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Drop Test Results of CRDM under Seismic Loads

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1. Introduction

A control rod drive mechanism is a reactor regulating system, which inserts, withdraws or maintains a control rod containing a neutron absorbing material within a reactor core to control the reactivity of the core. The top-mounted CRDM driven by the stepping motor for Jordan Research and Training Reactor (JRTR) has been developed in KAERI[1]. The CRDM for JRTR has been optimized by the design improvement based on that of the HANARO. It is necessary to verify the drop performance under seismic loads such as operating basis earthquake (OBE) and safe shutdown earthquake (SSE). Especially, the CAR drop times are important data for the safety analysis. This paper describes the test results to demonstrate the drop performance of CRDM under seismic loads.

2. Test Rigs

The JRTR is a pool type reactor with 5MW power which is open to the atmosphere. The reactivity control mechanisms of this reactor consist of four CRDMs and two SSDMs. The CRDM is composed of a CAR, a CAR guide tube, carriages, tracks, a tie rod, and a drive assembly as shown in Fig. 1. During the normal operation of the reactor, the CAR position is controlled by a stepping motor. The CAR drops by gravity into the core by de-energizing the electromagnet when a reactor trip is required by the reactor protection system.

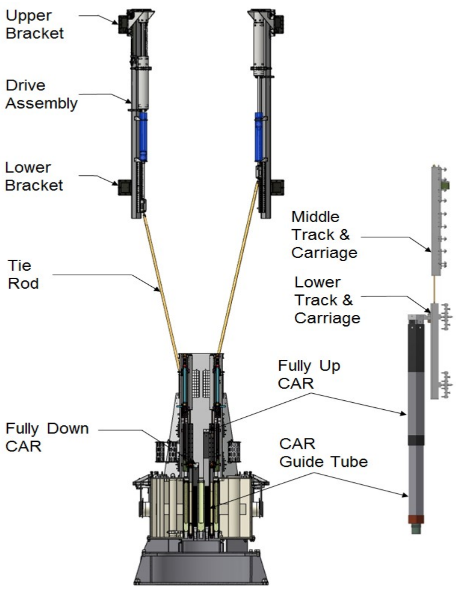


Fig. 1 Overall view of the CRDM

It is very difficult to simulate the seismic conditions with the full scale test rig because of different floor response spectra (RFS) for the reactor structure assembly and the pool top parts. Therefore, the seismic test rig is cut into two separate parts simulating the reactor structure assembly (Rig #2) and the reactor pool top (Rig #3). Rig #2 is used for the test of CRDM components installed on the UGS and core as shown in Fig. 2. Rig #3 consists of only the pool section and is used for the test of CRDM drive assembly.

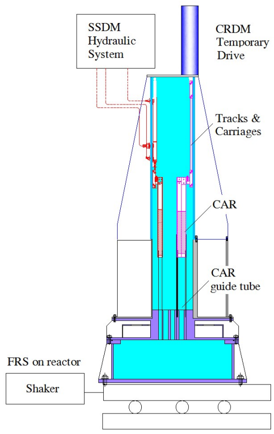


Fig. 2 Schematic view of test rig #2

3. Drop Test

The purpose of the drop test is to confirm that the CAR drops within the specified time during seismic loads. The drop tests are carried out by de-energizing the power of an electromagnet at full stroke height (650mm). The drop times are obtained from the high speed camera with 700fps at Rig #2 and the linear transducer attached to the drive assembly at Rig #3.

Fig. 3 shows typical floor and required response spectra of SSE on the reactor pool top. The seismic loads in the horizontal directions are applied to the shaker at the same time.

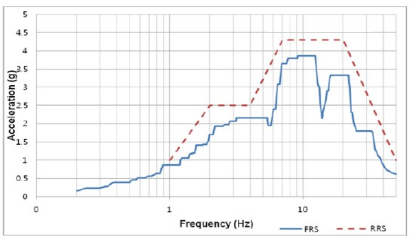


Fig. 3 Typical SSE load on reactor pool top(X-dir. SSE)

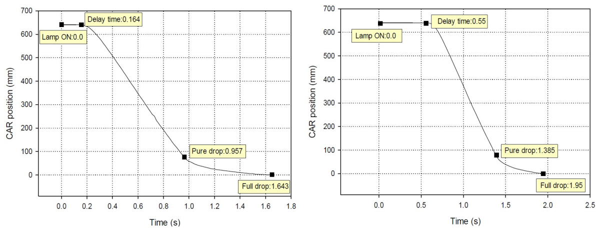
4. Results and Discussion

The drop performance test of prototype CRDM with AC type electromagnet was performed at test rig #1, and the longest pure drop time was measured as 0.98 sec [2]. This value is used to estimate the total drop time of CRDM under seismic loads.

Table 1 presents the summary of CAR drop test results at Rig #2. Fig. 4 shows the typical drop curves of CAR assembly measured before and after seismic test. At first, the drop time of CAR at Rig #2 was set to be equal to that measured at test rig #1 by adjusting the opening of orifice in the temporary drive assembly. The pure drop times under OBE and SSE loads are 1.1 and 1.75 sec, and are delayed up to 0.14 and 0.79 sec than those before the seismic test, respectively. The drop time measured after seismic test is 1.39 sec which is late than 0.96 sec before seismic test. It is found that this difference occurs because the long initial delay time is measured after seismic test as shown in Fig. 4.

Table 1 CAR drop times at test rig #2

No.	Pure drop time (sec)		Full drop time (sec)	Condition
	Measured[1)]	Req.	Measured[1)]	
1	0.98	1.5	1.75	Tuning
2	0.96		1.64	Before seismic test
3	1.10	2.0	1.95	During OBE
4	1.75		2.80	During SSE
5	1.39	1.5	1.95	After seismic test
1) High speed camera				



(a) before (b) after

Fig. 4 Typical CAR drop curves at Rig #2

Although it is not described here in detail, the drop tests under seismic loads at Rig #3 are also carried out. Unlike results of Rig #2, there is no difference between drop times measured at Rig #3 before and after seismic test. The reason is considered as due to the simple structure of Rig #3. Fig. 5 shows the drop curves of CRDM drive assembly measured at Rig #3 during seismic loads.

Table 2 presents the total drop times based on the drop test results of CRDM under OBE and SSE loads. The total drop time is the sum of pure drop time (0.98 sec.) measured at test rig #1 and total delay time due to seismic loads at Rigs #2 and #3. The total delay times for OBE and SSE loads are measured as 0.189 and 0.875 sec, respectively. In case of SSE load and Rig #2, the delay times due to seismic load are larger than those of OBE load and Rig #3. Finally it is found that the total pure drop time of CRDM for JRTR is 1.169 sec for OBE and 1.855 sec for SSE. All drop times are satisfied with the requirement, 2.0 seconds during the seismic situation excluding the damping time.

Table 2 Drop times of CRDM under seismic loads

Load	Seismic delay time[1)] (s)		Total delay time[2)] (s)	Total drop time[3)] (s)	Req. (s)
	at Rig #2	at Rig #3			
OBE	0.161	0.028	0.189	1.169	2.0
SSE	0.810	0.065	0.875	1.855	
1) Difference of results before and during seismic excitation 2) Sum of results at test rigs #2 and #3 3) Sum of pure drop time(0.98sec.) and total delay time due to seismic loads					

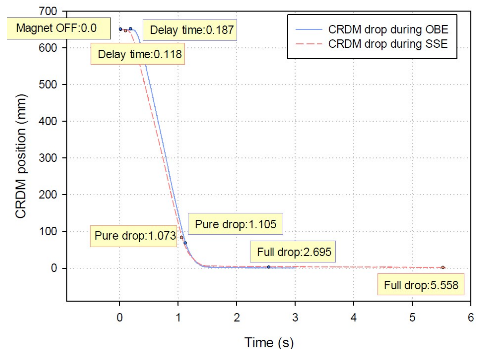


Fig. 5 Drop curves at Rig #3 during seismic loads

5. Conclusions

The drop tests of prototype CRDM are performed to confirm the drop performance under seismic loads. The delay of drop time at Rig #2 due to seismic loads is greater than that at Rig #3. The total pure drop times under seismic loads are estimated as 1.169 and 1.855, respectively. The test results using two test rigs show that the CRDM meet the drop time requirement, 2.0 seconds under seismic conditions, and maintains the good drop function before and after seismic loads of 5 OBE and 1 SSE.

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