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SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATING TO COMBUSTION ENGINEERING OWNERS GROUP

STEAM GENERATOR OVERFILL PROTECTION (GL 89-19)

PALISADES PLANT

DOCKET NO. 50-255

1.0 BACKGROUND

Pressurized water reactor steam generator (SG) overfill events have been identified by the NRC as potentially significant transients that could lead to unacceptable consequences. Review of how control systems failures contribute to these events was, therefore, a major part of the Unresolved Safety Issue A-47 program. This program evaluated control system failures that could be more severe than those previously analyzed in the Final Safety Analysis Report. NRC studies identified four potentially safety-significant failure scenarios for Combustion Engineering (CE) plants, two of which lead to overfilling the SG via the main feedwater system.

In response to the above concern, a CE Owners Group (CEOG) study of the operating experience was conducted for their plants. In all cases, the overfilling events were terminated by the control system or operator action. The study results were based on core-melt frequency and risk calculations performed for a generic plant. Adjustments were then made to the calculated values as necessary to account for plant-specific design differences.

The specific core-melt scenario of concern is an overfeed event which leads to flooding of the steamline with relatively cold feedwater, a possible water hammer, an unisolable main steamline break (MSLB) outside containment, multiple steam generator tube ruptures (SGTRs), and failure of emergency core cooling due to exhaustion of the refueling water storage tank (RWST) inventory. These overfill scenarios for CE plants are analyzed in NUREG/CR-3958, "Effects of Control Systems Failures on Transients, Accidents and Core-Melt Frequencies at Combustion Engineering Pressurized Water Reactors," dated March 1986. The estimated core-melt frequency due to overfill is approximately $4X10^{-6}$/yr. A summary of the key aspects of this estimate is shown in Table 1.

To reduce the risk from SG overfill, Generic Letter (GL) 89-19 recommends that all CE plants provide an automatic SG overfill protection system to mitigate main feedwater (MFW) overfeed events. Also, it recommends that procedures and technical specifications for all CE plants include provisions to periodically verify the operability of overfill protection and ensure that automatic MFW overfill protection is operable during reactor power operation.

CE-designed plants, except Palo Verde and St. Lucie, do not provide automatic SG overfill protection. By letter dated October 31, 1990, and during a subsequent meeting on November 20, 1990, the CEOG questioned the assumptions and information used in the cost/benefit analysis done to justify the recommended changes to the design of CE plants. The CEOG concerns on this issue are discussed below.

2.0 DISCUSSION

The recommendations in GL 89-19 for CE plants are based on the probabilistic risk assessment and value/impact analysis of control system failures performed by Pacific Northwest Laboratories (PNL) for the NRC in NUREG/CR-3958. The dominant scenario for core-melt risk identified in this report is a result of an SG overfill caused by control system failures. As the overfill occurs, water spills into the steamline eventually causing an MSLB at a non-isolable location, an SGTR or multiple SGTRs, and failure of emergency core cooling. The CEOG believes that PNL made several inappropriate assumptions related to the likelihood of events in the above scenario. If more realistic assumptions had been used in NUREG/CR-3958, the results would have been significantly different and would not have justified the recommended changes to CE plants. The pertinent assumptions and information provided by the CEOG are discussed below.

(1) Probability of SGTR

NUREG/CR-3958 used the draft NUREG-0844, "NRC Integrated Program for the Resolution of Unresolved Safety Issues A-3, A-4, and A-5 Regarding Steam Generator Tube Integrity," dated April 1985, which established the probability of tube rupture due to an MSLB as 0.034. The total probability of tube rupture due to an MSLB was revised to 0.0505 in the final NUREG-0844 report, dated September 1988. Although the overall SGTR probability was increased, the probability of rupturing greater than 10 SG tubes was decreased by nearly an order of magnitude, to 0.0005 from 0.003. The core melt estimate is dominated by the sequence of rupturing greater than 10 SG tubes and the shorter time to exhaust the RWST inventory. CE stated that replacing pertinent probabilities with revised information from the final NUREG-0844 report results in a reduction in exposure in NUREG/CR-3958 from 570 person-rem to 183 person-rem. Based on $1000/person-rem, this benefit is below the approximate cost of installation of an overfill protection system of $200,000 that NRC concluded was appropriate in NUREG-1218, "Regulatory Analysis for Resolution of USI A-47," dated July 1989.

(2) Probability of MSLB Given SG Overfill

The core damage estimates of NUREG/CR-3958 depend on the assumption that an MSLB will occur 50% of the time that an SG overfill event occurs. PNL recognized the important role of this assumption in Section 2.2.2 of NUREG/CR-3958 and stated that it is used to be consistent with previous value/impact analyses. The CEOG states that "if an MSLB probability of 0.001 given overfill is used, the estimate of core melt and risk drops by several orders of magnitude, making any cost-effective modifications difficult. The significance of the overfill scenarios and any need for plant changes must be evaluated in light of this uncertainty in the potential for MSLB."

The SG tube integrity program (final NUREG-0844) uses a 0.001 probability for MSLB from overfill following an SGTR. However, it should be noted that if the main steamline is flooded as a result of an SGTR as opposed to an overfeeding event, the water entering the steamline is saturated or nearly saturated. This has a much lower probability of resulting in a water hammer that causes an MSLB than an SG overfill event caused by subcooled water entering the steamline due to a control system malfunction. NUREG-1218 indicates that 0.5 is conservative and on the basis of actual experience the best estimate of conditional probability of MSLB (given overfill) is 0.13. NUREG-1218 goes on to state that if the probability of an MSLB event was further reduced by an order of magnitude, the proposed design could not be justified.

As can be seen, the estimate for probability of an MSLB has a wide range, from 0.5 to 0.001, with 0.13 being the best estimate of conditional probability. Using the 0.13 estimate, the averted risk would be reduced to about 120 person-rem.

(3) <u>MSLB Location</u>

The core-melt sequence of concern occurs as a result of a loss of reactor coolant system (RCS) inventory through an unisolable steamline break (in conjunction with SGTRs) which eventually exhausts the RWST inventory. The steamline break location probability is based on the assumption that an MSLB has an equal probability of occurring upstream or downstream of the main steam isolation valve (MSIV).

In reality, the MSIV is located relatively close to the outside containment wall. As a result, the majority of piping upstream of the MSIV is located inside containment. If the MSLB occurred inside containment, water lost through the break would be collected in the containment sump and would be available for recirculation. Thus, core melt should not occur without additional failures.

NUREG/CR-3958 assumes that an MSLB occurs upstream of the MSIV with a probability of 0.5. The CEOG estimates that the probability should more appropriately be the ratio of the main steamline piping length outside containment up to the MSIV, to the total main steamline piping up to the MSIV. Although this ratio is plant specific, the CEOG revises the probability of occurring upstream of the MSIV, but outside containment, to 0.16. The estimated risk would be reduced by about a factor of 3.

(4) <u>Credit for Operator Action to Prevent Core Melt</u>

The CEOG states that the analysis in NUREG/CR-3958 assumes that if an MSLB occurs in an unisolable location and SG tubes are ruptured, then core melt is inevitable. No operator recovery actions are credited. However, since it would take many hours to exhaust the RWST inventory, operator actions are possible to prevent core melt. Depressurization of the RCS would slow the inventory loss and prevent core melt. Since the steamline break and tube ruptures would themselves cause a depressurization, the RCS would reach low pressures in a relatively short period of time. In the NUREG-0844 report, Sequence 8C uses a value of 0.5 for operator failure based on an estimate for

Westinghouse plants with 20 ruptured tubes where pressure drops to the point that low pressure safety injection pumps inject. The CEOG believes that an unrealistically high flow rate is assumed which would not be applicable to CE plants. Therefore, CE believes that crediting operator recovery action would reduce the likelihood of core melt by at least a factor of 100. In the core-melt sequences for the events of a single SGTR, multiple SGTRs (2 to 10 tubes), and large multiple SGTRs (more than 10 tubes), values of 1.0E-3, 1.0E-2 and 0.5, respectively, are used for an operator failing to depressurize the RCS before the RWST is exhausted. This is based on having many hours to manually act before the RWST is emptied, as would be the case for all CE plants. With a more realistic operator failure probability selected, the exposure reduction due to installation of an overfill protection system could be decreased from 570 person-rem to 112 person-rem.

(5) Negative Impact of Spurious Operation

The automatic feedwater pump trip function can itself cause a loss of feedwater accident due to spurious actuation or testing failures. The CEOG believes that adverse consequences can also result from spurious actuation during other accidents.

To minimize a loss of feedwater accident due to spurious actuation or testing failures, GL 89-19 recommends that CE-designed plants provide water-level sensors with a coincident logic to isolate MFW flow on an SG high-water-level signal. Also, it is recommended that the overfill protection system be separated from the feedwater control system. Nevertheless, there would be some increase in risk from spurious actuations caused by the addition of automatic overfill protection to a plant design. A scoping analysis provided by the CEOG estimates an increase in core-damage probability of $1.4X10^{-6}$/yr due to testing of this feature at power.

3.0 CONCLUSION

The original cost/benefit analysis, as discussed in NUREG-1218, resulted in an estimated 570 person-rem risk reduction with a $200K proposed design fix cost. As stated above, this estimate depends on the probability of an MSLB, the MSLB location, the probability of an SGTR involving 10 or more tubes and the probability of the operator failing to properly respond. Our review of the CEOG information and the above NUREG/CRs and NUREGs indicates that overly conservative estimates and steamline break location assumptions were made that unduly influenced the risk estimate. We conclude that:

(1) the MSLB probability is very likely lower than 0.5

(2) the probability of an MSLB outside containment, but upstream of the MSIV, is lower than 0.5

(3) based on the final NUREG-0844, the probability of an SGTR involving 10 or more tubes, given an MSLB, is less than 0.034.

We conclude that the core-melt frequency for the likelihood of this sequence is closer to, and very likely less than $1X10^{-6}$/yr, rather than the $4X10^{-6}$/yr

TABLE 1

NUREG/CR-3958 Estimate of Core Melt Frequency from Overfill Events

Probability of overfill after reactor trip/turbine trip due to feedwater failure	$9X10^{-2}$/yr
Probability of failure of operator to terminate overfill	0.1
Probability of main steamline break (MSLB) given overfill	0.5
Probability of break being unisolable and outside containment	0.5
Conditional probability of core melt given MSLB* resulting from steam generator tube rupture and loss of RWST inventory	$1.7X10^{-3}$

Total CMF = $(9X10^{-2}/yr)\ (0.1)\ (0.5)\ (0.5)\ (1.7X10^{-3}) = 4x10^{-6}/yr$

*MSLB inboard of MSIV

Number of Steam Generator Tubes Ruptured	Probability of Rupture	Probability of Loss of RWST	Probability of Failure to Isolate SG	Net Core Melt Probability
1	0.017	$1X10^{-3}$	1	$1.7X10^{-5}$
2 to 10	0.014	$1X10^{-2}$	1	$1.4X10^{-4}$
10	0.003	$5X10^{-1}$	1	$1.5X10^{-3}$
Total	0.034		Total	$1.7X10^{-3}$