Bottom-mounted Reactor Shutdown Mechanism

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1. Introduction

The reactivity control mechanisms of Ki-Jang Research Reactor (KJRR), a new research reactor in Korea with plate type fuels, consist of four Bottom-Mounted Control Rod Drive Mechanisms (BM CRDMs) driven by an individual step motor and two Bottom-Mounted Second Shutdown Drive Mechanisms (BM SSDMs) driven by an individual hydraulic system located in Reactor Control Mechanism (RCM) Room as shown in Fig. 1. The CRDM acts as the first reactor shutdown mechanism and reactor regulating as well. The SSDM provides an alternate and independent means of reactor shutdown. The second shutdown rods (SSRs) of the SSDM are poised at the top of the core by the hydraulic system during the normal operation and drop by gravity within the specific time (see Table 1) for a reactor trip. The SSR drop is actuated by the Reactor Protection System (RPS), Alternate Protection System (APS), Automatic Seismic Trip System (ASTS), or by the reactor operator in KJRR.

Based on the proven technology of the design, operation and maintenance for HANARO and JRTR (Jordan Research and Training Reactor), the SSDM for the KJRR has been optimized by the design improvement from the experience and test [1-2].

This paper aims for the introduction of the BM SSDM in the process of the basic design. The major differences of the shutdown mechanisms are comparatively analyzed between HANARO and KJRR. And the design features, system, structure and future works are also suggested.

2. Design Features

The KJRR is a pool type research reactor with 15MW power. The layout of four Control Absorber Rods (CARs) and two SSRs in the core is shown in Fig. 1. The basic design of the BM SSDM has been started on the similar concept with the SO unit in HANARO. Therefore, some design features including hydraulic system have been applied to the new reactors. However, differences in the fuel types, core configuration, layout, etc. led to a design change and optimization for KJRR.

Table 1 presents the differences in design features of the shutdown mechanism driven by hydraulic system between HANARO and KJRR.

Table 1 Comparison of shutdown mechanism by hydraulic system between HANARO and KJRR

	HANARO	KJRR
Function	First shutdown mechanism	Second shutdown mechanism
No. of system	4	2
Absorber shape	Cylindrical tube	Square tube
Absorber mater.	Hf	Hf
Absorber stroke	700 mm	700 mm
Absorber drop time	<1.08s (Before damping)	<1.50s (Before damping)
	<1.5s (Including damping)	<5.0s (Including damping)
Absorber withdrawal time	>28s	15~60s
No. of gimbal joint in absorber	2 joints	N/A
Absorber guide tube	Cylindrical shroud tube & flow tube	Square tube
Guide concept out of core	Track & carriage above core	ES guide tube below core
Actuating mechanism	Hydraulic cylinder in reactor structure	Hydraulic cylinder in RCM room
Actuating system	Hydraulic system at top of reactor pool	Similar concept in RCM room
Solenoid & piston valve	2 out of 3 for normal function	1 out of 2 for normal function
Core Accessibility	Normal	Good
ASME code class	N/A (ND guide for design)	3 (Section III, ND, NF)

3. System and Structures Summary

The SSDM is consisted of a SSR, SSR guide tube, Extension Shaft Assembly (ESA), ES guide tube, connector assembly, seal valve, hydraulic cylinder and hydraulic system as shown in Fig.1. The hydraulic force derived from the hydraulic system raises the piston in the hydraulic cylinder which is pressure boundary. The piston is connected to the SSR through the ESA which is guided by the ES guide tube in the CRDM/SSDM penetration assembly. The SSR is guided by the Aluminum CAR/SSR guide tube in the core.

During the normal operation, the SSRs are raised to the top of the core and poised. When the reactor trip is required, the SSRs drop by gravity into the core by the de-energizing the two solenoid valves to dump the pumping water to the RCM tank through opening of the air-operating piston valves. There is a proper hydraulic damping mechanism in the hydraulic cylinder to absorb the impact during the SSR drop. The SSRs drop also under the abnormal operation transients such as a loss of electric power for the pump. The top and bottom positions of SSR are monitored by the two pressure switches respectively.

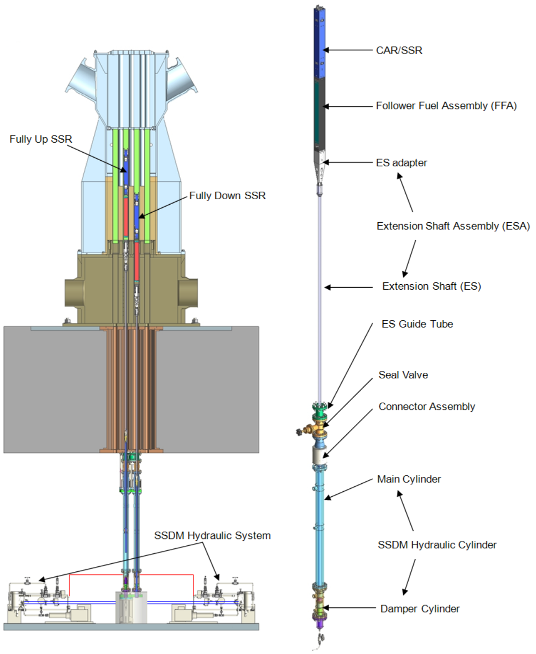

Fig. 1 Overall view of the SSDM.

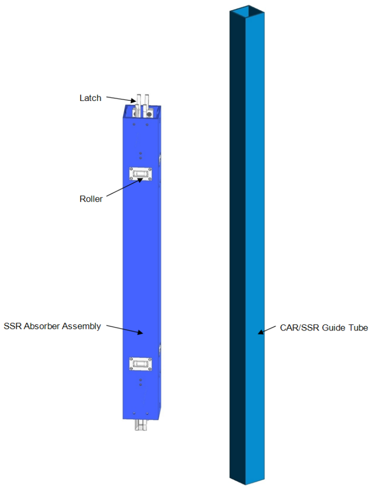

Fig. 2 Shape of the SSR and SSR guide tube.

3.1 SSR and SSR guide tube

The SSR and CAR/SSR guide tube are square shape as shown in Fig. 2. The SSR is a square tube with the neutron absorbing material of Hafnium with mechanical latches for connecting/disconnecting a Follow Fuel Assembly (FFA). The SSR is actuated by a hydraulic cylinder mounted to the CRDM/SSDM support structures aligned directly below the ES guide tube. The guide tube is aluminum single square tube supported coaxially with the SSR to absorb the flow induced forces on the exposed parts of the absorber element in the core. The lower part of the guide tube is mounted into the grid plate and the upper part is engaged in reactor cover assembly. The SSR is guided in its smooth slide motion by fixed and the spring rollers running on the inside surface of the SSR guide tube.

3.2 ESA and ES Guide Tube

The SSDM includes ESA and ES guide tube. The ES guide tube is mounted in the CRDM/SSDM penetration assembly for the guide of the ESA in the penetration assembly. The linkage formed by the ESA and the piston rod connects the absorber element to the hydraulic cylinder to effect and guide the motion of the absorber element.

3.3 Hydraulic Cylinder Assembly and Hydraulic System

The hydraulic cylinder is mounted to the CRDM/ SSDM support structures in RCM room by a set of support structure. The hydraulic cylinder consists of a cylinder, main piston, damper cylinder, damper piston, and so on. Mechanical and hydraulic dampings during drop are applied simultaneously in this system. The SSR is poised by hydraulic force and drops by loosing hydraulic force by bypassing the water pumping. The direct injecting and bypassing of water pumping are changed by two sets of solenoid-piston valves.

4. Future Works

At present, the basic design of the BM SSDM in KJRR was completed. The detail design for the fabrication has been carrying out along the project schedule. Also, the prototype BM SSDM will be fabricated and the qualification test using test rigs will be performed to verify the functionality, the drop times during normal operation and seismic conditions, and endurance performance.

5. Conclusions

A basic design of the BM SSDM for the KJRR has been completed on the basis of the HANARO's SO unit or JRTR's SSDM. The SSR and its guide tube are designed and optimized according to the geometrical core configuration. Many components including the ESA, ES guide tube, connector assembly, seal valve, the hydraulic cylinder assembly and support structures are developed and optimized with the improved operability and maintainability. Also, the detail design for the fabrication and the qualification test will be carried out in the near future.

REFERENCES

[1] K.R. Kim, Y.G. Cho, An experimental study on the factors for the performance of a shutoff unit in the half-core test loop of HANARO, Trans. of the KNS Autumn Meeting, 2005.
[2] S. Kim, et al., Reactor Shutdown Mechanism by Top-mounted Hydraulic system, Trans. of the KNS Spring Meeting, 2012.