Hydraulic test for sump strainer of ECCS recirculation

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1. Introduction

During LOCA, the screen in the sump for filtering debris of various types and sizes is installed. As the debris is accumulated in the screen, The head loss will take place and the redundancy of the ECCS or CS Pump will be lost, thereby causing the pumps to fail. It was confirmed during the precision evaluation of several power plants. The representative empirical formula, developed on the basis of experimental results, for evaluation of the head loss caused by the layer of debris formed in the sump filter, is the NUREG/CR-6224 correlation equation.

As the head loss varies depending on the inherent characteristics of Reactors, it is difficult to apply the NUREG/CR-6224 correlation equation directly to domestic Reactors. Accordingly, head loss test facilities for evaluation of the performance of the sump and deriving necessary design improvements are essential.

2. Methods and Results

To evaluate the head loss caused by the debris and derive the correlation when LOCA unique to a Reactor occurs in the sump screen of the nuclear reactor building, the head loss test equipment was developed.

2.1 Status of hydraulic performance researches

2.1.1 Investigation of overseas test equipments

In foreign countries suppliers of the passive filtration equipment for the emergency core cooling system are conducting hydraulic performance tests independently or jointly with professional performance test companies in a consortium. Organizations, possessed of the performance test technology, are ALDEN, CCI, ALION and VUEZ. They have individual physical head loss, individual chemical head loss, general hydraulic performance test and chemical performance test equipments. [1]

2.1.2 Investigation of the accident environment

During the LOCA inside the containment building of PWR the thermal insulator of the pipe near the broken part and other substances are dislocated due to the collision of the breaking jet, and part of them are destroyed. They move to the bottom of the containment building along with the fragments of coating materials and ultimately clog the sump screen, thereby increasing the pressure drop. The accumulation of foreign objects in the screen may be threatening to the sump's ability to provide cooling water for ECCS and CS on a long-term basis.

2.1.3 Development of test conditions

To evaluate the influence of individual factors on the head loss unique to the Reactor, there must be the following basic functions.[1]

- It must be possible to conduct head loss tests for the various kinds of debris unique to Reactor occurring during LOCA.
- It must be possible to evaluate the effect of various sump screen access speeds on the head loss.
- It must be possible to observe the debris layer accumulation process and to measure the thickness of the debris layer.
- The effect of the flow on the measurement of pressure drop due to the debris layer must be minimized.
- The debris layer must have a relatively uniform thickness.
- The screen access speed is perpendicular to the flow.
- The flux passing through the accumulated debris layer, temperature and the pressure difference, measured at the debris layer must be stable.

2.2 Design of the individual hydraulic test facilities

2.2.1 Test loop design

To evaluate the head loss caused by the debris at the sump screen of the nuclear reactor building during LOCA, an independent study, capable of evaluating the influence of individual factors on the head loss, was selected instead of a head loss test that simultaneously reflects all factors such as the movement of debris. To test the independent effect related to the head loss, a closed loop was selected as the head loss test equipment.

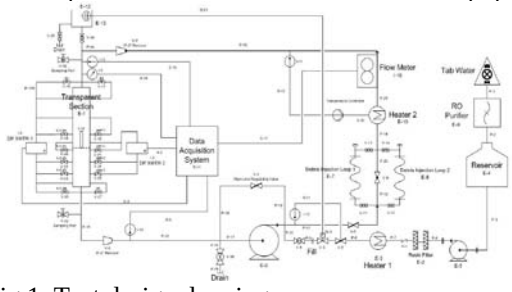

Fig 1. Test design drawing

2.2.2 design of measurement points

The screen was installed at the center of the transparent tube, and to measure the pressure difference at a location as much as the inner diameter of the pipe above and below the screen, 2mm holes were drilled, and PVC connectors are installed. It was then connected

to the differential pressure gauge and the 1/4 inch stainless steel tube. The transparent tube must be designed so that it could be detached. After the completion of the head loss test it was possible to measure the quantity of the debris accumulated in the screen and to observe the shape. In the head loss test equipment the screen for forming the debris layer will be a stainless steel plate with 2mm holes.

2.3 Establishment of test conditions

2.3.1 Quantity of debris

The kind and quantity of the debris for the head loss test will be determined by debris generation and the result of the analysis of the sump screen. The quantity of the debris required by the test will be calculated by the proportional relationship between the screen size and the area of the filter of the head loss test equipment.

$$M_{HTL} = M \times \frac{S_{HTL}}{S} \quad (1)$$

Here, M_{HTL} and M refer to the debris of the head loss test equipment and that of the Reactor, whereas S_{HTL} and S refer to the size of the loss test equipments and the Reactor. At this time the screen area of the head loss test equipment is 0.196ft^2.

2.3.2 Temperature of the water

The maximum temperature of the water in the sump of the reactor building is 139℃ after LOCA. The analysis showed that due to the recycling, the temperature of the water was lowered from 102℃ to 49℃. It is known that the temperature of the water greatly affects the passive loss occurring in the laminar flow region. It is attributed to the change in the density and viscosity of water due to the temperature change of water. Accordingly, to conservatively evaluate the head loss, 50℃ was selected as the standard temperature. [1]

2.4 Sampling according to the Debris by size and type.

The debris, which can be generated by LOCA, include heat insulation materials and jackets, fire protection materials and surface coating materials. Among them heat insulation materials account for the most. The debris generated by LOCA may be further broken to smaller pieces after LOCA and their mobility may be increased. Calcium silicate is a good example.

2.4.1 Fiber-type debris

Glass fiber heat insulation materials, installed in the nuclear reactor building, like NUKON, are made by fixing the approximately 2-inch-long fiber 5~7μm in diameter drawn from melted glass with a binder, and the density of the installed glass fiber heat insulation materials is 2 to 3lm/ft^3.

2.4.2 Granular debris

There are various debris such as pieces of stickers and tapes, but only dirt/dust will be thought of as potential debris in the head loss test.

2.5 Test matrix

If a matrix is made on the basis of the previously mentioned conditions, it can be expressed as shown in the two tables.

Table Ⅰ. The matrices based on the quantity, thickness of the fiber-type debris, and water temperature

Flow rate	Thickness(in)	Quantity(g)	Temp(℃)
0.01~0.6	1	15.9	40~50
0.01~0.6	2	31.8	40~50
0.01~0.6	3	47.7	40~50
0.01~0.6	4	63.6	40~50
0.01~0.6	5	79.5	40~50
0.01~0.6	6	95.4	40~50

Table Ⅱ. Test matrix according to the shape of the debris

Flow rate (ft/s)	Thickness (in)	Debris Type			Temp (℃)
		Fiber	Granular	RMI	
0.01~0.6	5.4	○	○		50
0.01~0.6	5.4	○		○	50
0.01~0.6	5.4	○	○	○	50

3. Conclusions

The head loss test equipment required for evaluating the performance of the sump and deriving necessary design improvements will be installed. The formula, established to find the quantity of the debris during LOCA, will be used to determine the quantity of debris of each Reactor, and the head loss test will be conducted under the multiple conditions of flux, thickness of debris, and temperature.

After all, the head loss test will be able to produce the basic data and correlation equation necessary for evaluating the head loss caused by the debris during LOCA in the sump screen of the nuclear reactor building in Reactors currently in operation or scheduled to be constructed in Korea.

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REFERENCES

[1] Procedure for Head Loss Test for Kori 1 Reactor Building Sump Screen Evaluation 2007 FNC Technology Co