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Experimental Study of Head Loss Induced by LOCA-generated Fiberglass Debris at New Type of ECCS Sump Screen

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1. Introduction

The LOCA in NPP would generate debris from thermal insulation and other materials in vicinity of the break location. A fraction of the LOCA-generated debris and pre-LOCA debris will be transported into the sump and accumulated on the sump screens resulting in adverse blockage effects that are degradation or loss of NPSH (Net Positive Suction Head) available for the ECCS pumps [1]. Assessments of the head loss across debris bed accumulated on the sump screen have been experimentally studied since the sump blockage has been issued. Nuclear Regulatory Commission (NRC) in U.S.A. sought a semi-theoretical approach for correlating the experimental data that is known as NUREG/CR-6224 correlation used to estimate the debris-induced head loss for PWR sump performance evaluation [2][3].

In Korea, the sump blockage issue has been addressed as a result of the periodic safety review (PSR). To resolve this issue, the sump performance analyses have been initiated since early 2006. And new types of sump screens have been developed since 2009.

2. Methods and Results

2.1 Description of Test Facility

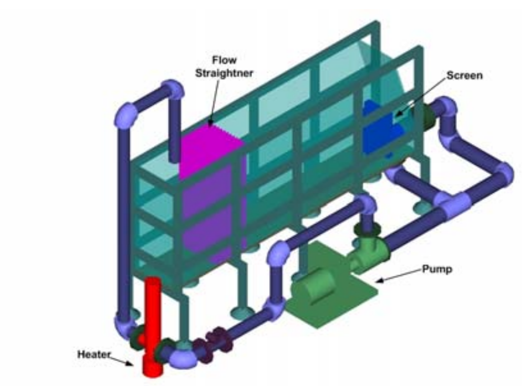

Fig. 1 3D-diagram of test facility

The head loss test facility has been developed for the evaluation of plant specific head loss across the containment sump screen of operating NPPs in Korea. Based on past experiments on the head loss test [1,4,5], the test facility shown in Figure 1 and 2 was designed as a open type with a horizontal screen module with an area of 6.35 ft^2. The flow rate in the test facility was controlled by 60 HP variable speed motor-pump and measured with electromagnetic flow meter.

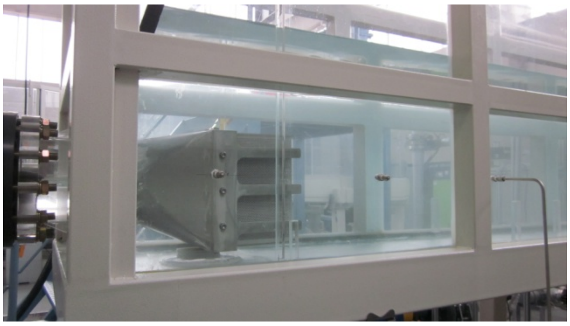

Fig. 2 Sump screen in test pool

2.2 Debris Condition

The quantities of fiberglass debris of the KSNP has been obtained from the walkdown process and scoping analysis on debris generation and sump screen sizing calculation. For the head loss test with plant specific debris, the debris quantities of KSNP are to be scaled to the screen area in the head loss test facility with the following equation[6];

$$W_{HLT} = W_{PWR} \times \frac{S_{HTL}}{S_{PWR}} \qquad (1)$$

where W_{HLT} is a scaled debris quantity, W_{PWR} is a debris quantity of KSNP plant, S_{HLT} is a screen surface area of head loss test facility, and S_{PWR} is a sump screen area of KSNP. Fiberglass debris was inserted by each 20% in order through 200%.

Temperature affects the head loss across debris bed by the density and viscosity of water. The density and viscosity of water decrease as the temperature increases. Hence, the head loss across debris bed decrease as the temperature increases. Water temperature for testing is selected as 30 °C to estimate head loss conservatively.

2.3 Test Results

NUKON™ debris accumulated on the screen is quantified in terms of its theoretical thickness which relates to its weight as follows;

$$W_{HLT,\,fiber} = \Delta L_0 \rho_f S_{HTL} \qquad (2)$$

where ρ_f is a theoretical density of NUKON™ given as 0.039 g/cm^3

Fiberglass blanket was shredded into small pieces. Shredded fiberglass debris was boiled in water to break down the bindings of fibers, and the boiled debris was dried in the oven to have aging effect. Weighed debris was processed in small batches through a household blender to break up the debris into relatively fine debris. Amount of 20% of the processed fiberglass debris is injected into the test loop. After stabilized the debris bed at the screen, head loss has been measured as a function of flow rate. And additional 20% of fiberglass debris is injected in the same manner, in succession.

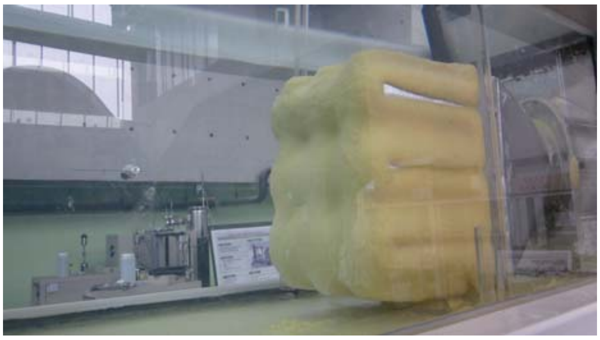

Fig. 3 Fiberglass debris accumulation at screen

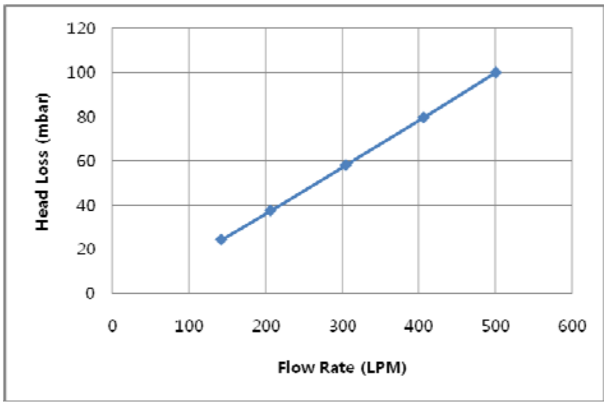

Fig. 4 Head loss by fiberglass debris of a similar condition with KSNP as a function of flow rate

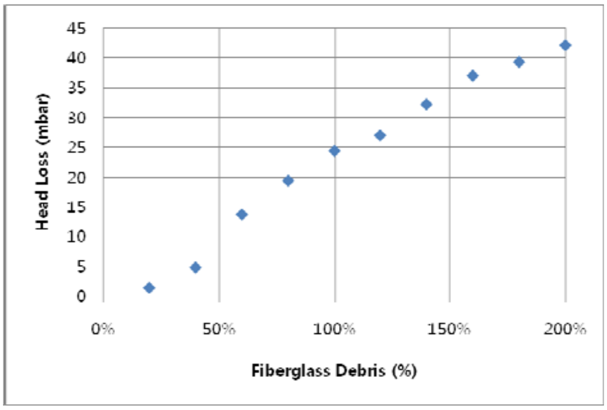

Fig. 5 Head loss as a function of amount of fiberglass debris

Figure 3 shows fully accumulated fiberglass debris at screen. Figure 4 and 5 exhibits the measured head loss across fiberglass debris bed as functions of flow rate and amount of debris, respectively. The measured head loss data exhibited consistent trends by amount of fiberglass and by flow rate.

3. Conclusion

Open-loop test facility was devised and fabricated to estimate debris-induced head loss for proposed new type of sump screen. Experimental results exhibited that induced head loss had consistent trends by amount of fiberglass and by flow rate.

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