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Comparative Analysis of Existing and Modified Parameters in MAAP-ISAAC 4.03 Code for MSGTR Accident

Chul-Kyu Lim[a*], Dong-Sik Jin[a], Kwang-Il Ahn[b], Soo-Yong Park[b], Hyun-Gyo Lee[c] and Seok-Won Hwang[c]
[a] *Atomic Creative Technology Co., Ltd., #204, IT Venture Town, 35, Techno 9-ro, Yuseong-gu, Daejeon, Korea*
[b] *Korea Atomic Energy Research Institute, 1045 Daeduck daero, Yuseong-gu, Daejeon, Korea*
[c] *Korea Hydro & Nuclear Power Co., Ltd. 70, 1312-gil, Yuseong daero, Yuseong-gu, Daejeon, Korea*
[*] *Corresponding author: happiness0902@actbest.com*

1. Introduction

Within a development of the level 2&3 PSA technologies based on the State-of-the Art technology, so called the KHNP-SOARCA Project [1], it is required to improve the existing parameter file reflecting the design characteristics of the Wolsong plants which are a typical CANDU-6 type. In the existing parameter file, the additional equipment and strategies for preventing and mitigating severe accidents have not been reflected and some input variables have been developed based on PWR (Pressurized Water Reactor).

The main purpose of this paper is to assess the effect of multi steam generator tube rupture (MSGTR) induced severe accident progressions using the existing and modified MAAP-ISAAC[1] [2] parameter files for the Wolsong plants.

2. Modification of the MAAP-ISAAC parameter file

Table 1: Status of the Modified Input Variables.

Classification	Number of the revised/added variables	Remarks
PHTS	319	Reflect the design characteristics of the Wolsong plants
Secondary side	72	
Calandria tank	59	
ESF	86	
Containment	428	
Aux. building	1047	Add 11 compartments for simulation of ISLOCA and airlock seal failure
Etc.	2	Apply the consultation results
Sum	2013	966(Revised) + 1047(Added)

As shown in Table 1, a total of 2013 variables have been revised or added based on design data, operation data, and plant procedures of the Wolsong plants. Among them, 1047 variables are related to the auxiliary building. The auxiliary building is developed for all severe accidents leading to the failure of reactor building airlock seal [3].

The rest are variables reflecting the specific data of Wolsong plants, excluding the two variables reflecting the consultation results [4,5]. And there are some of modified input variables reflecting the initial inventory of radionuclide and decay heat fraction using the latest ORIGEN code.

3. Method and Results

3.1 Description of Analyzed Cases and Assumptions

A chosen case is the multi steam generator tube rupture (MSGTR) accident. MSGTR is an accident that causes leakage of coolant to the outside of the reactor building. The reactor shutdown is successful after MSGTR occurs, but it leads to core damage due to failure of the ECCS. And, when MSGTR occurs, MSSVs are automatically opened because of ECCS signal. If core damage occurs, the radioactive material may be released directly to the environment through the opened MSSVs as shown in the Figure 1.The assumptions regarding the availability of systems are as follows:

- It is assumed that 10 steam generator tubes are ruptured and the maximum break flow rate is 80 kg/s.
- Main & Auxiliary Feed Water System (MFWS & AFWS), Emergency Water Supply (EWS) System, Moderator Cooling System (MCS), Shutdown Cooling System (SCS), End Shield Cooling System (ESCS), and Emergency Core Cooling System (ECCS) including Loop Isolation (LI) are assumed to be not available after reactor trip during the transient.
- Local Air Cooler (LAC), Containment Filtered Venting System (CFVS) are assumed to be not available right after an accident.
- All Passive Autocatalytic Recombiners (PARs) are assumed to be available and Dousing System (DS), Crash Cooldown (CC) are assumed to work normally.
- It is assumed that containment isolation is automatically initiated on a high containment pressure signal (3.45 kPa(g)).

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[1] MAAP is an Electric Power Research Institute (EPRI) software program that performs severe accident analysis for nuclear power plants including assessments of core damage and radiological transport. A valid license to MAAP4 and/or MAAP5 from EPRI is required.

- It is assumed that there is a reactor building airlock seal failure which occurs at 262 kPa(g) and the break area is assumed to be 0.027871 m^2.

Then, the analyses have been carried out for both existing and modified parameter values.

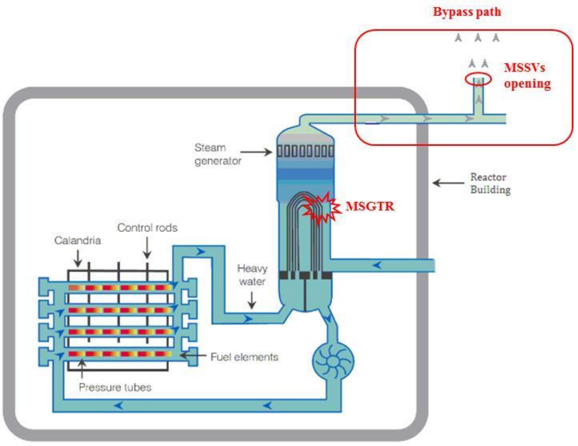

Fig. 1. Reactor Building Bypass Route due to MSGTR.

3.2 Results and Discussion

As shown in the Fig. 2, 3, and 4, the progress of the severe accident in the analysis case of using modified parameter file was delayed or mitigated significantly. The rupture of the pressure tube and calandria tube in loop 2 was slightly faster due to the reduced steam generator inventory in modified parameter file. But the timings of calandria tank failure and airlock seal failure were delayed from 40.14 hours to 50.85 hours, from 40.20 hours to 51.18 hours, respectively compared to the case using existing parameter file.

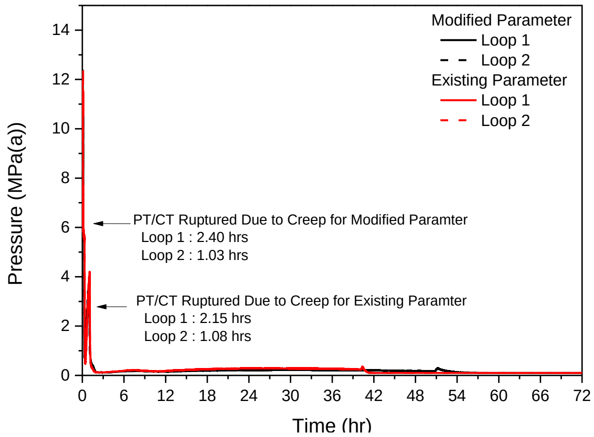

Fig. 2. Pressure Transient in the PHTS during MSGTR.

And these results have the effect of reducing the mass of Cs released to the external environment than case of using existing parameter file. The mass of Cs released to environment was sharply reduced from 6.448 kg to 1.873 kg as shown in Fig. 5 and 6 because the deposition effect in the reactor building is increased as the time of airlock seal failure is delayed.

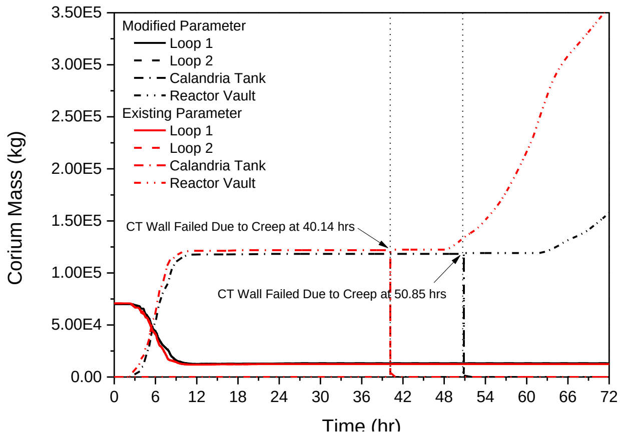

Fig. 3. Mass of Corium in the PHTS, Calandria Tank, and Reactor Vault during MSGTR.

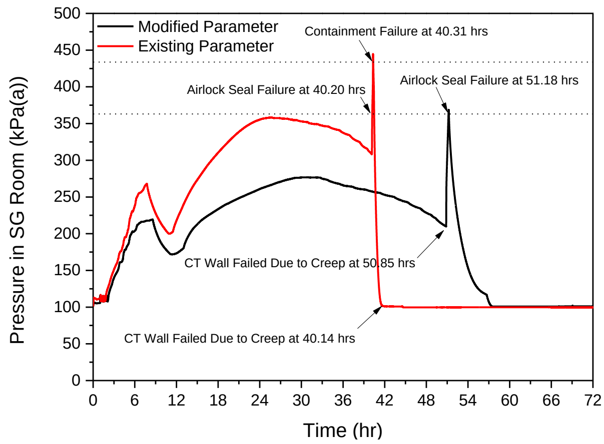

Fig. 4. Pressure Transient in the Reactor Building during MSGTR.

The major factors that delayed or mitigated severe accidents in the case of the modified parameters are four variables as followings:

First, change of FPRAT input variable value from "-2" to "-6". FPRAT is the fission product release correlation and control option parameter. The value of fission product release model through experiments was changed to CORSOR model. Thus, the amount of the Cs released to systems such as the PHTS (primary heat transport system) was decreased and to the reactor building was increased. These results indicate that more radionuclides may be released to the environment depending on when the airlock seal is failed. However, the Cs release occurs at or after the completion of the deposition of aerosolized Cs into the reactor building in most severe accidents. Therefore, the amount of Cs released to the environment is reduced because the time of airlock seal failure is delayed.

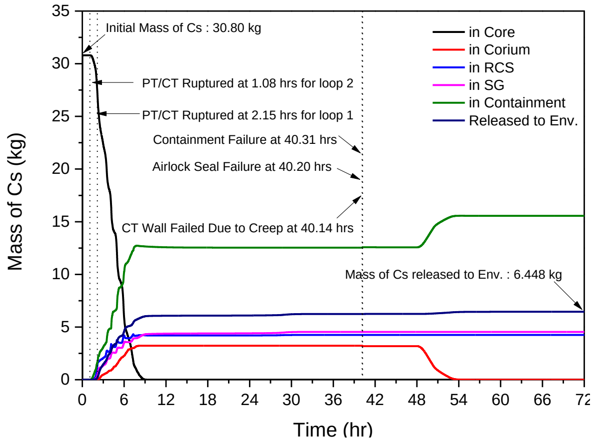

Fig. 5. Behavior of Cs during MSGTR (Existing Parameter).

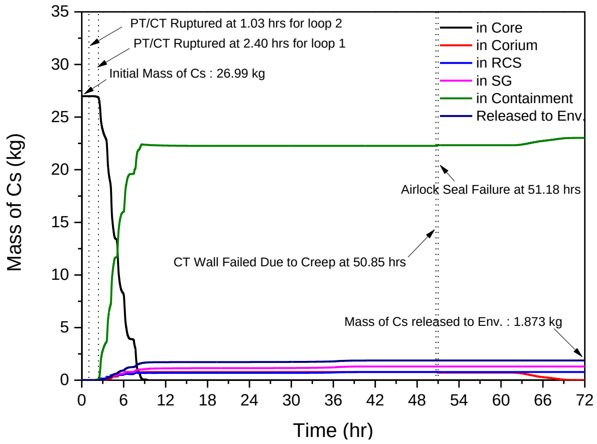

Fig. 6. Behavior of Cs during MSGTR (Modified Parameter).

Second, the input variable value of QC0 related to heat loss from PHTS to containment was changed from "9 MW" to "3 MW" based on Wolsong plant design. The QC0 variable is the parameter representing the amount of heat transferred from the PHTS to the reactor building. Excessive setting of 9 MW used for existing input variable value resulted in increased reactor building pressure.

Third, the input variable value of TIRRAD was changed from 295 days to 157 days based on the radioactive initial inventory calculation. TIRRAD is a variable that represents the core average irradiation time and is related to decay heat. The reduction of the core average irradiation time leads to a decrease in the decay heat of the radionuclides in the corium. Thus the heat transfer to the reactor vault is reduced. And it has the effect of reducing the reactor vault water level and delaying the time of the calandria tank failure.

Finally, the initial calandria vault water level was revised from 14.4 meters to 14.8 meters to reflect the design characteristics of the Wolsong plants. Increasing the water level in the calandria vault increases the external cooling effect on the corium in the calandria tank, and consequently delays the time of the calandria tank failure by creep.

4. Conclusions

For MSGTR-induced severe accident progress the impact of the MAAP-ISAAC 4.03 modified parameter file for the Wolsong plant, which was revised reflecting its design-specific features and the currently-available best-practice state of knowledge, was evaluated in this paper.

The comparative analysis between the existing and modified parameter files showed that the progress of the severe accident was delayed or mitigated in the analysis case of using modified parameter file. In other words, the times of airlock seal failure, reactor building failure, and calandria tank failure were delayed and the amounts of Cs released to the environment were sharply reduced than cases of using existing parameters. And it was confirmed that the four variables were the greatest influence of input variables as following: FPRAT, QC0, TIRRAD, and the initial calandria vault water level.

The present analysis result that reflects the modification of the input parameters can provide the valuable insights into the Level 2&3 PSA or the severe accident management guidance (SAMG) which uses the result of the severe accident analysis.

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