Validity and Utilization of the Out-Pile Testing Facilities at HANARO

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1. Introduction

The High Flux Advanced Neutron Application Reactor (HANARO) has been operating as a platform for basic nuclear research in Korea, and the functions of its systems have been improved continuously since its first criticality in February 1995 [1]. Various neutron irradiation facilities such as rabbit irradiation facilities, loop facilities and the capsule irradiation facilities for irradiation tests of nuclear materials, fuels and radioisotope products have been developed at HANARO [2,3]. Among these irradiation facilities, the capsule is the most useful device for coping with the various test requirements at HANARO.

To support the national research and development programs on nuclear reactors and the nuclear fuel cycle technology in Korea, new irradiation capsules have been developed and actively utilized for the irradiation tests requested by numerous users [2,3]. Recently, the development of future nuclear systems such as VHTR, SFR, and fusion reactors is one of the most important projects planned by the Korean government. The environmental conditions for these reactors are generally beyond present day reactor technology, especially regarding the higher neutron fluence and higher operating temperature. To effectively support the national R&Ds relevant to the future nuclear systems, the development of advanced irradiation technologies concerning higher neutron fluence and irradiation temperature are being preferentially developed at HANARO [4,5].

The performance and safety of the new irradiation technologies should be fully checked by using out-pile testing facilities before HANARO application. All of the inserted structures in the reactor core including the irradiation capsule are required to satisfy the HANARO criteria, as shown in Table I.

In this paper, the out-pile testing facilities at HANARO are described and the validity of the facilities are estimated.

Table I: Criteria of safety evaluation for a new device installed in the core of HANARO

Item	Criteria
Flow Amount (<19.6 kg/s)	ΔP ; 200±10 kPa (>209 kPa)
Vibration Amplitude	< 300 μm
Endurance	1/10 of Irradiation Period
Reactivity	< 12.5 mk

2. Out-Pile Testing Facilities at HANARO

The out-pile performance and endurance testing are performed by using the single channel test loop and half core test facility in the Engineering building, as shown in Fig. 1. Although the half core test facility seems to be more close to the reactor core environment of HANARO than the single channel test loop, the performance and safety of the capsule are usually measured in the single channel test loop for experimental convenience.

Fig. 1. An irradiation capsule and out-pile testing facilities at HANARO

There is a forced upward coolant flow in the core of HANARO. All of the inserted structures in the core including the irradiation capsule are required to satisfy the pressure drop criteria of 209 kPa. This criteria requiring enough cooling of reactor nuclear fuels, is measured in the single channel test loop, as shown in Fig. 2.

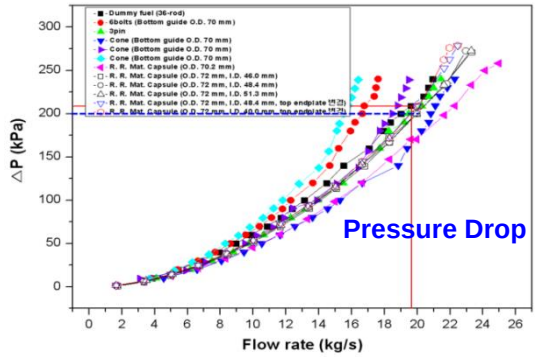

Fig. 2. Measurement of coolant pressure drops of the capsules with different designs

All of the inserted structures in the reactor core including the irradiation capsule are also recommended to satisfy the vibration displacement criteria of 300μm owing to the design characteristics of HANARO. This criterion was suggested to prevent contacting of the flow tubes having 1 mm gap. As the loaded capsule is exposed into a forced upward coolant flow of 19.6 kg/s during irradiation, the capsule has a coolant flow-induced vibration that results in a flow tube displacement. The vibration behavior of the capsule is measured using a laser vibrometer (Polytec Model VD-09) in the out-pile testing facilities, as shown in Fig. 3.

Fig. 3. Single channel out-pile test loop and Laser Vibrometer

The vibration amplitude and root mean square (RMS) of the capsule are measured at several points of the capsule under the 100% and 110% conditions of normal reactor coolant flow of 19.6 kg/s. The out-pile test of 110% of reactor coolant flow amount are performed in a conservative point of view and results in an increased coolant flow-induced vibration than the normal coolant flow condition. Figure 4 shows the vibration of a capsule installed in the single channel out-pile test loop measured at a point 1.42 m above the rod tip of the capsule under the accelerated 110% condition (in south-north direction).

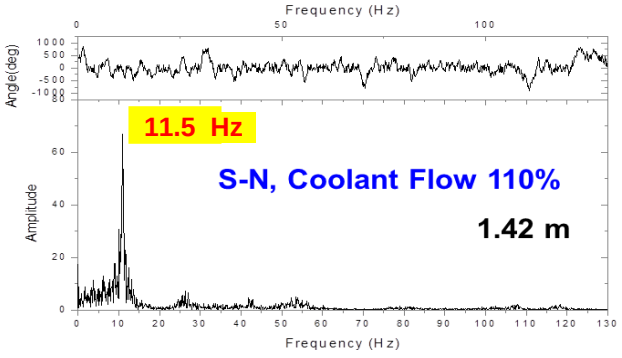

Fig. 4. Measuring the vibration of a capsule installed in the single channel out-pile test loop

The out-pile endurance test is performed by using the single channel test loop under the 110% accelerated condition of a reactor coolant flow amount to shorten the testing period.

3. Validity of the Out-Pile Testing Facilities

The irradiation safety of all new designed structures including capsules in the reactor core must be evaluated at the 'Reactor Safety Review Committee of HANARO'. The out-pile performance and safety results are obtained by using the out-pile testing facilities. Therefore, it must be proved that the out-pile testing facilities simulate properly the real operation condition of the reactor.

Table II shows a typical comparison of vibration behaviors of irradiation capsules obtained in the out-pile testing facilities and HANARO [6-8]. From the obtained results, it can be concluded that as mentioned below.

1. The natural vibration of an instrumented capsule was not greatly affected by capsule design changes.
2. The out-pile testing facilities have similar natural vibration to HANARO and doesn't provoke a resonance with irradiation capsules.
3. The maximal vibration amplitudes of the capsules obtained in the out-pile testing facilities are larger than that of HANARO.
4. The out-pile test under the 110% conditions of normal reactor coolant flow provides more conservative vibration results of maximal 38% increase than HANARO condition.

The validity of the out-pile testing facilities was also evaluated and proved to be effective for verifying the integrity of irradiation capsule by an independent research company of the FNC Technology Co., Ltd. [9].

Table II: Typical comparison of vibration behaviors of irradiation capsules obtained in out-pile testing facilities and HANARO

	HANARO	Single Channel Loop	Half Core Facility	
Natural Frequency	99 Hz	147.5 Hz	175 Hz	
Maximal Amplitude	182 μm	508 μm	191 μm	
Frequency	(Material) 7.0 Hz 12.2 Hz	(Material) 6.0 Hz 11.5 Hz	(Fuel) 7.5 Hz 17.5 Hz	(Material) 7.0 Hz 10.5 Hz

4. Summary

The utilization of the out-pile testing facilities to satisfy the criteria of safety evaluation for a new device installed in the core of HANARO was summarized. In addition, the validity of the out-pile testing facilities was evaluated and proved to be effective for verifying the integrity of irradiation capsule.

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