



Self-Calibrating Smart Pressure Transmitters and the Prospects for Extended Verification Intervals

Aigerim Amirkhanov^{1*}, Beatriz Bekele², Lars Joshi³

¹Department of Engineering, Amazon University Centre for Engineering, Greece

²Department of Engineering, Amazon Graduate Institute of Engineering, Kyrgyzstan

³Department of Engineering, Pannonian Graduate Institute of Engineering, Saudi Arabia

Article Info

Volume 1, Issue 1, 2026

doi: [10.62715/ijie.2026.v1.i1.pp8-14](https://doi.org/10.62715/ijie.2026.v1.i1.pp8-14)

Received: 31 March 2026

Accepted: 07 June 2026

Published: 28 July 2026

Abstract

Pressure transmitters are the most numerous measuring instruments in process plants, and their periodic calibration against a reference standard is among the largest recurring costs of instrument maintenance. Smart transmitters now carry diagnostics that are marketed as self-calibration or self-verification, and plant operators reasonably ask whether these functions justify longer intervals between manual checks. This narrative review examines that question. It first clarifies terms, since calibration in the metrological sense requires a comparison with a reference that most transmitters do not contain. It then surveys what is known about drift in pressure transmitters, the self-validating sensor concept and its standardised quality metrics, the diagnostic functions built into current devices, and the process-level monitoring methods developed largely in the nuclear industry. These are set against the frameworks that govern verification intervals: guidance on calibration intervals, measurement management standards and, for safety functions, proof-test requirements. The conclusion is that built-in diagnostics detect many failures promptly but cover slow, small drift of the sensing element only partially, and that an extended interval is best justified by combining device diagnostics with redundancy, drift history and an explicit statement of the faults that remain undetected.

Keywords: Pressure transmitter, Self-validating sensor, Calibration interval, Sensor diagnostics, On-line monitoring, Metrological traceability

© 2026 Aigerim Amirkhanov et al. This is an open access article under the CC BY license (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

1. Introduction

A medium-sized refinery or power station contains thousands of pressure and differential-pressure transmitters. They measure not only pressure but, through orifice plates and wet legs, most of the flows and levels as well. Each is normally removed from service at a fixed interval, isolated, connected to a pressure calibrator and compared with it at several points across the range. Experience in the nuclear industry, where records are kept with particular care, is that the large majority of these checks find the instrument within tolerance and lead to no adjustment (Hashemian, 2006). The work is expensive, it exposes technicians and plant to the hazards of breaking into process connections, and it occasionally

* Corresponding author: Aigerim Amirkhanov, Department of Engineering, Amazon University Centre for Engineering, Greece. E-mail: aigerim.amirkhanov@amazon.edu

© 2026 Aigerim Amirkhanov et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

introduces faults that were not there before.

Against this background the appeal of an instrument that checks itself is obvious. Transmitters built around a microprocessor have offered digital compensation and communication since the 1980s, and the trend towards embedding more intelligence in the sensor has been steady ([Kanoun and Tränkler, 2004](#)). Recent devices add functions described by their makers as self-diagnosis, self-verification or self-calibration, sometimes with a claim that verification intervals can be lengthened. The claim deserves scrutiny, because the interval is not only an economic choice. It is a statement about how long the measurement can be trusted.

This article reviews what the published literature and the relevant standards say about that claim. It asks what a transmitter can and cannot learn about its own accuracy, what evidence other than the device itself can supply, and what the rules that govern intervals would require before an extension is accepted.

2. Approach and Terms

The review is narrative. It draws on the academic literature on self-validating sensors and sensor fault detection, on monographs and regulatory reports dealing with on-line monitoring of instrument channels, and on international standards and guidance documents. Manufacturer literature is not cited, since its claims are specific to products and are not independently reviewed. No formal search protocol was applied and the coverage is selective.

Words matter here. The international vocabulary of metrology defines calibration as an operation that establishes a relation between the values provided by measurement standards and the indications of the instrument, each with its uncertainty ([JCGM, 2012](#)). Verification is the provision of objective evidence that an item fulfils specified requirements. Adjustment is what brings the indications into agreement with the standard. A device with no pressure reference inside it cannot calibrate itself in this sense. What it can do is compensate for known influences, test parts of itself, and report evidence that bears on whether its last calibration still holds. The term self-calibrating is retained in the title because it is the term in commercial use, but the functions it covers are better described as self-compensation and self-diagnosis.

3. How Pressure Transmitters Drift

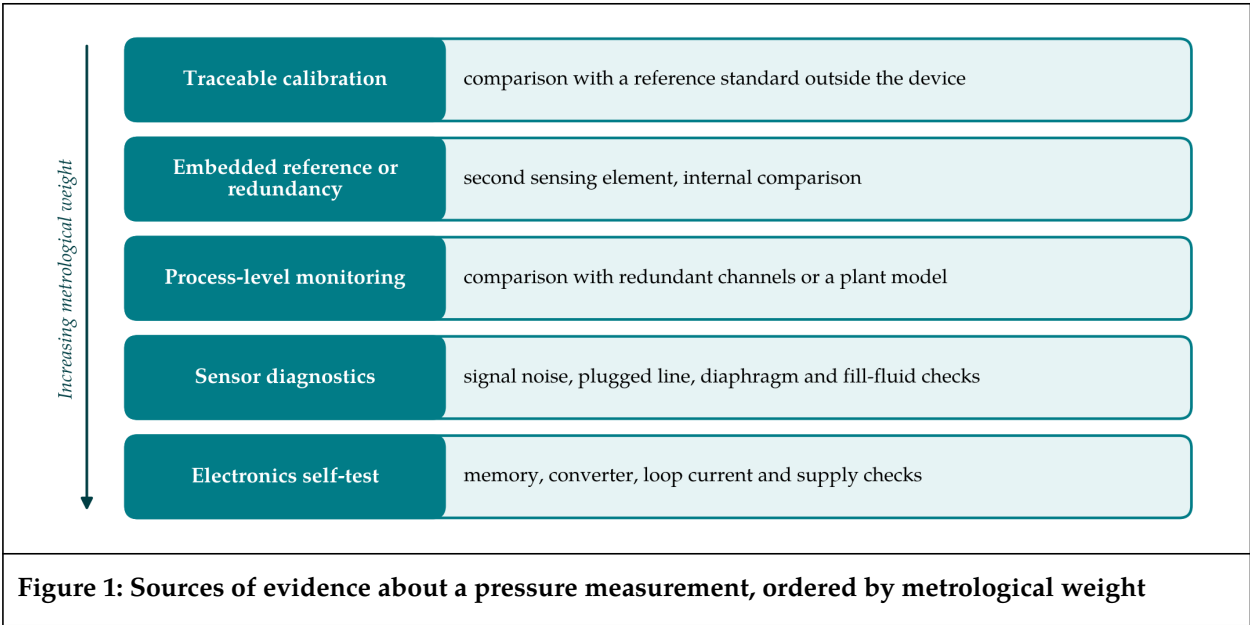
Most industrial transmitters sense pressure through the deflection of a thin diaphragm, read out as a change in capacitance, in the resistance of diffused piezoresistors, or in the frequency of a resonant silicon element ([Bentley, 2005](#)). The sensing element is usually isolated from the process by a second diaphragm and a fill fluid. Raw output depends on temperature and, in differential devices, on static line pressure. Smart transmitters remove most of this dependence by measuring sensor temperature and applying a correction characterised individually at the factory, and standard test methods exist for evaluating how well the correction works ([IEC, 2008](#); [IEC, 2014](#)).

Drift is the slow departure of the output from its calibrated value under constant conditions. Its causes are mechanical and chemical more often than electronic: relaxation of stresses locked into the diaphragm and its mounting, fatigue under pressure cycling, the after-effects of overpressure, gradual loss or degradation of fill fluid, and permeation of hydrogen through the isolating diaphragm in some services. Outside the transmitter, sensing lines block, leak, freeze or accumulate gas or condensate, and the resulting errors are indistinguishable at the output from a fault in the device. [Hashemian and Jiang \(2009\)](#) examine these contributions to transmitter accuracy in nuclear plants, the sensing lines among them. The important feature of most drift mechanisms is that they change zero or span without leaving any other trace in the signal.

4. What a Transmitter Can Know About Itself

The sources of evidence about a measurement can be arranged by how much metrological weight they carry, as in Figure 1. At the bottom are checks of the electronics, which are comprehensive and say nothing about the diaphragm. At the top is traceable calibration, which says everything and requires access. The interesting ground lies between. Table 1 summarises, for each kind of check, what it detects

and what it leaves undetected.



4.1. The self-validating sensor

The intellectual foundation for device self-assessment was laid by [Henry and Clarke \(1993\)](#), who argued that a sensor should report not a bare number but a validated measurement value, an on-line estimate of its uncertainty, and a status indicating how the value was obtained. In their scheme a measurement may be clear, blurred when a fault has been detected and corrected for with increased uncertainty, dazzled when the reading is temporarily replaced by a projection, or blind when no credible value can be produced. The idea was developed for several sensor types ([Henry, 2001](#)), was codified in a British Standard on data quality metrics ([BSI, 2005](#)), and has been reviewed by [Feng et al. \(2007\)](#). Its lasting contribution is the insistence that uncertainty is a live quantity that the instrument should compute, in the spirit of the Guide to the Expression of Uncertainty in Measurement ([JCGM, 2008](#)), and not a fixed figure from a data sheet.

4.2. Diagnostics in current devices

Present-day transmitters implement part of this programme. Electronics self-tests cover memory, the analogue-to-digital converter, the output stage and the supply. Sensor-level diagnostics look for a ruptured diaphragm, loss of fill fluid or a failed temperature element. Statistical monitoring of process noise exploits the fact that a healthy sensing line transmits the small fluctuations always present in a flowing process, so that a fall in noise amplitude suggests a blocked line. The results are reported to the control system using the four status signals of NAMUR recommendation NE 107: failure, function check, out of specification and maintenance required ([NAMUR, 2017](#)). These diagnostics are valuable and well suited to detecting abrupt or gross faults. By their nature they are weakest against the fault that concerns the calibration technician, a shift of a fraction of a per cent in an otherwise healthy sensor.

4.3. Embedded references and redundancy

A transmitter can say something about drift only if it contains a second source of information about pressure. Designs have been described that use two sensing elements of different construction and compare them, that switch the sensor periodically to a known internal condition such as equalised pressure in order to check zero, or that monitor a parameter of the sensing element, the resonant frequency or bridge resistance for example, that changes when the element degrades. A zero check is informative because zero shift is the commonest form of drift, but it does not test span. Dual elements detect disagreement, although two elements sharing a fill fluid and a process connection can drift together. None of these arrangements creates traceability, because the internal reference has itself no link

to a measurement standard after the device leaves the factory. They provide evidence that the calibration has not changed, which is a different and weaker thing than a calibration.

Table 1: Kinds of self-check and monitoring applicable to pressure transmitters, with what each detects and misses

Kind of check	What it detects	What it leaves undetected	Sources
Electronics self-test	Memory, converter, output and supply faults	Any change in the sensing element	NAMUR, 2017
Sensor integrity diagnostics	Diaphragm rupture, gross fill-fluid loss, failed temperature element	Small zero or span shift	IEC, 2014
Process noise monitoring	Blocked or restricted sensing lines	Steady offsets; quiet processes	Hashemian, 2011
Internal zero or dual-element comparison	Zero shift; disagreement between elements	Span error; drift common to both elements	Feng et al., 2007
Redundant-channel comparison	Drift of one channel relative to its peers	Drift common to all channels	Hines and Seibert, 2006
Model-based monitoring	Departure from the relation predicted by other plant signals	Faults inside model uncertainty; untrained operating states	Dunia et al., 1996

5. Evidence From Outside the Device

The strongest case for extending intervals has been made in the nuclear power industry, and it rests mainly on evidence from outside the transmitter. Safety-related parameters there are measured by three or four redundant channels. On-line monitoring compares each channel with an estimate of the true process value formed from its peers, by simple or weighted averaging, and tracks the deviation over the operating cycle. A channel whose deviation stays within a defined band is judged not to have drifted and is not calibrated at the outage ([Hashemian, 2011](#)). The technical basis, including the treatment of uncertainty in the process estimate, was examined for the United States regulator by [Hines and Seibert \(2006\)](#).

Where redundancy is absent, an estimate can be built from other measurements that are physically related to the one in question. Principal component analysis was applied to the identification of faulty sensors by [Dunia et al. \(1996\)](#), and it sits within a much larger family of analytical redundancy methods surveyed by [Venkatasubramanian et al. \(2003\)](#) and treated at length by [Isermann \(2006\)](#). Their common limitation is that the estimate is only as good as the model and the other sensors, and its uncertainty is usually larger than the tolerance of a good transmitter. Such methods detect a channel that has gone wrong. They are less able to confirm that a channel is right to within a tight specification.

Two weaknesses of comparison methods should be stated plainly. Common-mode drift, in which all redundant transmitters of the same model shift in the same direction, is invisible to them, and the nuclear programmes retain a periodic calibration of at least one channel on a rotating basis for that reason. In addition, on-line monitoring observes the instrument only at the pressures the process visits, typically one operating point, and cannot by itself verify linearity across the range.

6. The Rules That Govern Intervals

No general standard fixes a calibration interval for process transmitters. The accreditation standard for laboratories leaves the interval to the owner of the instrument ([ISO/IEC, 2017](#)), and the standard on measurement management systems requires that intervals of metrological confirmation be reviewed and adjusted when necessary to ensure continuing compliance ([ISO, 2003](#)). The joint guidance of the

international laboratory accreditation and legal metrology bodies describes several methods for doing so: stepwise adjustment according to whether the instrument was found in tolerance, control charts of calibration results, intervals based on time in use, in-service checking with a portable standard or built-in check, and statistical analysis of populations ([ILAC and OIML, 2007](#)). A recommended practice from the measurement science community gives the statistical methods in detail ([NCSL International, 2010](#)).

Two points follow. First, these documents already allow an interval to be lengthened on evidence, and the evidence they chiefly contemplate is the history of as-found results, which any plant with a calibration database possesses. Secondly, the in-service check they describe is close to what self-verification offers, provided the check is understood as a means of detecting change between calibrations and not as a substitute for them.

Transmitters in safety instrumented functions fall under a separate regime. The functional safety standards require periodic proof tests to reveal dangerous failures that automatic diagnostics do not detect, and the achievable test interval depends on the diagnostic coverage credited to the device ([IEC, 2010](#); [IEC, 2016](#)). Proof testing and calibration are often carried out together but answer different questions: one asks whether the function will operate on demand, the other whether the reading is accurate. Better diagnostics can support a longer proof-test interval through the reliability calculation, yet that argument says nothing by itself about measurement uncertainty.

7. Prospects and Open Questions

Taken as a whole, the literature supports a moderate position. Built-in diagnostics shorten the time to detection of many faults from months to minutes, and that alone weakens the case for frequent intrusive checks whose main yield was the discovery of such faults. For slow drift within the diagnostic threshold the device remains largely silent, and here the justification for a longer interval has to come from drift history, redundancy or process models. A defensible extension therefore combines sources: device status, an internal zero or dual-element check where available, comparison with related measurements, and a statistical record of past calibrations.

Several questions remain open. Independent, published evidence on the drift-detection capability of commercial self-verification functions is scarce, and the test standards for intelligent transmitters do not yet define how such a capability should be measured and declared. There is no agreed way to express the result of a self-check as a contribution to measurement uncertainty, which is what the self-validating sensor concept originally proposed. The treatment of sensing lines, which lie outside the device but inside the measurement, is uneven. And regulators in custody transfer, emissions reporting and pharmaceutical manufacture have their own expectations of periodic calibration that device diagnostics do not automatically satisfy. Each of these is a matter for standards committees and independent test laboratories as much as for designers.

8. Conclusion

A smart pressure transmitter does not calibrate itself, and the phrase should be read as shorthand for compensation and diagnosis. Those functions are nonetheless useful evidence about the state of the measurement, and existing guidance on calibration intervals already provides the means to give such evidence weight. The prospects for extended verification intervals are good where three conditions are met: the plant holds a drift history showing the transmitter population to be stable, there is some independent check on each measurement through redundancy or a process relation, and the residual faults that no automatic check can reveal, common-mode drift and span error above all, are named and covered by a reduced programme of traceable calibration. Where those conditions are absent, diagnostics improve availability but do not by themselves justify calibrating less often.

Conflict of interest

To be declared by the author(s) before publication.

Funding

To be declared by the author(s) before publication.

References

- Bentley, J.P. (2005). [Principles of Measurement Systems, 4th edition](#). Pearson Education, Harlow.
- BSI (2005). [BS 7986:2005 Data quality metrics for industrial measurement and control systems: Specification](#). British Standards Institution, London.
- Dunia, R., Qin, S.J., Edgar, T.F. and McAvoy, T.J. (1996). [Identification of faulty sensors using principal component analysis](#). *AIChE Journal*, 42(10): 2797-2812.
- Feng, Z., Wang, Q. and Shida, K. (2007). [A review of self-validating sensor technology](#). *Sensor Review*, 27(1): 48-56.
- Hashemian, H.M. (2006). [Maintenance of Process Instrumentation in Nuclear Power Plants](#). Springer, Berlin.
- Hashemian, H.M. (2011). [On-line monitoring applications in nuclear power plants](#). *Progress in Nuclear Energy*, 53(2): 167-181.
- Hashemian, H.M. and Jiang, J. (2009). [Pressure transmitter accuracy](#). *ISA Transactions*, 48(4): 383-388.
- Henry, M. (2001). [Recent developments in self-validating \(SEVA\) sensors](#). *Sensor Review*, 21(1): 16-22.
- Henry, M.P. and Clarke, D.W. (1993). [The self-validating sensor: Rationale, definitions and examples](#). *Control Engineering Practice*, 1(4): 585-610. [https://doi.org/10.1016/0967-0661\(93\)91382-7](https://doi.org/10.1016/0967-0661(93)91382-7)
- Hines, J.W. and Seibert, R. (2006). [Technical Review of On-Line Monitoring Techniques for Performance Assessment, Volume 1: State-of-the-Art \(NUREG/CR-6895\)](#). U.S. Nuclear Regulatory Commission, Washington, DC.
- IEC (2008). [IEC 61298-1:2008 Process measurement and control devices: General methods and procedures for evaluating performance, Part 1: General considerations](#). International Electrotechnical Commission, Geneva.
- IEC (2010). [IEC 61508:2010 Functional safety of electrical/electronic/programmable electronic safety-related systems](#). International Electrotechnical Commission, Geneva.
- IEC (2014). [IEC 60770-3:2014 Transmitters for use in industrial-process control systems, Part 3: Methods for performance evaluation of intelligent transmitters](#). International Electrotechnical Commission, Geneva.
- IEC (2016). [IEC 61511-1:2016 Functional safety: Safety instrumented systems for the process industry sector, Part 1: Framework, definitions, system, hardware and application programming requirements](#). International Electrotechnical Commission, Geneva.
- ILAC and OIML (2007). [ILAC-G24 / OIML D 10: Guidelines for the determination of calibration intervals of measuring instruments](#). International Laboratory Accreditation Cooperation and International Organization of Legal Metrology.
- Isermann, R. (2006). [Fault-Diagnosis Systems: An Introduction from Fault Detection to Fault Tolerance](#). Springer, Berlin.
- ISO (2003). [ISO 10012:2003 Measurement management systems: Requirements for measurement processes and measuring equipment](#). International Organization for Standardization, Geneva.
- ISO/IEC (2017). [ISO/IEC 17025:2017 General requirements for the competence of testing and calibration laboratories](#). International Organization for Standardization, Geneva.
- JCGM (2008). [Evaluation of measurement data: Guide to the expression of uncertainty in measurement \(JCGM 100:2008\)](#). Joint Committee for Guides in Metrology, Sèvres.
- JCGM (2012). [International vocabulary of metrology: Basic and general concepts and associated terms \(VIM\), 3rd edition \(JCGM 200:2012\)](#). Joint Committee for Guides in Metrology, Sèvres.

- Kanoun, O. and Tränkler, H.-R. (2004). [Sensor technology advances and future trends](#). *IEEE Transactions on Instrumentation and Measurement*, 53(6): 1497-1501.
- NAMUR (2017). [NE 107: Self-monitoring and diagnosis of field devices](#). NAMUR, User Association of Automation Technology in Process Industries, Leverkusen.
- NCSL International (2010). [Recommended Practice RP-1: Establishment and adjustment of calibration intervals](#). NCSL International, Boulder, CO.
- Venkatasubramanian, V., Rengaswamy, R., Yin, K. and Kavuri, S.N. (2003). [A review of process fault detection and diagnosis, Part I: Quantitative model-based methods](#). *Computers & Chemical Engineering*, 27(3): 293-311. [https://doi.org/10.1016/S0098-1354\(02\)00160-6](https://doi.org/10.1016/S0098-1354(02)00160-6)