Layout Study for the Equipment of Passive Containment Cooling System in Containment Building of iPOWER

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1. Introduction

Active safety systems in nuclear power plants constructed and operated in Korea have been applied to keep safety of the power plant by using active system components in the event of an accident. Since the Fukushima accident, the world nuclear power industry has been continuously and systematically pursuing research and development to improve nuclear technology of nuclear power plant (NPP) for the safety. In addition, it is expected that the passive safety systems in nuclear power plant, of which safety has been enhanced, will lead in the international market of NPP after 2020. The passive safety systems use only natural forces, such as those of gravity, natural circulation, and compressed gas to guarantee plant safety. They eliminate the need for safety grade AC power, the active pumps and support systems. Therefore, the risks that may occur due to the failure of the active components are reduced and the safety is innovatively increased. iPOWER (innovative Passive Optimized Worldwide Economical Reactor)[1] is being developed as a leading model to improve the safety function by adopting the passive safety systems and incorporate lessons learned from the Fukushima accident. iPOWER ensures safety through passive containment cooling system (PCCS), passive residual heat removal system (PRHRS), and passive emergency core cooling system (PECCS). This paper deals with the technical study of the equipment layout of PCCS located inside the containment building of iPOWER.

2. Passive Containment Cooling System

The Passive Containment Cooling System (PCCS) reduces the pressure and temperature below the design limits of the containment building by removing the heat of the atmosphere in the containment during the design basis accident such as LOCA, secondary pipe break accident, and etc. PCCS consists of four independent trains mechanically, electrically and physically separated except for passive condensation cooling tanks. Each train consists of a PCCS heat exchanger, isolation valves, piping, instruments, and etc. There are two passive condensation cooling tanks (PCCTs) and each tank supplies cooling water to two trains of the system. The PCCTs shall be installed at a higher position than the PCCS heat exchangers to enable natural circulation of cooling water. A brief concept of PCCS is as shown in figure 1.

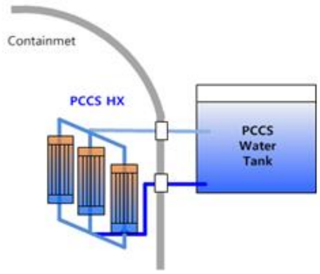

Fig. 1. Concept of passive containment cooling system

3. The layout of the equipment of PCCS

PCCS layout study is reviewed based on the layout of the containment building of iPOWER currently under development. First, we simply look at the characteristics of the containment building of iPOWER. Based on this, we review the optimal location of PCCS heat exchanger, which is an important equipment of PCCS inside the containment building.

3.1 The layout of the containment building of iPOWER

It is essential to consider the arrangement of the reactor coolant system (RCS) for layout of containment building. NSSS designer proposed a draft layout of RCS for iPOWER and some requirements. The main layout requirements of iPOWER RCS are to set the RCS hot leg center location at EL. 100'-0" and to be minimized the free volume below the direct vessel injection (DVI) nozzle in the containment building. The flooding elevation for long-term core cooling operation is determined at EL. 108'-0". The second floor is determined to be equal to the flooding elevation for long-term core cooling operation. Because of supplying cooling water, In-containment Refueling Water Storage Tank (IRWST) is located at a higher position than DVI and between AZ 180 ° ~ 360 ° of the containment building. There are two safety injection tanks (SITs) and two hybrid-SITs in the containment building [2]. The SITs and hybrid-SITs are placed at a higher position than DVI nozzle, and the cooling water is injected by the water head through the position. SITs and hybrid-SITs are arranged between AZ 0 ° ~ 180 ° space opposite to the IRWST in consideration of interference elimination. The PCCS shall be located at the dome part of the containment building because of the natural circulation. The plan of operation floor and section in containment building of iPOWER are as shown in figure 2 and figure 3.

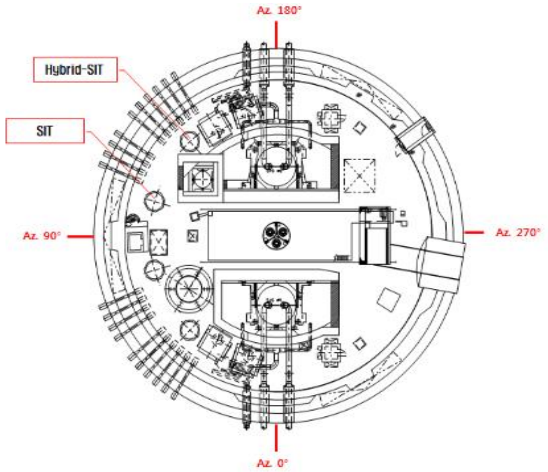

Fig. 2. The plan of operation floor in containment building of iPOWER

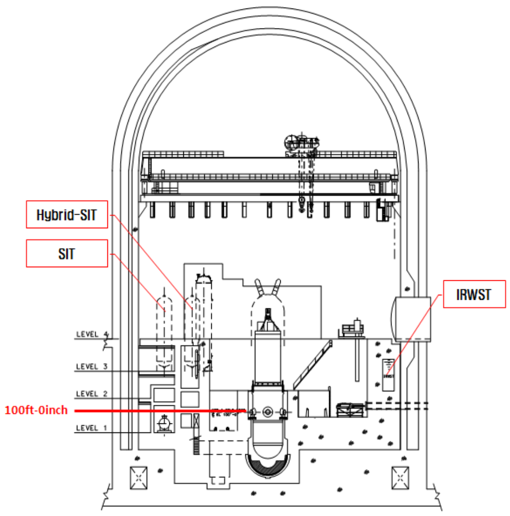

Fig. 3. Section in containment building of iPOWER

3.2 The requirement of layout for PCCS and the configuration of PCCS heat exchangers

3.2.1. The requirement of layout for PCCS[3][4]

PCCS heat exchangers shall be located at a high position inside the reactor building to maximize heat removal performance. PCCTs shall be located at a higher position than PCCS heat exchangers to enable natural circulation of cooling water. The equipment shall be accessible for maintenance and in-service inspection.

3.2.2. Configuration of a PCCS heat exchanger.

The supplier information for PCCS is as shown in figure 4. A PCCS heat exchanger consists of 8 bundles. Four PCCS heat exchangers are arranged inside the containment building and are required to be arranged as symmetrically as possible.

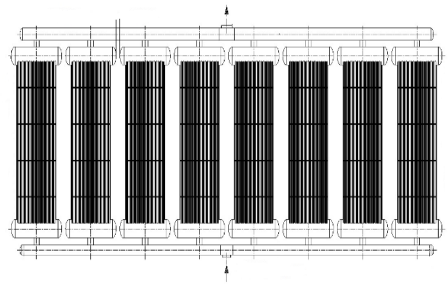

Fig. 4.The configuration of PCCS heat exchanger.[5]

3.3 The layout of PCCS heat exchangers

In the dome of the containment building, there is a polar crane for lifting the reactor vessel, the steam generators and other equipment. In order to determine the location of PCCS heat exchangers, the interference with the polar crane should be examined closely. Two locations was selected for the heat exchanger, considering the polar crane, one is to place the heat exchangers in the upper area of the polar crane, and the other is to place heat exchanger in the lower area. Two layout studies are reviewed.

3.3.1. The arrangement of PCCS heat exchangers in the upper area of the polar crane

When placed in the upper area of the polar crane, the arrangement of the PCCS heat exchangers is possible. But the layout requirement which defines the elevation between the PCCS heat exchangers and PCCT is not satisfied, because PCCTs are located on the roof of the auxiliary building. The plan and section of the arrangement of PCCS heat exchangers in upper are of the polar crane are as shown in figure 5 and figure 6.

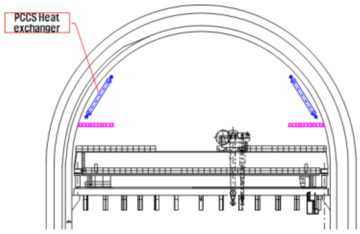

Fig. 5. The section of PCCS heat exchangers in the upper area of the polar crane

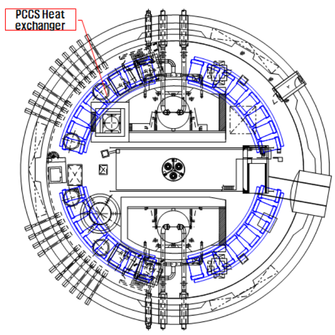

Fig. 6. The plan of PCCS heat exchangers in the upper area of the polar crane

3.3.2. The arrangement of PCCS heat exchangers in the lower area of the polar crane.

In the case of the arrangement of PCCS heat exchangers in lower area of the polar crane, the lower position is advantageous in terms of seismic resistance design. Also, the layout requirement for PCCS heat exchangers is satisfied. As a result, it is decided to place the PCCS heat exchangers in the lower area of the polar crane. When placed in the lower space of the polar crane, the height of the PCCS heat exchangers is determined as the height of the bottom of the PCCTs in the auxiliary building, which can satisfy the system requirements for natural circulation. The upper bundle header of PCCS heat exchangers is placed at the height of EL 200’-0” in consideration of the system requirements. When the PCCS heat exchangers are arranged symmetrically, interference occurs as shown in figure 7.

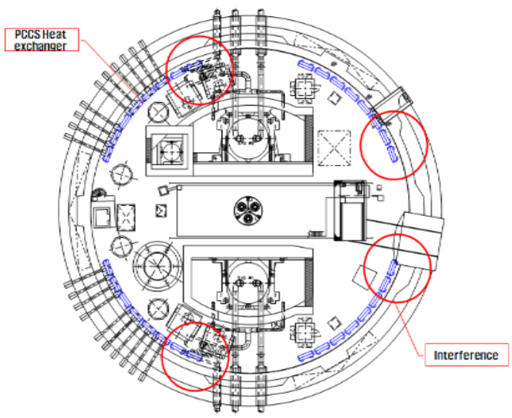

Fig. 7. The interference of PCCS heat exchangers in operation floor of iPOWER.

In consideration of eliminating the interference of symmetrical layout, each PCCS heat exchanger is rotated and placed without interference as shown in the figure 8 and figure 9.

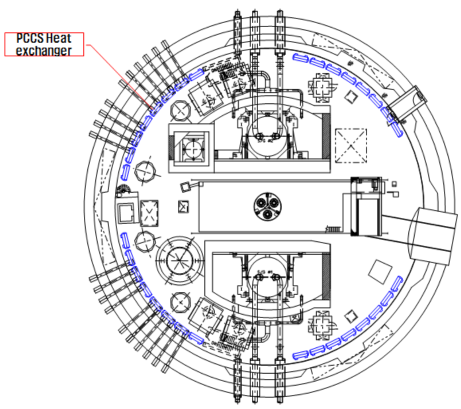

Fig. 8. The relocation of PCCS heat exchangers to eliminate the interferences.

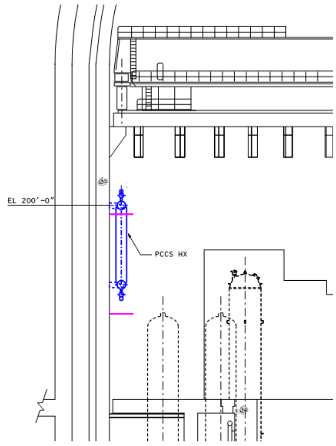

Fig. 9. The section of PCCS heat exchangers

4. Conclusions

iPOWER, which adopts the passive safety systems, is being developed to improve the NPP safety and the competiveness of international market, including lessons learned from Fukushima accident. The containment building is designed for fission product confinement and control, protection against external hazards, and biological shielding. PCCS, which cool down the building and reduce the inside pressure during the accident, has main role to secure the integrity of the reactor containment building to prevent releases of radioactive materials into the environment. It is concluded that the arrangement of the components inside the containment building can be feasible through the layout study. However, it will be necessary to continue developing the layout of systems and establishing the containment arrangement of iPOWER based on information which will be developed or designed in the next design phase.

ACKNOWLEDGEMENTS

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