A Study on the Equipment Arrangement of Passive Containment Cooling System for Severe Accident of APR+

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1. Introduction

This paper deals with the results of reviewing the layout of APR+ reactor building and the layout of PCCS equipment according to APR+ Passive Containment Cooling System (PCCS) application.

APR+ is equipped with an Emergency Containment Spray Backup System (ECSBS) as an alternate means of providing the Containment Spray System (CSS) in the event of a beyond a Design Basis Accidents (DBA) in which both Containment Spray Pumps (CSPs), both Shutdown Cooling Pumps (SCPs), and/or the IRWST are unavailable. APR+ PCCS is dedicated system for severe accident to replaces the ECSBS function.

2. APR + PCCS system information

The APR+ Passive Containment Cooling System (PCCS) consists of two series of 50% capacity. The cooling water is supplied from the Passive Condensation Cooling Tank (PCCT) to the heat exchanger of the PCCS based on the gravity and density difference.

High temperature cooling water that receives heat from the heat exchanger recovered to the PCCT through the return piping.

2.1 System Layout Requirements

The layout requirements of APR + PCCS are:

1) The heat exchanger is located inside the reactor building and the passive condensation cooling tank is located outside the reactor building.

2) The heat exchanger shall be a vertical type and shall be installed on proper location to enable natural circulation of cooling operation.

3) The heat exchanger of passive containment cooling system is composed of 2-trains of 50% capacity heat exchanger.

4) The center elevation of the upper header of the heat exchanger shall be lower than the floor height (EL.200'-0 ") of the passive condensation cooling tank (PCCT).

5) The cooling water source of the passive containment cooling system shares cooling water of the Passive Auxiliary Feedwater System (PAFS). The PCCTs as cooling water source of the PCCS are also used to the water source of the Passive Auxiliary Feedwater System (PAFS). The PCCTs are shared by the PCCS and PAFS.

2.2 Design Information of APR+ PCCS Heat Exchanger

Figures 1 and 2 show details of the heat exchanger inside the reactor building provided by Doosan Heavy Industries & Construction [4]

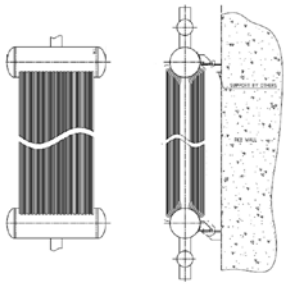

Fig. 1. Layout Drawing of APR+ PCCS Heat exchanger (1)

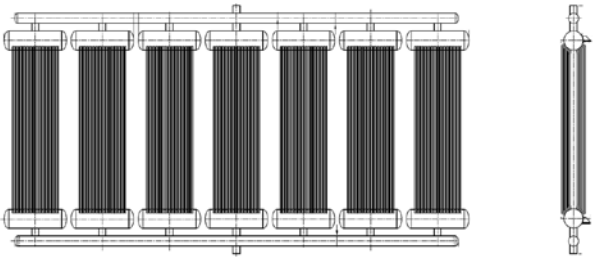

Fig. 2. Layout Drawing of APR+ PCCS Heat exchanger (2)

The APR+ PCCS heat exchanger consists of seven modules. Distributors are formed at the top and bottom of the module to connect each of the seven modules. There is a nozzle at the center of each distributor to connect the supply and return pipes.

3. Layout Review of APR+ PCCS Heat Exchanger

The layout review of heat exchanger was conducted based on the layout design requirements of the PCCS heat exchanger and the heat exchanger configuration information, in accordance with the general arrangement layout of APR+ reactor building. It is advantageous to install the PCCS heat exchanger in the dome area, which is the highest position of the reactor building, considering the characteristics of the fluid (water vapor) generated inside the reactor building during the accident condition.

However, it is difficult to secure a space for the PCCS heat exchanger in the dome area because piping

of the containment spray system was already arranged in the dome area.

On the other hand, the height of the PCCT bottom floor is located in EL.200'-0".

Therefore, the center of the upper header of the module of the heat exchanger is arranged at EL.200'-0" in the lower region of Polar Crane. Because it meets the requirement that the center of the upper header of the module of the heat exchanger must be lower than the floor height of the passive condensation cooling tank.

In the case of PCCS supply and return piping arrangement, slope shall be applied to the heat exchanger to prevent cooling water drainage and non-condensable gas capture, and PCCT and PCCS heat exchangers in the auxiliary building are connected.

As a result, the PCCS heat exchanger and the supply/return piping are located at the upper part of the reactor building, so there is no influence on the lower part of the operation floor.

Additionally, influence on the upper part of the operation floor is reviewed.

Therefore, the present status of the APR+ operation floor was reviewed and the optimal location of the PCCS heat exchanger was examined.

3.1 The layout status of APR+

3.1.1. The layout status of the Operation floor of APR+ Reactor Building

The height of operating floor is EL.156'-0 'and there is an equipment hatch for reactor and steam generator access.

In addition, Safety Injection Tank (SIT) is placed in each quadrant, and Reactor Containment Fan Cooler (RCFC) is installed.

In the case of APR+, the diameter of the reactor building increased compared to the previous plant SKN 3&4, which was caused by the size change of the Reactor Coolant System (RCS).

Due to the application of PAFS, the pipeline penetration has been increased, and the penetration of the Containment Filtered Vent System (CFVS) will be additionally arranged.

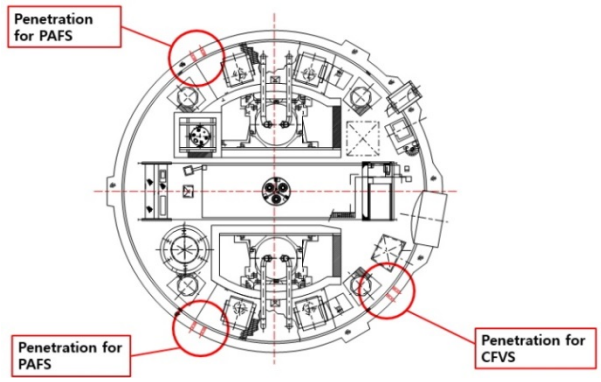

Fig. 3. The plan view of operation floor in containment building of APR+

3.1.2. The layout of PCCT of Auxiliary Building

The PCCT of the PAFS is located at the top of the auxiliary building as a division as shown in figure 4.

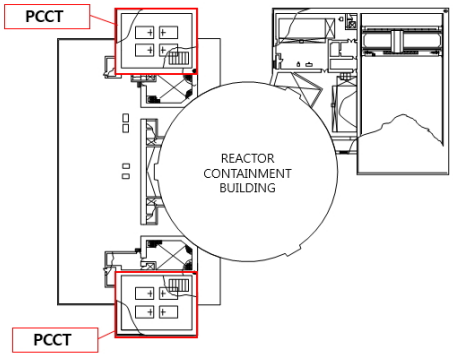

Fig. 4. The plan view of PCCT in auxiliary building of APR+

3.2 Review of PCCS Heat Exchanger Arrangement

3.2.1. Symmetrical arrangement of heat exchanger Modules (7EA) to north-south (N-S) direction

Considering the previously developed APR+ layout, the PCCT of PAFS is symmetrically arranged on division basis above the auxiliary building.

Accordingly, the PCCT is also symmetrically arranged on division basis.

For the uniform heat removal in the reactor building, a study was conducted on the symmetrical arrangement of the heat exchanger consisting of the 7EA modules in the N-S direction as shown in Figure 5.

As a result, interference with the Main Steam (MS) piping support is expected and the heat exchanger placement is difficult due to the narrow area around the RCFC.

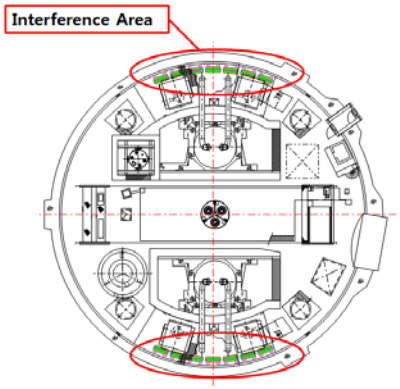

Fig. 5. Interference Area in Heat Exchanger North-South Direction

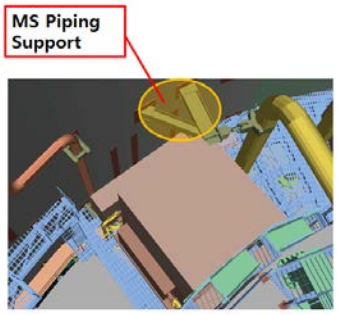

Fig. 6. Interference around the RCFC

3.2.2. Eccentric arrangement of heat exchanger Modules (7EA)

It is difficult to implement the 7EA modules in the N-S direction due to the interference with the MS/ Feedwater(FW) piping support and the narrow area around the RCFC.

Therefore, the eccentric arrangement was considered to minimize interference between other structures in the reactor building of APR+.

The eccentric arrangement of the 7EA modules is somewhat disadvantageous in terms of the air flow inside the reactor building rather than the symmetrical arrangement of 7EA Modules of N-S direction. however, it is advantageous in terms of interference between other structures in reactor building.

The eccentric arrangement of the 7EA modules in Quadrant A and Quadrant B areas is difficult to place due to RCFC narrow space constraints and interference between the MS piping supports, RCB exhaust ducts, CFVS penetration areas and elevators.

When eccentrically layout 7EA modules are placed in Quadrant C zone, Quadrant D zone, AZ 0 ° and AZ 120 °, it is biased as shown in Figure 7, but 7EA modules can be connected to one distributor.

Besides, there is not a large temperature difference or stratification impact in the interior of the reactor building.

In addition, it is possible to avoid the interference by moving and arranging the air conditioning duct (vertical direction) based on APR1400 detailed arrangement, and it is judged that it is optimal for solving the interference.

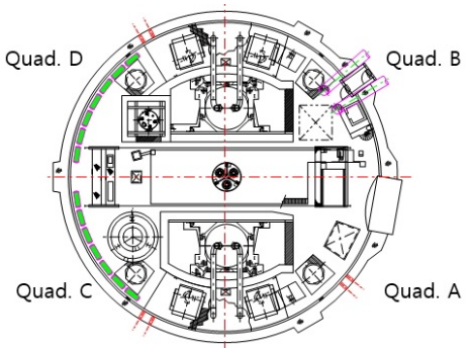

Fig. 7. The plan view of Module 7EA Eccentric layout

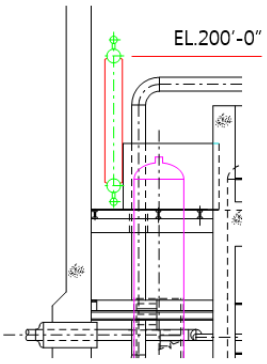

Fig. 8. The section view of PCCS heat exchangers layout

4. Conclusions

In order to improve the utilization of PCCS technology, we reviewed the arrangement of PCCS heat exchanger for APR+ to cope with severe accidents.

As a result of review two layout schemes (In a symmetrical arrangement of 7EA Modules of N-S direction, in eccentric arrangement of Module 7EA), the center of the heat exchanger of 7EA modules was eccentrically arranged at AZ 60 ° and AZ 120 °.

It is reviewed that the eccentric arrangement is better than others in terms of interference resolution, system implementation, and it is confirmed that is appropriate solution as the concept of APR + PCCS heat exchanger layout.

ACKNOWLEDGEDMENTS

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[4] Doosan Heavy Industries & Construction, APR + Passive Heat Exchanger Preliminary Drawing, Rev.1