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A Reactor Head Package Upgrade Applicable to OPR1000 Nuclear Power Plants

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1. Introduction

For OPR1000 nuclear power plants, a number of components such as a lift rig for reactor vessel closure head (RVCH), head area cable tray with missile shield, a cooling system with air ducts and control element drive mechanisms (CEDMs) are installed over the RVCH. During refueling outages, the removal of the RVCH and re-installation on the reactor vessel requires individual dismantling and reassembly of these components. These result in a very complicated and time consuming process, and draw the safety concerns for workers. To enhance the safety to the workers and to reduce the outage duration, the concept of the duct simplified reactor head package was proposed in the previous research [1].

Recently public concerns have focused on safety for the nuclear power plants against earthquake. In the past research, it was found that the CEDM seismic support help to reduce deformation of the CEDM and ensure CEA drop within the limited time since vertical CEDMs mounted on reactor head are likely to be vulnerable to lateral deflection [2].

This paper proposes the best options of the reactor head package upgrade including reactor head package with a CEDM seismic support applicable to the OPR1000 nuclear power plants, where the Integrated Head Assembly is not applied.

2. Design Concepts and Features

2.1 Duct Simplified Reactor Head Package

Currently, OPR1000 plants at Hanbit and Hanul sites have many head area components including head lift rig, cooling air ducts, head area cable tray for cable supporting and missile protection, and piping for CEDM Air Handling Unit (AHU), which are shown on Fig.1. Prior to removal of the RVCH from the reactor vessel, disconnection and removals of the piping to the CEDM AHU, hundreds of cable connectors located at the refueling disconnect panels and CEDMs, tens of duct segments, cooling manifolds around head lift rig are required. Those components should be separately removed and transferred to the designated storage area. Especially, removal of duct assembly costs a lot of hours, and requires risky activities and radiation exposure for workers. The ducts consisted of many pieces need many picks of containment polar crane. The duct segments take large space for storage.

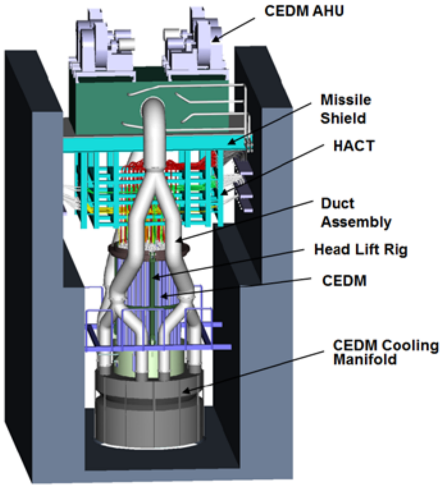

Fig. 1 OPR1000 Components in Reactor Head Area

The past upgrade for the reactor head package was developed focusing on the duct simplification [1]. The design of the head package is shown on Fig.2.

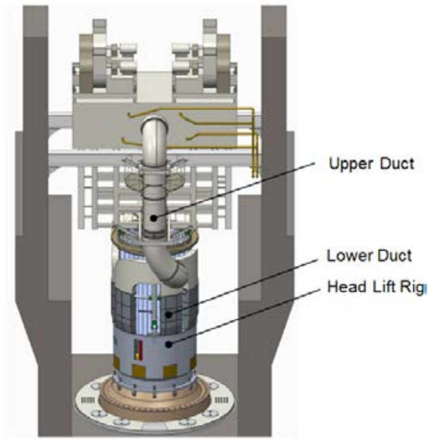

Fig. 2 Duct Simplified Reactor Head Package

Ducts and cooling manifold around head lift rig are replaced with integral type lower ducts which are permanently attached to the head lift rig. Branches of ducts in the previous design are merged into lower ducts. Along with the lower duct concept, the head lift rig has been modified increasing the diameter and installing the inner baffle. As shown on Fig.2, upper duct has a two points of quick-connection at the lower ducts and CEDM AHU. Prior to removal of lifting reactor head, the upper duct should be safely disconnected from the lower duct and the CEDM AHU.

It was decided that the components in the Head Area Cable Tray (HACT) area such as a CEDM AHU, HACT and missile shield should be reused in order to reduce the solid rad waste. The computational fluid analysis was performed to verify the pressure drop and cooling air distribution of the CEDMs. It was found that the pressure drop of the new cooling air path was increased by 4.4%. However the number is within the current CEDM AHU capacity. It implies that CEDM AHU is capable of providing enough cooling air for CEDM in the duct simplified reactor head package.

Structural integrity of the simplified duct head structure assembly was evaluated by performing stress analysis under dead weight, head lift, seismic and branch line pipe brake loading conditions. The stresses of the elements were evaluated according to the applicable code requirements of ASME NF or AISC N690. As a special lifting device, head lift rig are designed to meet the requirements of NUREG-0612 and ANSI N14.6.

Due to the changes of the design and the weight, it was expected that structural responses of reactor vessel and reactor vessel internals were varied. From the RCS analysis, the loads of the RCS components were developed and evaluated. It is concluded that there is a negligible effect on the existing RCS components.

2.2 CEDM Seismic Support Design

For the CEDMs in the OPR1000 NPPs, they are vertically mounted on the reactor vessel head in free standing without support. Even though the CEDMs in OPR1000 NPPs were designed to withstand design basis earthquake, the design concept supporting CEDMs was investigated to enhance the seismic capability of the CEDM against the postulated earthquake. In the past the relationship between the CEDM support elevation and seismic responses of the CEDM [2] was investigated and it was concluded that the CEDM deformation in any supporting elevation satisfies the acceptance criteria.

Although it was revealed that supporting the CEDMs help to reduce the CEDM deformation, it is very difficult to implement the design CEDM seismic support for the operating plants. In order to install the CEDM seismic support, concrete wall of the building should be modified. In case of Shin-Kori and Shin-Wolsong 1 and 2 NPPs as well as APR1400 NPPs, the Integrated Head Assembly (IHA) with seismic support system has been applied in the construction stages. Since the installation of wall brackets for seismic support is considered in the initial stage of design, there are no construction issues of the building. The details of the APR1400 IHA are presented by Kang et.al [3]. Since plant modification for operating NPPs surely develop a safety issues related to wall bracket, it was searched to minimize the change of existing plant configuration. Considering the issues, the design concept for the current head lift rig combined with CEDM seismic support is proposed in Fig. 3.

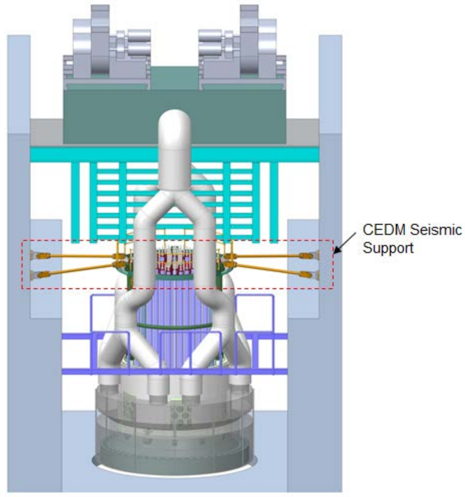

Fig. 3 CEDM Seismic Support for the Existing Reactor Head Package

The pool wall is enclosed by liner stainless steel plate. In case that the pool wall with liner plate is used for wall bracket installation, it surely requires removal and re-weld construction of liner plates. It will cause the licensing and safety issue by regulation. As an alternative option, the use of the primary shield wall just above the operating floor is proposed for the location of the wall bracket.

This option, which is to install the CEDM seismic support the OPR1000 NPPs, provides two benefits. First one is that no large change is needed in the existing reactor head package. Most of the components are maintained so that cost to upgrade can be minimized. Second one is that it will not cause the removal and re-weld construction of liner plates.

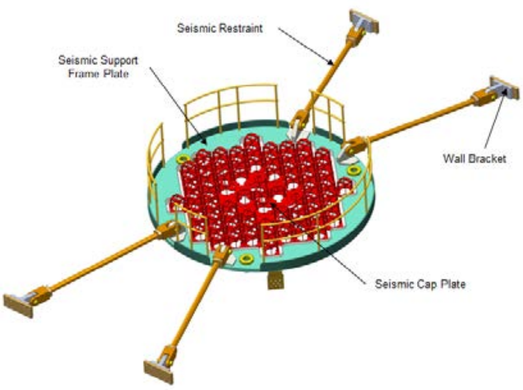

Fig. 4 Details of CEDM Seismic Support

The CEDM seismic support consists of seismic support frame plate, seismic cap plates, seismic restraints and wall brackets which are shown on Fig. 4. Each seismic cap plate is directly installed on the CEDM upper shroud and restrains the CEDM's horizontal movements during earthquake event. The peripheral cap plates are enclosed by the seismic support frame plate. The plate also has a role of walk platform. The plate is connected and supported on three main columns. The seismic restraints transfer the seismic loads from CEDMs to the building. The end of the seismic restraints is connected to the wall bracket on the primary shield wall.

The CEDM seismic support develop new load path from CEDM to containment building during earthquake events. As a pressure boundary component, CEDM are classified into and designed KEPIC MN code item. Based upon the rules, the CEDM seismic support shall be classified into safety class and meets the requirements of KEPIC MNF. The changes of safety classes and construction rules for the head lift rig also should be reviewed and justified according to ANSI 51.1 and/or NSSC Notice. With respect to the load path, the structural interaction and changes of the dynamic characteristics should be reviewed.

The concept of the CEDM seismic support described above can be applied to the design of the duct simplified reactor head package. The design concept combining the duct simplified reactor head package with CEDM seismic support is illustrated in Fig. 5.

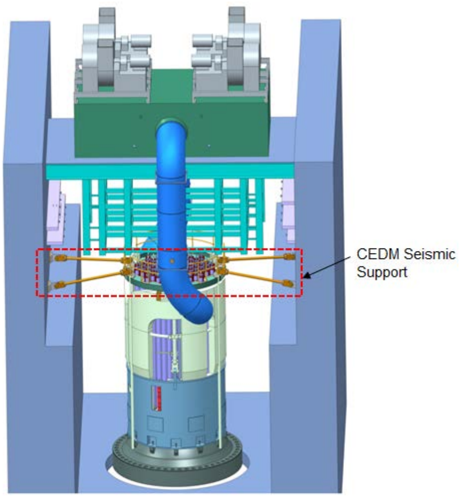

Fig. 5 Duct Simplified Reactor Head Package with CEDM Seismic Support

Although duct simplified reactor head package with CEDM seismic support needs broad range of plant modification, the design provides multiple benefits for operating plants. With respect to the safety, it is expected that risky activities regarding duct dismantling and re-assembly are decreased. By reducing the working steps, the refueling outage duration and radiation exposure for workers are much reduced. By analyzing the refueling outage process, it was observed that the almost 70 hours were required to dismantle and re-assemble the head area components including ducts. Once the duct simplification of the reactor head package as well as CEDM seismic support is applied in the operating plants, it is estimated to save up as much as 40% working hours. Furthermore, for component safety, it is insisted that the seismic capability for CEDMs is able to be improved for postulated earthquake.

3. Conclusions

The design features and concepts of a reactor head package upgrade including duct simplified reactor head package and CEDM seismic support applicable for OPR1000 nuclear power plants are proposed. Focusing on a design of CEDM seismic support, two design concepts for the reactor head package are suggested. First, the existing head package is used for the CEDM seismic support, which provides only for the increase of the seismic capability on the CEDM. As a second option, the duct simplified reactor head package with CEDM seismic support is presented to increase the safety of the CEDM and workers during refueling outage.

Based on the proposed design, additional engineering efforts are required. The connection between the reactor head package with containment building may cause a structural interaction between reactor vessel and wall.

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