Introduction of the I&C System for the Fuel Irradiation Tests

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1. Introduction

Initial stages of the capsule development program in Korea were concentrated on developing the material capsules and the related facility such as a cutting device for 3 years from 1992. Since 1995, 121 capsules (100 non-instrumented and 21 instrumented capsules) for the fuel and material irradiation tests have been designed, fabricated and successfully irradiated in HANARO. Although fruitful experiences were obtained from various in-pile tests for about ten years, it is necessary for us to have leading-edge technology to satisfy the specific test requirements of the recent R&D activities such as the high-fluence- and high-burnup-related tests[1~2]. To meet one of the demands for the high burnup test at HANARO, a new I&C system for the fuel irradiation tests is required in the HANARO reactor. The basic design of the system started at the beginning of 2000. A detailed review of the design concept and an applicable methodology for controlling the temperature of the specimens were accomplished in 2001. Detailed design of the system was completed by 2002. The I&C system(GSF-2002) for the fuel irradiation tests was manufactured and installed for the qualification tests in an engineering laboratory.

2. Description of the I&C System

The I&C system designed for the user required tests consists of two major sub-systems: a temperature control system and a fuel failure monitoring system[3]. Figure 1 shows the photograph of the I&C system(GSF-2002) for the fuel irradiation tests. The temperature control system controls the surface temperature of the specimens by adjusting the mixing ratio of the gas in an annular gas space. It can control a wide range of specimen temperatures.[4] It will also monitor the process variables and trigger specific alarms or safety functions.

In addition, an emergency gas supply system is actuated to supply 100% helium gas to the capsule in the event that the reactor temperature becomes too high and it is the main safety action.

The fuel cladding failure monitoring system is of primary importance and has a role to detect the fission products in the annulus gap due to a fuel cladding failure in each capsule separately mounted inside the basket. Monitoring the gas mixture of the fission products is an appropriate way of confirming the integrity of the fuel cladding[5]. If fission products are detected in the gas mixture coming out from the capsule outlet then safety actions and a release of the contaminated gas via a delay and trap arrangement are considered in this system. The main items in the delay system are a shielded holding vessel, which will collect any radioactive gas and store it for decay. An activity monitor will be installed near the holding vessel, which will measure the radiation levels with time. The gas trap system is to be operated in a similar manner to the holding vessel, but it will incorporate a charcoal bed to absorb the fission gas at an ambient temperature, and it will be removable.

Figure 1. I&C System(GSF-2002) for Fuel Irradiation Tests

The I&C system also has several subsidiary functions, such as a data acquisition and storage function, a self-diagnosis function, and an alarm-indicating function. Hardware configuration of the system is divided into four parts: the vacuum controller, the fission product monitor and trap, the gas mixing ratio controller, and the personnel computer. The system has three operational modes: manual mode, auto mode, and a computer-aided mode. Start or restart of an automatic operation mode will be done after a stable power condition of the research reactor is reached and by a manual intervention of an operator. There will be some automatic safety functions. The logic for this may be hard-wired or Programmable Logic Controllers(PLC). All the safety functions directly interfacing with the HANARO reactor instrumentation are only of a hard-wired type. Especially, the concept of a quasi-dual system will be taken: two controllers such as RTP[6] will be adopted to prevent a common mode failure.

3. Performance Tests

This performance test which started in 2004, was undertaken to investigate the thermal response of the capsule mockup[7] connected to the gas mixing system of the new I&C system(GSF-2002) in the cold test loop, as shown in Figure 2, under the HANARO hydraulic operational condition. Main test parameters are the mass flow rates of 25, 50 and 100 cc/min of He/Ne gas, a gas pressure of 1 to 3 kg/cm^2, a heater power of 1 to 3.4kW and a few gas mixing ratios of He to Ne.

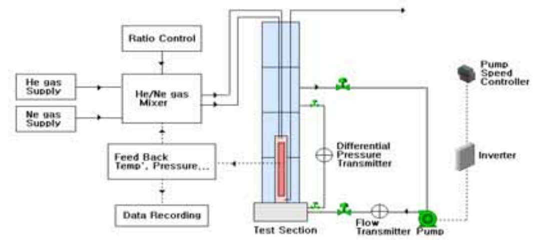

Figure 2. Schematic Diagram of Cold Test Loop and I&C System

From this test, as expected in the previous results[7], the effects of the mass flow rate of the gas and the gas pressure on the surface temperature of the simulated fuel (hereafter called "fuel") are found to be negligible in the ranges of both the flow rate of 50 and 100 cc/min and the pressure of 1 to 3 kg/cm^2 as shown in Figure 3. The effects of the heater power and the gas mixing ratio of the He/Ne gas on the fuel specimen temperature was found to be altered noticeably and showed a good dependency, indicating that the heat transfer coefficient is very dependent on the heat source and the conductivity of the gas composition. It is concluded that the applied temperature control methodology is feasible to control the surface temperature of the fuel.

To comprehend the integrated time-temperature processing of the mini-capsule, a series of tests was implemented by observing the temperature characteristics of the specimen during a heating and a cooling cycle. The heat-balanced surface temperature of the specimen at the above flow rate of 50 cc/min was found to be constant. This experimental data shows that a specimen does not reach a thermally balanced temperature instantaneously and the minimum flow rate of the gas for the effective control of the specimen temperature is above 50 cc/min.

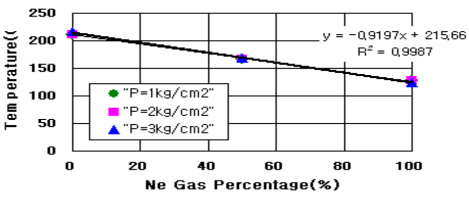

Figure 3. Effects of the Gas Mixing Ratio and the Gas Pressure

4. Conclusion

From the out-pile tests, it was confirmed that the new type of I&C system (GSF-2002) would be feasible for a fuel irradiation using a fuel capsule in the HANARO research reactor. After the completion of a series of out-pile experiments, this system will be used for the fuel experiments related to advanced fuel development programs.

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