Journal of the Korean Society for Nondestructive Testing
Vol. 25, No. 3 (2005. 6)

Development of Performance Demonstration Programs for Eddy Current Data Analysis

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Abstract The Korea Electric Power Research Institute (KEPRI) has developed performance demonstration programs for non-destructive testing personnel who analyze ECT(eddy current testing) data for steam generator tubing since 2001. The purpose of these performance demonstration programs is to ensure a uniform knowledge and skill level of data analysts and contribute to safe operation of nuclear power plants. Many changes have occurred in non-destructive testing of steam generator tubing such as inspection scope, plugging criteria and qualification requirements. According to the Notice 2004-13 revised by the Ministry of Science and Technology (MOST), the analyst for steam generator tubing shall be qualified as the qualified data analyst (QDA), and the site specific performance demonstration (SSPD) program shall be implemented. KEPRI developed these performance demonstration programs and they are being successfully implemented. The analyst's performance is expected to be improved by the implementation of these programs.

1. Introduction

Each of the eddy current test signals encountered during the steam generator examination needs to be recognized and correctly classified. A single missed or incorrectly classified defect indication can lead to a plant shutdown or a tube rupture event. Therefore the analyst's performance should be demonstrated by proper tools. The Notice 2004-13 states that all analysts shall be qualified as QDA, and the SSPD program shall be implemented (Most, 2004).

An individual who successfully completes the requirement described in the Pressurized Water Reactor Steam Generator Examination Guidelines, Appendix G: Revision 6 (EPRI, 2002) is recognized as the QDA. KEPRI worked with EPRI (Electric Power Research Institute) to establish a performance demonstration program. The QDA program was introduced from EPRI and installed on KEPRI server.

The SSPD can make analysts overcome the lapse of memory on their plant-specific knowledge since the previous outage at the plant. KEPRI developed the SSPD procedures and database from previous ECT data of all units in Korea. The SSPD database in Korea is categorized into five models: W-delta 60, W-F, Framatome, KSNP (Korea Standard Nuclear Power Plant), and CANDU model. These performance demonstration programs for ECT data analysts have been implemented since July 1, 2004 in accordance with the Notice 2004-13 of MOST.

2. Performance Demonstration

All analysts for steam generator tubing in nuclear powers plant shall be qualified by QDA and SSPD programs according to the Notice 2004-13 of MOST in Korea. In this section, requirements and procedures for QDA and SSPD programs are described in detail.

Received: April 8, 2005. Accepted: June 9, 2005. Korea Electric Power Research Institute, Daejeon 305-380,
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2.1. Qualified Data Analyst

An individual who successfully completes the requirements described in the Pressurized Water Reactor Steam Generator Examination Guidelines, Appendix G: Revision 6 is recognized as the QDA. An individual seeking the qualification as a data analyst shall be the certified Level II or Level III holder in ECT. To be eligible for the examination, applicants shall have completed the training course which consists of at least 40 hours of classroom and laboratory exercises. To be 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 qualifying examination, a question bank containing at least twice the number of questions shall be available. Each qualifying 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 ECT data sets that are randomly selected and contain indications of all damage mechanisms covering the steam generator operating experience. Each damage mechanism shall be represented by a data set. Eddy current data from the pulled tube shall be included in the data sets to the extent of practical examination. 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 Inter Granular Attack/Stress Corrosion Cracking(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. In constructing Table 1, calculations from the binomial distribution determined the minimum number of successes, x required in examining a flaw data set of size n

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	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.

to ensure, at a CL of 90%, that the actual POD is 80% or greater. The binomial distribution provides the probability of each possible outcome over a specified number of trials when only two outcomes are possible on each trial-success or failure-and the likelihood of a success or failure is known or assumed. The probability of exactly x successes in n trials, when the probability of success on each trial is p, is calculated as follows:

$$P(x|\ n, p) = \frac{n!}{x!(n-x)!} p^x (1-p)^{n-x} \quad (1)$$

This expression can be used to calculate the minimum number of detections required from a sample set of given size to be ensured, at a confidence level of 90%, that the actual POD is equal to or greater than 0.80. Starting with the largest number of detections possible (n), the probability of that number of detections is calculated and that of each lesser number of detections (n-1, n-2, etc.) so that when the probabilities are added together they do not exceed a combined probability of 0.10.

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 at least twice the number of flawed grading units. 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 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's applicability to 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 $\geq$ 40% TW, length (axial) $\geq$ 0.4 in. (10.2 mm), length (circumferential) $\geq$ 40° or amplitude $\geq$ 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 $\geq$ 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 size measurements of a specific damage mechanism if a root mean square error (RMSE) of less than or equal to 10% is demonstrated. In the sample set, RMSE, is calculated as follows:

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

where M_i is the measured flaw parameter judged by the individual analyst for the ith indication, T_i is the measured flaw parameter for the ith indication determined by experts, 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.

Re-qualification shall be required every five years. The re-qualifying practical examination shall consist of a randomly generated set of data from the test database for the techniques and damage mechanisms that were successfully completed in prior QDA qualification. The grading shall be based on POD, CL, RMSE, false calls, and orientation depending on the technique's applicability. The POD shall be based on an all-inclusive grading scheme (a single POD for all techniques and damage mechanisms). If the individual fails to meet any of the POD,

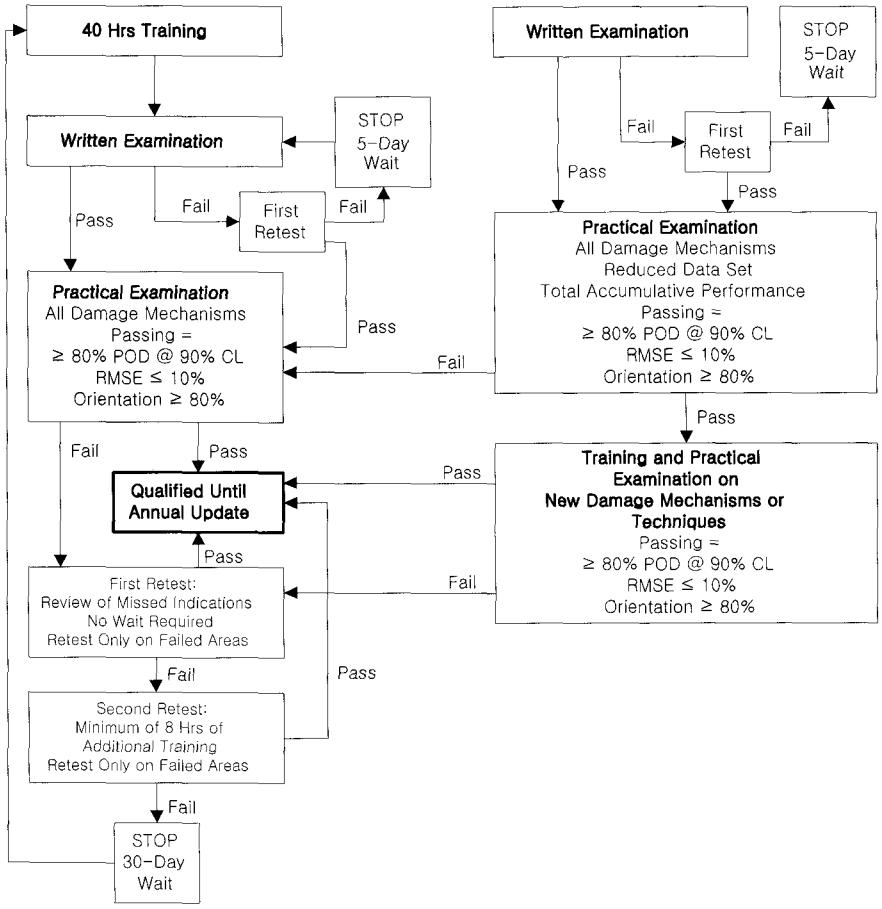

Fig. 1 Flow Diagram of Qualification and Requalification Processes

CL, RMSE, false calls, or orientation on the first attempt, a full QDA test shall be required. Fig. 1 shows the flow diagram for the initial and requalification process of QDA test.

The performance demonstration of QDA in Korea was officially commenced on July 1, 2004. The total of twenty six candidates have been applied for QDA test, and twenty two completed successfully by March, 2005.

2.2 Site Specific Performance Demonstration

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 analysts to demonstrate the application of their skills to evaluate data from that plant. The SSPD can make the 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 interests with sufficient variety so that the rule of the analysis guideline 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

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				

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. Since there are many types of operating steam generators in Korea, the SSPD database is categorized into five models: W-delta 60, W-F, Framatome, KSNP, and CANDU model.

The following rules are applied in the 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 the 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 holder shall be performed on missed indications and any general area deemed necessary by the Level Ⅲ holder. The scoring scheme of the practical examination is shown in Table 2.

The total of 224 analysts have taken the SSPD examination by March, 2005: 30 for W-delta 60, 48 for W-F, 29 for Framatome, 85 for KSNP, 32 for CANDU model.

3. Conclusion

A single missed or incorrectly classified defect indication in ECT data of steam generator tubing can lead to a plant shutdown or a tube rupture event. To reduce the possibility of such consequences, the analyst's performance should be throughly demonstrated. KEPRI established QDA and SSPD programs for performance demonstration of steam generator tubing analysts. QDA software was introduced from EPRI and installed on the KEPRI server. The QDA program has been operated since 2004 in accordance with the EPRI PWR Steam Generator Examination Guidelines, Revision 6, Appendix G [2]. KEPRI developed the SSPD procedures and ECT database. These performance demonstration programs are being successfully implemented in accordance with the Notice 2004-13 of MOST in Korea. The analyst's performance is expected to be improved by the implementation of these programs.

References

EPRI (2002) *Pressurized Water Reactor Steam Generator Examination Guidelines*: Revision 6, Appendix G

MOST (2004) Notice 2004-13, *The Regulation on In-Service Inspection of Nuclear Facilities*

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