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A Preliminary Study on the Propagation of RCP Pressure Perturbation into Reactor Vessel Downcomer

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1. Introduction

In the normal operation of PWR nuclear power plant, a pressure wave perturbation is generated due to the rotation of the blades of a reactor coolant pump (RCP), and it propagates into the reactor vessel downcomer. In the APR+, an "ECC Duct" can be adopted as an advanced design feature for the DVI in order to mitigate an ECC bypass fraction during LBLOCA and to prevent switching an ECC outlet to a break flow inlet during a DVI line break [1]. The pressure wave propagation into the reactor vessel downcomer equipped with the ECC ducts was examined in the present study.

2. Experimental Setup and Results

The 1/5 scale test facility was manufactured for the APR+ reactor vessel. A total of 16 dynamic pressure transducers were installed. 15 transducers were installed on the core barrel wall (Fig. 1) and 1 transducer was installed at the Cold Leg-1B (Fig. 2). The transducer was manufactured by PCB Inc. and the model number was 106B52 with a sensitivity of 725 mV/kPa. Four 1/5 scaled "ECC Ducts" were also attached on the core barrel wall. A magnetic actuator (or vibration exciter) was connected to Cold Leg-1B in order to simulate the pressure wave perturbation of the RCP. The nozzle end of Cold Leg-1B was covered by a thin rubber membrane, and a vibrating plate of the magnetic actuator was attached to the center of the membrane. Therefore, the pressure wave generated by the actuator could propagate into the reactor vessel downcomer. The length of Cold Leg-1B nozzle was about 1 m, and the dynamic pressure transducer was located 420 mm away from the reactor vessel outer wall. The magnetic actuator was the model V455 of LDS Inc, and it has a maximum force of 490 N and a maximum displacement of 19 mm at zero load condition.

Tests were performed at 20, 30, 60 Hz frequency conditions. The force of the magnetic actuator was varied at 20, 40, 60, 80, 100 % for each frequency condition. The reactor vessel downcomer was filled with water at room temperature. There were 6 vent valves at the top of the reactor vessel, and these valves were closed after filling the system with water. The other cold legs, hot legs, and DVI nozzles were blocked at the nozzle necks in order to make the downcomer an isolated system.

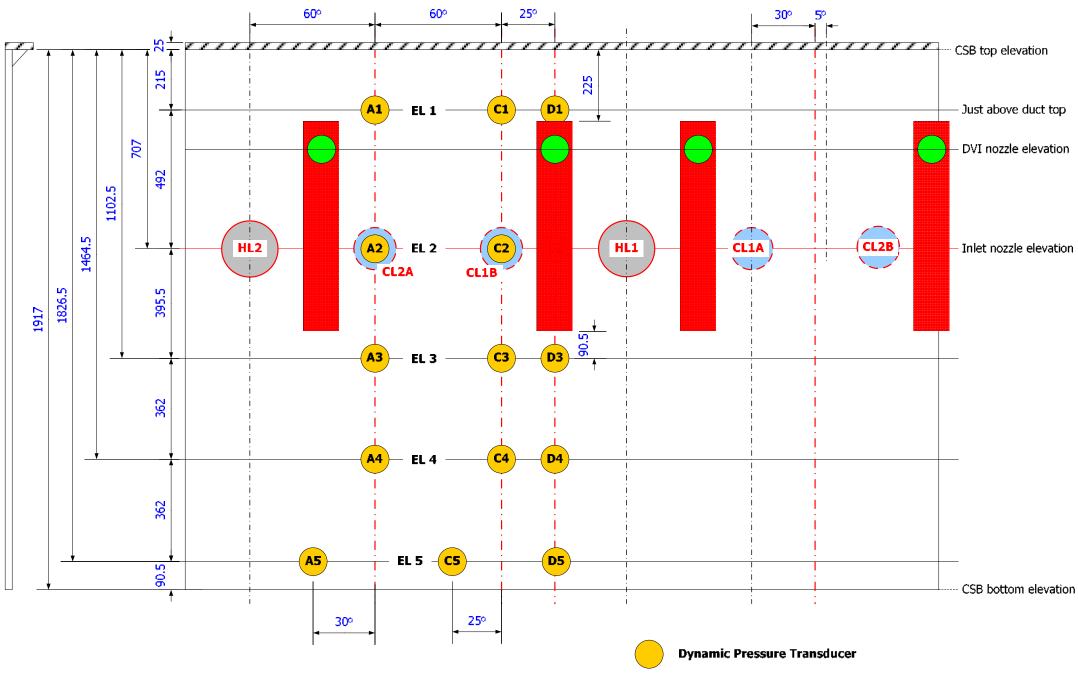

Fig.1 Planar view of core barrel wall for the dynamic pressure transducer location

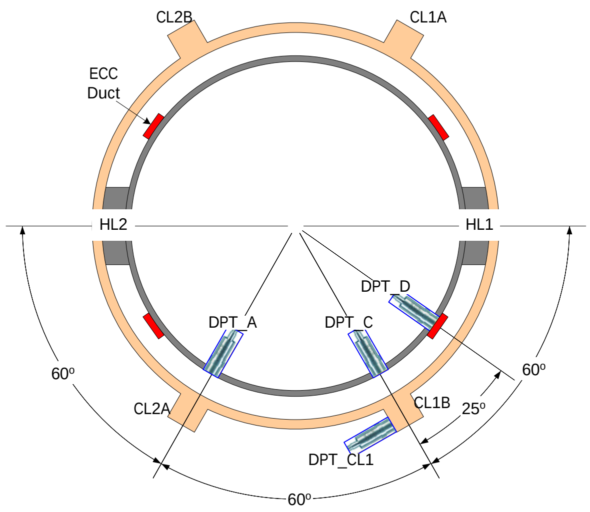

Fig. 2 Cross-sectional diagram of the reactor vessel downcomer for the dynamic pressure transducer location

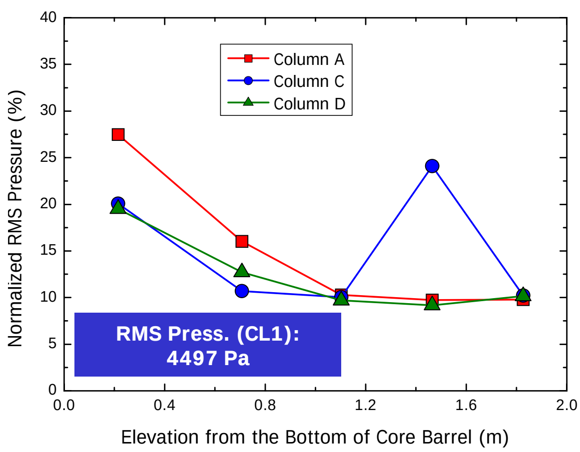

Fig. 3 Pressure wave propagation for 20 Hz perturbation

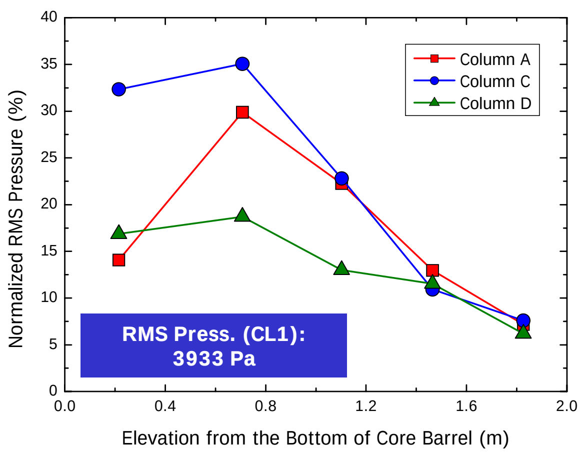

Fig. 4 Pressure wave propagation for 30 Hz perturbation

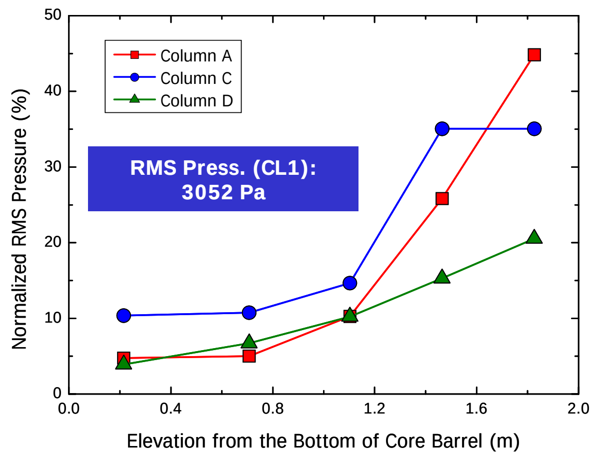

Fig. 5 Pressure wave propagation for 60 Hz perturbation

Figures 3~5 show RMS pressures measured on the core barrel wall at the maximum force condition for each frequency. The pressure on the core barrel wall was normalized by the pressure measured at the Cold Leg-1B.

The pressure amplitude at the Cold Leg-1B decreased as the frequency increased because the displacement of the magnetic actuator decreased as the frequency increased. The dynamic pressure distribution on the core barrel wall was not consistent with the change of the pressure wave frequency (Figs. 3~5). That is, the maximum pressure location was different with regard to the applied frequency. However, the pressure distribution pattern was not sensitive to the applied force of the magnetic actuator for a given frequency. The maximum RMS pressure was lower than 50 % of the pressure at the Cold Leg-1B.

3. Conclusions

The pressure wave propagation from the RCP into the reactor vessel downcomer equipped with the ECC ducts was examined for the frequency of 20, 30, and 60 Hz. Further tests are being carried out at higher frequency conditions, and tests for an open system will be performed.

REFERENCES

[1] T. S. Kwon, S. Lee, and C.-H. Song, Development of an advanced DVI+, The fourth Korea-China Workshop on Nuclear Reactor Thermal-Hydraulics (WORTH-4), Jeju, Korea, May 18-20, 2009.