High-Pressure Core Spray Executive Summary

This report presents a performance evaluation of the high-pressure core spray (HPCS) system at eight U.S. commercial boiling water reactors (BWRs) that have this system. The evaluation is based on the operating experience from 1987 through 1993, as reported in licensee event reports (LERs). The objectives of the study were (a) to estimate the system unreliability based on 1987–1993 experience and to compare these estimates with the assumptions, models, and data used in Probabilistic Risk Assessments and Individual Plant Examinations (PRA/IPEs) and (b) to review the operational data from an engineering perspective to determine trends and patterns in the data and obtain insights into the failures and failure mechanisms associated with the HPCS system.

The study used LERs identified using the Sequence Coding and Search System (SCSS). The SCSS database was only used to identify LERs for review and classification for the study. The reportability requirements of 10 CFR 50.73 (LER rule) were not used to define or classify any events used in the study. The full text of each LER was independently reviewed by a team of experienced U.S. commercial nuclear power plant engineers from a risk and reliability perspective. Each event was either excluded from the study or classified and subsequently used in the study based on this independent review of the full text of the LER.

The HPCS system unreliabilities were estimated using a fault tree model to associate event occurrences with broadly defined failure modes such as failure to start or failure to run. The probabilities for the individual failure modes were calculated by reviewing the failure information, categorizing each event by failure mode, and then estimating the corresponding number of demands (both successes and failures). Seven plant risk reports (i.e., PRAs, IPEs, and NUREGs) were used for comparison with the HPCS reliability results calculated in this study. The information extracted from the source documents contains data for the eight plants that have an HPCS system.

Since there are only eight U.S. BWR plants that have an HPCS system, the operating experience data, including demand counts, failure counts, and run times, for estimating HPCS system unreliability are limited. However, there is sufficient data to reasonably estimate the reliability of the system and its associated uncertainties, but information regarding dominant contributors and trends are less robust and could change as additional experience is obtained.

The notable observations and findings made from the limited data are as follows:

- The mean HPCS system operational unreliability (including recovery) estimate calculated from the 1987–1993 experience is 0.075. None of the actual HPCS demands to operate involved a loss of offsite power requiring the Division III emergency diesel-generator to energize the bus, nor did any last long enough to require pump suction transfer to the suppression pool. Only one demand failure was observed during 29 operational demands and accounted for 67 percent of the total system unreliability. This failure occurred in the injection subsystem as a result of the system being in a maintenance-out-of-service condition when the system was demanded. The only other failure used in the operational unreliability estimate occurred during quarterly testing and had less impact on the estimate, accounting for only 7 percent of the total system unreliability.

- HPCS unreliability estimated from the 1987–1993 experience for comparison with PRA/IPE results and the HPCS unreliability calculated from the PRA/IPE data are plotted in Figure ES-1. For missions typical of those considered in PRAs and IPEs, the operational-data based unreliability is 0.23. This is higher than the equivalent unreliability estimated using the PRA/IPE data. The unreliability of the injection subsystem estimated from the operational experience is a

factor of five higher than that estimated using the PRA/IPE data. The difference in the estimates is primarily attributed to a factor of 50 difference in the average hourly failure rates used in calculating the HPCS injection pump failure to run (FTR) probability.

- The PRA/IPE data appear to use generic FTR data for all pumps rather than plant-specific (or system-specific) data. The operating experience data for the HPCS showed no failures in a total of 316 hours of run time, primarily consisting of runs of one hour or less. The operational experience failure rate was estimated from this limited data and was assumed to remain constant for a typical PRA/IPE mission requirement of 24 hours. Thus, the operating experience estimate for FTR may be pessimistic. Additional data is necessary to ascertain whether the differences between the reliability estimates based on the operating experience data and the PRA/IPE data are real or an artifact of the limited available data.

- There was only one failure in 29 unplanned demands and one failure in a total of 299 test demands that were used in the estimation of the system operational reliability over the seven year period of this study. From this limited data, no trends over time for the reliability would be expected to be observed. None were observed in the statistical analyses of the unreliability versus calendar year, and none in the unreliability versus plant age (see Figures ES-2 and ES-3).

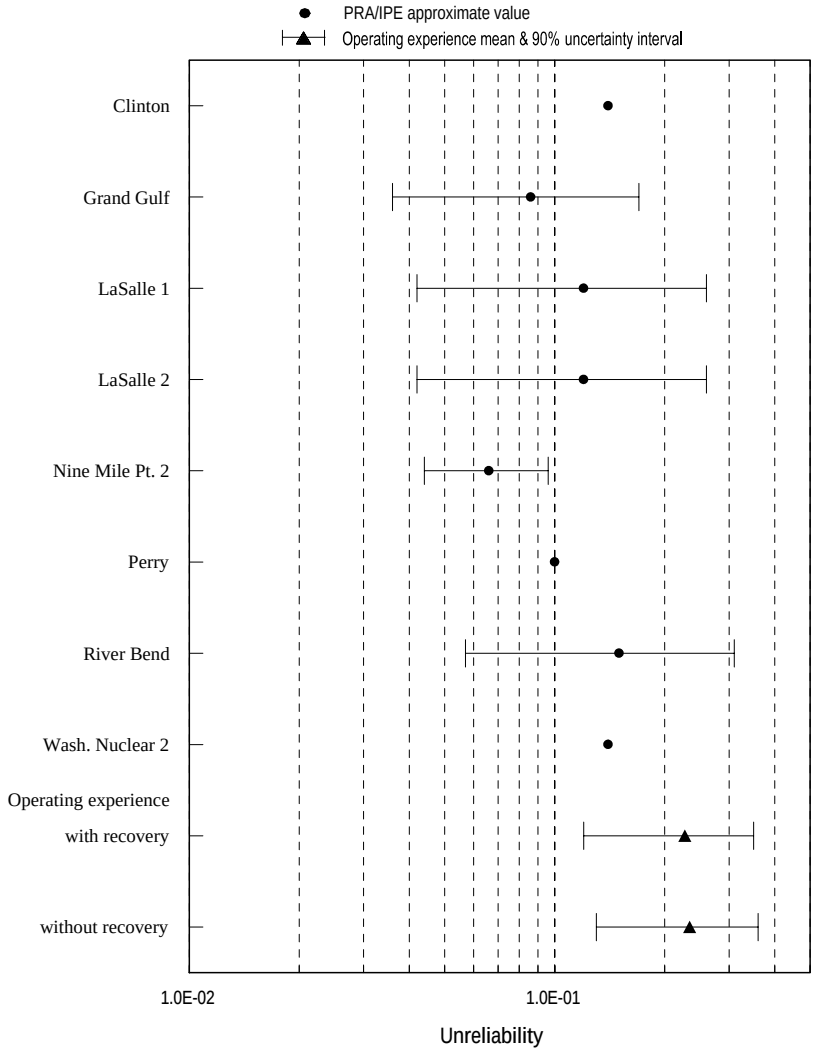

Figure ES-1. Plot of the PRA/IPE and industry-wide (derived from the 1987–1993 experience) estimates of HPCS unreliability and uncertainties based on system operation for 24 hours. (No plant-to-plant variation was observed in the 1987–1993 experience; therefore, the industry mean and uncertainty derived from the 1987–1993 experience applies to all plants.)

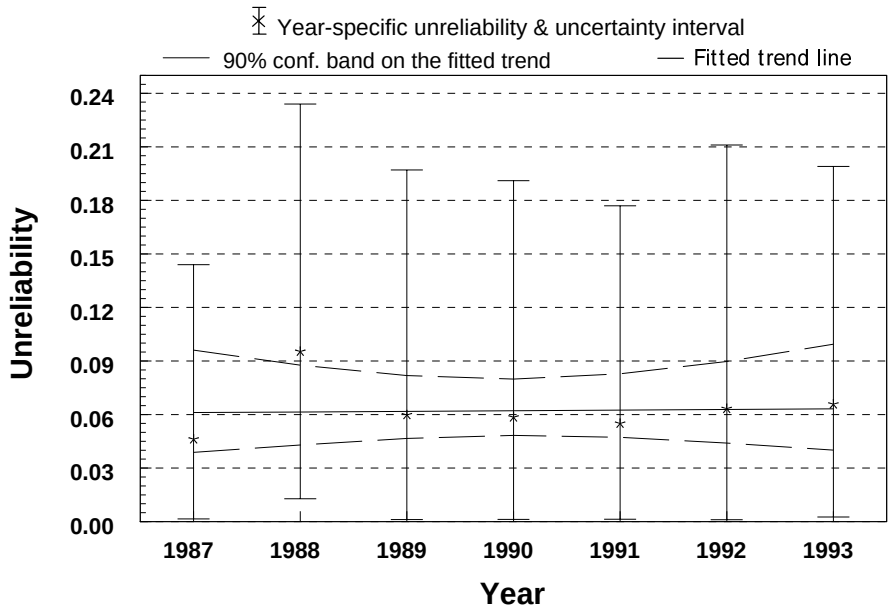

Figure ES-2. HPCS system unreliability by calendar year, which includes recovery actions. The plotted trend is not statistically significant (P-value = 0.91).

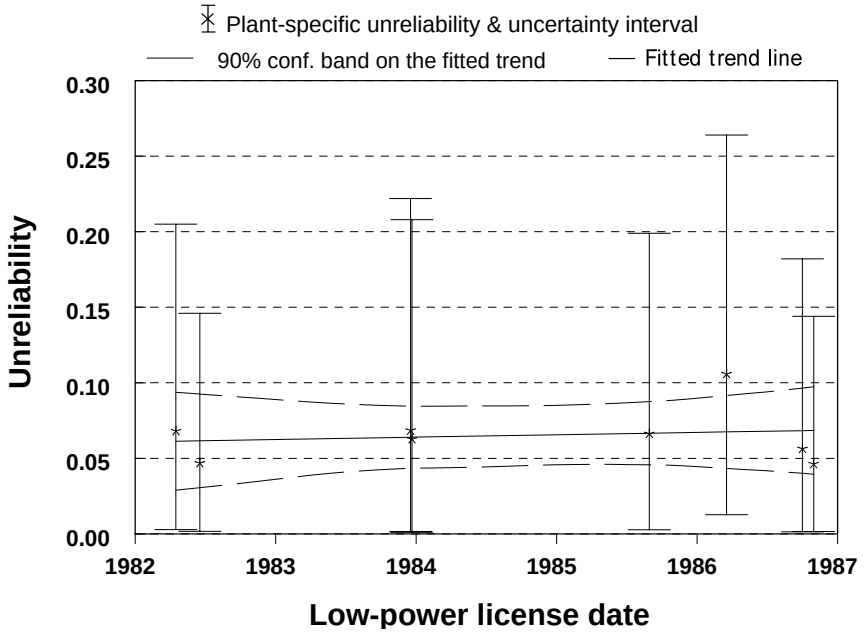

Figure ES-3. Plant-specific HPCS system operational unreliability plotted by low-power license dates. The plotted trend is not statistically significant (P-value = 0.71).