White Paper
Industry Proposals on Option 3
LOCA Redefinition

1. Introduction

In its Staff Requirements Memorandum (SRM) dated March 31, 2003, the Commission directed NRC staff to complete the technical basis supporting the large break Loss of Coolant Accident (LB-LOCA) break size redefinition and to provide proposed rule changes to the Commission by March 31, 2004. While the SRM provides guidance on considerations toward development of proposed rule changes and supporting guidance, significant latitude is provided NRC staff in completing the task.

The SRM also directs the staff to seek early public and stakeholder comments on the SRM proposals. On June 9, 2003, NRC staff held a public meeting with NEI, industry representatives and other interested stakeholders to solicit industry's input to identify issues that require resolution for rulemaking on risk-informed changes to 10 CFR 50.46. Future meetings are planned to continue this dialogue.

This white paper describes industry proposals for redefinition of the design basis large break LOCA, taking into consideration the direction provided by the Nuclear Regulatory Commission in its March 31 SRM. These proposals are intended to support ongoing discussions between industry and NRC staff on the full range of topics necessary to support risk-informed changes to 10 CFR 50.46.

2. Rule Attributes and Rule Change Proposals

An important element of the discussions regarding redefinition of the design basis LB-LOCA, is the specific rule language that would enable licensees to modify their design basis LOCA break size. Identification of proposed changes to 10 CFR 50.46 was acknowledged in the June 9, 2003 public meeting as a key near-term objective and is seen as a necessary first-step toward developing the accompanying implementation guidance.

While the SRM directs the staff to develop proposed changes to 10 CFR 50.46, latitude is given to the staff regarding the specific rule language. Two proposals for rule language have been put forward. The first was proposed by NEI in a February 6, 2002 petition for rulemaking (PRM-50-75). The second, proposed by Chairman Diaz, was identified in the SRM as an example change to 10 CFR 50.46.

Both proposals maintain the current LB-LOCA definition of maximum break size and offer a voluntary risk-informed alternative for determining the maximum break size. The PRM-50-75 proposal[1] provides necessary enabling language that would allow a licensee to pursue an alternative LOCA break size; however, the risk metrics and manner in which the alternative break size is to be determined are not specified. The Diaz proposal[2] is more specific in that it identifies a risk metric for determination of an acceptable alternative maximum break size (e.g., break size includes at least XX% of LOCA failure contribution to core damage frequency).

The enabling language offered in PRM 50-75 provides a means to accommodate future changes to the maximum LB-LOCA break size but provides no guidance as to how such changes would be developed. The simplicity of the language is seen as an advantage in that it provides a straightforward rule change and avoids complications surrounding the development of implementation guidance. This offers a means to open up the opportunity for changing the maximum LB-LOCA break size, but leaves much to be decided before such a change could be accomplished. Commissioner McGaffigan, in his voting record on the SRM, expressed support for PRM 50-75:

> *…I support simply granting the NEI petition for rulemaking (PRM-50-75) which would permit the industry to propose, subject to NRC approval, an alternative to the current LBLOCA definition. This rulemaking would not in any way commit NRC to a new LBLOCA definition using a smaller break size. Rather, the change would signify that the NRC is open to allowing an applicant the chance to make a case for a smaller break size.*

The proposal offered by Chairman Diaz goes beyond the simple enabling language of PRM 50-75 by including a risk metric for determining the acceptability of an alternative maximum break size. The metric would be based on the percentage of LOCA contribution to total core damage frequency. The identification of a risk metric in the rule is desirable in that it is expected to facilitate the development of supporting implementation guidance and would provide a stable risk basis for

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[1] PRM 50-75 proposed change to 10 CFR 50.46(c):

As used in this section: (1) Loss-of-coolant accidents (LOCA's) are hypothetical accidents that would result from the loss of reactor coolant, at a rate in excess of the capability of the reactor coolant makeup system, from breaks in pipes in the reactor coolant pressure boundary up to and including a break equivalent in size to the double-ended rupture of the largest pipe in the reactor coolant system, **or up to and including an alternate maximum break size that is approved by the Commission**.

[2] SRM proposed change to 10 CFR 50.46(c):

As used in this section: (1) Loss-of-coolant accidents (LOCA's) are hypothetical accidents that would result from the loss of reactor coolant, at a rate in excess of the capability of the reactor coolant makeup system, from breaks in pipes in the reactor coolant pressure boundary up to and including a break equivalent in size to the double-ended rupture of the largest pipe in the reactor coolant system, **or up to an alternative maximum break size determined by including at least XX% (e.g., 95%, 96%...] of the LOCA failure contributors to core damage frequency.**

future alternative break size proposals. The Commission SRM offered this proposal as an example of possible rule language, but also identified that a LOCA risk metric (i.e., metric based on a percentage of LOCA contributors to risk versus percentage of total CDF risk) could unnecessarily penalize plant designs where the preponderance of overall risk results is from accidents other than LOCAs.

3. NEI Proposal for LBLOCA Redefinition

Upon consideration of Commission guidance contained in the SRM, NEI offers a third proposal for rule change to enable development and implementation of an alternative maximum LB-LOCA break size. The proposed changes, shown in Table 1, affect 10 CFR 50.46, paragraph (c), Appendix A and Appendix K to Part 50 by adding the words:

> *…or up to an alternative break size defined by an approved risk-informed process.*

As with the PRM 50-75 and SRM proposals, the NEI proposal maintains the current maximum break size based on double-ended guillotine break of the largest pipe in the reactor coolant system, and offers an option for a voluntary risk-informed alternative break size. In the NEI proposal the alternative break size would be determined by the break size that "is determined by an approved risk-informed process."

The intention of this language is that it would enable the use of established risk metrics and review guidance used to support a broad range of risk-informed decisions. Regulatory guidance developed to support risk-informed decisions (e.g., Reg. Guide 1.174) would provide the necessary structure and guidance to determine the appropriate range of break sizes. Consistent with other risk-informed regulatory activities, application specific guidance would be developed to expand upon the framework of Reg. Guide 1.174 and address items that are unique to LB-LOCA redefinition (e.g., scope of changes considered, reversibility).

Use of the Reg. Guide 1.174 approach and structure would provide a defensible connection with other risk-informed regulatory changes and would ensure a necessary level of consistency among risk-informed activities.

The evaluation would demonstrate that break sizes above the alternative maximum break size are non-significant contributors to risk using appropriate risk-informed acceptance guidelines and risk metrics.

The risk metrics provided in Reg. Guide 1.174 provide a measure for determining whether the break sizes above the proposed alternative break size are non-significant contributors to risk.

Table 1
NEI Proposed Rule Change Language
For LB LOCA Redefinition

§50.46 Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors.

(c) As used in this section: (1) Loss-of-coolant accidents (LOCA's) are hypothetical accidents that would result from the loss of reactor coolant, at a rate in excess of the capability of the reactor coolant makeup system, from breaks in pipes in the reactor coolant pressure boundary up to and including a break equivalent in size to the double-ended rupture of the largest pipe in the reactor coolant system***, or up to an alternative break size defined by an approved risk-informed process.***.

Appendix A to Part 50 -- General Design Criteria for Nuclear Power Plants

Definitions and Explanations

Loss of coolant accidents. Loss of coolant accidents mean those postulated accidents that result from the loss of reactor coolant at a rate in excess of the capability of the reactor coolant makeup system from breaks in the reactor coolant pressure boundary, up to and including a break equivalent in size to the double-ended rupture of the largest pipe of the reactor coolant system, ***or up to an alternative break size defined by an approved risk-informed process.***

Appendix K to Part 50 -- ECCS Evaluation Models

I. Required and Acceptable Features of Evaluation Models.

C. Blowdown Phenomena

1. *Break Characteristics and Flow*. a. In analyses of hypothetical loss-of-coolant accidents, a spectrum of possible pipe breaks shall be considered. This spectrum shall include instantaneous double-ended breaks ranging in cross-sectional area up to and including that of the largest pipe in the primary coolant system, ***or up to an alternative break size defined by an approved risk-informed process.*** The analysis shall also include the effects of longitudinal splits in the largest pipes, with the split area equal to the cross-sectional area of the *largest* pipe, ***or up to an alternative break size defined by an approved risk-informed process.***

One of the concerns expressed in the Option 3 SRM was the potential for significant disparity in treatment between plants where the preponderance of risk is from accidents other than LOCA. This concern is directly related to the rule language where the alternative break size would be determined based upon the contribution to LOCA CDF. This concern is allayed by basing the alternative break size on its contribution to total CDF. As noted in the SRM:

> *In order to avoid this dilemma, it might be appropriate to consider an approach in which the alternative maximum LOCA to be included within the design basis is established on a plant-specific basis using some percentage of the total CDF risk, rather than the risk associated only with LOCA. Regardless of the specific approach, any proposed changes should be risk-informed and consistent with the principles of RG 1.174.*

Use of Reg. Guide 1.174 Evaluation Guidance

The guidance of Reg. Guide 1.174 provides a solid basis for addressing the key principles of risk-informed decision-making. These principles, as stated in RG 1.174 are:

1. The proposed change meets current regulations unless it is explicitly related to a requested exemption or rule change
2. The proposed change is consistent with defense-in-depth philosophy
3. The proposed change maintains sufficient safety margins
4. When proposed changes result in an increase in core damage frequency or risk, the increases should be small and consistent with the intent of the Commission's Safety Goal Policy Statement
5. The impact of the proposed change should be monitored using performance measurement strategies

Defense in Depth

Consistent with Reg. Guide 1.174, the evaluation supporting the proposed alternative break size and any design basis changes resulting from the change in break size would need to show consistency with the defense-in-depth philosophy by demonstrating:

- A reasonable balance is preserved among prevention of core damage, prevention of containment failure, and consequence mitigation
- Over-reliance on programmatic activities to compensate for weaknesses in plant design is avoided
- System redundancy, independence, and diversity are preserved commensurate with the expected frequency, consequences of challenges to the system, and uncertainties (e.g., no risk outliers)
- Defenses against potential common cause failures are preserved, and the potential for the introduction of new common cause failure mechanisms is assessed.
- Independence of barriers is not degraded
- Defenses against human error are preserved.

- The intent of the General Design Criteria in Appendix A to 10 CFR Part 50 is maintained.

Safety Margins

While more properly considered a subset of Defense-in-Depth, the need to maintain sufficient safety margins is addressed separately in the Integrated Decision Making process outlined in Reg. Guide 1.174. Safety margins are applied to the design, analysis and operation of nuclear systems and account for parameter, modeling, and completeness uncertainties.

Regulatory Guide 1.174 outlines two acceptance guidelines for maintaining sufficient safety margins:

- Codes and standards or their alternatives approved for use by the NRC are met, and
- Safety analysis acceptance criteria in the licensing basis (e.g., updated FSAR, supporting analyses) are met, or proposed revisions provide sufficient margin to account for analysis and data uncertainty.

Application specific guidance and measures for assuring adequate safety margins have also been developed for a number of risk-informed applications. A similar approach may be appropriate for the development and review of alternative break size determinations.

Small Change In Risk

The assessment of the risk-informed spectrum would utilize input from probabilistic risk assessments to define the spectrum of LOCAs. LOCAs that could be shown to have very small contribution to risk could be excluded. The proposed risk metrics for use in determining the range of break sizes to be considered are taken directly from the acceptance guidelines of Reg. Guide 1.174 and addresses impact of the change on both core damage frequency (CDF) and large early release frequency (LERF).

Proposed Risk Metrics

The combined contribution to risk from break sizes greater than the alternative break size contribute less than 10^{-6} to total CDF and less than 10^{-7} to total LERF.

The proposed risk metrics are identified in Reg. Guide 1.174 as “Region III” and identify that region where the calculated increase in CDF or LERF is very small. Region III changes are considered regardless of whether there is a calculation of total CDF or total LERF.

The proposed risk metrics consider the impact of break-size redefinition on both CDF and LERF and as such provides a level of risk-insight beyond that which is obtained by consideration of CDF impact alone.

The proposed use of RG 1.174 metrics and associated guidance is also consistent with the SRM guidance, where it states:

> *Regardless of the specific approach, any proposed changes should be risk-informed and consistent with the principles of RG 1.174.*

PRA Scope, Level of Detail and Technical Acceptability – As identified in Reg. Guide 1.174 (Section 2.2.3):

> *The quality of a PRA analysis used to support an application is measured in terms of its appropriateness with respect to scope, level of detail, and technical acceptability. The scope, level of detail, and technical acceptability of the PRA are to be commensurate with the application for which it is intended and the role the PRA results play in the integrated decision process.*

While the specifics with respect to scope, level of detail and technical acceptability remain to ironed out, it is important for the measures of acceptability to have solid tie to the application ("commensurate with the application") and avoid a "high-bar" approach that sets expectations for scope, level of detail and technical acceptability that are unattainable at present and would potentially serve as a deterrent to plant-specific application of risk-informed changes to regulatory requirements.

The March 31, 2003 Option 3 SRM states, in regard to revision to Part 50:

> *The rule should be very specific, ensuring that the pertinent risk parameters are addressed and only the non-significant contributions to risk are handled through severe accident risk management.*

The proposed rule language avoids setting a basis that could lead to inconsistencies with other risk-informed activities and decisions.

Implementation and Monitoring Program

An acknowledged key element in risk-informed changes to plant design is the need to identify and monitor the aggregate effect of changes. This need is discussed in Section 3 of Reg. Guide 1.174, "Element 3: Define Implementation and Monitoring Program." As discussed in RG 1.174, an implementation and monitoring plan is necessary to ensure that the engineering evaluation conducted to examine the impact of proposed changes continues to reflect the actual reliability and availability of structures, systems and components that have been evaluated. The monitoring is also necessary to ensure that the conclusions that have been drawn from the evaluation remain valid. These considerations are directly applicable and will apply to the changes resulting from redefinition of the LB-LOCA break size.

Beyond monitoring of changes resulting from a redefinition of the LB-LOCA break size, consideration should also be given to broader monitoring of all plant design

changes (whether they are related to the original LB-OCA redefinition or not). It is anticipated that a "50.59" like process could be used to monitor and address the impact of plant design changes and modifications.

Examination of SRM Statement Related to LB LOCA Redefinition		
1.	**SRM, Page 1, paragraph 2** The staff should provide the Commission a comprehensive "LOCA failure analysis and frequency estimation" that is realistically conservative and amenable to decision-making subject to the comments and considerations noted below. Realistically conservative estimations, with appropriate margins for uncertainty, should be used. **Also see:** CVR, Diaz, paragraph 17	• Should be addressed as part of RES Expert Panel.
2.	**SRM, Page 1, paragraph 3** The staff should use a 10-year period for the estimation of LOCA frequency distributions, with a rigorous re-estimation conducted every 10 years and a review for new types of failures every 5 years. There should be careful consideration of the implications of the 10-year frequency for the reexamination of LOCA frequency distributions. Operational changes should be reversible if the re-estimation results in unacceptable LOCA frequency increases. The staff will define what is considered "acceptable." **Also see:** CVR, Diaz, paragraph 18	• "operational changes should be reversible" – tie-in to item 11 • Need to define threshold that would trigger reversal of change. • Impact of 10 yr. re-estimation could be evaluated using the same general process supporting original redefinition (e.g., RG 1.174)
3.	**SRM, Page 1, paragraph 4** The staff should conduct a practical reconciliation of LOCA frequency distributions by the 1) expert use of service-data, 2) Probabilistic Fracture Mechanics (PFM) and 3) expert elicitation to converge the results. Both service-data and PFM estimates should be "reduced" to an appropriate set by "expert discrimination" of what data should be treated. Not all data is "born" equally nor should it be treated equally. For the purpose of LOCA estimation, a better discrimination of failure data is needed before it is used as predictive data. Service-based LOCA estimates (a statistical analysis of service experience data) are more useful than PFM, especially if the projection is limited to 10 years. PFM (a phenomena-based method using fracture and failure analysis) can make a contribution, more so if it is used to selectively converge to service data predictions. **Also see:** CVR, Diaz, paragraph 18	• To be addressed by RES Expert Panel • It is important that that a "process" for re-estimation be defined to provide necessary stability

Examination of SRM Statement Related to LB LOCA Redefinition		
4.	**Consider an approach in which the alternative maximum LOCA to be included within the design basis is established on a plant-specific basis using some percentage of the total CDF risk, rather than the risk associated only with LOCAs.** **SRM, Page 2, paragraph 1** There are some operating plants for which the preponderance of the overall risk results from accidents other than LOCAs (e.g., all BWRs). Thus, defining the LBLOCA on a plant-specific basis in terms of only the LOCA contributors to risk will create significant differences from plant to plant. That is, a plant with small LOCA contributors to overall core damage frequency (CDF) would have to consider initiating events with much lower frequencies than plants with relatively large contributions from LOCAs to overall CDF. This would have the perverse result of penalizing a plant for which LOCAs already comprise a relatively small percentage of overall CDF. In order to avoid this dilemma, it might be appropriate to consider an approach in which the alternative maximum LOCA to be included within the design basis is established on a plant-specific basis using some percentage of the total CDF risk, rather than the risk associated only with LOCAs. **Also see:** CVR, Meserve, paragraph 4	• Industry proposed rule language and use of RG 1.174 structure and guidance is fully in line with SRM direction and avoids concern with potential disparate treatment between BWRs and PWRs • Use of 10-6 delta CDF/10-7 delta LERF thresholds instead of % total CDF avoids impact from changes to total CDF from unrelated causes.
5.	**SRM, Page 2, paragraph 1** Regardless of the specific approach, any proposed changes should be risk-informed and consistent with the principles of RG 1.174	• Industry proposed rule language and use of RG 1.174 structure and guidance is fully in line with SRM direction
6.	**SRM, Page 2, paragraph 2** Consider the full range of contributors to LOCAs, even if those contributors do not include actual pipe breaks. These include not only large pipe breaks, but also failures of large components, such as steam generator manways and reactor vessel head penetrations. **Also see:** CVR, Meserve, paragraph 5	• To be addressed by RES Expert Panel • Calculations supporting determination of alternate break size will need to address full range of contributors to LOCAs

Examination of SRM Statement Related to LB LOCA Redefinition		
7.	**SRM, Page 2, paragraph 3** The staff should credit leak-before-break considerations only in conjunction with the establishment by a licensee of reliable and comprehensive means to detect primary system leaks of the relevant size. **Also see:** CVR, Meserve, paragraph 6 CVR, Diaz, paragraph 19	
8.	**SRM, Page 2, paragraph 4** The staff should use expert elicitation to converge (whenever possible) service-data and PFM results to provide the Commission a comprehensive "LOCA failure analysis and frequency estimation" predictive envelope that is realistically conservative.	• Should be addressed as part of RES Expert Panel.
9.	**SRM, Page 2, paragraph 5** The staff must establish the appropriate risk "cutoff" for defining the maximum LOCA size. The risk metric recommended by the staff should take into account the uncertainties in PRA analysis as well as the uncertainties in estimating the initiating event frequencies for rare events (e.g., 95% probability with a 95% confidence limit). **Also see:** CVR, Meserve, paragraph 8	• The proposed risk metrics from RG 1.174 along with associated guidance on addressing PRA uncertainties provides a good starting basis. Additional, application specific guidance can be developed.

Examination of SRM Statement Related to LB LOCA Redefinition		
10.	**SRM, Page 2, paragraph 6** In parallel with the above technical work, the staff should prepare a proposed rule change to 10 CFR Part 50 that allows for a risk-informed alternative to the present maximum LOCA break size. The rule should be very specific, ensuring that the pertinent risk parameters are addressed and only the non-significant contributions to risk are handled through severe accident risk management. For example, the modified definition of the LOCA, for use throughout Part 50 and wherever applicable, could read: Loss of coolant accidents (LOCA). Loss of coolant accidents mean those postulated accidents that result from the loss of reactor coolant at a rate in excess of the capability of the reactor coolant makeup system from breaks in the reactor coolant pressure boundary up to and including a break equivalent in size to the double-ended rupture of the largest pipe of the reactor coolant system *or up to an alternate maximum break size determined by including at least XX% [e.g., 95%, 96%...] of the LOCA failure contributors to core damage frequency.* **Also see:** CVR, Diaz, paragraph 22	• The proposed rule change, use of RG 1.174 risk metrics and guidance, meet the intent of SRM guidance.
11.	**SRM, Page 3, paragraph 2** While pertinent changes in the design basis and associated analysis would be expected to occur naturally, the Commission agrees with the staff that changes in hardware and operation "would require that it be demonstrated that the ECCS functional reliability is commensurate with the frequency of accidents in which ECCS success would prevent core damage or a large early release". The Commission does not support changes to functional requirements unless they are fully risk-informed and protective of public health and safety. For example, the Commission would not support actual changes to ECCS coolant flow rates or containment capabilities to mitigate accidents, but would support changes that provide for risk-informed sequencing of equipment with demonstrated functionality and reliability requirements that arise from the alternate criteria. The staff should maintain similar margins in future plant design certifications, even if we ultimately adopt a revised LBLOCA definition. **Also see:** CVR, Meserve, paragraph 7 CVR, Diaz, paragraph 24	• The scope of plant design changes that could be considered as part of a redefined LBLOCA could be addressed during the rulemaking process as part of the statements of consideration associated with the rule. • Further definition of allowed changes could be addressed as part of implementation guidance.

Examination of SRM Statement Related to LB LOCA Redefinition		
12.	**SRM, Page 3, paragraph 3** The redefinition of the LBLOCA would also require strict configuration controls and a high quality PRA, including low power and shutdown operations. In establishing guidance for these configuration controls, the staff should, to the maximum extent practical, make use of the existing regulatory infrastructure provided through the Reactor Oversight Process, the Maintenance Rule and Regulatory Guide 1.174. Once the appropriate standards are in place, the PRA should be a level 2 internal- and external-initiating event all mode PRA, which has been subjected to a peer review process and submitted to and endorsed by the NRC. **Also see:** CVR, Diaz, paragraph 25	• Proposed process, consistent with SRM, would make full use of existing guidance via RG 1.174.
13.	**SRM, Page 3, paragraph 4** The technical basis supporting the LB-LOCA break size redefinition, supported by a 10-year estimation of LOCA frequencies, should be completed by March 31, 2004. The proposed rule changes should be provided to the Commission.	• Capability to meet 3/31/2004 date is enhanced through use of existing guidance (e.g., RG 1.174)
14.	**SRM, Page 4, paragraph 4** …licensees who seek to benefit of the changes that redefine the design basis LBLOCA requirements should be required to use best-estimate codes. The staff should include such a modification in the proposed 10 CFR 50.46 rulemaking. **Also see:** CVR, Meserve, paragraph 15 CVR, Dicus, paragraph 4	• Expectations regarding code methods, scope of changes and PRA quality can be addressed via statements of consideration associated with rule change and application specific guidance.
15.	**CVR, Diaz, paragraph 26** The conservative CDF and LERF safety criteria of Option 3, and particularly the capability of Reg. Guide 1.174 to deal both with absolute (CDF) and relative (delta-CDF) changes, are essential to effect an alternative break size with reasonable assurance of adequate protection.	• NEI proposal consistent with CVR comment.