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Field Demonstration of Fuel Crud Filtration System at Ulchin Plant

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1. Introduction

Crud deposited onto the fuel assemblies in nuclear power plants was not a serious problem until an upper core flux depression named Axial Offset Anomaly (AOA) was found at Callaway, USA in 1989. Though the mechanism of an AOA is not completely understood, crud is believed to be a key component of initiating AOA. After the sufficient amount of corrosion products in the reactor cooling system are deposited on the fuel clad by a sub-cooled nucleate boiling, boron is adsorbed in the crud. Thus a measurable reduction in the neutron flux occurs which causes an AOA problem. A filtration system has been developed to remove the fuel crud from irradiated fuel assemblies for mitigating the axial offset anomaly under a technical cooperation agreement with DEI (Dominion Engineering Inc.). This filtration system with a fuel cleaning fixture was successfully demonstrated at Ulchin plant unit 2. Within several minutes, detachable crud deposits were effectively removed from the clad surfaces of the fuel assembly. Also, to characterize the crud particles for each fuel assembly, a small crud sampling device and radiation monitor devices were connected to the filtration system during the cleaning operation.

In this study, we completed a functional test and demonstration of an ultrasonic fuel cleaning system by using four spent fuel assemblies. It took only 5 minutes to remove the fuel crud from each fuel assembly. In addition, collective dose rates indicated an average of 8 R/Hr per assembly.

2. Radioactive Crud Removal

2.1 Fuel Crud Filtration System

Figure 1 shows the independent underwater Crud filtration system used to collect deposits that are loosened in the cleaning fixture. This system is assembled on a system mounted to the wall of the cask loading pit and supported by the adjacent floor. The system comprises: 1) fully redundant process pumps, 2) parallel flow filter sets [four filters in each set], 3) flow control valves 4) flow, pressure and temperature sensors, 5) radiation monitor devices on both the filter inlet stream and the filter cartridges, and 6) isokinetic sampler for the filter inlet. The system takes suction from the fuel cleaning fixture via a hose connection.

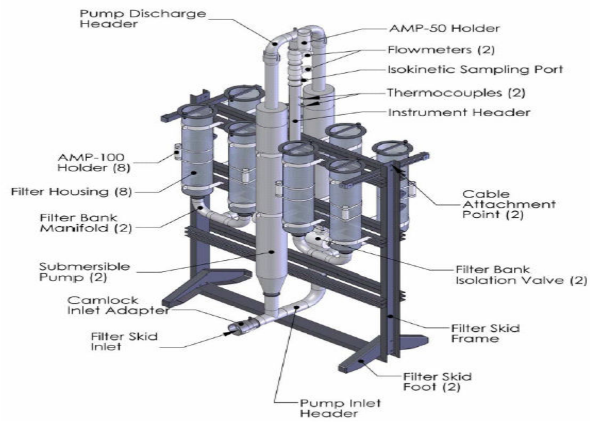


Figure 1. Filtration system overview

The cleaning process is monitored by a gamma detector at the inlet to the pumps, tuned to Co-58 and Co-60. Gamma detectors are provided on each filter canister in each filter bank to monitor the activity of crud captured by the filters. Water flow rate, water temperature, and differential pressure across the filters are also monitored during cleaning process. Cleaning performance is visually confirmed by underwater camera aimed at the fuel assembly as it is inserted into and removed from the cleaning fixture.

2.2 Analysis of crud

Particle size information is necessary to select an adequate pore size of the filter to collect the cruds released from the fuel assembly by an ultrasonic operation. Thus, a size distribution measurement was carried out with well crystallized samples. Crud samples were taken from two spent fuel rods of Yonggwang Unit-1 cycle 14 in the post irradiation examination facility of KAERI (Korea Atomic Energy Research Institute). Sticky tape and steel knife were used to collect the cruds from the fuel rods. For the P09-B17 fuel rod, samples were taken with sticky tapes at 3,000mm and 400mm from the bottom of the fuel rod. Cruds at 3,000mm produced well crystallized particles while those taken at 400mm produced non-crystalline particles. It indicates that the upper part of the fuel assembly provides a better condition to form a crud deposit due to its higher temperature.

Figure 2 shows the size distribution of the crud particles taken at 3,000mm of the P09-B17 fuel rod. Even though fine particles smaller than 0.5 μm were abundant, the total weight was less than 5%. It indicates that more than 95wt% crud particles can be collected by using a 0.5 ㎛ filter.

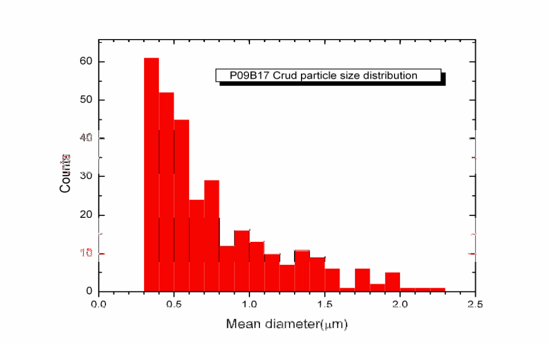


Figure 2. Particle size distribution of crud sample at 3,000mm of P09-B17

3. Field demonstration at Ulchin plant

The crud filtration system was successfully installed in the cask loading pit at Ulchin Unit 2. Figure 3 shows the cleaning fixture and filtration system in the cask loading pit.

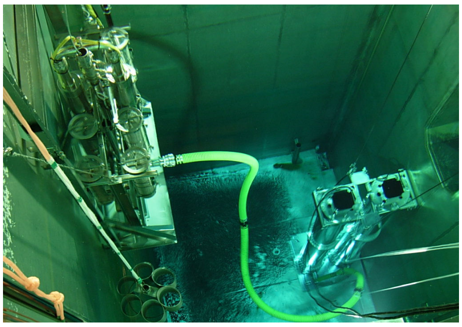
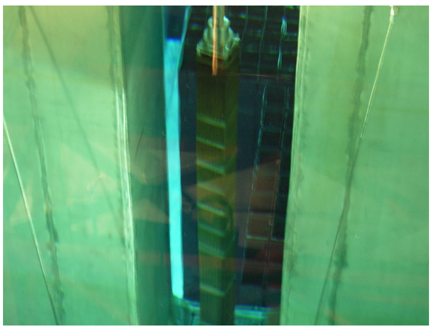


Figure 3. Cleaning fixture and filtration system

Four fuel assemblies were cleaned using ultrasonics to assess the performance of filtration system and cleaning fixture. These fuel assemblies were all twice-burned Vantage 5H assemblies with burn-ups between 42,000 and 45,000 MWD/MTU. Each fuel assembly was cleaned for six minutes while recirculating flow through the filtration system at approximately 165 gpm. To assess cleaning efficiency, visual inspections on all four sides of each fuel assembly were performed and recorded before and after cleaning. Figure 4 shows the typical appearance of a fuel assembly before and after ultrasonic fuel cleaning.



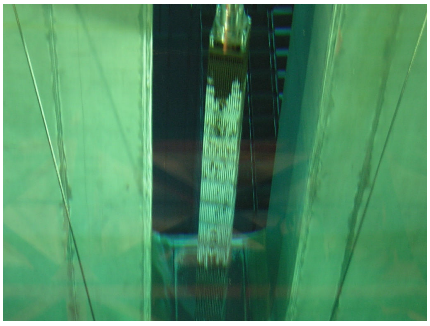


Figure 4. Appearance of fuel assembly before and after fuel cleaning

Three gamma detectors were located in the filtration system to measure the dose rates on one of the four main filters, on suction line between cleaning fixture and filtration system, and on the isokinetic sampling system filter. Figure 5 shows the dose rate measurements for one of four fuel assemblies during cleaning. The main filter dose rate typically increased approximately 2 R/hr per fuel assembly. Inline detector dose rate typically peaked at between 80-130 mR/hr and the isokinetic sampling filter typically reached between 80-120 mR/hr. Judging from figure 5, a typical cleaning cycle to remove all friable crud required only about 5 minutes of cleaning.

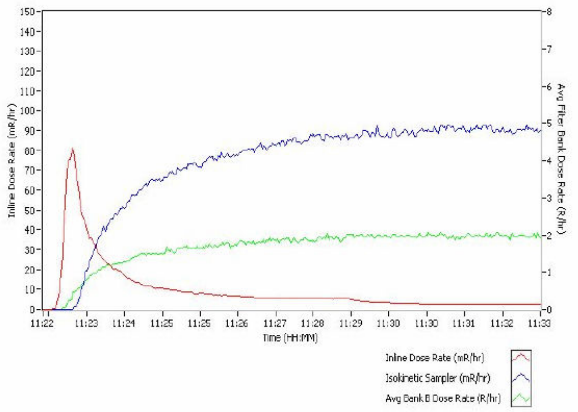


Figure 5. Gamma dose rate measurements during cleaning of fuel assembly M8

After the first trial of fuel cleaning, the system was successfully demobilized with no radiological problem.

4. Conclusion

Fuel cleaning efficiency test was successfully performed at Ulchin unit 2 using a filtration system and cleaning fixture. Significant amount of crud were released and captured within 5 minutes. We believed that this crud filtration system in accordance with ultrasonic fuel cleaning fixture will contribute to AOA mitigation and dose rate reduction in the reactor coolant system.