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The Design and the Irradiation Test of a Capsule with Two Specimens for a Creep Test

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1. Introduction

A creep capsule with two specimens was designed, fabricated and irradiated during the period from Feb, 2004 to May, 2005. In the design stage, the reactivity effect was reviewed and an analysis for the structural and thermal integrity was performed to review the safety of the creep capsule. During the irradiation test, the temperature of the components and the displacement of the specimen were measured and analyzed. The temperature of the specimen during the test was 550±5℃ over the whole irradiation period. The measured temperature of the components showed differences of not more than 90℃ when compared with the design values and this indicates the error range to be 18% or so when compared with the design values.

2. The analysis at the design stage

The reactivity effect, the neutron fluence and the heating rate caused by loading the capsule into the test hole were estimated. The reactivity worth by the insertion of the creep capsule is no more than +9.2mk, this indicates that the reactivity effect does not exceed +12.5mk as specified in "the HANARO operation technical specification[1]". This value appears to be a little big if it is compared with the reactivity worth +6.2mK of the 02S-08K creep capsule previously installed in IR2. This is because the neutron absorbing materials, STS304 and STS316, in this capsule are used more than in the 02S-08K creep capsule.

The structural integrity for the capsule's outer tube was analyzed. Table 1 represents the results of the stress analysis and the strength evaluation based on the ASME code requirements. This shows that the results satisfy the code requirements.

Table 1. Stress at the capsule outer tube. (unit : MPa)

Item		Calculation Stress	Allowable Stress	Code requirement
P_{cr}		1.2	15.52	$P_{cr} > 3P^*$
P_m		4.36	114.92	$P_m < S_m$
30MW	P_m+P_e	66.7	344.76	$P_m+P_e < 3S_m$

* Coolant pressure (P=0.4 MPa)

During the irradiation test, some abnormal accidents can be assumed by a damage or breakage of the bellows in the stress loading unit in the capsule because it works normally at a high pressure of 30~40kgf/cm^2. For this case, a stress analysis was performed to confirm the structural integrity of the capsule outer tube.

The model for the temperature calculation in the cross section of the capsule is shown in Fig. 1.

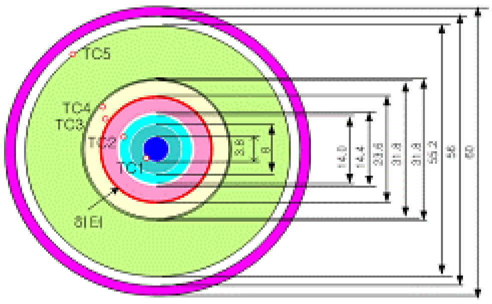

Figure 1. Model for the temperature calculation of the specimen section

The estimated temperature distribution at the 30MW$_{th}$ HANARO power is shown in Table 2. The temperatures of the specimen ranged from 403℃ to 540℃ by a change of the internal He pressure in the capsule. Therefore, the requirements for the specimen temperature are satisfied. This range satisfies the required temperature 550℃(±10%).

Table 2. Temperature distribution (IR2, control rod 450mm)

Parts	30MW		
	0.4k (~30torr)	0.6K (~70torr)	1K (1atm)
Specimen	540	463	403
Spacer 2	495	426	368
Connector	216	195	171
Thermal media	108	106	102
Outer tube	46	46	46

3. Irradiation Test

3.1 The results from the irradiation test

The temperatures of the capsule components and the displacement at the specimen were measured through an irradiation test. The target temperatures of the specimens in this capsule were 550℃(±10%)[2]. The results for the temperatures of the capsule components measured by depending on the HANARO power are shown in the Fig. 2. As a result of the irradiation, the temperatures of the specimens were 550±5℃ over the whole irradiation period. The temperatures of the upper and lower specimen were respectively 490 ℃ and 488℃ at the condition that the HANARO power is 30MW and the internal pressure of the capsule is 760torr. This initial temperature starts to rise up to the target temperatures by a control of the heater power and the internal vacuum pressure. The pressures at the upper and lower specimens were 20kgf/cm^2 and 15kgf/cm^2 respectively. However, these pressures were not changed due to the abnormal signal of the LVDTs. The performances of the LVDTs at a high temperature and a high radiation were analyzed to establish the cause of their abnormal signal.

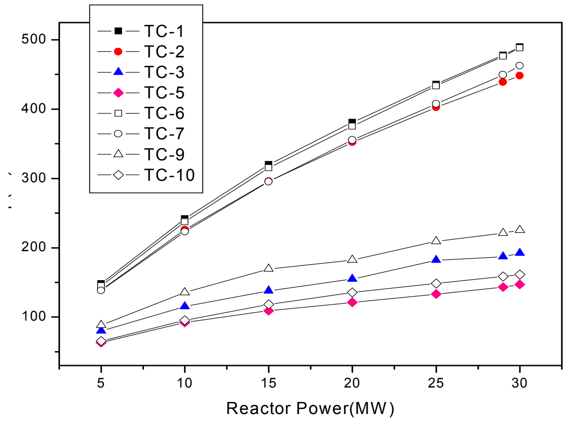

Figure 2. Temperature distribution depending on the power

3.2 The Temperatures for the design and the measurement

Table 3 shows the design and the measured temperatures for the specimen and the components. For the temperature of the specimen, the measured value shows higher than 18~30% depending on the degree of vacuum when compared with the design temperature. The temperature calculated before the irradiation test was estimated as lower than 90℃ when compared with the measured one.

Table 3 The design and measured temperatures

Vacuum	70 torr		760 torr	
	design	measure	design	measure
TC-1	463	655	402	490
Tc-2	426	588	368	448
Tc-4	195	254	171	192
Tc-5	106	179	102	147

3.3 The LVDT signal vs. the specimen temperatures

To analyze the cause of the abnormal signal which occurred at the LVDTs, the relation between the temperatures of the upper specimen and the displacement signal was plotted in the Fig. 3. The lines with 10 peaks represent the temperature changes of the specimen according to the control of the heater power and the degree of the vacuum. The first 3 peaks represent the status where the temperatures were rising to the degree of the vacuum at a 0 power condition of HANARO, the other 7 peaks represent the temperatures rising by controlling the degree of the vacuum at 5, 10, 15, 20, 25, 29, and 30 MW. When the temperatures of the capsule components are rising with an increase of the HANARO power, the signals of the LVDTs show the tendency of an increase in the negative(-) direction, which is the elongation direction of the specimen[3].

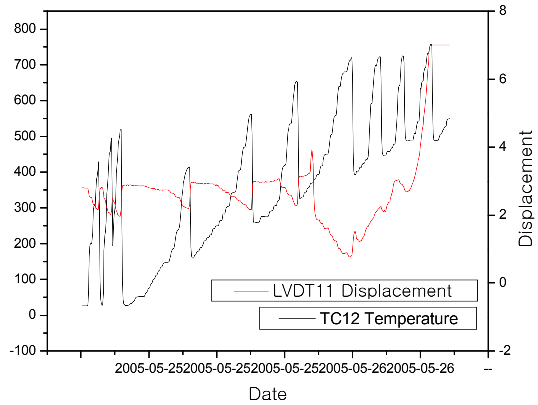

Figure 3. Temperature of the specimen and the displacement

4. Conclusion

In the design stage, the reactivity effect was reviewed and the structural integrity was confirmed for the normal and abnormal conditions. The irradiation test of a creep capsule with 2 specimens was performed in the IR2 hole in May, 2005. During the irradiation test, the temperatures of the upper and lower specimens were respectively 490℃ and 488℃ at a HANARO power of 30MW. The temperature of the specimen was maintained at 550℃ over the whole irradiation period by a control of the He pressure and the heater power. As the pressure in the capsule is dropping from 760 torr to 10 torr, the temperature of the specimen rises rapidly at a pressure lower than 50 torr. As for a displacement, the cause of the abnormal signal at the LVDTs was reviewed to be a deterioration of the performance by the high radiation in the core region.

ACKNOWLEDGEMENT

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