June 6, 2008

MEMORANDUM TO: Eric J. Leeds, Director
Office of Nuclear Reactor Regulation

THRU: John A. Grobe, Associate Director **/RA/**
for Engineering and Safety Systems
Office of Nuclear Reactor Regulation

FROM: Michele G. Evans, Director **/RA/**
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SUBJECT: PRESSURIZER NOZZLE ALLOY 82/182 WELD FLAWS IDENTIFIED IN A RETIRED PRESSURIZER IN FEBRUARY 2008, LIC-504 ASSESSMENT, INTEGRATED RISK-INFORMED DECISION MAKING PROCESS FOR EMERGENT ISSUES

The purpose of this memorandum is to document the decision making process used to determine what regulatory action to recommend as the result of new information received regarding potential flaws in Alloy 82/182 welds in reactor coolant pressure boundary piping.

The Office of Nuclear Reactor Regulation issued Office Instruction LIC-504, "Integrated Risk-Informed Decision Making Process for Emergent Issues," Revision 2, on February 12, 2007. The process described in this document formed the basis for the decision making process that the staff used to address the results of the preliminary inspections of dissimilar metal welds in the nozzles of a retired pressurizer. These results were obtained from EPRI in mid-February and early March 2008. The purpose of this memorandum is to document the integrated risk-informed assessment of the options considered in the regulatory decision reached. The LIC-504 assessment for this issue is provided in Enclosure 1. The decision authority and evaluation team for this issue are listed in Enclosure 2. The timeline of related events to support the LIC-504 Assessment is provided in Enclosure 3.

In mid-February 2008 the NRC staff received the results of inspections of the nozzles of a retired pressurizer (ML080701017). This pressurizer was removed from service and was donated to NRC for research purposes and the inspections were performed to determine the research value of the nozzle welds. These inspections found indications using both dye penetrant testing (PT) and manual phased array ultrasonic examination (UT). The nozzle welds of most interest were the three safety nozzles. The inspection concluded that under normal field NDE conditions, these three welds would be reported as containing 360° circumferentially-oriented linear planar flaws of significant through-wall depth.

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The deepest indications found were sized at 89% through-wall on the 'A' safety nozzle. The deepest indication found in the 'B' and 'C' safety nozzles were 75% and 69% through-wall, respectively. Based on this information NRC staff determined that the inspection results needed to be evaluated against the advanced finite element analysis (FEA) work the staff completed in September 2007, since the advanced FEA formed the basis for the continued operation of 9 plants with pressurizer welds that had not yet been inspected as of the end of 2007, as mandated by industry guidelines. To help perform such an evaluation, the NRC staff requested that EPRI estimate the flaw profile for safety nozzle 'A' and provide some of the raw UT signals recorded during the inspection. EPRI provided this information to the NRC staff by letter dated March 4, 2008 (ML080701020). EPRI estimated that the 'A' safety nozzle weld contained a continuous deep indication 360° around the circumference. This reported flaw profile was more severe than any predicted flaws in the above-referenced advanced finite element analyses that would have led to leakage that would be detectable with sufficient time for plant shutdown prior to rupture. This information led the NRC staff to question whether the advanced finite element analyses would still support the spring 2008 pressurizer inspection schedules (ML072430836).

In making a regulatory decision to address the retired pressurizer nozzle weld inspection results, the NRC staff considered three options. Option 1, the base case, would result in no change to existing regulatory and industry programs; i.e., the affected plants would operate until their scheduled spring 2008 outage and inspect or mitigate the affected welds at that time. Option 2 would allow continued operation of the plants for a short time period while NRC staff gathered additional information. Option 3 would require all affected plants to shutdown immediately and not restart until the basis for operation until the spring outages was reestablished or until inspection or mitigation activities were completed.

The NRC staff based its regulatory decision on an assessment of the pros and cons of these options using the principles of risk-informed decision making.

The NRC staff concluded that Option 2 was the appropriate decision; the staff judged that it had an appropriate basis to take a short period of time (within a week) to gather information to make a more informed decision. The initial inspection results were somewhat uncertain given the type of inspection that was performed. More refined inspection was judged to be prudent to reduce some of this initial uncertainty. Nevertheless, the NRC staff determined that the questions raised by the March 4, 2008, EPRI letter were safety significant questions and the staff put industry on notice that it was considering regulatory action. A discussion of the actions taken to gather additional information and the conclusions of the staff's evaluation of the additional information is contained in a March 14, 2008 memorandum from Michele Evans to Catherine Haney (ML080740419).

Relative to Option 1 the NRC staff concluded that for the plants to continue to operate until their spring 2008 outages, the NRC staff needed additional information to determine whether the advanced finite element analyses (FEA) continued to support continued operation. Without such information, the NRC staff would have lacked the requisite reasonable assurance that the health and safety of the public would be protected by continued operation of these plants until their spring 2008 outages.

The proposed actions for Option 3 would provide the requisite reasonable assurance that the health and safety of the public would be protected upon restart of the affected plants.

However, the NRC staff judged that (1) additional information relevant to the decision could be obtained in a very short time period and (2) continued operation for a very short time frame would not be inimical to public health and safety.

For a more complete understanding of the decision making process used to address the retired pressurizer nozzle weld inspection results, please refer to the enclosed LIC-504 assessment.

Enclosures:
1. LIC-504 Assessment on the Retired Pressurizer Nozzle Weld Flaws
2. LIC-504 Decision Authority and Evaluation Team
3. Timeline of Events Leading up to the LIC-504 Recommended Decision

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PRESSURIZER NOZZLE ALLOY 82/182 WELD FLAWS IDENTIFIED IN A RETIRED PRESSURIZER IN FEBRUARY 2008

LIC-504 ASSESSMENT, INTEGRATED RISK-INFORMED DECISION MAKING PROCESS FOR EMERGENT ISSUES

1. PURPOSE

The context of this assessment is the safety issues related to nozzle weld indications identified in the dissimilar metal butt welds in a retired pressurizer. The indications were identified during inspections performed in February 2008. This assessment discusses the options considered in addressing the associated safety issues and the assessment of those options as part of the decision making process used to determine what regulatory actions to take to address the issues.

2. BACKGROUND

On October 13, 2006, the Wolf Creek Nuclear Operating Corporation performed pre-weld overlay inspections using ultrasonic testing (UT) techniques on the surge, spray, relief, and safety nozzle-to-safe end dissimilar metal and safe end-to-pipe stainless steel butt welds. The inspection identified five circumferential indications in the surge, relief, and safety nozzle-to-safe end dissimilar metal (DM) butt welds that the licensee attributed to primary water stress corrosion cracking (PWSCC) (ML063380456) and that were significantly larger and more extensive than previously seen in the industry.

During public meetings with the industry on November 30, 2006, and December 20, 2006, the Nuclear Regulatory Commission (NRC) staff presented the results of a fracture mechanics based scoping study that assessed the safety significance of the UT indications found at Wolf Creek. As a result of these analyses, the staff concluded that there may be little or no time margin between the onset of leakage and rupture in pressurizer nozzle DM butt welds containing flaws similar to those found at Wolf Creek.

In March 2007, the NRC issued Confirmatory Action Letters (CALs) to 40 nuclear power plant licensees with pressurized water reactors (PWR), confirming commitments from those licensees to resolve concerns regarding potential flaws in specific reactor coolant system (RCS) DM butt welds by the end of 2007. The remaining 29 PWR plants had either completed the requisite actions or do not have pressurizer welds susceptible to PWSCC.

Nine of the plants receiving CALs did not have outages scheduled in 2007. These plants committed to accelerate outages into 2007 if the industry was not able to demonstrate an adequate level of safety to the NRC. The nine plants are Braidwood 2, Comanche Peak 2, Diablo Canyon 2, Palo Verde 2, Seabrook, South Texas Project 1, V. C. Summer, Vogtle 1, and Waterford 3.

By letter dated February 14, 2007, the Nuclear Energy Institute indicated that the Electric Power Research Institute (EPRI) Materials Reliability Program (MRP) would be undertaking a task to refine the crack growth analyses pertaining to the Wolf Creek pressurizer DM weld ultrasonic indications. These additional advanced finite element analyses (FEA) were performed to address the NRC staff's concerns regarding the potential for rupture without prior evidence of leakage from circumferentially-oriented PWSCC in pressurizer nozzle welds. The goal of these studies was to demonstrate that PWSCC in pressurizer DM butt welds would progress

through-wall and exhibit detectable leakage prior to causing a possible rupture event. These studies reduced unnecessary conservatisms and some of the uncertainties in previous analyses.

Industry completed these analyses and documented the results in MRP-216, Revision 1, "Advanced FEA Evaluation of Growth of Postulated Circumferential PWSCC Flaws in Pressurizer Nozzle Dissimilar Metal Welds: Evaluations Specific to Nine Subject Plants" (ML072410235). These results were provided to the NRC staff by letter dated August 13, 2007.

The NRC staff completed independent analyses to enable the staff to perform an in-depth review and critique of the industry's analyses and to extend the scope of the industry's analyses. The NRC staff documented its safety assessment on the industry's analyses in an enclosure to a memorandum from Michele Evans to Catherine Haney on September 7, 2007 [ML072430836]. The staff's assessment used advanced finite element analyses of the fabrication, loading, and postulated flaw growth in the pressurizer nozzle welds to assess crack growth rates and shapes based on an array of starting flaw sizes. It was concluded that PWSCC in pressurizer DM butt welds of the nine plants analyzed would progress through-wall and exhibit detectable leakage prior to causing a possible rupture event. Therefore, the conclusion of the NRC staff's safety assessment was that there is reasonable assurance that the nine plants addressed by the evaluation can operate safely until their next scheduled refueling outages in the spring of 2008.

In mid-February 2008, the NRC staff received the results of inspections of the nozzles of a retired pressurizer (ML080701017). This pressurizer was removed from service to eliminate the possibility of extended plant outages resulting from cracking associated with the heater sleeves. The pressurizer was donated to NRC for research purposes and the inspections were performed to determine the research value of the nozzle welds. These inspections found indications by dye penetrant (PT) and manual-phased array ultrasonic examination (UT). Circumferential and axial indications were found in five of six nozzles. The nozzle welds of most interest were the three safety nozzles. The inspection concluded that these nozzles had 360°, circumferentially-oriented indications with non-uniform depths around circumference. The deepest indications found were sized at 89% through-wall on the 'A' safety nozzle. The deepest indication found in the 'B' and 'C' safety nozzles were 75% and 69% through-wall, respectively.

Based on this information NRC staff determined that the inspection results needed to be evaluated against the advanced FEA work the staff completed in September 2007 since the advanced FEA element analyses formed the basis for the continued operation of 9 plants with pressurizer welds that had not yet been inspected, as mandated by industry guidelines. To help perform such an evaluation, the NRC staff requested that EPRI estimate the flaw profile for safety nozzle 'A' and provide some of the raw UT signals recorded during the inspection. EPRI provided this information to the NRC staff by letter MRP 2008-014, dated March 4, 2008 (ML080670004). EPRI estimated that the 'A' safety nozzle weld contained a continuous deep indication 360° around the circumference. This reported flaw profile was more severe than any of the predicted flaws in the above-referenced advanced finite element analyses that led to leakage that would be detected with sufficient time for plant shutdown prior to rupture. The flaw profile caused NRC staff to question whether the advanced finite element analyses would still support the spring 2008 pressurizer inspection schedules (ML072430836).

Degree of conservatism in the regulatory analysis of this issue

The industry program for inspecting and mitigating welds subject to this PWSCC was developed based on the information available prior to the Wolf Creek inspection findings. This program is described in "Materials Reliability Program (MRP): Primary System Piping Butt Weld Inspection and Evaluation Guidelines," dated July 2005 and known as MRP-139. The information available at the time MRP-139 was issued indicated to the NRC staff that there was a serious safety issue with PWSCC in dissimilar metal butt welds. Based on operating experience, the NRC staff believed the industry baseline inspection schedule for pressurizer nozzle welds under MRP-139 was generally adequate, if completed according to the schedule outlined in MRP-139. Based on the results of advanced finite element analyses of pressurizer nozzle welds performed after the discovery of the large circumferential indications at Wolf Creek, the NRC staff concluded that it was acceptable for nine plants to continue to operate until their spring 2008 outages to perform the pressurizer weld inspections rather than shutdown by December 31, 2007, consistent with MRP-139.

This decision was based on extensive flaw growth analyses for the pressurizer nozzle welds and the enhanced leakage monitoring and shutdown criteria adopted by these plants. Performing these analyses required nozzle-specific information of the weld configuration and fabrication history, the applied loading, the material properties, crack growth rates for the specific weld materials for each of the 9 plants, and consideration of possible initial flaw shapes, sizes, and locations. As discussed in the NRC staff safety assessment (ML072400199), there are potential conservatisms and non-conservatisms in the analysis that are difficult to quantify. Therefore, the NRC staff extended the industry's analyses by considering additional sensitivity cases and applying higher safety factors to evaluate the acceptability of the results. The NRC staff concluded, based on these analyses and the enhanced leakage monitoring, that if a PWSCC flaw were to initiate and grow in one of the pressurizer nozzle DM welds before the Spring 2008 refueling outages, there is reasonable assurance that leakage would occur and be detected such that adequate time would be available to safely shutdown the plant prior to rupture at the nozzle weld.

3. EVALUATION AND ASSESSMENT OF REGULATORY OPTIONS CONSIDERED BY THE STAFF AGAINST THE FIVE KEY PRINCIPLES OF RISK INFORMED REGULATION

The following three options were developed based on the estimated severity of the retired pressurizer flaw in safety nozzle 'A' and the associated concerns discussed previously.

Option	Description of Regulatory Option
1	Base Case – No change to existing regulatory and industry program
2	Continued operation of the plants for a short time period while NRC staff gathers additional information
3	Issue orders for immediate plant shutdown

As discussed in the following sections, these options were assessed so that a recommendation could be reached based on the information available on March 7, 2008.

3.1 Option 1 - Base Case: No changes in the existing regulatory and industry programs or inspection/shutdown schedule. The eight plants[1] still operating with uninspected pressurizer

[1] One of the nine plants had already shutdown to perform weld overlays by the time the March 4, 2008 EPRI report was received, leaving eight plants involved in this decision.

nozzle welds proceed on their present schedule to shutdown and mitigate/inspect these welds during their planned spring 2008 outages based on the results of the advanced finite element analyses completed in August 2007

3.1.1 Compliance with Regulations

This issue involves the potential reduction in the capability in the reactor coolant system pressure boundary at the cited plants. The reactor coolant system pressure boundary is one of the principal fission product barriers in the general design criteria and is integral to defense-in-depth of the plant.

The indications discovered in the nozzle welds of the retired pressurizer were considered to be potentially due to PWSCC. If the flaw profile in the March 4, 2008 EPRI report was assumed to be due to PWSCC, the weld may have had sufficient ASME Code, Section XI, margin on structural integrity under design basis loadings at the time the retired pressurizer was taken out of service. Regardless, if this flaw was in an operating pressurizer and was due to PWSCC, it could not have been left in service because of the potential high growth rate of PWSCC, and the repair/replacement criteria specified in ASME Code, Section XI. Therefore, such a degraded condition would have required corrective actions in accordance with the ASME Code, which is incorporated by reference into NRC regulations by 10 CFR 50.55a.

Additionally, as discussed above, the previous decision to allow continued operation until Spring 2008 was based, in part, on the advanced FEA analyses. However, the flaw profile reported on March 4th was more severe than any predicted flaws in the above-referenced advanced FEA that led to leakage that would be detected with sufficient time for plant shutdown prior to rupture. Therefore, based on the information available on March 7, 2008, the NRC staff questioned the continued applicability of the advanced FEA analyses if any of the plants with uninspected pressurizer welds had PWSCC of a similar, or greater, extent than the reported flaw profile .

3.1.2 Defense-in-Depth

This issue potentially impacts the integrity of the reactor coolant system pressure boundary, which is one of the principal fission product barriers. The effect is a potential increase in the probability of failure for that boundary, not an assured loss of the boundary. This issue may increase the frequency of a loss of coolant accident (LOCA) in the size range requiring emergency core cooling system (ECCS) operation in the recirculation mode.[2] The other two principal fission product barriers, the fuel cladding and containment, are not impacted.

The decision in September 2007 that it was acceptable for nine plants to continue to operate until their spring 2008 was based, in part, upon reliance on plant leakage monitoring programs. This option would continue to require a high degree of reliance on plant leakage monitoring programs. The questions raised by the flaw profile in the March 4, 2008 EPRI report potentially impacted the ability to rely on leakage monitoring as a suitable compensatory action.

[2] While the decision makers were aware that some of the eight plants may still have been working to resolve the containment slump clogging issue of Generic Safety Issue (GSI)-191, the compounding affect of GSI-191 on LOCA frequency was not explicitly considered in the decision making because the decision involved allowing the plants to operate only for one additional week to gather information.

3.1.3 Safety Margins

Assuming the flaws in the retired pressurizer were due to PWSCC, the safety margin impacted is the predicted time between leakage and failure from the advanced FEA. For any weld affected by PWSCC of the size shown on the March 4th EPRI flaw profile, the potential reduction in safety margin could be significant, because a pipe failure would result in a loss of coolant accident (LOCA), up to and including a large break LOCA. Failures of the subject butt welds due to large circumferential cracks would produce medium or large LOCAs at the pressurizer. PRAs typically indicate conditional core damage probabilities (CCDPs) for these types of LOCAs are in the 10^{-3} to 10^{-2} range.

This option would allow the industry to continue operating until the spring 2008 outages based on the conclusions of the advanced finite element analyses. During the spring 2008 outages the pressurizer welds are scheduled to be inspected and mitigated. As noted above, the NRC staff had questions concerning the continued applicability of the advanced finite element analyses if any of the plants with uninspected pressurizer welds had PWSCC of a similar, or greater, extent than the reported flaw profile. This option would have allowed for a potential reduction in safety margin for up to approximately seven weeks after the staff received the letter from EPRI dated March 4, 2008.

3.1.4 Risk Assessment

EPRI provided a letter report, "Implications Of Wolf Creek Pressurizer Butt Weld Indications Relative to Safety Assessment and Inspection Requirements," MRP 2007-003, dated January 2007 [ML070240159]. The NRC staff reviewed this report and documented its conclusions in Section 3.1.4 of the Wolf Creek LIC-504 assessment [ML070990071]. The staff conclusion in this review that the available data and current lack of understanding of the underlying physics of the degradation mechanism made any estimates of the risk insufficient to support a regulatory decision.

EPRI subsequently updated its probabilistic study with the report, "Evaluation of Pressurizer Alloy 82/182 Nozzle Failure Probability," provided in Appendix E to MRP-216, Revision 1, "Advanced FEA Evaluation of Growth of Postulated Circumferential PWSCC Flaws in Pressurizer Nozzle Dissimilar Metal: Evaluation Specific to Nine Subject Plants," EPRI, Palo Alto, CA, August 2007 [ML072410235]. The staff reviewed the updated probabilistic study and, for reasons stated in its advanced FEA safety assessment [ML072430836], found it difficult to develop a basis for accepting the probability of failure estimates in Appendix E and, therefore, based its conclusions on its evaluation of the deterministic analyses and results.[3]

3.1.5 Performance Measurement

For Option 1, the performance measurement strategies or compensatory measures are the enhanced leakage monitoring programs and shutdown criteria in effect at the subject plants. However, the results of the inspection of the nozzle welds in the retired pressurizer led staff to question the continued applicability of the advanced finite element analyses. These analyses demonstrated that PWSCC in pressurizer DM butt welds of the nine plants analyzed would

[3] While not explicitly considered in the decision making, this issue does potentially impact the risk from seismic events, because a degraded pipe will be more likely to fail during an earthquake than a non-degraded pipe. However, given the low probability of a seismic event in the timeframe for Option 1, the risk contribution from seismic events is judged to be very low.

progress through-wall and exhibit detectable leakage prior to causing a possible rupture event. Therefore, the staff questions about the applicability of these analyses also calls into question the viability of the enhanced leakage monitoring to serve as a compensatory measure.

3.2 Option 2 - Continued operation of the plants for a short time period while NRC staff gathers additional information

3.2.1 Compliance with Regulations

The NRC staff reached the judgment that the questions raised by the March 4, 2008 EPRI letter were safety-significant and the staff communicated to the industry that regulatory action was being considered. Based on the information available to the staff from the March 4th letter, the staff considered that it would be appropriate to take up to one week to gather additional information before taking regulatory actions that may have led to shutdown of the plants. While considering the significance of the data provided by the EPRI letters, one week is a relatively short time to allow continued operation, given typical crack propagation rates and prior operating history. Therefore, it was judged that this small delay in taking action would not be inimical to public health and safety. In addition, the staff believed that conclusive information could be developed over this short period of time. The following paragraphs discuss why the NRC staff did not have sufficient information to determine whether the advanced FEA continued to be applicable and why the NRC staff judged that information from the EPRI letters was not sufficiently conclusive as to warrant immediate plant shutdown.

(1) The February 15, 2008 EPRI report was not conclusive regarding whether or not the UT indications recorded on the three safety nozzles were indicative of PWSCC or preexisting fabrication defects. The report noted that performing additional automated UT on these three nozzle welds would allow for more accurate flaw characterization. One area of uncertainty was that the report indicated that UT sound beams that were projected normal to the surface (straight beams) did not pick up the indications. This would lead to the conclusion that the indications were service-induced. However, the staff was aware that while UT techniques can be used to detect construction flaws, no information was provided on the capability or qualifications of the straight beam inspection to detect construction flaws. Another area of uncertainty was that the results of the PT examinations of the inside surface, where PWSCC would initiate, showed a small number of short linear indications, but the PT results did not approach the circumferential extent of the UT indications. Although PT of PWSCC may have been affected by surface grinding, the PT results were inconsistent with the flaw profile shown in the March 4, 2008 EPRI report.

(2) The NRC staff and industry had performed ten of thousands of hours of advanced analyses to understand flaw growth in the pressurizer nozzles of the plants still operating. These analyses were based on actual fabrication histories that covered a range of practices. A flaw similar to the profile shown in the March 4, 2008 EPRI report was contrary to the results of the NRC staff's analytical flaw growth studies and would not have been expected. Based on the information available to the staff about Combustion Engineering pressurizer units, the staff could not postulate a set of conditions that could develop the reported flaw profile in the retired pressurizer safety nozzle weld from typical configurations, fabrication processes, fabrication flaws, fabrication repairs, and operating loads.

For example, the staff was aware that the Combustion Engineering (CE) pressurizer units studied had high margins between leak and rupture based on the known fabrication processes. The CE processes resulted in low residual stresses on the inside surface of the pipe and

postulated flaws either arrested or led to large margins between leakage and rupture. St. Lucie is a Combustion Engineering design but was not one of the plants that were specifically analyzed. Therefore, the staff did not have plant specific information on St. Lucie's pressurizer nozzle configuration, fabrication, or nozzle loadings or any other information that would provide insights on why the advanced FEA would no longer be applicable. Option 2 would allow time for industry to provide information on why the original FEA would or would not continue to be applicable in light of the reported, retired pressurizer nozzle weld flaw profile.

(3) The flaw profile in the March 4, 2008 EPRI report was not consistent with prior operating experience. The staff is aware of the PWSCC identified in butt welds in domestic as well as foreign pressurized water reactors. Long flaws have been previously identified but no flaws have been reported approaching the depth of the circumferential 360° inside surface connected flaws found in the retired pressurizer safety nozzle welds.

3.2.2 Defense-in-Depth

The assessment of defense-in-depth for Option 1 in Section 3.1.2 is unchanged for Option 2.

3.2.3 Safety Margins

This option would allow the affected licensees to continue operating for up to one week while additional information was gathered. The NRC staff needed additional information to determine whether the advanced FEA continued to support the original decision for allowing the plants to operate until Spring of 2008. Therefore, this option would have allowed for a potential reduction in safety margin for up to one week after March 7, 2008. As discussed in Section 3.2.1, the staff believed that it would be appropriate to take this time to gather additional information before taking regulatory actions in order to address questions and reduce uncertainties.

3.2.4 Risk Assessment

As discussed in Section 3.1.4, the available risk estimates associated with PWSCC in DMBWs are insufficient to support a regulatory decision.

3.2.5 Performance Measurement

The assessment of performance measurement for Option 1 in Section 3.1.5 is unchanged for Option 2.

3.3 Option 3 - Issue orders for immediate plant shutdown

3.3.1 Compliance with Regulations

The proposed actions for Option 3 would provide the requisite reasonable assurance that the health and safety of the public would be protected upon restart of the affected plants. However, the staff needed additional information to determine whether the advanced FEA continued to support continued operation of the eight remaining plants with spring 2008 outages. Further, the NRC staff judged that (1) additional information relevant to the decision could be obtained in a short time period and (2) continued operation for a short time period would not be inimical to public health and safety. The NRC staff judged that information from the March 4th EPRI letter raised safety questions but was not sufficiently conclusive as to warrant immediate plant shutdown.

3.3.2 Defense-in-Depth

This option would remove the contribution of potentially degraded welds to concerns about defense-in-depth.

3.3.3 Safety Margins

Option 3 would promptly provide assurance that the intended safety margins are restored to at least the same level as that prior to discovery of the potentially adverse condition of the safety nozzle welds in the retired pressurizer. These eight plants would not have restarted until the questions about the continued applicability of the advanced FEA were answered or until the welds were either inspected or mitigated. For plants that would inspect their nozzles but not mitigate the welds, safety margin would be adequate because the required inspections and reinspection frequency would provide reasonable assurance that PWSCC would not compromise the reactor coolant pressure boundary. For plants that would mitigate the welds, the safety margin would be restored to a level similar to that of plants when first placed into operation.

3.3.4 Risk Assessment

As discussed in Section 3.1.4, the available risk estimates associated with PWSCC in DMBWs are insufficient to support a regulatory decision.

3.3.5 Performance Measurement

For Option 3 no performance measurement strategies or compensatory measures are proposed or necessary since the option requires prompt shutdown of the affected plants to either inspect or mitigate the affected welds.

4. CONCLUSIONS

The indications discovered in the nozzle welds of the retired pressurizer were considered to be potentially due to PWSCC. If the flaw profile in the March 4, 2008 EPRI report was assumed to be due to PWSCC, the weld may have had sufficient ASME Code, Section XI, margin on structural integrity under design basis loadings at the time the retired pressurizer was taken out of service. Regardless, if this flaw were in an operating pressurizer and were due to PWSCC, it could not have been left in service because of the potential high growth rate of PWSCC, and the repair/replacement criteria specified in ASME Code, Section XI. Therefore, such a degraded condition would have required corrective actions in accordance with the ASME Code, which is incorporated by reference into NRC regulations by 10 CFR 50.55a.

The previous decision to allow continued operation until Spring 2008 was based, in part, on the advanced FEA analyses. However, the flaw profile reported on March 4, 2008 was more severe than any predicted flaws in the above-referenced advanced FEA that led to leakage with sufficient time for plant shutdown prior to rupture. Therefore, based on the information available on March 7, 2008, the NRC staff questioned the continued applicability of the advanced FEA analyses if any of the plants with uninspected pressurizer welds had PWSCC of a similar, or greater, extent than the reported flaw profile.

On March 7, 2008 when a regulatory decision was made to allow the eight plants to continue to operate, at least for a short period of time, staff involved in the decision making considered

three options. The NRC staff performed an assessment of the three regulatory options against the principles of risk-informed decision making. The NRC staff recommended Option 2 - continued operation of the plants for a short time period while NRC staff gathers additional information.

At that time the NRC staff was aware of the risk assessment previously performed in connection with the Wolf Creek LIC-504 assessment. The NRC staff had prepared an evaluation of a risk assessment performed by industry and concluded that available data and current lack of understanding of the underlying physics of the degradation mechanism made any quantitative estimates of the risk insufficient to support a regulatory decision. Therefore, the NRC staff's assessment of the options in this case was based primarily on the other principles.

This decision was based on the judgment that taking up to one week to gather additional information gave appropriate consideration to each of the following factors:

(1) the need to quickly restore confidence in the safety margins of the eight remaining plants potentially impacted by the inspection results.

(2) for the plants to continue to operate until their spring 2008 outages, the NRC staff needed additional information to determine whether the advanced FEA continued to support operation until the outage.

(3) the NRC staff believed that conclusive information could be developed in a short period of time.

(4) the NRC staff judged that information from the March 4, 2008 EPRI letter raised safety questions but was not sufficiently conclusive as to warrant immediate plant shutdown.

Factors (1) and (2) led the staff to reject Option 1. The staff judged that a one week information gathering period is short enough to maintain public health and safety, given typical crack propagation rates and prior operating history. Option 2 was supported by factor (3). Factor (4) led the staff to reject Option 3.

LIC-504 Evaluation Team

Decision Authority

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Timeline of Related Events to Support LIC-504 Assessment of Pressurizer Nozzle Alloy 82/182 Weld Flaws Identified in a Retired Pressurizer in February 2008

October 19, 2005:

- St. Lucie Unit 1 pressurizer removed from service and shipped to a decontamination and reduction facility.

October 13, 2006:

- Wolf Creek discovered 5 circumferential indications in the pressurizer relief, safety, and surge nozzles.

November 30, 2006:

- NRC staff presented the results of a fracture mechanics based scoping study at a public meeting that assessed the safety significance of the Wolf Creek indications.

December 20, 2006:

- As a result of the NRC analyses, the staff concluded that there may be little or no time margin between the onset of leakage and rupture in pressurizer nozzle DM butt welds containing flaws similar to those found at Wolf Creek.

February 14, 2007:

- Nuclear Energy Institute (NEI) indicates that the Electric Power Research Institute (EPRI) Materials Reliability Program (MRP) would refine the crack growth analyses pertaining to the Wolf Creek pressurizer dissimilar metal butt weld (DMBW) indications to address NRC staff concerns.

March 2007:

- NRC issued Confirmatory Action Letters to 40 PWRs, confirming commitments from those licensees to address concerns regarding potential flaws in pressurizer nozzle DMBWs by 12/31/07. Of the 40 PWRs receiving CALs, 9 plants did not have scheduled outages in 2007, but, committed to enhanced leakage monitoring and to accelerate their outage schedule into 2007 if the industry was not able to demonstrate an adequate level of safety to the NRC. The nine plants were Braidwood 2, Comanche Peak 2, Diablo Canyon 2, Palo Verde 2, Seabrook, South Texas Project 1, V. C. Summer, Vogtle 1, and Waterford 3.

March-August 2007:

- Advanced Finite Element Analysis (AFEA) Project undertaken to address NRC staff's concerns regarding the potential for rupture without prior evidence of leakage from circumferentially oriented primary water stress corrosion cracks in pressurizer nozzle welds.

Spring-Summer 2007:

- NRC Office of Research (RES) learns of the availability of the retired St. Lucie Unit 1 pressurizer and takes the opportunity to acquire the DMBW nozzles to potentially address several Office of Nuclear Reactor Regulations (NRR) user need requests. RES staff negotiates ownership and disposal issues with Florida Power and Light Company.

August 13, 2007:

- Industry completed their AFEA analyses and documented the results in MRP-216, Revision 1, "Advanced FEA Evaluation of Growth of Postulated Circumferential PWSCC Flaws in Pressurizer Nozzle Dissimilar Metal Welds: Evaluations Specific to Nine Subject Plants."

September 7, 2007:

- NRC staff's confirmatory AFEA analyses completed and decision to allow operation of the 9 plants until June 2008 is documented in the AFEA Safety Assessment.

September 28, 2007:

- RES initiated a commercial contract to section the St. Lucie pressurizer top (spray, safety, and relief) and bottom head (surge) nozzles from the main pressurizer housing.

February 4-8, 2008:

- Final surface preparation performed and initial surface and volumetric NDE exams performed. Exams included liquid dye penetrant inspection of both the outside and inside surfaces of each DMW and manual phased-array ultrasonic examination of the volume of each DMW.

February 15, 2008:

- NRC staff received the Materials Reliability Program (MRP) Letter 2008-012 with attached report entitled "St. Lucie Pressurizer Nozzle DM Weld Examination Project." Report documents the results of the initial PDI-qualified manual ultrasonic tests. Staff informs management of the initial findings.

February 19, 2008:

- Staff sets up a conference call with cognizant EPRI staff members for Wednesday February 27, 2008 to discuss results and path forward.

- Staff informs management that results of Letter 2008-012 need to be evaluated against the AFEA work the staff completed in September 2007.

February 27:

- Staff discusses the preliminary St. Lucie NDE results and path forward with EPRI staff during the scheduled teleconference. EPRI representatives indicate that the NDE indications are deeper on one side and shallower on the opposite side. Staff requests a profile of the indication be provided as soon as possible and compares the qualitative flaw description to the previous AFEA results.

March 4:

- EPRI Report (Letter 2008-014) provided to NRC showing manual UT's estimated flaw profile. The profile in this report depicts a single indication with significant through-wall depth at 19 points spaced somewhat evenly around the circumference of the "A" safety nozzle. This profile depicts substantially more cracked area than originally anticipated.

March 5:

- Briefings and meetings
    - Staff notes that flaw profile from manual UT may not be bound by AFEA results used to support the decision to allow the 9 plants to operate beyond 12/31/07.
    - Staff discusses whether industry should conduct an accelerated, more accurate NDE inspection of St. Lucie nozzles.

March 6:

- Management share views regarding concerns that NRC may not have an adequate basis for allowing the 9 plants to operate without additional assurances given the available information concerning the St. Lucie reported indication.

- Management agrees to promptly revisit the decision to allow continued operation of 9 plants and brief OEDO of the conclusions of those discussions.

March 7:

- Meeting involving NRR and RES management and staffs to determine actions going forward
    - Decision made to escalate the issue on the basis that a question was raised regarding continued applicability of the Advanced Finite Element Analysis (AFEA) results.
    - Decision made to recommend continued operation of the plants for a short time period while NRC staff requests that licensees provide information to address the basis for continued operation of the 9 plants.

- Briefing of DEDO on recommendation. DEDO agrees with recommendation.

- Chief Nuclear Operations officers of all 8 plants were informed of NRC staff concerns and the need for information to address the basis for continued operation, and were put on notice that the staff was considering regulatory action.