Developing a Methodology for Identifying Correlations between LERF and Early Fatality

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1. Introduction

One of the reasons to use the measures such as core damage frequency (CDF) and the Large Early Release Frequency (LERF) is to assess, from a risk perspective, the impact on the current licensing basis of any changes that may be proposed by various licensees. The use of CDF and LERF has been judged appropriate since the regulatory utilities have performed level-1 and level-2 Probabilistic Safety Assessments (PSA). Therefore, information on core damage frequency, containment failure likelihood, containment failure mode, and radiological releases, are readily available from these studies.

Difficulties exist in defining "large" release frequencies, since there are wide spectrums of fission product releases that are estimated as likely to occur following severe accidents, with their expected release quantities ranging over several orders of magnitude and occurring at various times following accident initiation.

In this study MELCOR, MACCS, and AIMS code are used in sequence for evaluating source terms quantitatively regarding health effects, which depend on release characteristics of radioisotopes during severe accidents [1].

2. DEFINITIONS OF LERF

Within the current NRC regulatory framework, RG 1.174 adopts CDF and LERF as a "suitable metrics for making risk-informed regulatory decisions." LERF is "defined as the frequency of those accidents leading to significant, unmitigated releases from containment in a time frame prior to effective evacuation of the close-in population such that there is a potential for early health effects." It is stated in RG 1.174 that LERF is used as a "surrogate for the early fatality QHO (quantitative health objective)".

The objective to use the measure of LERF is to evaluate, from a risk perspective, the impact on the current licensing basis (CLB) of any changes in plant procedures. Since most plants have not performed the Level 3 PRAs yet, it is difficult to address the significance of proposed changes in terms of their impact on the Safety Goals. However, since most plants have undertaken a Level 2 PRA it is, in principle, more feasible to obtain information regarding the timing and magnitude of various types of potential releases from severe accidents which are significant for the early fatality calculation [3].

The purpose of this section is to explore the concept of using the Safety Goal quantitative health effects (QHO) on early fatalities to derive lower tier risk acceptance criteria for application on a plant-specific basis. A starting point for expressing the early fatality QHO in a form that can be used to derive different tier criteria is the following working definition for the risk of early fatalities for any specific plant in terms of the normal determinations of probabilistic risk assessments (PRAs) [3].

$$\text{Mean number of EF} = \sum_i (STCF)_i (C_{ef})_i \quad (1)$$

where i refers to the spectrum of accident sequences

$(STCF)_i$ the source term release category frequency for sequence i,

$(C_{ef})_i$ the early fatality consequences given the sequence i which has associated with it a source term, that may be defined in terms of the equivalent release of iodine to the outside environment.

The QHO objective for early fatalities is expressed in terms of individual risk. The Safety Goal Policy Statement specifically states that the early fatality QHO is to be determined by calculating the cumulative individual fatalities within one mile of the site boundary, C_{ef}, and dividing that by the population within that same one mile region, P. Therefore, Equation 1, for purposes of comparing with the early fatality QHO, should be rewritten as

$$\text{Individual risk} = \sum_i (STCF)_i (C_{ef})_i / \text{P} \quad (2)$$

In order to proceed further, we first note that, in general, the individual early fatality (IEF) within one mile of the site boundary can be related to the total effective dose expressed in terms of the equivalent release of iodine by the relationship

$$IEF = C_{ef} / P = 1 - \exp[-k] \quad (3)$$

$$k = 0.693 \left(H / D_{50} \right)^{\beta} \quad (4)$$

where H total effective acute dose to the target organ

D_{50} dose required for producing an effect in 50 percent of the exposed individuals

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β	beta or exponential parameter in the hazard function that defines the steepness of the dose response function.

The items on Equation are those that are determined by a full-scope Level 2 PRA with source term capability and a site characterization parameter. The items on the right contain the result of a Level 3 consequence analysis for individual risk. This parameter can easily be determined using an appropriate computed output. The ULJIN FSAR and PSA report was used to determine site-specific early fatality consequences.

The individual early fatality risk provides a measure of the average probability that a specific individual within one mile of the plant would be exposed to a lethal radiation dose (given that a release occurs from the plant of sufficient magnitude to produce lethal doses) and assuming that the individual does not evacuate.

$$IEFR = LERF * IEF \qquad (4)$$

where IEFF Individual Early Fatality Risk
LERF Large, Early Release Frequency
IEF Individual Early Fatality

$$LERF = \sum_{i=1}^{N_{STC}} STCF_i \left[IEF \geq one\ person \right] \qquad (5)$$

where N_{STC} number of source term release categories
$STCF_i$ the frequency of source term release category i
IEF $\left\{1 - \exp\left[-0.693(H/D_{50})^{\beta}\right]\right\}$

This study discusses those parameters that are important to early fatality risk. This includes those parameters that are determined by plant design/plant operations and that should be captured in a proper definition of the LERF. The second category includes those parameters that are determined by site characteristics. The plant design/plant operations related parameters potentially important to early fatality risk:

1) Source Term Characteristics
   A. magnitude of the fission product release from containment
   B. release thermal energy and release height,
2) Timing Characteristics (evacuation)
   A. timing of release – effective evacuation begins before the start of radionuclide release.
   B. absolute time of release relative to reactor shutdown

Figure 1 illustrates the impact of these various evacuation assumptions on the early fatality risk. This figure plots the early fatality risk against the iodine release fraction. Individual data points for the three release category subgroups are shown with different symbols. This figure illustrates the effectiveness of early evacuation in reducing the Individual Early Fatality Risk.

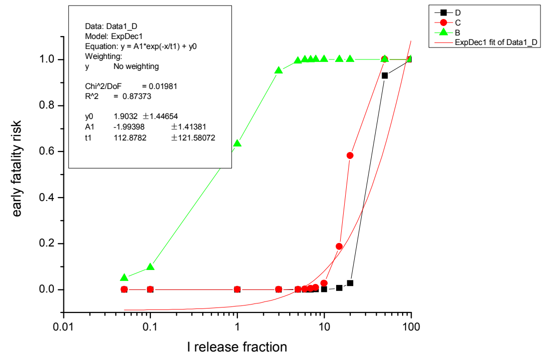

Figure 1. Early Fatalities as a function of 1-131 Release and evacuation assumptions

3. Conclusion

This paper defines a simple relationship between the Safety Goal QHO for Individual Early Fatality and a Large Early Release Frequency (LERF) that can be used to estimate the Safety Goal QHO for a specific plant. And this also provides a quantitative definition of the LERF. The relationship utilizes simple site-specific characteristics and results from a Level 2 plant-specific probabilistic risk assessment (PRA) (release category frequencies and source term characteristics).

And also, this produces the correlation factor between early fatality and LERF and has calculated the early fatality to validate the results, according to the residential distance using MACCS code. This methodology may provide a simple and easy to use approach for providing reasonably robust estimates for the individual early fatality frequency for PRA analyses lacking a detailed Level 3 offsite consequence.

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