



**Indian Point 2 Steam Generator Tube Failure
Lessons-Learned Report
(TAC No. MA9163)**

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EXECUTIVE SUMMARY

The February 15, 2000 Steam Generator Tube Failure Event

A single tube in one of four steam generators (SGs) at Consolidated Edison's (Con Ed's) Indian Point 2 (IP2) plant failed leading to a transient and shutdown of the reactor. In addition to the reactor itself, the SGs are the major components that transfer reactor heat into steam to drive the electric turbine at a nuclear power plant. They are located inside the containment structure and are equipped with safety features to detect and initiate automatic protection actions and provide indications to the plant operators if problems develop. The tube failure consisted of a small through-wall crack in one of the 3,260 SG tubes that allowed reactor cooling water to flow through the crack into the steam generating side of the SG at the rate of about 150 gallons per minute. The radioactivity was detected and contained. The reactor was safely shutdown by the plant systems and operators. The event resulted in a minor radiological release to the environment that was well within regulatory limits.

Charter

The IP2 SG Tube Failure Lessons-Learned Task Group and Charter were proposed by the Director of the Office of Nuclear Reactor Regulation (NRR) and approved by the Executive Director for Operations in June 2000. The objective of the effort was to evaluate the NRC staff's regulatory processes related to assuring SG tube integrity in order to identify and recommend areas for improvements applicable to the NRC and/or the industry. A multi-disciplined Task Group was set up in accordance with the charter consisting of staff from the Office of Research, Region I and NRR. Support was provided by the Office of the General Counsel.

The Task Group was not expected to identify the processes for resolving areas of potential weakness. The responsibility for dealing with the recommendations would be with the applicable line organization.

The charter directed that the Task Group review the staff safety evaluation report (SER) associated with restart of IP2 with their current SGs and provide concerns or issues to the staff for action. This activity was terminated when Con Ed decided to replace their SGs.

Report

This report is the result of the Task Group effort. Conclusions and recommendations were developed by the Task Group based on reviews of documents and discussions with NRC staff, nuclear industry representatives involved in SG programs, and NRC SG expert consultants. Public input was not sought as part of the Task Group effort based on the understanding that the report and other efforts would be integrated into an activity that would allow for input from a broad range of stakeholders.

The Task Group was directed to focus attention on issues directly related to the February 15, 2000 tube failure event and operation of the current SGs at IP2. Documents reviewed by the Task Group included Con Ed SG examination and NRC SG inspection procedures and reports, nuclear industry generic SG examination guidance and associated NRC review information, NRC and Con Ed license amendment proposals and safety evaluation reports, and the Con Ed event root cause analysis and the associated NRC Special Inspection Report.

not chartered to study.

Two additional reports were important to the Task Group effort:

- 1) The Office of Research (RES) independent technical review dated March 16, 2000. Following the IP2 tube failure event, NRR requested RES to review the SG inspection interval extension safety evaluation report that had been issued by NRR prior to the event. The Task Group considered this review in the development of conclusions and recommendations.
- 2) The Office of the Inspector General's (OIG) Event Inquiry on the "NRC's Response to the February 15, 2000, Steam Generator Tube Rupture at Indian Point Unit 2 Power Plant." The Task Group addressed the findings of the OIG report related to SG issues.

The Task Group effort did not consider IP2 issues unrelated to SG tube integrity or issues being addressed by other regulatory processes, such as a 2.206 petition or a differing professional opinion.

The conclusions and recommendations developed represent the views of the Task Group. While reasonable efforts were made to check on facts and an understanding of particular events or issues, the report was not issued for comment outside the group. The conclusions reached were those believed necessary to support recommendations to continue to maintain safety, increase public confidence, increase the efficiency and effectiveness of NRC programs, and reduce unnecessary regulatory burden.

Safety Significance

The Task Group evaluated the safety significance of the event using safety assessment studies performed before and after the event. The NRC Special Inspection Report noted that there were no actual radiological consequences of the event, and that the event did not impact the public health and safety. The Task Group agreed with this assessment.

The Task Group also considered the NRC staff's preliminary risk assessment of the IP2 event associated with the NRC significance determination process (SDP). The staff concluded that the IP2 tube failure resulted from degraded conditions allowed to exist in the SGs during the operating cycle. The staff determined that deficiencies in the licensee's SG tube integrity program led to 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 (SGTR) during IP2's operating cycle 14. The Task Group considers the preliminary staff assessment appropriate for the SDP process and agrees with its conclusion.

The Task Group also evaluated the overall significance of the event and condition of SG tubes relative to the NRC measures for maintaining safety in the Agency Strategic Plan. The risk from the IP2 SG event and risk from the tube condition prior to the event were well within NRC measures for maintaining public health and safety.

The Task Group concluded that 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.

Steam Generator Tube Integrity Program Regulatory Framework

All PWR reactor plant licensees are required by NRC regulations to provide reasonable assurance of SG tube integrity. A significant number of NRC regulations and standards apply and are incorporated into the licensing basis of each facility. These requirements include design, operation, and surveillance activities. The surveillance requirements are important to maintaining integrity since different types of tube degradation are expected to occur over the life of the SG. Current plant technical specifications typically require that a representative sample of tubes be examined for defects using eddy current testing once every two years during the periodic plant shutdown period. Eddy current testing is a method of inspecting SG tubes by passing a probe that generates an electromagnetic field through the tubes. Tubes that are identified as containing defects of a specified depth are removed from service, typically by plugging both ends of the defective or degraded tube.

In recent years, the NRC staff has examined the regulatory programs which comprise the framework for ensuring the integrity of SG tubes. In the mid 1990's the staff concluded that existing regulations provided an adequate regulatory basis for dealing with SG issues, but thought them to be prescriptive, out of date, and not fully effective. In 1997, the Commission approved the staff's approach to upgrade plant technical specifications, and the Nuclear Energy Institute voted to adopt NEI 97-06, "Steam Generator Program Guidelines," as a formal industry initiative to provide a consistent industry approach for managing SG programs and for maintaining SG tube integrity. In 1998, the Commission approved a revised approach to work with the industry consistent with Direction Setting Initiative 13, "The Role of Industry" to more efficiently resolve program concerns and move toward NRC endorsement of NEI 97-06, coupled with voluntary industry implementation of improved SG technical specifications.

Steam Generator Tube Integrity Program Lessons-Learned

The Task Group concludes that there are a number of plant specific and generic lessons-learned that support recommendations to improve industry SG tube integrity programs.

Con Ed

The Task Group reviewed major aspects of the 1997 Con Ed SG examinations and plans leading up to these examinations. These same activities were the subject of an NRC Special Inspection Team review and are documented in its report of August 31, 2000. The Task Group agrees that the inspection findings are of potential high significance, as proposed but believe that comment from Con Ed in accordance with the process is both appropriate and necessary. The key deficiencies noted were that:

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- 1) During the 1997 SG eddy current examination by Con Ed, a defect caused by primary water stress corrosion cracking (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
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the susceptibility of similar tubes to this degradation during the upcoming operating cycle.

- 2) During the 1997 SG examination, forms of degradation called tube denting and hour-glassing, were 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. *MA* ✓
- 3) During the 1997 examination significant eddy current signal interference (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 account for the noise, particularly when the new PWSCC defect was found in this area of the SG.

The Task Group believes that the findings of the Special Inspection Team are reasonable and that corrective actions at IP2 should proceed in accordance with the ongoing inspection and enforcement process.

Industry / NEI / EPRI

Along with the plant specific examinations conducted by Con Ed at IP2 during 1997, the Task Group reviewed the industry SG examination guidance used by Con Ed during the 1997 outage and concluded that weaknesses in the guidance contributed to the inadequate examinations. *existing (weak) while regulatory requirements are revised as different, the situation could be improved if industry guidance*

The guidance was developed and is maintained by the Electric Power Research Institute (EPRI). Since the EPRI guidance is a cornerstone of the industry initiative now being coordinated with the Nuclear Energy Institute (NEI), the Task Group believes that the industry should be requested by the NRC to expeditiously ensure that the lessons-learned from the IP2 event are incorporated into the guidelines and implemented by all licensees and that feedback be provided to the NRC on the status.

Particular improvements to the EPRI guidelines to improve the effectiveness of SG examinations are discussed in detail in Section 6 of this report. The Task Group believes that the guidance in use during the 1997 IP2 examinations are vague with respect to the quality of eddy current data and the significance of noise in the data. The need for increased licensee attention when "new" types of degradation are found is not emphasized. The Task Group understands that industry is already taking steps to make improvements and believe they should be discussed with the staff, and schedules determined for incorporation. *emphasized the need for staff*

The following additional issues that should be pursued with the industry for improvements in the guidance and implementation by licensees were identified by the Task Group:

- 1) Licensees should review 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 probes to perform inspections is fundamental to an adequate inspection.
- 2) Parameters that are needed to assess SG tube structural integrity such as probability of detection of certain flaw size and growth rates are based on unqualified sizing techniques. This leads to a lack of consideration of uncertainties when licensee's determine flaws that are left in service or select tubes for in-situ pressure testing.