Parametric Studies for SG Water Levels and Locations of Tube Ruptures Using MAAP-ISAAC 4.03 Code during MSGTR Severe Accident

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1. Introduction

An MSGTR (Multiple Steam Generator Tube Rupture) accident is characterized as a RB (Reactor Building) bypass scenario in the CANDU-6 type reactors. Although the probability of the MSGTR accident is very low below 5.5 x 10^{-8}/ry [1], a direct release of radioactive nuclides to the environment can cause radiation exposure to residents around the plant. However, this scenario affords the possibility for the pool scrubbing of fission products as they are discharged into SG (Steam Generator) inventory. In this case, feed-water injection may be resumed to allow for a water pool to be maintained in the ruptured steam generator [1].

The main purpose of this paper is to evaluate the impact of pool scrubbing on fission products release according to SG water levels and locations of tube ruptures using MAAP-ISAAC (Modular Accident Analysis Program - Integrated Severe Accident Analysis Code for CANDU Plant)[1] code [2] when the mitigation action such as external injection to the SG secondary side is accomplished.

2. Background

2.1 MAAP-ISAAC 4.03 Computer Code

The MAAP-ISAAC code is constructed in modules covering individual regions in the plant: the primary heat transport system, pressurizer, SGs, calandria, calandria vault, end shields, degasser condenser tank, and the containment [3]. The generic models of MAAP-ISAAC code are evolved from the MAAP4 code developed by FAI (Fauske and Associstes, LLC), for pressurized light water reactors. As MAAP-ISAAC code was derived from MAAP4 code for PWRs (Pressurized Water Reactors), it adopts most of the MAAP models for severe accident phenomena in general. The detailed qualification level of MAAP-ISAAC code is well described in IAEA-TECDOC-1594 and 1727 [4, 5].

2.2 Pool Scrubbing Model in MAAP-ISAAC code

The MAAP-ISAAC code calculates the scrubbing of fission products in water using the aerosol scrubbing model using the results generated by SUPRA [6], coupled to the non-dimensional aerosol particle size spectrum correlation developed by FAI [7]. SUPRA is a mechanistic suppression pool scrubbing model, and pool scrubbing for flow through a break during MSGTR into water in the SUPRA model is simulated as a Side Vent. However, the Side Vent injection mode only considers pool heights up to 1.8 m. That is, for pool heights greater than 1.8 m, the DF (Decontamination Factor) will be calculated assuming a pool height of 1.8 m [3].

3. Assumptions and Results

3.1 Description of Analyzed Cases and Assumptions

A MSGTR is a transient sequence initiated by the rupture of several SG tubes, allowing PHTS (Primary Heat Transport System) coolant to discharge into the secondary side of the SG, which causes leakage of coolant to the outside of the RB. If core damage occurs, the radioactive material may be directly released to the environment through the open MSSVs (Main Steam Safety Valves), as shown in Fig. 1 because SG MSSVs open automatically once the ECCS (Emergency Core Cooling System) signal is initiated. And it is assumed that ten SG tubes in loop 1 are ruptured and the maximum break flow rate is 80 kg/s based on safety analysis for CANDU reactor using CATHENA (Canadian Algorithm for THErmalhydraulic Network Analysis) code.

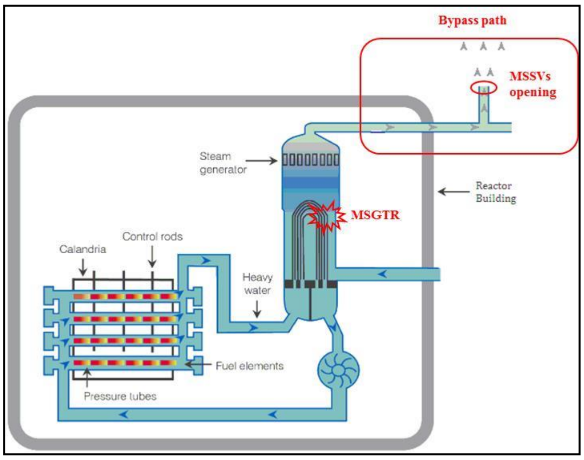

Fig. 1. Reactor Building Bypass Route due to MSGTR [3].

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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.

The assumptions are as follows:

- 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.
- MSSVs are assumed to become stuck open once the valves are open.
- Local Air Coolers (LACs) and Containment Filtered Venting System (CFVS) are assumed to be not available immediately after the accident.
- All Passive Autocatalytic Recombiners (PARs) are assumed to be available and the Dousing System (DS) and Crash Cooldown (CC) are assumed to work normally.
- Containment isolation is automatically initiated on a high containment pressure signal (3.45 kPa(g)).
- Analysis credits reactor building airlock seal failure which occurs at 262 kPa(g) with a break area of 0.027871 m^2.
- It is assumed that an operator can manually supply feed-water to a broken SG using a portable pump and fire hoses as mitigation actions in the mitigated case after SAMG entry conditions are met.
- It is assumed that external injections to secondary side are performed at 5.5 kg/s per SG as mitigation actions in the mitigated case.

3.2 Results and Discussion

The analysis for the influence of steam generator water level and MSGTR break location has performed. Fig. 2 and Fig. 3 are the analysis results of the influence of steam generator water level. The break location is -0.1 meters from the steam generator tube top. Base case is the unmitigated case, and the others are the cases in which the water level of the steam generator is raised by 1 meter from SG tube top up to 5 meters. In the cases of the steam generator water level of 1.1 meter from the break location, the Cs release fraction is reduced compared to the base case, but there is no big difference from the steam generator water level above 2.1 meters from the break location because the Side Vent injection mode in MAAP-ISAAC code only considers pool heights up to 1.8 m.

Fig. 4 and Fig. 5 are the analysis results of the influence of MSGTR break location. Likewise, the mitigation action for MSGTR is the injection of water to the broken steam generator. The steam generator water level was fixed at 4 meters from the steam generator tube top, and the analysis was performed by changing the break location. There is no significant difference per break location as in the case of changing the steam generator water level.

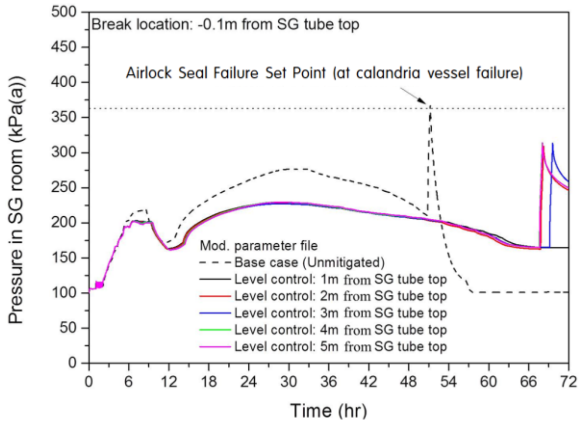

Fig. 2. Pressure transient in the reactor building according to SG water level during MSGTR.

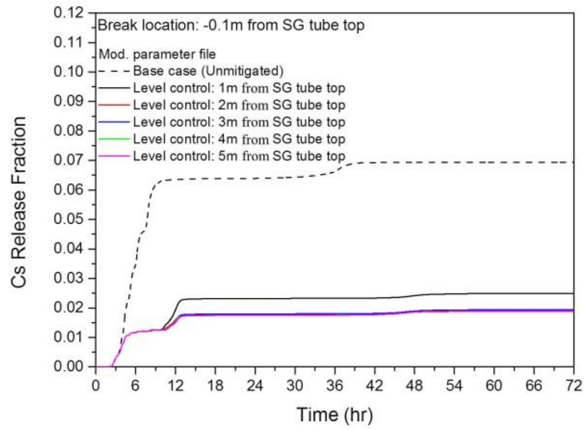

Fig. 3. Cs fraction released to environment according to SG water level during MSGTR.

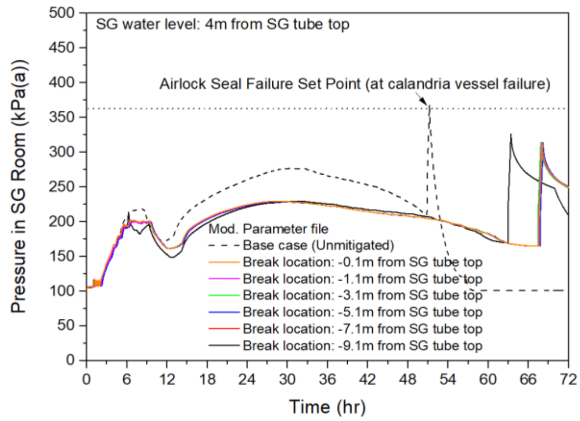

Fig. 4. Pressure transient in the reactor building according to break location during MSGTR.

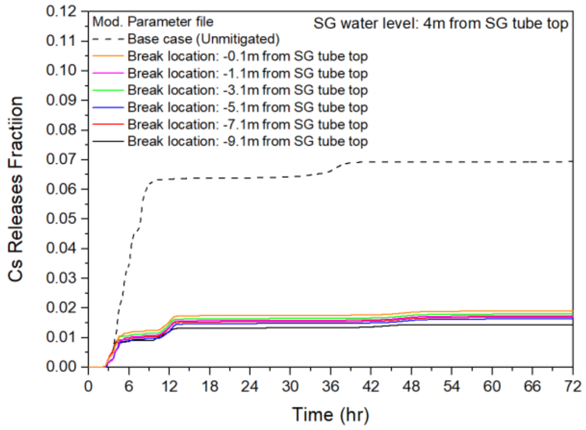

Fig. 5. Cs fraction released to environment according to break location during MSGTR.

4. Conclusions

The effects of the parameters relevant to pool scrubbing of the MAAP-ISAAC 4.03 severe accident analysis code were evaluated for the MSGTR accident in the CANDU-6 type reactors.

As a result of the analysis, it was confirmed that there is no big difference from the steam generator water level above 2 meters and locations of tube ruptures because the Side Vent injection mode in MAAP-ISAAC code only considers pool heights up to 1.8 m. Therefore, it may be necessary to improve the pool scrubbing model.

The present analysis result can provide the valuable insights into the Level 2&3 PSA (Probabilistic Safety Assessment) or SAMG (Severe Accident Management Guidance) which uses the result of the severe accident analysis.

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