The Methodology on Exposure Dose Evaluation Modeling Related to Arbitrary Accident in the Temporary Storage Facility for Low and Intermediate Level Waste - 9133

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ABSTRACT

For the establishment of arbitrary accident scenarios in temporary storage facility for LILW, the initiating event was derived by master logic diagram (MLD) method based on the fault tree analysis (FTA), and then arbitrary accident scenarios were developed by the event tree analysis (ETA) through the derived initiating events. The main initiating events led to the arbitrary operational accident, which is the dropping of a drum and fire, were derived from MLD method. The exposure effects resulted from release of radioactive materials related to arbitrary accident in the temporary storage facility for LILW can be divided with the internal exposure caused by breathing and external exposure by radioactive lump. The 14 radionuclides for internal and external exposure dose evaluation were considered: ^{3}H, ^{14}C, ^{55}Fe, ^{58}Co, ^{60}Co, ^{59}Ni, ^{63}Ni, ^{90}Sr, ^{94}Nb, ^{99}Tc, ^{129}I, ^{137}Cs, ^{144}Ce, and Gross α. According to the U.S. NRC regulatory guide 1.145, the atmospheric relative concentrations (χ/Q) were derived by meteorological data measured in NPP site: wind speed, wind direction, and a measure of atmospheric stability. For the evaluation of internal exposure, the breathing rate (m^3/sec) described in U.S. NRC regulatory guide 1.8 was considered. Consequently, the internal exposure dose by breathing can be derived by the combination with the following elements: the atmospheric relative concentrations, release amounts of each radionuclide due to the arbitrary accident in temporary storage facility, breathing rate and dose conversion factor by breathing. Similarly, the exposure dose by radioactive lump can also be calculated by the contents considered in the internal exposure dose evaluation except for the element of the breathing rate.

INTRODUCTION

In Korea, the low and intermediate level wastes (LILW) generated from the operation of NPPs have been gradually increased since 1977 because of the absence of the repository for the disposal of LILW [1]. And then, the LILW has being stored in the temporary storage facility at each reactor sites. Fortunately, in 2005, the Gyeongju city was selected by the resident's vote in four competitive provinces for the LILW disposal facility. The repository for the disposal of LILW will be operated in end of 2009.

In opposition to many of researches on the disposal of LILW, however, the risk assessment on the temporary storage facility has scarcely been conducted. Furthermore, the details in regards of the safety analysis on this facility have not been considered in the preliminary and final safety analysis report because this report focused on the nuclear reactor system rather than this facility. As a consequence of these situations, the number of the researches on the arbitrary accidents occurring in the temporary storage facility has not been enough.

The objective of this study is to establish the modeling method when the exposure dose for workers and public with regard to the temporary storage facility of LILW is evaluated.

For the establishment of arbitrary accident scenarios in temporary storage facility for LILW, the initiating event was derived by master logic diagram (MLD) method based on the fault tree analysis (FTA), and then arbitrary accident scenarios were developed by the event tree analysis (ETA) through the derived initiating events. The main initiating events led to the arbitrary operational accident, which is the dropping of a drum and fire, were derived from MLD method. The exposure effects resulted from release of radioactive materials related to arbitrary accident in the temporary storage facility for LILW can be divided with the internal exposure caused by breathing and external exposure by radioactive lump. The 14 radionuclides for internal and external exposure dose evaluation were considered: ^{3}H, ^{14}C, ^{55}Fe, ^{58}Co, ^{60}Co, ^{59}Ni, ^{63}Ni, ^{90}Sr, ^{94}Nb, ^{99}Tc, ^{129}I, ^{137}Cs, ^{144}Ce, and Gross α. According to the U.S. NRC regulatory guide 1.145, the atmospheric relative concentrations (χ/Q) were derived by meteorological data measured in NPP site: wind speed, wind direction, and a measure of atmospheric stability. For the evaluation of internal exposure, the breathing rate (m^3/sec) described in U.S. NRC regulatory guide 1.8 was considered.

MASTER LOGIC DIAGRAM

The Master Logic Diagram (MLD) is a basic method identifying the initiating event. This method is based on the FTA but without the formal mathematical properties [2]. Furthermore, the FTA is expressed in logical symbols with regard to all cases in which the experimental targets cannot be used anymore. Once the system failure was defined by top event in fault tree, a variety of pathways related to system failure can be deductively pursued. The fault tree has the advantage of being able to direct the analysis to ferret out failures, allowing the analyst to concentrate on one particular system failure at a time, and to provide an insight into system behavior [3].
In this study the initiating events needed for risk-based accident scenarios were deductively derived by the MLD method based on the FTA. In order to develop the initiating events, three accident branches were considered: failure when moving radioactive waste drums to transfer system (vehicles), failure when transferring the drums to temporary storage facility, and failure when lifting and managing the drums at temporary storage facility. Each accident branch is further divided into three kinds of failure conditions: failure induced by mechanical conditions, failure induced by thermal conditions, and failure induced by both mechanical and thermal conditions (Fig. 1-4).
A variety of factors based on the comparative review of documents related to the management of the LILW in the temporary storage facility, including the site drawing regarding the temporary storage facility, and of similar research conducted in other countries, were considered in order to select the initiating events in this study.

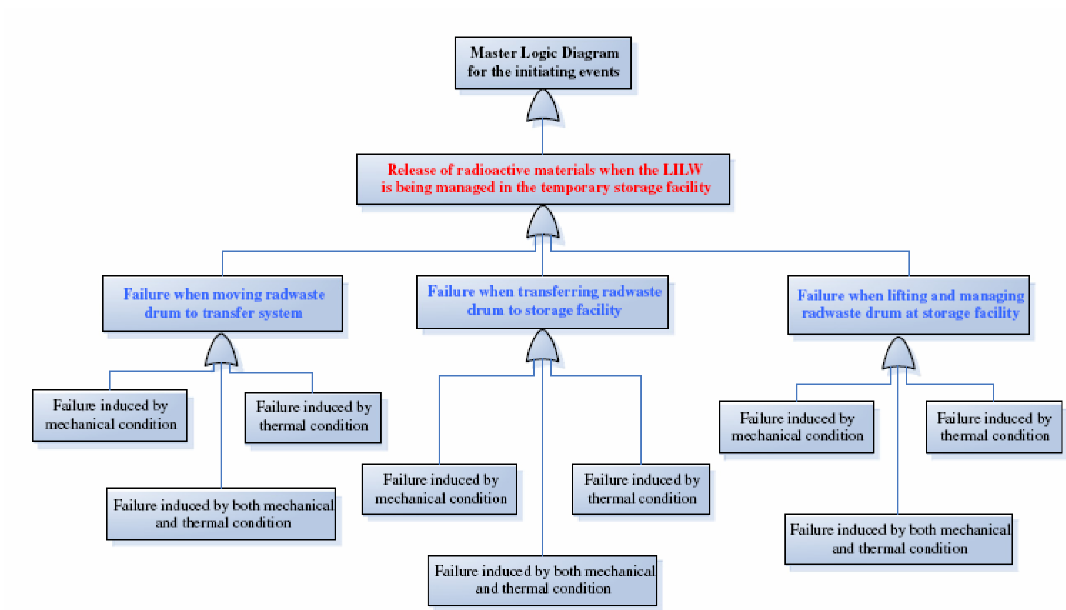

Fig. 1. Master logic diagram for selecting the initiating events

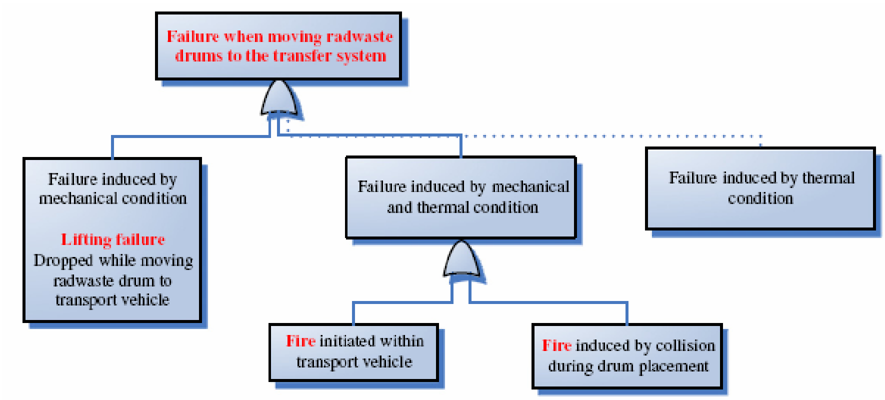

Fig. 2. Failure when moving radwaste drums to the transfer system

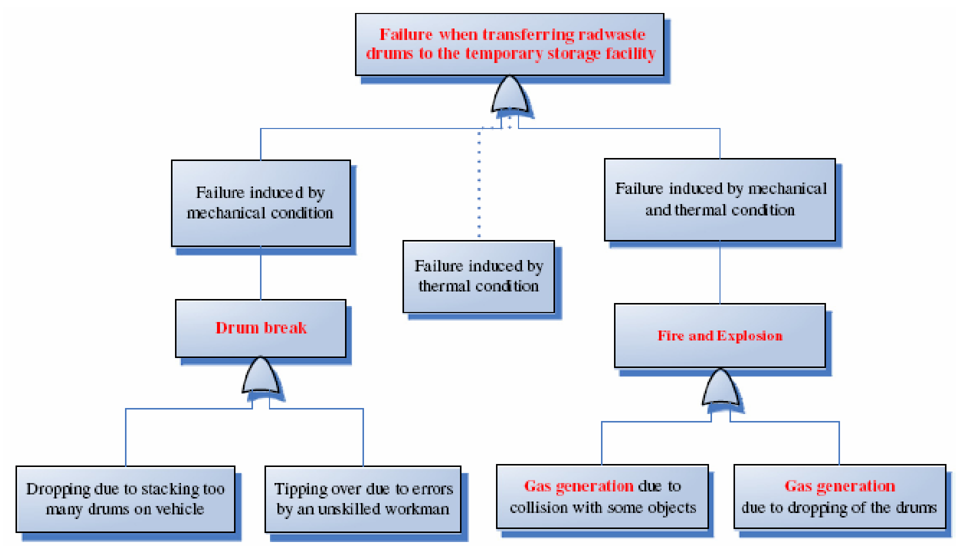

Fig. 3. Failure when transferring radwaste drums to the temporary storage facility

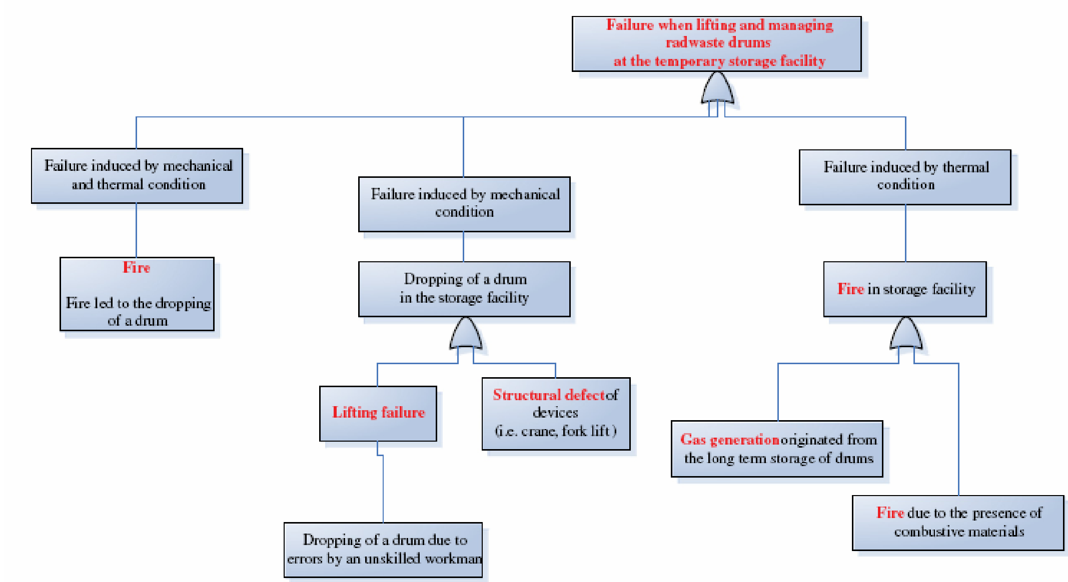

Fig. 4 Failure when lifting and managing radwaste drums to the temporary storage facility

ESTABLISHMENT OF THE INITIATING EVENT

The risk-based accident scenarios concerned to LILW management in the temporary storage facility could be readily derived by the ETA method. However, it could be taken over a long period of time and a great deal of to make whole event tree with regard to all of initiating events considered in this study. According to this reason, all initiating events developed by the MLD could be eliminated by a filtering process if they are out of research scope, and could be grouped by a common event in case that they consist of duplicated events.

The main initiating events led to arbitrary operational accidents, the dropping of a drum and fire were derived from the MLD. Table 1 shows the initiating events that will be used by the heading event of the ETA for final risk-based accident scenarios. The initiating event with regard to the drop of drum is expressed with the lifting failure and worker's error due to piling too many drums on vehicle and errors caused by an unskilled workman. Then, the initiating event of fire is represented in both the gas generation due to the dropping of a drum and collision with some objects and fire initiated the within transport vehicle or the presence of combustive materials in the temporary storage facility.

Table 1. List of the initiating events used in the event tree analysis

<table>
<tr><th colspan="2">Drop</th><th colspan="2">Fire</th></tr>
<tr><th>Lifting failure</th><th>Worker's error</th><th>Gas generation</th><th>Fire</th></tr>
<tr><td colspan="2">- Tipping over due to errors caused by an unskilled workman
- Dropping due to stacking too many drums on the vehicle
- lifting failure due to the mechanical defects</td><td>- Gas generation due to the dropping of drums and collision with some objects
- Gas generation by the long term storage of drums</td><td>- Fire initiated within the transport vehicle
- Fire due to the presence of combustive materials</td></tr>
</table>

METHODOLOGY FOR THE EXPOSURE DOSE MEDING

The main initiating events led to the arbitrary operational accident, which is the dropping of a drum and fire, were derived from MLD method. The exposure effects resulted from release of radioactive materials related to arbitrary accident in the temporary storage facility for LILW can be divided with the external exposure by radioactive lump and internal exposure caused by breathing. The equation (1) for the external exposure dose by radioactive lump consisted of following parameters: dose conversion factor in respect of each radionuclide, atmospheric relative concentration (χ/Q), the release amount of each radionuclide, and constant. And then, the equation (2) for the internal exposure dose by breathing was also constituted by similar contents used in the equation (1), except for considering the breathing rate (m^3/sec) [4].

$$DP = \sum_i \left(\frac{1}{3600}\right)\left(\frac{\chi}{Q}\right)_i fQ_i DFP_i \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (1)$$

$$DH = \sum_i \left(\frac{\chi}{Q}\right)_i fQ_i Br_i DFH_i \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad (2)$$

Where

- DP = external exposure dose (mSv)
- i = radionuclides; j = release time
- $\frac{\chi}{Q}$ = relative air concentration (sec/m^3)
- Q_i = the amount of release with respect to each radionuclide (Bq)
- DFP_i = dose conversion factor for the external exposure (mSv/hr per Bq/m^3)
- DH = internal exposure dose (mSv)
- Br_i = breathing rate (m^3/sec)
- DFH_i = dose conversion factor for the internal exposure (mSv/Bq)

The 13 radionuclides and gross α were considered for the source term with respect to the internal and external exposure dose evaluation: ^{3}H, ^{14}C, ^{55}Fe, ^{58}Co, ^{60}Co, ^{59}Ni, ^{63}Ni, ^{90}Sr, ^{94}Nb, ^{99}Tc, ^{129}I, ^{137}Cs, ^{144}Ce, and Gross α. Furthermore, according to the U.S.NRC regulatory guide 1.145, the atmospheric relative concentrations (χ/Q) were derived by meteorological data measured in NPP site: wind speed, wind direction, and a measure of atmospheric stability. For the evaluation of internal exposure, the breathing rate (m^3/sec) described in U.S.NRC regulatory guide 1.8 was considered.

CONCLUSION

The initiating event analysis was used to identify the full spectrum of potential risk related to LILW management in the temporary storage facility. Furthermore, the initiating events needed for the risk-based accident scenarios were deductively derived by the MLD method based on the FTA. Then, the risk-based accident scenarios were developed by the ETA method through the derived initiating events.

In this study three accident branches were considered to develop the initiating events. One of them is the failure when moving radioactive waste drums to the transfer system. Another branch is the failure when transferring radwaste drums to the temporary storage facility. The third branch is the failure when lifting and managing radwaste drums at the temporary storage facility. Each of these accident branches is also divided with three kinds of failure conditions: failure induced by mechanical conditions, failure induced by thermal conditions, and failure induced by both mechanical and thermal conditions.

The main initiating events led to arbitrary operational accidents, the dropping of a drum and fire were derived from the MLD method. The initiating event with regard to the drop of drum is expressed with the lifting failure and worker's error due to stacking too many drums on the vehicle and errors caused by an unskilled workman. Then, the initiating event related to fire is represented in both the gas generation owing to the dropping of a drum and collision with some objects and the fire initiated within transport vehicle or the presence of combustive materials in the storage facility.

The exposure effects resulted from release of radioactive materials related to arbitrary accident in the temporary storage facility for LILW can be divided with the internal exposure caused by breathing and external exposure by radioactive lump. The 13 radionuclides for internal and external exposure dose evaluation were considered. According to the U.S. NRC regulatory guide 1.145, the atmospheric relative concentrations (χ/Q) were derived by meteorological data measured in NPP site. For the evaluation of internal exposure, the breathing rate (m^3/sec) described in U.S. NRC regulatory guide 1.8 was considered. Consequently, the internal exposure dose by breathing can be derived by the combination with the following elements: the atmospheric relative concentrations, release amounts of each radionuclide due to the arbitrary accident in temporary storage facility, breathing rate and dose conversion factor by breathing. Similarly, the exposure dose by radioactive lump can also be calculated by the contents considered in the internal exposure dose evaluation except for the element of the breathing rate.

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