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# A Design of PWR Hydraulic Test Loop

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## 1. Introduction

It is very important to verify the reliability of a fuel assembly from the view of a flow induced vibration (FIV) in order to improve the safety of the PWR plant. KAERI (Korea Atomic Energy Research Institute) recently initiated a new test program sponsored by MOST (Ministry of Science and Technology) in order to obtain the measuring technique in the full scale hydraulic test loop for the design qualification of the PWR fuel assembly from the aspect of the hydraulics and FIV. The PWR hydraulic test loop is being renovated not only to accommodate the new test requirements of the flow induced vibration test but also to replace the aged equipments and measuring systems. In this paper we would like to introduce the renewed loop for the hydraulic test, including the pressure loss test and lift-off test, as well as the flow induced vibration test, including the fuel rod, fuel assembly, housing, and vessel vibration test. As the beginning stage, the pressure drop test has been performed to assure the performance of test loop.

## 2. Test Loop

The test loop consists of a recirculating, pressurized water loop with a pump, vertical test chamber, heat exchangers, electric heaters, a pressurizer, and an injection pump as shown in the simplified flow sheet of Fig. 1.

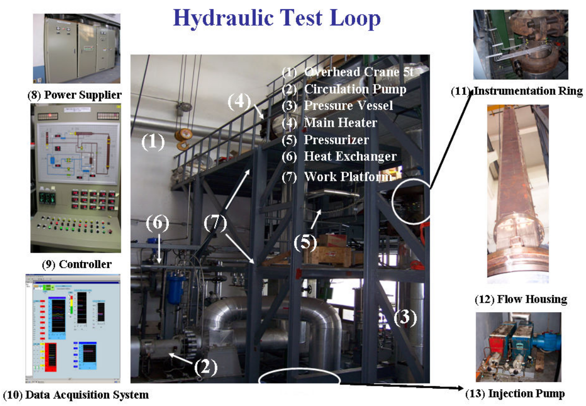


Figure 1. PWR hydraulic test loop

The operating pressure range is 3 to 30 Bar. Pressure is adjusted either manually or automatically by varying the temperature of the fluid contained within the pressurizer. A SCR (Silicon Controlled Rectifier) controlled heater, located in the pressure vessel, is used to adjust the fluid temperature for a pressure control from 3 to a full operating pressure of 30 bar.

The maximum loop design flow rate is 500 $m^3$/hr. The flow rate is changed by increasing or decreasing the pump speed by means of the VVFV (variable voltage variable frequency).

Water is heated by an impeller friction heat and an electric loop heater. The electric heater is adjusted from room temperature to 120 °C, automatically operated by a pre-set temperature or manually operated by adjusting the potentiometer located in the control room.

## 3. Instrumentations

The differential pressures for the components are all measured by pressure transducers (Rosemount model 3051). All the 1/8” diameter stainless steel pressure transmission lines attached to the pressure taps on the flow housing wall penetrate the pressure vessel through an instrumentation ring located above the test chamber . The resulting 4-20 mmA current output signal from the transmitter can be transformed to a 0-5V voltage signal by a transformer (Myung Model M8DY1) and then through the end plug (HPVXI E1419A) the signal is monitored and recorded by the HP VEE.

The Lift-off flow rate is determined by detecting a sudden variation of the bottom end piece region due to a flow path change as a lift-off for the fuel assembly and also crosschecked by the microphone detecting the acoustics near the bottom end piece.

The rod vibration will be monitored via the measurement of the acceleration signals obtained from the two uni-axial accelerometers (PCB model 352B23) axially positioned with a right angle rotation in a fuel rod [1], [2]. The accelerometer can measure a 0 to 10 KHz. The voltage signal from 7 to 11 V goes through the amplifier (PCB442B104) and then it is monitored and recorded by the analyzer (MTS T-DAS).

DVRT (Differential Variable Reluctant Transducer) is used to measure the fuel assembly vibration and displacement. DVRT can measure a vibration from 0 to 7 KHz, with a range of 0-5 mm, which is more than twice that of the gap between the outer strip and the housing. The DVRT mounted on the flow housing walls measures the grid motion relative to the flow housing.

The housing and vessel vibration is measured by an uni-axial accelerometer (PCB 352C65, PCB3701G3FA3G) mounted by screws on the flow housing and vessel, respectively. The accelerometer can measure a 3 Hz to 3 KHz. The signals from the accelerometers pass through the amplifiers to the VXI end plug. The signals are analyzed by the MTS T-DAS program.

### 4. Pressure Drop Test

The pressure drop test was performed for the 17X17 fuel assembly and the results compared with the reference data [3]. The Table 1 shows the test conditions of the pressure drop test. The pressure drop tests are performed by varying the flow rate with different temperature, 60 °C, 80 °C, and 120 °C. The system pressure at 120 °C is 10 Bar to maintain sub-cooled condition.

Table 1. Test Conditions

| Test Condition | Flow rate ($m^3$/hr) | Temperature (°C) | Pressure (bar) | Reynolds Number ($x10^4$) |
|---|---|---|---|---|
| Run 1 | 200 ~ 500 | 60 | 3 | 5.2~13.1 |
| Run 2 | 200 ~ 500 | 80 | 5 | 6.3~15.9 |
| Run 3 | 200 ~ 500 | 80 | 4 | 6.3~15.9 |
| Run 4 | 200 ~ 500 | 80 | 3 | 6.3~15.9 |
| Run 5 | 200 ~ 500 | 120 | 10 | 11.4~23.0 |

The reference data has been reduced to compensate the geometric dimension of flow housing. The width of flow housing applied in present test is 0.24 inch wider than that of the flow housing on reference test. The simple pressure drop model has been applied to convert the reference test data to the present test condition. The Fig. 2 shows comparison of the pressure loss coefficient of fuel assembly between measured and reference data. The trend of the pressure drop as the variation of the Reynolds number is similar to each other, but the measured data is about 4.4 % lower than that of the reference data. The discrepancy is caused by measurement uncertainties and conversion model error. Even though there is the some discrepancy of the pressure drop measurement, the test loop is proper to perform the hydraulic test.

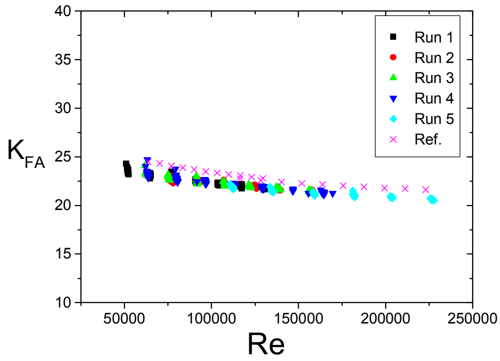


Figure 2. Comparison of Pressure Loss Coefficient of the Fuel Assembly between Measured and Reference Data

### 5. Summary

KAERI is performing a project on out-pile test technology development for a full scale PWR fuel assembly. We have established the hydraulic test loop and obtained the pressure drop test results.

As the results of the pressure drop test, the loop is proper to perform the hydraulic test. The established test loop and measuring technique will contribute to the satisfaction of domestic needs for the design verification to improve the reliability of a PWR plant operation. The main test will be accomplished by the end of 2006.

### ACKNOWLEDGEMENT


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### REFERENCES


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[2] Dong Seok Oh, Tae Hyun Chun, Wang Kee In, Chang Hwan Shin, Hyung Kyu Kim, Young ho Lee, Kang Hee Lee, Bong Soo Kim, and Kun Woo Song, Mounting Device of Uni-acial Acceleration Sensors to Measure Bi-axial Acceleration Signal by Using Two Accelerometer Sensors in the Tube. Application Number 2006-26276

[3] Private Communication.