



NRC NEWS

U.S. NUCLEAR REGULATORY COMMISSION

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No. 00-178

November 15, 2000

NOTE TO EDITORS: NRC ISSUES “LESSONS LEARNED” REPORT ON INDIAN POINT 2 STEAM GENERATOR TUBE FAILURE

The Nuclear Regulatory Commission has issued a “lessons learned” report on the Indian Point 2 steam generator tube failure that led to a declaration of an alert at the site in Buchanan, N.Y. on February 15.

The report evaluated the NRC staff’s regulatory processes related to assuring steam generator tube integrity. It identifies and recommends areas for improvements applicable to the NRC and the industry.

The NRC staff is developing an action plan that will include the disposition of the lessons learned report in an integrated manner with other ongoing steam generator issues. Recommendations in the report that apply to the industry will be considered by the staff in the context of its review of ongoing industry initiatives.

The report’s executive summary is appended to this note. The “Indian Point 2 Steam Generator Tube Failure Lessons Learned Report,” is available from the NRC Public Document Room, Rockville, Maryland, (301) 415-4737. The full text of the 144-page report has been posted at: <http://www.nrc.gov/NRC/REACTOR/IP/index.html> on the NRC web site.

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EXECUTIVE SUMMARY

The February 15, 2000 Steam Generator Tube Failure Event

On February 15, 2000, 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 through-wall crack in one of the 3,260 tubes in one of the SGs 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 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 established 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 before restart.

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 information 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.

The Task Group also reviewed the following reports:

- 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 NRC safety evaluation associated with an IP2 license amendment that approved an extension to the SG inspection

interval. The Task Group considered the issues raised in the RES review as discussed in Sections 6.2, 6.4, 7.0, and 8.1 of this report.

- 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," dated August 29, 2000. The Task Group addressed the findings of the OIG report related to SG issues as discussed in Sections 6.3 and 8.1 of this report.

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 Task Group review included the licensee's results of the IP2 SG examinations and root cause evaluation in accordance with the charter. The Task Group did not evaluate Con Ed performance relative to regulatory requirements.

The conclusions and recommendations in this report represent the views of the Task Group. The recommendations were developed to address the conclusions/lessons-learned that were reached, so that with respect to SG tube integrity, the NRC can continue to maintain safety, increase public confidence, increase the efficiency and effectiveness of NRC programs, and reduce unnecessary regulatory burden. Quantitative costs and benefits were not developed for each recommendation. The objective was to provide a basis for each recommendation to support both the internal NRC planning process and the appropriate regulatory process for considering actions for the industry.

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 Team 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 the licensee's SG tube integrity and quality assurance program was 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 (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 NRC's Strategic Plan. The risk from the IP2 SG event and risk from the tube condition prior to the event were well within NRC Strategic Plan 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.

The Task Group concluded that communicating the safety significance of the IP2 experience is difficult. During the NRC significance determination process related to the IP2 tube failure, the staff

found that the SG tube condition during Cycle 14 was risk significant due to the degradation of safety margin. Notwithstanding 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, and the IP2 event resulted in no adverse consequences to the public health and safety. This distinction may not be understood by all stakeholders. NRC will probably face this communications challenge again because SG tube failures and ruptures have occurred before and will likely occur again. Therefore, the Task Group recommends that the NRC should incorporate experience gained from the IP2 event and the SDP process into planned initiatives on risk communication and outreach to the public.

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 to four 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. The key deficiencies noted were that:

- 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 the susceptibility of similar tubes to this degradation during the upcoming operating cycle.
- 2) During the 1997 SG examination, a form of degradation called tube 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.
- 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 compensate 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 SG 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 there were weaknesses in the guidance as well as in their implementation. 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 was not explicit 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 should be emphasized in the guidance. 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 their incorporation.

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 techniques to perform inspections is fundamental to an adequate inspection.
- 2) Licensees should use caution when assessing SG tube structural integrity by using unqualified sizing techniques for growth rates and threshold of detection. Licensees should use a conservative approach to screen tubes for in-situ testing.
- 3) A noise study performed by NEI indicates that SG tube U-bend noise may be significant regardless of tube age or outside deposits. Flaw detection capabilities in the U-bend region should be assessed for all SGs.
- 4) Vendors that conduct the actual examinations, including collection and analysis of the data, are important to the SG examination process. The industry initiative should address vendor oversight by licensees.

Other recommendations to improve the effectiveness of the guidance can be found in Section 6 of this report.

Industry Initiative and Framework

The Task Group considered the implications on the industry initiative and framework, given the IP2 event and its lessons-learned, the weaknesses in the EPRI guidance, and the safety significance of the issues. The Task Group believes that the industry initiative remains an effective means to continue to maintain safety in this area. However, the lessons-learned discussed above identify issues that should be incorporated into the framework in an integrated way. The Task Group concludes that the industry should be requested to evaluate and propose modifications to the framework that consider the lessons-learned from IP2. These should include, as a minimum:

- 1) means to ensure plant-specific licensee attention to lessons-learned;
- 2) improvements to the EPRI guidelines, and
- 3) content of the improved technical specifications relating to SG degradation mechanisms, examination techniques, primary-to-secondary leakage limits, and reporting requirements (both content and schedule of reports).

As stated above, the Task Group believes these activities should receive a high priority. Therefore, in the interim, the Task Group believes that 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.

NRC Regulatory Processes

Based on a review of the licensing, inspection and oversight processes associated with the IP2 event and SG tube integrity, the Task Group believes that there are areas that should be improved in these processes to make them more effective, as discussed below.

Licensing

The license amendment process is used by the NRC to review facility operating license changes proposed by a licensee. Such a request was made by Con Ed in December 1998 to extend its SG examination from June 1999 to June 2000. In effect, because of an approximate 10 month period the plant was shut down, the licensee was actually requesting an extension of the examination interval of approximately 2 months beyond the already authorized 24 months (June 1997 to June 1999). This is illustrated in the Appendix A timeline of this report. Because the licensee followed industry guidelines for maintaining water chemistry in the SGs to minimize corrosion of the SG tubes and the reactor coolant system was at low temperature conditions during the shutdown, any degradation that would have occurred during the shutdown period should have been negligible.

The 1997 SG examination performed by Con Ed, which has now been determined to be deficient as discussed above, was the underlying basis for the SG inspection interval extension amendment that was requested by Con Ed. Thus, the Con Ed amendment request and the NRC licensing review provided an opportunity for Con Ed and the NRC to reevaluate the adequacy of the 1997 examination. After the February tube failure event, NRR requested RES to review this extension request along with the associated NRR safety evaluation of the proposal. The RES technical review was provided in a report dated March 16, 2000. The OIG also evaluated this licensing review and provided its findings in a report dated August 29, 2000. Both of these reports identified shortcomings in the licensing review. They were considered in detail by the Task Group, along with the specific licensee and staff documents and review guidance, in reaching conclusions and recommendations.

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

- 1) 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 one that failed in February 2000 (PWSCC at tube apex in a small radius U-bend).
- 2) In hindsight, during the amendment review process, the issue regarding the PWSCC degradation could have been pursued further by the NRC staff. If the staff had denied the amendment request, an examination would have been required prior to the tube failure. However, based on a review of information available to the licensee and the staff during the amendment review, it is not clear to the Task Group if additional staff questions posed during the review would have changed the outcome of the license amendment request or uncovered the issues related to the root cause of the tube failure. For example, Con Ed had performed an examination of all other similar tubes using an inspection plan previously reviewed and approved by the staff.

- 3) The IP2 tube failure occurred on February 15, 2000, which was approximately 8 months after the originally scheduled inspection date (i.e., less than the duration justified by the 10 month shutdown). Therefore, the extension of approximately 2 months did not contribute to the tube failure event. This is illustrated in the Appendix A timeline of this report.
- 4) While the staff used existing NRC review guidance in performing the review, no specific guidance exists for SG inspection interval extensions, especially how to consider previous inspection reports, or how to consider or reference the inspection program.

A detailed discussion of the Task Group review of the licensing review process associated with the Con Ed amendment request to extend the SG inspection interval (including Task Group comments on the related OIG report findings) is included in Section 8.1 of this report. The Task Group's review of the issues addressed in the RES technical review is included in Sections 6.2, 7.0, and 8.1 of this report.

While the Task Group did not evaluate the area of staff SG expertise in detail, this was brought up by the OIG report, and was mentioned in conversations with NRC staff and managers responsible for these programs. The Task Group believes that agency SG expertise is limited and focused primarily at headquarters. The Task Group recommends that NRC take steps to evaluate SG expertise needs to support the licensing (as well as inspection) program.

In summary, the Task Group believes that the problem relates back to the quality of the Con Ed 1997 examination. Improvements to industry SG examinations (discussed above) and NRC regulatory inspection processes that focus on these examinations (discussed below) will maintain plant safety and improve the efficiency and effectiveness of NRC programs. The Task Group believes that additional review guidance for SG examination license amendments will improve the effectiveness and efficiency of these reviews.

Inspection

The objective of the NRC inspection program is to obtain factual information providing objective evidence that power reactor facilities are operated safely. The SG tube failure at IP2 occurred at a time when the NRC was transitioning to a new reactor oversight process (ROP). Effective April 2, 2000, the NRC implemented this new process for all plants. The Task Group reviewed both the old and new NRC inspection processes to develop lessons-learned and recommendations.

The baseline inspection in the new ROP for inservice inspection (ISI) is to be performed at all operating reactors, once every two years during a refueling outage. Supplemental inspections are performed as a result of risk-significant licensee performance issues that are identified by either PIs, baseline inspections, or event analysis.

Prior to April 2000, an NRC ISI inspection was performed at each facility in accordance with the core inspection program. This program was in effect during the NRC inspection of IP2 in 1997. The scope of the inspector's review was based on a judgement regarding current significant issues and also as directed by the inspector's supervisor. The planning did not usually involve NRC headquarters personnel. It did not require that industry information be factored in, although it sometimes was. New industry and generic information, such as Information Notices and Generic Letters, did not always get to the regional inspectors in time enough to be factored into their inspection activities. The site inspection involved one inspector for a period of one week and was not necessarily limited to SG activities, but it could also include non-destructive examination (NDE) activities on other components.

NRR has routinely held conference calls with each licensee during their refueling outage to assess the adequacy of the licensee SG tube eddy current inspections. These conference calls involve

regional participation on occasion and include discussion of the results of the licensee generator inspections and repair plans. In the last few years, the staff has focused on plants with known SG tube degradation issues. This effort has not been a formal part of the inspection program, and the results are not documented in inspection reports. During consideration of the NRC inspection activities, the Task Group interviewed NRC staff involved in the phone calls and reviewed some of the records of the 1997 outage NRC/Con Ed telephone calls held on June 2, 3, and 29, 1997. Some staff members interviewed by the Task Group indicated that they had specifically asked Con Ed during the phone calls if any U-bend degradation in small radius U-bends had been identified. There was no indication that the crack discovered in the tube similar to the tube that failed was discussed. The timing of the phone calls relative to when the flaw was identified was not clear. The Task Group determined that these calls are important activities that should be factored into the inspection process.

The new ROP baseline inspection procedure for ISI does not include guidance on the scope and depth of NRC inspection of licensee SG tube examinations. The inspection procedure contains significantly less guidance for conduct of the inspection than the previous core inspection procedure. Available supplemental procedures contain considerably more detail. Under the new ROP, risk-informed thresholds are to be applied to inspection findings to determine when a significant degraded condition has occurred that warrants additional NRC interaction and supplemental inspection above the baseline program. Such thresholds do not currently exist to identify when the number or types of SG tube defects have reached a level that warrants additional NRC action.

There are no specific requirements for ISI inspector training or expertise. Region staff interviewed indicated that as part of the training program, prior to conducting individual inspections, inspectors assist other inspectors on NRC's NDE inspections at other reactor sites. A number of inspectors have received detailed training in eddy current examination and have personal NDE experience.

The Task Group also carefully reviewed the licensee submittal to the NRC dated July 29, 1997, regarding the IP2 1997 SG examination. The level of detail provided in the 1997 examination report submitted by Con Ed was not sufficient to pinpoint the technical and implementation problems, such as the eddy current data quality and noise issues discussed above (and in Section 6.1 of this report). The Task Group noted that the tube that failed was not reflected in the report as a degraded tube, since it was not identified by the licensee as such during the 1997 examination. The NRC's OIG report dated August 29, 2000, concluded that had the NRC staff or contractor with technical expertise evaluated the 1997 results of the IP2 SG inspection, the NRC could have identified the flaw in the U-bend of the row 2, column 5 (R2C5) tube in SG 24 that was indicated in the licensee's inspection (examination) report. After careful review, the Task Group concluded that the NRC staff could not have identified the tube that failed from its review of the licensee's inspection report. That report did not indicate that there was a flaw in the tube or provide any information on the tube. Even if the staff should have been prompted by the report's identification of a new degradation mechanism (PWSCC) in a similar tube that was plugged, it would have required further discussion with the licensee, additional staff review of the 1997 raw eddy current data of the failed tube, and identification of the flaw from the data, which clearly was of poor quality due to noise. Experts that the Task Group interviewed held different views on whether the flaw in R2C5 could have reasonably been detected from the data. Licensee reports in general, and this report in particular, do not provide this information or related discussions or evaluation of eddy current data. For the NRC to have this information, an eddy current specialist would have to review the raw data independently. This is not typically included within the scope of NRC inspection or review.

Details of the Task Group review of the NRC SG inspection program are provided in Section 8.2 of the report. Overall, the Task Group believes that:

- 1) The NRC should develop additional SG inspection guidance for the baseline inspection program.

- 2) Inspector training should be reviewed and tailored to support the objectives of the SG inspection program.
- 3) Information needs and processes to support the objective of the SG inspection program should be determined. In this regard, the Task Group believes that the telephone calls conducted with licensees during the outages are effective and should be formally incorporated into the inspection program.
- 4) Risk-informed thresholds should be established to identify when increased NRC interaction is warranted in response to SG tube degradation.
- 5) The baseline program and/or performance indicators should be modified to identify adverse trends in primary-to-secondary leakage. Risk-informed thresholds should be established to identify when increased NRC interaction is warranted in response to an adverse trend.

Conclusions and Recommendations

Sections 5.0 through 8.0 of this report include sub-sections (as indicated in the report Table of Contents) that provide the conclusions/lessons-learned and recommendations for the respective section. Section 9.0 provides a table (Table 9-1) that lists all the report recommendations with a reference back to the supporting section in the report. The recommendations fall into the following areas:

- 1) Con Ed must correct the deficiencies in its SG tube integrity program;
- 2) Industry should improve the EPRI guidelines;
- 3) Industry should improve the SG technical specifications;
- 4) Industry should improve the NEI 97-06 initiative;
- 5) The NRC should improve its SG oversight and inspection process;
- 6) The NRC should improve its licensing review process;
- 7) The NRC should assign a high priority to its review of the NEI initiative and the associated EPRI guidelines;
- 8) The NRC should issue a generic communication regarding SG tube integrity program guidance; and
- 9) The NRC should improve risk communication to the public.

Overall, the Task Group believes that the lessons-learned from IP2 are important relative to assuring SG integrity and that the industry initiative should expeditiously incorporate the lessons-learned into the regulatory framework.

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