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Debris Transport Visualization System (DTVS) Test Facility for Closing the GSI-191 (Generic Safety Issues) in Nuclear Power Plants

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1. Introduction

During the long-term cooling (LTC) phase of a loss-of-coolant accident (LOCA) in a pressurized water reactor (PWR), water is supplied from the containment sump to the reactor coolant system (RCS) by the flooded sump water to the Reactor Vessel (RV) through the broken pipes. As part of the technical efforts for resolving GSI-191 (Generic Safety Issue-191), "Assessment of Debris Accumulation on PWR Sump Performance and Fuel Assembly (FA) Blockage Issues" [4], consideration is needed for the consequences of debris penetrating the sump screen and propagating downstream into the RV. Injection of debris (fiberglass) into the RV during the LTC recirculation phase needs special attention to assure that reactor core cooling is maintained [2, 3]. The point of concern is the potential for debris to adversely affect the reactor core flow paths or heat transfer. However, all the experiments for proving the coolability of RV have been done with the assumption of the most of debris would be transferred to the RV and the bottom nozzle of the FAs.

Maintaining a coolable geometry for LTC (assumed to be 30 days) along with the acceptance criteria specified in 10CFR50.46 [1].

In reality, most of debris would be settle down to the lower plenum of the RV is the main assumption of this research even the density of debris (fiberglass) is a lot lower than the water.

The purpose of the tests is to quantify the amount of the debris that would be accumulated at the lower plenum and the debris that passes through the FAs.

The most important thing is the 'Visualization' and 'Quantification' of debris so the test facility is designed by acrylic material to see the 'Debris Transporting Phenomena' inside the vessel.

2. Test Methods, Facility

The actual size of the RV ID is around 4m and the size of the model RV is scaled down to 1.56m ID. The ratio is about 1/2.56. The cylindrical section height of the test facility is 3m and the ID of Lower Plenum is 0.75m. So the total height of the model RV is 3.75m. To simulate the various height of flood-up level of plants, the water level inside the Coolant Supply Tank (CST) can be controlled by the level gauge. When the corresponding water level (flood-up level) is set, then the water level inside the CST would be maintained with the set level. In reality, steam would be evaporated from the RV vigorously. To simulate those phenomena, water will be transferred from the RV to the CST by a pump. Below Figure 1 shows the conceptual design of the test facility.

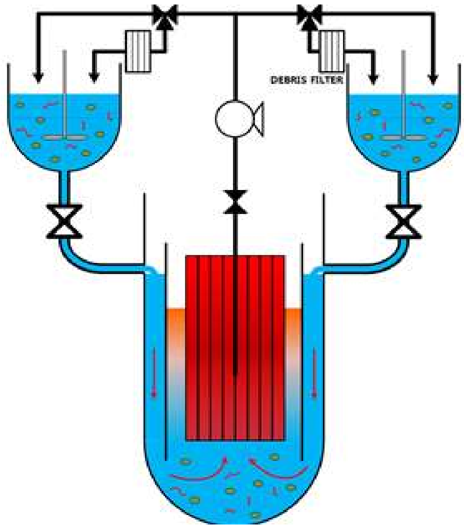

Figure 1. Conceptual Design of the Test Facility

2.1 Test Methods and Procedure

In order to evaluate the amount of debris that is accumulated at the lower plenum, an indirect method will be used to measure the mass of debris at the filters. As shown in Figure 1, four filter bags will be installed for each CST. Exactly measured amount of debris will be mixed in each CST, and then the water with debris is injected to the RV by the gravity (natural circulation). The water mixture will be transferred to the CSTs by the suction pump. Before the mixture water is transferred to the CST, four filters will be used to capture all the debris and be dried to measure the captured amount of debris. The assumption is that the debris will not be accumulated at any other places other than CST, Lower Plenum, and the Filters.

To simulate the postulated accident, Hot Leg Break and Cold Leg Break modes have been decided.

Even the flow path of Hot Leg will not pass through the Downcomer in actual plants, the purpose of this study is to prove and to quantify the debris amount at the Lower Plenum, thus the flow path of Hot Leg should also pass through the Downcomer to see the effect of pipe size and the elevation.

Figure 2 shows two different modes of injections.

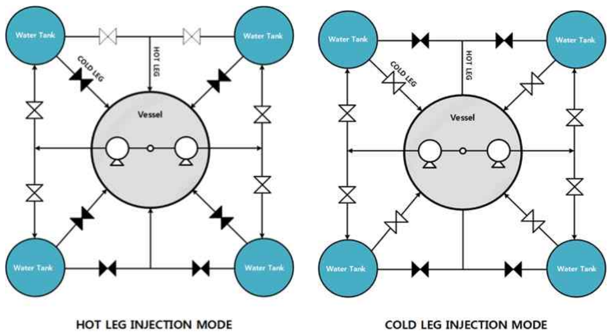

Figure 2. Hot Leg Break and Cold Leg Break Injection Methods

As shown in Figure 2, it is possible to simulate each injection mode and is also possible to show 'Single End Break' or 'Double End Break' by switching the valve positions. The flow rate is also scaled and is calculated. Based on the plant conditions, the flow rate is between 10 ~ 40kg/s. These flow rates can cover the range of the actual plants.

2.2 Test Facility

Test Facility has been scaled based on the Thermal-Hydraulic considerations and the cost. As described in Section 1, the material of the test section is Acrylic for visualization with many kinds of limitations of making the test section.

The dimensions of the Test Facility have been decided as below with considering Scaling, Thermal Hydraulic effects, and the cost. Table. 1 shows the major dimensions of the Test Facility.

Table 1. Test Facility Dimensions

구 분	Length/Diameter
원자로노심 외경 [mm]	1700
원자로노심 내경 [mm]	1560
Downcomer 외경 [mm]	1350
Downcomer 내경 [mm]	1310
원자로 하부 반구의 내경 [mm]	750
Hot Leg ID [mm]	77.9
Cold Leg ID [mm]	52.5
Hot Leg Height [m]	3.05
Cold Leg Height [m]	3.25
Flange Height [m]	0.75
Test Section Total Height [m]	3.75

Figure 3 shows the overall dimensions of the Test Facility. The total height and the width of the test section is about 6.5m and is about 5m, respectively.

Temperature effect is also very important. However, the material of the test section is acrylic and has temperature limit about 40°C. Thus, the experiments will be performed with ambient temperature and 40°C conditions to investigate the temperature effects.

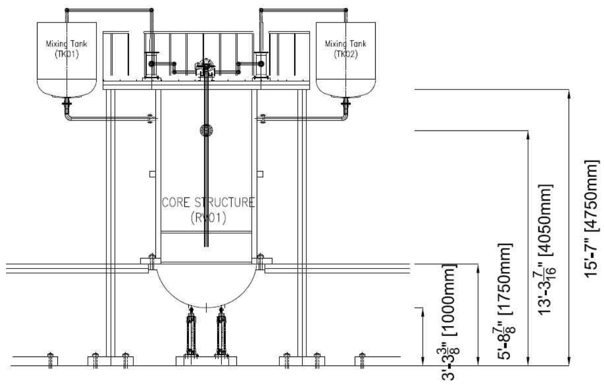

Figure 3. Overall Dimension of Test Facility

2.3 Future Work

Various kinds of tests will be performed based on the test matrix. For example, Hot Leg Break tests with changing the water head (flow rate) and Cold Leg Break tests with changing the water head (flow rate). Once the ambient temperature conditions tests have been done, high temperature tests (40°C) will be performed with same conditions with ambient temperature conditions. Then the amount of debris that is accumulated at the Lower Plenum will be quantified by measuring the debris amount that is captured in the filter bags.

CFD will be also used in the future for verifying the experiment results.

3. Conclusions

An acrylic Test Facility has been designed to simulate the debris amount that is accumulated at the Lower Plenum. The purpose of the tests is to quantify the actual amount of debris that is accumulated at the Lower Plenum and is transferred to the Fuel Assemblies. The importance of this study is, 1) can support and provide reference for closing a licensing issue (GSI-191), 2) Visualization of flow paths in the Reactor Vessel, 3) can investigate multi-dimensional effect in the Reactor Vessel with visualization (First in the world).

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