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Reactor Shutdown Mechanism by Top-mounted Hydraulic System

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1. Introduction

There are two types of reactor shutdown mechanisms in HANARO. One is the mechanism driven by a hydraulic system, and the other is driven by a stepping motor. In HANARO, there are four Control Rod Drive Mechanisms (CRDMs) with an individual step motor and four Shutoff (SO) Units with an individual hydraulic system located at the top of reactor pool. The absorber rods in SO units are poised at the top of the core by the hydraulic force during normal operation. The rods of SO units drop by gravity as the first reactor showdown mechanism when a trip is commended by the reactor protection system (RPS). The rods in CRDMs also drop by gravity together as a redundant shutdown mechanism. When a trip is commended by the reactor regulating system (RRS), the absorber rods of CRDM only drop; while the absorber rods of SO units stay at the top of the core by the hydraulic system.

The reactivity control mechanisms of in JRTR, one of the new research reactor with plate type fuels, consist of four CRDMs driven by an individual step motor and two second shutdown drive mechanisms (SSDMs) driven by an individual hydraulic system as shown in Fig. 1. The CRDMs act as the first reactor shutdown mechanism and reactor regulating as well. The top-mounted SSDM driven by the hydraulic system for the JRTR is under design in KAERI. 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 for the reactor trip. Based on the proven technology of the design, operation and maintenance for HANARO, the SSDM for the JRTR has been optimized by the design improvement from the experience and test [1]. This paper aims for the introduction of the SSDM in the process of the basic design. The major differences of the shutdown mechanisms by the hydraulic system are compared between HANARO and JRTR, and the design features, system, structure and future works are also described.

2. Design Features

The JRTR is a pool type research reactor with 5MW power. The layout of four Control Absorber Rods (CARs) and two SSRs in the core are shown in Fig. 1. The basic design of the top-mounted SSDM has been started on the same or similar concept with the SO unit in HANARO. Therefore, many design features of components can be applicable to the new reactors. However, due to the differences in the fuel types, core configuration and so on, it is necessary to modify and optimize for the new reactors.

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

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

	HANARO	JRTR
Function	First shutdown mechanism	Second shutdown mechanism
No. of system	4	2
Absorber shape	Cylindrical tube	Cylindrical tube
Absorber mater.	Hf	B_4C (Powder type)
Absorber stroke	700 mm	655 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	1 joint
Absorber guide tube	Cylindrical shroud tube & flow tube	Cylindrical tube
Guide above core	Track & carriage	Same concept with optimized
Actuating mechanism	Hydraulic cylinder with damper	Same concept with optimized
Actuating system	Hydraulic system	Same concept with optimized
Solenoid & piston valve	2 out of 3 for normal function	1 out of 2 for normal function

3. System and Structures Summary

The SSDM is consisted of a SSR, SSR guide tube, carriage, track, hydraulic cylinder and hydraulic system as shown in Fig.2. The hydraulic force derived from the hydraulic system raises the piston in the hydraulic cylinder. The piston is connected to the SSR through the carriage which is guided by the track in the Upper Guide Structure (UGS). The SSR is guided by the Zircaloy (Zr) SSR guide tube in the core. There are various universal joints on the connection points to improve the drop or withdrawal performance of the moving parts.

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 reactor pool 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 or a low-low level of pool water. The top and bottom positions of SSR are monitored by the two pressure switches respectively.

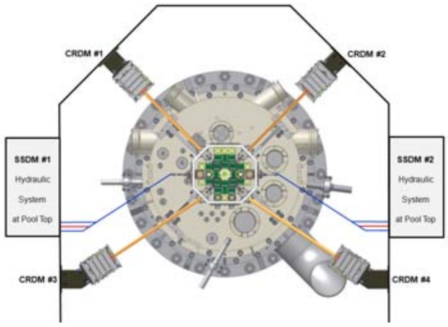

Fig. 1 Layout of the CRDMs and SSDMs.

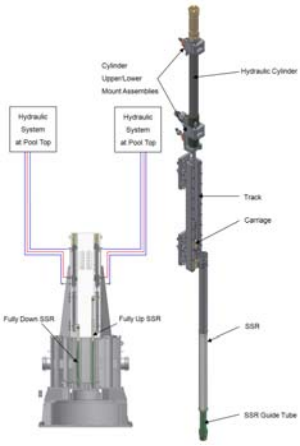

Fig. 2 Overall view of the SSDM.

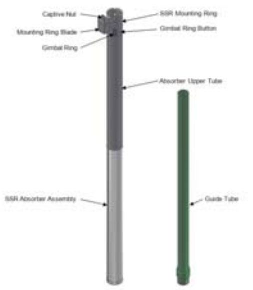

Fig. 3 Shape of the SSR and SSR guide tube.

3.1 SSR and SSR guide tube

The SSR and SSR guide tube as shown in Fig. 3 are cylindrical shape. The SSR is a cylindrical tube with the neutron absorbing material of B_4C powder that is contained in inconel cladding can with a certain tap density. It consists of a bearing skirt, an absorber element, a support tube and a mounting ring. The mounting ring and support tube is connected by a gimbal joint which permits the absorber element and guidance components to be misaligned within the limit of the tolerances. The SSR guide tube is zirconium alloy single cylindrical 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 thread-mounted into the grid plate. The SSR is guided in its motion by a bearing running on the outside of the SSR guide tube.

3.2 Track and Carriage

The SSDM includes one set of track and carriage. The track is mounted on the upper guide structure (UGS) wall for the guide of the carriage above the core. The linkage formed by the carriages 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 assembly is mounted by the upper and lower brackets which are attached to the UGS. 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 SSDM in JRTR was completed. The detail design for the fabrication has been carrying out along the project schedule. Also, the prototype 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 top-mounted SSDM for the JRTR was performed on the basis of the HANARO's SO unit. The SSR and SSR guide tube are designed and optimized according to the geometrical core configuration. Many components including the track, carriage, piston rod, the hydraulic cylinder assembly and brackets are optimized with the improved operability and maintainability. Also, the detail design for the fabrication and the qualification test will be carried out in the 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.