INNOVATING NUCLEAR TECHNOLOGY
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May 19, 2021

U.S. Nuclear Regulatory Commission
11555 Rockville Pike
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Document Control Desk
Attention: Mr. Joseph Holonich, Project Manager
Washington, DC 20555-0001

Subject: Response to Request for Additional Information for Analysis and Measurement Services Corporation Topical Report AMS-TR-0720R1, "Online Monitoring Technology to Extend Calibration Intervals of Nuclear Plant Pressure Transmitters" (Docket No. 99902075)

References:

(1) AMS letter dated October 9, 2020, *Submittal of Analysis and Measurement Services Corporation Topical Report AMS-TR-0720R1, "Online Monitoring Technology to Extend Calibration Intervals of Nuclear Plant Pressure Transmitters"* (ADAMS Accession No. ML20317A111)

(2) NRC Email to AMS dated March 5, 2021, *Final RAIs for AMS re Topical Report AMS-TR-0720R1.pdf* (ADAMS Accession No. ML21067A674)

(3) AMS letter dated May 7, 2021, *RAI Response #2 AMS-0521-RAI2* (ADAMS Accession No. ML21130A109)

Dear Mr. Joseph Holonich:

Analysis and Measurement Services Corporation (AMS) submitted Topical Report AMS-TR-0720R1 by Reference 1. NRC issued seven Request for Additional Information (RAI) by Reference 2. AMS provided a response to RAI-2 by Reference 3. By this letter, AMS is providing a response to all seven RAIs including RAI-2 (with a few editorial changes).

AMS requests that the proprietary presentation documents be withheld from public disclosure. In accordance with 10 CFR 2.390, "Public inspections, exemptions, requests for withholding," an affidavit is enclosed identifying the specific portions of the above documents that are proprietary and the basis for making that determination. Non-proprietary versions of the documents are also provided with the proprietary information redacted.

Enclosure 1 provides the proprietary version of the responses to the NRC request for additional information. Attachment 1 to Enclosure 1 contains the proprietary version of the AMS Topical Report pages affected by the responses to the NRC request for additional information. The pages show the planned changes in a line-in/line-out format.

Enclosure 2 provides the non-proprietary version of the responses to the NRC request for additional information. Attachment 1 to Enclosure 2 contains the non-proprietary version of the AMS Topical Report pages affected by the responses to the NRC request for additional information. The pages show the planned changes in a line-in/line-out format.

Enclosure 3 provides an affidavit related to the proprietary material.

Please contact me at (865) 691-1756 ext. 128 or by email at hash@ams-corp.com with any questions.

Best regards,

H.M. Hashemian, Ph.D.
President and CEO
AMS Corporation

AMS Document #: AMS-0521-RAIs1-7-R1-NON-PROPRIETARY

AMS-TR-0720R1

Response to RAIs 1-7

May 19, 2021

This document was prepared in response to seven RAIs issued by the NRC from the review of the AMS Topical Report referred to as AMS-TR-0720R1.

Each RAI is identified and the AMS response to the RAI is provided together with a description of changes made to the Topical Report to accommodate the RAI. Chapter 11 was substantially revised/rewritten and three new chapters (12, 13, and 14) were added to the Topical Report. Chapter 11 addresses RAI-1, Chapters 12-13 address RAI-2, and Chapter 14 addresses RAIs 3 and 5. Chapters 11-14 are attached here for reference.

Appendix A in AMS-TR-0720R1 was removed from the Topical Report and the remaining 3 appendices were renamed A, B, and C. Of these, Appendix B was revised in response to RAI-6 and Appendix C was revised in response to RAI-7. The revised marked-up TR including the revised Appendices B and C will be placed on SharePoint for NRC's viewing.

The AMS response to RAI-2 was submitted separately on May 7, 2021. This document has been assigned document number ML21130A109 by the NRC, and has been included here again (with minor editorial changes) to produce a complete response to all seven RAIs.

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RAI-1

AMS provided the OLM implementation methodology in Section 11, "OLM Implementation Methodology," of the TR; however, it is not clear, from the contents of Section 11, what specific content a license amendment request referencing this TR should include or how to determine the acceptability of the provided information. For example, Section 11.1, "Data Acquisition and Analysis to Monitor for Drift," Step No. 1, "Select Transmitters to be Monitored," contains one requirement: "As a first step towards OLM implementation, a list of transmitters to be included in the OLM program must be developed." There is no method or criteria to determine which make and model, service function, or other classification criteria should be used for identifying transmitters having adequate historical data, or how one would determine whether a new or different make and model of transmitter is similar enough to the covered transmitters to allow it to be included in the OLM program. In addition, there is no method or criteria to determine which specific application (service function) is appropriate for OLM. **Where appropriate, please provide the step-by-step instructions and methods for implementing an OLM program, using descriptive criteria for each of the steps in Section 11. This would enable licensees and applicants to accomplish the implementation appropriate for their own facilities, as well as enable the NRC staff to evaluate, in a consistent manner, whether licensees are accurately proposing an implementation of the OLM processes described in the TR.**

RAI-1 AMS Response:

Chapter 11 was substantially revised in response to this RAI. Step-by-step instructions were added to Chapter 11 to describe exactly how a licensee may implement OLM for calibration drift monitoring and detection of dynamic failure modes. These steps were designed not only to help licensees to properly implement OLM but also facilitate the NRC's inspection of OLM implementation process and compliance with this TR.

Topical Report Changes:

The revised Chapter 11 prepared in response to this RAI is attached.

RAI-2

The TR provides anecdotal evidence for the Sizewell B and McGuire plants in which the results of manual calibrations are compared against conclusions drawn during OLM sampling as to whether a manual calibration is warranted. Referenced documents in the TR provide a catalogue of data comparing OLM results against subsequent manual calibration results. The data shows that in a small number of instances, non-conservative drift of a transmitter was discovered during a subsequent manual calibration that had not been detected with the OLM processes implemented. There is minimal analysis of the anecdotal evidence, however, within the TR or within the referenced documents which support a technical basis for concluding that undetected common mode drift is not of concern when implementing OLM processes. A recent (February 21, 2021) addition to the Audit Documents library provides a clearer justification supporting a conclusion that common mode drift and occasional drift that was not detected by OLM techniques is not a concern. However, this more thorough explanation and citing of specific data analyses from other studies does not appear in the TR. The TR simply makes conclusions based on these previous studies. **Please provide a summary of your analysis of the data referenced in those studies which justifies continued long-term operation of OLM transmitters without a periodic calibration against a known standard of at least one transmitter within a functional service grouping, at a maximum period of time that can reasonably be justified.**

<u>RAI-2 AMS Response</u>:

In response to this RAI, AMS will add two new chapters to the topical report (TR): Chapter 12 and Chapter 13. These chapters are attached to this RAI. The existing Chapter 12 (Conclusion) will be moved to the end of the TR.

<u>Topical Report Changes:</u>

Chapter 12. This chapter provides references to substantiate AMS' claim that common mode drift is not a problem with OLM implementation for the existing generation of nuclear grade transmitters. It also provides a reference to substantiate AMS' claim that OLM is successful in about 99 percent of cases in identifying drifting transmitters. That is, OLM fails in only about 1 percent of cases compared to traditional calibrations that fail in about 5 percent of cases.

Chapter 13. This chapter describes a process to establish backstops as defense against any possibility of common mode drift.

RAI-3

AMS stated that setpoints were determined to be within 10 percent of the operating levels for all transmitters in historical OLM programs as a means of substantiating the idea that OLM data collected over only a portion of the transmitter span experienced under startup, normal operations, and shutdown can support calibration accuracy assumptions at the safety actuation setpoint levels even if these levels are not achieved during normal plant operation. **The NRC staff requests AMS to provide a description of how an OLM program would establish a method for analyzing the OLM data in relation to the instrument safety setpoints. This analysis should include either criteria for determining if OLM data can be used to provide assurance of accuracy at the instrument setpoint level even though only a portion of the range is monitored, or it should include a method of establishing such criteria to be used by licensee's when implementing an OLM program.**

<u>RAI-3 AMS Response</u>:

A new chapter (Chapter 14) was written in response to this RAI, and a new step was added to OLM implementation methodology in Section 11.1 to provide a method of analyzing the OLM data in relation to transmitter safety setpoints. This method established criteria for determining if OLM data can be used to provide assurance of accuracy at transmitter setpoints when only a portion of transmitter range is monitored by OLM.

<u>Topical Report Changes:</u>

A new Chapter 14 will be added to TR and the rest of the document will be rearranged to make room for the new chapter. Section 14.1 (attached) provides the answer to this RAI. In addition, Step 3 was added to OLM implementation methodology in Section 11.1 to accommodate this RAI.

RAI-4

The NRC staff's expectation is that the plant OLM program would include a method of evaluating the characteristics (e.g., dynamics) of the process being measured by a group of transmitters within each service function to determine the required minimum sample rate and minimum duration of data collection needed for OLM. **The NRC staff requests AMS to provide a description of how a licensee or applicant implementing an OLM program for its facility would determine the minimum sample rate and data collection duration appropriate for a group of pressure transmitters serving specific processes to be included in the OLM program.**

RAI-4 AMS Response:

A step in the OLM implementation methodology in Chapter 11 was revised and a section was added to TR (Section 11.3.1) to answer this RAI. The revised step relates to OLM data for drift monitoring and the added section relates to OLM noise analysis technology to assess dynamic failure modes.

Topical Report Changes:

Section 11.1 Step 6 was revised and section 11.3.1 was added to accommodate this RAI.

RAI-5

The NRC staff notes that smaller exercised ranges during normal plant operation would result in greater uncertainties in the unexercised portions of a transmitter span. An analysis of the uncertainties associated with unexercised portions of transmitter span could be used to support assumptions of calibration accuracy in these regions of transmitter operation. **The NRC staff requests AMS to provide a description of how an OLM program will address uncertainties associated with the portions of transmitter range that are not exercised during normal plant operation. This discussion should explain how uncertainties are to be quantified and how assumptions of calibration accuracy in these regions of transmitter operation will be supported as part of an OLM program. If appropriate, include a discussion regarding the expected systematic effects of transmitter zero or span shifts in predicting the impact on transmitter performance when operating at the portion of the range where the instrument channel setpoint is expected to activate.**

RAI-5 AMS Response:

A new chapter (Chapter 14) will be added to TR and a new step incorporated in the OLM methodology in Chapter 11 to answer this RAI. These additions provide a method as to how the OLM program will address uncertainties associated with the portions of transmitter range that are not exercised by OLM during normal plant operation.

Topical Report Changes:

A new Chapter 14 will be added to TR and the rest of this document rearranged to make room for the new chapter. Section 14.2 (attached) has been written to answer this RAI and Step 17 was added to the OLM methodology in Section 11.1.

RAI-6

Example TS changes were provided for illustration (in TR Appendix C) in response to an NRC request, as an example of changes that may be needed, but they were not provided as TS changes to be approved by the NRC. These TS mark-ups were useful for stimulating discussion; however, there is still ambiguity on how these proposed changes are to be described and implemented. Additional explanation is needed for licensees to identify the type of information that may need to be changed within a TS table of instrument channel surveillance requirements. For example, the "OR" proposed in Appendix C means the licensee can switch back and forth between the two "FREQUENCIES" in the final TS; however, there is no explanation (in the TR) of how this is expected to b implemented. Also, if the other "FREQUENCY" is a fixed calibration interval, and if there was inadequate data collected during the monitoring period, then the transmitter should be calibrated at the next calibration interval. However, if the other "FREQUENCY" is "In accordance with the Surveillance Frequency Control Program," how is the timing of the next calibration determined. Finally, the TS Bases section should be modified to explain how the incorporation of OLM affects the TS surveillance, since applies to only the transmitter within the channel, and not the other devices in the loop. **Please provide additional information using either examples or simple narratives to provide guidance for licensees as to the *type of information* that is needed to mark up their TS surveillance tables as well as the TS Bases. This guidance should clearly differentiate what portion of the TS SR is applicable to the transmitter versus what portion is applicable to the balance of the instrument channel.**

RAI-6 AMS Response:

Example TS changes will be modified to clarify the scope of the ONLINE MONITORING Program and the implementation of the new condition-based transmitter calibration frequency using ONLINE MONITORING results. The ONLINE MONITORING Program provides a method to defer calibration of the transmitters included in the ONLINE MONITORING Program based on ONLINE MONITORING results. The ONLINE MONITORING Program is not used to extend the calibration of any other elements in the safety signal path (e.g., signal converters or adjustable parameters in I&C rack equipment).

The Surveillance Requirement frequency for these other components in the signal path remains in effect. The Surveillance Requirement frequency for these other components can be calendar-based by specifying a calendar interval, risk-based using a Surveillance Frequency Control Program, or modified based on self-testing features of a digital I&C platform-based system. The use of the logical connector "OR" provides flexibility for the licensee to address cases where ONLINE MONITORING cannot be performed during the monitoring period. In the case of a calendar-based Surveillance Requirement frequency, the transmitter would need to be calibrated within the specified calendar interval measured since the last valid ONLINE MONITORING assessment. In the case of a risk-based Surveillance Requirement frequency, the transmitter would need to be calibrated within the specified risk-based interval measured since the last valid ONLINE MONITORING assessment.

Using the noise analysis technique, ONLINE MONITORING also provides a means for in-situ dynamic response assessment and detects failure modes that are not detectable by drift monitoring.

Topical Report Changes:

Topical Report Section 11.5 and the Example TS changes in Appendix B (formerly Appendix C) were revised to modify the definition of ONLINE MONITORING and the Bases associated with the Surveillance Requirements changes. The ONLINE MONITORING Program description was revised to remove the optional items related to RESPONSE TIME testing and the following statement was added: Perform ONLINE MONITORING using noise analysis to assess in-situ dynamic response of transmitters.

RAI-7

The NRC staff have determined that the following documents are necessary for staff use in evaluating AMS-TR-0720R1. These documents contain explanations which serve to enhance the staff's understanding of OLM processes described in the TR, as well as provide evidence that OLM techniques are successful at predicting when transmitters are drifting beyond their designated monitoring acceptance limits and should be scheduled for manual calibration during the upcoming outage. **Please submit the following documents for staff use in evaluating AMS-TR-0720R1**.

Note: Documents are listed using the file names they were referred to during the recent audit.

Audit Documents

Agenda – NRC Audit of Understanding (1.26.21-1.27.21)

AMS Presentation for NRC Audit 1-26-2021

AMS Supporting References 02-21-2021

AMS Talking Points for NRC Discussion 02-17-2021

NRC Audit Questions and AMS Responses 1-25-2021

Reference Documents

(17) PWROG WDS1601R2 (May 2017)

(24) PWROG-15057-P

(38) OLM at ATR

(40) Sizewell B OLM Acceptance Criteria

(42) DOE/ER84626 Volume1 and DOE/ER84626 Volume2

(43) OLM at Vogtle 1 VOG1905R0

(44) OLM at Vogtle 2 VOG1906R0

(45) OLM at Vogtle 1 VOG2005R0

(49) Sizewell Sensor Calibration Extension ESR-503

RAI-7 AMS Response:

AMS is providing the following Audit Documents in response to this RAI. Table 1 summarizes NRC's request for documents and AMS' response to this request.

Attachment 1 - Agenda – NRC Audit of Understanding (1.26.21-1.27.21)

Attachment 2 - AMS Presentation for NRC Audit 1-26-2021

Attachment 3 - AMS Talking Points for NRC Discussion 02-17-2021

Attachment 4 - NRC Audit Questions and AMS Responses 1-25-2021

Table 1. Summary of AMS Response to NRC Request for Documents

Ref	Document Title	Provided (Y/N)	Alternative Provided
N/A	Agenda – NRC Audit of Understanding (1.26.21-1.27.21)	Y	N/A
N/A	AMS Presentation for NRC Audit 1-26-2021	Y	N/A
N/A	AMS Supporting References 02-21-2021	N	Summarized in a new Chapter 12 added to the TR
N/A	AMS Talking Points for NRC Discussion 02-17-2021	Y	N/A
N/A	NRC Audit Questions and AMS Responses 1-25-2021	Y	N/A
17	PWROG WDS1601R2 (May 2017)	N	See new Chapter 12 added to the TR
24	PWROG-15057-P	N	See Section C.15 in Appendix C of the TR
38	OLM at ATR	Y	Replaced with reference INL/CON-17-41453
40	Sizewell B OLM Acceptance Criteria	N	See Section C.27 in Appendix C of the TR
42	DOE/ER84626 Volume1 and DOE/ER84626 Volume2	Y	N/A
43	OLM at Vogtle 1 VOG1905R0	N	See Section C.28 in Appendix C of the TR
44	OLM at Vogtle 2 VOG1906R0	N	See Section C.28 in Appendix C of the TR
45	OLM at Vogtle 1 VOG2005R0	N	See Section C.28 in Appendix C of the TR
49	Sizewell Sensor Calibration Extension ESR-503	N	See new Chapter 12 added to the TR

Additionally, AMS is providing a public Reference Document [38] (Attachment 5) which NRC requested.

AMS is not able to provide the Audit Document identified as AMS Supporting References 02-21-2021. This document was provided to NRC on SharePoint by AMS to facilitate the audit. The document contains proprietary information from AMS-TR-0720R1 references [17], [18], [19], and [49], for which AMS is not the owner and has no ongoing project activities that can be used to obtain proprietary releases from the owners. As an alternative, AMS has added a new Chapter 12 in the TR to summarize the content of the proprietary references that cannot be shared with NRC. Additionally, AMS is providing the following two documents (Reference [47] of AMS-TR-0720R1, Volume 1 and Volume 2) that are publicly available from the Electric Power Research Institute website:

Attachment 6 - EPRI-TR-1013486, “Plant Application of On-Line Monitoring for Calibration Interval Extension of Safety-Related Instruments: Volume 1”, 2006.

Attachment 7 - EPRI-TR-1013486, “Plant Application of On-Line Monitoring for Calibration Interval Extension of Safety-Related Instruments: Volume 2”, 2006.

AMS is not providing Reference Documents [17], [24], [40], [43], [44], [45], and [49]. AMS is not the owner of these documents and has no ongoing project activities that can be used to obtain proprietary releases from the owners. As an alternative, AMS is providing the following two documents (Reference [42] of AMS-TR-0720R1, Volume 1 and Volume 2) that are now publicly available:

Attachment 8 - DOE Report No. DOE/ER84626, DOE Grant No. DEFG02-06ER84626, “On-line Monitoring of Accuracy and Reliability of Instrumentation and Health of Nuclear Power Plants”, Phase II+ Final Report, Volume 1, 2011.

Attachment 9 - DOE Report No. DOE/ER84626, DOE Grant No. DEFG02-06ER84626, “On-line Monitoring of Accuracy and Reliability of Instrumentation and Health of Nuclear Power Plants”, Phase II+ Final Report, Volume 2, 2011.

AMS has added summary information for references [24], [40], [43], [44], and [45] in Appendix C (formerly Appendix D) of the TR.

<u>Topical Report Changes:</u>

Topical Report Sections 3.3.1, 3.3.2, 3.3.3, 3.4.3, 10.1.3, Table 3.1, and Appendix C (formerly Appendix D) are revised to reflect the information provided in the Audit Document identified as AMS Supporting References 02-21-2021.

NON-PROPRIETARY

AMS-TR-0720R1-A-DRAFT

CHAPTERS 11-14

11 OLM IMPLEMENTATION METHODOLOGY

This chapter provides general guidelines as to how nuclear facilities must implement OLM in a way to ensure that data is properly acquired, qualified, analyzed, interpreted, reported, and documented. These tasks must be carried out by formally trained personnel under an approved Quality Assurance (QA) program in compliance with 10 CFR Part 50 Appendix B. All software products used for OLM data acquisition, qualification, and analysis must be developed and tested using a documented software verification and validation (V&V) program (e.g. NQA-1 software controls).

The guidelines provided in this chapter are based on OLM implementation experience in ten nuclear facilities conducted by AMS under experimental R&D projects or commercial contracts over the period of 1990 to 2020. These activities started with the McGuire nuclear power plant in the U.S. and the Sizewell B nuclear power plant in the U.K.

This chapter begins in Section 1 with steps that must be taken to acquire and analyze OLM data for transmitter drift monitoring. This is followed by Section 13 with an example illustrating the data analysis process, Section 11.3 on data acquisition and analysis for assessment of in-situ sensor dynamic response, Section 11.4 with training requirements for the OLM analyst, and Section 11.5 describing the changes that should be made in plant technical specifications to implement OLM. Together, Sections 11.1 through 11.5 constitute the "OLM Program".

11.1 DATA ACQUISITION AND ANALYSIS TO MONITOR FOR DRIFT

This section provides the steps that must be taken by nuclear facilities implementing OLM to acquire and analyze data to identify drifting transmitters. In formulating these steps, the verb *must* is used to identify actions that are essential to OLM implementation and the verb *should* is used to identify other actions that are helpful but not essential to OLM implementation. These steps are divided into two sets. The first set identified in Section 11.1.1 is performed only once to initiate the OLM implementation process and the second set identified in Section 11.1.2 is repeated at each operating cycle to identify the transmitters that should be scheduled for a calibration check.

11.1.1 Steps to Initiate the OLM Implementation Process

The steps listed below must be followed if the OLM program is being established for the first time in a nuclear facility. These steps are designed to arrive at a list of transmitters that can be included in an OLM program, determine how to obtain OLM data, and establish methods of OLM data analysis.

1. **Determine if Transmitters are Amenable to OLM.**

   Chapter 12 includes a table of nuclear grade transmitter models that are amenable to OLM. Any transmitter model that is not listed in this table should only be added to the OLM program if it can be shown by similarity analysis that its failure modes are the same as the listed transmitter models or otherwise detectable by OLM.

2. **List Transmitters in Each Redundant Group.**

   [[ ]]a,b,f

3. **Determine if OLM Data Covers Applicable Setpoints.**

   [[ ]]a,b,f

4. **Calculate Backstops.**

   A backstop, as described in Chapter 13, must be established for each group of redundant transmitters amenable to OLM as a defense against common mode drift. The backstop identifies the maximum period between calibrations without calibrating at least one transmitter in a redundant group.

5. **Establish Method of Data Acquisition.**

   OLM data is normally available in the plant computer or an associated data historian. If data is not available from the plant computer or historian, a custom data acquisition system including hardware and software must be employed to acquire the data.

6. **Specify Data Collection Duration and Sampling Rate.**

   OLM data must be collected during startup, normal operation, and shutdown periods at the highest sampling rate by which the plant computer takes data. **[[ ]]a,b,f** Chapter 8 describes a process to help determine the optimal sampling rate and minimum duration of OLM data collection.

   [[ ]]a,b,f

7. **Identify Data Analysis Methods.**

   OLM implementations must employ both simple averaging and parity space methods for data analysis as described in Chapter 6. The use of other OLM analysis methods including empirical and physical modeling must be approved separately from this TR.

8. **Establish OLM Limits.**

   OLM limits must be established as described in Chapter 7 for each group of redundant transmitters. Calculation of OLM limits must be based on combining uncertainties of components of each instrument channel from the transmitter in the field to the OLM data storage. As described in Chapter 7, **[[**

   ]][a,b,f]

11.1.2 Steps to be Followed Each Operating Cycle

The steps listed below must be followed each operating cycle to identify the transmitters that should be scheduled for a calibration check at the ensuing outage. These steps must be performed for startup, normal operation, and shutdown periods.

9. **Retrieve OLM Data.**

   OLM data must be retrieved according to the data acquisition method established in Section 11.1.1.

10. **Perform Data Qualification.**

    OLM data sometimes contains anomalies such as spikes, missing data, stuck data, and saturated data. The portion of data containing these anomalies must be excluded, filtered, and/or cleaned prior to analysis. Chapter 6 includes examples of potential anomalies in OLM data that must be excluded, cleaned, and/or filtered to qualify the data for analysis.

11. **Select Appropriate Region of Any Transient Data.**

    [[

    ]][a,b,f]

12. **Perform Data Analysis.**

    This step must be performed for startup, each month of normal operation, and shutdown. Analysis of OLM data must be performed according to the following procedure. A comprehensive example of the OLM data analysis process is presented in Section 11.2 to illustrate this procedure.

    a. **Calculate the process estimate.** The process estimate for each data sample must be calculated from the OLM data for each redundant group of transmitters. Chapter 6 describes how process estimates are calculated.

    b. **Calculate the deviation of each transmitter from the process estimate and plot the outcome.** The process estimate must be subtracted from OLM data to determine each transmitter's deviation for each data sample. The outcome of this calculation must be plotted for the OLM analyst to visualize the deviation versus time for each transmitter and compare it with OLM limits.

c. **Partition the deviation data into region(s) by percent of span.** This step must be performed to create multiple regions for startup and shutdown data and one region for normal operation data.

d. **Calculate and plot the average deviation for each region versus percent of span.** This step must be performed to allow the OLM analyst to visualize the deviation versus span for each transmitter and compare it with OLM limits. The deviation versus span plot provides a means to evaluate each transmitter's calibration at multiple points along its range.

e. **Select appropriate process estimation techniques, filtering parameters, and remove any outliers. [[**

]][a,b,f]

f. **Determine if average deviations exceed OLM limits for any region. [[**

]][a,b,f]

g. **Review, document, and store the details and results of analysis. [[**

]][a,b,f]

13. Plot the Average Deviation for Each Transmitter.

[[

]][a,b,f]

14. Produce a Table for Each Group That Combines All Results.

[[

]][a,b,f]

15. Determine OLM Results for Each Transmitter.

The OLM results must be produced by the OLM analyst upon completion of data analysis for a complete operating cycle. **[[**

]][a,b,f]

16. Address Uncertainties in the Unexercised Portion of Transmitter Range.

[[

]]^{a,b,f}

17. Select Transmitters to Be Checked for Calibration as a Backstop.

[[

]]^{a,b,f}

18. Perform Dynamic Failure Mode Assessment.

[[

]]^{a,b,f} This step must be performed using the noise analysis technique described in Section 11.3 to cover dynamic failure modes that are not detectable by the OLM process for transmitter drift monitoring (see Chapter 3).

19. Produce a Report of Transmitters Scheduled for Calibration Check.

The results of OLM analysis must be compiled in a report and independently reviewed. The transmitters that have been flagged must be scheduled for a calibration check at the next opportunity.

11.2 EXAMPLE OF THE OLM DATA ANALYSIS PROCESS

This section presents an example of the OLM data analysis process to illustrate the steps that were outlined in Section 11.1.2. This example comes from analysis performed for a complete operating cycle of about 18 months using the Sizewell B nuclear plant data collected from the beginning of startup in May 2013 to end of shutdown in October 2014.

The OLM data sampled during plant startup is first partitioned and then analyzed partition-by-partition. An example using four redundant transmitters is illustrated in Figure 11.1. The partitioning windows are selected by the OLM analyst based on experience and characteristics of the OLM data (Figure 11.1a). The process estimate is calculated using simple averaging or parity space technique for each partition (Figure 11.1b). This value is then subtracted from the reading of each redundant transmitter to arrive at the deviation of each transmitter from the process estimate for the redundant group. The deviation results are then plotted versus time for the redundant transmitters (Figure 11.1c).

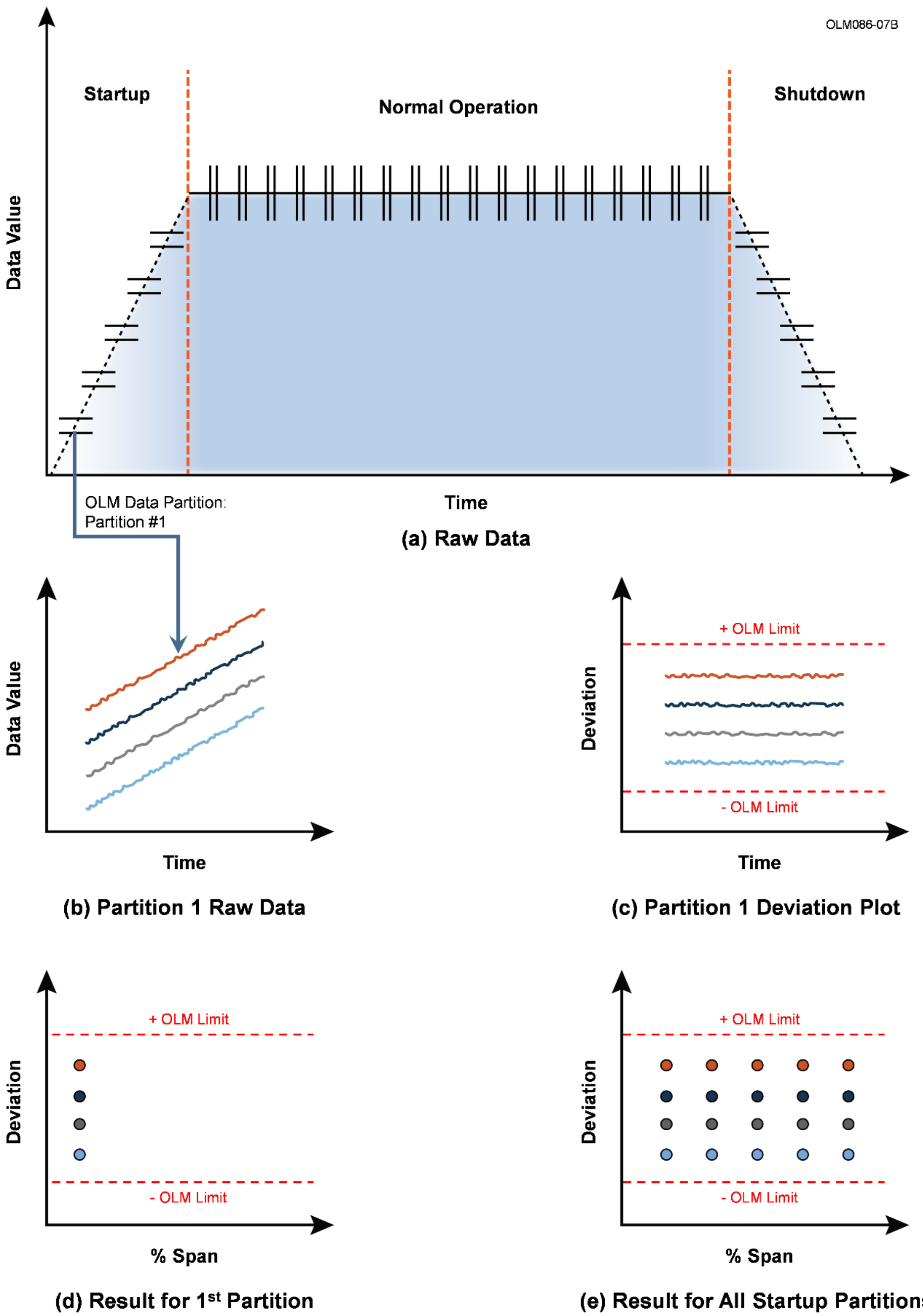


Figure 11.1. Startup Data Analysis Process

Next, the deviations over the partition window are averaged to arrive at a single deviation value for each transmitter. This value is then plotted on an x-y axis where y is the average value of the transmitter deviation over the partition window and x is the operating point in percent of span at which the OLM data was collected (Figure 11.1d). This procedure is repeated for all partitions to arrive at the transmitter deviations over the operating span (Figure 11.1e).

The OLM data sampled during normal operation is then analyzed month by month (Figure 11.2a, b, and c) and the results plotted versus time as illustrated in Figure 11.2d. Then, after the plant is shut down, the OLM data for the shutdown period is promptly analyzed partition-by-partition.

The results from the startup, normal operation, and shutdown periods are then combined in a full-cycle results table that indicates if any transmitter deviation exceeded the OLM limit at any time during the cycle. An example table is shown at the top of Figure 11.3. The table contains a row for each transmitter in the redundant group and a column for startup (SU), each month of normal operation, and shutdown (SD). For each transmitter, an 'X' is placed in the column for any period where the OLM limit was exceeded. Additionally, plots of transmitter deviations at startup, shutdown, and normal operation periods are included with the table to provide the OLM analyst with a complete picture of how each transmitter in the redundant group performed over the full cycle.

The final results are produced by the OLM analyst upon completion of data analysis for the complete operating cycle. Table 11.1 shows an example of how the final OLM results can be compiled through evaluation of transmitter deviation during a complete operating cycle. In this example, four redundant transmitters are shown with one having exceeded its OLM limits most of the time during the complete fuel cycle, one that never exceeded the OLM limits, and two which exceeded the OLM limits on one or two occasions. Obviously, the transmitter that exceeded its OLM limits often (ABC-104) is flagged as "bad" meaning that its calibration must be checked during the outage. Also, the transmitter that never exceeded its OLM limits (ABC-103) is flagged as "good" meaning that the transmitter does not need a calibration check. As for those transmitters that have occasionally exceeded their OLM limits during the fuel cycle (ABC-101 and ABC-102); the analyst should evaluate the raw OLM data, the results of OLM analysis, and all other factors such as transmitter location, service, any extraneous effects, plant activities during OLM data acquisition, and use best engineering judgement and experience as to whether the transmitter should be flagged as "good" or "bad". Generally, a conservative approach is to flag the transmitter as "bad" if there is any doubt about the results of the analysis.

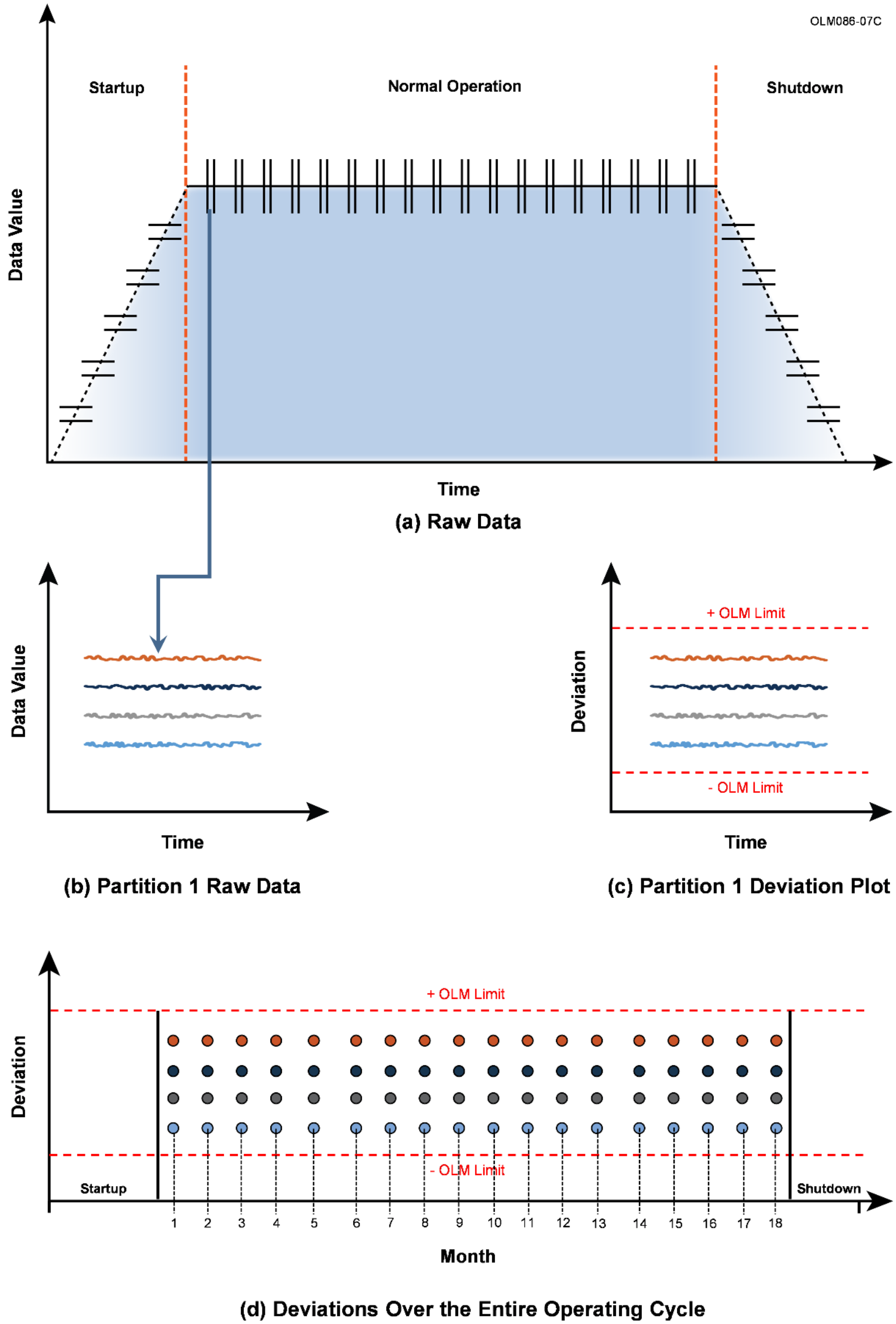


Figure 11.2. Analysis Process for OLM Data Collected During Normal Plant Operation

	Tag	SU	18 June 2013	16 July 2013	06 Aug 2013	03 Sept 2013	01 Oct 2013	29 Oct 2013	26 Nov 2013	24 Dec 2013	21 Jan 2014	18 Feb 2014	18 Mar 2014	15 Apr 2014	13 May 2014	10 Jun 2014	08 Jul 2014	05 Aug 2014	02 Sept 2014	SD	Final
	1BB-L-0465-W																				
	1BB-L-0466-W																				
	1BB-L-0467-W																				
	1BB-L-0468-W	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

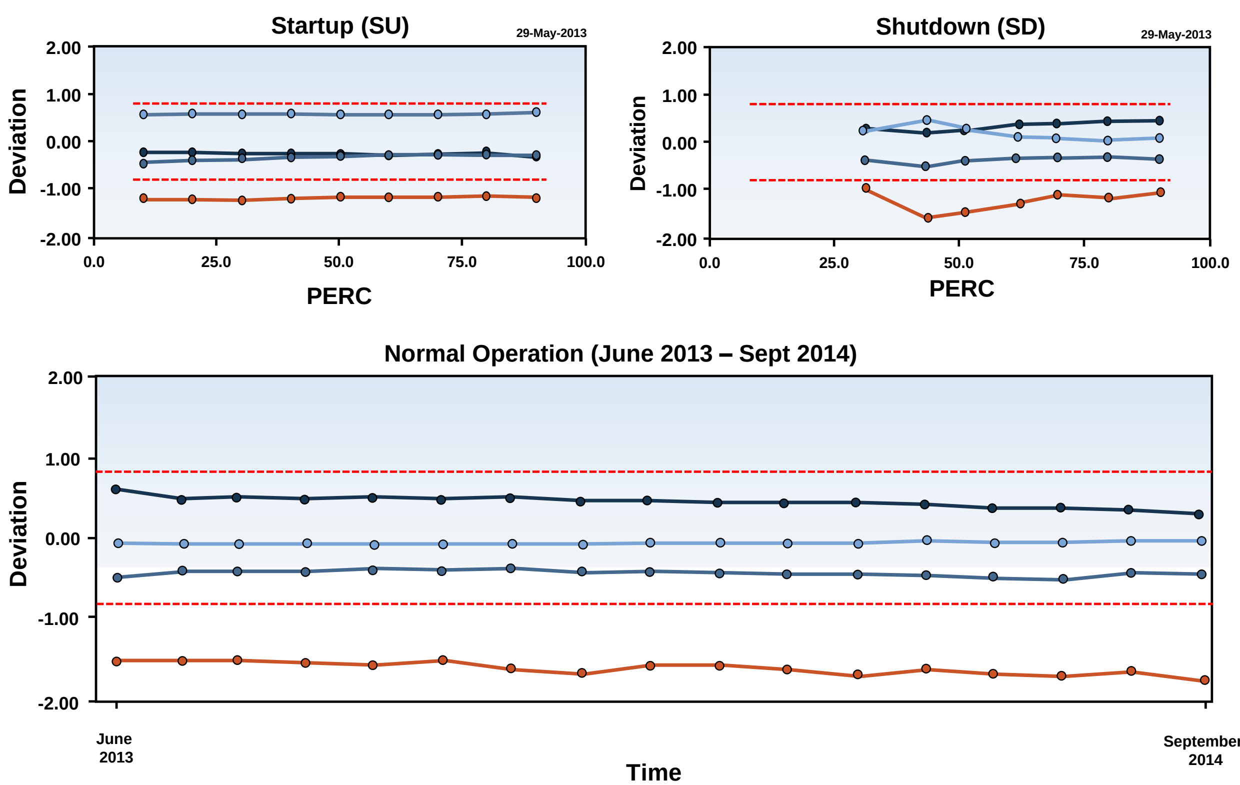


Figure 11.3. Example of Full-Cycle Results for Sizewell B Transmitters

Table 11.1. Illustration of Cycle Summary Table for Four Redundant Transmitters

Tag Number	SU	Month 1	Month 2	···	Month 18	SD	Result
ABC-101			X				Good
ABC-102	X						Good
ABC-103							Good
ABC-104	X	X	X	X		X	Bad

Figure 11.4 shows OLM results for three redundant pressurizer level transmitters at Vogtle Nuclear Power Plant Unit 1 together with the OLM plots for startup, shutdown, and normal operation periods. This is an example of an OLM test where the bad transmitter is clearly identified. Figure 11.5 shows OLM results for three redundant steam pressure transmitters at Farley Nuclear Power Plant Unit 1 as an example of OLM results where the transmitters are well within their OLM limits throughout the cycle.

All transmitters must be identified as either “good” or “bad” depending on results of OLM analysis and interpretation of the outcome by an OLM analyst. Transmitters that have been identified as “bad” must be scheduled for a manual calibration check during the next calibration opportunity which is typically the next refueling outage.

Table 11.2 shows an abbreviated list of OLM results for eleven redundant transmitters in three different services at Sizewell B plant indicating that only one of the eleven transmitters is “bad.”

TABLE067-05

	Tag	SU	31 Oct 2018	30 Nov 2018	31 Dec 2018	31 Jan 2019	28 Feb 2019	31 Mar 2019	30 Apr 2019	31 May 2019	30 Jun 2019	31 Jul 2019	31 Aug 2019	30 Sep 2019	31 Oct 2019	30 Nov 2019	31 Dec 2019	31 Jan 2020	14 Feb 2020	SD	Final
	L0480																				
	L0481																				
	L0482	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

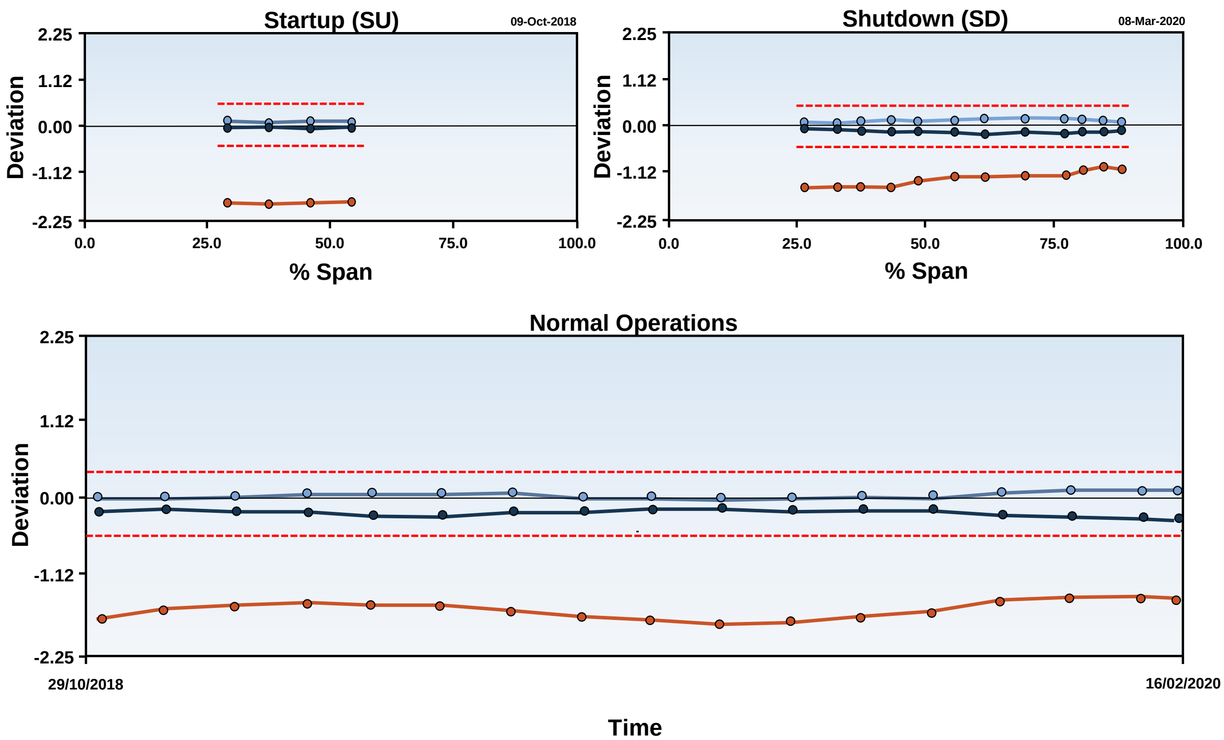


Figure 11.4. OLM Results for Redundant Pressurizer Level Transmitters at Vogtle

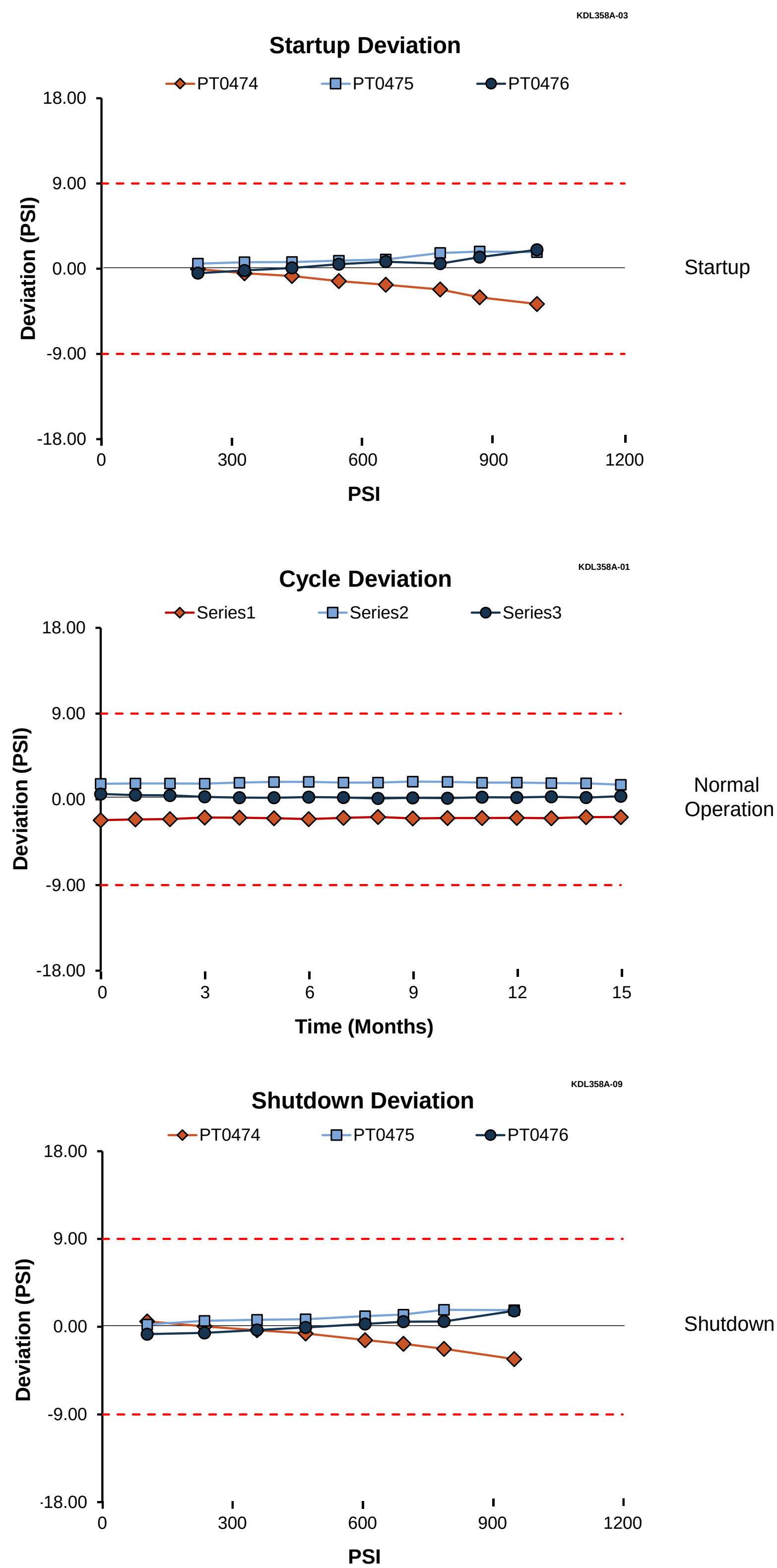


Figure 11.5. OLM Results for Three Redundant Steam Pressure Transmitters at Farley

Table 11.2. Abbreviated Table of OLM Results for Sizewell Transmitters

Item	Group Name	Tag Name	Result
1	SG C Outlet Pressure	PT0494	Good
2	SG C Outlet Pressure	PT0495	Good
3	SG C Outlet Pressure	PT0496	Good
4	Pressurizer Level	LT0459	Good
5	Pressurizer Level	LT0460	Good
6	Pressurizer Level	LT0461	Good
7	Pressurizer Level	LT0462	Bad
8	Pressurizer Pressure	PT0456	Good
9	Pressurizer Pressure	PT0457	Good
10	Pressurizer Pressure	PT0444A	Good
11	Pressurizer Pressure	PT0445a	Good

11.3 DATA ACQUISITION AND ANALYSIS TO ASSESS DYNAMIC FAILURE MODES

OLM can be used to assess dynamic failure modes of transmitters using the noise analysis technique in addition to monitoring for drift. This requires OLM data to be acquired with a high sampling frequency such as 2000 Hz. Since plant computers do not normally sample process data at such a high frequency, a separate data acquisition system with isolation capability must be used. This chapter describes the aspects of the noise analysis technique that relate to dynamic performance monitoring of transmitters.

11.3.1 Transmitter Amenability to OLM Noise Analysis Technology

The noise analysis technique involves processing the random fluctuations (noise) that naturally exist at the output of most transmitters during plant operation. Examples of services that have adequate process fluctuations and are therefore amenable to noise analysis are **[[**

]][a,b,f] Examples of services with little or no fluctuations are **[[**

]][a,b,f]

11.3.2 Impact of Transmitter Response Time Elimination on OLM

Some licensees have extended or eliminated transmitter response time testing requirements with NRC approval based, in part, on the performance of manual calibrations. Manual calibrations will not be performed except on transmitters that are flagged by OLM. The noise analysis methodology is provided in this TR to enable licensees to assess the dynamic failure modes of transmitters that are not covered by the OLM process for transmitter drift monitoring.

Any licensee implementing the OLM methodology to extend transmitter calibration intervals should assess its impact on any prior licensing actions to extend or eliminate periodic response time testing requirements. This TR does not recommend that licensees implementing OLM should resume transmitter response time testing using the conventional practice if this requirement has already been eliminated. Rather, the noise analysis technique is provided here as an alternative to address dynamic failure modes which covers transmitter response time degradation, sensing line blockages, and issues with fill fluids in sensing modules of some transmitters.

11.3.3 Steps for Implementation of Noise Analysis Technique

The following steps must be taken to assess dynamic failure modes of pressure transmitters.

1. **Select Qualified Noise Data Acquisition Equipment.**

   The equipment to acquire noise data in a nuclear plant must have a number of important characteristics such as qualified isolation to allow testing of live safety-related transmitters while the plant is operating. **[[ ]]**[a,b,f] and Figure 11.6 shows how noise data is extracted from the output of a transmitter.

2. **Connect the Noise Data Acquisition Equipment to Plant Signals.**

   The noise data acquisition system should be connected to as many transmitters as allowed by the number of data acquisition channels and the plant procedures. Multiple transmitters (e.g., up to 32) can be tested simultaneously to reduce the test time. Each data acquisition channel must be connected to the transmitter current loop as shown in Figure 11.7.

3. **Collect and Store Data for Subsequent Analysis.**

   The noise data should be collected during normal plant operation at full temperature, pressure, and flow and analyzed in real time or stored to be analyzed later. However, noise data taken at other conditions is acceptable as long as there is enough process fluctuation with sufficient amplitude and frequency content to drive the transmitters to reveal their dynamic characteristics. Section 11.3.1 describes how to determine the amenability of a nuclear plant transmitter to OLM noise analysis technology.

4. **Screen Data for Artifacts and Anomalies.**

   During collection of noise data, potential exists for spikes, jumps, and other artifacts to contaminate the data. These artifacts are normally benign to plant operation but can complicate the analysis of the noise data. Therefore, any identified anomalies must be excluded from the data before analysis. Figure 11.8 shows typical noise data from a transmitter in a nuclear power plant after the data was acquired and cleaned. This graph shows only 50 seconds of data from a 60-minute recording that is typically collected to measure the response time of a nuclear plant pressure transmitter.

5. **Perform Data Analysis.**

[[

]]a,b,f

Two sets of PSD plots are shown in Figure 11.9, each for a transmitter in a PWR plant. Each plot contains two PSD traces; one with degraded dynamic sensor response (which happened to be a sensing line blockage) and another after the dynamic sensor response was restored (when the blockage was cleared).

6. **Review and Document Results.**

The OLM results must be reviewed by qualified personnel and documented.

Table 11.3. Minimum Requirements for Portable Noise Data Acquisition System

Item	Characteristic	Minimum Requirement

[[ ]]a,b,f

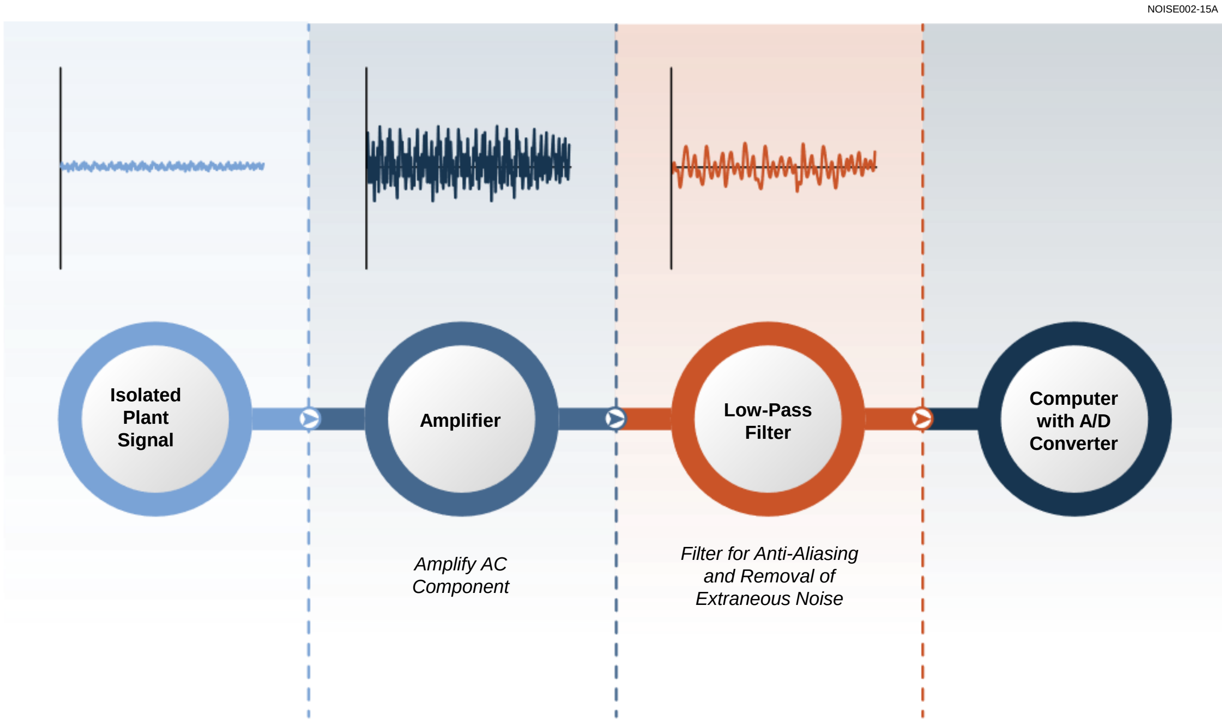


Figure 11.6. Noise Data Acquisition Process

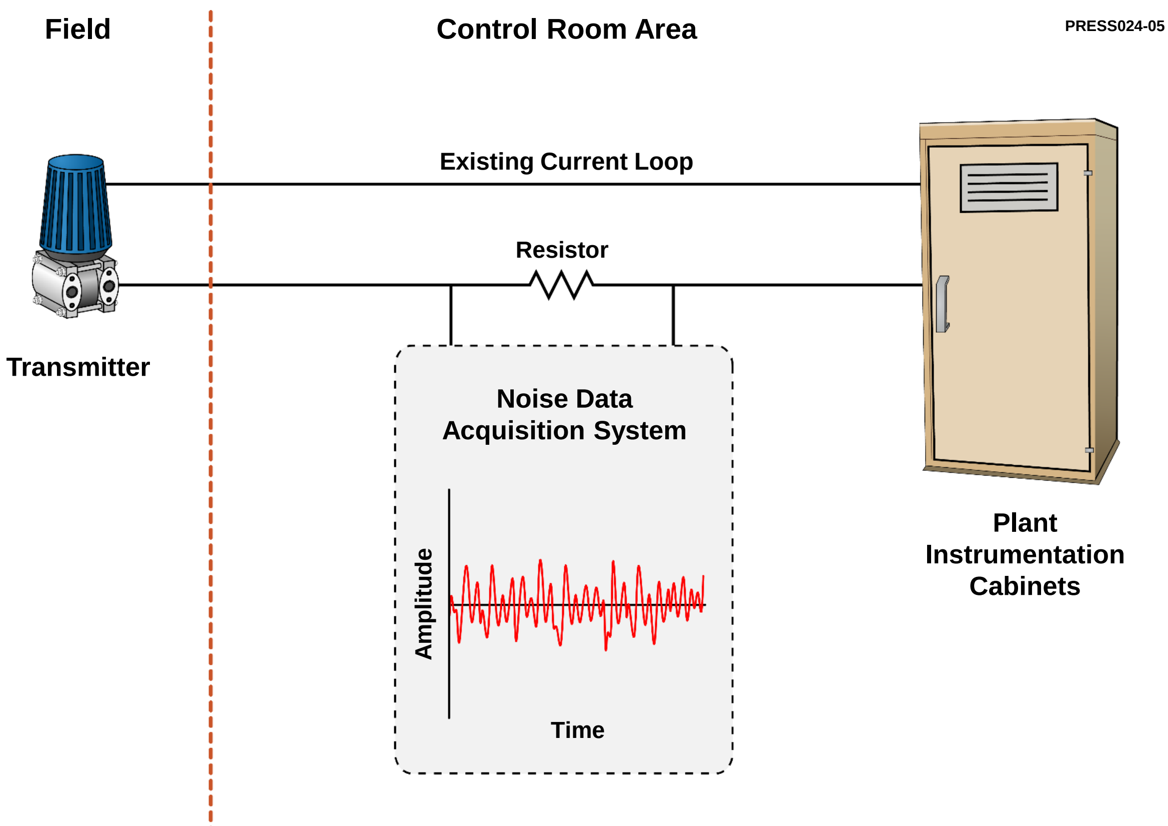


Figure 11.7. Noise Data Acquisition from a Transmitter Loop

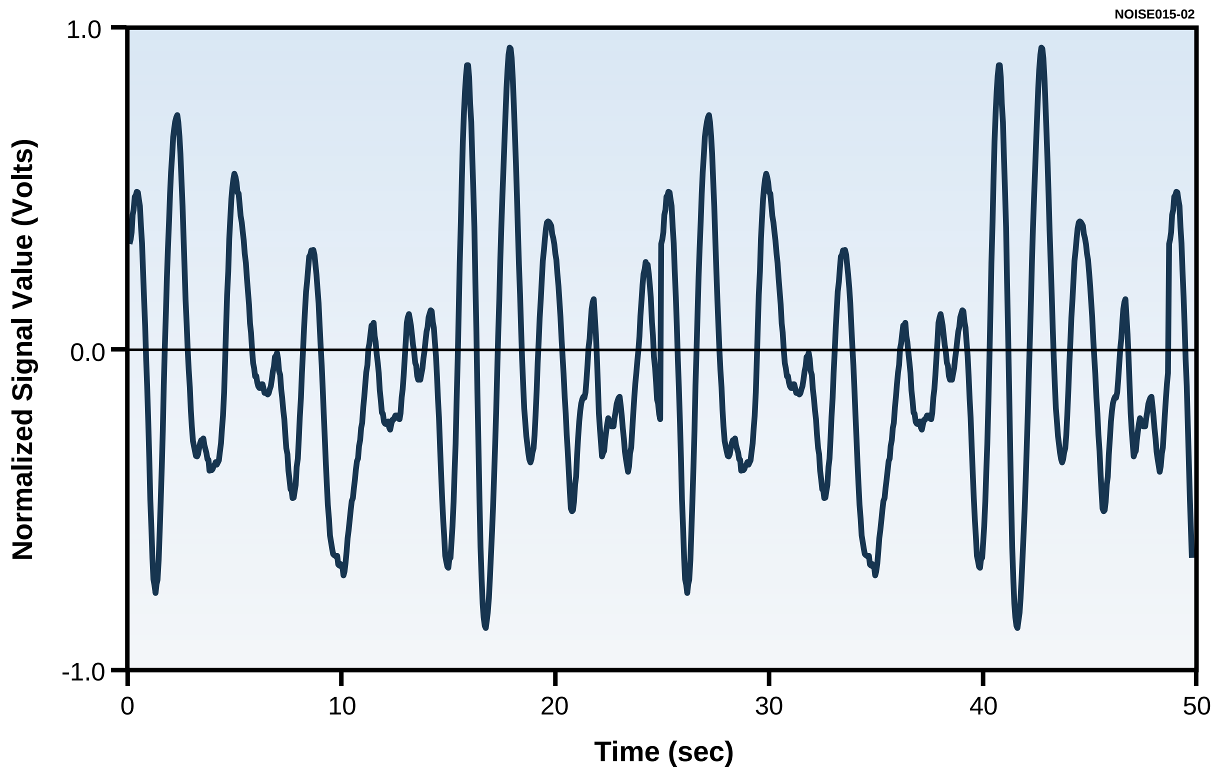


Figure 11.8. Raw Noise Data from a PWR Pressure Transmitter

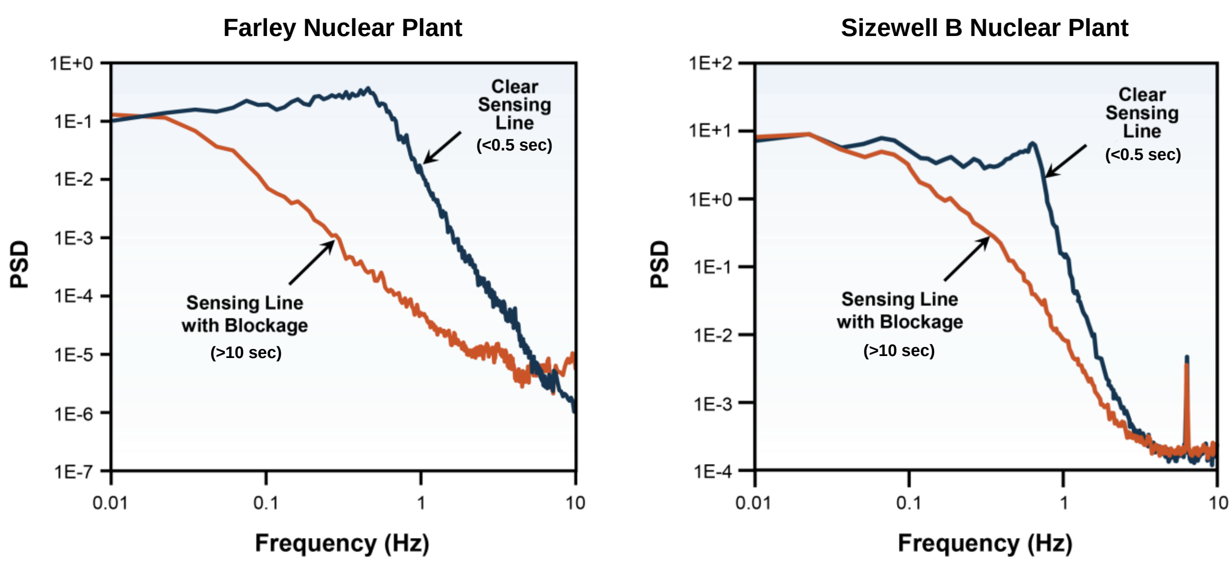


Figure 11.9. Noise Analysis Results for Transmitters in Two Nuclear Power Plants With and Without Degraded Dynamic Sensor Response

11.4 TRAINING OF OLM ANALYST

The OLM analyst must be trained in both static and dynamic performance verification of transmitters. A great deal of research has been performed worldwide to automate the reading and interpretation of OLM data and results, but none can yet replace the need for a human analyst. The human analyst must have knowledge of the OLM fundamentals and skills in the OLM implementation details. As a minimum, the analyst must have education or experience in process measurement, instrumentation and control, system analysis, and training to perform the following tasks. **[[**

]][a,b,f]

11.5 REQUIRED TECHNICAL SPECIFICATIONS CHANGES

The plant Technical Specification must be modified as shown in Appendix B to implement OLM. The typical Technical Specification changes must include the addition of a definition for ONLINE MONITORING. A new ONLINE MONITORING Program to Extend Transmitter Calibration Intervals must be added. A new Surveillance Requirement option to use the ONLINE MONITORING Program to Extend Transmitter Calibration Intervals to determine the frequency of transmitter CHANNEL CALIBRATION must be adopted. The new SURVEILLANCE REQUIREMENT option is added as an “OR” option to the existing requirement.

The purpose of the OLM Topical Report is to provide a method to defer calibration of the transmitters included in the ONLINE MONITORING Program based on OLM results. The OLM methodology described in the Topical Report is not used to extend the calibration of any other elements in the safety signal path (e.g., signal converters or adjustable parameters in I&C rack equipment). The Surveillance Requirement frequency for these other components in the signal path remains in effect. The Surveillance Requirement frequency for these other components can be calendar-based by specifying a calendar interval, risk-based using a Surveillance Frequency Control Program, or defined based on self-testing features of a digital I&C platform-based system.

The use of the logical connector “OR” provides flexibility for the licensee to address cases where OLM cannot be performed during the monitoring period. In the case of a calendar-based

Surveillance Requirement frequency, the transmitter would need to be calibrated within the specified calendar interval measured since the last valid OLM assessment. In the case of a risk-based Surveillance Requirement frequency, the transmitter would need to be calibrated within the specified risk-based interval measured since the last valid OLM assessment.

Example changes to Standard Technical Specifications (STS) and associated Bases are provided in Appendix B based on the style used in TSTF-425.

12 REFERENCES TO SUBSTANTIATE AMS CLAIMS

This chapter provides evidence in support of the following two AMS claims in this TR with respect to performance characteristics of nuclear grade pressure, level, and flow transmitters.

Claim 1. Drift behavior of existing generation of nuclear grade pressure, level, and flow transmitters is random and common-mode drift is not a problem in using OLM to identify drifting transmitters.

Claim 2. OLM fails to identify drifting transmitters in about 1 percent of cases which is better than traditional calibrations which fails in about 5 percent of cases.

12.1 SUBSTANTIATE ABSENCE OF COMMON-MODE DRIFT

Evidence in support of AMS' claim that common-mode drift is not a problem in the existing generation of nuclear grade pressure transmitters is provided in two EPRI reports, a Sizewell internal report, and a PWROG report. These reports are identified here and relevant quotations in support of AMS' claim are presented verbatim in italic font or paraphrased to clarify the intent of the information.

12.1.1 EPRI Drift Study Reported in TR-104965-R1

This EPRI report is titled "On-Line Monitoring of Instrument Channel Performance" and is the one to which the NRC SER of the year 2000 on the subject of OLM is attached. It states the following on Page 3-14:

- *"For the transmitters evaluated, drift was a random event. The transmitters were as likely to drift up as they were to drift down. No significant bias effects were observed.*
- *Redundant transmitters associated with a particular parameter did not exhibit a tendency to drift as a group. One transmitter out of calibration did not indicate that the other redundant transmitters were likely to be out of calibration."*

These statements are based on transmitter calibration data from 18 nuclear power plants in the U.S. involving 1139 instruments, 6700 calibration records, and 33,890 AF/AL data points. This data covered the span of May 1975 to November 1996 and included the transmitters shown in Table 12.1.

Table 12.1. Transmitters Involved in EPRI Drift Study Reported in TR-104965-R1

Manufacturer	Model			
Rosemount	1151	1152	1153	1154
Barton	384 752	386	763	764
Foxboro	NE11	NE13	E11	E13
Veritrak	59	76		
Tobar	32			
GE	555			
Delaval	XM-54852			

12.1.2 EPRI Drift Study Reported in 1009603

This EPRI report is titled “Instrument Drift Study” and involved 140 transmitters at Sizewell B including 28 Barton model 763 transmitters, 84 Barton model 764 transmitters, and 28 Barton model 752 transmitters. This report covered transmitter drift data from 1995 to 2002 and was completed after publication of EPRI TR-104965-R1. The two reports were compared by EPRI providing the following conclusions:

- The drift values for the Sizewell B transmitters are comparable to drift results in the EPRI drift study of transmitters in other nuclear power plants.
- There is no consistent trend indicating that the drift behavior of Sizewell B transmitters is different than drift of transmitters in EPRI drift study of transmitters in other nuclear power plants.

12.1.3 Sizewell Internal Report on Transmitter Drift

The Sizewell report is titled “Transmitter Single Calibration Regression Methodology E/REP/SXB/0015/00 Issue 1” and documented a drift study performed by British Energy (now EdF) and published as an internal report covering drift data from January 1995 to February 2001. Table 12.2 shows the transmitters that were covered in this study which included not only the KDG Mobrey transmitters used at Sizewell B, but also Barton transmitters of the type included in EPRI drift study published in 1009603 report.

Table 12.2. Transmitters Included in Sizewell’s Internal Drift Study

Manufacturer	Model		
KDG-Mobrey	4020	4305	4320
ITT-Barton	752	763	764

The Sizewell report states the following on pages 63 and 65:

- *“Results for drift in span and zero clearly show no biasing effects and are random (zero centered) in direction.”*
- *“there is no noticeable relationship between the calibration period and the amount of drift”*
- *“it is reasonable to expect that increasing the calibration period further will have little or no effect on the amount of drift”*
- *“The results of the drift analysis show that drift is present but is small, and there is evidence that it is random in direction, indicating that extending the calibration periods should not give increased drift since the drift will average out to zero.”*

12.1.4 PWROG Drift Study

The PWROG drift study titled “Pressure and Differential Pressure Transmitter Calibration Frequency Extension: Generic Transmitter Drift Study” was performed by AMS for PWROG involved over 20,000 calibration records from forty-one PWR units representing three PWR NSSS design vendors and spanned a period from 2000 to 2010. The transmitters in this study were manufactured by Rosemount, Barton, Foxboro, Tobar-Veritrak, Gould-Statham and others as shown in Table 12.3.

Table 12.3. Transmitters Included in PWROG Drift Study

Manufacturer	Model			
Rosemount	1151	1153	3051	
	1152	1154		
Barton	386A	752	763	764
Foxboro	E11	E13	N-E11	N-E13
Gould Statham	PD3200			
Tobar	31			
Tobar/Veritrak/WEC	32			
Veritrak/WEC	76			
Veritrak	59			
FCI	8-66MA			
Honeywell	STD130			
Gems Delaval	XM-36495		XM-54854	
Transamerica Delaval	36562			
GEMS Sensors	60163			
Westinghouse	2837			
Fischer-Porter	50			
GE DPT	555			

This drift study resulted in the following conclusions in support of AMS's claim about random characteristics of existing generation of nuclear grade transmitters:

- *A majority of pressure & differential pressure transmitters do not exhibit evidence of time-dependent drift.*
- *Drift is typically random rather than systematic*.

12.1.5 Transmitters Amenable to OLM

Based on the referenced information, AMS produced a table of nuclear grade transmitters that are amenable to OLM (Table 12.4). This table can be used by Licensees to identify the transmitter models that can be included in an OLM program without a need to perform a drift study, similarity analysis, or FMEA.

Table 12.4 Nuclear Grade Transmitters Amenable to OLM

Manufacturer	Model
KDG-Mobrey	4020 4305 4320
ITT-Barton	288 332 384 386A 763 764 289 351 386 752 763A
Rosemount	1151 1152 1153 1154 3051
Foxboro	E11 E13 N-E11 N-E13
Weed	N-E11AH N-E11DM N-E11GM N-E13DM
Tobar	31
Tobar/Veritrak/WEC	32
Veritrak/WEC	76
Veritrak	59
Gould Statham	PD3200
GE	555
Delaval	XM-54852
FCI	8-66MA
Honeywell	STD130
Gems Delaval	XM-36495 XM-54854
Transamerica Delaval	36562
GEMS Sensors	60163
Westinghouse	2837
Fischer-Porter	50

12.2 FAILURE OF OLM VERSUS FAILURE OF TRADITIONAL CALIBRATIONS

This section includes references with supporting information to substantiate AMS's claims that OLM fails in less than 1 percent of cases while traditional calibrations fail in about 5 percent of cases. The references provided are from EPRI reports written based on Sizewell's experience with implementation of OLM.

The EPRI report number 1013486 Volume 1 contains the following on page 3-5.

> ***"Benefits to Plant Safety and Transmitter Maintenance***
>
> *Reviews of calibration procedures and calibration data from nuclear power plants have shown that mistakes can be made during manual calibrations – in some cases, errors have upset transmitters with good calibration and have negated any benefit of the calibration [9]. An analysis of the history of Sizewell transmitter revealed that about 5% of transmitters sustained operator-induced errors during an outage. The errors required that additional calibrations be made within a couple of months of a refueling outage.*
>
> *Furthermore, the calibration of some transmitters is affected by the environmental temperature and static pressure that are taken into account by OLM but neglected in conventional calibrations. Therefore, OLM implementation increases safety in a number of ways – notably, OLM results in fewer human errors, less calibration-induced damage to the transmitters and other plant equipment, traceability of the effects of environmental and process conditions on calibration, and timely detection of out-of-calibration transmitters."*

The same EPRI report includes the following on page 8-1.

> ***"8 Resolving Non-Conservative Results***
>
> *In the comparison of Sizewell OLM results for Cycles 5-7, there were 12 cases in which transmitters were classified as good by OLM that were subsequently found by traditional calibrations to be bad. This is significant not only because of the disagreement between the two methods, but also and more importantly, because the disagreement is non-conservative. The term non-conservative is used to describe a situation in which OLM identifies a transmitter as good but manual calibration identifies the same transmitter as bad. The term conservative is used to describe a situation in which OLM identifies a transmitter as bad when it is actually good.*
>
> *Table 8-1 shows the 12 transmitters in question and explains the reasons for the discrepant results. These reasons were arrived at in consultation with BE personnel. Overall, 11 of the 12 discrepancies were resolved, as explained in the following section."*

The EPRI report ends on page 8-15 with the following:

> ***"Summary***
>
> *Of all the results from the three cycles (Cycles 5-7), only one of the 12 non-conservative results had no discernable explanation. Also, it is curious that all 12 transmitters were found to exceed their high manual calibration limit. One would expect the nature of the deviation to be random and exhibit failures on both the high and low sides of the manual calibration limits. A possible explanation for this observation is a bias that results from the calibration test equipment being at the high end of its measurement uncertainty. This could cause transmitters to fail when they are marginally high."*

The Sizewell plant engineers maintain a tally of transmitters involved in OLM. This information has been recorded in a Sizewell report entitled "Sizewell Sensor Calibration Extension ESR-503". An updated table from this report received from Sizewell in March 2020 concluded that of 921 transmitters monitored from Cycle 5 (in 2005) to Cycle 15 (in 2020) only 11 transmitters were found to be good by OLM but bad in manual calibrations. **This is about 1 percent compared to about 5 percent of transmitters that are miscalibrated during plant outages according to data provided to AMS by Sizewell engineers in charge of OLM.**

13 PROCESS TO ESTABLISH BACKSTOP

As a defense against common-mode drift, one transmitter from each group of redundant transmitters involved in OLM must be checked for calibration at a given interval. This chapter provides a process that plants implementing OLM must use to establish this interval which is referred to as a "backstop". A backstop that is established based on the process herein will not be the same for all groups of redundant transmitters or all plants. It varies based on transmitter redundancy, service in the plant, and each plant's experience with calibration behavior of its transmitters. The backstop is a dynamic number meaning that it can change (increase or decrease) as more history on calibration behavior of transmitters is accumulated and analyzed by each plant.

13.1 STEPS TO ARRIVE AT BACKSTOP

The backstop for each group of redundant transmitters in each plant must be established through an objective analysis and the details of this analysis must be documented. Any change in the backstop requires a new analysis together with supporting documentation. AMS has arrived at the following steps to establish backstops. These steps are used later in this chapter to arrive at examples of backstops based on transmitter calibration histories of two PWRs in the U.S. who agreed to provide calibration data for this project.

Step 1. Verify Drift of Transmitters is Random

In implementing OLM, it is assumed that the drift behavior of transmitters is random and follows a Gaussian (i.e., normal or bell shaped) probability distribution. This means that a transmitter is as likely to drift in the positive direction as it is to drift in the negative direction regardless of the direction of previous drift.

Plants implementing OLM must verify through an objective analysis that the drift behavior of their transmitters involved in the OLM program is random and follows a Gaussian distribution. Plenty examples of industry practice are publicly available to assist plants with this step.

Step 2. Determine Probability that All OLM Transmitters Drift in Same Direction

For common-mode drift to occur, transmitters in a redundant group must all drift in the positive direction or all drift in the negative direction. The probability that drift occurs in the same direction is given by:

$$P_S = \frac{1}{2^{(n-1)}} \qquad \text{Eq. 13.1}$$

where n is the number of transmitters in a redundant group. Tables Table 13.1 and Table 13.2 show all permutations of drift directions for 2-way and 3-way redundant transmitters (XMTRs) with the symbol '+' denoting drift in the positive direction and the symbol '-' denoting drift in the negative direction. This is followed by Table 13.3 listing P_S values for 2, 3, and 4-way redundant groups.

Table 13.1 All Permutations of Drift Direction for Two-Way Redundant Transmitters

Transmitter	XMTR 1	XMTR 2	Same Direction?
Case 1	+	+	Yes
Case 2	-	+	No
Case 3	+	-	No
Case 4	-	-	Yes
Result (P_S)			**50.0%**

Table 13.2. All Permutations of Drift Direction for Three-Way Redundant Transmitters

Transmitter	XMTR 1	XMTR 2	XMTR 3	Same Direction?
Case 1	+	+	+	Yes
Case 2	-	+	+	No
Case 3	+	-	+	No
Case 4	-	-	+	No
Case 5	+	+	-	No
Case 6	-	+	-	No
Case 7	+	-	-	No
Case 8	-	-	-	Yes
Result (P_S)				**25.0%**

Table 13.3. Probability of Drift in Same Direction Versus Transmitter Redundancy

Redundancy	P_S
2	0.500
3	0.250
4	0.125

Step 3. Determine Probability of Calibration Adjustments

Using manual calibration records for each transmitter in a redundant group, determine how many calibration checks were performed, how many times the transmitter was adjusted, and the average time interval between calibration checks. Note that calibration adjustments are sometimes performed to improve the calibration even when the transmitter is not out of calibration which makes this approach more conservative. A transmitter is said to have been adjusted if its zero and/or span was changed during a calibration to bring its reading to within its as-left calibration tolerance.

Now, let P_i denote the probability of each adjustment of the i^{th} transmitter in a redundant service and write it as:

$$P_i = \frac{\#\ of\ calibration\ adjustments}{\#\ of\ calibration\ checks} \qquad \text{Eq. 13.2}$$

Next, let P_A denote the probability that all redundant transmitters will need adjustment at the same time and write it as:

$$P_A = \prod_{i=1}^{n} P_i \qquad \text{Eq. 13.3}$$

Given Equations 13.1, 13.2, and 13.3, the probability that redundant transmitters will need to be adjusted because they drifted in the same direction over the average time interval between calibrations (typically 18 months) may be written as:

$$P_{CM} = P_S \times P_A \qquad \text{Eq. 13.4}$$

This product is referred to as probability of common mode drift (P_{CM}) and is used in the next step to calculate backstops.

Step 4. Calculate Backstops

The probability of common-mode drift of a group of redundant transmitters increases as the time between calibrations is increased. The maximum value of this probability (P_{max}) must be selected by the plant implementing OLM. For example, P_{max} can be set at 5% for calculating the backstop. Once P_{max} is selected, the plant can use the following equation to arrive at the maximum interval between calibrations:

$$\frac{P_{MAX}}{P_{CM}} = \sqrt{\left(\frac{Max\ Interval}{Average\ Calibration\ Interval}\right)} \qquad \text{Eq. 13.5}$$

Or,

$$Max\ Interval = (Average\ Calibration\ Interval)\left(\frac{P_{MAX}}{P_{CM}}\right)^2 \qquad \text{Eq. 13.6}$$

The backstop is equal to the maximum interval identified but bounded on the low side by the average calibration interval and on the high side by the time span of plant calibration data. For example, if the average calibration interval is 18 months and the time span of plant calibration data is 20 years, then the backstop that is calculated should have a value between 18 months and 20 years. In this case, if the backstop turns out to be less than 18 months, it will still be set at 18 months and if it turns out to be greater than 20 years, it will still be set at 20 years. Section 13.3 presents two tables of backstop values for a variety of services in two PWR plants that provided calibration history data for this project.

13.2 BACKSTOP PROVISIONS

The established backstop may be used as is or updated for the following cases.

1. The backstop calculated for existing transmitters can be used as is for any new transmitters of the same make and model.
2. The backstop calculated for existing transmitters can be used for other transmitters of a different make or model for which an objective similarity analysis has verified that these other transmitters are equivalent to existing transmitters.
3. Backstops must be recalculated as more calibration data becomes available. This may result in longer or shorter backstops. Any recalculation of backstops must be verified and documented.

13.3 EXAMPLES OF BACKSTOP CALCULATIONS

Using the formulas in Section 13.1, the data in Table 13.4 was arrived at from actual calibration records of a U.S. PWR plant for a three-way redundant group of transmitters.

Table 13.4. Calculation of Probability of Adjustment for a 3-Way Redundant Service

Transmitter	# Adjusted	# Calibration Checks	Probability	Average Calibration Interval
1	6	12	0.50	18 months
2	5	12	0.42	18 months
3	4	12	0.33	18 months
Total			P_A = (0.50)(0.42)(0.33) = 0.0693	18 months

Using values of P_S from Table 13.2 or Table 13.3 and values of P_A from Table 13.4, the total probability of common mode drift, P_{CM}, over an average calibration interval of 18-months may be calculated as follows for a 3-way redundant group of transmitters:

$$P_{CM} = P_S \times P_A = (0.25)(0.0693) = 0.017325 \text{ Over 18 Months}$$

Thus, for a P_{MAX} of 5%, the backstop becomes:

$$Backstop = (18)\left(\frac{0.05}{0.017325}\right)^2 = 150\ Months = 12\ Years$$

Using thisprocess, backstops were calculated for a number of transmitter services as shown in Table 13.5 and Figure 13.1 for PWR plant Unit 1 and Table 13.6 and Figure 13.2 for PWR plant Unit 2. These results are based on calibration records of the two PWR plants over a period of about 19 years from 2001 to 2020 and a value of 5 percent for maximum probability of common mode drift.

Table 13.5. Backstop Calculations for PWR Unit 1

XMTR Set	XMTR ID	Service	# Adjusts	Total Records	P	P_{CM}	Avg. Cal. Interval (Years)	Max Interval (Years)	Cal Date Range (Years)	Backstop (Years)
I	1	Aux FW Flow	3	5	0.600	0.003	1.6	630.8	7.7	**7.7**
	2		1	5	0.200					
	3		3	6	0.500					
	4		2	6	0.333					
II	5	Ctmt Pressure	3	13	0.231	0.000	1.5	2410266.1	19.5	**19.5**
	6		1	13	0.077					
	7		1	13	0.077					
	8		3	13	0.231					
III	9	Pzr Pressure	8	13	0.615	0.013	1.5	21.8	19.5	**19.5**
	10		10	13	0.769					
	11		5	13	0.385					
	12		8	14	0.571					
IV	13	RCP Thermal Barrier ACCW Flow	2	6	0.333	0.002	1.9	1609.9	12.0	**12.0**
	14		3	7	0.429					
	15		2	7	0.286					
	16		2	6	0.333					
V	17	RCS WR Pressure Transmitter	3	6	0.500	0.042	2.0	2.9	12.0	**2.9**
	18		1	6	0.167					
VI	19	EHC Pressure	6	12	0.500	0.017	1.5	12.3	19.4	**12.3**
	20		5	12	0.417					
	21		4	12	0.333					
VII	22	Main Steam Pressure Loop 1	4	8	0.500	0.011	1.4	28.0	14.0	**14.0**
	23		3	10	0.300					
	24		3	10	0.300					
VIII	25	Main Steam Pressure Loop 2	4	9	0.444	0.004	1.4	254.1	12.9	**12.9**
	26		1	10	0.100					
	27		3	9	0.333					
IX	28	Main Steam Pressure Loop 3	5	9	0.556	0.002	1.4	1225.9	12.9	**12.9**
	29		1	9	0.111					
	30		1	9	0.111					
X	31	Main Steam Pressure Loop 4	2	13	0.154	0.004	1.5	245.5	13.0	**13.0**
	32		3	10	0.300					
	33		3	9	0.333					
XI	34	Steam Generator Narrow Range Level Loop 1	7	8	0.875	0.219	1.4	0.1	10.4	**1.4**
	35		8	8	1.000					
	36		7	7	1.000					
XII	37	SG NR Level Loop 2	8	8	1.000	0.125	1.5	0.2	6.0	**1.5**
	38		2	4	0.500					
	39		4	4	1.000					
XIII	40	SG NR Level Loop 3	9	12	0.750	0.188	1.5	0.1	6.0	**1.5**
	41		4	4	1.000					
	42		4	4	1.000					
XIV	43	SG NR Level Loop 4	6	12	0.500	0.094	1.5	0.4	6.0	**1.5**
	44		3	4	0.750					
	45		8	8	1.000					
XV	46	RCS Flow Loop 1	6	12	0.500	0.036	1.5	2.8	18.0	**2.8**
	47		7	12	0.583					
	48		6	12	0.500					
XVI	49	RCS Flow Loop 2	2	12	0.167	0.008	1.5	56.9	18.0	**18.0**
	50		5	12	0.417					
	51		6	13	0.462					
XVII	52	RCS Flow Loop 3	5	12	0.417	0.011	1.5	31.9	18.0	**18.0**
	53		5	12	0.417					
	54		3	12	0.250					
XVIII	55	RCS Flow Loop 4	4	12	0.333	0.009	1.5	41.6	16.4	**16.4**
	56		3	11	0.273					
	57		5	12	0.417					
XIX	58	Pzr Level	4	9	0.444	0.037	1.5	2.7	7.5	**2.7**
	59		2	5	0.400					
	60		5	6	0.833					

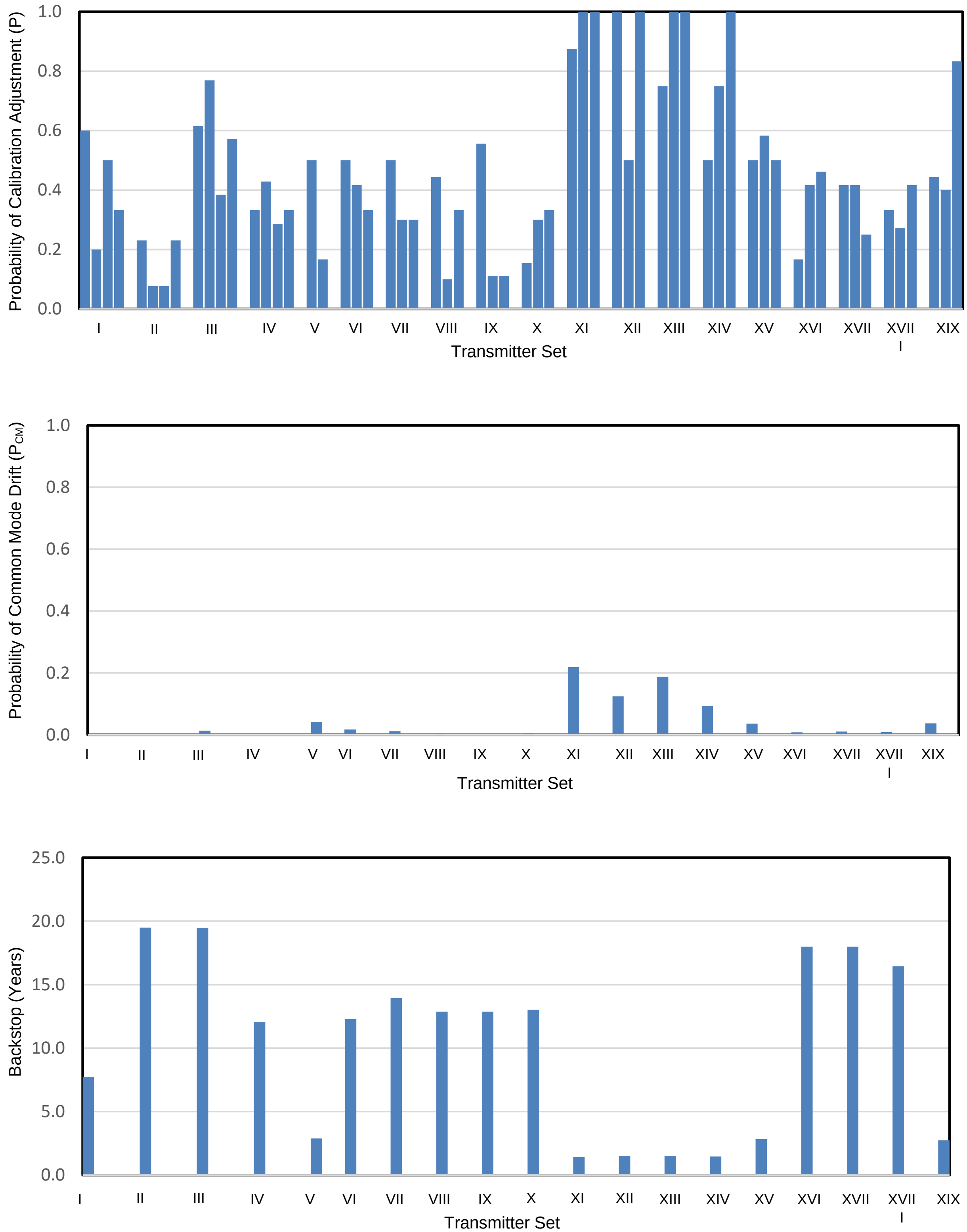
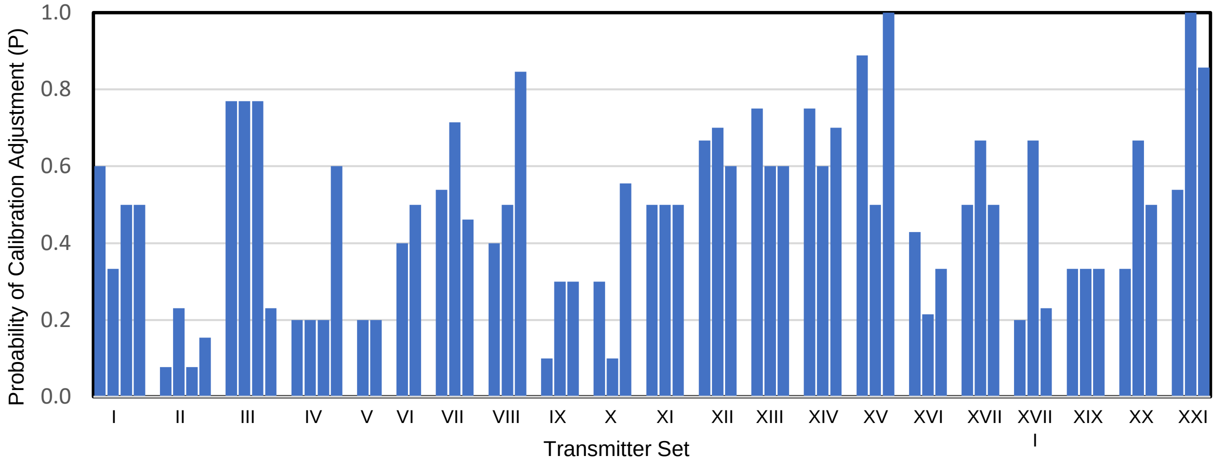
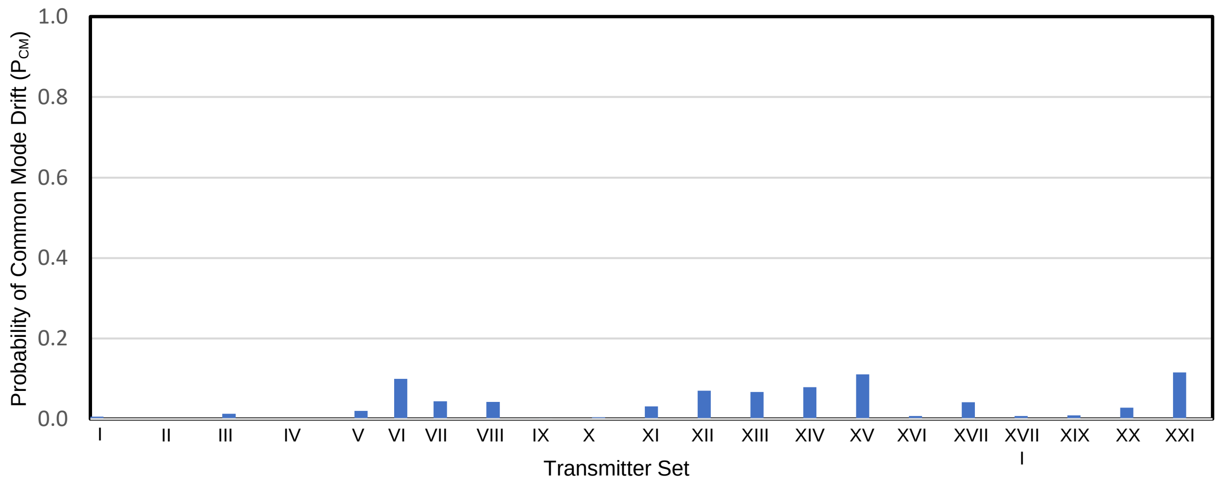


Figure 13.1. Bar Charts of Results of Table 13.5 for PWR Unit 1

Table 13.6. Backstop Calculations for PWR Unit 2

XMTR Set	XMTR ID	Service	# Adjusts	Total Records	P	P_{CM}	Avg. Cal. Interval (Years)	Max Interval (Years)	Cal Date Range (Years)	Backstop (Years)
I	1	Aux FW Flow	3	5	0.600	0.006	1.5	96.7	6.1	**6.1**
	2		2	6	0.333					
	3		2	4	0.500					
	4		3	6	0.500					
II	5	Ctmt Pressure	1	13	0.077	0.000	1.5	5423098.7	19.3	**19.3**
	6		3	13	0.231					
	7		1	13	0.077					
	8		2	13	0.154					
III	9	Pzr Pressure	10	13	0.769	0.013	1.5	21.6	19.4	**19.4**
	10		10	13	0.769					
	11		10	13	0.769					
	12		3	13	0.231					
IV	13	RCP Thermal Barrier ACCW Flow	1	5	0.200	0.001	3.0	20717.6	14.9	**14.9**
	14		1	5	0.200					
	15		1	5	0.200					
	16		3	5	0.600					
V	17	RCS WR Pressure Transmitter	1	5	0.200	0.020	3.0	18.6	14.9	**14.9**
	18		1	5	0.200					
VI	19	Turbine First Stage Pressure	4	10	0.400	0.100	1.5	0.4	16.3	**1.5**
	20		5	10	0.500					
VII	21	EHC Pressure	7	13	0.538	0.044	1.5	1.9	19.5	**1.9**
	22		10	14	0.714					
	23		6	13	0.462					
VIII	24	Main Steam Pressure Loop 1	4	10	0.400	0.042	1.4	1.9	13.3	**1.9**
	25		5	10	0.500					
	26		11	13	0.846					
IX	27	Main Steam Pressure Loop 2	1	10	0.100	0.002	1.4	673.5	12.8	**12.8**
	28		3	10	0.300					
	29		3	10	0.300					
X	30	Main Steam Pressure Loop 3	3	10	0.300	0.004	1.4	206.0	12.8	**12.8**
	31		1	10	0.100					
	32		5	9	0.556					
XI	33	Main Steam Pressure Loop 4	5	10	0.500	0.031	1.3	3.4	13.2	**3.4**
	34		5	10	0.500					
	35		5	10	0.500					
XII	36	SG NR Level Loop 1	6	9	0.667	0.070	1.5	0.8	7.4	**1.5**
	37		7	10	0.700					
	38		3	5	0.600					
XIII	39	SG NR Level Loop 2	6	8	0.750	0.068	1.5	0.8	7.4	**1.5**
	40		3	5	0.600					
	41		3	5	0.600					
XIV	42	SG NR Level Loop 3	6	8	0.750	0.079	1.5	0.6	7.4	**1.5**
	43		3	5	0.600					
	44		7	10	0.700					
XV	45	SG NR Level Loop 4	8	9	0.889	0.111	1.5	0.3	7.4	**1.5**
	46		4	8	0.500					
	47		5	5	1.000					
XVI	48	RWST Level	6	14	0.429	0.008	1.5	62.2	19.8	**19.8**
	49		3	14	0.214					
	50		4	12	0.333					
XVII	51	RCS Flow Loop 1	3	6	0.500	0.042	1.5	2.1	8.9	**2.1**
	52		4	6	0.667					
	53		3	6	0.500					
XVIII	54	RCS Flow Loop 2	1	5	0.200	0.008	1.6	66.9	8.9	**8.9**
	55		4	6	0.667					
	56		3	13	0.231					
XIX	57	RCS Flow Loop 3	2	6	0.333	0.009	1.5	43.3	8.9	**8.9**
	58		2	6	0.333					
	59		4	12	0.333					
XX	60	RCS Flow Loop 4	2	6	0.333	0.028	1.5	4.8	8.9	**4.8**
	61		4	6	0.667					
	62		3	6	0.500					
XXI	63	Pzr Level	7	13	0.538	0.115	1.5	0.3	4.4	**1.5**
	64		3	3	1.000					
	65		6	7	0.857					





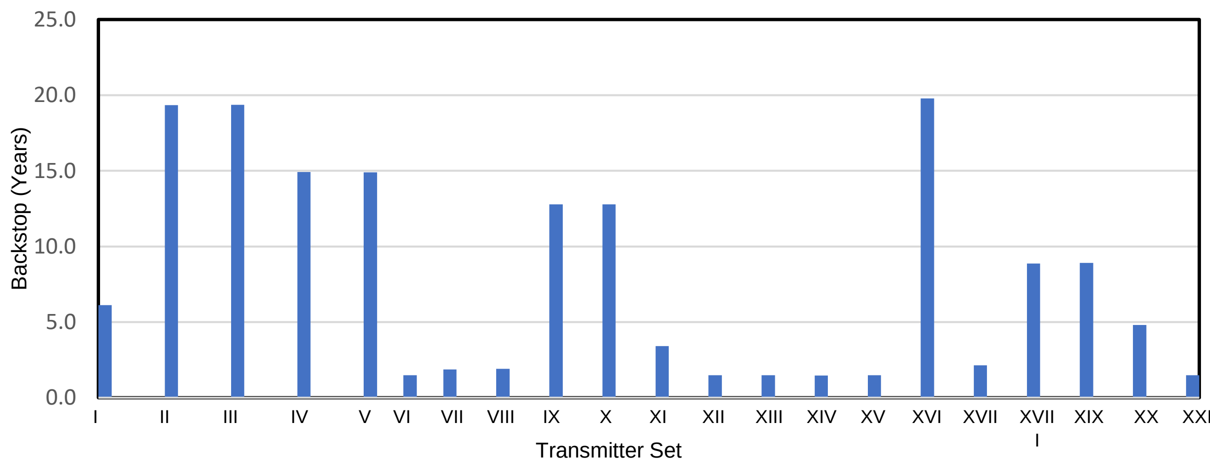


Figure 13.2. Bar Charts of Results of Table 13.6 for PWR Unit 2

14 OLM COVERAGE OF TRANSMITTER SETPOINTS AND RANGE

This chapter describes processes to address **[[ ]]**[a,b,f] Section 14.1 is concerned with OLM coverage of safety setpoints and Section 14.2 is concerned with OLM coverage of the full range of transmitters. **[[ ]]**[a,b,f]

14.1 COVERAGE OF SAFETY SETPOINTS

[[ ]][a,b,f]

Table 14.1 presents examples of typical transmitter services in a PWR plant and shows **[[ ]]**[a,b,f]

[[

]]a,b,f

Table 14.1. OLM Coverage Versus Setpoints for Representative PWR Services

Service	OLM Coverage	Setpoint	Difference	≤12.5%	Include in OLM?

[[ ]]a,b,f

14.2 COVERAGE OF FULL RANGE

[[

]]a,b,f

[[

]]a,b,f

[[

]]a,b,f

[[ ]]a,b,f

Figure 14.1. Examples of Deviation Versus Span Data for PWR Transmitters

Table 14.2 Data and Results of Evaluation of Unexercised Portions of Range

Item	Service	OLM Coverage	Setpoint	<50?	Difference	≤12.5?	Exceeds OLM Limit at 100%?	Schedule for Calibration Check?

[[ ]]a,b,f