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Preliminary Assessment of Equivalency for a New Eddy Current System

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1. Introduction

Eddy current techniques used for steam generator tubing inspection should be qualified in accordance with the EPRI examination guidelines. When components of a qualified system are changed, verification of equivalency to the originally qualified system must be performed. The Steam Generator Management Program (SGMP) guidelines require that Examination Technique Specification Sheets (ETSS) define essential variables for equipment, techniques, and analysis. Examination techniques with essential variables that vary within the ranges identified in the ETSS are considered equivalent. Steam generator tubes have been inspected using the ZETEC system, which is qualified in ETSSs, in Korea. The Korea Hydro & Nuclear Power Co., Ltd. (KHNP) has developed a new eddy current testing system for steam generator tubing inspection. This system is composed of SM-25 fixture controller, eddy current tester, probe push-puller control system, data acquisition and analysis software. The control system of SM-25 remote fixture is used to place the guide-tube at the correct and accurate position of each steam generator tube. The eddy current tester is composed of synthesizer, analog processor, and analog-to digital conversion board. The probe push-puller system is used to move the bobbin and rotating probe for data acquisition. The newly developed data acquisition, analysis, and management programs are based on the Windows operating system, while the ZETEC on the Unix-based. This paper describes characteristics of the new system and preliminary assessment of equivalency to the qualified system in detail.

2. Newly developed Eddy Current System

2.1 Characteristics of New Eddy Current System

The new eddy current system being developed by KHNP is composed of not only hardware such as SM-25 fixture controller, eddy current tester, and probe push-puller control system as shown in figure 1 but software for data acquisition, analysis, and management. The SM-25 remote fixture is installed in the steam generator chamber for tube inspection. The fixture controller makes the position of inspection probe place correctly and accurately on the spot of the tube end which is to be inspected based on the test plan. The eddy current tester comprises a central processing unit, a frequency synthesizer, an analog processor, and an analog to digital converter. It performs all testing functions including wide-range frequency generation, in-phase, and quadrature signal digitalization. The probe push-puller control system includes motion control circuitry which allows precise control of the probe's travel speed and provides smooth transition between low- and high-speeds without time consuming gear changes.

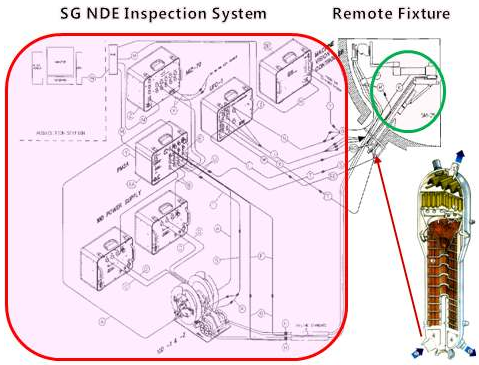

Fig. 1. Eddy Current System for SG Tube Inspection

The data acquisition program provides the functions of fixture movement, adjustment of guide-tube location, probe movement, and eddy current data storage. Flaw detection and sizing for bobbin and rotating probe data can be obtained from the data analysis program. It also allows the comparison for two separate analysts' results and resolution of their discrepancies. An example of flaw signals from data analysis program is shown in Fig. 2. Integrated test management such as inspection plan, data segment recall, historical management of data is achieved from the data management program. The acquisition, analysis, and management programs run on the Windows operating system.

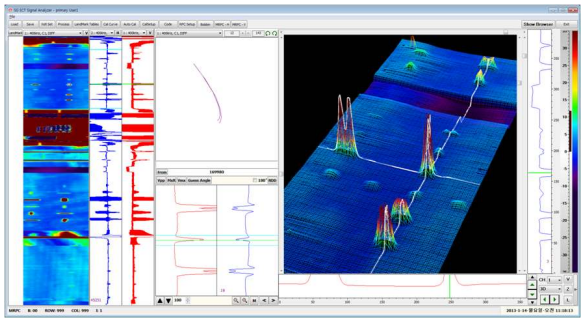

Fig. 2. Data Analysis Program for SG Tube Inspection

2.2 Technique Equivalency for Eddy Current Test

The qualified techniques for SG tubing inspection are listed on the EPRI performance demonstration database

as the form of ETSS [1]. An ETSS defines essential variables for equipment, techniques, and analysis such as tube material, diameter, wall thickness, probe type, probe length, fill factor, instrument, extension cable, frequency, gain, sample rate, test speed, calibration standard, and software. When components of a qualified system are changed, verification of equivalency to the originally qualified system must be performed. Examination techniques with essential variables that vary within the ranges identified in the ETSS are considered equivalent. Tolerances were categorized from the EPRI equivalency project are as follows [2]:

For bobbin techniques,

- The amplitude voltage response from the 4x20% through-wall flat-bottom holes (TW FBHs) must be ≥ 80% of the raw signal response from the qualified technique.
- All normalized FBH responses must be within ±40% of the qualified technique.
- If the tube diameter is the same as that in the qualified technique, then the normalized amplitude voltage response of the 100% deep TW hole must be within ±40% of the qualified technique.
- The phase angle responses of the FBH and TW hole flaws must be within 20 degrees (±20 degrees).

For rotating probe techniques,

- The non-normalized amplitude voltage response from the 100% TW hole by 0.375”(9.5mm) long axial notch must be ≥ 80% of the raw signal response from the qualified technique.
- All normalized notch amplitude voltage responses (0.375”[9.5mm] long, ID and OD 40%, 60%, and 100% TW) must be within ±20% of the qualified technique.
- The phase angle responses of the EDM notches must be within 10 degrees (±10 degrees).

3. Results

It is necessary that the newly developed system be satisfied with the requirements of equivalency stated above. Equivalency test only for bobbin data was performed in this study. The qualified EPRI ETSS 96007.1 [1] was chosen for the assessment, which is used in the field inspection of steam generator tubes in Korea. This ETSS is applied for the detection of IGA/ODSCC (Inter Granular Attack/Outside Diameter Stress Corrosion Cracking) at non-dented drilled tube support plates. Table 1 shows the comparison for essential variables of ETSS 96007.1 and the new system. Normalized voltage and phase of the process frequency were measured for the comparison. Raw (non-normalized) signal response is not included in this preliminary assessment. The differences of the measurements between the ETSS and the new system are shown in Table 2. As shown in Table 2, the newly developed system is satisfied with the equivalency requirements.

Table 1. Essential Variables of ETSS and New System

Essential Variables	ETSS 96007.1	New System
Material	I-600	I-690
Tube OD (in.)	0.750/0.875	0.750
Tube wall (in.)	0.043/0.050	0.043
Relative Current Density	19.65@550kHz 45.34@130kHz	22.24@550kHz 48.15@130kHz
Coil Spacing (in.)	0.06	0.06
Probe Type	Bobbin MR	Bobbin MR
Instrument	MIZ-18	New System
Acquisition Software	Eddynet/ANSER	New Software
Probe Manufacturer	Zetec	Zetec
Fill Factor	86	86
Frequency	550/130	550/150
Sample Rate	33	40
Test Speed (in./sec)	12	40
Analysis Software	Eddynet	New Software
Calibration Standard	ASME	ASME

Table 2. Comparison Data for ETSS and New System

Flaws	ETSS 96007.1	New System	Difference
4x20% FBH (V)	2.36@550kHz	-	-
Non-normalized	8.28@130kHz	-	-
4x20% FBH (V) Normalized	4@550/130kHz	4@550/130kHz	0%
40% FBH (V) Normalized	4.28@550/130	4.61@550/130	8%
60% FBH (V) Normalized	6.17@550/130	6.78@550/130	10%
100% TWH (V) Normalized	6.39@550/130	7.10@550/130	11%
4x20% FBH (deg.) Normalized	133°@550/130	122°@550/130	-11°
40% FBH (deg.) Normalized	108°@550/130	105°@550/130	-3°
60% FBH (deg.) Normalized	90°@550/130	85°@550/130	-5°
100% TWH (deg.) Normalized	35°@550/130	35°@550/130	0°

4. Conclusions

The KHNP is developing a new eddy current testing system for steam generator tubing inspection. Performance of the new system should be verified in accordance with requirements for the equivalency in order to be used for field inspections. Preliminary assessment of equivalency was carried out in this study. The results show that the new system is satisfied with the equivalency requirements for bobbin probe data. Further study for rotating probe data will be conducted to determine whether the new system can be used for steam generator tubing inspection in nuclear power plants.

REFERENCES

[1] Pressurized Water Reactor Steam Generator Examination Guidelines: Revision 7, EPRI SGMP TR-1013706, Appendix H, 2007.
[2] Development of Documentation for Examination Technique Equivalencies, EPRI SGMP TR-1020992, 2010.