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A Review of The Deposit Influenced BOW Signals in The SG Tubes

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1. Introduction

Steam generator tube, as a barrier isolating primary to the secondary coolant system of nuclear power plants, must maintain the structural integrity and function as well. In the EC examination of the steam generator tubes in the domestic nuclear power plants, BOW signals are often encountered in the upper free span area. BOW signals represents the locally curved and even abnormally approaching condition to the neighboring tubes. In the event of Palo Verde Nuclear Generation(PVNG)[1,2], BOW signals detected in the upper bundle area caused serious tube rupture in 1991. In this review, BOW signals screened by the deposit clusters and ding signals are discussed. And finally diagnostic methods for the detection of flaws affected by the BOW signals are presented as a way of proactive measures to the integrity of the steam generator tubes.

2. Methods and Results

In this section, characteristic BOW signals formation and deposit accumulation processes are introduced and deposit cluster and ding signals screening the BOW signals are also explained by means of EC signal in the Lissajous plane. In order to detect flaws covered and mixed by deposit cluster, signal mixing processes are very significant factors in the signal analysis aspects. As results of this review, signal mixing methods are to be presented.

2.1 BOW and Deposit Signal Formation Process

The BOW signals are primarily caused by the locally curved area in the upper tube support structure. Due to the broadly curved condition of the tube, dispersed ding signals are detected and BOW signals are formed at the opposite side of circumferentially 180 deg. off. BOW signals are also to be formed in the neighboring tube, since these two tubes are abnormally approached and facing each other. According to the condition of these two tubes the circumferential deg. difference of these two signals are 180.

In the BOW signal detected secondary side of the steam generator tubes, the atmosphere is different from the normal part of the tube and the flow of secondary water is restricted. Consequently deposit cluster is formed and deposit is built up without being flushed. Figure 1 is the integrated C-scan graphics of ding, deposit and BOW signals. Due to the affects of the curved shape, ding signals are shown in the upper side tube.

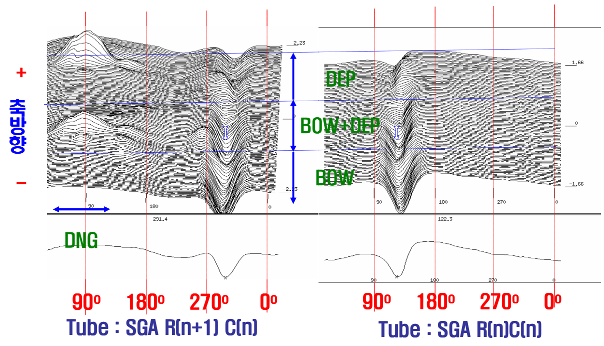

Figure 1. C-scan graphics of ding, deposit and BOW signals. Abnormally curved tube in the upper side(left) and normally configured lower tube(right) produce BOW and deposit signals in both tubes. Output signal is 100kHz EC Motorized Pancake Coil(RPC)

2.2 BOW Signal Screening by Deposit Accumulation

EC signals are characterized by the analysis of the amplitude and the phase angle of the signal.[3] According to the study on the influences of secondary side foreign materials to the tube[4], signal amplitude stands for the dimension of the affecting factors to the tube and phase angle reflects the material's electrical conductivity. In this review, deposit and BOW signals are assumed to be affected by foreign materials such as hard sludge and alloy600(the material of the SG tube), respectively.

Table 1 shows the amplitude and phase angle variation of foreign materials contacting to the secondary side of the tube.

Table 1. Amplitude and phase angle variation of materials

Frequency / Material	400 kHz		300 kHz		100 kHz		10 kHz	
	Amplitude	Phase	Amplitude	Phase	Amplitude	Phase	Amplitude	Phase
Copper (Cu)	1.9	24°	2.85	7°	2.23	310°	0.16	235°
Titanium (Ti)	5.18	1°	7.28	342°	4.00	277°	0.09	192°
Inconel600 (I600)	3.43	357°	4.72	339°	2.46	272°	0.05	180°
Stainless steel (Ss)	2.68	354°	3.55	332°	1.77	258°	0.06	117°
Monel (Mo)	1.59	255°	2.67	234°	3.31	171°	0.59	93°
Carbon steel (Cs)	1.81	250°	2.94	232°	3.54	171°	0.66	93°
SUS430 (Su)	1.43	242°	2.37	224°	2.79	163°	0.46	88°
Pure Nickel (Ni)	1.97	240°	3.18	222°	3.59	161°	0.54	87°
Hard SLG (H SLG)	2.04	217°	3.08	201°	2.84	147°	0.34	82°
SLG (SLG)	0.98	210°	1.49	192°	1.23	138°	0.13	78°

As stated in Fig. 1, BOW and deposit area is divided into three regions, ie. BOW, transition and deposit regions. BOW and deposit elements coexist in the transition region. Fig. 2 shows the lissajous plane signals varying from BOW to deposit region. From the experimental results of the phase angle of materials contacting the secondary side of the tube[4], the phase angle of BOW and deposit is approximately 270° and 140°, respectively[4]. As the signal changes from BOW region(1,2,3) to the deposit region(7,8), phase angle decreases toward to the CCW direction.

In the transition region(4, 5, 6), the components of horizontal signal is more dominant than that of vertical signal. Accordingly, it's imperative to employ the adequate technique to discriminate the deposit signals from BOW signals, since the deposit signals formed on the BOW area can screen the BOW signals and eventually accelerate the degradation atmosphere of the tube.

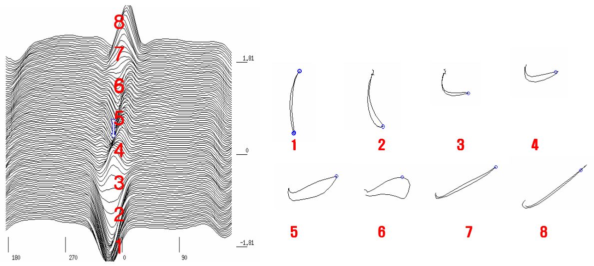

Figure 2. Phase angle shift tendency from the BOW region to the deposit region in the Lissajous plane. In the Lissajous plane, 0° is set on the –X and increases to the CW direction. Output signal is 100kHz EC Motorized Pancake Coil(RPC)

2.3 Analysis Technique Development for Detecting Flaws in the BOW and Deposit area

On the basis of safety oriented measures and the lessons learned from the cases of PVNG SG tube rupture, EC RPC data sets of SG tubes of domestic nuclear power plants retaining BOW signals are reviewed. In the process of analyzing, some undefinable but not reportable signals are found especially in the transition area. As a conventional EC analysis method of eliminating unwanted signals is mixing process[5]. However, in the case of holding variety of variables in the tube, some ambiguous residual signals are not clearly eliminated in the interesting area. In order to correctly diagnose and detect the flaws in the complicated area, corresponding signal mixing process is needed.

3. Conclusion

For the purpose of detecting and characterizing flaws in the deposit influenced BOW area, it is imperative to understand the BOW signal formation process, deposit accumulation sequences and even classified signal mixing skills. Providing BOW signals detected area is inspected and analyzed by applying properly developed signal evaluation techniques, the integrity of the tube is to be maintained and degradation of the tube is timely prohibited

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