SUNSI Review Complete
Template = ADM-013
E-RIDS=ADM-03
ADD: Jazel Parks

COMMENT (1)
PUBLICATION DATE: 5/3/2019
CITATION 84 FR 19132

PUBLIC SUBMISSION

As of: 6/7/19 2:25 PM
Received: June 06, 2019
Status: Pending_Post
Tracking No. 1k3-9abw-2vz7
Comments Due: July 02, 2019
Submission Type: Web

Docket: NRC-2019-0113
Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology to Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors

Comment On: NRC-2019-0113-0001
Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Methodology To Inform the Licensing Basis and Content of Applications for Licenses, Certifications, and Approvals for NonLight Water Reactors

Document: NRC-2019-0113-DRAFT-0001
Comment on FR Doc # 2019-09089

Submitter Information

Name: Richard Denning
Address:
2041 Hythe Rd
Columbus, OH,
Email: denningrs.8@gmail.com

General Comment

The attached PDF provides a discussion of the concerns that we (Richard S. Denning and Vinod Mubayi) have about technical weaknesses in the interpretation of the frequency-consequence curve (Farmer curve) as applied in DG-1353. An alternative interpretation as a limit on the Complementary Cumulative Distribution Function directly provides a limit on risk. The associated change in perspective could be implemented in DG-1353 with only minor changes in the approach to application of the curve. Both Drs. Mubayi and Denning have had extensive experience in supporting the NRC in the implementation of risk-informed regulation.

Attachments

Comments on DG-1353 Use of the Frequency-Consequence Curve

Review Comments on Draft Regulatory Guide DG-1353, Guidance for a Technology-Inclusive, Risk-Informed Methodology to Inform the Licensing Basis and Content of Applications for Certifications and Approvals for Non-Light Water Reactors

By

Richard S. Denning (denningrs.8@gmail.com) and Vinod Mubayi (vinodmubayi@gmail.com)

We believe that the effort undertaken by NEI [1] and tentatively supported by the NRC staff in DG-1353 [2] represents an excellent start toward the development of a technology-inclusive (technology-neutral) approach to the development of a licensing basis for non-light water reactors. However, the approach taken to the development and interpretation of the frequency-consequence curve (Farmer Curve [3]) does not have a strong technical basis, as discussed below. This is an issue that can be readily resolved by a change in perspective that would have limited impact on the manner in which the curve would be implemented.

Technical Basis for Frequency-Consequence Curve

The proposed approach for identifying and classifying licensing basis events adopts a frequency versus consequences limit curve approach first proposed by Reginald Farmer [3] and subsequently employed in a 2007, NRC staff proposal referred to as the Technology Neutral Framework (NUREG-1860) [4]. A limitation to this approach that was recognized by both Farmer and the Technology Neutral Framework authors is that the limit curve, as interpreted, could be altered by preferences of the analyst. By redefining an accident scenario (for example splitting the scenario into two similar scenarios) one could change an unacceptable scenario into one or more scenarios that each satisfy the curve. Furthermore, a plant with multiple vulnerabilities could conceivably have a very large number of scenarios that each satisfied the frequency-consequence curve but have a very large associated risk. The implication of these issues is not that an applicant would attempt to game the system or that constraints couldn't be placed to limit the impact of these issues, but rather that there is a basic underlying weakness in the logic of the approach to the interpretation and application of the limit curve in the proposed context under DG-1353.

In the proposed application of the frequency-consequence curve, the analyst makes an assessment of the frequency and consequence of each candidate licensing basis event (LBE). Based on the assessed frequency, the analyst identifies the event as an Anticipated Operational Occurrence (AOO), Design Basis Event (DBE) or Beyond Design Basis Event (BDBE) and establishes a target consequence in terms of a dose at the exclusion area boundary (EAB) not to be exceeded for that event. The fundamental issue with the approach is that there is some degree of arbitrariness in the manner in which the analyst defines an accident sequence. In effect the analyst integrates over some region of parameter space. For example, there is a spectrum of break sizes in a loss of coolant accident in a light water reactor. An analyst could classify the full spectrum of loss of coolant accidents under a single category "LOCA" with some averaged (or conservative) consequences or alternatively could define multiple sequences, Large Break LOCA, Intermediate Break LOCA and Small Break LOCA combined with failure of emergency core cooling systems leading to different conditional probabilities of core damage. The concept of a limit curve for individual accident scenarios in which a specific value of consequence is associated with a specific value of frequency is inconsistent with the recognition that there is not an a priori unique way to characterize an accident sequence. Indeed a designated LBE is typically intended to be a surrogate for a group of sequences that although ostensibly similar extend over an area of the frequency-consequence graph. A method is needed that can rigorously account for different approaches to parsing the spectrum

of conditions associated with different types of events. Furthermore, as used in the NEI approach, the frequency consequence curve may appear to provide a sophisticated method of relating the frequencies and consequences of LBEs but is inherently ambiguous when used with the objective of constraining risk.

However, there is an interpretation of the frequency consequence curve that not only makes sense but is directly related to constraining risk. The frequency-consequence curve can be interpreted as a bound on the complementary cumulative distribution function (CCDF) of accident sequences.

$R_{ab} = \int_a^b cf(c)dc,$ where f(c) is the probability density function and risk, R, is defined as the first moment of the density function. The complementary cumulative distribution F is defined as

$$F = \int_c^\infty f(c)dc$$

$dF = -f(c)dc$

$$R_{ab} = \int_{F(b)}^{F(a)} c(F)dF$$

Thus, in a plot of the CCDF the area from Fa to Fb to the left of the curve is equal to R_{ab}. If we constrain the CCDF for accident sequences by the limit curve, we are not only constraining risk, but we can tailor the limit curve to assure that a given level of risk is not exceeded. For example, if we perform a best-estimate plus uncertainty analysis for a specific scenario, the CCDF of the scenario must fall below the frequency-consequence curve. Furthermore, for multiple licensing basis event scenarios, the aggregate CCDF must be constrained by the curve. We will discuss in a later paragraph under what conditions it is necessary to consider the acceptability of the aggregate of LBEs in addition to compliance by individual events.

Although we provide an example in the following paragraphs of how a limit curve could be constructed, we assume that the details of the curve would be developed collaboratively by the NRC and NEI. In this example, we use a slope of -1 for Log F vs Log C in the AOO range with an associated annual dose limit (mean risk) at the EAB less than 100 mrem/yr, consistent with 10CFR20. Note that because of the interpretation of the dose-limit curve, the specification in NEI 18-4 is that "The total frequency of exceeding an offsite boundary dose of 100 mrem shall not exceed 1/plant year." Although that may be a necessary condition to satisfy 10CFR20, it is not the same requirement and specifically does not include the aggregation of small doses to which a person at the site boundary could be exposed.

For the DBE and BDBE range we use a slope of -2. The result is shown in Figure 1. In this case the risk contribution from DBEs is determined to be less than 1.5E-4 rem/yr approximately 15 percent of the risk from AOOs. The CCDF limit at 1000 rem is 5E-8/yr, which is more restrictive than the early fatality probabilistic safety goal. The 25 rem dose occurs at 7.5E-5 per yr, which is approximately at the lower bound of the DBE region. The shape of this Frequency-Consequence curve is very similar to the curve in NEI 18-04 other than the low consequence region for which the NEI curve has a discontinuity at the boundary between AOOs and DBEs, which does not exist in the curve we developed. The principal difference is in the interpretation of the curve.

Also shown in the figure are CCDFs for two hypothetical Licensing Basis Events (LBEs) based on uncertainty distributions, as could be developed from best-estimate plus uncertainty analyses. Within the context of NEI 18-04, each LBE would be considered separately. In the proposed reinterpretation of the Frequency-Consequence curve the aggregated CCDF would be required to fall to the left (below) of the curve to satisfy the intended risk constraint. An importance measure has been developed previously to

assess the proximity of a scenario to a limit curve, referred to as a Limit Exceedance Factor [5]. For the example demonstrated, the aggregated CCDF contacts the limit curve, even though the individual CCDFs satisfy the criterion. Whether a 95% uncertainty limit should be added to provide margin to the limit curve is a policy decision that requires discussion. It is our suggestion that the shape of the CCDF for an event would be determined based on aleatory variability and that epistemic uncertainties would be treated as margin on the frequencies and consequences of LBEs.

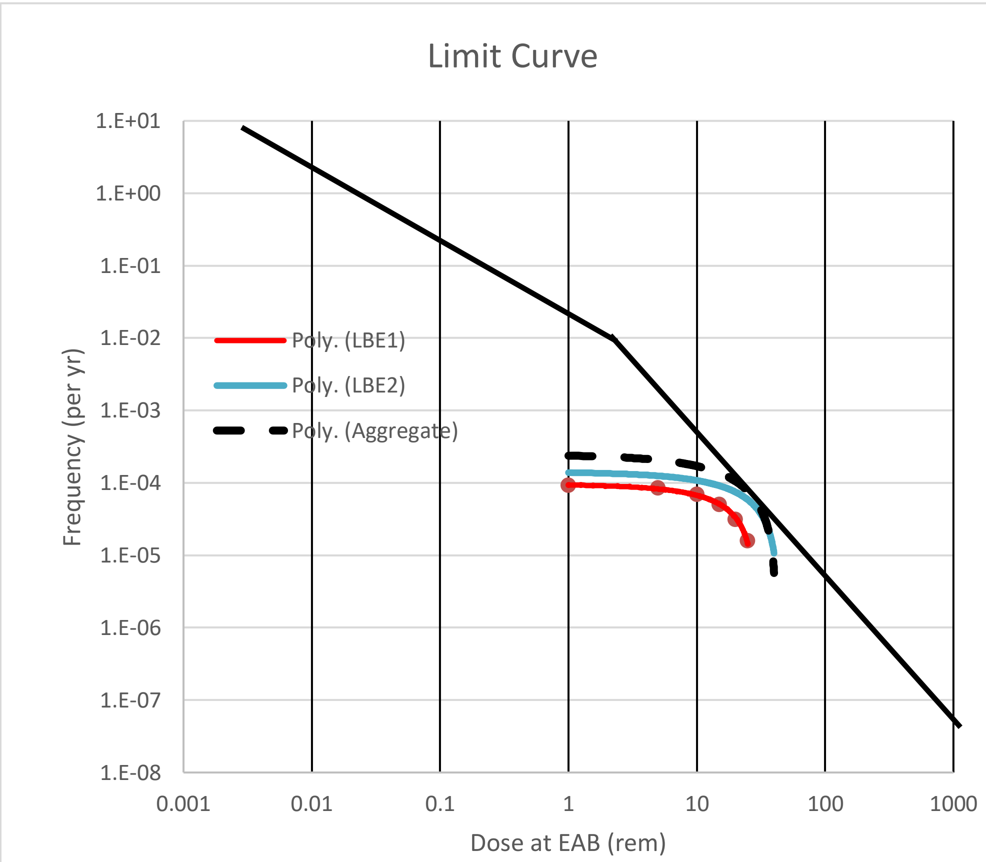

Figure 1. Frequency-Consequence Curve Interpreted as a Limit on the Complementary Cumulative Distribution Function for Licensing Basis Events

Within the context of the CCDF interpretation of the Farmer Curve, LBEs would be treated individually as in the NEI 18-04 interpretation, as a necessary condition. However, consideration would be required of the aggregated LBEs if the results would approach the limit curve and the LBEs cover the same region of the limit curve.

We discussed earlier why the CCDF interpretation of the limit curve is important to considering the spectrum of loss of coolant accidents. It also provides a more natural approach to the consideration of external events, such as seismic events. For seismic events, the frequency of the hazard decreases very fast with the magnitude of the hazard level (e.g. peak ground acceleration) but the fragility of equipment conversely increases as the cumulative logarithmic normal distribution of the hazard. Thus, it is essential to convolve the hazard and fragility distributions over a broad range of the seismic hazard sizes to predict

the associated core damage frequency. The comparison of a CCDF for seismic risk with a CCDF limit curve is a natural product of a seismic risk analysis.

Other Considerations

An important additional element of the NEI approach is to demonstrate the satisfaction of the NRC's probabilistic safety goals by advanced reactor designs. These should be easy criteria to satisfy. As demonstrated by NUREG-1150 [7] these goals are satisfied by large margin for existing large LWRs. More recent SOARCA analyses [8] further illustrate how large that margin is. Certainly, our expectation for advanced reactors would be at least as safe as existing LWRs. Focusing on the EAB doses would be in our opinion an appropriate expectation for advanced reactors, without necessarily requiring a change in the safety goals.

References

1. NEI, "Risk-Informed Performance-Based Guidance for Non-Light Water Reactor Licensing Basis Development," NEI 18-04, September 2018.
2. NRC, "Guidance for a Technology-Inclusive, Risk Informed and Performance-Based Approach to Inform the Content of Applications for Licenses, Certifications, and Approvals for Non-Light Water Reactors, Proposed New Regulatory Guide, DG-1353, (2019).
3. F.R. Farmer, "Reactor Safety and Siting: A Proposed Risk Criterion," *Nuclear Safety*, **8**, 539, (1967).
4. M. Drouin, "Feasibility Study for a Risk-Informed and Performance-Based Regulatory Structure for Future Plant Licensing", *NUREG-1860*, U.S. Nuclear Regulatory Commission (2007).
5. B.C. Johnson, G.E. Apostolakis, and R.S. Denning, "Application of a Limit Exceedance Importance Measure to Risk-Informed Design," *Nuclear Technology*, **172**, pp.108-119 (2010).
6. R. Denning, T. Aldemir, J. Lee and D. Grabaskas, "Concepts for Demonstrating Compliance with Safety Limits," PSA 2015, 2015.
7. NRC, "Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants," NUREG-1150, December 1990.
8. NRC, "State of the Art Reactor Consequence Analyses (SOARCA) Report, NUREG-1935, November 2012.