Comparison of Frequency-Consequence (F-C) Curves or Criteria in Foreign Countries

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1. Introduction

For currently operating LWRs, surrogate objectives related to core damage frequency (CDF), and large early release frequency (LERF) or conditional containment failure probability (CCFP), have been developed and used as surrogates for the quantitative health objectives (QHOs) expressed in the NRC commission's 1986 Safety Goal Policy Statement. For new, non-LWR types of reactors, the quantitative values for CDF and LERF will be no longer applicable. Instead, a criterion that specifies limiting frequencies for a spectrum of consequences, from none to very severe, needs to be established. This can be denoted via a frequency-consequences (F-C) curve or F-C criteria. This paper summarized and analyzed the results of comparison of F-C curves or F-C criteria in foreign countries.

2. Comparison of F-C Criteria in Foreign Countries

Required data depending on the type of the F-C Curve are changed depending on the degree of consideration of the design and siting.
The consequence chosen by Farmer in 1967 was the amount of Iodine-131 released. The consequence measure did not require knowledge of the site. F-C curve developed by the USNRC for the selection of Licensing Basis Events uses the dose to individual at a specific distance from the site as a consequence measure. Only weather data or models are needed to calculate this consequence. The FN-curves in the Netherlands, U.K. and Swiss correspond to F-C, societal risk criteria which requires characteristic knowledge of the site and the plant.
The comparison of F-C criteria and QHOs in foreign countries is summarized as follows.

2.1 Frequency-Consequence (Dose)

United States of America(NRC)

In the NRC's Technical Neutral Framework, the F-C Curve relates the frequency of potential accidents to acceptable radiation doses around the site boundary from these accidents. It is based on, and derived from, current regulatory requirements in 10 CFR Part 20, 50 and 100. The F-C Curve proposed in Draft NUREG-1860, "Framework for development of a risk-informed, performance – based alternative to 10 CFR part 50" is shown as the line, #1 in Fig. 1.
The ANSI 51.1 specifies that the spectrum of normal operations and events is identified in accordance with their best-estimate frequency of occurrence and offsite radiological dose criterion and divided into 5 categories (Plant conditions). These criterion is based on 10 CFR 50 App. I and 10 CFR 100.

U.K.(HSE)

The targets for the total predicted frequencies of accidents on an individual facility, which could give doses to a person off the site are specified in the HSE document, "Numerical targets and legal limits in safety assessment principles for nuclear facilities – An explanatory note." This target sets BSL (Basic Safety limit) and BSO (Basic Safety Objective) on the frequencies for doses off the site within the specified bands. The F-C criteria of HSE is depicted in the line, #3 (BSO) and #4 (BSL) of Fig. 1.

IAEA

A quantitative safety goal is developed by dividing the allowable risk domain into series of regions that roughly correspond to the various plant conditions, i.e., normal operations, anticipated operation occurrences (AOO), accident conditions (AC) and severe plant conditions (SPC). AOO contains the consequences of events above a frequency of $\sim 10^{-2}$/yr. AO includes the consequences of accident sequences that fall into frequencies between 10^{-2}/yr and 10^{-6}/yr. Severe plant conditions are associated with the consequences of accident sequences with frequencies less than 10^{-6}/yr. The draft IAEA-TECDOC proposes example of possible consequences values based on the doses derived from IAEA-SS No. 115. Doses to the public are 1mSv for normal operations and 5mSv/yr for AOO, AC and SPC.

South Africa

LG-1037, Basic Licensing Requirements for Pebble Bed Modular Reactor stipulates specific radiation dose limits for categories of initiating event frequency. They are plotted in Fig. 2.

Japan(NSC)

The bases for nuclear (radiological) safety regulations in Japan represent the regulatory limit of public dose (1mSv/yr) for normal conditions. For abnormal and accidental conditions, dose limits for design basis accident ($\sim 10^{-2}$/yr) and site evaluation ($\sim 10^{-4}$/yr) for power reactors are 5mSv and 250mSv, respectively. Safety target is set by $\sim 10^{-6}$/yr for frequency with no cliff edge dose. They are represented in Fig. 2.

2.2 Frequency-Consequence (Number of fatalities)

FN curves are used in some European countries such as the Netherlands and the United Kingdom, for the purpose of societal risk management.

Netherlands

For each source of activity, the upper bound of acceptable individual level risk is 10^{-6}/yr, while the de minimis value is 10^{-8}. For all hazardous sources or activities, the maximum

acceptable level of risk is 10^{-5}/yr. Regarding societal risk, a curve relating the exceedance frequency of N or more fatalities to the number of fatalities is used at the plant level according to the risk management policy (Versteeg, 1992).

Swiss

The F-C curve proposed by the Swiss Ordinance (Buwal, 1991) consists of probability of exceedance per site per year, with the consequence being the aggregate measure of 9 parameters.

2.3 Case of pre-applications concerning F-C curves for U.S.A.

The dose limit for the frequency region (AOO) below ~10^{-2}/yr for PBMR (South Africa) pre-application was 2.5Rem (i.e. 10% of 10 CFR 100) same to that of PC-3 of ANSI 51.1 as depicted in Fig. 3. This led to less conservative limit than that of draft NUREG-1860.

2.4 Quantitative Health Objectives

The level of safety that future reactors are expected to meet are the risk objectives, i.e., the QHOs, embedded in the NRC's safety goal policy. The above frequency consequence curve is not substitute for the QHOs which express goals for the cumulative latent and early fatality risk from accidents. The risk summed over all of the accident sequences in the PRA must satisfy both the latent cancer QHO and the early fatality QHO. And quantitative goals were proposed as health risks due to radiation exposure from accidents of nuclear energy facilities in the NSC's safety goals. The comparison of safety goal between the NRC and NSC is as follows.

	Latent Safety Goal	Early Safety Goal
NRC	2 x 10^{-6}(in the region between the site boundary and 10 miles)	5x10^{-7}(in the region between the site boundary and 1 mile)
NSC	10^{-6}(within a specified distance of nuclear facility)	10^{-6}(in boundary area of nuclear facility)

3. Conclusion

This paper surveyed the F-C curves or F-C criteria and the role of QHOs for new reactor or existing LWRs in foreign countries. In general, the frequency and consequence (Dose) curves or criteria proposed by draft NUREG-1860 are more conservative than those of any other guide except for some ranges such as ANSI 51.1 (10^{-5}/yr ~ 10^{-6}/yr) and South Africa's pre-application (10^{-4}/yr ~ 10^{-6}/yr) shown in Fig. 1 and Fig. 2, respectively. QHOs need to be established as quantitative safety goals of highest level considering the NRC and NSC case. These results would be usefully utilized in determining the technology-neutral or specific F-C curves or criteria and QHOs for new reactors in Korea.

REFERENCES

[1] Draft NUREG-1860, Framework for development of a risk-informed, performance based alternative to 10 CFR Part 50.
[2] ANSI 51.1, Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plant.
[3] IAEA-TECDOC-xxxx, Proposal for the Development of Technology Neutral Design Safety Requirements for Nuclear Reactors.
[4] MIT-NSP-TR-023, The use of Frequency-Consequence Consequences in Future Reactor Licensing.
[5] LG-1037, Basic Licensing Requirements for Pebble Bed Modular Reactor.
[6] The HSE document, "Numerical targets and legal limits in safety assessment principles for nuclear facilities – An explanatory note.

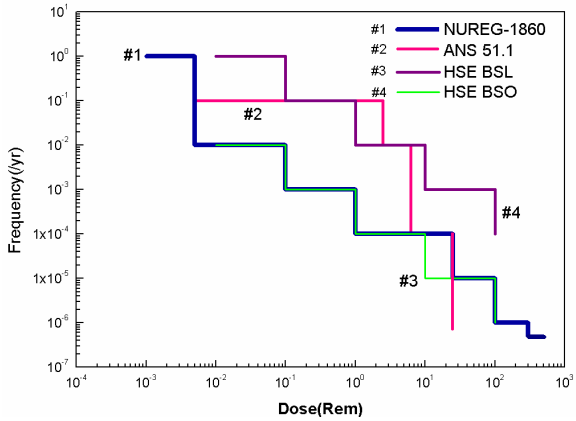

Fig. 1 Comparison of F-C Criteria for Each Guide

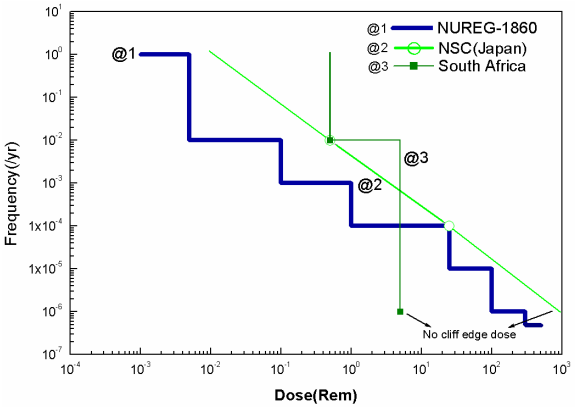

Fig. 2 Comparison of F-C Criteria for Each Country

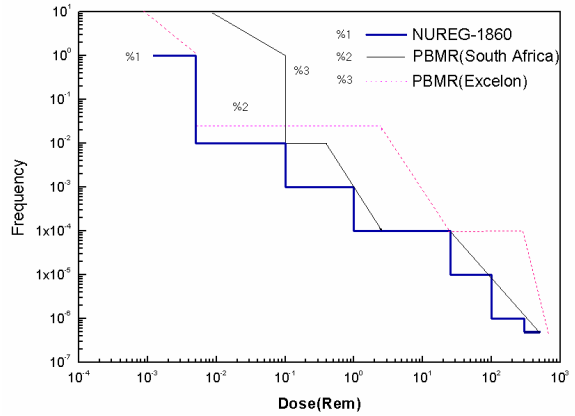

Fig. 3 Comparison of F-C Curves of Draft NUREG-1860 and Pre-application Cases