Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 19-20, 2022

Quantitative Risk Assessment Study for KAERI Accidentally Gained Nuclear Material

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1. Introduction

KAERI has an obligation to ensure that IAEA Safeguards are applied to ensure that all nuclear material is not diverted for non-peaceful purposes. Because old research rooms and laboratories have been using nuclear materials since there was no concept of safeguards, they were discovered late and reported as “Accidental Gain” of IAEA safeguards. In terms of Safeguards, Accidental Gain is one of the factors that reduce reliability. If we apply this study to KAERI, to which I belong, I think that it can be a way to increase the reliability of safeguards by evaluating the level of risk for each building and increasing the frequency of self-inspection for buildings with higher risk. For the issue of accidental gained nuclear material that requires voluntary and systematic safety management, we established process risk recognition, risk assessment, and risk reduction measures through quantitative risk assessment (QRA), just like overseas chemical plants. It should be possible to calculate a reasonable quantitative risk and determine the level of risk acceptance to enable emergency response planning and effective accident prevention.

2. Quantitative Risk Assessment

2.1 Definition of Quantitative Risk Assessment

Risk has a problem that may cause confusion because the use of the term varies between publications. It is generally defined as “a measure of economic loss or loss of life in terms of the likelihood of an accident and the degree of loss or injury”, although other definitions may be used occasionally. It also includes several definitions of risk.

○ Risk is the combination of uncertainty and harm.

○ Hazard refers to the ratio of Hazards to Safeguards.

○ Risk refers to the three components of an event, probability, and damage result.

In addition, although accidents can be defined in various ways, they can be defined as “loss of energy or contained substances” and the consequences of accidents can be defined as “physical indications of accidents”.

Quantitative risk assessment (QRA) can be defined based on this definition as “a method of quantifying the probability and loss of an accident as a measure of economic loss or personal injury in order to quantitatively analyze the combined risk of uncertainty and damage”.

2.2 Purpose of Quantitative Risk Assessment

○ Assessment of the scope of risk reduction measures : The major causes of risk are identified and prioritized. A range of risk reduction measures are then given for the main causes and the relative benefits are evaluated. Setting a risk goal considers risk-reducing measures that will not only meet the goal, but also exceed it, if cost permits.

○ Prioritize safety investments : All organizations have limited resources. You can use CPQRA to rank your risks and focus your safety management costs on the most risky sectors.

○ Assessment of financial risk : Even when there is no risk of personal injury, CPQRA is used to evaluate the possibility of financial loss or business interruption, and is typically used to calculate workplace insurance.

○ Risk assessment for residents : As with worker risk, resident risk standards have been proposed or adopted as “acceptable risk” levels. CPQRA can be used to verify compliance. If such criteria are not met, risk reduction measures may be investigated as discussed above. The main causes of risk to residents outside the workplace are major accidents and catastrophic accidents.

○ Compliance with legal or regulatory requirements : Laws in force in Europe, Australia and some states in the United States (eg NJ and CA) also require a CPQRA. Emphasis is placed on specific resident risks and emergency response plans, although regulations vary.

○ Support for emergency response plans : CPQRA can be used to estimate the sphere of influence to be used in an emergency response plan. If the emergency response plan includes field personnel, all incident classes should be considered. In the case of dwellings, the major and hazard class accidents are emphasized.

2.3 Procedures and Methods for Conducting Quantitative Risk Assessment

Quantitative risk assessment is generally [Fig. 1] as the procedure shown.

2.3.1 Method of conducting quantitative risk assessment

1) Hazard identification

Hazard identification is a qualitative risk assessment and is a method of identifying and analyzing potential risks in the process. The goal of risk factor analysis during quantitative risk assessment is to develop scenarios through the following methods and to discover the most beneficial accident scenarios among them. In the risk factor analysis, not all risks can be identified and not all risks can be eliminated. At this time, the development of the accident scenario requires skill, experience, and considerable knowledge about the process. In other words, it should be possible to explain what is wrong with the process, the state of the released hazardous substances (solid, liquid, vapor, etc.), and the release mechanism (ruptured pipe, hole in the storage container, etc.).

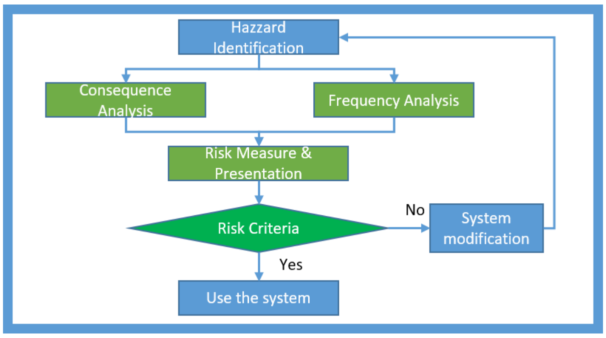

Fig. 1. Quantitative risk assessment process

2) Consequence analysis (CA)

Modeling the leakage and diffusion of hazardous and hazardous chemicals due to accidents is an important part of process risk management.

Various technical problems related to the assessment of the diffusion of hazardous and hazardous chemicals were developed according to the need to develop many analytical procedures and techniques.

Modeling in CA is the calculation of numerical values (or representations of these figures) that describe reliable physical outcomes associated with the loss of containment, including flammable, explosive and toxic substances, with respect to their potential impact on persons, assets, or safety functions, or presumption, the consequences of an accident due to loss of containment are as follows.

- ○ Leaks
- ○ diffusion of air and water
- ○ Fire and heat radiation
- ○ Explosion
- ○ Smoke and gas penetration
- ○ Toxic

In general, leakage results, weather conditions, and topography are big variables in determining whether the CA evaluation is optimal or not. First, the data required for diffusion modeling include leak data, which include physical and chemical characteristics of the leaked material, the geometry of the leak location, process safety devices, time variation, and surface characteristics. The physical and chemical characteristics of the leaking material require dispersibility, conductivity, boiling point, etc. of the material, and in the case of a mixture, characteristics of each component are required. The geometric shape of the leak location includes the size of the leak source such as a pipe or tank, and whether a safety valve or rupture disk is installed as a safety device in the process acts as a factor in the diffusion model. Time variation is an item that must be considered in diffusion modeling because the time after leakage has a large effect on the damage environment to the human body.

Second, as meteorological data, wind speed, temperature, relative humidity, and atmospheric stability at the facility affect diffusion. In addition, the size of tanks, equipment, and operation information should be considered in the diffusion model.

3. Conclusions

In chemical plants, risk assessment (CPQRA) is used to evaluate process risks and perceived risks, determine risks, and establish and implement risk reduction measures. However, in the field of nuclear safeguards, quantitative risk assessment methods are not applied to accidentally gain nuclear material. Therefore, in this study, we tried to analyze the current situation of quantitative risk assessment at home and abroad for the introduction of CPQRA in the field of domestic nuclear safeguards, and to suggest a way to introduce it.

Theoretically, in order to perform QRA, it is necessary to calculate a reasonable damage effect through Consequence Analysis (CA) and to obtain a frequency value through Frequency Analysis (FA). In the meantime, there has been a lot of experience and development in the domestic chemical process CA field, but in order to perform FA, the frequency value must be accurately obtained using FTA (Fault Tree Analysis). I thought. Therefore, CPQRA has hardly been performed in Korea. In the general field, due to the lack of reliability of the necessary data, FA was performed through ETA with little use, and personal and social risks resulting from QRA were saved. Therefore, in this study, by using the analysis results of these domestic cases, frequency analysis was performed through the ETA method without FTA, and it was possible to present a CPQRA standard that can obtain individual risk (IR) and social risk (SR).

In order to establish a risk criterion suitable for the domestic nuclear safeguards situation, additional research considering the results of the overseas risk criterion analysis performed this time and the domestic conditions is needed.

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