

November 21, 2001

LICENSEE: AmerGen Energy Company, LLC (AmerGen)  
FACILITY: Three Mile Island Nuclear Station, Unit 1 (TMI-1)  
SUBJECT: SUMMARY OF NOVEMBER 9, 2001, MEETING WITH AMERGEN  
REGARDING TMI-1 STEAM GENERATOR SEVERED TUBE ROOT CAUSE  
(TAC MB3305)

On November 9, 2001, a public meeting was held between the U.S. Nuclear Regulatory Commission (NRC) and Exelon/AmerGen (the licensee), at NRC Headquarters, One White Flint North, 11555 Rockville Pike, Rockville, Maryland. The purpose of the meeting was for the licensee to provide its root cause assessment of the TMI-1 once-through steam generator (OTSG) severed tube that was discovered during the 2001 refueling outage (1R14) steam generator eddy current inspection. A short presentation was also made by a representative of the Babcock & Wilcox Owners Group (B&WOG) regarding their interactions with the licensee during the 1R14 OTSG inspections. Enclosure 1 is a list of attendees. Enclosure 2 is a copy of the licensee's handout used at the meeting. Enclosure 3 is copy of the B&WOG's presentation slides. Enclosure 4 is the list of the NRC staff's follow-up questions from the meeting. The licensee is requested to provide docketed responses to questions 1 through 4, 3 working days prior to restart from 1R14, and docketed responses to the remaining questions by January 18, 2002.

Background:

During performance of the 1R14 steam generator eddy current inspections, the licensee identified four tubes in the B OTSG that exhibited signs of tube wear near the secondary face of the upper tubesheet (UTS). There had been no signs of tube wear on these tubes during the prior steam generator tube inspections performed approximately 2 years earlier.

As a result of the pattern and location of wear, the licensee suspected a plugged tube located in Row 66 Tube 130 (B66-130) may have caused the wear on the active tubes. The plug in the UTS for B66-130 was removed and a video inspection of the tube was performed. The video inspection indicated the tube severed near the secondary face of the UTS. This tube had been plugged in 1986 with an alloy-600 mechanical plug as a result of intergranular attack near the fifth tube support plate (TSP). There was no observable degradation at the location of the severance at the time the tube was originally plugged. The original plug in this tube was replaced in 1997 with an alloy-690 mechanical plug as part of a program to replace many of the alloy-600 plugs in the UTS.

To investigate the severity of the wear indications, the licensee performed in-situ pressure testing of a few of these tubes and removed the degraded portion of two of these tubes for destructive examination. This testing revealed that two of the tubes adjacent to B66-130 challenged the design-basis structural performance criteria for steam generator tubes that are discussed in the Nuclear Energy Institute's (NEI's) guidelines, NEI 97-06, "Steam Generator Program Guidelines."

In addition to removing the degraded portion of two of the tubes with wear indications for destructive examination, the licensee also removed the lower portion of the fractured surface of the severed tube to assess the root cause.

Licensee's Analysis/Assessment and Root Cause Evaluation:

The licensee discussed the methodology they have used to analyze and assess the as-found condition. They also presented the preliminary findings of their root cause evaluation.

The licensee stated that, in addition to the eddy current data analysis, the analysis methodology has included in-situ pressure testing, tube sample removal, laboratory analysis, and flow induced vibration analysis. The removed samples have been subjected to visual examination, laboratory pressure testing and electron microscope inspection as part of the laboratory analysis. Additionally, the licensee stated that the OTSG inspection scope was expanded to include de-plugging and inspection of tubes in both steam generators that have rolled plugs installed.

The licensee discussed the results of the inspection of tube B66-130 and the results of the increased inspection scope with the NRC staff. The licensee stated that tube B66-130 exhibits signs of swelling along much of its length, and appears to have Outer Diameter - IGA, as well as fatigue and ductile tearing on the fracture surface.

The licensee stated further that, as of November 8, 2001:

- One additional circumferentially severed tube has been identified in the "A" OTSG
  - A2-24
    - severed at the fifteenth (15<sup>th</sup>) TSP
    - no damage to adjacent tubes identified
- Two plugged OTSG tubes with significant axial flaws discovered
  - B150-14
    - multiple non-continuous axial inner diameter (ID) indications from the UTS to the 15<sup>th</sup> TSP
    - one axial flaw was completely throughwall for approximately 1.4 inches
    - no damage to adjacent tubes identified
  - A12-1
    - long axial ID indications identified in the span between the 15<sup>th</sup> TSP and the secondary face of the UTS
    - no throughwall opening identified
    - no damage to adjacent tubes identified

The following information is common to all of these failures:

- all tubes had mechanical plugs
- swelling of all four tubes had occurred to some extent
- all were exposed to similar flow velocity conditions
- all are located in the outer periphery of the tube bundle

Additionally, results of the expanded inspection scope as of November 8, 2001, show that a total of 23 tubes, which had previously been removed from service, in both OTSGs, exhibit signs of swelling.<sup>1</sup> A number of the tubes that have been de-plugged for additional inspection were found to contain water, which indicates that either the tubes were not free of water before they were plugged, or that the installed plugs were leaking by.

With regard to the tubes that are adjacent to tube B66-130 and exhibit signs of wear from contact with B66-130, the licensee indicated that their inspection and evaluation revealed that two tubes (B65-130 and B66-131) failed to meet the structural performance criteria of NEI 97-06.

#### *Root Cause Evaluation*

The licensee presented their preliminary root cause evaluation. They postulate that the circumferential severing failure of the B66-130 and A2-24 OTSG tubes is the result of three simultaneous phenomena: a tube expansion effect, flow-induced vibration, and OD - IGA. The tube expansion effect is the result of an expansion of water in a plugged tube during unit operation. If an installed plug leaks by and allows water to enter the tube faster than it can escape, the thermal expansion of the water can result in tube deformation by swelling. Once a tube has fully expanded, it is effectively clamped at the fifteenth TSP and the secondary face of the UTS. High cycle fatigue, which leads to tube failure, then results from the tube being located in a high flow region (flow-induced vibration). If it is present, OD - IGA in the UTS region seems to contribute to the failure of the tubes, however, it is not entirely clear that the presence of OD - IGA is a pre-requisite for failure to occur.

#### Corrective Actions:

The licensee stated that they will continue to de-plug tubes that have been removed from service for inspection. These inspections will be done with a bobbin probe and, if swelling or indications are observed, a rotating probe inspection will be performed. Additional corrective actions will include installation of stabilizers in all plugged tubes in both OTSGs from the hot leg, regardless of their location in the OTSG and, therefore, regardless of their exposure to high flow velocities (i.e., the old UTS plugs are being removed, the tubes are being inspected, stabilizers and new UTS plugs are being installed). In some cases, the licensee will "cage" a tube, or group of tubes, by stabilizing and plugging the surrounding tubes (e.g., if unable to

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<sup>1</sup> On November 16, 2001, the licensee notified the NRC staff that they have identified a total of 29 swelled tubes in both OTSGs.

remove an already installed plug). The stabilizers to be installed extend down to the fourteenth TSP.<sup>2</sup>

Independent Review Group:

The licensee provided a short discussion regarding an independent review group that they established in order to provide a critical overview of the root cause investigation of the B66-130 tube failure. This group provided an independent review of the plans for inspection and metallurgical work, as well as the approach for determining the root cause of the failure.

B&WOG:

A representative of the B&WOG made a short presentation which discussed the interactions that the owners group has had with the licensee during the TMI-1 1R14 OTSG inspections and repairs.

Evaluation of time of tube failure:

The licensee provided the NRC staff with information regarding their evaluation to estimate the approximate time of the tube failure. This additional information is included in Enclosure 2 and annotated as part of the addenda to the presentation handout.

Follow-up Questions:

The NRC staff and the licensee discussed the process by which any follow-up questions from the NRC staff would be handled. The licensee stated that they will provide written docketed responses to any questions included as an enclosure to the meeting summary. The NRC staff's follow-up questions are included in Enclosure 4. The licensee is requested to provide docketed responses to questions 1 through 4, 3 working days prior to restart from 1R14, and docketed responses to the remaining questions by January 18, 2002.

Corrections and Addenda:

Following a conference call with the NRC staff on November 13, 2001, the licensee provided to the NRC staff a corrected version of slide 18 in the presentation handout. In response to an NRC staff question regarding the labeling of that slide, the licensee determined that they had inadvertently transposed the labels for the ID and OD on the fractograph presented in the slide.

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<sup>2</sup> On November 13, 2001, the licensee verbally informed the NRC staff during a conference call that they have decided to install full-length stabilizers in tubes that show indications of swelling.

The corrected slide 18 is included in Enclosure 2 and is annotated as being a corrected slide. Additionally, also in response to an NRC staff request, the licensee provided the NRC staff with a composite cross section view of the failed tube, and a scanning electron microscope fractograph that provides dimensional information. These two additional images are also included in Enclosure 2 and annotated as addenda to the presentation handout.

***/RA by D Collins for/***

Timothy G. Colburn, Senior Project Manager, Section 1  
Project Directorate I  
Division of Licensing Project Management  
Office of Nuclear Reactor Regulation

Docket No. 50-289

Enclosures:

1. List of Attendees
2. AmerGen Handout - TMI Once Through Steam Generator Inspection/Repair w/ addenda
3. B&W Owner's Group Presentation Slides
4. NRC Staff Follow-Up Questions

cc w/enclosures: See next page

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\* as modified

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NOVEMBER 9, 2001  
MEETING WITH AMERGEN ENERGY COMPANY, LLC  
THREE MILE ISLAND NUCLEAR STATION, UNIT 1

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L. Raghavan	NRC/NRR/DLPM/LPD1
T. Colburn	NRC/NRR/DLPM/LPD1
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S. Long	NRC/NRR/DSSA/SPSB
C. Moyer	NRC/RES/DET/MEB
S. Freeman	NRC/NRR/DRIP/REXB
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M. Sears	Exelon
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J. Meister	Exelon
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D. Salter	HGP, Inc.
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C. Colpo	Self