APPENDIX B

GENERAL PRA MODELING CONSIDERATIONS

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The PRA models used to demonstrate ECCS safety function reliability in a risk-informed ECCS application would typically need to meet the Capability II requirements of the ASME PRA Standard as expected to be endorsed (with exceptions, if necessary) by the NRC in a forthcoming regulatory guide. Some additional modeling issues that would need to be addressed for this specific application, since they may have a significant impact on the results, are discussed below.

Dynamic Effects

Dynamic effects of LOCAs include pipe whip, jet impingement, and asymmetric loads on reactor coolant system components. Leak-before-break analyses have been used to exclude dynamic effects from the design basis. However, the LOCAs modeled in PRAs are representative of fast developing RCS failures where leak-before-break arguments may not be applicable to exclude all dynamic effects. Despite this fact, dynamic effects initiated by LOCAs have generally not been addressed in past PRAs. For risk-informed ECCS applications, the potential for the dynamic effects of LOCAs causing additional failures that could significantly affect LOCA progression and ECCS response should be examined and included in the PRA as appropriate. Modeling of dynamic effects should include any degradation of vessel internals or RCS components that have been identified. The presence of engineered features to minimize the impact of dynamic effects (e.g., pipe supports and jet impingement shields) provides acceptable reasons for excluding the applicable dynamic effects from the PRA evaluation.

Single or multiple steam generator tube ruptures could occur as a result of a LOCA or main steamline break. The influx of secondary water into the RCS during a LOCA can result in steam binding that prevents or delays core reflooding to the extent that core damage occurs. In addition, the rupture of the tubes during either a LOCA or main steam line break will provide a containment bypass path should core damage occur. The potential for these phenomena may need to be included in the PRA as appropriate, depending on the extent of tube degradation at a particular plant.

Delayed LOOP

Currently, a simultaneous loss of offsite power (LOOP) must be postulated in design-basis LOCA analyses. However, the electrical disturbance triggered by the LOCA and the conditions of the offsite transmission-system grid can contribute to the occurrence of a LOOP. Since this LOOP occurs as a consequence of the LOCA, it is called a consequential LOOP. Also, the LOOP does not occur simultaneously with the LOCA, but some time elapses during the electrical disturbance after the LOCA. For this reason, this LOOP also is called a delayed LOOP.

The likelihood and timing of delayed LOOP are plant-specific. They depend on the status and configuration of the surrounding grid, the timing of separation of the plant generator from the grid, the timing of bus transfers, and the time delays incorporated into loss of voltage and degraded voltage relaying.

NUREG/CR-6538 [Ref. B.1] analyzed and evaluated the risk-impact of Generic Safety Issue (GSI) 171, "Engineered Safety Features Failure from Loss-of-Offsite-Power Subsequent to a Loss-of-Coolant Accident," which included the study of a delayed LOOP, and found that if a LOOP occurs as a consequence of a LOCA, it is most likely to be delayed. Issues related to safety that were identified by GSI 171 are: overload of emergency diesel generators (EDGs), block-loading of ECCS loads, non-recoverable-damage to EDGs and ECCS pump motors, lockout energization of safety loads, lockup of the load sequencers, double sequencing, water hammer, pumps tripping on overload, and switchyard undervoltage.

The results of a survey of the computerized IPE Data Base [Ref. B.2] and individual reviews of 20 IPEs, as reported in NUREG/CR-6538, indicate that the “IPEs do not model nor do they discuss LOCA/LOOP, i.e., LOCA with consequential or delayed LOOP, along with the GSI-171 concerns relating to damage to EDGs and ECCS pumps, nor the loss of this equipment due to overloading, lockup of the load sequencer, and lockout energization of breakers.” Additional issues related to delayed LOOP are also likely not to have been addressed in typical PRAs, for example:

- Impact of degraded voltage during the first start of an ECCS pump motor on its reliability during a successive start
- Capacity of the Class 1E DC batteries to handle successive restart of the ECCS equipment
- Water hammer effects in systems with the potential for restarting with voids in the outlet piping
- Flashing of containment coolers

Issues associated with a delayed, consequential LOOP should be addressed in an ECCS-reliability application, and included in the PRA as appropriate.

Credit for Non-ECCS Systems

In demonstrating that the ECCS functional reliability is commensurate with the frequency of accidents in which ECCS success would prevent core damage, it is currently envisioned that non-ECCS systems would be credited in risk evaluations. However, sensitivity studies to examine the affect of crediting non-ECCS systems would also be required. Credit for non-ECCS systems in PRAs for providing coolant to the core can significantly affect the importance of the ECCS. If the staff allows credit to be given for a non-ECCS system in PRA evaluations to support a risk-informed ECCS application, adequate justification should be provided to show the system can provide the necessary coolant flow. Use of best-estimate thermal-hydraulic calculations is an acceptable method. In addition, the use of the system in the scenarios modeled in the PRA must be directed by the plant procedures and be possible considering the time available to prevent core damage. The assigned human error probabilities for failing to initiate the system must properly reflect the procedural guidance and training as well as the timing and factors present during the accident scenarios. In addition, if credit for a non-ECCS system is used in the PRA model to justify a change to an ECCS system, the non-ECCS system may need to be subjected to an increased level of regulatory treatment.

References

B.1 Martinez-Guridi, G., et al., “Evaluation of LOCA With Delayed LOOP and LOOP With Delayed LOCA Accident Scenarios,” NUREG/CR-6538, BNL-NUREG-52528, Brookhaven National Laboratory, Upton, New York, July 1997.

B.2 Lehner, J., et al., “IPE Data Base: Plant Design, Core Damage Frequency and Containment Information,” Proceedings of 23rd Water Reactor Safety Information Meeting, NUREG/CP-0149, Vol. 2, p. 505, 1995.