Development of Integrated Head Assembly Design for the Operating WEC-Type NPP

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1. Introduction

This paper outlines the Integrated Head Assembly (IHA) type that applicable to the operating WEC-type NPP in Korea, such as Kori 2, 3&4 and YGN 1&2, as an effort to reduce refueling steps as well as radiation exposure of the operating personnel.

Recently, IHA [1] and Simplified Head Assembly (SHA) have been developed for the reactor head area structure in the nuclear power plants worldwide. Each IHA/SHA type has its own characteristics according to the plant owner's request and the supplier's design. A need for developing IHA is well recognized for the operating WEC-type NPP.

2. Design Concept

The necessity of the IHA development is based on the EPRI URD [2] and KURD [3] recommendation that an integrated head disassembly capability should be provided which enables the entire head package and all related components (e.g., control rod drive mechanisms, insulation, cooling ducts, cable tray, etc.) to be lifted as a single unit by the reactor building crane.

2.1 Basic Design

Main components in the reactor head area consist of reactor head lifting structure, CRDM cooling fans/ducts, missile shield, seismic restraints and removable cable trays. It takes a long time and many refueling steps when they are assembled and disassembled during refueling outage. Reactor head area structure for operating 3-loop WEC-type NPP (Kori 3&4 and YGN 1&2) is shown in Figure 1.

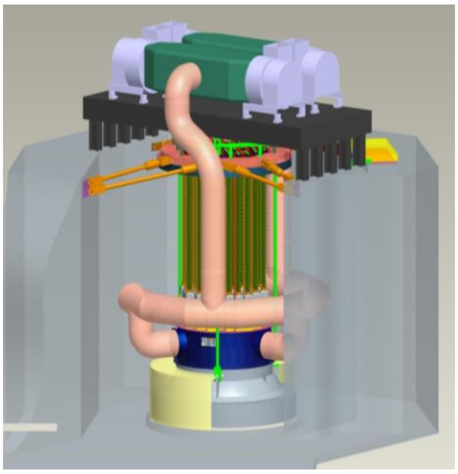

Figure 1. Operating Reactor Head Area Structure of 3-loop WEC-Type NPP

The operating 2-loop WEC-type NPP (Kori 2) structure is similar to those of 3-loop WEC-type NPP except CRDM cooling fans are installed on the operating floor.

An IHA-type has a lifting capability of the reactor head components by simplifying those components as a single unit. The IHA has been designed to perform the following functions:

- lifting the reactor head
- supporting the reactor head area components
- providing the CRDM cooling air path
- absorbing the seismic loads
- shielding the missile

Classified design effects of the each component for the IHA of WEC-type NPP in Korea are shown in Table 1.

Table 1. Classified Design Effects for the IHA

No.	Component	Reuse	Replace
1	Cooling ducts/supports		●
2	Head lift rigs		●
3	Seismic restraints		●
4	Cable trays		●
5	CRDM cooling fans		●
6	CRDM cooling fan cables		●
7	Head vent pipe	●	
8	CRDM, DRPI cables		●
9	Missile shield		●
10	RCFC	●	
11	SST/SDT	●	
12	Cooling air plenum		●
13	RV head (Kori 34, YGN 12)	●	
14	RV head (Kori 2)		●
15	CRDM & DRPI assemblies	●	

The IHA lifting system is a vertical structural frame designed to support the weight of the IHA and consists of main columns, tripod assembly, fan support frame and missile shield. This system provides a connection between the containment polar crane and the IHA. The missile shield on the IHA is a steel plate designed to protect safety related components from postulated missiles in the RV head area.

The CRDM cooling system is a ventilation system that includes the lower cooling shroud, vertical cooling shroud, upper air plenum and cooling fans. The lower cooling shroud assembly and upper air plenum are to guide the cooling air through the CRDM coil stacks, to collect the CRDM cooling air to exhaust through the cooling fans. The vertical cooling shroud provides the path from the lower cooling shroud assembly to the upper air plenum. 3-loop type has three (3) cooling fans with 50% capacity each and 2-loop type has two (2) cooling fans with 100% capacity each in the IHA top. They shall provide sufficient CRDM cooling air to remove heat generated from the CRDM coil stacks, RV head region and their nozzles.

The head area cable support system provides effective routing and structural supporting of the head area cables from the equipment to the connector plates on the operation floor. The system mainly consists of two sub-systems. One is a messenger wire and its supports to support and route the cables above the CRDM to the cable bridge assembly. The other is the cable bridge assembly to provide path for the cables from the IHA to the connector plates. The cable bridge shall be designed to carry the IHA cables.

The CRDM and IHA seismic support system is to provide lateral support to the CRDMs and IHA during seismic and LOCA. This assembly includes seismic plates attached to the every CRDM assembly to carry the load to seismic support platform and seismic restraints. The seismic restraints are tie rods connected to the seismic platform on one end and to refueling pool wall on the other end.

2.2 Design Considerations

A new RV head is considered for the Kori 2, therefore the RV pads for the new IHA will be added to accommodate increasing weights.

Kori 3,4 and YGN 1,2, which the current RV head is reused, have been taken into account structural characteristics and arrangement to minimize the integrated component loads, and the vertical loads for the bottom shroud have been distributed to the main column by coupling.

2.3 Structural Analysis

In order to verify the CRDM cooling performance within the IHA, Computational Fluid Dynamic (CFD) analysis [4] is done considering the heat from the CRDM and RV head. The structural integrity is also analyzed under dynamic loading conditions including seismic and LOCA. Since the IHA with reactor head is handled by containment polar crane during refueling outage, head lifting condition is simulated by static analysis. The loads and stresses resulted from heat sources of reactor head are also analyzed by thermal distribution analysis and thermal structural analysis. Furthermore, structural integrity of the missile shield is confirmed by the CRDM missile impact analysis.

3. Developed Design

The IHA has been developed as a ductwork integrated model for 3-loop and a shroud shell integrated model for 2-loop both combined with CRDM cooling fans & cable bridges. Developed models of the WEC-type NPP IHA for 3-loop and 2-loop are shown in Figure 2 and Figure 3, respectively.

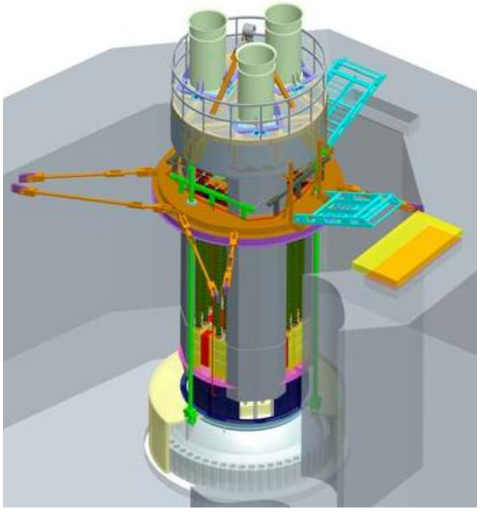

Figure 2. Developed IHA Model for 3-loop WEC-Type NPP

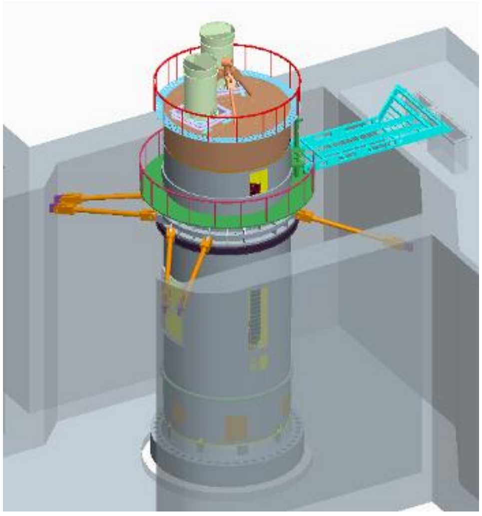

Figure 3. Developed IHA Model for 2-loop WEC-Type NPP

4. Conclusions

Judged from the recent oversea trend for simplifying reactor head area structure, the compatible IHA models for the operating WEC-type NPP were developed herein. The IHA is expected to greatly improve the plant operation ratio and economical efficiency as well as the reduction of radiation exposure and the usage of containment building.

REFERENCES

[1] Yeon-Ho Cho, Hyun-Min Kim, et al., "Development of Integrated Head Assembly for the Operating OPR1000", Journal of KNS, May, 2007

[2] EPRI, "Advanced Light Water Reactor Utility Requirement Document", Rev.07, 1995.

[3] KHNP, "Korean Utility Requirements Document", Rev.01, 2002.

[4] ANSYS Inc., 2011, FLUENT V13.0 Theory Guide.