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Evaluation Methodology for Kori Unit 1 ECCS Strainer Design

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1. Introduction

Debris may be generated from thermal insulation, coating and other materials inside containment after LOCA and transported to the recirculation sump screen resulting in adverse blockage and loss of NPSH margin required for ECCS and CSS pumps. The USNRC has identified this safety issue as GSI-191, "Assessment of Debris Accumulation on PWR Sump Performance". To resolve this issue, USNRC issued GL 2004-02 [1]. This GL requires that all PWR owners perform an engineering assessment of recirculation sumps to ensure that LOCA-generated debris will not degrade the performance of the ECCS and CSS pumps. The Korean regulatory body determined the sump clogging issue as the safety improvement item to be resolved, through the PSR of operating nuclear power plants.

The first ECCS sump performance assessment was performed for Kori Unit 1. The assessment determined the limiting break location to be hot leg in terms of debris generation and major debris sources such as NUKON™, RMI, coatings and latent debris. It was turned out that the analysis refinements using CFD calculation reduce the required screen capacity and can be utilized as the method to optimize the required screen area which satisfies the NPSH margin. Also, the assessment results showed that WCAP-16530-NP [2] evaluation methodology for chemical effect can not be applied in the determination of the sump screen area due to excessive conservatism. Therefore, it is needed to develop improved chemical effect evaluation methodology.

Based on the performance assessment, detailed design of ECCS strainer has been performed. The design includes tests for coatings and chemical effect, debris interceptor, and the optimization of containment spray operation. In this paper, the overall design process for Kori Unit 1 ECCS strainer is summarized.

2. Evaluation Methodology

Overall design process for Kori Unit 1 is illustrated schematically in Figure 1. Prior to the determination of strainer capacity, tests for protective coating and chemical effect, optimization of containment spray operation and the debris interceptor design have to be done. After that, the strainer and debris interceptor supplier is determined based on the strainer capacity design. Strainer supplier performs hydraulic and structural analysis to meet the design requirements. Finally, the strainer and the debris interceptor will be installed during overhaul at the end of 2009.

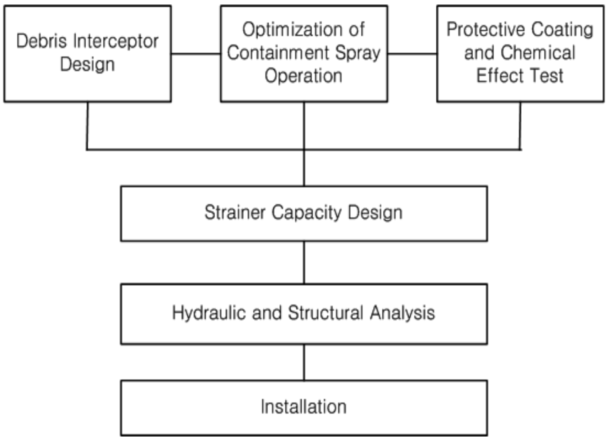

Fig.1 Design Process for Kori Unit 1 ECCS Strainer

2.1 Chemical Effect Test

Chemical effect test was performed based on 30 day test program. The purpose of the test is to evaluate the chemical effect on the head loss across debris bed accumulated on the sump screen by using plant specific chemical materials and produce the data for improvement of ECCS sump strainer performance. Figure 2shows a schematic diagram of the chemical effect test apparatus. The apparatus consists of five chambers having individual loops. Each test loop is equipped with a test chamber, recirculation pump, heater, water chemistry measurement box, piping, and valves with sampling tabs.

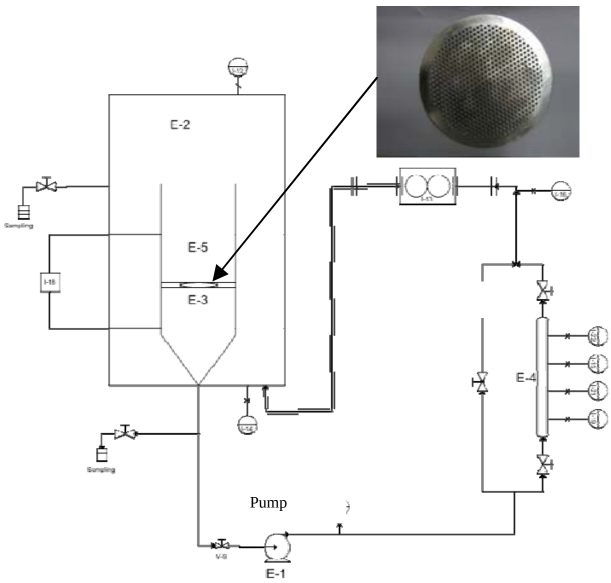

Fig.2 A Schematic of Chemical Effect Test Facility

The head loss across the screen, flow rate, temperature, pH, oxidation-reduction potential, and water conductivity are measured online through a data acquisition system. The water is sampled periodically from both upstream and downstream of the screen during the test and it composition is analyzed with Inductively Coupled Plasma with Atomic Emission Spectroscopy (ICP-AES).

2.2 Debris Interceptor Design

The debris interceptor was turned out to be effective design option to reduce particulate debris such as unqualified coatings and to save strainer installation cost by reducing required screen area. The logical design process for Kori Unit 1 debris interceptor was set up. First, conceptual design is fixed. After that, the amount of unqualified coatings transported to recirculation sump is determined and the detailed specifications such as height, length, and depth are finalized. Using the velocity distribution within the containment calculated by CFD, the most suitable installation location for debris interceptor is determined. To confirm the interception performance, a verification test is performed by measuring the interception ratio. Figure 3 shows 3-D configuration of debris interceptor test facility.

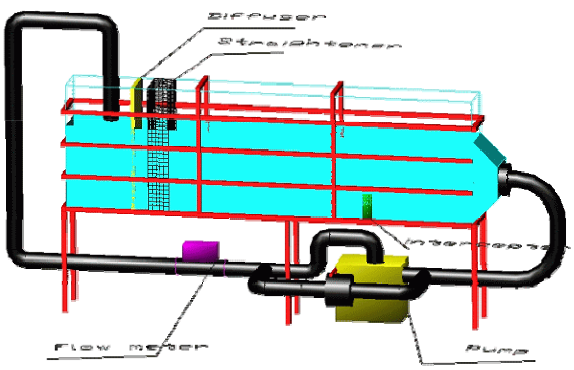

Fig.3 3-D Configuration of Debris Interceptor Test Facility

2.3 Optimization of Containment Spray Operation

The optimization of containment spray operation can be a effective design option to improve ECCS sump strainer by reducing the debris transported to the sump and minimizing the generation of chemical products in the sump. Fort Calhoun plant in the United State adopted design change not to operate containment spray following LOCA. In order to optimize the spray operation, mass and energy release analysis has to be performed to verify that the containment temperature and pressure can be enveloped by the current EQ curve. KIMERA evaluation methodology [3] was applied to containment thermal hydraulic analysis for various LOCA scenarios.

3. Results and Discussion

The chemical effect test results show that the head loss increase can be divided into two stages. At the first stage, the head loss rapidly increases due to dissolution and precipitation of aluminum and zinc. The duration of the first stage depends on the amount of material exposed to the reactor building water solution. After passivation of aluminum and zinc by corrosion, i.e., at the second stage, the head loss increases slowly, mainly by materials such as calcium, silicon, and magnesium leached from NUKON^{TM} and concrete.

Debris interceptor and the optimization of containment spray operation were evaluated to be effective means to reduce the amount of debris transported to recirculation sump and finally screen area. This can save the cost of ECCS sump strainer installation. The benefit of these design options is not accounted in the determination of strainer capacity to maintain additional safety margin for uncertain licensing environment changes such as regulatory body's position on the chemical effect.

4. Conclusions

A systematic evaluation methodology for ECCS sump strainer design has been established for Kori Unit 1. This includes debris interceptor design, optimization of containment spray operation, and the various tests for chemical effect, debris interceptor and coatings. It can be applied to other operating plants in Korea to resolve GSI-191 safety issue.

Acknowledgements

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