IRWST Elevation Change for Passive In-Vessel Retention Strategy

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1. Introduction

After Fukushima accident, the importance of severe accident management strategy is being emphasized. In Korea, APR1400 adopt in-vessel retention strategy through external reactor vessel cooling which is the key strategy for severe accident. As a simple explanation, IVR-ERVC is to fill the cavity with water from IRWST (In-containment Refueling Water Storage Tank) in order to cool reactor vessel and prevent molten core from being released to external vessel.

The purpose of this paper is to achieve the design concept of passive IVR through IRWST elevation change in APR1400. Also, the effects from the changed design were considered in views of ECCS (Emergency Core Cooling System) and system arrangements.

2. IVR Design of APR1400 and AP1000

For APR1400 in Korea, SCP (Shutdown Cooling Pump) which is operated by EDG (Emergency Diesel Generator) is used to fill the cavity with water for IVR in a severe accident of APR1400. If SBO (Station Black Out) like Fukushima accident occurs in a Korean reactor, IVR strategy would not be accomplished and there will be one system that is CFS (Cavity Flooding System) driven by gravity for ex-vessel retention. However, few studies have reported on this problem.

In case of AP1000 designed by Westinghouse in the United States, the water injection for IVR is achieved by gravity. That is because the bottom elevation of IRWST is similar with the centerline of hot legs.

Some design features related with IVR-ERVC are arranged in Table 1.

Table 1. Design Parameters for IVR strategy

	APR1400	AP1000
Injection Method	active (pump)	passive (gravity)
Hot legs Elevation	117` 4``	102` 8``
IRWST Elevation	81`	103`
Needed Mass	700 ton	850 ton
Time to fill	37 min. (one SCP)	30 min. (2 pipes) 65 min. (1 pipe)

3. Passive In-Vessel Retention Strategy

Even if there is no AC power, passive safety systems can be operated by natural phenomena like pressure difference, gravity and natural circulation. The simple method for passive IVR strategy is to fill the cavity with water by gravity from water elevation difference. The water elevation target of IVR is to submerge the bottom of cold legs on reactor vessel. Therefore, if the water elevation in IRWST is higher than that in cavity, the water will be naturally injected into cavity. Dependent on the elevation of IRWST, the mass flow rate and the cavity filling time for success will be changed.

In AP1000, the elevation difference between IRWST and the center line of hot legs is about 0.1m. In comparison with that, the elevation of IRWST in APR1400 is needed to be increased to submerge the cavity by gravity. The current elevation difference is about 11m. According to that, it is needed to get the reasonable elevation change, not roughly 11m.

Two calculation criteria were made to get the results. Firstly, time to submerge the cavity should be less than 40 minutes which is the mission time of APR1400 IVR. Related with economics and system stability, the second criterion is to set IRWST elevation as low as possible.

All of the calculations are in conditions of APR1400. The calculation was performed based on unsteady-state Bernoulli equation with one second time step. Three variables were set for sensitivity analysis. They were elevation of IRWST, remaining IRWST water volume and injection line diameter.

Figure 1 displays the results of time to submerge up to target elevation from the difference of IRWST elevation. For simplicity, this calculation assumed most of the water inventory was mostly remained in IRWST for simplicity.

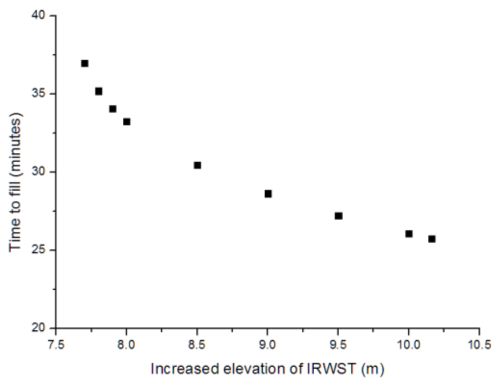

Fig. 1. Time to fill upon IRWST elevation change

As the second consideration, the results of time to submerge up to target elevation by varying with remaining IRWST water volume are shown in Figure 2.

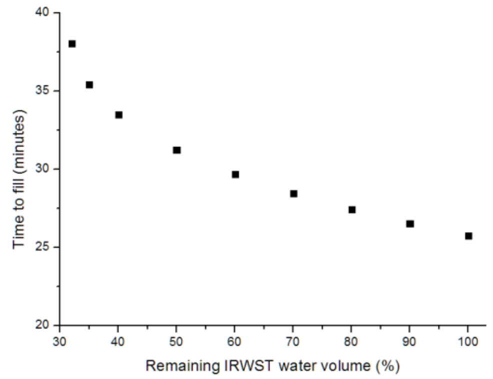

Fig. 2. Time to fill upon water inventory in IRWST

Thirdly, varying with the diameter of injection line, the results of filling time for IVR were calculated. It is proven that the diameter of injection line must be larger than 10 inch.

All the passive safety systems can be categorized by some characteristics from IAEA TECDOC-626 [1]. The initiation concept of this passive IVR is that valves on the line between IRWST and reactor cavity have to be open using battery power by operator`s actuation. Accordingly, it is included in passive system category D.

4. Effects from IRWST elevation change

4.1 Effects on Emergency Core Cooling System

IRWST has many significant functions in APR1400. One of the main purposes is the water source of safety injection system (SIS). In order to find the effects of IRWST elevation change in a view of SIS, LBLOCA accident of APR1400 was analyzed by using MARS (Multi-dimensional Analysis of Reactor Safety) [2]. In this paper, the results of peak cladding temperature (PCT) were made for short term in Figure 3.

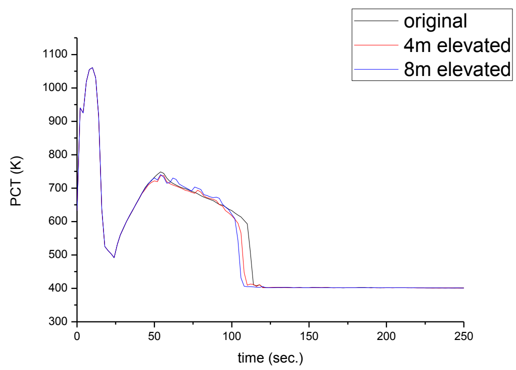

Fig. 3. PCT variation in LBLOCA for each IRWST elevation

4.2 Effects on System Arrangement

Because IRWST occupies large part in containment, many considerations are needed for system function and arrangement. In this paper, three things are analyzed. First of all, if it is changed, the process for recirculation has to be changed and enhanced. The elevation of HVT (Holdup Volume Tank) and the lines from cavity sump to IRWST has to be designed again. Secondly, rearrangement of some components including reactor drain tank, letdown heat exchanger and pressurizer valve room must be elevated with earthquake-resistant design [3]. For the third consideration, the size of containment is needed to increase because the volume which is occupied by the original IRWST should be filled with concrete for stability of all the components. It may dominantly cause a bad effect on economics of the plant.

5. Discussion and Conclusion

The feasibility of IRWST elevation change is estimated focused on passive in-vessel retention strategy in APR1400. In order to meet the mission time for IVR, it is proven that the elevation of IRWST has to increase about 8m dependent on accident scenarios. In a view of ECCS, the elevated IRWST makes the good effects in LBLOCA. The case with 8m increased elevation shows PCT reaches stable state earlier than the original case. Finally, the effects on system rearrangement are considered and should be evaluated from the quantitative method.

This study has taken a basic step for passive IVR. Many problems including views of SCS (Shutdown Cooling System) and SBO (Station Black Out) will be analyzed and solved as future works.

REFERENCES

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[3] Korea Atomic Energy Research Institute, Development of a New Design Concept for APR1400 Safety System, KAERI, 2007