

Conceptual Design of Bottom-mounted Control Rod Drive Mechanism

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1. Introduction

The Control Rod Drive Mechanism (CRDM) is a device to regulate the reactor power by changing the position of a Control Absorber Rod (CAR) and to shut down the reactor by fully inserting the CAR into the core within a specified time. The Bottom-Mounted CRDM (BMCRDM) for the KiJang Research Reactor (KJRR) is a quite different design concept compared to the top-mounted CRDM such as HANARO and JRTR [1-3]. The main drive mechanism of the BMCRDM is located in a Reactivity Control Mechanism (RCM) room under the reactor pool bottom, which makes the interference with equipment in the reactor pool reduced. The arrangement of the BMCRDMs and irradiation holes in the core is therefore easier than that of the top-mounted CRDM. Hence, many foreign research reactors, such as JRR-3M, JMTR, OPAL, and CARR, have adopted the BMCRDM concept. The purpose of this paper is to introduce the basic design concept on the BMCRDM. The major differences of the CRDMs between HANARO and KJRR are compared, and the design features and individual system of the BMCRDM for the KJRR are described.

2. Design Features

The KJRR is a pool type research reactor with 15 MW power. The reactivity control mechanisms of the reactor consist of four BMCRDMs driven by an individual stepping motor and two Bottom-Mounted Second Shutdown Drive Mechanisms (BMSSDMs) driven by an individual hydraulic system located in the RCM room. The CRDMs control the position of the CARs and the Follower Fuel Assemblies (FFAs) in the core during the normal operation by the command from the Reactor Regulating System (RRS). The four CARs drop by force of gravity when required by the Reactor Protection System (RPS), Alternate Protection System (APS), Automatic Seismic Trip System (ASTS), or an operator for reactor shutdown.

The basic functions of CRDMs for the HANARO, JRTR, and KJRR are similar, but the design features of KJRR CRDM are quite different from those of HANARO and JRTR's which adopted top-mounted CRDM. Whereas the driving force of the HANARO and JRTR CRDM is directly transmitted to the CRDM moving parts, the driving force of the KJRR CRDM is transmitted to the moving parts by the non-contacting electromagnetic force. In addition, the KJRR CAR is connected to the FFA, and moves with the FFA. Table I compares the design features of the HANARO and KJRR.

Table I: Comparison of the CRDM design features between HANARO and KJRR

	HANARO	KJRR
Power	30 MW	15 MW
Mounting type	top-mounted (pool top)	bottom-mounted (RCM room)
CAR	circular, Hf	square tube, Hf
No. of system	4	4
CAR stroke	700 mm	650 -700 mm
CAR guide tube	cylindrical shroud tube & flow tube	square tube
Driving force transmission	solid transmission by carriages and tie rods between drive mechanism and moving parts	soft transmission by magnetic force between drive mechanism and moving parts
Drive mechanism	stepping motor	same mechanism with improved damping & maintainability
Core accessibility	Normal	Good

3. System Description

The CRDM comprises a CAR, a CAR guide tube to protect the absorber element from the turbulence of the primary cooling system flow, an extension shaft assembly (ESA), a seal valve, a connector, an armature, an armature guide tube, an electromagnet, and a drive assembly, as shown in Fig. 1. There is a penetration assembly located between the reactor pool bottom and the RCM room top to guide the CRDM/SSDM ESAs. The CRDM components in the RCM room are supported by the CRDM support structures.

During normal operation, the CRDMs vertically control and indicate the position of the CAR. During a reactor trip, the CRDMs drop the moving parts of the CRDMs including the CARs, the FFAs, the ESAs, and the CAR armatures. The four CRDMs contain identical, interchangeable assemblies.

3.1. CAR and CAR Guide Tube

The rectangular tube type CAR consists of a hafnium absorber element, latches, and rollers. The CAR is jointed and locked to a FFA by mechanical latches. The latch is a mechanism to connect/disconnect the CAR

to/from the FFA when it is needed to refuel the FFA or shuffle the FFA and the CAR. The CAR guide tube is an aluminum square tube supported at the grid plate and at the reactor cover. The CAR guide tube guides the CAR, and absorbs the flow induced force on the parts of the CAR from the fuel channels' coolant flow. The gap space between the CAR guide tube and the CAR allows the free passage of the absorber element with contact possible only at the absorber element's rollers.

3.2 CAR ESA and ES Guide Tube

The CAR ESA connects the CAR and FFA to the CAR armature. The ESA transfers the driving force of the driving system to CAR. The armature is attached at the lower end of the ESA by means of a locking mechanism. The ES guide tube is a part of the CRDM/SSDM penetration assembly. It guides the ESA, and protects the ESA from external loads.

3.3 Seal Valve and Connector

The seal valve locates between the CAR ES guide tube and the connector. The seal valve is closed when the maintenance and inspection of the CRDM components below the seal valve are needed. The connector is a mechanism to connect/disconnect the ESA to/from the CAR armature when it is needed to eject the ESA. The connector is located between the seal valve and the CAR armature guide tube. The connector electromagnet supplies electromagnetic force to unlock the locking mechanism between the ESA and the CAR armature.

3.4 CAR Armature and its Guide Tube

The CAR armature is magnetized when the CRDM electromagnet is energized. The armature piston, the bottom part of the CAR armature, directly pushes downwards the damper piston installed in the damper cylinder of the CAR armature guide tube. The armature guide tube guides the CAR armature assembly and retains the reactor coolant. When the CRDM electromagnet assembly moves up/down along the CAR armature guide tube outside, the CAR armature follows the electromagnet position along the armature guide tube inside.

3.5 CRDM Electromagnet

The CRDM electromagnet assembly consists of magnetic coil stacks and coil housings. The coils supply electromagnetic force to actuate the CAR armature for driving the CAR, the FFA, and the ESA. The CRDM electromagnet assembly holds the moving parts, i.e. CAR, the FFA, the ESA, and the CAR armature during normal operation. During a reactor trip, the CRDM electromagnet is de-energized, which makes these moving parts dropped by force of gravity.

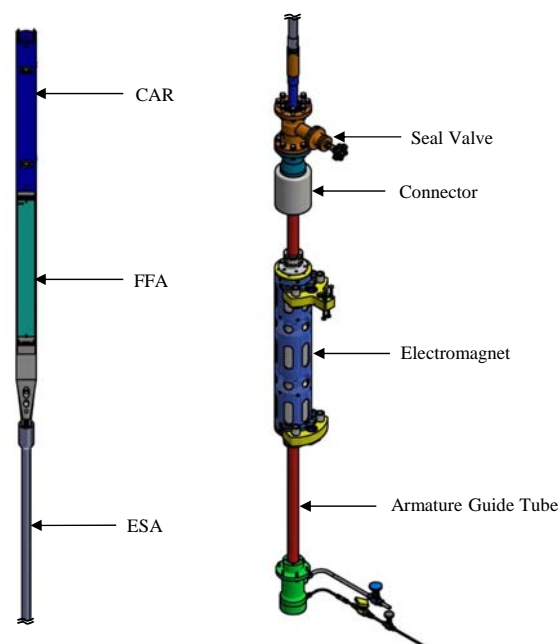


Fig. 1. The bottom-mounted control rod drive mechanism.

3.6 Drive Assembly

The drive assembly mainly consists of a stepping motor, a ball screw, two linear guides, instruments, and their mount structures. The stepping motor functions in conformity to the step signals from directly receiving from the RRS. When the power is removed from stepping motor, the CAR coasts into the core.

4. Summary and Future Works

A basic design concept of the BMCRD for the KJRR was compared with the HANARO and JRTR, and its features and individual system were described. The components should be further revised and optimized considering the design requirements, structural integrity, operability and maintainability. The prototype of the BMCRD has been being fabricated, and the qualification test using test rigs will be performed to verify the functionality, the drop time, and endurance performance.

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