

## Devices and Instrumentations for Nuclear Fuel Irradiation Tests in HANARO

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### 1. Introduction

HANARO (High flux Advanced Neutron Application Reactor), one of the multipurpose research reactors in the world, has a maximum thermal power of 30MW. HANARO has been operated and the functions of its systems have been improved continuously[1] since its first criticality in February 1995, and it is now being successfully utilized in such areas as fuel and materials irradiation tests, neutron beam research, radioisotopes production, neutron activation analysis, and neutron transmutation doping, etc. Experimental facilities, such as capsules, FTL including control system and others, have been developed and installed in field of irradiation tests since the beginning of the reactor's operation, and continued efforts to develop more equipments and to enhance an irradiation technology are in progress. The support of the government for HANARO users has promoted new researches in a wide range of neutron application, which is demonstrated by the high growth record of HANARO's utilization every year. In this paper, experimental equipments for irradiation tests of nuclear fuels and instrumentation to measure some characteristics of fuels during irradiation in HANARO are described.

### 2. Irradiation Devices

The equipments for the irradiation tests of nuclear fuels and materials in HANARO are classified into two categories, such as, a capsule and an FTL (Fuel Test Loop). Capsules for the irradiation tests of nuclear fuels and materials in the HANARO have been developed. And, the irradiation plans related to the developing the Gen-IV reactor systems by using capsules in HANARO will result in more emphasis on the development of capsules focusing on the irradiation tests of materials or nuclear fuels for the Gen-IV reactor systems, such as the SFR and the VHTR. The FTL is one of the irradiation devices, which can conduct an irradiation test for a nuclear fuel in HANARO under the operating conditions of commercial nuclear power plants. Three-test fuel rods can be irradiated in HANARO by using the FTL. The installation of the FTL was completed in March 2007. Currently, the commissioning test of the FTL is being performed.

#### 2.1 Capsules

The main activities of the capsule development and utilization programs in HANARO are focused on in-

reactor material tests, new and advanced nuclear fuel research and development, safety-related research and development for nuclear reactor materials and components, and basic research. At present, capsules have been developed and are being utilized for the irradiation tests of materials and nuclear fuels in HANARO, and creep and fatigue capsules have also been developed to study the creep and fatigue behavior of materials[2-9]. A capsule for a nuclear fuel irradiation test is applicable to study the irradiation characteristics of a nuclear fuel pellet and to obtain the in-core performance and the design data of the nuclear fuel in HANARO. The non-instrumented capsule was developed in 1999, and is been utilized for the irradiation characteristics test of the DUPIC (Direct Use of PWR spent fuel in CANDU) fuel and advanced PWR fuel pellets. The design verification test of an instrumented capsule was completed in one of HANARO's test holes in 2003. Now, the instrumented capsule can be used to measure the fuel temperature, the internal pressure of fuel rod, the fuel deformation and a neutron flux during a fuel irradiation test.

#### 2.2 Fuel Test Loop (FTL)

The FTL (Fuel Test Loop) simulates commercial NPPs' steady state operating conditions such as their pressure, temperature, flow, water chemistry conditions and neutron flux levels to conduct the irradiation and thermo-hydraulic tests[10]. The installation of the FTL was completed successfully in March 2007. At present, the commissioning of the FTL is being conducted. The FTL will be used for the irradiation test of high burn-up PWR fuels after its commissioning is completed. The irradiation tests for the PWR fuels (3 test fuel rods) will be started after the commissioning is completed. Three thermocouples are installed at the inlet, middle and outlet points of the test rig. A LVDT is installed to measure the fission product pressure, and thermocouples are installed to measure the centreline temperature of a test fuel. And, three SPNDs are installed in the upper, middle and lower parts of the irradiated section.

### 3. Instrumentations

Figure 1 shows the typical instrumented capsules for the irradiating nuclear fuels. Two kinds of thermocouples, K- and C-type, LVDTs and SPNDs are installed in an instrumented capsule to measure certain

characteristics during an irradiation of the nuclear fuels. KAERI has performed in-pile tests of nuclear fuels in HANARO by using this capsule. The measured results from the C-type thermocouples for  $UO_2$  pellets during an irradiation at the 24 MW thermal powers of HANARO were shown as an example in Figure 2. Some degradation and drift of the instrumentations were found during an irradiation and between the operating cycles of HANARO. To yield more reliable data from the irradiation tests of nuclear fuels in HANARO, it is necessary to determine a re-calibration method for the instrumentations between the operating cycles of HANARO. So, KAERI will start to research for a re-calibration method of the instrumentations, and proceed with an international cooperative study if necessary.



Figure 1. Instrumented capsule for nuclear fuel

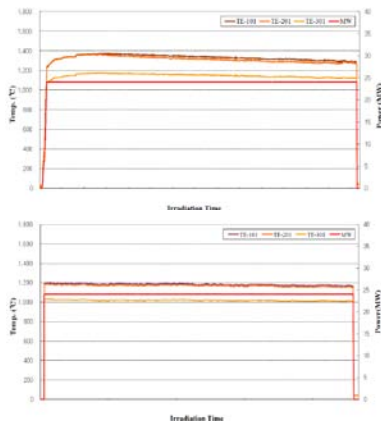


Figure 2. Measured center temperatures of  $UO_2$  pellets during irradiation in HANARO

#### 4. Conclusion

Some capsules for the irradiation tests of materials and nuclear fuels have been developed and used in irradiation tests, and the development of capsules will be carried out continuously to support the development of the Gen-IV reactor systems, in HANARO. The commissioning of the FTL will be finished in 2009. The FTL will be used for an irradiation test of a high burn-up PWR fuels after its commissioning has been completed. The capsule and FTL will also be used for

materials and nuclear fuel irradiation tests in HANARO in succession and could help in maximizing the utilization of HANARO. And, in order to obtain more reliable data from the instrumentations during an irradiation of materials and nuclear fuels in HANARO, KAERI is going to establish a re-calibration method of the instrumentations between the operating cycles of HANARO.

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#### REFERENCES

- [1] Chang-oong Choi, et. al., "Present Situations and Perspective on the Advanced Utilization of HANARO", *Physica B*, 311 (2002) 34-39.
- [2] Special Issue on International Symposium on Research Reactor and Neutron Science in commemoration of the 10<sup>th</sup> anniversary of HANARO, *Nucl. Eng. and Tech.*, Vol. 38, No. 5, 2006.
- [3] B.G. Kim, et. al., Neutron Irradiation Technology in the HANARO, The Korean Superconductivity Society Meeting 2008 (KSS 2008), July 9-July 11, 2008, Youngpyoung, Korea.
- [4] B.G. Kim, et. al., Status and Perspective of Material Irradiation Test in the HANARO, International Symposium on Material Testing Reactors, July 16-July 17, 2008, Oarai, Japan.
- [5] K.N. Choo, et. al., Irradiation of High Temperature in the OR5 Test Hole in HANARO, Transaction of the Korean Nuclear Society Autumn Meeting, Pyeongchang, Korea, Oct. 30-13, 2008.
- [6] M.H. Choi, et. al., Temperature evaluation of an instrumented capsule after material irradiation tests in HANARO, *J. of Nucl. Mat.*, 362(2007) 19-25.
- [7] K.N. Choo, et. al., Development of Irradiation Capsule Technology in HANARO, Proceeding of the Korean Nuclear Society Spring Meeting, May, 2006, Kangchon, Korea.
- [8] K.N. Choo, et. al., Irradiation experience and technology development of a material capsule, International Symposium on Research Reactor and Neutron Science, Apr. 11-13, 2005, Daejeon, Korea.
- [9] K.N. Choo, et. al., Status of the material capsule irradiation and the development of the new capsule technology in HANARO, Proceeding of 2005 JAEA-KAERI joint seminar on advanced irradiation and PIE technologies, Nov. 16-18, 2005, Oarai, Japan.
- [10] S. K. Park., et. al., "Prediction on the Nuclear Fuel Cladding Temperatures for the LBLOCAs of the HANARO Fuel Test Loop", *Journal of Korea Society of Mechanical Technology*, Vol.9, No. 3, pp. 53-58, 2007.