Quotations on Uncertainty in Regulatory Guide 1.174

An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis

- **Many references to NUREG-1855 for more detailed guidance**

[The RG] …permit[s] **only** small increases in risk and only when it is reasonably assured … that sufficient defense-in-depth and sufficient safety margins are maintained … **because of uncertainties** …

Appropriate **consideration of uncertainty** is given in the analyses and interpretation of findings, including use of a program of monitoring, feedback, and corrective action to address **key sources of uncertainty**.

The licensee should appropriately **consider uncertainty** in the analysis and interpretation of findings.

Quotations on Uncertainty in Regulatory Guide 1.174

An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis

Defense-in-Depth …has been and continues to be an effective way **to account for uncertainties** in equipment and human performance and, in particular, to account for the potential for unknown and unforeseen failure mechanisms or phenomena, which … are not reflected in either the PRA or traditional engineering analysis.

One of the strengths of the PRA framework is its ability to characterize the **impact of uncertainty** in the analysis, and it is essential that these **uncertainties be recognized** when assessing whether the principles are being met.

[T]he state-of-knowledge, or **epistemic, uncertainties** associated with PRA calculations **preclude a definitive decision** with respect to the region in which the application belongs **based purely on the numerical results**.

Uncertainty Discussion in Regulatory Guide 1.174

Majority of discussion on addressing uncertainties in licensing actions is contained in

Section 2.5, *Comparison of Probabilistic Risk Assessment with the Acceptance Guidelines*

2.5.1 Types of Uncertainty and Methods of Analysis
2.5.2 Parameter Uncertainty
2.5.3 Model Uncertainty
2.5.4 Completeness Uncertainty
2.5.5 Comparison with Acceptance Guidelines

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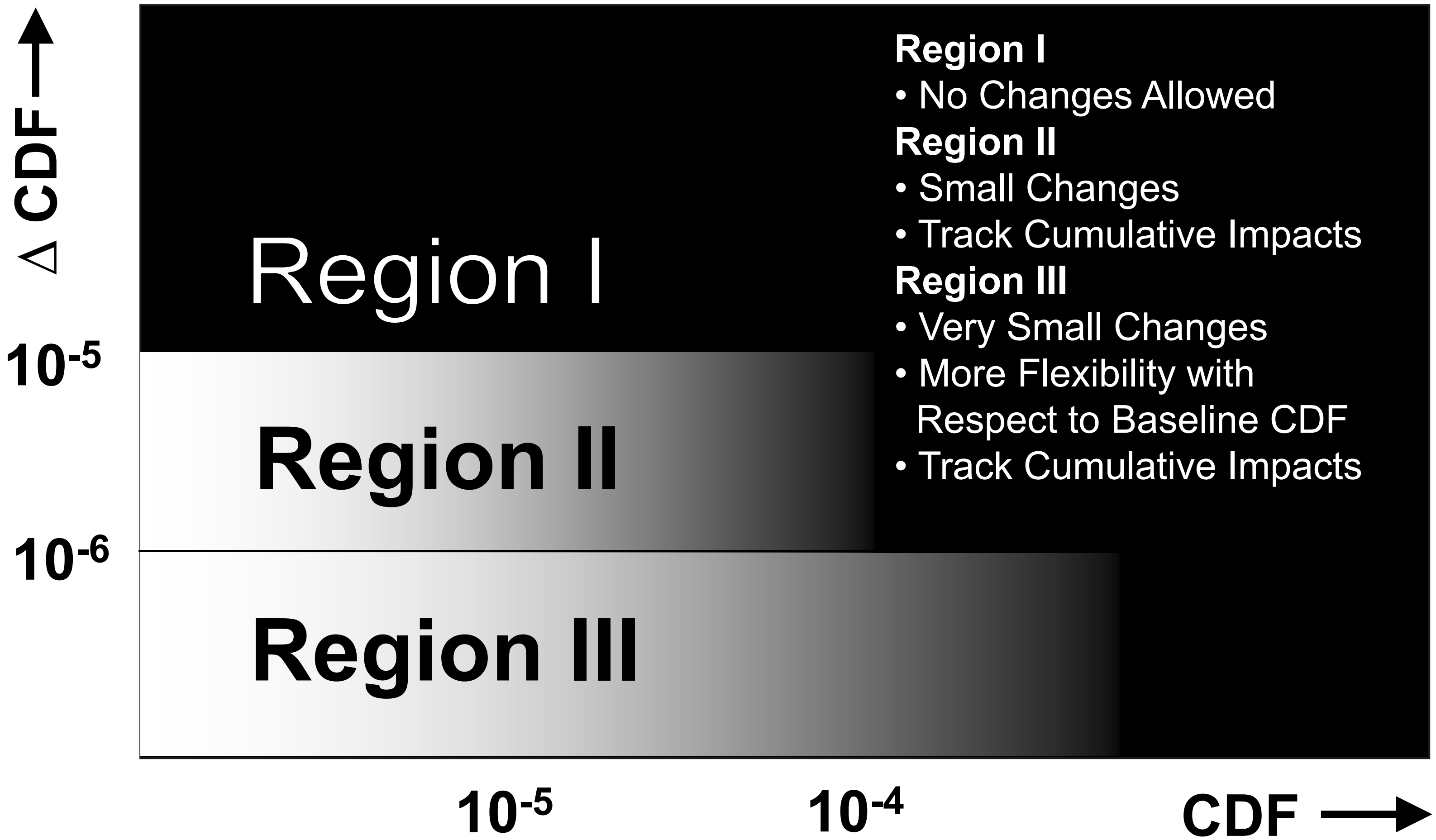
Figure 3. Acceptance Guidelines for Core Damage Frequency (CDF)



Quotations on Uncertainty in Regulatory Guide 1.174, Section 2.5.5

Because of the way the acceptance guidelines (Section 2.4) were developed, the appropriate numerical measures to use in the initial comparison of the PRA results to the acceptance guidelines are **mean values**. The mean values referred to are the means of the probability distributions that result from the propagation of the uncertainties on the input parameters and those model uncertainties explicitly represented in the model.

While the analysis of parametric uncertainty is fairly mature and is addressed adequately through the use of **mean values**, the analysis of the model and completeness uncertainties cannot be handled in such a formal manner.

Quotations on Uncertainty in Regulatory Guide 1.174, Section 2.5.5

[I]t will be incumbent on the licensee to demonstrate that the choice of reasonable alternative hypotheses, adjustment factors, or modeling approximations or methods to those adopted in the PRA model would not significantly change the assessment. This demonstration can take the form of **well-formulated sensitivity studies or qualitative arguments**. The alternatives that would drive the result toward unacceptability (i.e., those associated with key sources of model uncertainty) should be identified and sensitivity studies performed or reasons given as to why they are not appropriate for the current application or for the particular plant.

In general, the results of the sensitivity studies should confirm that the guidelines are still met even under the alternative assumptions (i.e., change generally remains in the appropriate region). Alternatively, this analysis can be used to identify candidates for compensatory actions or increased monitoring.

Typical Licensing Actions

- Applications may or may not address parameter uncertainty in their original submittal
  - Addressed if NRC requests

- Applications typically do not address model uncertainty in their original submittal
  - Addressed if NRC requests
  - If addressed, usually is qualitative and at a high level
  - Exception to level of detail may be NFPA 805 applications, where the discussion on uncertainty related to the fire PRA can be fairly extensive

Example 1
Typical NFPA 805 Application RAI

Explain how parametric data uncertainty was propagated and the state of knowledge correlation (SOKC) was evaluated for fire CDF and LERF. Identify fire-PRA-specific parameters (e.g., hot short probabilities, fire frequencies) that can appear in FPRA cutsets and how they were correlated. NUREG-1855 states that all basic events (regardless of system) must be correlated if their failure rates for a given failure mode are derived from the same data set. Therefore, if SOKC was applied only to basic events within the same system, provide a justification.

Example 1
NFPA 805 Application Response

The … FPRA quantifies individual cutsets for each fire source scenario. These cutsets were combined into a single cutset file … Basic events (BEs) were renamed in a manner to allow random failures, fire induced failures, and fire induced hot shorts for the same component to have unique names within the same combined cutset file. Once combined, the cutset basic events were reviewed to determine if appropriate uncertainty parameters were used for each basic event, and additions were made where appropriate.

The UNCERT … program was run to evaluate the combined cutset file. Based on a Monte-Carlo sampling approach, the mean CDF/LERF was generated along with a probability distribution histogram ... The mean CDF/LERF calculations, based on the data uncertainty, were consistent with the CDF/LERF, based on the point estimated solution.

The UNCERT solution for the parametric uncertainty can evaluate the impact of the SOKC for correlated data if a single uncertainty parameter is applied to multiple basic events, as is the case for reliability data using "type coded" values. No other basic event uses a single uncertainty parameter for multiple components. Because the mean point estimate CDF/LERF results match those of the CDF/LERF values from the UNCERT solution, it is concluded that there are no correlated random failure events requiring SOKC additions to frequency. For the fire PRA, various events in the combined solutions were reviewed for evaluation for SOKC. The following table … discusses the identification of fire data types reviewed for SOKC.

Example 1

NFPA 805 Application Response

	Area of Uncertainty	Discussion
1	Fire ignition frequency	The … fire scenarios are based on single ignition sources. Therefore, there are no correlated ignition frequencies within an individual cutset, precluding SOKC occurrence concerns.
2	Non-detection probabilities	A generic non-detection probability is used in quantifying the scenario frequencies. Multiple detectors are not credited, so that for individual scenarios, there is no correlated data.
3	Non-suppression probabilities	There is no correlation between various types of suppression, in that they are uniquely different.
4	Heat release rate severity factor/split fraction	See Item 1. In addition, the source target relationship is based on a single distance that is used to calculate the HRR severity factors. The split of the generic HRRs is quantified as two individual scenarios, precluding any correlated data in a single cutset.
5	Circuit failure probabilities	With the exception of basic events where the hot short probability of 1.0 is used, cutsets including the same component type and failure mode with the same hot short probabilities are assumed completely correlated. The UNCERT code does not address this correlation, so an analysis showing the potential change in CDF/LERF is supplied below.

Example 1
NFPA 805 Application Response

Based on the conclusions of the above table, only those combinations of events with hot short failure probabilities less than 1.0 are evaluated for SOKC.

The merged cutsets were reviewed to identify correlated hot short failure combinations above the truncation of 1.0E-9 for CDF and 1.0E-10 for LERF. The types of events, presented in the cutsets requiring SOKC consideration, are spurious operation of air-operated valves (AOVs) and motor-operated valves (MOVs). A SOKC multiplier, based on the number of correlated events in a cutset and calculated using the standard deviation for the hot short probabilities, was developed and multiplied by the CDF/LERF Fussell-Vesely (F-V) contribution of each SOKC combination to calculate the increase in CDF/LERF due to SOKC.

No cutset was found with correlated events from multiple systems. Only correlated failures within the same systems were present within the cutset solution, so that the SOKC multipliers affect one system only. This is expected, given cutsets are based on loss of functions, and functions typically have redundant components at the system level. Also, this may be due in part to the limited number of altered events that are used in the … FPRA. A more extensive use of hot short probabilities with altered events could potentially result in correlated events from different systems existing within the same cutset.

Example 2
Typical NFPA 805 Application RAI

Explain how uncertainty was treated with respect to CDF, LERF, ΔCDF, and ΔLERF. Clarify the extent to which statistical quantification of uncertainty was used to evaluate fire CDF, LERF, ΔCDF, and ΔLERF. Identify significant fire scenarios where uncertainty was characterized qualitatively. For these scenarios, explain (per Supporting Requirement QU-E4) how the FPRA is affected by these sources of uncertainty.

Example 2
NFPA 805 Application Response

As outlined in the *[previous example]* parameter uncertainties are assigned to basic events in the FPRA model to account for the aleatory uncertainty, based on randomness of elements in the FPRA, for fire induced failures … uncertainty parameters were propagated to obtain an uncertainty distribution on the calculated CDF and LERF using Monte Carlo methods. There was no appreciable contribution to risk associated with parametric uncertainty or state of knowledge correlation. In that regard, no evaluation of aleatory uncertainty was performed for ΔCDF or ΔLERF, as it would not be expected to provide new insights.

The risk importance of *epistemic* uncertainties, based on level of knowledge of FPRA elements, is best assessed via sensitivity analyses by assuming an alternative outcome or method for each modeling issue or combinations of issues. Thus, the risk importance of a given epistemic uncertainty was assessed by calculating the change in CDF or LERF using an alternate modeling assumption. The procedure outlined in NUREG/CR-6850 for the Fire PRA uncertainty and sensitivity analysis (i.e., Task 15) was used to identify the important epistemic uncertainty issues associated with the … Fire PRA.

[Sensitivity Analysis Report] provides the following quantitative sensitivities for CDF, LERF, ΔCDF, and ΔLERF:

- Ignition Frequency from NUREG/CR-6850 versus Supplement 1 to NUREG/CR-6850,
- Removal of credit for control power transformer affect on alternating current (AC) circuit failure probabilities, and
- Treatment of closed MCCs ignition sources as opening for fire.

Engineering Change *[Report]* provides quantitative sensitivities for CDF, LERF, ΔCDF, and ΔLERF for the use of incipient detection in the main control boards (MCBs) (i.e., Unit 1 only).

Example 2
NFPA 805 Application Response

… sources of model uncertainty and related assumptions were qualitatively characterized by category, with the associated impact on the FPRA but usually without specific linkage to a particular significant fire scenario …

Category	Item	Conservatism
Ignition Frequency	Ignition Frequencies are based on data in the Fire Events Database that includes "potentially challenging" fires and not actual observed fires.	Yes Clearer and more detailed collection of generic data may reduce ignition frequency (IGF).
Source HRR	Closed cabinet treatment for MCCs … assumes certain MCCs are closed sources; however, guidance indicates that 480V MCCs can experience energetic faults which can create openings to support fire growth. To account for this, an additional factor of 0.1 is applied to the scenario specific ignition frequency (SSIF) to account for the fraction of the time the MCC stays closed	No The data for the guidance is interpreted conservatively. At best, only a small portion of the MCC fires would lead to an open cabinet situation.

26 more entries in the Table covering:

Ignition Frequency, Source HRR, Source HRR profile, Target Selection, Damage Time, HGL possibility in Electrical Tunnel (ET) and Pipe Tunnel (PT), Time to HGL, Non-Suppression, Circuit Analysis, HRA, Quantification, Quantification Tools

Example 3
NFPA 805 Application RAI & Response

Request

F&Os note that uncertainty and importance analysis was not performed for fire LERF. Describe the sources of uncertainty and results of importance analyses of fire LERF.

Response

The sources of model uncertainty and related assumptions which are listed in the *[previous]* response … are considered applicable to LERF. Of these, the most significant area of epistemic uncertainty with regard to LERF is in the area of circuit analysis, specifically as related to spurious operation of containment isolation valves. …

Followed by about 16 pages of discussion on LERF-related results