Performance Demonstration for Steam Generator Tubing Analysts in Nuclear Power Plants

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1. Introduction

Korea Electric Power Research Institute (KEPRI) has developed performance demonstration programs for non-destructive examination personnel who analyze eddy current data for steam generator tubing since 2001. The purpose of these performance demonstration programs is to ensure a continuing uniform knowledge base and skill level for data analysts and contribute to safely operate nuclear power plants. According to the Notice 2004-13 of Ministry of Science and Technology (MOST), the analyst for steam generator tubing shall be qualified to QDA (Qualified Data Analyst) and SSPD (Site Specific Performance Demonstration). The analyst's performance is expected to be improved by the implementation of these programs.

2. Performance Demonstration

The performance demonstration programs for eddy current data analysts have been implemented since July 1, 2004 in accordance with the Notice 2004-13 of MOST [1]. In this section, requirements and procedures for QDA and SSPD are described in detail.

2.1 Qualified Data Analyst (QDA)

An individual who successfully completes the requirements described in Pressurized Water Reactor Steam Generator Examination Guidelines, Appendix G: Revision 6 [2] is recognized as a Qualified Data Analyst (QDA). An individual seeking qualification as a data analyst shall be certified Level Ⅱ or Ⅲ in eddy current examination. To be considered eligible for the examinations, applicants shall have completed the training course which consists of a minimum of 40 hours including classroom and laboratory exercises. To be considered a QDA after the completion of training, an analyst shall successfully pass both written and practical examinations for all damage mechanisms available at the time of testing.

For each written examination administered as part of the qualification examination, a question bank containing at least twice the minimum number of questions shall be available. Each qualification examination shall be assembled from the question bank using a random sampling process. The written examination shall contain a minimum of forty questions covering the lecture material. A grade of at least 80% shall be required to pass the written examination.

The practical examination shall consist of eddy current data sets that are randomly selected and contain indications indicative of all damage mechanisms covering steam generator operating experience. Each damage mechanism shall be represented by a data set. Pulled tube eddy current data shall be included in the data sets to the extent practical. The expert opinion is used to establish eddy current truth for grading purposes. Damage mechanism categories to be included in the practical examination are thinning, pitting, wear, outside diameter IGA/SCC, primary-side SCC and impingement damages. Adequate numbers of flawed and unflawed grading units shall be used to meet the probability of detection (POD), statistical confidence level (CL), and false-call requirements of Table 1. The practical examination shall contain a minimum of 11 flawed grading units for each damage mechanism category where only detection is being applied. The number of unflawed grading units selected for the practical examination shall be equal to at least twice the number of flawed grading units.

Table 1. Performance Demonstration Test Matrices for Flaw Detection and Sizing

Flaw Detection Acceptance Criteria for a Given Damage Mechanism Category					False Call Acceptance Criteria	
Total No. of Flawed Units	No. of Flawed Grading Units		Minimum Acceptance Criteria for Detection		Minimum No. of Unflawed Grading Units	Maximum No. of False Calls
	<40% <*	≥ 40% ≥ *	<40% <*	≥ 40% ≥ *		
16	5	11	4	11	32	3
17	5	12	4	12	34	3
18	6	12	5	12	36	4
25	8	17	7	17	50	5
26	8	18	7	17	52	5
36	12	24	10	23	72	7
37	12	25	10	23	74	7
46	15	31	12	29	92	9
47	15	32	12	29	94	9

* 80% POD, 90% CL applicable to the ≥ 40% TW data set.
* 80% POD, 90% CL applicable to the ≥ 1 volt with a voltage data set.
* 80% POD, 90% CL applicable to the ≥ 0.4 in. for axial length data set.
* 80% POD, 90% CL applicable to the ≥ 40° for circumferential length data set.

The practical examination shall contain a minimum of 16 flawed grading units for each damage mechanism category where both detection and sizing are being applied. The number of unflawed grading units selected for the practical examination shall be equal to at least twice the number of flawed grading units. For each practical examination data set, the individual shall be provided with a description of the examination

techniques performed along with a set of analysis guidelines for each technique.

Practical examinations for each data set shall be graded by one or more of the following methods depending on the technique applicability of detection, sizing, and orientation. Personnel shall be considered qualified for detection of a specific damage mechanism if all of the following requirements are met:

● A POD of at least 80%, at a 90% CL for flawed grading units≥ 40% TW, length (axial)≥ 0.4 in. (10.2 mm), length (circumferential)≥ 40° or amplitude≥ 1.0 volt.

● Detection of at least 80% of the flawed grading units <40% TW, length (axial)<0.4 in.(10.2 mm), length (circumferential)<40° or amplitude≥ 0.5 and <1.0 volt.

● The number of reported false calls is no more than 10% of the total number of unflawed grading units.

Personnel shall be considered qualified for performing sizing measurements on a specific damage mechanism if a root mean square error (RMSE) of less than or equal to 10% is demonstrated. The sample set, RMSE, is calculated using the following equation:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(M_i - T_i)^2} \quad (1)$$

where M_i is the eddy current measured flaw parameter assigned by the individual analyst for the *i*th indication, T_i is the eddy current measured flaw parameter for the *i*th indication determined by expert opinion, and *n* is the number of measured grading units in the data set. Personnel shall be considered qualified for determining orientation of a specific damage mechanism if the correct orientation is reported on at least 80% of the flawed grading units.

2.2 Site Specific Performance Demonstration (SSPD)

It is to a utility's advantage to orient and refresh the analyst to the current plant for which the analysis is being conducted and for the analyst to demonstrate the application of their skills to evaluate data from that plant. The SSPD can make analysts overcome the loss of their plant-specific knowledge due to the time that has passed since the previous outage at the plant. To assist the analyst in completing the SSPD, training on plant specifics is presented in classroom and laboratory sessions or by self-study. All individuals who will be involved in the analysis shall be required to participate in each examination of the formal SSPD process. Examination data shall contain plant-specific indications of interest with sufficient variety so that the analysis guidelines rule base is covered. For units with limited operating experience, or a lack of active damage mechanisms and associated data, examination data from similar plants with active damage mechanisms should be relied on when assembling the performance demonstration data set. An additional supplemental written examination may be warranted to cover additional points in the guidelines that are not readily demonstrated with the practical examination. The SSPD program in Korea is categorized with 5 models: W-delta 60, W-F, Framatome, KSNP, and CANDU model.

The following rules are applied in written examination: A score of 80% is required to pass. A time limit of 2 hours is allowed for the test. In the event that an 80% score is not achieved, additional training and re-examination will be required. In the event that an 80% score is not achieved on the re-examination, the individual will not be allowed to analyze data at that plant during that outage. In practical examination, the following rules are applied: A score of 80% minimum is required to pass. Only two attempts are permitted. All missed indications shall be reviewed with the examinee. If the examinee fails the first demonstration, additional one on one training by the Level Ⅲ shall be performed on missed indications and any general area deemed necessary by the Level Ⅲ. The scoring scheme of the practical examination is shown in Table 2.

Table 2. Scoring Scheme for the Practical Examination

Indication Category	Actual %TW	Not Called	Sizing Error	Mismatched Code	Location Error
TW Indication	40-100%	-10	-1	NA	-1
	20-39%	-5	-1	NA	-1
	<20%	-2	-1	NA	-1
SAI,MAI,SCI,MCI	ALL	-10	NA	-5	-1
Other 3-L Codes	ALL	-2	NA	-1	-1
Orientation	ALL	NA	NA	-2	NA
False Call	-1 per 10 false calls				

3. Conclusion

A single missed or incorrectly classified defect indication in eddy current data of steam generator tubing can lead to a plant shutdown or a tube rupture event. To reduce the likelihood of these consequences, the analyst's performance shall be thoroughly demonstrated. KEPRI established QDA and SSPD programs for performance demonstration of steam generator tubing analysts. QDA software was introduced from EPRI and has been operated since 2004 in accordance with the EPRI Guidelines, Appendix G [2]. KEPRI developed SSPD database and this program is being implemented in accordance with the Notice 2004-13 of MOST. The analyst's performance is expected to be improved by the implementation of these programs.

REFERENCES

[1] Ministry of Science & Technology, Notice 2004-13, The Regulation on In-Service Inspection of Nuclear Facilities, 2004.

[2] Electric Power Research Institute, Pressurized Water Reactor Steam Generator Examination Guidelines: Revision 6, Appendix G, 2002.