Review of Issues Regarding Cs-137-related Safety Goal

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1. Introduction

The question "How safe is safe enough?" has been raised since the start of nuclear power plant (NPP) operations in the 1950s, and the NRC introduced the concept of safety goals in the mid-1980s as a way to address this issue [1]. The safety goals are criteria for judging whether the residual risk remaining after reducing the inherent risk of NPPs through various methods such as the defense-in-depth and the safety margin is low enough for society to accept. These NRC's safety goals have since become the basis for the IAEA and other nuclear power states to establish their own nuclear safety goals [2].

However, after the Fukushima nuclear accident, several countries adopted a new safety goal requiring that the frequency of accidents involving the release of more than 100 TBq of cesium (Cs)-137 should be less than 1.0E-6 per year to protect the environment. This safety goal was introduced in Korea in 2016, as was the 0.1% rule of the NRC. However, the safety goal regarding Cs-137 has several issues in implementation. This paper reviews these issues.

2. Review of the Technical Basis of Safety Goals

In 1986, the NRC proposed the 0.1% rule as safety goals for NPPs [1]. The U.S. safety goals require that the additional risk imposed on society by the operation of a new NPP should not exceed one-tenth of one percent (0.1 percent) of the total risk resulting from other factors to which members of the U.S. population are generally exposed.

In other words, the additional risk of prompt fatality for individuals in the vicinity of an NPP (in the U.S., within 1.6 kilometers of the plant) due to the introduction of a new NPP into society should be less than 1 in 1,000 of the total risk of early fatality that those individuals already face from many other factors. In addition, the increased risk of cancer death for people living near the plant must be less than to 1 in 1,000 of the total risk of cancer death in the U.S. In the U.S., if an NPP meets these safety goals, it is considered to have an acceptable level of risk to society. Because it is not easy to determine whether a particular plant has met the 0.1% rule, the following safety objectives have been established in conjunction with the Probabilistic Safety Assessment (PSA):

(1) Core Damage Frequency (CDF) < 1.0E-4/year
(2) Large Early Release Frequency (LERF) < 1.0E-5/year

These U.S. safety goals have since become the basis for the IAEA and other nuclear power states to establish their own nuclear safety goals [2]. In particular, the IAEA has proposed the following safety goals for new NPPs, which are more stringent than the NRC's safety objectives:

(1) CDF < 1.0E-5/year
(2) LERF < 1.0E-6/year

The Korean safety goals were introduced with the amendment of the Nuclear Safety Act in 2016 [3]. The same safety goal as the NRC's 0.1% rule was introduced, and a safety goal related to Cs-137, which is not present in the U.S., was also introduced. This goal requires that the total frequency of accidents with a release of more than 100 TBq of radionuclide Cs-137 should be less than 1.0E-6/year.

Although this goal was introduced as a safety goal to protect the environment, it is currently only adopted in a few countries worldwide, including Korea, Finland, and Canada. The Cs-137-related safety goal is directly or indirectly based on the Swedish government decision in 1985 regarding severe accident mitigation, i.e., "0.1 % of an 1800 MWt core", corresponding to a release of 100 TBq of Cs-137 [3]. However, the safety goal regarding Cs-137 has several issues in implementation. And we review these issues in next section.

3. Issues of Implementing Cs-137-related Safety Goal

This section examined issues related to Cs-137-related safety goal from three perspectives: consistency, assessment, and application.

3.1 Consistency

In other countries, CS-137-related safety goal is set based on large releases. On the other hand, the current safety goals in Korea have both LERF and Cs-137-related safety goal for large releases. The Cs-137-related safety goal is generally recognized as the more stringent one. In practice, the LERF safety goal has become meaningless in Korea.

Furthermore, the 100 TBq limit is intended to apply equally to all NPPs, regardless of their power output. In the Swedish study, it was specified as 0.1% or 100 TBq of Cs-137 in the core of an 1800 MWth NPP, but

subsequent studies in other countries have removed any reference to power size or percentage.

There is also the question of whether the Cs-137-related safety goal is an effective safety goal, as shown in Figure 1. In Figure 1, NPP A does not meet the Cs-137-related safety goal, but NPPs and C do. However, it is questionable whether it can be said that NPPs B and C are safer than NPP A.

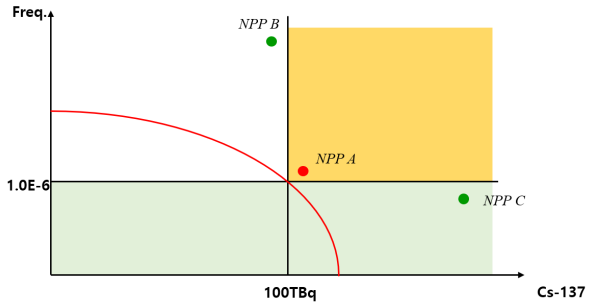

Fig.1 One of Issues of Cs-137 Related Safety Goal

3.2 Adequacy of the Assessment

We still do not have enough knowledges on severe accidents. Therefore, the assessment of Large Late Release Frequency (LLRF) is subject to much more significant uncertainty than that of LERF. This is one reason why the NRC uses LERF as a safety objective. The results of the LLRF are heavily influenced by the expert judgment related to the severe accident phenomena.

It is also necessary to check whether the current domestic Level 2 PSA models have adequate quality for the evaluation of Cs-137-related safety goal. Currently, there is no PSA standard endorsed by the NRC to confirm the PSA quality related to the estimation of the LLRF or LRF (Large Release Frequency).

The results of the internal event and external event PSAs should be combined to confirm the CDF and LERF safety goals. However, there is a debate on whether it is appropriate to mathematically combine the results of external event PSAs with considerable uncertainty, such as seismic PSA, compared to an internal event PSA. As described earlier, the evaluation of the Cs-137-related safety goal from the internal event PSA is also subject to very large uncertainties related to severe accident phenomena. Therefore, it is not clear how reliable the evaluation results of Cs-137-related sequences resulting from the external PSAs are. In consideration of this aspect, Japan utilities present the evaluation results regarding Cs-137-related safety goal from each PSA but does not combine them.

3.3 Issues related to Application

Nevertheless, Cs-137-related safety goal is not a major problem overseas because other countries except Korea and Japan only require that Cs-137-related safety goal be met for new NPPs. Moreover, even Finland, the originator of the Cs-137 safety goal, has made it clear that the goal is a recommendation, not a regulatory requirement.

There is also no guidance on what to do if a safety goal is unmet. For example, the NRC set a threshold of $1,000 per person-rem for follow-up to meet the safety goal [5]. This guideline is intended to encourage the efficient allocation of resources in safety-related activities by providing that the expected reduction in public risk that would be achieved should be commensurate with the costs of the proposed safety improvements.

4. Conclusions

Safety goals are essential as a basis for confirm the level of the residual risk of NPPs. However, there are several problems in implementing the Cs-137-related safety goal. Finland has recognized this and has made the following comments in their report [3]: “This unacceptable release is not necessarily large, and the definition includes no timing aspects, which makes the scope of the criterion very wide. Therefore, additional release criteria may be beneficial for the sake of efficient analysis and utilization of results.”

In this paper, we review some issues related to the Cs-137 safety goal. Currently, this goal has resulted in many issues in Korea. Therefore, further discussion on domestic Cs-137 safety goals is required to setup a reasonable safety goals, considering the following factors:

(1) The definition of Cs-137-related safety goal,
(2) The framework of assessing Cs-137-related safety goal,
(3) Application scope of Cs-137 related safety goal, and
(4) Guidelines for the cases that Cs-137 related safety goal is not met.

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