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Review of Design Basis Accidents (DBAs) in Hot Cell Facility (HCF) Safety Analysis Report

Seok-Jun Seo *, Woojin Jo, Siwan Noh, Gil-Sung You, Seung Nam Yu
Nuclear Fuel Cycle Strategy Division, Korea Atomic Energy Research Institute (KAERI),
989-111 Daedeok-daero, Yuseong-gu, Daejeon, South Korea
sjseo@kaeri.re.kr

1. Introduction

One of the significant issues in South Korea is a management of nuclear spent fuels (SFs) from nuclear power plants (NPPs). Korea has relatively less appropriate territory and lower public acceptance for a SF repository. In addition, an aqueous reprocessing of SFs is prohibited in aspects of non-proliferation. Thus, a pyroprocess as a dry process or a non-aqueous recycle technology would be an essential option to minimize volume of high-level radioactive waste as well as required repository sites [1]. Korea Atomic Energy Research Institute (KAERI) has been developing a pyroprocess technology in terms of electro-reduction, electro-recovery, waste treatment, safeguards, and safety. In order to fulfill the pyroprocess safety, establishment of a robust hot-cell structure as a physical barrier is one of important requirements. This hot-cell is constructed with about 1 m-thick heavy concrete walls including seismic design, radiation shielding windows, negative pressure HVAC systems, and an inert atmospheric condition such as argon gas. Thus this structure is regarded to inherently retain safety features against radiation, earthquake, and fire. Regardless of its inherited integrity, safety analysis should be conducted whether it meets regulatory requirements and guidelines under selected scenarios of design basis accidents (DBAs).

A Safety Analysis Report (SAR) of Hot Cell Facility (HCF) in Sandia National Laboratories (SNL) [2] was prepared and released in 2000 in compliance with the requirements of DOE Order 5480.23 [3] and DOE-STD-3009 [4]. This SAR provides an assessment of the hazards and potential accidents; potential consequences and likelihood; safety-related structures, systems, and components; and safety functions. In HCF SAR, eight types of DBAs and three beyond design basis accidents (BDBAs) were identified.

In this review study, the DBAs selected in HCF and their likelihood and consequence ranges are examined for applications to safety studies of pyroprocess in KAERI.

2. List of DBAs in HCF

The hazard analysis was conducted using preliminary hazard assessment (PHA) and failure modes and effects analysis (FMEA) on processing operations and maintenance. The eight DBAs and three BDBAs are summarized in Table 1 and Table 2, respectively.

Table 1 List of design basis accidents selected in HCF SAR [2].

DBA #	Accident Description	Type
1	Operator error or mechanical failure releases volatile contents of the target and/or acid cocktail inside an SCB	Spill
2	Deflagration of hydrogen in the Zone 2A canyon elevator pit	Explosion, Fire
3	Fire in an SCB releases volatile contents of the target, iodine trap, and/or acid cocktail	Fire
4	Energetic fork lift accident which breaches target cask, breaches the target, and releases volatile radioactive components in the target; with and without a fork lift fire	Spill, (Exposure, Fire)
5	Combustion of hydrogen gas or flammable material in the Room 109 waste storage area	Fire
6	Ventilation system failure (loss of off-site power)	External Event
7	Fire in a HCF associated radioactive material storage area releasing radioactive material from the stored inventory	Fire
8	Design Basis Earthquake	Earthquake

Table 2 List of beyond design basis accidents selected in HCF SAR [2].

BDBA #	Accident Description	Type
1	Multiple simultaneous errors or events that affect multiple SCBs, resulting in release of the contents of multiple targets	Spill
2	BDBA Earthquake	Earthquake
3	Explosion	Explosion

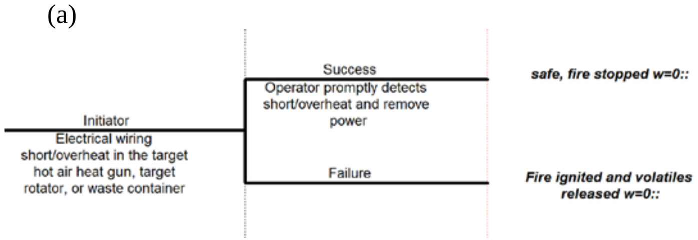
3. Safety Analysis Results for DBAs

Radiological dose consequences and likelihood of occurrence were systematically evaluated. For each DBA, as shown in Fig.1, an event tree methodology was conducted to develop probable sequences. Furthermore, a very conservative source term was selected for the consequence calculations.

Table 3 Summary of results of accident analysis in HCF SAR [2].

DBA	Sequence	Likelihood	Dose Consequence
Process Spill	Single target, filtered release	> 1/yr	3.2 mrem
	Single target, degraded filters	< 1/yr	14 mrem
	Single target, unmitigated	$<10^{-4}$/yr	300 mrem
	Multiple targets, filtered	<.1/yr <.01/yr	6 mrem 19 mrem
	Multiple targets, degraded filters	<.01/yr $<10^{-3}$/yr	28 mrem 90 mrem
	Multiple targets, unmitigated	$<10^{-5}$/yr $<10^{-6}$/yr	600 mrem 1.8 rem
H_2 Deflagration	All	$<10^{-4}$/yr	Negligible
SCB Fire	Filtered release	$<10^{-5}$/yr	3.5 mrem
	Unmitigated release	$<10^{-8}$/yr	2 rem
Forklift Accident	All	$<10^{-3}$/yr	< 1 mrem
Room 109 Fire	All	Not assessed	0.1 mrem
Ventilation Failure	Target, SCB intact	<.01/yr	Negligible
	Simultaneous loss of power and in-process target	$<10^{-5}$/yr	No off-site dose; minor on-site containment
Radioactive Material Storage Area Fire	Unmitigated Release	<.01/yr	44 mrem
Design Basis Earthquake	Ventilation system operating, entire target source term released	$<10^{-8}$/yr	192 mrem

(a)



(b)

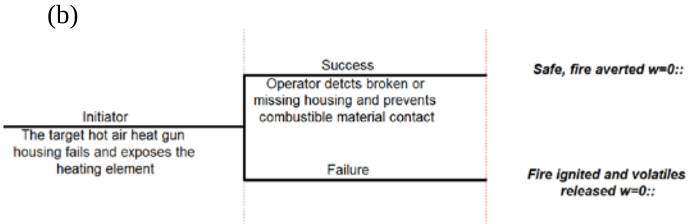


Fig. 1. Event tree analyses for a steel confinement box (SCB) in HCF SAR [2].

In Table 3, maximum consequences of the DBAs are steel confinement box (SCB) fire and process spill of 2 rem and 1.8 rem, respectively, with likelihoods of below 10^{-8}/yr and 10^{-6}/yr at the exclusion area boundary (EAB) of 3,000 m. These likelihood ranges are assigned to a frequency category of extremely unlikely.

4. Conclusion

The DBAs and BDBAs selected in HCF were reviewed for a purpose of safety analysis studies of pyroprocess. Each dose consequence and likelihood of the DBA was examined. In addition, each sequence of scenario was reviewed with event tree methodology. This information could be utilized for performing safety analysis of pyroprocess.

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