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# Indian Point 2
# Steam Generator Tube Failure
# Lessons-Learned

October 23, 2000



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# Agenda

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# IP2 Event Overview

- February 15, 2000 - One tube (R2C5) in SG24 failed at tube apex
- Primary-to-secondary leakage ≈ 150 gpm
- Reactor was safely shutdown
- Minor radiological release well within regulatory requirements (no radioactivity measured off-site above normal background levels)

# Lessons-Learned Task Group

- Assembled in accordance with Charter dated May 24, 2000
- Objective - evaluate staff's technical and regulatory processes related to assuring SG tube integrity in order to identify and recommend areas for improvement applicable to the NRC and/or the industry
- Multi-disciplined Task Group consisting of staff from NRR, RES, Region - support from OGC and others as needed

# Task Group Organization

Task Group
Scott Newberry, Chairman
Joe Donoghue, NRR/DLPM
Rick Ennis, NRR/DLPM
Louise Lund, NRR/DE
Alan Rubin, RES
Jimi Yerokun, Region I

Supporting Staff
Maitri Banerjee, NRR/ADPT
Tim Frye, NRR/DIPM
Jack Goldberg, OGC

# Scope of Task Group Review

- Review included technical and regulatory process issues related to assuring SG tube integrity
- Conclusions & Recommendations were developed based on reviews of documentation and discussions with NRC staff, NRC SG expert consultants, nuclear industry representatives involved in SG programs, and Con Ed staff

# Scope of Task Group Review (Cont.)

- Documents reviewed included:
  - IP2 plant-specific SG documents (e.g., Con Ed SG examination results, NRC inspection reports, NRC/Con Ed correspondence, IP2 Tech Specs)
  - NRC generic SG-related documents (INs, GLs, RGs, NUREGs, inspection procedures)
  - Nuclear industry generic SG-related documents (e.g., NEI, EPRI)
  - RES Technical Review dated 3/16/00
  - OIG Event Inquiry dated 8/29/00

# Scope of Task Group Review (Cont.)

- Scope of review did not include:
  - IP2 SG issues being addressed by other regulatory processes (e.g., Differing Professional Opinion (DPO), 2.206 petitions)
  - Event follow-up issues not specifically related to SG tube integrity (e.g., EP, degraded equipment)
  - Evaluation of Con Ed performance relative to regulatory requirements (e.g., Appendix B)

## Scope of Task Group Review (Cont.)

- Charter directed Task Group to review staff SE associated with IP2 restart following tube failure. This activity was terminated when Con Ed decided to replace their SGs before restart.
- Charter states Task Group not expected to identify the processes for resolving areas of potential weakness (i.e., how to implement recommendations is responsibility of applicable line organization).

# Task Group Interfaces with Stakeholders

- NRC staff and management from NRR, RES, and Region (discussions, interviews, briefings)
- NRC SG expert consultants (discussions, interviews)
- Con Ed (visit to Peekskill office)
- NEI/EPRI (public meeting on NEI 97-06)
- ACRS (possible briefing)
- Additional external stakeholders (TBD)

# IP2 Steam Generators

- Westinghouse Model 44 (at time of event)
- 4 SGs (SG21, SG22, SG23, SG24)
- Each SG has 3,260 tubes
- 92 tubes in rows 1 - 4 (low row tubes)
- Row 1 plugged prior to initial operation
- In service since 1974

# Regulatory Requirements

- IP2 Tech Specs (TS) require examination of representative sample of SG tubes by eddy current testing at least every 24 months.
- Tubes with degradation > 40% through-wall are considered defective and must be repaired or plugged.
- Degraded means service-induced cracking, wastage, pitting, wear, or corrosion. Defective means degradation is > plugging limit.
- Sample size is expanded based on amount of degraded/defective tubes that are found.
- IP2 TS require NRC approval for restart if:
  > 10% of total tubes examined are degraded or
  > 1% of total tubes examined are defective.

# Regulatory Requirements (cont.)

- IP2 Tech Specs require:
  - SG examination results be submitted to NRC within 45 days after exam is complete
  - Immediate report be submitted if significant increase in rate of denting found
  - Evaluation addressing long term integrity of small radius U-bends be submitted within 60 days of finding significant hour-glassing of upper support plate flow slots
- Denting (tube deformation) is precursor to hour-glassing
- Hour-glassing is closure of flow slots - causes tube legs together putting stress on tube apex

# Regulatory Requirements (cont.)

- IP2 TS on primary-to-secondary leakage allow operational limit of 0.3 gpm (432 gpd) in any SG that does not contain tube sleeves, or 150 gpd for any SG that contains sleeves
- If limit exceeded, or leakage in two or more SGs in any 20-day period is observed, plant shutdown in 24 hours required
- Leakage from SG24 prior to 2/15/00 tube failure was about 3 - 4 gpd

# Industry Intitiatves and Guidance

- In five years preceding IP2 tube failure, the NRC staff plans to develop an appropriate regulatory framework to assure SG tube integrity has evolved from rulemaking to GL to reliance on an industry initiative
- Nuclear Energy Institute (NEI) document NEI 97-06, "Steam Generator Program Guidelines," provides the fundamental elements expected in a SG Program
- NEI 97-06 refers to EPRI guidelines for detailed development of program attributes

# Eddy Current Testing

- ECT is method of inspecting SG tubes by passing a probe that generates an electromagnetic field through the tubes
- Types of ECT probes: bobbin coil, rotating pancake coil (PlusPoint by Zetec), Cecco-5
- Probe senses the disturbance of the electromagnetic field due to flaws in the tube
- ECT signals may be affected by noise (e.g., deposits on OD of tubes, tube geometry defects, electrical interference)

# SG Degradation Mechanisms

- Stress corrosion cracking (SCC) in SG tubes caused by simultaneous presence of tensile stress, specific corrosive medium, and susceptible material
  - SCC on tube ID is called primary water stress corrosion cracking (PWSCC)
  - SCC on tube OD is called outside diameter stress corrosion cracking (ODSCC)

# SG Degradation Mechanisms (cont.)

- Denting of tubes caused by restriction of gap between tube outer wall surface and hole in tube support plate (TSP) due to secondary side corrosion of the carbon steel TSP.
- Hour-glassing of flow slot caused by deformation of TSP due to denting. PWSCC more likely at tube U-bend apex if there is hour-glassing (forces tube legs together and concentrates tensile stress at apex)

# Conclusions and Recommendations

## Safety Significance/Risk Insights

- The IP2 tube failure resulted from degraded conditions allowed to exist in the SGs during the operating cycle. Con Ed's SG tube integrity program and QA program were deficient and did not detect the degraded conditions. These tube conditions presented a safety concern because of a reduction in safety margin and an increased risk of SG tube rupture during IP2's operating cycle 14. Con Ed must correct the deficiencies in its SG tube integrity program that led to the degraded conditions otherwise the long-term risk of SG tube rupture at IP2 could be affected.
- Communicating the safety significance of the IP2 event is difficult. Nonwithstanding the loss of safety margin, IP2 is designed to mitigate the effects of SG tube failure or tube rupture, IP2 shut down safely following the tube failure, there was no measurable radioactivity offsite above normal background levels, and the event resulted in no adverse consequences to the public health and safety. The risk from the IP2 event and risk from the tube condition prior to the event were well within NRC Strategic Plan measures for maintaining reactor safety. The NRC should incorporate the experience gained from the IP2 event and the SDP process into planned initiatives on risk communication to the public.

# Conclusions and Recommendations

## Safety Significance/Risk Insights (cont.)

- The weaknesses in the Con Ed program that contributed to the poor condition of the failed SG tube have generic implications. The examination guidance in use is common throughout the pressurized water reactor (PWR) industry. While the IP2 SGs now being replaced are the last of their particular model, Task Group review of other SG designs and tube materials indicate potential generic applicability of the IP2 lessons. Review of PWR risk analysis confirms that SG tube integrity is important at all PWRs. Therefore, the Task Group concludes that a high priority should be assigned to improvements in the SG tube integrity program at IP2, for the industry guidance on SG tube integrity programs, and associated NRC regulatory programs.

# Conclusions and Recommendations

Con Ed SG Program

- Weaknesses in Con Ed's implementation of the industry guidelines, combined with shortcomings in the technical guidance itself, contributed to the situation encountered at IP2.
- The NRC Special Inspection Team findings are reasonable and corrective actions at IP2 should proceed in accordance with the ongoing inspection and enforcement process. Findings related to the 1997 SG examinations by Con Ed included:
  - PWSCC was identified for the first time in a tube similar in type and location to the tube that failed at IP2, and Con Ed did not effectively evaluate the susceptibility of similar tubes to this degradation during the upcoming operating cycle.
  - Denting was identified when restrictions were encountered as the eddy current probes were inserted into the U-bend portion of similar tubes. Con Ed did not evaluate the potential for, and significance of, this degradation.
  - Significant noise was encountered in the data obtained from a number of tubes similar to the tube that failed, and Con Ed's program was not adjusted to compensate for the noise, particularly when the new PWSCC defect was found in this area of the SG.

# Conclusions and Recommendations

## Industry / NEI / EPRI SG Programs

- NEI/industry should ensure that lessons-learned from IP2 are being implemented by licensees. NEI should provide feedback to the NRC on the status of licensee implementation.
- NEI/industry should use the IP2 lessons-learned to strengthen the NEI 97-06 industry initiative. Specific recommendations include:
  - Licensees should ensure that contractors supporting the SG examination program perform in an acceptable manner.
  - TSs should ensure that technical requirements are strengthened to reflect the current knowledge of SG degradation mechanisms, examination techniques, and methodology.
  - The adequacy of the TSs for operational leakage limits should be assessed.
- In the interim, the NRC should issue a generic communication to clarify the current NRC position on industry guidance and to highlight SG tube integrity program weaknesses manifested by the IP2 experience that could exist at other plants. (Action complete 11/3/00 - RIS 2000-22)

# Conclusions and Recommendations

Industry / NEI / EPRI SG Programs (cont.)

- The EPRI guidelines and the licensees implementation of the guidelines should be improved based on the lessons-learned from IP2. Specific recommendations include:
  - Data quality criteria should incorporated in the guidelines including how to assess and address noise.
  - The guidelines should be revised to address measures to be taken in response to the first occurrence of a new form of SG tube degradation.
  - The guidelines should be revised to address how to evaluate flow slot hour-glassing.
  - Licensees should review the generic industry guidelines carefully to ensure that the conditions/assumptions supporting the guidelines apply to their plant-specific situation. The plant-specific qualification of eddy current techniques is fundamental to an adequate inspection.
  - Licensees should use caution when assessing SG tube structural integrity by using unqualified sizing techniques for growth rates and threshold of detection. A conservative approach should be used to screen tubes for in-situ testing.

# Conclusions and Recommendations

## NRC Licensing Review Process

The significant conclusions and recommendations from the Task Group review of the licensing review process associated with a Con Ed amendment request to extend the SG inspection interval are:

- There was an opportunity for Con Ed during preparation of the amendment request and subsequent response to an NRC request for additional information to recognize the significance of a new degradation mechanism that was observed during the 1997 SG examination in a tube similar to the tube that failed in February 2000 (PWSCC at tube apex in a small radius U-bend).
- There were two opportunities during the license review process for the NRC staff to find inadequacies in the Con Ed's operational assessment. However, it is not clear if further follow-up in either one of these cases would have yielded a different result (e.g., denial of the amendment request).
- The IP2 SG tube failure occurred approximately 8 months after the originally scheduled inspection date which was less than the duration justified by the recapture of the 10 month shutdown. Therefore, the SG inspection interval extension of 2 months did not contribute to the tube failure event.

# Conclusions and Recommendations

## NRC Licensing Review Process (cont.)

- Since no specific guidance is available for NRC technical reviewers to perform license amendment reviews associated with SG inspection interval extensions, the knowledge of individual NRR senior staff members is relied on heavily. Formal guidance should be developed to ensure that all reviewers are able to efficiently and effectively prepare safety evaluations. The guidance should address when the staff should review previous licensee SG examination reports.
- The NRC staff safety evaluations should be specific as to what information was relied on to form the basis for its conclusions (i.e., basis for approving the amendment). NRR Office Letter No. 803 should be revised accordingly.

# Conclusions and Recommendations

## NRC Inspection Program

- The new Reactor Oversight Process (ROP) baseline inspection program for inservice inspection (ISI) does not include guidance on the scope and depth of NRC inspection of licensee SG tube examinations. The staff should develop additional guidance on when and how much of its inspection in this area should be completed.
- The regional inspector training is not designed to develop inspectors' technical expertise in the area of eddy current examination. Therefore, the inspection process may not be reasonably expected to preclude a situation such as the IP2 SG tube failure from occurring. The training of inspection staff should be reviewed and tailored to support the objectives of the SG inspection program.
- The NRC outage phone calls with the licensees can be effective, but are not formally included in either the licensing or inspection process. The phone calls should be factored into the inspection process.
- New industry and generic information (e.g., IN, GL) does not always get to the regional inspectors in time enough to be factored into their inspection activities. Relevant technical information should be communicated to the inspectors on a consistent, timely basis.

# Conclusions and Recommendations

NRC Inspection Program (cont.)

- Risk-informed thresholds have not been established for either the baseline inspection program or the performance indicators (PIs) to identify adverse trends in primary-to-secondary leakage that warrants increased NRC interaction. The NRC staff should assess how the inspection program or PIs could be revised.
- Risk-informed thresholds are necessary in the ROP to identify those plants experiencing a level of SG tube degradation that warrants NRC interaction above the baseline inspection program. The NRC staff should establish risk-informed thresholds that can be applied to the results of the SG examinations to identify SG tube degradation that warrants increased NRC attention.

# Conclusions and Recommendations

## General Recommendations

- The NRC should take steps to ensure that SG expertise is available to support the objective of the NRC's licensing and inspection programs. This could be done through formal training, through written guidance, or a mentoring program.
- The NRC staff should assess the need for, and the process for the staff review of, the TS required reports that document the results of licensee's SG tube examinations. If the staff determines that such reports should be required, then the staff should also determine the information to be included in such reports, and the timing for submittal of the reports to the NRC. The staff should also develop a well-defined process to review such reports, and the specific purposes and objectives of such reviews.
- The NRC staff should develop a process for handling the requests and associated responses for inter-office independent technical reviews.

# ATTACHMENTS

Attachment 1 - Task Group Evaluation of OIG Report

Attachment 2 - Task Group Evaluation of RES Review

Attachment 3 - IP2 SG Inspection Timeline