Overview of High Burn-up Fuel Irradiation Test in Fuel Test Loop

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I. Introduction

The steady state FTL (Fuel Test Loop) was installed in the multi-purpose research reactor HANARO. Recently, many LWR fuel plants have been increasing their fuel discharge burn-up and power level due to economic advantages. KAERI has developed advanced fuel claddings and large grain UO_2 pellets. But the development of a nuclear fuel material and fuel requires various performance verification tests under simulated commercial reactor conditions. The FTL is the first test facility that can provide PWR and CANDU operation conditions in the Korea. The in-pile performance of the developed fuel under the steady state condition will be verified in FTL. A plan for the irradiation test of an advanced cladding and UO_2 pellet has been prepared in collaboration with the relevant divisions of HANARO. At present, a rod manufacturing and test capsule assembling are progressing and various analyses are being carried out for a confirmation of their safety. Irradiation test will be started in November, 2008.

II. Characteristics of Fuel Test Loop

The FTL has been constructed in the HANARO at KAERI. HANARO is an open-pool type multi-purpose research reactor which can be used for various purposes such as an irradiation test of fuel and material, a radioactive isotope production and a neutron radiography.[1] The neutron power is 30MW and an average effective full power day is about 280 days per year. The FTL was installed in the IR1 hole.

The FTL consists of the OPS (Fig. 1) and IPS (Fig. 2). The OPS (Out-Pile System) is composed of a main cooling water system, emergency cooling water system, instrument cooling water system, etc. The design value of the pressure and temperature of the FTL is 17.5MPa and 350℃ respectively. The boron concentration limit is 1500ppm.

The IPS (In-Pile System) consists of inner and outer pressure tubes, flow tube, fuel and bundle head, closure head, and associated instruments. The IPS which is connected to the OPS is controlled and regulated by means of the systems pressure and temperature and its water quality. The coolant which comes in through inlet connection flows down between the inner pressure vessel and the flow divider tube, and then it comes up past the test fuel and flows out through the outlet connection.[2] In the IPS, the coolant temperature is measured at three points, bottom, middle and top of the test fuel and the power variation is measured by nine neutron sensors which are attached to the outer pressure vessel. The design and maximum operation conditions of the OPS and IPS are summarized in Table 1.

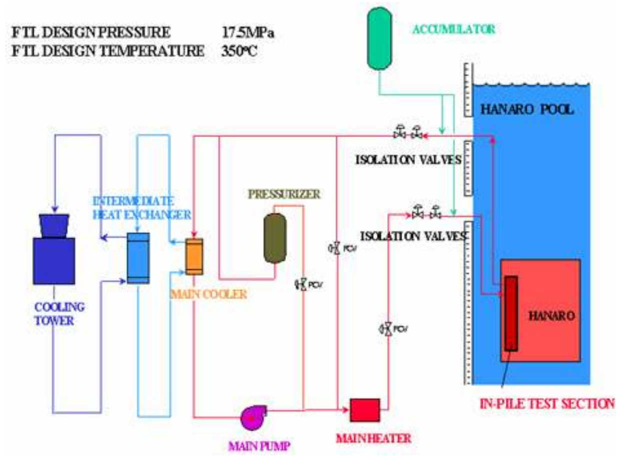

Fig. 1. A diagram of the FTL OPS

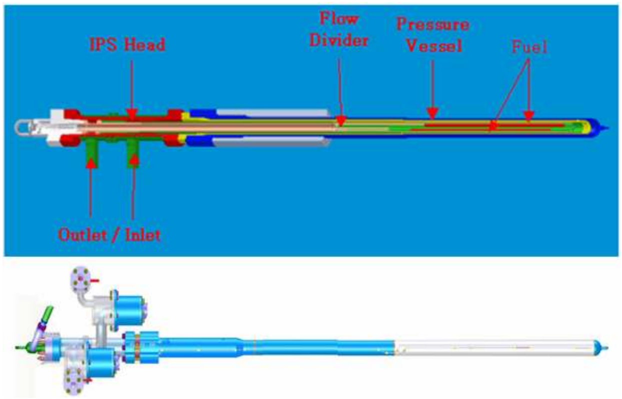

Fig. 2. The IPS features

Table 1. Design and operation condition of OPS and IPS

Design & Operation condition		PWR Mode	CANDU Mode
Design condition	Temperature (IPS/OPS)	350 ℃	350 ℃
	Pressure (IPS/OPS)	17.5 MPa	17.5 MPa
IPS Maximum operation condition	Generated heat	112.3 kW	116.2 kW
	Outlet pressure	15.5 MPa	10.0 MPa
	Inlet temperature	303.3 ℃	276.7 ℃
	Outlet temperature	312.0℃	290.0 ℃

III. Description of Test Fuel Rod

The IPS has a triangular type lattice as shown in Fig. 3. Among the three installed rods, two rods are divided into two small rods for a diversity of experiment and these two rods dimensions are identical except for their insulating pellet length and measuring equipment existence or nonexistence. The two lower small rods contain a thermocouple for a centerline temperature measurement and the upper ones have no instrumentation. The longest rod, which isn't divided into two rods, has various instrumentations such as a thermocouple, LVDT and pressure transducer. In conclusion, five rods can be loaded into the IPS but for this type of rod it is three. Detailed test rod descriptions can be seen in Fig. 4.

The test fuel rods were made of HANA^{TM} claddings and large grain UO_2 pellets which were developed for the high burnup application in KAERI. HANA^{TM} claddings showed better corrosion and creep resistance than the commercial claddings in out-of-pile tests. [3] A large grain UO_2 pellet was developed by a U_3O_8 seed addition method. The grains size of UO_2 pellet is 14~16 ㎛, while the grain size of commercial UO_2 pellet is 8 ㎛. [4]

Prior to an irradiation test of the advanced PWR fuel cladding and UO_2 pellet in the FTL, it is necessary to carry out a preliminary analysis for their in-reactor behaviors so that safe irradiation in the FTL can be ensured while producing valuable measured data. In this study, important performance factors of the in-pile fuel performance such as a cladding corrosion, fission gas release, rod internal pressure and fuel centerline temperature were evaluated.

IV. Summary

The fuel test loop was constructed in the research reactor HANARO. The FTL consists of the OPS and IPS and PWR & CANDU type fuel can be loaded into the IPS and an irradiation test can be performed under simulated commercial reactor conditions. The first test fuel of the FTL was determined as an advanced Zr based cladding and a large grain UO2 pellet which were developed for the purpose of a high burnup PWR fuel application. For an irradiation test safety confirmation, a preliminary fuel performance analysis was performed and the important performance factors were reviewed such as the fuel temperature, FGR, rod internal pressure and cladding oxide thickness, and it was evaluated that test fuel can maintain its integrity up to the target burnup.

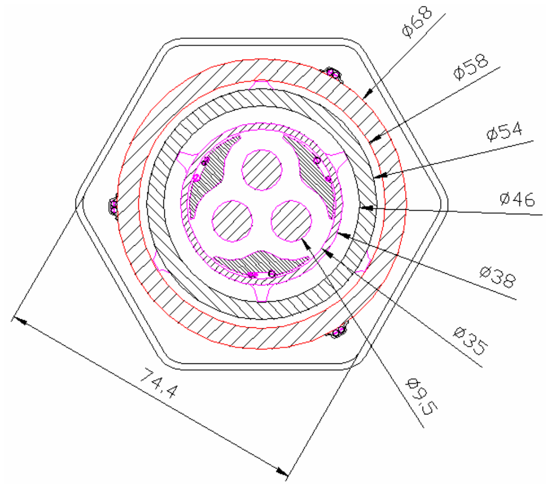

Fig. 3. Cross section view of IPS

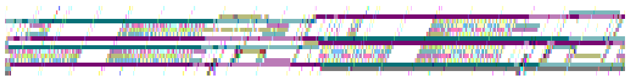
Fig. 4. Test fuel rods of FTL

Acknowledgments

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