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ON-LINE MONITORING OF I&C TRANSMITTERS AND SENSORS FOR CALIBRATION VERIFICATION AND RESPONSE TIME TESTING WAS SUCCESSFULLY IMPLEMENTED AT ATR

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ON-LINE MONITORING OF I&C TRANSMITTERS AND SENSORS FOR CALIBRATION VERIFICATION AND RESPONSE TIME TESTING WAS SUCCESSFULLY IMPLEMENTED AT ATR

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ABSTRACT

The Advanced Test Reactor (ATR) has always had a comprehensive procedure to verify the performance of its critical transmitters and sensors, including RTDs, and pressure, level, and flow transmitters. These transmitters and sensors have been periodically tested for response time and calibration verification to ensure accuracy. With implementation of on-line monitoring techniques at ATR, the calibration verification and response time testing of these transmitters and sensors are verified remotely, automatically, hands off, include more portions of the system, and can be performed at almost any time during process operations. The work was done under a DOE funded SBIR project carried out by AMS. As a result, ATR is now able to save the manpower that has been spent over the years on manual calibration verification and response time testing of its temperature and pressure sensors and refocus those resources towards more equipment reliability needs. More importantly, implementation of OLM will help enhance the overall availability, safety, and efficiency.

Together with equipment reliability programs of ATR, the integration of OLM will also help with I&C aging management goals of the Department of Energy and long-time operation of ATR.

Key Words: on-line monitoring, OLM, instrumentation and control, I&C, condition based maintenance, transmitters, sensors, in-situ

1 INTRODUCTION

In today's world, there are numerous opportunities to collect and analyze significant amounts of plant or system data. Most plants collect mind numbing amounts of data in many forms; operator recorded rounds, computer data acquisition systems, monitoring technologies, craft maintenance feedback, etc. There is too much data to analyze without a purpose and not enough readily analyzed for needed decisions. If you attempted to analyze all this information, it would take a very large team of properly trained engineers and technicians to analyze the data generated by even a small plant.

This should cause you to ask the question, "Is collection and analysis of all this data important?" The short answer is no! So, the key questions really become, “What data should be analyzed?” and “What data should be collected to support the analysis?” The cost of collecting and storing data is fairly inexpensive. The cost of performing an analysis of that data to show that a system or component is performing its intended function must offset the risk of not having a reasonable level of assurance that the system or component will perform its intended function.

Historically, the Advanced Test Reactor (ATR) has always had a comprehensive program to verify the performance of its essential transmitters and sensors. This paper focuses on pressure, level, and flow transmitters along with RTDs and their associated temperature transmitters. As a useless side note, level and flow transmitters are just pressure transmitters with a different configuration.

The transmitters and sensors are a body of equipment where there are requirements for us to evaluate their performance. These transmitters and sensors have been periodically tested for response time and calibration verification to ensure accuracy of the process values. There is the need to have a reasonable level of assurance that there is:

- reliability in a safety system to perform its intended safety function, and
- confidence in plant equipment to perform its intended mission support function.

The key to meeting these purposes is not just the collection of data but, the analysis of the data collected and the actions that come from the analysis!

The established manual methods for response time testing and calibration verification have required numerous craft hours and some have a direct impact on outage durations to perform the verifications and make any required adjustments. The default frequency of annual is pervasive within this group of transmitters. Manually checking transmitter calibrations and response times can also have hazardous elements in performing the task. The tasks of taking out of service, performing the verification, and returning to service is subject to numerous opportunities for human error. Optimally, such data collection would be automatic and in-situ, without impacting operations.

As much as I hate to say it, how do we improve on these old established tried and true methods? If we take a moment to look at the advancements in the manufacture of pressure and temperature transmitters we find that for the most part they are far more stable than transmitters of yester years. Other advances have made it much easier to collect signal data, especially while the equipment is on-line. Advances in signal analysis, application strategies, and even system modeling have provided opportunities to verify the calibration of multiple transmitters instead of using a signal injection method for a single transmitter.

For this paper, the term "*On-line Monitoring*" (OLM) is referring to the ability to collect the data needed for analysis while the plant or system is performing its intended function (in-situ). The one area of on-line monitoring that causes even the most ardent equipment reliability advocate to cringe is that of Instrumentation and Control. ATR has implemented on-line monitoring data collection techniques to accomplish calibration verification and response time testing of pressure and temperature transmitters-sensors, which are verified remotely, automatically, hands off, and in an in-situ manner.

The knowledge that a single transmitter is out of calibration has more benefit than knowing that 100 transmitters are in calibration. What does it take to transition from a manual method to On-line Monitoring and gain the benefit in a cost-effective manner?

The first step was to establish a technical basis and the data collection methods. This was done under a Department of Energy funded SBIR project carried out by AMS. The technical basis took a good deal of effort but it was a proof of concept and a meets or exceeds analysis that showed this method provided the same or better results. The technical basis was also assessed against somewhat related basis established by others.

The technical basis that was developed recognizes that there are multiple situations where techniques that use multiple sensing instruments for the same process parameter, typically found in plant protective systems, allow for simple data analysis techniques such as averaging. Averaging results support calibration verification or identify transmitters that require complete manual calibration. It also recognizes that nonredundant transmitter calibrations can often be validated using more advanced empirical and physical modeling techniques. The basis also applies a graded approach to technique selection.

Once a technical basis was established, implementing procedures were required along with a strategy to perform the analysis and communicate the results for action. Procedures took an excessive amount of time as the new technical basis had to be communicated and trained to for the various reviewers from the different organizations. It’s always hard to move away from tried and true. Because of this effort, ATR is now able to capitalize on the efficiencies and re-direct the manpower that has been spent over the years on manual calibration verification and response time testing of its temperature and pressure sensors towards other important equipment reliability needs.

So what techniques were accepted by the technical basis? ATR has a plant computer with sufficient sampling capabilities to retrieve the necessary data for verifying sensor calibration. Typical minimum sampling window requirements are 60 seconds of data steady state and 10 seconds of data from start-up and shutdown. Start-up and shutdown data is important as this allows the ATR to verify the calibration of the pressure transmitters over their entire operating range rather than at single operating point. The basic process for using OLM to verify the calibration of pressure, level, and flow transmitters at the ATR is provided in Figure 1.

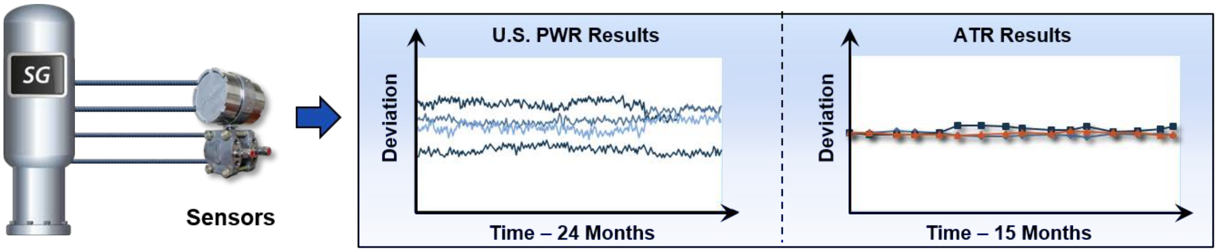


Figure 1. Process of On-Line Calibration Monitoring of the ATR Pressure, Level, and Flow Transmitters

At many plants, pressure transmitters, among other sensors, are arbitrarily calibrated every year. Usually, a transmitter does not need to be adjusted for several years. Over a 2-year period for example, industry experience shows that only 5% of the transmitters require calibration. On-line monitoring can track and trend the calibration of the transmitter allowing the analyst to see when the sensor starts to drift toward the fringe of an allowable tolerance.

Calibration of equipment costs time and money, possible down-time, and the cost of the actual calibration. In addition to the potential cost from human error when technicians are removing the sensors from service, performing the work, and returning them to service. With on-line monitoring, calibration (if or when needed) can be coordinated with planned outages or other maintenance at longer intervals, again saving calibration expenses.

The one area of manual calibration constantly taxes plants because of; transmitter bypass valves not being fully seated, or air being trapped in flow transmitters after calibration and the need to vent them before being operable. At the ATR, there are nearly 140 pressure, level, and flow transmitters and two to three human performance issues a year regarding transmitters occur.

Pressure, level, and flow transmitters are important components of most Plant Protective Systems and periodic response time verifications are performed on a routine basis. This normally requires a technician to connect an apparatus to the transmitter so they can induce a signal on and take a reading from the transmitter. This can only be performed when the transmitter has been shut down and placed in a safe condition. One might have to invalidate the safety function for this instrument with this technique.

As a substitute to this method, on-line monitoring can be used to verify response time automatically. This typically requires the connection of an additional high speed data acquisition system to the existing system, while on line. Data from pressure or flow transmitters is acquired and noise analysis is then performed on the data signals to test response time of the transmitters. Every data signal has a certain amount of fluctuation in the signal, or noise. Data analysis equipment can isolate the noise by removing the DC component of the data and amplifying the AC component and perform analysis in the time and frequency domains to determine response time. As with hydraulic step response testing currently performed by technicians in the field at ATR, the noise analysis data can be recorded and the trends tracked for early indications of out of tolerance conditions. The main requirement of the noise analysis technique is that the data needs to be recorded at speeds greater than 1000 samples per second which typically exceeds the ability of existing plant computers.

An additional advantage with the response time testing method of the pressure transmitter is the inclusion of the sensing line portion of the system which can provide indication of problems that may be developing in those lines as illustrated in Figure 2.

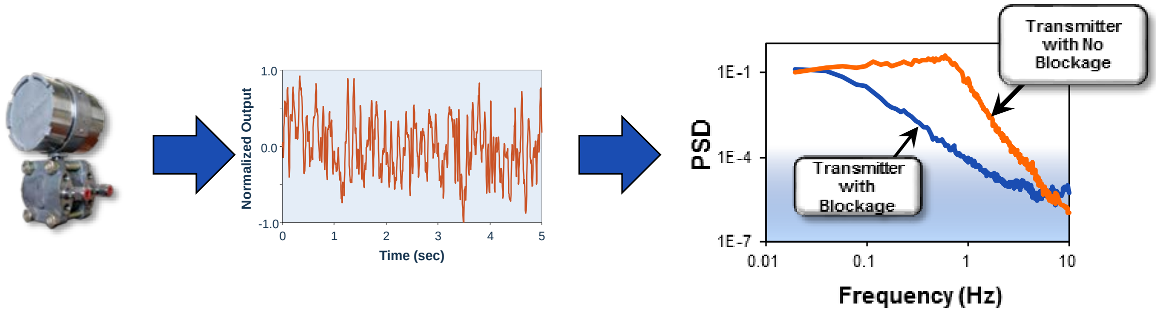


Figure 2. Illustration of the Noise Analysis Method for Measuring In-Service Response Time of Pressure, Level, and Flow Transmitters

As with pressure, level, and flow transmitters, the ATR also has requirements for verifying the calibration and response time of the primary system Resistance Temperature Detectors (RTDs). To calibrate RTDs, they have historically been removed from their thermowells, calibrated in an oil bath, and re-inserted into the thermowell.

ATR is in the process of implementing a plant computer cross-calibration technique whereby the calibration of all the RTDs can be verified on-line without removing them from the reactor as illustrated in Figure 3. This is accomplished by analyzing data from the plant computer in isothermal conditions prior to reactor startup. The analysis employs an averaging technique to identify sensors which are outside of pre-defined acceptance criteria.

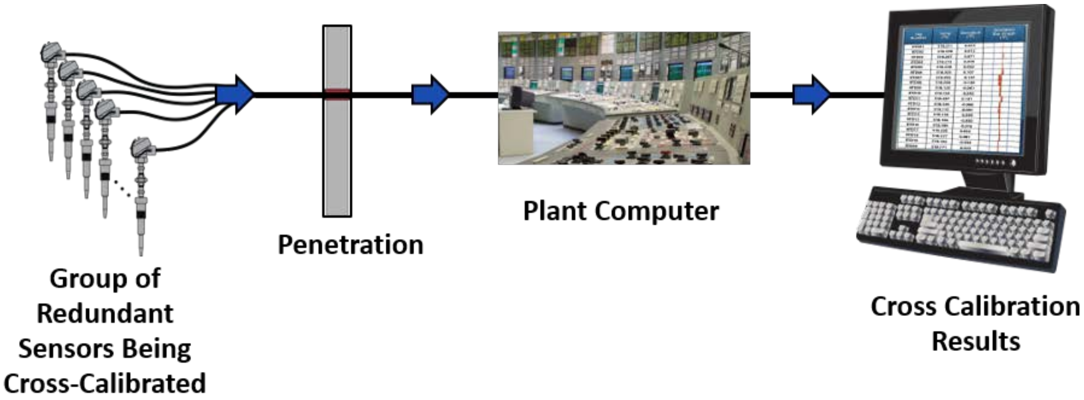


Figure 3. Process of RTD Cross Calibration using the ATR Plant Computer

For response time testing of RTDs, the Loop Current Step Response (LCSR) method has recently been validated at the reactor. ATR is currently using a reactor SCRAM to measure RTD response time. The LCSR test will help eliminate the need to perform a reactor SCRAM for temperature sensor response time testing and provide greater operational flexibility in the event that RTDs fail or are replaced. The LCSR test applies a step change in current to the RTD, which causes Joule heating in the sensor. The resultant temperature transient is measured and the data is analyzed to determine the RTD time response. The LCSR test is usually repeated several times on the same RTD and the results averaged so as to obtain a smooth transient for analysis. The basic process for performing the LCSR test is provided in Figure 4.

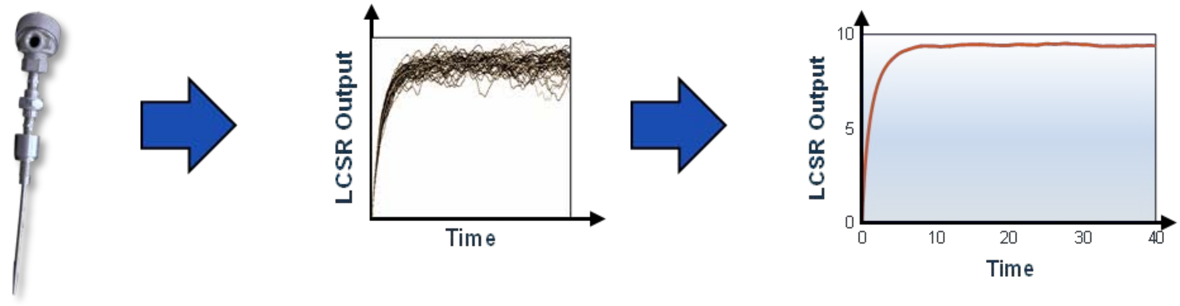


Figure 4. Illustration of the LCSR method for Measuring In-Service Response Time of RTDs

2 EXAMPLE LESSONS LEARNED THROUGH OLM IMPLEMENTATION

2.1 RTD Response Time

Historically, a SCRAM technique has been used by ATR to measure the response time of installed RTDs requiring a rapid shutdown of the reactor to approximate a step change in primary coolant temperature. The SCRAM test is conducted once a year per ATR procedures. The RTD response to the SCRAM temperature transient is recorded with a dedicated data acquisition system. The method includes the response time of the RTD as well as the temperature transmitters and other components in the instrument string. The LCSR method, as described in this paper, is now being used as an approved substitute to this method providing ATR with numerous benefits, including the ability to perform the testing in essentially any plant mode, if necessary, as well as improved insight into the health of all components in the primary coolant temperature instrumentation channels.

Figure 5 below provides response time results for 12 primary coolant RTDs at the ATR as measured by the LCSR test. Note that the ATR has a 14.5 second requirement and all the RTDs passed the acceptance criteria. The RTDs provide input to temperature transmitters which convert the RTD resistance to a voltage that is subsequently processed by downstream components in the instrument channel. The lessons learned from these results were as follows:

1. As ATR has a total temperature channel response time requirement, the temperature transmitters which take input from the RTDs were also response time tested. This was done by providing a step change to the transmitters through use of a decade box resistor network. It was discovered through the temperature transmitter testing that a slow transmitter, which employed the use of electronic dampening, was paired with the slowest RTD in the group (i.e. RTD #5 in Figure 5). This discovery was a previously unrecognized condition at the ATR and was discovered only through use of the LCSR technique. The slow temperature transmitter was changed to a different channel which was paired with a faster RTD thereby providing ATR additional safety margin for the associated channel.

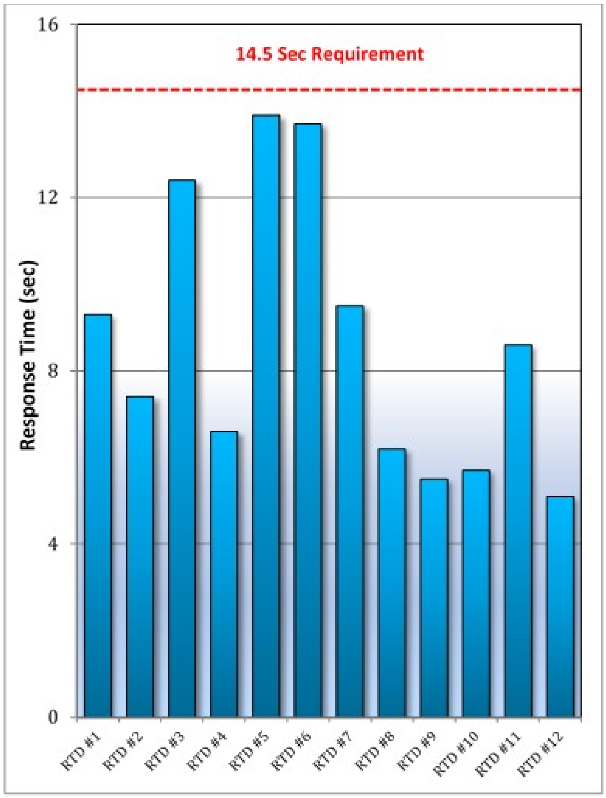


Figure 5. RTD Response Time Results at ATR as measured by the LCSR Method

2. RTD response time varied significantly ranging from 6 – 14 seconds. This variation was also previously unrecognized and is believed to be a result of deviation in the fit of each RTD in their respective thermowells. Through use of the LCSR method, this variability will continue to be tracked as part of the ATR predictive maintenance philosophy to ensure no adverse trends begin.

2.2 RTD Cross Calibration

Traditionally, ATR has removed primary coolant RTDs from the plant and calibrated them in a test bed. Although this procedure produces reliable results, it is time consuming and can cause damage to the RTD and especially affect the dynamic performance of the sensors. As importantly, review of historical RTD calibration data from the nuclear industry has shown that high quality RTDs such as those at ATR do not normally all lose their calibrations over a period of one or two years. Therefore, a method that can identify the few RTDs that lose their calibration is important and annual calibrations of all RTDs as performed at ATR are unnecessary. The RTD cross calibration method, which verifies the accuracy of the RTDs in their normal configuration using data from the ATR plant computer, is now used to verify the accuracy of the sensors without removing them from the reactor.

Figure 6 below provides RTD cross calibration data for an analysis performed at the ATR using 15 minutes of plant computer data. The results of the analysis are provided in Figure 7. Note that TE-2 is noticeably deviating from the other RTDs in the group. The acceptance criteria for ATR cross calibration analysis is ± 0.2 °F which required this RTD to be re-calibrated. Fortunately, with this particular OLM method, a new calibration curve was generated using the data itself and thereby precluded the removal and recalibration of the RTD. The calibration constants were entered into the ATR plant computer and no hands-on and error prone work was necessary.

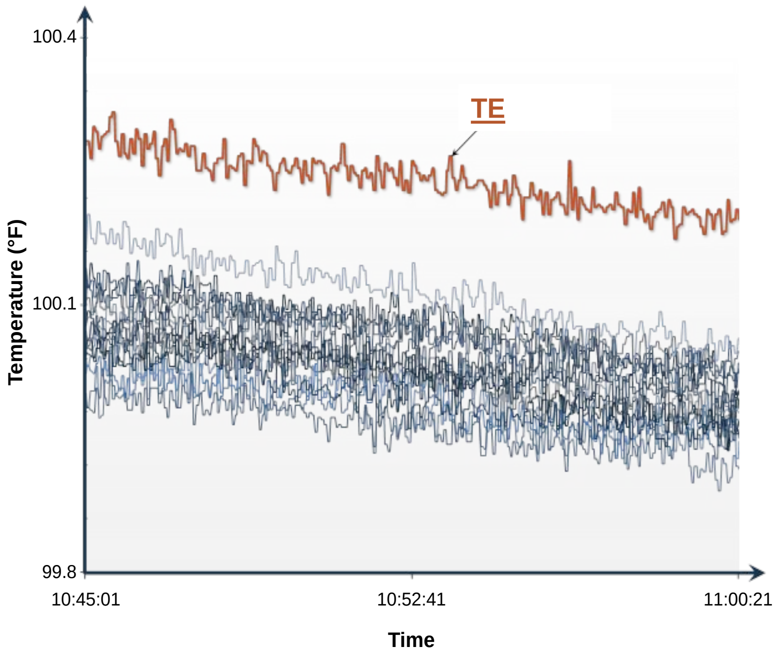
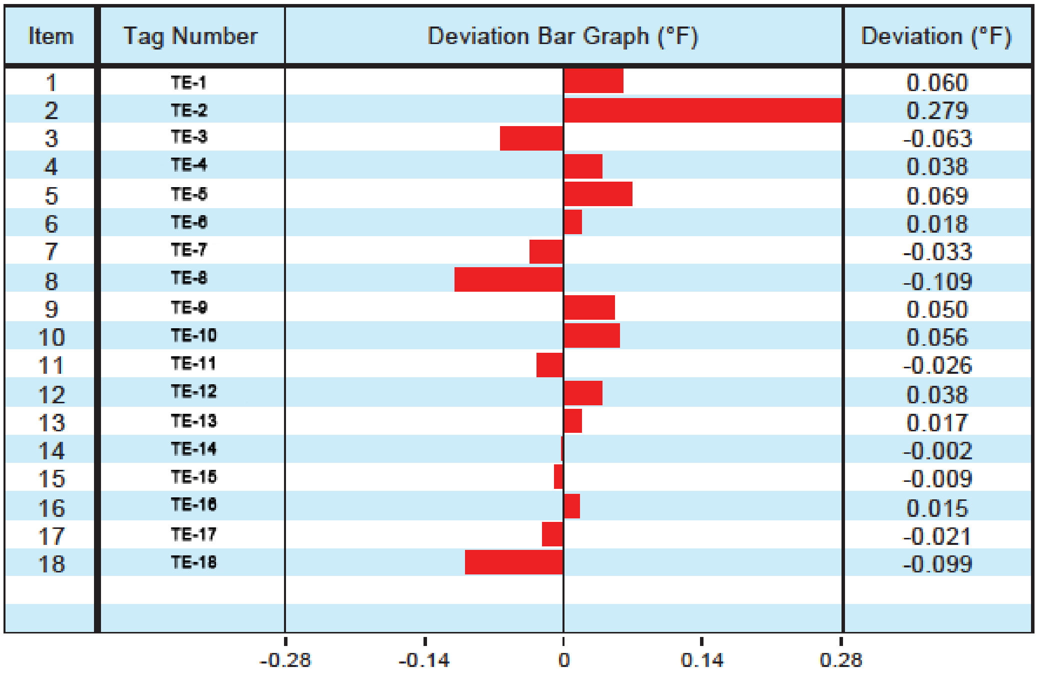


Figure 6. RTD Cross Calibration Data at ATR



Item	Tag Number	Deviation Bar Graph (°F)	Deviation (°F)
1	TE-1		0.060
2	TE-2		0.279
3	TE-3		-0.063
4	TE-4		0.038
5	TE-5		0.069
6	TE-6		0.018
7	TE-7		-0.033
8	TE-8		-0.109
9	TE-9		0.050
10	TE-10		0.056
11	TE-11		-0.026
12	TE-12		0.038
13	TE-13		0.017
14	TE-14		-0.002
15	TE-15		-0.009
16	TE-16		0.015
17	TE-17		-0.021
18	TE-18		-0.099

Figure 7. Analysis Results for ATR as measured by the Cross Calibration Method

3 CONCLUSION

The Advanced Test Reactor has implemented on-line monitoring and taken the opportunity to use existing data collection resources to; 1) conduct in-situ calibration verifications and response time testing of pressure and temperature transmitters, 2) reduce human performance issues, and 3) capitalize on manpower efficiencies.

4 ACKNOWLEDGMENTS

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