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Integrated Passive Safety System (IPSS) for Ultimate Safe Nuclear Power Plants

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1. Introduction

The integrity of reactor core could be preserved if there was a passive safety system enough to remove the decay heat in the Fukushima accident. Also, even if the core was molten and there was no electrical power, the reactor vessel would not be damaged and the release of radioactive materials could be prevented by using safety systems of containment cooling and filtered venting. Not only for the Fukushima accident, there is a possibility that a nuclear power plant can experience a severe accident in a case of SBO (Station Black Out). Even if it is sure that the reasonable proportion of active and passive safety system has to be considered based on the safety and economics of a nuclear power plant, the researches to enhance the safety of a nuclear power plant must be continued for the future.

In order to solve the problem and enhance the safety of nuclear power plants, integrated passive safety system (IPSS) is proposed. It is the wholly passive system by natural phenomena like gravity, natural circulation and pressure difference. The purpose of this paper is to propose the conceptual design of the integrated passive safety system and make the overall evaluation of IPSS characters.

2. IPSS Design

Integrated passive safety system consists of integrated passive safety tanks (IPST), pipes, sprays, valves and heat exchangers which are related with main functions. IPST can be installed on the top of auxiliary building for high head. The number of IPST can be more than two. For the first design, two IPST are installed outside containment like PCCT in APR+. Figure 1 shows the conceptual design of the integrated passive safety system.

The integrated passive safety system has five main design functions. They are described with each character as follows.

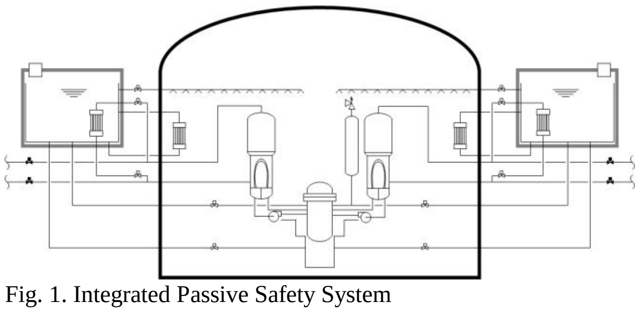

Fig. 1. Integrated Passive Safety System

2.1 Passive Decay Heat Removal

The first function of IPSS is to remove decay heat in the secondary circuit including isolation valves and heat exchangers in IPST. The driving force is natural circulation with vaporization in steam generators and condensation in heat exchangers. The first concept of this system was proposed with the development of CP-1300. After about fifteen years, the concept is applied in passive auxiliary feedwater system of APR+ which is replacing the current auxiliary feedwater system operated by AC electrical power.

2.2 Passive Safety Injection

The passive safety injection system consists of the pipe from IPST to RPV and valves. The coolant in IPST can be injected into RPB in low pressure. It is the supplementary system for current active safety injection systems like safety injection pumps and IRWST. Accordingly, the operation of this function would be carefully considered due to the direct line from RPV to IPST. Also, in order to inject the coolant in a case of loss of coolant accident, the depressurization of reactor coolant system is needed. Actually, the depressurization of reactor coolant system is indispensable for all the accidents for prevention of high pressure core melt ejection.

2.3 Passive Containment Cooling

In order to protect the containment integrity, it has to be accomplished to decrease the temperature and pressure of containment. For the containment cooling, most of the nuclear power plants use containment cooling pumps and IRWST as an active safety system. IPSS has two design concepts for this function. The first cooling method is the closed loop using internal condenser shown in Figure 2. The second cooling method is the passive spray system operated by gravity to condensate the steam in containment.

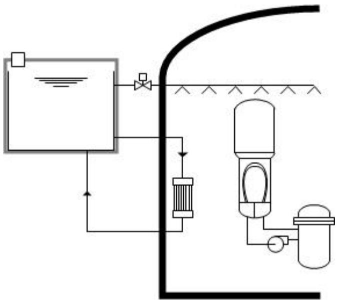

Fig. 2. Passive Containment Cooling System in IPSS

2.4 Passive In-Vessel Retention

In-Vessel Retention through external reactor vessel cooling is the key strategy for severe accident. The Korean nuclear reactors adopt IVR strategy in order to mitigate the core melt accident. However, the system for IVR is set to fill the cavity by the use of shutdown cooling pump. It can be the problem in a case that there would be no electrical power. Accordingly, the installation of pipes from IPST to cavity can accomplish the concept of passive IVR strategy. The cavity can be filled with water from IPST by the driving power of water elevation difference.

2.5 Filtered Venting System

The filtered venting system is to control the radioactive steam and non-condensable gas. In the Fukushima accident, it is proven that the effect of water scrubbing makes the decrease of radioactive level from the comparison of unit one and two. The emission through the suppression pool was much lower than that through the dry well. By pressure difference between containment and IPST, steam is extracted into filtered venting system in IPST. The schematic design of filtered venting system is presented in Figure 3.

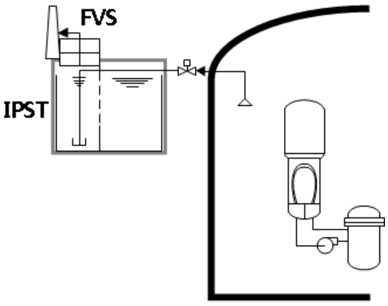

Fig. 3. Filtered Venting System in IPSS

3. Strong Points of IPSS Design

IPSS has lots of strength and expected effects in a view of design and safety of nuclear power plants.

Firstly, all the safety concepts are wholly passive. Most of the functions become the supplementary safety systems for the current active systems. A few safety features can substitute current active safety systems. Secondly, it is possible to fill coolant from outside into IPST when containment is not accessible. It means very long term cooling is possible in accidents like Fukushima. Thirdly, maintenance and accessibility is easy because IPST is outside containment. The fourth is that the concept of IPSS is simplified and integrated. Fifthly, IPSS can be installed on current operating nuclear power plants because it does not need lots of design change. The concept of IPSS can be applied on various types of nuclear power plants as well as pressurized water reactors. Lastly, the filtered venting system on IPST can prevent the release of large radiation and decrease the containment pressure by treating non-condensable gases. IPSS can be applied as various options. Some functions selected from all the functions can be installed in a nuclear power plant.

4. Conclusions

IPSS is designed to use high head of coolants and form natural circulation in high elevation for passive safety features. With the specific and optimized design of IPSS, it is expected that nuclear power plants does not need the evacuation plan.

The specific and overall analyses based on this conceptual design will be investigated and evaluated.

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