FEEDWATER SPARGER DAMAGE

SAFETY ASSESSMENT

FOR

NCR 88-0321

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1.0 INTRODUCTION:

On Saturday, April 23, 1988, at approximately 1730 hours, the Unit 2 reactor internals were being reinstalled following completion of core reload during the second refueling outage. During the shroud head (steam separator) installation, the guide rods were not engaged in the shroud head guide rod lugs prior to lowering into the vessel. As a result the weight of the shroud head was applied to the feedwater spargers and three nozzles each on two spargers were crushed. The incident is detailed in Reference 3.2.

Following the incident, the shroud head was removed to its storage pool. Detailed visual inspections were performed to determine the extent of damage. Only the C&F spargers (3 nozzles each) and one shroud head guide lug were found to be damaged. The guide lug damage is documented in the Reference 3.9 NCR. Additional information on the observed damage can be found in Section 4.2.

The following assessment is narrowly focused on nuclear safety issues. No consideration of issues such as commercial risk, reliability of generation, or personnel safety are expressed.

2.0 SUMMARY:

Nuclear Design, Engineering Operations, Nuclear Fuels and System Engineering, and the General Electric Company have performed extensive reviews of the damage to the feedwater spargers and associated equipment. As a result, PP&L is performing a repair DCP on one nozzle to close a tear which could have caused cooler water jetting on reactor internal surfaces. We are also performing a controlled installation of the shroud head with video inspections to ensure proper fit-up. All other damage has been determined to have no adverse safety consequences on plant operation for one additional fuel cycle. We are also installing an instrumentation package which will monitor feedwater thermal sleeve piston seal leakage (see Reference 3.6). This information combined with additional inspection results obtained during the next refueling outage will assist in producing a final disposition.

3.0 REFERENCES:

3.1 GE Report RDE-16-0588/DRF B11-00419 "Susquehanna Unit 2 Feedwater Sparger Damage Assessment"

3.2 "Moisture Separator Incident", PLIS 30166, K. W. Chambliss, May 10, 1988

3.3 "Separator Event Recovery Invessel Inspection Results", PLIS 30174, J. T. Lindberg, May 13, 1988

3.4 "Deformed Sparger IGSCC Probability", PLI-55572, L. E. Willertz, May 23, 1988

3.5 (Deleted)

3.6 DCP 88-3028, "Feedwater Nozzle Surveillance Instrumentation System"

3.7 DCP 88-3029, "Feedwater Sparger Nozzle Repair"

3.8 "Feedwater Sparger Damage and Repair Assessment" PLI-55562, J. G. Refling, May 23, 1988.

3.9 NCR 88-0337, Shroud Head Damage

3.10 NCR 88-0321, Feedwater Sparger Damage

4.0 DISCUSSION:

The following sections detail the technical issues associated with sparger damage.

4.1 Design Basis of Sparger:

G.E has provided the information summarized in this section in Reference 3.1. The feedwater sparger is a non-safety related, non-code, reactor internal component. The purpose is to distribute feedwater in the vessel. It also provides a flowpath for HPCI (spargers A, B & C) and RCIC (spargers F, E & D). The non-safety classification was based on the absence of failure modes that could prevent the performance of the HPCI/RCIC safety function.

The physical arrangement of the sparger is as follows: Six spargers comprise a segmented circle around the Reactor Pressure Vessel (RPV) above the core in the area where recirculating coolant flows downward from the dryer and steam separators. Each sparger is made of two arms welded to a tee in the middle. The arms are 6" schedule 80s pipe with 9 top mounted orificed elbows. The orifices are either 1.25 or 1.75 inches and are aimed toward the center of the RPV. The branch side of the tee is fitted with a triple thermal sleeve to protect the RPV nozzle and safe-end from fatigue damage induced by the relatively cool feedwater flowing past the hot vessel wall. The thermal sleeve is interference fit into the nozzle safe end in the piston seal housing area. There is a primary seal and a secondary seal. Any leakage past the primary is routed between the thermal sleeves and the feed pipe. A secondary seal is provided to prevent leakage between the thermal sleeve outer surface and the RPV nozzle.

The purpose of the spargers is to uniformly distribute feedwater within the reactor so that recirculating water will be a homogenous mixture. By mixing incoming feedwater with saturated water rejected from the steam separators and dryer, adequate subcooling is assured for jet pump and recirculation pump NPSH. The spargers also prevent the cooler feedwater from impinging directly on hotter RPV surfaces thereby preventing high cycle fatigue damage. The sparger design bases are: to provide core inlet enthalpy uniform within 0.2 percent, and to operate with less than 25 psi sparger differential pressure at 105% of rated flow.

4.2 Damage to Sparger:

After the NCR was generated, many remote underwater visual examinations were performed to detail the extent of damage. These are documented in Reference 3.3. There are areas which are inaccessible for inspections where damage can only be inferred by calculation.

The visible damage included six sparger nozzles (three on each side separated by 180°). Five of these show partially closed orifices while one (169° Azimuth) is severely crushed and has a tear that appears to have been made by the corner of the shroud head guide rod follower.

Calculated damage is predicted to have occurred at the sparger pipe, the thermal sleeve seal housing and the shroud head guide rod follower. The sparger and thermal sleeve damage are assessed in Section 4.4 and 4.5, respectively. The shroud head damage is the subject of NCR 88-0337 (Reference 3.10).

4.3 Sparger Nozzle Integrity:

There are two concerns with sparger nozzles. First, the most severely damaged orificed elbow assembly, "C2S", has been torn by the shroud head guide rod lug. The tear is about 1-1/2" long and is located on top of the elbow. The tear is unacceptable and will be repaired by underwater welding per reference 3.7. The second concern is that this nozzle, as well as the five other damaged nozzles, has been cold worked. Cold work in the range seen here has caused IGSCC in 316L stainless steel in the laboratory. Based on the evaluation in Reference 3.4, it is likely that some cracking will occur, but no through-wall cracks or lost parts are expected.

4.4 Sparger and Support Integrity:

Stress calculations were performed on the feedwater sparger to determine the nature of damage (Reference 3.1). A finite element model of the sparger was created and loaded with half the weight of the shroud head less buoyancy. The load was applied at the centerline of the third sparger nozzle from the end (the farthest from the supports). At the thermal sleeve, two sets of support conditions were run to bound the loads and deflections. The results predict local yielding in the sparger pipe near the point of load application. The loads generated at the thermal sleeve were used to predict leakage (see Section 4.5). The loads at the ends of the sparger pipes were used to evaluate the end brackets and the support brackets welded to the RPV wall. The resultant stresses in the brackets were well below the material yield strength. The load to the RPV nozzle was found to be small compared to the yield strength.

4.5 <u>Seal Leakage and Consequences</u>:

Using the finite element model described in Section 4.4, an estimate of seal housing deflection was made. Using conservative assumptions, an upper bound leakage estimate of 0.201 gpm was calculated. This leakage rate was used to perform high cycle fatigue usage calculations for the RPV nozzle. The additional fatigue usage for one fuel cycle is very small. Assuming leakage exceeds the estimate, the worst consequence would be high cycle fatigue cracks on the bore of the nozzle. The maximum depth would be 1/4" in one fuel cycle. Major stress cycles could propagate such cracks at most 0.04 inches. Therefore cracking due to leakage of the piston seals is not a safety concern.

In order to assess actual seal leakage, the G.E. leakage surveillance instrumentation package is being installed per DCP 88-3028 (Reference 3.6). This information will be factored into future corrective actions such as seal refurbishment or sparger replacement.

4.6 <u>Nozzle Repair Leakage</u>:

In the unlikely event of a failure of the tear weld repair, a path for cold water jetting could open. This could impinge on hot RPV interior surfaces. The effect would be similar to excessive piston seal leakage and in the extreme case could lead to cracks with a maximum depth of 0.25". Refer to Section 4.5 for more details of high cycle fatigue and the reasons these cracks do not pose a safety concern.

4.7 <u>Thermal Hydraulics</u>:

The thermal hydraulic performance of the damaged spargers was evaluated in four areas: design basis pressure drop and differential enthalpy, steady state plant operation, transient operations, and HPCI/RCIC operation. See reference 3.8 for more information.

The damaged spargers were evaluated using the original sparger design code by GE. Even in the damaged condition, differential pressure and core inlet enthalpy variations are within acceptance criteria (Reference 3.1).

Normal plant operations will not be affected by the sparger damage because the increased pressure drop is within the feedwater system design basis.

All plant transients were reviewed to determine whether sparger damage could affect expected results. For all events, the severity of the transient is either unchanged or reduced due to increased pressure drop.

The affect of sparger damage on HPCI and RCIC flowrate was also examined. Due to significantly lower flowrate of these systems as compared to feedwater, and the small increase in differential pressure at rated flow, sparger damage will have negligible impact on HPCI or RCIC performance.

4.8 Lost Parts Analysis:

A lost parts analysis was performed. Lost parts are not expected to occur. Postulated lost parts from the damaged sparger nozzles have the potential to perturb jet pump flow resulting in a forced outage, cause recirculation pump impeller damage, and cause localized fuel damage due to fretting wear. None of these is a nuclear safety concern. Localized fuel damage has the potential to increase coolant activity, however, Technical Specification limits on coolant activity (T.S. 3/4.4.5), are still binding. Damage to the Reactor Coolant Pressure Boundary or control rod binding are not considered credible. See reference 3.4 and 3.8.

4.9 Unreviewed Safety Question Determination:

The questions from 10CFR50.59 have been asked and answered to determine if an unreviewed safety question exists.

4.9.1 Description of Proposed Action: Operation of SSES Unit 2 for one additional fuel cycle with damaged feedwater spargers. The damage consists of six deformed nozzles with reduced flow area and cold worked material, two sparger arms that have been stressed to or above their yield strength, and thermal sleeve piston seals which have been deformed so that some leakage is expected.

4.9.2 Does the proposed action increase the probability of occurrence or the consequences of an accident or malfunction of equipment related to safety as previously evaluated in the FSAR?

The feedwater sparger is a non-safety related component, however, its performance affects two safety-related items. The HPCI/RCIC flowpaths use the damaged spargers. Since the pressure drop in the damaged spargers does not reduce flow from these relatively low flow systems, no further evaluation is required. The second item is the RPV feedwater nozzle. FSAR Question 112.7 and 121.7 discusses the possibility and consequences of piston seal leakage and draws the same conclusions as Section 4.5 of this report. All of the classes of transients/accidents described in FSAR Section 15.1 through 15.7 were evaluated by G.E. No accidents or transients become more likely or more severe as a result of operating with damaged spargers. Therefore, the answer is no.

4.9.3 Does the proposed action create a possibility for an accident or malfunction of a different type than any evaluated in the FSAR?

FSAR Sections 3.9.5, 4.4, 5.3, and various other sections were reviewed to locate specific information relative to review of the sparger.

All possible failure modes of the damaged spargers have been considered in the previous sections of this safety assessment. These include restriction of flow, loss of mechanical integrity, piston seal leakage, high cycle fatigue cracks, and loose parts. None of these could lead to an accident or malfunction of a different type than any evaluated in the FSAR. No other failure modes are considered reasonable. Therefore, the answer is no.

4.9.4 Does the proposed action reduce the margin of safety as specified in the basis for any Technical Specifications?

The bases for 3/4.1 "Reactivity Control Systems", 3/4.2 "Power Distribution Limits", and 3/4.4 "Reactor Coolant System" were reviewed. No bases were found to be impacted by the sparger damage. Therefore, the answer is no.

5.0 CONCLUSIONS:

5.1 The accidental lowering of the shroud head onto the feedwater spargers caused the following damage: deformation of six sparger nozzles, severe crushing and tearing of one nozzle, local yielding of two sparger headers, deflection of thermal sleeve piston seals, damage to the shroud head.

5.2 The torn nozzle is unacceptable and must be repaired. DCP 88-3029 has been issued to do so.

5.3 All other damage is acceptable to operate the plant for one cycle with no adverse safety consequences.

5.4 The above action is not an unreviewed safety question.

5.5 The nozzle surveillance instrumentation package must be installed in accordance with DCP 88-3028 to allow operations beyond one cycle to be justified.

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