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Preliminary Design of a Reflector Dump System for an Advanced HANARO Research Reactor

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1. Introduction

Recently, the IAEA [1] has recommended that at least one automatic shutdown system shall be incorporated in the design of a research reactor, and a second independent shutdown system shall be considered and may be required, depending on the characteristics of the reactor. According to the recommend, it would be required to reflect the strengthening of the IAEA's safety policy for developing a project of an AHRR (Advanced HANARO Research Reactor) which is based on the experiences in HANARO construction and operation. The reflector dump system for an AHRR is required for safety system diversity. It is considered that the safety system of an AHRR shuts the reactor down to a safe sub-critical state by dropping hafnium control absorber rods into the reactor core and by dumping the volume of the D_2O reflector tank into the dump tank. This paper summarizes the preliminary design on the heavy water dump system which may be considered as a second safety system for a new research reactor.

2. Preliminary Design

2.1 Reflector Dump System

RDS (Reflector Dump System) protects the reactor against Loss of Regulation Accidents (LORAs), Excessive Coolant Temperature Accidents (ECTAs), and Gross Loss of Flow Accidents (GLOFAs). The RDS is required for safety system diversity. The electromagnetic type rod drop system has been postulated to be susceptible to an unspecified common mode failure. In the unlikely event that the electromagnetic rod drop system to be designed to the first safety system of an AHRR is disabled by something, a reactor shutdown is still possible with the RDS. When activated by the trip logic system, the RDS shuts the reactor down to a safe sub-critical state by quickly draining the heavy water from the reflector tank into the dump tank. The heavy water within the inner annulus has the greatest effect on the reactivity of the reactor core and is therefore dumped first. But, the heavy water in the outer annulus has only a minimal reactivity effect and is partially dumped at a slower rate. The RDS is a subsystem of the Reflector Cooling System (RCS), and then the RCS interfaces with the RDS at the reflector tank.

The heavy water in the reflector tank provides a large volume of thermal neutrons for a target irradiation as well as serving as a reflector. Circulation of the heavy water through the heat exchanger removes the heat generated and transferred to the heavy water while it is resident in the reflector tank. Consequently, the RCS is designed to accommodate changes due to the dumping of the reflector. Upon receipt of shutdown control signals, the pressure equalization valves open, the gas pressure in the inner annulus vent line of the reflector tank pressurizes to the dump tank pressure. This allows a portion of the heavy water in the reflector tank to drain by gravity into the dump tank. When the reflector is dumped, the circulating pump is shutdown and an isolation valve on the pump discharge is closed. These steps are initiated automatically by the reactor control computer. During a re-poising, the pressure equalization valves and the feed valves are closed and the reflector tank vent valve is opened. Helium pressure in the dump tank forces heavy water to flow into the reflector tank. The feed and bleed valves are used to control the re-poising as it approaches its final level. The helium displaced from the reflector tank is vented to the active exhaust system.

2.2 Case Studies for other reactors

In order to figure out the design concept for the reflector dump system, it is required to know the driving mechanism of the other cases applied to the research reactors.

In the case of the MAPLE reactor, which is almost similar with the reactor type of HANARO, the RDS is classified as safety class III, and it belongs to seismic category I, and quality class Q. The maximum dump time takes less than 3.6 seconds to complete the process. The hydrostatic head of the heavy water provides the driving force for the dump [2].

On the other hand, in the case of OPAL, Second Shutdown System provides an alternate means of a fail-safe reactor shutdown by dumping about half of the heavy water in the reflector tank into a dump tank below the core on command from the Second Reactor Protection System. The dump time takes less than 30 seconds to complete the process. The heavy water in the reflector tank is released into the dump tank by 6 fail-safe normally open valves installed in parallel for a redundancy. On a trip signal or power failure, the valves are de-energised and open naturally to allow the heavy water to flow [3].

In CARR, which is being designed in China, the reflector dump system is planed as a backing support system to reduce the reactivity of the reflector tank not a safety shut down system. The dump time takes about

60 seconds by dumping about half of the heavy water in the reflector tank into a dump tank placed below the core. The heavy water is drained by gravity into the dump tank.

The biggest difference of them is the dump time. Dump time is defined as the time from the pressure equalization valves being fully opened and the reflector tank level reaching about half or a specific set point from the interval at the bottom of the reflector tank, which corresponds to an allowable reactivity removal point. It surely depends on how one determines the safety criteria and the design requirements for operating the RDS.

2.3 Basic Flow Diagram

The RDS belongs to the safety system of the reactor, and it is surely classified as safety class III according to ASME section III, seismic category I, and quality class Q. The RDS must be a highly reliable system and the reliability targets are to be achieved through a channelization and redundancy. Three independent channels are to be used within the second shutdown system and the trip actuation logic is to be configured as requiring general coincidence of two out of three channels. Nevertheless, the RDS mechanism may become unavailable due to failures that cause an unintentional dump or failures that compromise the effectiveness of the dump action. So, interlocks are required that shutdown the reactor or prevent an operation if the reflector dump is unavailable.

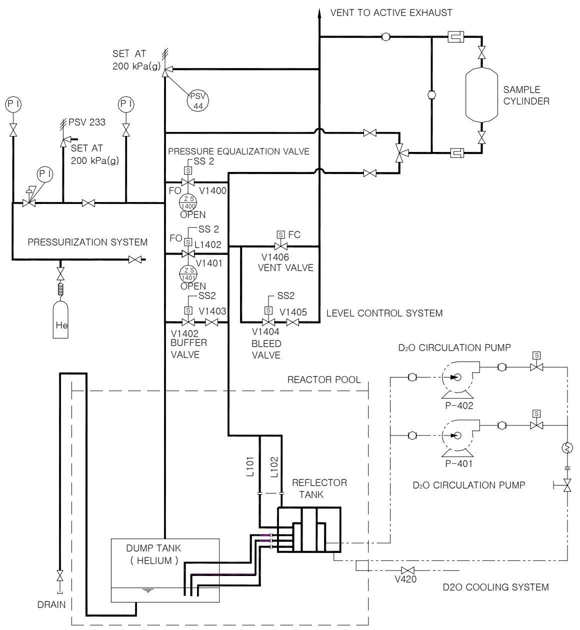

Figure 1. Flow diagram of the reflector dump system

Referring to the flow sheet of Figure 1, which was proposed as a flow diagram to verify the RDS, the pressure equalization valves (V1400, V1401) and vent valve (V1406) are closed during a normal operation. The helium pressure in the dump tank supports the heavy water in the reflector tank and the reflector system piping. If the reflector tank is full, the inner annulus vent line level control system maintains the level above the bottom surface of the reflector tank top tube sheet. Heavy water from the RCS enters the reflector tank at the bottom of the outer annulus. It flows upwards, through the clearance gaps in the baffle cap, into and down into the inner annulus. The heavy water exists near the bottom of the inner annulus, where it returns to the RCS. The isolation valve on the heavy water main circulation pump is open, and the decay heat removal pump is off. The pressure equalization valves (V1400, V1401) on a trip signal are opened and the vent valve remains closed. The gas pressures within line L101 and dump tank equalize, allowing the heavy water to drain from the reflector tank into the dump tank through the dump line. The hydrostatic head of the heavy water above the level in the dump tank provides the driving force for the dump.

3. Future works and Conclusion

The design concept and requirements of the reflector dump system has been reviewed in the applied cases, which were being used in other research reactors. It was considered that the reflector dump system as a second safety system is required for a strengthening of the recent safety policy proposed by the IAEA. There is no way to get the second safety system unlike the typically rod drop mechanism for the research reactor except to consider the reflector dump system.

The design objective of the RDS is to realize the second safety system, which can be operated safely with regards to the reactor. The RDS model proposed in this paper is based on the experiences in HANARO and the design concepts applied in other reactors. In upcoming the basic design, it shall be verified that the RDS will be suitable enough to cover the failure of the first safety system or the unintended events. This paper introduces how to implement the RDS as a second safety system for the new research reactor. It is also supposed that this paper provides a basis by which a basic design of the RDS will be continued.

REFERENCES

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