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Visual Inspection of the Flow Distribution Plate Bolts of a Nuclear Steam Generator

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1. Introduction

To develop a system for visually inspecting the flow distribution plate (FDP) bolts of a nuclear steam generator, we reviewed several types of similar inspection equipments. The equipments which are currently available are mostly for inspecting lower part of a steam generator such as tube sheets and annulus except ELVS (Eggcrate Visual Inspection System). However, the design concept of ELVS could not be used for developing a device which enables the visual inspection of flow distribution plate bolts. Therefore, based on the current state of the art technology on the similar equipments, we conceptually designed a new inspection system for checking the FDP bolts.

2. SG Visual Inspection System

The visual inspection plans are essential to obtain the most pertinent visual inspection information from the steam generators given the finite amount of time available for this service. The inspection scope and plan can be focused by reviewing the known and/or projected steam generator conditions and working together with utility and service leads to identify the inspection priorities and expectations. Data collected during steam generators visual inspections document the condition of the steam generator and are used in junction with other SG secondary side status/condition monitoring input to develop the SG secondary side operational assessment and make recommendations for future steam generator maintenance activities.

Currently, steam generator visual inspection services were performed as the followings in many areas.

2.1 Top of the Tubesheet Inspection

Video probes by manual operation provide a basic and limited inspection capability for looking at the tubelane, annulus, and in-bundle areas on the top of tubesheet. The use of this technique requires an operator stationed at the hand-hole to manipulate and control the probe. To perform a more extensive annulus inspection and foreign object and retrieval at the TTS while ALARA objectives, Westinghouse and R. Brooks Associates have developed SWATS (Shell/Wrapper Annulus Transport System) for use in most SG.

2.1.1 Remote Annulus FOSAR Services

Remote inspection of the annulus can be performed to locate and subsequently retrieve foreign objects. The designed system for this service is called as SWATS (Shell/Wrapper Annulus Transport System). The SWATS system is capable of performing remote horizontal and vertical visual inspection of the tubesheet and upper/lower wrapper support structures in the downcomer/annulus region on the secondary side of steam generators

2.2 Tube Bundle Visual Inspection

In accordance with NRC Generic Letter 97-06, a program to address degradation of steam generator internals needs to consider the integrity of tube support plates and the tube bundle wrapper. Visual inspection within the steam generator tube bundle is a viable technique to provide this assessment. Currently, there are four techniques available to perform a remote visual inspection of the tube bundle region. They include, upper bundle in bundle (UBIB) inspection system, eggcrate lattice visual inspection system (ELVS), support inspection device (SID), and CECIL-4.

2.2.1 Upper Bundle in Bundle (UBIB) Inspection System

UBIB is the tool capable of remotely inspecting into the tube bundle at various upper support plate elevations. The system provides variable information on the tube support plate fouling, quatrefoil blockage, in-bundle deposit accumulation and corrosion. It is installed horizontally through an existing handhole, then raised to a vertical position and remotely extended upward through the flow slots to examine in-bundle regions of square pitch steam generators.

2.2.2 Eggcrate Lattice Visual Inspection System (ELVS)

The Eggcrate Lattice Visual Inspection System (ELVS) is a remotely operated inspection tool capable of inspecting the periphery region and support lattices on the secondary side of Combustion Engineering designed steam generators.

2.2.3 Support Plate Inspection Device (SID)

SID provides remote visual inspection services in the upper bundle flow slot areas of the steam generator. The system is installed horizontally through an existing handhole. SID moves radially toward the center stayrod until it is located under one of the flow slots, thereafter it is raised to a vertical position. SID is remotely elevated by a hydraulic system to fully extend upward.

2.2.4 CECIL-4

CECIL-4 is designed to remove sludge accumulated on the top of tubesheet and in the tube bundle. It is designed for tubesheet lancing. However, in-bundle inspection is also possible using the fiberscope which is embedded in the flexible lance. The flexible lance is designed to be able to move along the gap between the tubes for removing hardened scale more effectively using pressurized water.

3. Design of FDP Visual Inspection System

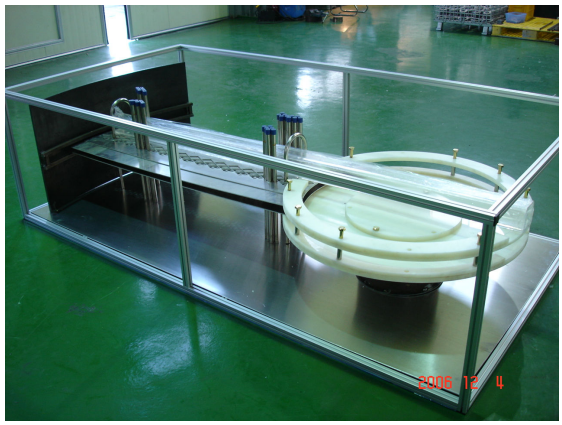
Two FDPs are installed to the Ulchin #5, 6 System-80 steam generators to minimize flow induced wear and vibration of U-bend area of SG tube bundle. The FDPs are attached to the eggcrate by bolts. The bolts are tightened and welded to the FDPs. However, inspection of the bolts during plant outage is recommended by KINS (Korea Institute of Nuclear Safety). Therefore, a project to develop a system for visually inspecting the FDP bolts is started on September 2006 by KEPRI (Korea Electric Power Research Institute).

3.1 Conceptual Design

Two methods for visually inspecting the FDB bolts were carefully reviewed. One is making a new handhole on the shell and wrapper of SG which enables the FDP bolts to be accessed. This is the easiest way for inspecting the FDP bolts. However, KHNP does not like this idea because it makes another licensing issue. The other is making a tool for approaching the FDP bolts. Several tool designs were developed and carefully reviewed. Among the design candidates, we selected a video probe approach imbedded in a urethane strip of rectangular cross section. Thereafter, we made a dummy tool using urethane and put it into the Ulchin #5, 6 SG for evaluating the feasibility of the conceptual design. However, approaching the FDP bolts was not easy using the dummy tool. Therefore, we developed a modified design which use video probe embedded in aluminum guide tube. The inspection system based on the new design would be lighter and easier to handle

3.2 Steam Generator Mock-up Design

We designed a SG mock-up for testing the feasibility of various design concepts. The wrapper, the eggcrate, the FDPs, and the FDP bolts are designed and fabricated based on the drawing supplied by Doosan Heavy Industries and Construction Co. The picture below shows the SG mock-up..



3.3 Selection of Video Probe

Video probe was selected for visually inspecting the FDP bolts because it was water proof, able to access very narrow space and transmit light. However, our major concern was the radiation effects on glass fiber. Based on the data provided by video probe maker, we concluded that the life expectancy of a video probe is dependent on fiber material. Light output decreased as the fiber is exposed to radiation. Light output of grass fiber is reduced to a half when it is exposed to 727 Rads compared to 352,000 Rads of quarts fiber. However, video probe made of quartz fibers is more expensive and the radiation level of the inspection area of FDP bolts is relatively low. Therefore, using a video probe made of quartz fibers is not indispensable in our case. We are going to decide which type of probe to use based on data from Ulchin #5, 6.

4. Conclusions

SWATS, UBIB, ELVS, and SID are reviewed for developing a new visual inspection system. A conceptual design was developed for visually inspecting FDP bolts of Ulchin #5, 6 SG. The KEPRI developed inspection system is composed of a video probe, the guide tube, and servo motors etc. The components which are put inside of SG are minimized to remove any possible risk caused by loose parts. Furthermore, the system could be completely removed from inside of SG by electrical and/or manual means.

REFERENCES

[1] Woo Tae Jeong et al., “Development of FOSAR Remote control Equipment for Kori #3,4 SG,” Internal Technical Report, KHNP, 2004.