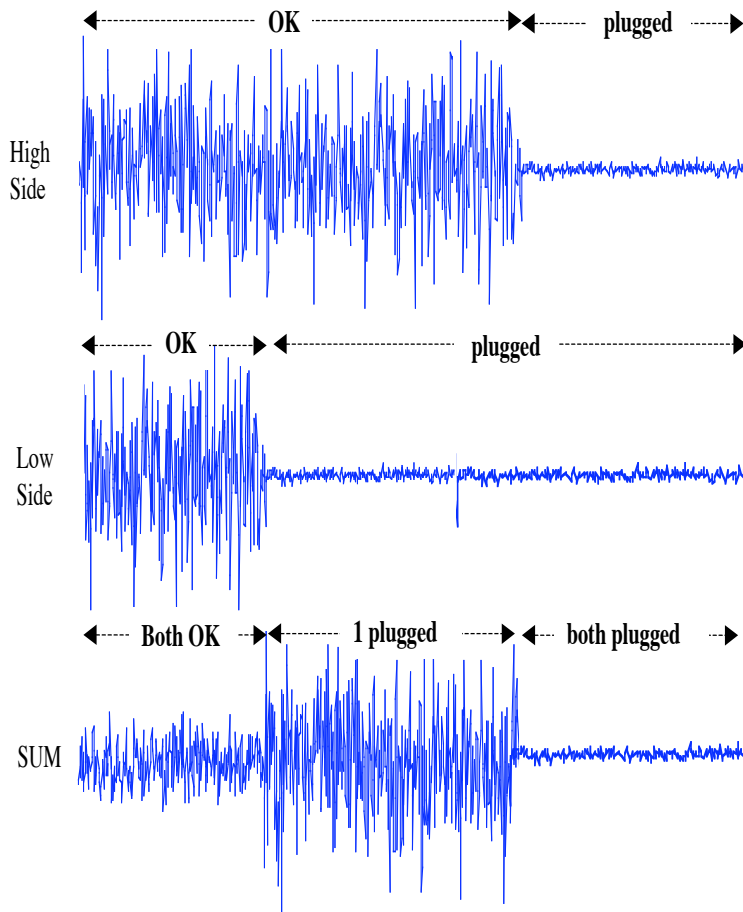
Why Locate Predictive Maintenance Diagnostics in the Field – Resolution and Speed

Many users have significant investments in “expert” software which uses data from the DCS to predict failures. However, much better diagnostic information is available at the field device. To understand why, consider again the “nail in tire” analogy. If a vibration sensor is located in the seat of the car, it will read a smooth, well damped signal. This is because the car’s suspension is designed to smooth out bumps in the road – the sensor will detect a tree (for example), but will probably not detect an embedded nail. Similarly, the process signal entering a control system is smooth and well damped – this is ideally suited to smooth, continuous control, but is unsuited to diagnostics.

Instead, the sensor should be located as close as possible to the process, before the suspension – or the filters – have had a chance to damp out the signal. A diagnostic located in the transmitter itself has a much better chance of detecting a process problem before it causes a failure, just as a sensor on the tire itself has a much better chance of detecting the minute vibration caused by a nail in the tire before it causes a blowout.

Examples of Predictive Diagnostics Available Today

Detecting and Predicting Plugged or Frozen Impulse Lines – Figure 7 shows the undamped signals in the impulse lines measured by the differential pressure transmitter in a typical orifice meter installation.

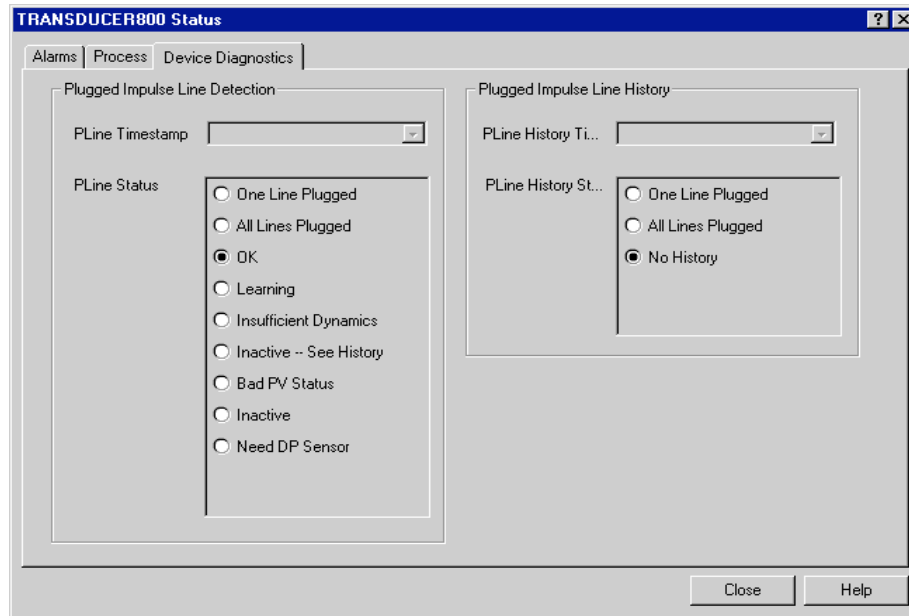
Figure 7 – Impulse Line Signals

Observations from Figure 7 :

- An open (unplugged) impulse line has high frequency noise due to fluid turbulence – comparable amplitude of noise for both high and low side lines.
- If both lines are open, the physical offset between the high and low impulse lines creates a phase shift. As a result, the SUM has half the amplitude of either signal.
- If either line plugs, its signal will become flat – with minimal cancellation, the SUM will have twice the amplitude of the “OK” SUM.
- If both lines are plugged, both will become flat, and as a result the SUM will be flat.

To perform this diagnostic, the transmitter must calculate “Variability Index”. The transmitter must “learn” the process and characterize an “OK” condition for a varying flowrate. Once the process is “learned”, and the diagnostic is online, an Index trending high will alert one line plugging, and an Index trending low will alert both lines plugging. A screen capture from the Asset Management software is shown in Figure 8.

Figure 8 – Asset Management Screen Capture for Plugged Impulse Line Diagnostic



It should be clear that this diagnostic will only be practical with a very fast pressure sensor. Since the diagnostic is performed in the transmitter itself, update rate to the DCS is not important, but a fast sensor – 50 msec or less – is vital. Many pressure transmitters available today exceed this maximum response time by a factor of two to five times.

Detecting RTD Drift with a Redundant Sensor: Multivariable temperature transmitters with two sensor inputs now have the ability to diagnose drift in a RTDs. The temperature transmitter monitors the differential temperature from either a dual-element sensor or two single element sensors. When both sensors are working properly the temperature difference between them should be close to zero. However, as the sensors drift at different rates, the difference between the two measurements increases. If the two RTD's have been "sensor-matched" by the supplier, the difference should be less than 0.25 °C. If the difference exceeds some user-defined maximum acceptable drift limit, say 3 °C, the transmitter alerts the maintenance technician monitoring the Asset Management station. The user can then schedule a time to replace the sensor(s).

Detecting Onscale Failures for Improved Safety

Most transmitter failures are easy to detect – the output of the transmitter goes either high or low offscale. More dangerous are *onscale* failures – the output of the transmitter is within normal range, but the measurement is very inaccurate. Onscale failures tend to be associated not with the transmitter itself but with the rest of the measurement system:

- Differential pressure flowmeters – impulse lines, orifice plate
- Temperature – RTD, thermocouple, thermowell
- Flow – flowtube or vortex shedder bar

Many of these diagnostics overlap with those used to enable predictive maintenance.

The Future of Advanced Diagnostics

This paper has only presented diagnostics which exist today in real field devices. However, the future is bright for additional diagnostics which operate on similar principles to those already described, including:

- DP Flow – detect eroded orifice plates
- Temperature – predict RTD or thermocouple failure
- Vortex – predict sensor failure

Diagnostic capabilities can also be located in the Asset Management software, which can combine alerts from multiple field devices to provide new, loop-based diagnostics.

In conclusion: advanced diagnostics can provide significant improvements in process safety and availability. To ensure that they receive the maximum benefit of advanced diagnostic capabilities in their field devices, users need to:

- Ensure that they use open protocols such as HART or FOUNDATION Fieldbus.
- Gain experience with Asset Management software.
- Ask their suppliers – what diagnostics are available now, and what are planned for the future?