A Design of PWR Hydraulic Test Facility at KAERI

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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 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 facility for the design qualification of the PWR fuel assembly from the aspect of the hydraulics and FIV. The PWR hydraulic test facility 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 facility and the test methodology for the hydraulic test, including the pressure loss test and lift-off test, as well as the vibration test, including the fuel rod, fuel assembly, housing, and vessel vibration test.

2. Test Loop

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

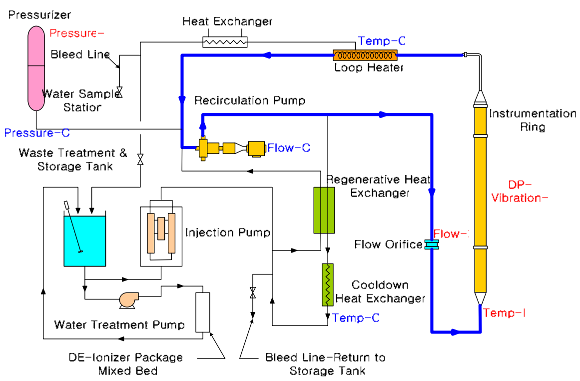

Figure 1. Schematic diagram of the PWR hydraulic test facility

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 pressure for the components is all measured by a pressure transducer (Rosemount model 3051). Fig. 2 shows the locations of the differential pressure taps in the test section. 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. 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 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]. 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). 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 to 3 KHz. The signals from the accelerometers pass through the amplifiers to the VXI end plug. The signals are annualized by the MTS T-DAS program.

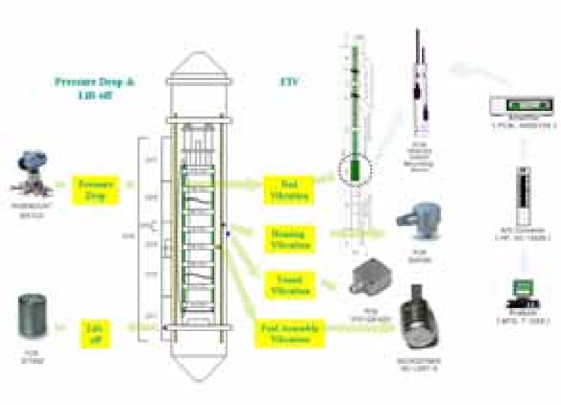

Figure 2. Schematic diagram of Measuring Device

4. Test Condition

The Table 1 shows the test condition for the hydraulic and vibration test. The Pressure loss test is to be performed by varying the flow rate at two different temperature, 40 °C and 120 °C The differential pressure is measured for the 8 spans as shown in Fig. 2. The pressure loss coefficient for the core condition can be calculated by extrapolating the measured results for the core condition as a function of the Reynolds number [2]. Lift-off flow rate is needed to assure the hold down spring force.

Table 1. Test Condition

Test	Flow rate (m^3/min)	Temperature (°C)	Pressure (bar)	Reynolds Number ($x10^4$)
Pressure Loss	3~8	40 & 120	5	3.7~26.2
Lift-off Flow-rate	6~8.2	40	5	7.4~10
FA Vibration	0, 3~8.2 $0.3 \triangle \dot{V}$	Room Temp. & 120	5	3.7~26.2
Rod, Housing & Vessel Vibration	3~8.2 $0.3 \triangle \dot{V}$	120	5	3.7~26.2

The lift-off test is performed at 40 °C . The frequency and amplitude of the fuel assembly is measured to assure the vibration behavior of the fuel assembly by the DVRT mounted on the housing wall. Prior to installing the housing with a fuel assembly to the pressure vessel, the initial position is measured. And then in the loop condition, the distance between the housing wall and the spacer grid is measured at a stagnation flow condition and a flow rate from 3 m^3/min to the 8.2 m^3/min at 120 ° C. The amplitude and frequency of the fuel rod which is excited by the axial coolant flow and an interaction of the fuel and spacer grid support system is measured under the flow rate condition from 3 m^3/min to 8.2 m^3/min with 0.3 m^3/min increments. The vessel and housing vibration is measured to assure that the pump dynamic source does not affect the vibration of the fuel assembly and the fuel rod at the same flow condition with the fuel rod test.

5. Summary

KAERI is performing a project on out-pile test technology development for a full scale PWR fuel assembly. We have introduced the hydraulic test facility, a test assembly, test parameters, test methods, and a data acquisition system. The start up test will be in the middle of March 2005 and the main test will be accomplished by the end of 2006. The established test facility and measuring technique will contribute to the satisfaction of domestic needs for the design verification to improve the reliability of a PWR plant operation.

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