Source Term Sensitivity Evaluation under SBO Induced Severe Core Damage Using MAAP-ISAAC in Wolsong Unit 2 Plants

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INTRODUCTION

◈ The main objective of this paper is to evaluate a station blackout (SBO) accident resulting in hypothetical severe core damage using MAAP-ISAAC (Integrated Severe Accident Analysis code for CANDU plants), mainly about the fission product behavior, as ex-containment (= environmental release) source term evaluation for the R/B failure case.

◈ This work is done for providing code comparison basis with CAISER (CANDU Advanced Integrated SEveRe) code [1] which is an up-to-date PHWR severe accident code developed and being improved at KAERI (Korea Atomic Energy Research Institute) following a demand for an accurate and detailed code in a CANDU society.

[1] KAERI (Jun Young Kang, Yong Mann Song, Dong Gun Son, Keun Sang Choi, Jong Yeob Jung, Jun Ho Bae, Byeonghee Lee), Comparative Analysis of CANDU Severe Accident Using CAISER, Annals of Nuclear Energy, Vol.227, February (2026), 11931

ISAAC Fission Product Models

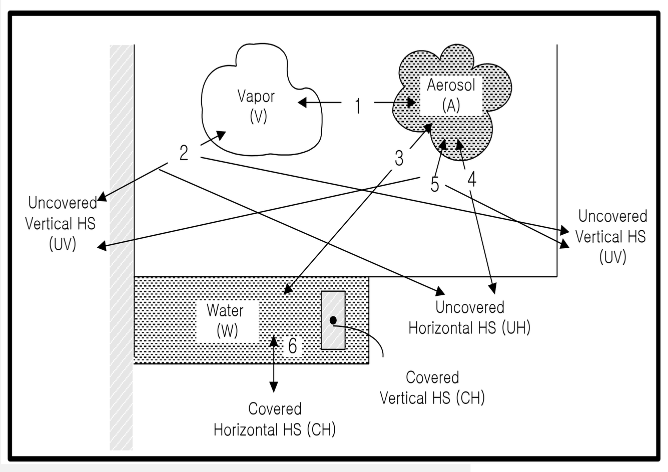
- The ISAAC model employs temperature dependent vapor pressure correlations and the ideal gas law to calculate the driving force for a condensation or an evaporation
- Aerosol formation from the supersaturated vapor allows us to calculate the vapor diffusion rate to the walls; if the mass of the vapor is supersaturated in a time step, the excess mass is assumed to form aerosols
- Vapor deposition removal rate is

$$\lambda = D_f \frac{Sh}{h_c}$$

- Diffusion coefficient near the heat sinks is

$$D_f = 4.7 \cdot 10^{-3}\ T_m^{1.5} / \left[10 \cdot P_{gas}\left(1 + 829 / T_m\right)\right]$$

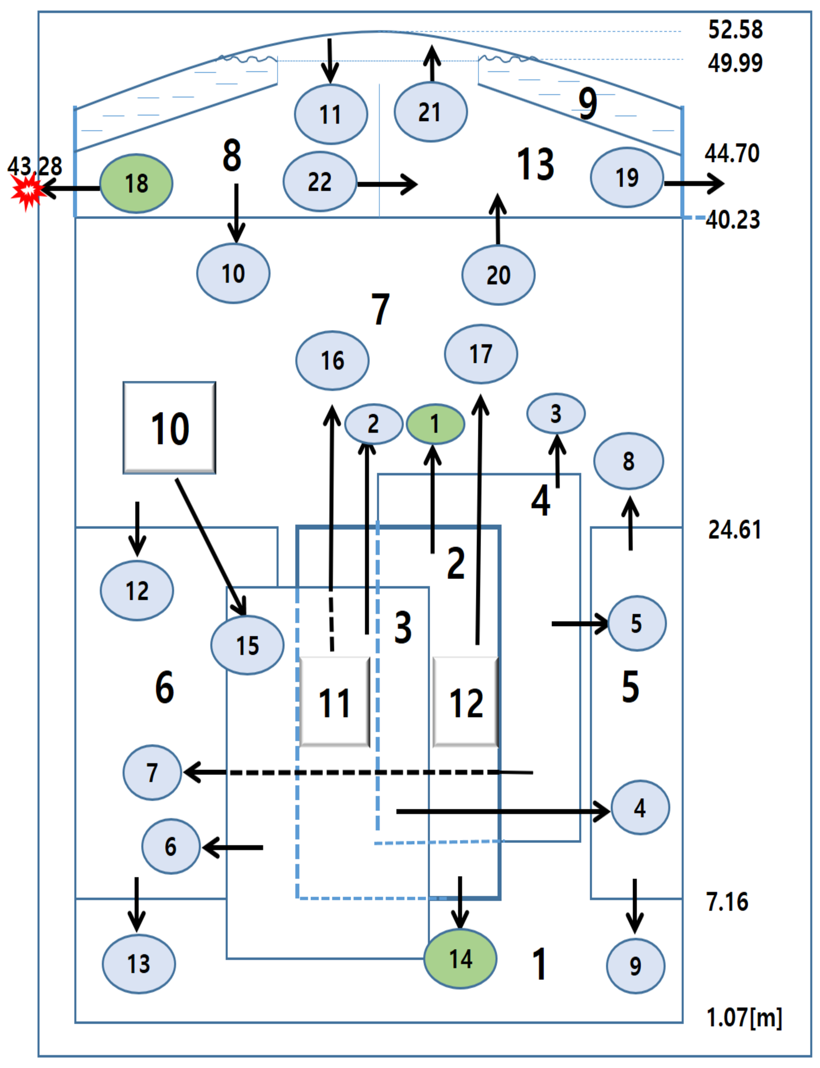
Where,
Sh = Sherwood number
h_c = Characteristic length of condensation
P_{gas} = Gas pressure, $T_m = 0.5\,(T_g + T_{WALL})$



CANDU6 R/B Nodalization Scheme in ISAAC (with R/B rupture failure)

ISAAC Configuration for Reactor Building (R/B)

Node	Compartment
1	Basement
2	Reactor vault
3, 4	Fueling machine room
5	Moderator room
6	Access area
7	Boiler room
8, 13	Upper dome
9	Dousing tank
10	Degasser condenser tank
11, 12	End Shield



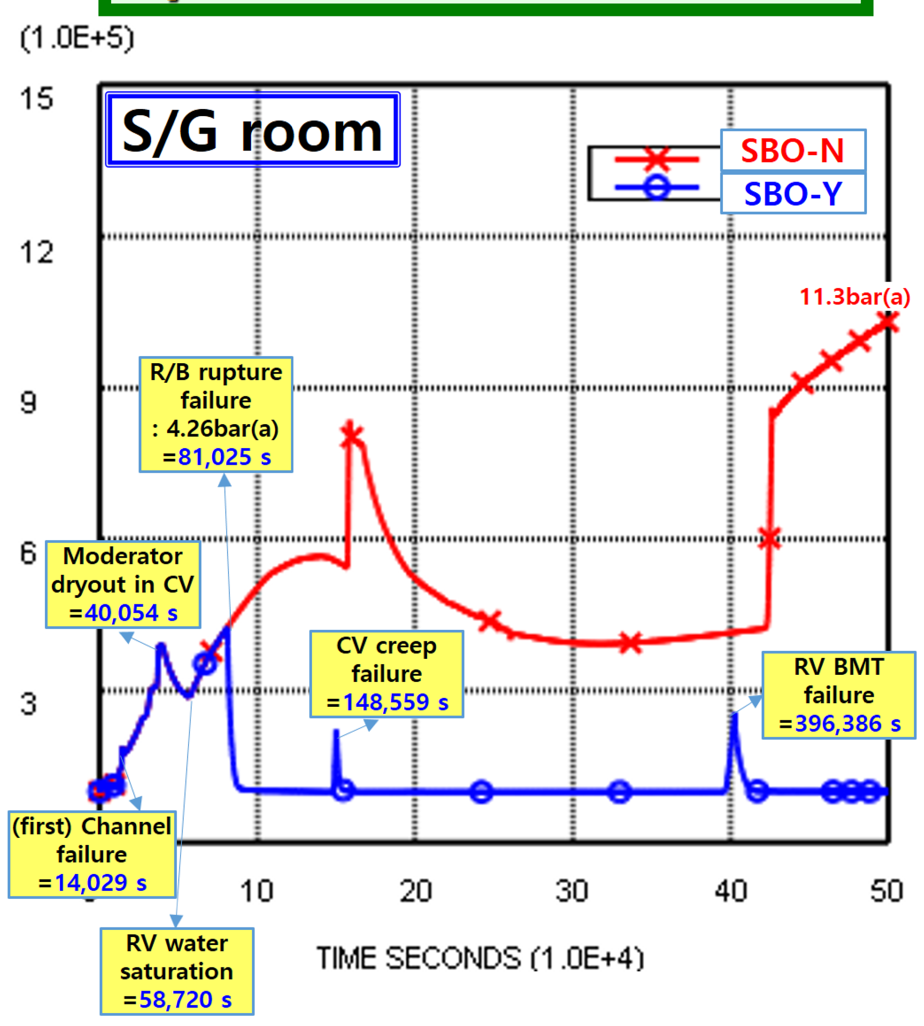
Status of Major Safety System in SBO

Cases	Rx Trip	PHTS loop Isolation	MFW or AFW	ECCS	MCS	ESC	R/B Failure	Comments
SBO-N	O	X	X	X	X	X	X	no AC power
SBO-Y	O	X	X	X	X	X	O	

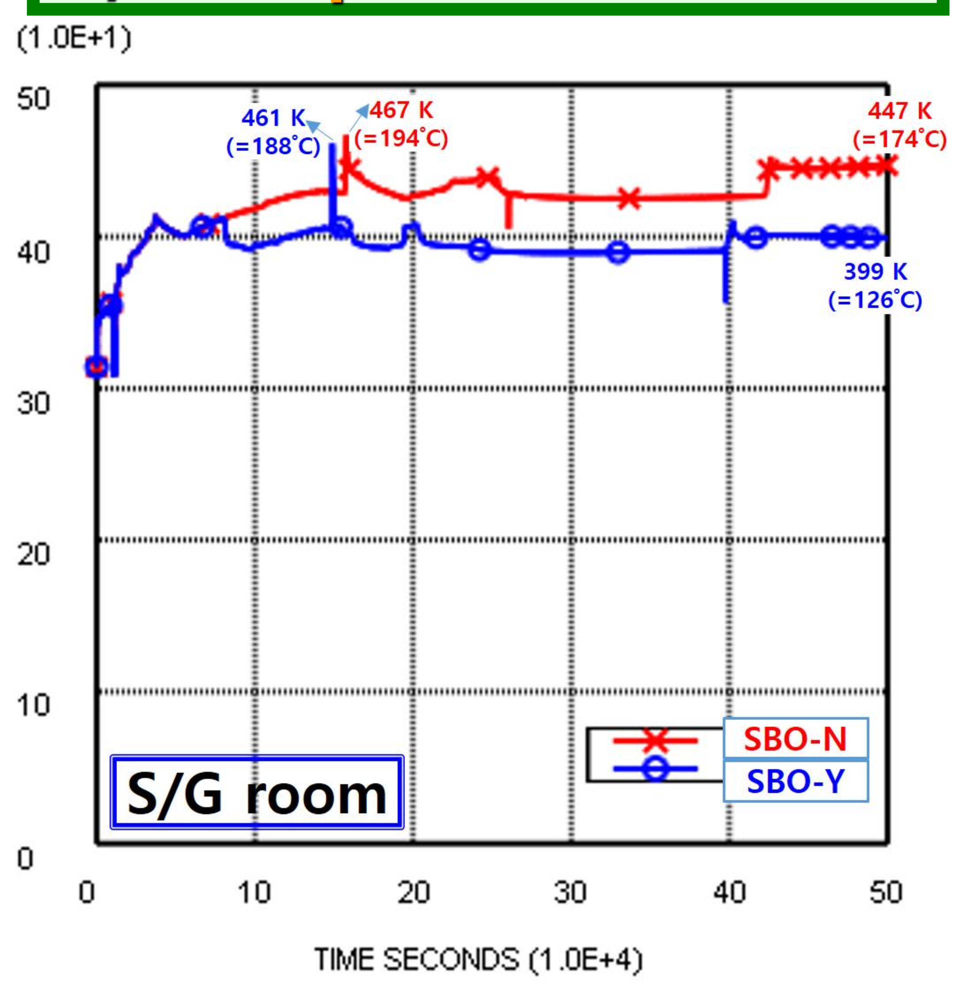
SBO Main Event Progress in ISAAC4.03

Event Timing (4x4 checker: local balloon)	MAPP-ISAAC [sec] SBO-Y	SBO-N
SBO start	0	
Dousing spray operation	10,494~11,531 (Δt: ~1,000)	
(first) Channel (PT/CT) failure	14,029/21,758(Loop 1/2)	
100% fuel channel relocation	36,569	
Moderator dryout / Corium debris melt	40,054 / 48,313	
RV water saturation /	58,720 /	
RV water dryout	162,057	166,690
R/B rupture failure	81,025	N/A
CV creep failure	148,559	157,163
RV floor MCCI start	171,307	175,730
RV floor peak ablation rate	224,542	224,736
Zr 100% oxidation	232,822	240,591
RV BMT failure	39,6386	425,736
Calculation end	500,000	

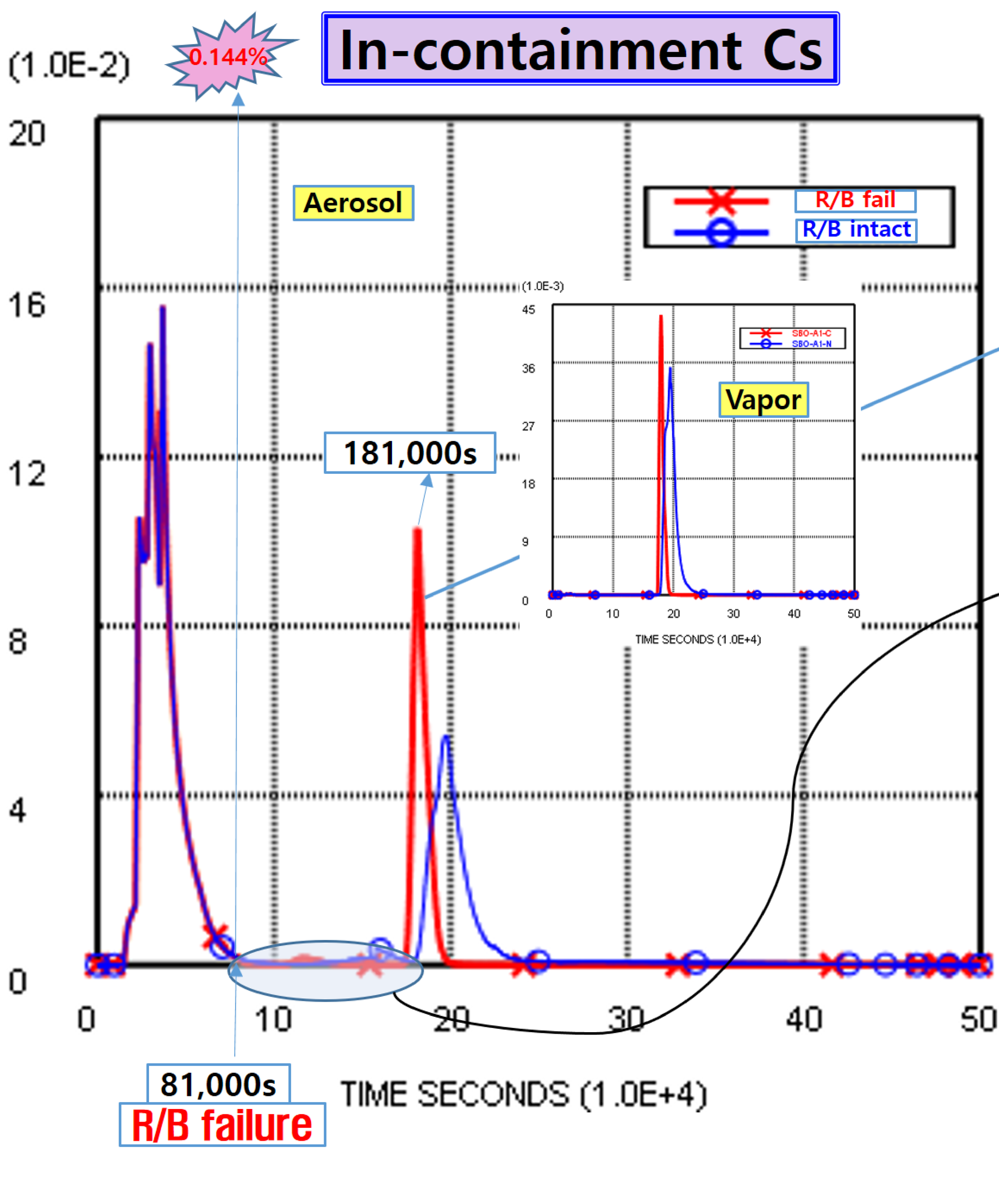
R/B Pressure Prediction

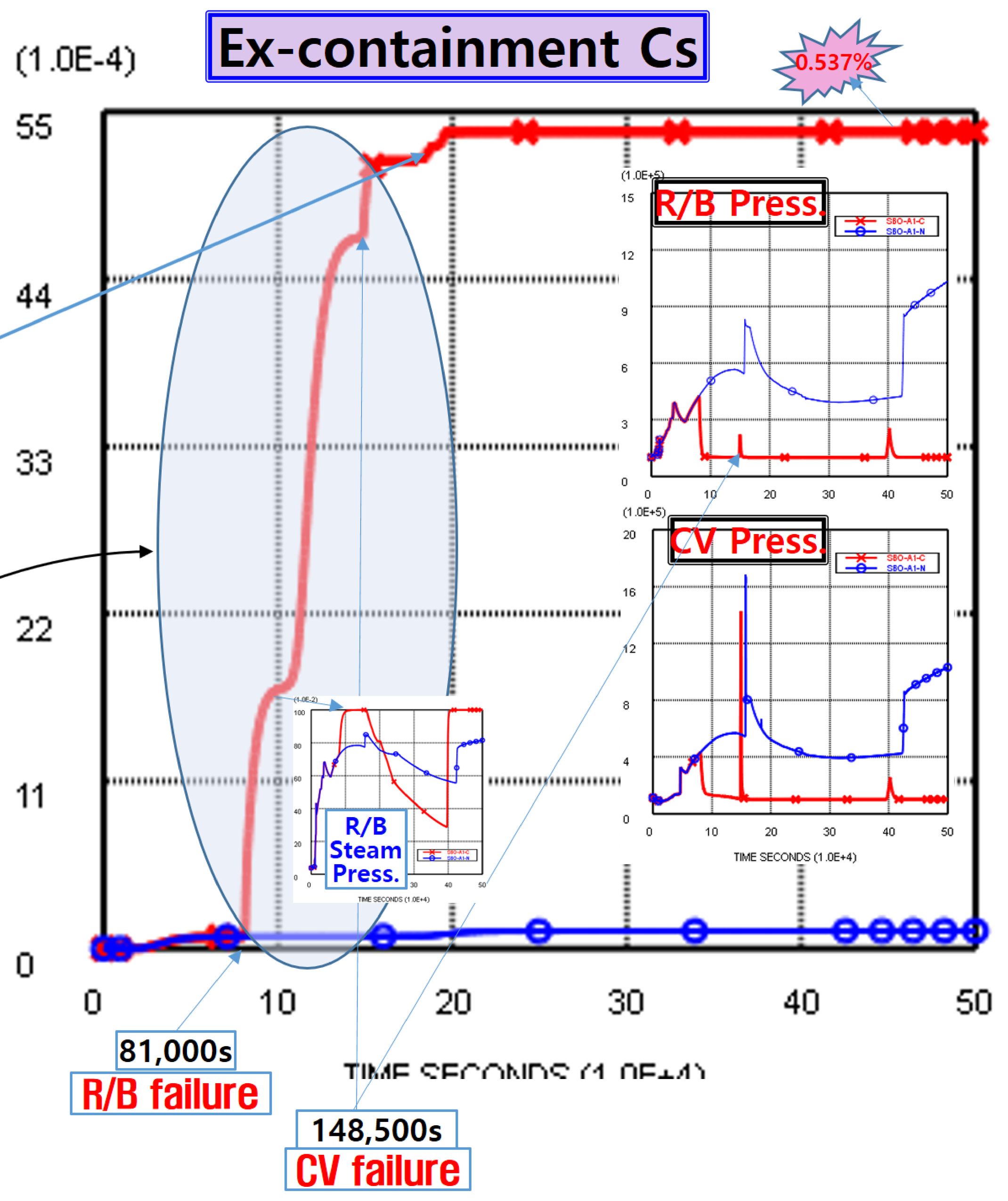


R/B Temperature Prediction



In-/Out-Containment Source Term Evaluation for Cs





CONCLUSIONS

① In intact R/B scenario (SBO-N), the tiny radiation leakage is calculated from the R/B (= containment) design leakage which is a background/basis leakage (= 0.01% (3.6g) of Cs initial inventory until 500,000 seconds). This is approximately 2% compared to the case of R/B rupture failure (SBO-Y).

② In failed R/B scenario (SBO-Y), when R/B failure occurs at approximately 81,000 seconds (~1 day), in-core FPs released to the R/B atmosphere (almost of aerosol form) are mostly deposited. Nevertheless both the suspended aerosols (left in the atmosphere (=0.144%)) and the resuspended aerosols (which are agitated from the deposited by pressure difference) have chances to become ex-containment ST. At approximately 200,000 seconds (~2.3 days when CV already failed and MCCI has started), the cumulative ex-containment ST becomes saturated at 0.537% (= 165g) for Cs elements. This is about 5 times (using 93.5% conversion factor of Cs into Cs-137) higher than the domestic AMP standard (= 100 TBq of Cs-137).

③ The release fraction order among 12 FP groups (including Cs and I) in ISAAC code is as follows.

✓ Noble>CsOH/CsI>Sb>TeO_2>Te_2>MoO_2>SrO>BaO>CeO_2>La_2O_3>UO_2