Enclosure 2

Review of Industry Responses to Staff Comments
Concerning Prescriptive Steam Generator Inspection Intervals

During a public meeting on August 29, 2001 (Reference 1), NEI and industry representatives presented a summary of draft guidelines concerning prescriptive steam generator (SG) inspection intervals which the industry was considering for inclusion into Revision 6 of the EPRI PWR Steam Generator Examination Guidelines. The staff documented its comments on these draft guidelines in an internal NRC memorandum dated September 18, 2001 (Reference 2), which was provided to the industry and other external stakeholders. The industry presented its response to the staff's comments at a public meeting on June 13, 2002 (Reference 3). The staff's review of these responses is documented herein.

NRC Comment No. 1

The one fuel cycle limitation should be one fuel cycle or 24 EFPM, whichever is shorter. Similarly, the two cycle limitation should not exceed 48 EFPM and the three cycle limitation should not exceed 72 EFPM.

Industry Response

Industry agrees. Section 3 in Revision 6 removes reference to “skipping” fuel cycles and establishes limits of of 24 EFPM for 600MA, 48 EFPM for 600TT, and 72 EFPM for 690TT as the maximum length of time that the SG can operate without being inspected.

Staff Review of Industry Response

Although the industry states it is agreement with the staff comment, the proposed resolution is not consistent with the staff's comment. The latest version of Revision 6 deletes the 1, 2, and 3-cycle limitation for 600MA, 600TT, and 690TT tubing, respectively, and replaces them with the 24, 48, and 72 EFPM limitations.

The industry response is not acceptable without technical justification for deleting the fuel cycle limitations. In particular, it needs to be demonstrated that SCC growth is dominantly a linear function of time at temperature with little contribution from growth associated with plant heatup and cooldown cycles.

NRC Comment No. 2

The staff made a number of comments concerning the definition of “active degradation mechanism.” These comments included (1) that any finding of cracks would constitute active degradation, (2) that loose parts related damage should be considered active degradation irrespective of whether the causal object is believed to have been retrieved, and (3) that the growth increment criteria should be adjusted as necessary to reflect the length of the next planned inspection interval.

Industry Response

The industry has addressed the first element of the staff's comment by revising the definition of "active degradation mechanism" in Revision 6 to include any crack indication. Regarding the second element of the staff's comment, loose parts related damage, the Revision 6 definition would exclude such damage from the definition. The industry states that the nature of loose parts does not fit the definition of active degradation mechanism. (The staff assumes this to be a mis-statement since it is making a circular argument; i.e., it doesn't fit the definition because the industry is proposing to exclude loose parts damage from the definition. The staff assumes that what the industry actually means is that the term "active degradation mechanism" should not be applied to loose parts induced damage.) As justification, the industry states that the actions required upon identification of loose parts induced damage are not the same as would be pursued in response to other forms of degradation. The industry further states that an evaluation is required that addresses the programmatic and inspection limitations as well as the specifics of the actual condition.

Regarding the third element of the staff's comment, that the growth increment criteria should be adjusted as necessary to reflect the length of the next planned inspection interval, the industry states that is in agreement that growth rate should be defined on an inspection to inspection interval. The industry further states that application of growth rate (including growth rate adjustment) in defining an acceptable inspection interval is addressed in the EPRI SG Integrity Assessment Guidelines.

Staff Review of Industry Response

The Revision 6 definition of active degradation mechanism is responsive to only the first of the three elements of the staff's comment; namely, any crack indication will constitute active degradation.

Regarding the second element of the staff's comment, loose parts related damage, the Revision 6 definition would exclude such damage from the definition. That is, loose parts related damage would, by definition, not be active degradation, even if the causal loose part is not found and removed. The staff believes this to be inappropriate. Loose parts related damage has historically been a major contributor to loss of tube integrity and tube rupture. Although the industry statement that actions required upon identification of loose parts induced damage are not the same as would be pursued in response to other forms of degradation, the staff believes this and other industry statements have no relevancy to how active degradation should be defined. Revision 6 of the guidelines contains no criteria dictating a secondary side inspection in response to the finding of loose parts related damage nor does it dictate retrieval of the causal loose part. It is the staff's experience that licensees may elect not to perform a secondary side inspection in response to loose parts damage, may not be able to find the causal loose part or other loose parts in the SGs, and/or may be unable to retrieve the causal loose part or other loose parts present in the steam generators. It is also the staff's experience that loose parts related damage can be chronic over several cycles (e.g., Byron 2).

Regarding the third element of the staff's comment, that the growth increment criteria should be adjusted as necessary to reflect the length of the next planned inspection interval, the industry states that is in agreement that growth rate should be defined on an inspection to inspection interval. However, the industry did not address the thrust of the staff's comment; namely the growth increment between inspections should be adjusted to consider the length of the next planned inspection interval. The staff notes, for example, that a wear flaw that is observed to grow 39% over a single cycle inspection interval would not in-of-itself cause the wear mechanism to be an active mechanism under the Revision 6 definition. However, if the next inspection interval is going to be three fuel cycles rather than one, then it is highly likely that a wear flaw will occur during that period which will leak or rupture. The staff acknowledges the industry argument that this growth rate would be factored into the operational assessment which should alert the licensee that a three cycle inspection interval is inappropriate. While the staff comment stands, the Revision 6 proposal is not unacceptable given the guidance that an operational assessment be performed. Previously expressed staff concerns (References 2 and 4) about the guidance for operational assessments is most acute for cracks; however, the finding of any crack would be considered to constitute an active mechanism under Revision 6 and subsequent inspection intervals would be limited to one fuel cycle. The staff believes that industry is better able to manage volumetric degradation mechanisms such as wear, pits, and wastage from the standpoint of meeting the performance criteria.

Staff Comment No. 3

For plants with Alloy 690 TT tubing, three cycle inspection intervals shall be preceded by a two cycle inspection interval.

Industry Response

Preceding a three cycle interval by a two cycle interval is not necessary. A 100% inspection to compare actual tube condition to their pre-service condition is performed at the first refueling outage inspection. Tubes are in their best condition early in life. Operating history of SGs with alloy 600TT and 690TT tubing indicates that any problems that may eventually occur do not exhibit themselves until well after three cycles. All inspection intervals are to be supported by an operational assessment.

Staff Review of Industry Response

The staff's comment is based on the uncertainties associated with application of growth rates observed during a previous one fuel cycle inspection interval to a subsequent three cycle interval. The industry response does not address this concern.

Staff Comments No. 4 and 5

The initial finding (industry wide) of indications associated with a cracking mechanism shall define the "time to detectable cracking threshold" for Alloy 600 TT SGs or Alloy 690 TT, as applicable. The time to cracking threshold shall be normalized to a reference temperature. The licensee shall take action as necessary to ensure that cognizant personnel at all plants utilizing the same tubing material are promptly informed of the finding. Upon receipt of such information, the other licensees shall consider the information as part of the degradation assessment which is to be performed prior to the next scheduled refueling outage to assess the need for modification to the schedule for the next SG inspection. Inspections shall be performed at each refueling outage after the equivalent accumulated full power operating time on the SGs (i.e., normalized for reference temperature) exceeds 75% of the "time to detectable cracking threshold."

The "time to detectable cracking" should be revised downward as necessary to lower bound subsequent findings (industry wide) of crack indications occurring after equivalent, accumulated full power operating times less than that observed earlier. Again, the affected licensee shall take action as necessary to ensure that cognizant personnel at all plants utilizing the same tubing material are promptly informed of the finding. The other licensees shall respond as described above.

Industry Response

The industry states that proposed inspection intervals are conservative with respect to operating experience with 600TT and 690TT materials. Expanded guidance for degradation assessments has been provided in Revision 6 of the EPRI SG Examination Guidelines, which includes consideration of industry experience. Steam Generator Management Program (SGMP) meetings provide frequent opportunities for plants to exchange SG operating experience. EPRI SG Database updates are required within 120 days. The use of a "time to detectable cracking threshold" tied to one plant does not take into account the unique nature of each SG's operating conditions.

Staff Review of Industry Response

The industry response does not fully address the staff's concern. Revision 6 of the guidelines would not require or direct licensees to inspect at single cycle intervals once the "time to detectable cracking threshold" is crossed. The industry has provided no information supporting the conservativism of the proposed inspection intervals, in-of-themselves, to ensure that cracks just below the inspection threshold during a given inspection will continue to satisfy the tube integrity performance criteria at the next scheduled inspection two or three fuel cycles hence. The Revision 6 SG examination guidelines and the SG integrity assessment guidelines for performing degradation assessments do not provide reliable, quantitative tools which have been demonstrated to be capable of conservatively predicting the initial onset of cracking in alloy 600TT or 690TT tubing for actual site-specific conditions.

The staff acknowledges that the industry's degradation data base and frequent SGMP meetings provides a mechanism for ensuring that information concerning initial crack activity at one site would eventually be available to all licensee's for their consideration. In addition, the staff acknowledges that it is appropriate to consider plant unique conditions when evaluating equivalent full power operating time at a plant versus the "time to detectable cracking threshold." Should the "time to detectable cracking" at another unit reflect causal factors not in play at the subject plant, it is appropriate that this be considered in the degradation assessment when determining whether a change to the inspection schedule is needed. The staff hereby modifies its September 18, 2001 comment accordingly. The staff's comment in its September 18, 2001 letter also noted that it would be appropriate to normalize operating times for a reference operating temperature. The staff now expands this comment to acknowledge that other normalizing parameters may also be appropriate to the extent they are quantifiable with a firm engineering basis.

Staff Comment No. 6

For purposes of tube integrity assessments supporting multi-cycle inspection intervals, ligament tearing of volumetric flaws shall be considered "burst." That is, volumetric flaws should have a factor of three margin against such ligament tearing.

Industry Response

NRC position is not consistent with the definition approved by the staff at a 7/24/99 meeting. NUREG/CR 5117 provides test data confirming the burst resistance of deep pit-like defects. Adding requirements concerning leak rates above MSLB pressures is considered to be in excess of currently agreed to deterministic performance criteria.

Staff Review of Industry Comment

The staff is revising its comment as follows: Section M.2.2 of the EPRI Steam Generator Integrity Guidelines, which discusses the definition of burst, should include additional discussion to clarify what constitutes burst for volumetric flaws such as wear, wastage, and loose parts damage. Specifically, the minimum size of a volumetric perforation of the tube wall constituting burst should be discussed.

The staff has previously agreed to the following definition of burst: Burst is defined as the gross structural failure of the tube wall. The condition typically corresponds to an unstable opening displacement accompanied by ductile tearing of the tube material at the ends of the degradation.

The industry prepared a white paper in June 1999 to discuss this definition. This white paper is now included as part of Appendix M in the EPRI Steam Generator Integrity Assessment Guidelines. Although agreement was reached on the definition of burst, the staff did not review or endorse the white paper. The white paper makes a couple of key points regarding the interpretation of the definition. One, it states that the definition is not intended to characterize local instabilities. The staff agrees with this interpretation in principle. The white paper does not define "local, but gives an example; an axial crack 0.5-inches long with a uniform depth of 98% through wall. The white paper states that deformation during pressurization would be expected to lead to failure of the remaining ligament (extension of the crack tip in the radial or thickness direction) at a pressure below that required to cause extension at the tips in the axial direction. The staff agrees with the white paper conclusion that this example would represent a leakage situation as opposed to a burst situation. However, the white paper goes on to state that similar conditions have been observed for deep wear scars. The staff notes this may be true for very localized wear flaws such as may be associated with very small pits, for example, but it is certainly not true for all wear flaws. It certainly wasn't true for the wear scars that caused steam generator tube rupture (SGTR) events at Prairie Island in 1979 and at Ginna in 1982.

So, the question needing clarification in the guidelines is how much tube surface area does a deep wear flaw or other volumetric flaw have to involve before "burst" at pressures less than three times normal operating pressure becomes a concern? Burst is defined as a gross structural failure of the tube wall. When do we have a gross structural failure? From a design basis point of view, the staff believes that it is reasonable to assume we have a gross failure of the tube wall when there is a large enough perforation of the tube wall to cause leakage exceeding the minimum threshold for a steam generator tube rupture (SGTR) event (accident), leading to actuation of engineered safeguard features (ESF), etc. That is, a failure of the tube wall that results in leakage which equals or exceeds the normal makeup capacity of the primary system constitutes a gross structural failure of the tube wall or burst. The normal makeup capacity is plant-specific, ranging to as low as 100 gpm. A round perforation of the tube wall, 0.3 inches diameter, is sufficient to approach this magnitude of leakage.

Industry representatives have stated during meetings that tests show that pressurization of specimens with simulated deep, but relatively small wear flaws indicate initial ligament tearing tends to resemble that of a deep crack of length comparable to that of the major surface dimension of the wear flaw. This tends to significantly limit the leakage relative to that for a complete loss of ligament of the wear flaw. The staff notes, however, that this is not entirely the point. The perforation at the bottom of the wear flaw will continue to open with increasing pressure. Licensees need to demonstrate that there is at least a factor of three relative to burst under normal operating pressure conditions. This means there must be a factor of 3 relative to gross structural failure of the tube wall. To the extent that the perforation could open sufficiently to allow leakage of tube rupture accident proportions, the staff believes it is difficult to argue that this does not constitute a gross structural failure of the tube wall (burst).

Staff Comment No. 7

Inspection intervals extending over multiple fuel cycles should be preceded and followed by inspections which utilize qualified NDE techniques for all potential degradation mechanisms and locations. Axial SCC is a potential degradation mechanism over the entire tube length. Circumferential SCC is a potential degradation mechanism at locations of geometry variations with length, including expansion transitions, u-bends, and dings or dents.

Industry Response

The industry agrees that qualified NDE techniques should be used. Section 3.1 of Revision 6 of the PWR SG Examination Guidelines requires that all examinations be conducted with qualified techniques selected in accordance with the degradation assessment.

Staff Review of Industry Response

The staff comment can be resolved by clarifying the draft Revision 6 guidelines for tube integrity assessment as is discussed in the accompanying enclosure entitled "NRC Staff Comments Pertaining to EPRI PWR Steam Generator Examination Guidelines, Revision 6 (draft dated May 8, 2002)."

Staff Comment No. 8

Indications shall be considered service induced flaw indications in the absence of compelling evidence that the indications are actually associated with manufacturing flaws, surface deposits, tube and/or tube geometry variations, or other inspection artifacts for purposes of determinating whether there is active degradation.

Industry Response

Each of the signals encountered during an SG examination needs to be recognized and correctly classified. The signal analysis process should be conservative and sufficient to determine if there are active degradation mechanisms. All crack like indications should be considered active degradation mechanisms in accordance with the definition.

Staff Review of Industry Response

The industry response nor Revision 6 of the guidelines addresses the concern identified in the staff's September 18, 2001 letter underlying the staff comment. Guidance addressing the staff comment is needed. For example, when faced with anomalous signals at the expansion transitions such as happened in recent years at the Turkey Point units, what actions (e.g., tube pulls, data analysis look-backs to prior inspections) are necessary to establish with high confidence that such indications are not service related such that multi-cycle inspection intervals can continue to be implemented.

Staff Comment No. 9

If primary-to-secondary leakage exceeds 5 gpd prior to shutdown for a refueling outage, an inspection in accordance with the EPRI SG Examination Guidelines for leaker forced outages shall be performed as a minimum.

Industry Response

Note: the industry response presented at the June 13, 2002 meeting (Reference 3) has been revised in the industry's August 13, 2002 letter (Reference 4). The industry now intends to revise the May 8, 2002 draft of Revision 6 such that should leakage exceed 5 gpd prior to entering a scheduled refueling outage, a primary-to-secondary leakage assessment would be performed in accordance Section 5.5 of the guidelines. Section 5.5 provides general guidance for locating the source of the leakage, characterizing the source of leakage, establishing the root cause and implementing corrective action. The root cause evaluation should include evaluation of the need to perform eddy current inspection and/or secondary side visual inspections. In addition, Section 5.5 provides for updating and revising the degradation assessment.

If the source of the leakage cannot be identified visually in conjunction with hydrostatic testing, bubble testing, or helium leak testing, Section 5.5 states that 100% eddy current examination should be considered. Finally, if the source of the leakage cannot be identified, subsequent assessment during future refueling outages is not required if the primary-to-secondary leakage trend is not increasing.

Staff Review of Industry Response

The context of the staff's comment is a plant which is implementing multi-cycle inspection intervals and where the plant enters a refueling outage during which no inspection of the subject steam generator has been planned. Such a plant, by definition, is one with no previously identified cracks and with no more than low level, previously identified volumetric degradation; e.g., wear, pitting, loose parts induced damage. Under this circumstance, a primary to secondary leak of any magnitude constitutes an early warning of either degradation mechanisms not previously observed at the plant or growth rates for previously observed degradation mechanisms higher than were anticipated by the operational assessment. This warning does not relate to simply the leaking tube or tubes, but to the degradation mechanism causing the leak and tubes other than the leaker affected by the degradation mechanism. Whether caused by a new degradation mechanism or higher than anticipated flaw growth rates, an update to the previous degradation and operational assessments is needed to ensure that tube integrity will be maintained until the next scheduled inspection. However, these assessments cannot be performed without information concerning the source of the leakage and its root cause.

The industry's latest proposal is largely responsive to the staff's September 18, 2001 comment and the underlying concern. However, one area of needed improvement is to clarify the circumstances under which eddy current inspections should be performed in the event that the source of leakage cannot determined visually from hydrostatic pressure testing, etc. For example, the size and stability of the leak in the months leading up to the outage may speak volumes about the likelihood that such a leak will continue to grow during the next fuel cycle. Clearly, the aggressiveness of diagnostic measures such as eddy current testing should be stepped up in cases where the leakage has been trending up.

References:

1. NRC memorandum dated September 21, 2001, "Summary of August 29, 2001 Public Meeting with the Nuclear Energy Institute Regarding NEI 97-06 Accession No. ML012690666.

b. NRC memorandum dated September 18, 2001, "NRC Staff Comments on Steam Generator Inspection Intervals" Accession No. ML0112610664.

c. **[Meeting summary to be issued.]**

d. NRC letter dated August 2, 2001, "NEI Steam Generator Generic Change Package" Accession No. ML012200349.