An Establishment of a Calculation Framework For the Operational Safety Assessment of KRS - 11267

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ABSTRACT

In this study, we established the methodology and a calculation framework for the safety assessment of a radioactive waste repository in South Korea. The most important factor in the construction and operation of a radioactive waste repository is to ensure safety and to protect the public and environment. The procedures required for safety assessment are an identification of initiating events, performance assessment of safety systems, an identification of accident scenarios, an exposure dose assessment for the workers and the public resulting from the release of radioactive material. In order to identify initiating events, we adopted a qualitative hazard identification method. We suggested a PSA (Probabilistic Safety Assessment) method to assess the performance of safety systems and to identify accident scenarios. We established methodologies for the exposure dose assessment by selecting exposure pathways and establishing methodologies for the estimation of exposure doses for each pathway. Then we established a SSAT (Systematic Safety Analysis Tool) for the operational safety assessment of the disposal facilities for radioactive waste. This systematic safety analysis tool will enable a safety analysis of a potential interim spent nuclear fuel storage facility. The systematic safety analysis tool provides an integrated framework that streamlines the propagation of design modifications and alternatives into the safety analysis. For the event tree and fault tree analysis in the systematic safety analysis tool, the AIMS-PSA (Advanced Information Management System for Probabilistic Safety Assessment) Manager and the sub-modules CONPAS (CONtainment Performance Analysis System) and KwTree (KIRAP window Tree) will be used. The RSAC (Radiological Safety Analysis Computer) program will be used in the estimation of exposure doses. We made sample calculation for the drop accident at the surface facilities of the KRS (Korean Reference disposal System) in order to check the applicability of the operational safety assessment framework. This paper focuses on the development of the event tree and fault tree analysis module and the identification of the applicability of the CONPAS and KwTree. The methodologies and the tool for the operational safety assessment of a radioactive waste repository established in this study will be used in the design modification as well as the safety assessment.

Key words: KRS, Operational safety assessment, Probabilistic safety assessment, Exposure dose, CONPAS, KwTree, RSAC

INTRODUCTION

The most important factor in the construction and operation of a radioactive waste repository is to ensure safety and to protect the public and the environment. The safety assessment for a radioactive waste repository is divided into pre-closure and post-closure periods. Thus, the safety assessment is also divided into an operational safety assessment for the pre-closure period and safety assessment for the post-closure period.

The PSA (Probabilistic Safety Assessment) methodology has been studying for the development of a tool and establishment of reliability data, etc. since it is used as a tool to assess the safety for a nuclear power plant (NPP). The PSA methodology is used as a tool to analyze safety not only for the safety assessment of NPP, but also for the radioactive waste repository, the spent fuel storage facility or other industry fields. Therefore, we chose the PSA methodology to perform the operational safety assessment for a radioactive

waste repository [1]. Generally, PSA procedures consist of 1) collection of information, 2) selection of initiating events, 3) analysis of event tree, 4) analysis of fault tree, and 5) consequence analysis.
In this study, we constructed a framework for an operational safety assessment of a radioactive waste repository by establishing an analysis procedure and by choosing a necessary tool and reviewed the applicability of the established framework through a sample calculation for a drop accident at the surface facilities of the KRS (Korean Reference disposal System) which is now being developed as a repository for the disposal of high level radioactive waste in Korea [2].

OPERATIONAL SAFETY ASSESSMENT FRAMEWORK CONSTRUCTION

Fig. 1 shows the framework of a PSA tool for the operational safety assessment of KRS including the applicable fields of the safety assessment results. As shown in Fig. 1, the establishment frame of a PSA tool includes the collection of information and development of a PSA tool module. In the stage of information collection, it is necessary to obtain the site information, facility design and operation material, and spent fuel characteristic data planned to be stored for the safety assessment. These data will be constructed as database by referring to the reference sites and reference facilities and used as base data for fault tree and event tree analysis and dose evaluation.

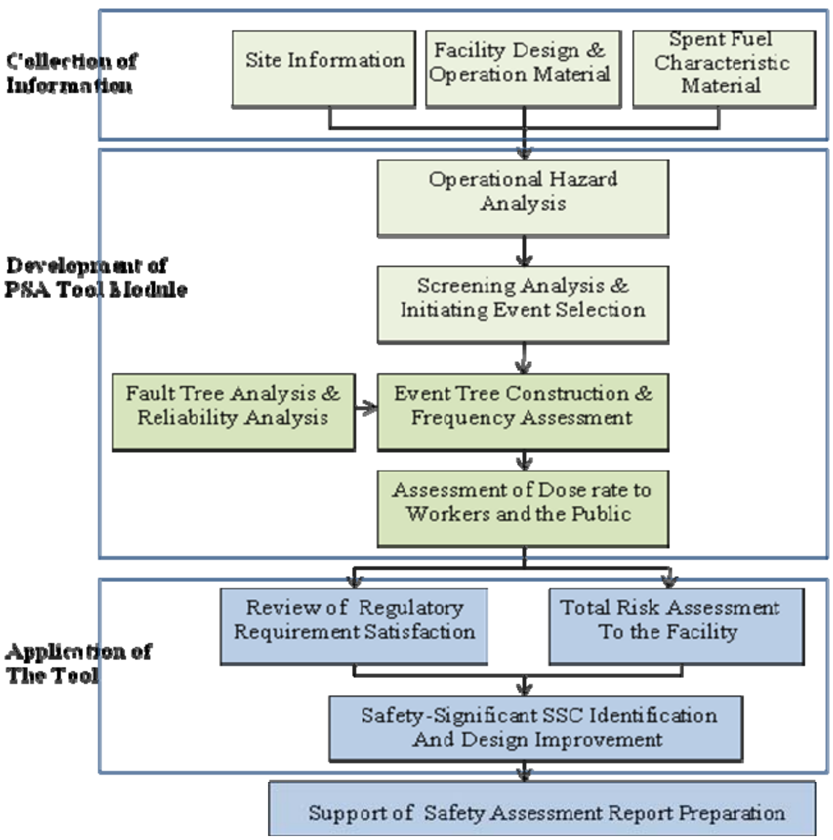

Fig. 1. Main frame of PSA tool development

The steps of operational safety assessment are established based on a review of the safety assessment procedures and methodologies which are used in other industries including a nuclear power plant. The constructed procedure follows:

1. Selection of initiating events: the risk analysis being able to occur during operation, and the risk analysis due to environment and human error
2. Event tree and fault tree analysis: Construction of an accident scenario through ETA methodology and estimation of failure probability by FTA
3. Safety assessment: the risk analysis and exposure dose analysis for workers and the public

Operational hazard analysis is the module for the selection of initiating events being able to occur during operation of KRS. The initiating event is defined as the event that can induce the collapse of the normal state and can create radioactive exposure to the workers and the public.
Usually, the initiating events for a nuclear power plant PSA are selected based on the various experiences. However, the initiating events are not common to PSA for a radioactive waste repository and they should be selected by considering the specificity of the site and facility and by applying the appropriate screening criteria. For selection of initiating event, what-if Procedures, FMEA (Failure Mode and Effect Analysis) or HAZOP (HAZard and Operability) methodology will be used.

We chose the ETA (Event Tree Analysis) methodology for an accident scenario analysis. In the event tree analysis step, accident scenarios are developed and the frequencies of each accident scenario that consequently induce release of radioactive material by considering the operability of safety systems to mitigate the accident after occurrence of an initiating event. FTA is used for the probability estimation for a mitigating system. CONPAS (CONtainment Performance Analysis System) was selected as a tool for ETA. CONPAS is included within AIMS-PSA (Advanced Information Management System for PSA) manager developed for the safety assessment of nuclear power plant by KAERI (Korea Atomic Energy Research Institute) [3]. FTA is applied to the failure probability evaluation of the system in the event tree. KwTree is selected as a tool for FTA. KwTree (KIRAP window Tree) is also included in the AIMS PSA Manager.

Consequence analysis is the module to estimate the dose for all of accident scenarios inducing release of radioactive material. Exposure dose evaluation is planned to be estimated by using the appropriate exposure dose path and dose factor for outdoor workers and the public respectively. The result of consequence analysis will be provided with mean value and confidence interval for the probabilistic analysis. In addition, CCDF (Complementary Cumulative Distribution Function) form will be provided for convenience and application of the result analysis.
There are many programs for exposure dose analysis. Thus, we can choose a program appropriate for the purpose. In this study, RSAC (Radiological Safety Analysis) Program [4] is selected as a dose evaluation tool.
Figure 2 shows the main screen for each program which we chose, respectively.

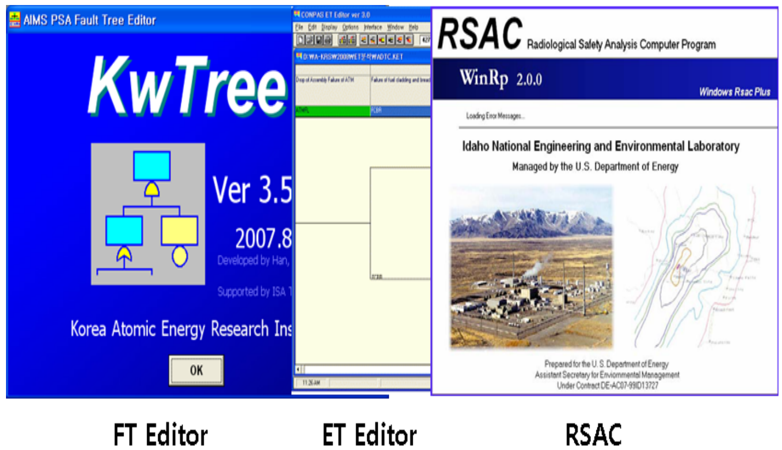

Fig. 2 Computational framework for the operational safety assessment

EXAMPLE ANAYSIS: AN ACCIDENT SCENARIO ANALYSIS AT A SURFACE FACILITY OF THE KRS

We performed safety assessment for an accident scenario at a surface facility of the KRS to review the applicability of the constructed operational safety assessment framework.

Description of an Accident Scenario at a Surface Facility of the KRS

For performing the ETA and the FTA for a surface facility of a radioactive waste repository, we assumed an accident occurred when a crane being used to transport spent fuel dropped it at a surface facility. The considered accident is a case according to the integrity of HVAC (Heating, Ventilation and Air Conditioning) system and HEPA (High Efficiency Particulate Air) filter system after radioactive materials are released due to the damage of spent fuel cladding by the drop.

Failure Probability Used and Assumptions

The failure probability data and the number of transportation used in the accident scenario frequency analysis are as follows:

- Drop rate of crane: 5.6e-5 drops/lift (Assumed value based on NUREG-1774) [5]
- The number of spent fuel assembly transported for a year: 12000/yr (assumed)
- Crane damage probability: 5.65drops/lift * 12,000 lift/year = 0.672 drops/year
- Spent fuel cladding damage probability: 1 (assumed)

Conservatively, if the drop is occurred, it is assumed that the spent fuel cladding is breached.

Event Tree Analysis

The assumed accident scenario in this paper is shown in Fig 3.
The description of each scenario is as follows;

- The state of accident sequence 1 is OK because the spent fuel cladding is intact.
- The accident sequence 2 is that the spent fuel cladding is breached, and the HVAC system and HEPA filter succeed, but noble gas is released.
- The accident sequence 3 is that the spent fuel cladding is breached, and the HVAC system succeeds but the outdoor workers and the public are exposed to noble gas and radioactive material particles since HEPA the filter system fails.
- The accident sequence 4 is that the spent fuel cladding is breached, and the HVAC system fails. Therefore, noble gas and radioactive material particle are released to indoor workers.
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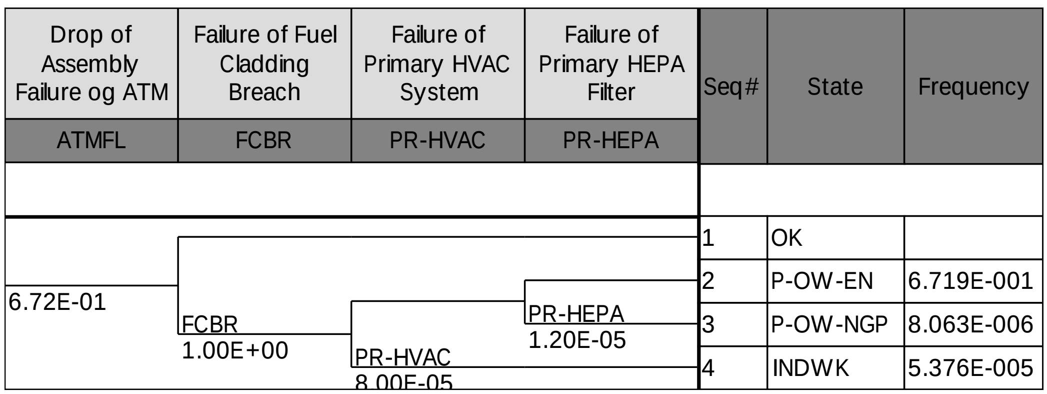

Fig. 3. Accident scenarios for a drop accident

Fault Tree Analysis

For FTA, we assumed that the HVAC system consists of a normal exhaust fan and a redundant exhaust fan, and the HEPA filter consists of two filters, A and B.
The system failure probabilities for the HVAC system HEPA filter system for mitigation of a drop accident are evaluated through the FTA. The failure probability of HVAC system and HEPA filter system is 8.1×10^{-5} and 1.2×10^{-5}, respectively. The data for the FTA were obtained from the references [5, 6].
Fig 4 shows the fault tree for HVAC system and HEPA filter, respectively.

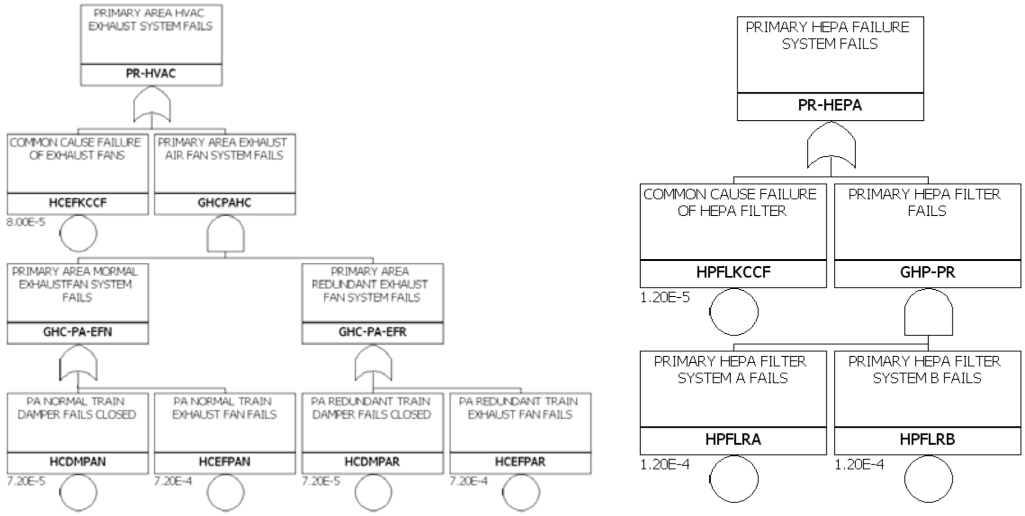

Fig. 4. Fault Tree for Primary HVAC System and HEPA Filter System

Consequence Analysis

We used a core inventory for base spent fuel of PWR plant to estimate the exposure dose. The assumed repository site for the estimation of exposure doses is Wolsong in South Korea. The used annual average wind speed is 2.87 m/sec. This speed estimated is based on the meteorological data at the Wolsong area for a year. To obtain conservative results we assumed the release occurred at one meter above the ground. We did not consider precipitation by rainfall. Also, atmospheric stability class was assumed to be neutral, and plume rise is not considered in order to obtain conservative results. The deposition velocity was assumed to be 0.01 m/sec for halogen elements such as iodine and 0.001 m/sec for other elements, and no deposition was assumed to occur for the noble gases. The average breathing rate was assumed to be 3.34×10^{-4} m^3/sec for the estimation of inhalation dose. The dose coefficients for the estimation of exposure doses for each pathway were the values derived from the default values in the RSAC program.
The exposure dose estimation result for the accident scenario 3 is summarized in Table 1.

Table 1. Exposure dose as a function of distance

Exposure dose distance (m)	Internal exposure (Sv)	External exposure (Sv)	Total (Sv)
200	1.04E-03	5.40E-07	1.04E-03
300	5.09E-04	2.64E-07	5.09E-04
500	2.09E-04	1.08E-07	2.09E-04
700	1.16E-04	6.04E-08	1.17E-04
1,000	6.29E-05	3.27E-08	6.29E-05
2,000	1.99E-05	1.04E-08	1.99E-05

CONCLUSION

We established a methodology to assess the safety for the spent fuel repository facility and constructed a PSA tool framework to evaluate the risk systematically. Then we constructed an event tree for a spent fuel drop accident due to crane failure and analyzed the accident scenario to review the applicability of the constructed framework for operational safety assessment. We can find the existence of potential risk factors during the construction or operation of a facility through an operational safety assessment. Also we can remove the risk factors and suggest or decide an action to protect the public or environment. In case that the result of exposure dose to the workers and the public do not meet regulatory or performance criteria, we can derive the design improvement items by performing importance analysis with the safety assessment result. Therefore, the accident scenario analysis through ETA and FTA methodology can be applied to the safety assessment for a spent fuel repository facility and also used as a method for deriving design improvement items. However, it is recommended that the reliability database must be developed for more reliable estimations of the operational safety of a radioactive waste repository.

ACKNOWLEDGEMENT

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