AmerGen Energy Company, LLC
200 Exelon Way
Suite 345
Kennett Square, PA 19348

www.exeloncorp.com

AmerGen
An Exelon/British Energy Company

10 CFR 50.55a

August 1, 2002
5928-02-20156

U. S. Nuclear Regulatory Commission
Attn: Document Control Desk
Washington, DC 20555-0001

Three Mile Island Unit I (TMI Unit 1)
Operating License No. DPR-50
Docket No. 50-289

Subject: Additional Information Regarding Kinetic Expansion Inspection and Repair Criteria

References: (See list on next page)

In accordance with reference 1, AmerGen Energy Company, LLC (AmerGen) submits the attached additional information regarding kinetic expansion eddy current examination acceptance criteria. This information is submitted for NRC's review/acceptance in accordance with Section IWB-3630 of ASME Code Section XI.

If you have any questions or require further information, please contact us.

Very truly yours,

Michael P. Gallagher
Director, Licensing & Regulatory Affairs
Mid-Atlantic Regional Operating Group

Attachment: Responses to Prior NRC Issues/Questions

cc: H. J. Miller, USNRC, Administrator Region I,
J. D. Orr, USNRC, Senior Resident Inspector
T. G. Colburn, USNRC, Senior Project Manager
File No. 02068

A001
A047

REFERENCES

1. NRC Letter, Colburn to Warner, "Assessment of the Three Mile Island Nuclear Station, Unit 1 (TMI-1) Once-Through Steam Generator Kinetic Expansion Inspection and Repair Criteria (TAC M99388)", August 24, 2001.

2. U. S. Nuclear Regulatory Commission Letter, J. F. Stolz to H. D. Hukill, (5211-85-3012), "License Amendment No. 103, 'Steam Generator Tube Repair and Return to Operation, Three Mile Island Nuclear Station, Unit 1 (TMI-1)'", December 21, 1984.

3. Keller, George, "Hydraulic Systems Analysis", published by the Editors of Hydraulics and Pneumatics Magazine, Penton/IPC, Cleveland, 1978.

4. AmerGen Letter #5928-01-20169, M. E. Warner to U. S. Nuclear Regulatory Commission, "Additional Information – License Change Application No. 291 – Once Through Steam Generator (OTSG) Surveillance Specifications Applicability Following Cycle 13", July 13, 2001.

5. GPUN Technical Data Report (TDR) GPUN-TDR–007, (Babcock & Wilcox Report BAW-1760), "Three Mile Island Unit 1 Once Through Steam Generator Repair Kinetic Expansion Technical Report", November, 1982. (PROPRIETARY)

6. GPU Nuclear Letter #6L20-98-20004, "Cycle 12 Refueling (12R) Outage Once Through Steam Generator (OTSG) Tube Inspection Report with ASME NIS Data Reports for Inservice Inspections (ISI)", J. W. Langenbach to U. S. Nuclear Regulatory Commission, January 12, 1998.

7. AmerGen Letter #1920-99-20679, "Cycle 13 Refueling (13R) Inservice Inspection (ISI) – ASME NIS-1&2 Owner's Data Report Forms with Reports of the Once Through Steam Generator (OTSG) Tube Inspections, Pressure Tests and ASME Section XI Subsection IWE & IWL Containment Inspections", J. B. Cotton to U. S. Nuclear Regulatory Commission, January 14, 2000.

8. AmerGen Letter #5928-02-20036, "Cycle 14 Refueling (T1R14) Inservice Inspection (ISI) Summary Report", M. P. Gallagher to U. S. Nuclear Regulatory Commission, March 5, 2002.

9. GPU Nuclear Letter #6710-97-2348, J. W. Langenbach to U.S.Nuclear Regulatory Commission, "Once-Through Steam Generator Kinetic Expansion Inspection Acceptance Criteria", August 8, 1997.

10. GPU Nuclear Letter #6710-97-2441, J. W. Langenbach to U. S. Nuclear Regulatory Commission, "Once-Through Steam Generator (OTSG) Kinetic Expansion Examination", November 26, 1997.

11. GPU Nuclear Letter #1920-99-20412, J. W. Langenbach to U. S. Nuclear Regulatory Commission, "GPU Nuclear Response to NRC Requests Regarding the OTSG Kinetic Expansion Region Inspection Acceptance Criteria for 12R Examinations", July 30, 1999.

12. GPU Nuclear Letter #1920-99-20448, J. W. Langenbach to U. S. Nuclear Regulatory Commission, "Once Through Steam Generator Kinetic Expansion Inspection Acceptance Criteria", August 20, 1999.

13. EPRI NP-3596-SR, "PICEP: Pipe Crack Evaluation Program (Revision 1), Electric Power Research Institute, December, 1987. PROPRIETARY

14. EPRI NP-6897-L, "Steam Generator Tube Leakage Experiments and PICEP Correlations", Electric Power Research Institute, July, 1990. PROPRIETARY

15. U. S. Nuclear Regulatory Commission Letter, T. G. Colburn to M. E. Warner, "Three Mile Island Nuclear Station, Unit 1 (TMI-1) – Issuance of Amendment Re: Once-Through Steam Generator (OTSG) Surveillance Following Cycle 13 (TAC No. MB0664)", October 5, 2001.

ATTACHMENT

RESPONSE TO PRIOR NRC ISSUE/QUESTIONS

RESPONSES TO PRIOR NRC ISSUES/QUESTIONS

The following are responses to NRC issues or questions regarding previous submittals on TMI-1's kinetic expansion acceptance criteria. These issues are those identified in the NRC's letter of August 24, 2001. (Reference 1). (Note that, where possible, we have provided the NRC's wording in italics. Note also that the numbering of the questions below does not correspond with any numbering in Reference 1.)

Question 1

Reference 1 states, "*Explain whether LBB was credited at TMI-1 when the design of the kinetic expansion was developed. If so, this is inappropriate. Explain why the joints are acceptable for operation given the possibility of an LBLOCA in the candy cane region of the main coolant loop.*"

Response

Leak-Before-Break (LBB) was not credited at TMI-1 for the 1980's design of the kinetic expansions. The design of the kinetic expansion included an assessment of the strength of the joints during a postulated hot leg LOCA. GPU Nuclear Technical Data Report 007 (GPUN-TDR-007; Reference 5) included a review of the kinetic expansion joint during postulated LOCA conditions. For example, the following is stated on Page 2-26 of that report regarding the effect of a postulated hot leg LOCA on the kinetically-expanded joints:

> "...Because of the higher coefficient of thermal expansion of the Inconel tube, interference increases with temperature. The only case that would cause decreased interference is a large, rapid decrease in primary coolant temperature, which would cause the tube to cool faster than the tubesheet. This does not occur during any normal or upset condition transient. In fact, it occurs only during a hot leg LOCA, and analyses have determined its effect on joint interference and strength. The conclusion is that the delta T does not reduce the interference of the joint to an unacceptable level at any time..."

GPU Nuclear Technical Data Report (TDR) 007 was submitted to the NRC and was Reference #6 of the NRC's NUREG 1019 (Reference 2), the safety evaluation for the kinetically-expanded tubing joints. (Refer to responses to questions #2-4 below for additional information regarding the kinetic expansions during postulated LOCAs.)

Question 2

Reference 1 states, "*Recently, the B&W Owners Group submitted a risk-informed analysis to the NRC which included a topical report BAW-2374, "Risk Informed Assessment of Once-Through Steam Generator Tube Thermal Loads due to Breaks in Reactor Coolant System Upper Hot Leg Large Bore Piping," dated March 2001, supporting, in part, the LBLOCA aspect of the licensing basis for steam generator tube loading in B&W plants. Is TMI-1 covered by this topical report, especially for the kinetic expansion joints? Is the licensee planning to submit a risk-informed amendment request to revise TMI-1's licensing basis, referencing this topical report?*"

Response

Note that, as described in the preceding response to question #1, hypothetical hot leg LBLOCA loads were addressed during the original 1980's design review of the TMI-1 kinetic expansion joints. TMI-1 is a member of the B&W Owners Group and the TMI-1 plant's steam generators, including kinetic expansions, are covered under topical report BAW-2374.

TMI-1 desires that the hot leg LBLOCA issue be addressed under the BAW-2374 submittal since, as described in Section 2.0 of BAW-2374, there are many aspects of the TMI-1 Once-Through Steam Generators (e.g. tube repair products, replacement steam generator design) affected by the LBLOCA issue.

AmerGen is not currently planning to make an additional submittal referencing Topical Report BAW-2374. However, it may be necessary for AmerGen to make an additional submittal, pending the NRC's review of that report.

Question 3

Reference 1 states: "*Describe the analyses that have been performed to demonstrate that the kinetic expansion joints and the potential defects identified and left in service in this region are acceptable for the range of design basis accidents (including LOCA and MSLB).*"

Response

There were a large number of analyses and tests performed to demonstrate that the kinetic expansion joints are acceptable. NUREG-1019 (Reference 2), Section 3.4 contains a summary of the analyses and tests conducted for the original qualification of the joints. These tests included axial load testing, thermal and pressure cyclic loading tests, analyses of tube operational and vibrational characteristics, residual stress analyses, leak tests, mechanical integrity tests, and fatigue tests.

Since the installation of the kinetic expansion additional analyses have been performed to qualify the joints for an extended period of time. (The original analysis for the fatigue life-cycle of the joints was for a duration of 5 years.) Additional analyses were performed to verify that the joints had an expected fatigue life that would allow the joints to be used through 2014, the current license expiration date for the TMI-1 plant. Additional analyses were also performed to evaluate the flaw tolerance of the kinetic expansion joints. (The joints are relatively flaw-tolerant since they are captured within the tubesheets.) These analyses were forwarded to the NRC in References 9 and 12, and were the basis of the kinetic expansions' MRPC examination acceptance criteria used during the plant's 1997 (12R), 1999 (13R), and 2001 (1R14) refueling outages (References 6,7,8).

Question 4

Reference 1 inquires, "*Notwithstanding the above discussion, has the potential for thermal loads during the bounding LBLOCA been considered when evaluating the potential defects identified and left in-service in this region?*"

Response

LBLOCA loads, as described above, were considered during the original design analyses of the kinetic expansions. However, the most recently calculated LBLOCA thermal loads have not been used to evaluate structural integrity of the kinetic expansions. Technical justification for not considering the most recent LBLOCA thermal loads is provided in BAW 2374, Revision 1, "Risk-Informed Assessment of Once-Through Steam Generator Tube Thermal Loads Due to Breaks in Reactor Coolant System Upper Hot leg Large-Bore Piping."

Question 5

Reference 1 cites the following as an inconsistency : "*...The licensee initially states that the kinetic expansion inspection criteria identify the minimum required "defect-free" kinetically expanded tube that must be present within the inspected distance for axial flaws. However, Table 3-5 in MPR-1820, Revision 1, which contains a comprehensive summary of the inspection acceptance criteria, identifies the inspection acceptance criteria for the OTSG kinetic expansion region in terms of "allowable defect length." These two criteria are utilized in discussions throughout the documents. During discussions with the NRC staff, the licensee has stated that the criteria do not conflict and are simply two different ways of expressing the same concept. The licensee also indicated that the "defect-free" concept is that which is used in the field. The NRC staff believes that without adequate explanation, this issue leads to confusion. In addition, when this issue is combined with the other inconsistencies identified below, the intended inspection and acceptance criteria are even less clear.*"

Response

Table 3-5 in MPR-1820, Revision 1, (an Attachment to Reference 11) provides results of analyses that were based on finite element modeling of a 5.5" kinetic expansion length plus a 0.5" expansion transition. [Note 4 of that table states, "These criteria are only applicable for the fully-expanded region from 0.5" to 6" above the bottom of the kinetic-expansion joint." The length of the kinetic expansion transitions at the bottom of the kinetic expansions is approximately 0.5".] Table 3-5 provides "allowable defect lengths" within the 5.5" fully expanded length. For example, for a given tube location Table 3-5 may report that the allowable defect length is 4.4". Another way to state this is that a minimum of (5.5" minus 4.4", or) 1.1" of the kinetic expansion must be "defect free". In summary, the "required defect-free" lengths of the kinetic expansions, based on the finite element analysis, is the 5.5" modeled length of the kinetic expansions minus the calculated "allowable defect length".

Note that the expansion transition (i.e., the first 0.5") is considered freespan for indication disposition purposes. The original design included the expansion transition in the 6" defect-free zone measurement. The expansion transition is now considered equivalent to freespan tubing for the purposes of inspection.

Note also that TMI Unit 1 uses lengths more conservative than those calculated in the MPR-1820 report's analysis model in order to account for examination uncertainties. (These lengths are given in Table 1 in Response #6 of this submittal.)

TMI Unit 1 has found that the "defect-free" concept is more useful for field application than the allowable defect length. For example, suppose a kinetic expansion has a required defect-free length of 3.4". An eddy current analyst reviews the data from that kinetic expansion and if no flaws are detected over the lower 3.4" length of that kinetic expansion then there is sufficient defect-free expansion length to conclude that the expansion's integrity is intact.

If any flaws are detected within a kinetic expansion, the eddy current analysts document the locations, measurements, and types of flaws within the expansions. Evaluation of the flaws with respect to the repair criteria, and leakage estimates, are performed by the plant's engineers.

Question 6

Reference 1 states, "*The licensee states that the structural criteria are based on 6 inches of the kinetic expansion. This would imply that inspection data is routinely collected and assessed on 6 inches of the kinetic expansion. However, the licensee has verbally stated that the actual field practice is to only inspect/assess the minimum distance necessary to identify adequate "defect-free" tubing. This is not clearly documented.*"

Response

The original 1980's installation of the kinetic expansions was based on a 6" length (e.g. 6" of defect-free material based on a bobbin coil probe examination was required *before* a kinetic expansion was installed), therefore much of the written material has referred to the kinetic expansions as 6" long. In actual practice the in-service tubes were fully expanded to kinetic expansion lengths of either 17" or 22" depth in the upper tubesheets.

As described in the response to question 5, above, the finite element analysis that was used to evaluate the flaw tolerance of the kinetic expansions was a 6" long model (consisting of 5.5" of fully expanded tubing and a 0.5" transition.)

As described above, TMI-1 uses required kinetic expansion lengths that are conservative and are longer than those defined by the analysis model. TMI inspects and dispositions only these required expansion lengths. (Refer to Table 1, below.) A TMI-1 eddy current analyst reviews the tube's MRPC signal to locate the top of the kinetic expansion transition (i.e., that point where the tube is fully kinetically expanded against the tubesheet bore). This point is designated by the eddy current analyst as ETL+0.00". (ETL = Expansion Transition Location) The analyst reviews the eddy current signals from the fully-expanded section; if no flaws are detected over the minimum required defect free length then the tube is dispositioned as "NDD" (i.e., No Detectable Degradation). If a flaw is detected, it is characterized, located with respect to the ETL+0.00" reference point, and additional kinetic expansion length is reviewed by the analyst to detect/characterize any other flaws that might be present. If the additional analyzed length contains flaws such that sufficient defect free tubing is not identified, the tube is repaired. If the additional kinetic expansion length is analyzed and sufficient defect free tubing length is identified, the expansion then may be left in service (provided it meets all other criteria to remain in service).

TABLE 1
Minimum Axial Kinetic Expansion Length Values

Kinetic Expansion Length	Radius From Center of Tube Bundle	$AKEL_{min}$ (inches)
17"	0.00" – 20.00"	3.40"
	20.01" – 42.00"	3.20"
	42.01" – 46.00"	3.00"
	46.01" – 50.00"	2.70"
	50.01" – 55.00"	2.40"
	>55.00"	2.10"
22"	0.00" – 20.00"	8.40"
	20.01" – 42.00"	8.20"
	42.01" – 47.00"	8.00"
	47.01" – 50.70"	5.20"
	50.71" – 54.30"	4.20"
	>54.30"	3.20"

In summary, the inspections determine whether the conservatively calculated minimum kinetic expansion length is present and "defect free". If this length is present and defect free, then no further eddy current analysis is performed. No further eddy current analysis is needed once the required kinetic expansion length has been established by acceptable inspection results.

It should be noted that the above discussion pertains to the evaluation of the kinetic expansions (i.e., fully expanded tubing). During the examinations the kinetic expansion transitions are also examined with the MRPC probes, evaluated for the presence of flaw indications, evaluated as freespan tubing, and repaired if required.

Figure 1, which follows, provides an illustration of a typical kinetic expansion.

17" KINETIC EXPANSION (TYPICAL)

(NOT TO SCALE)

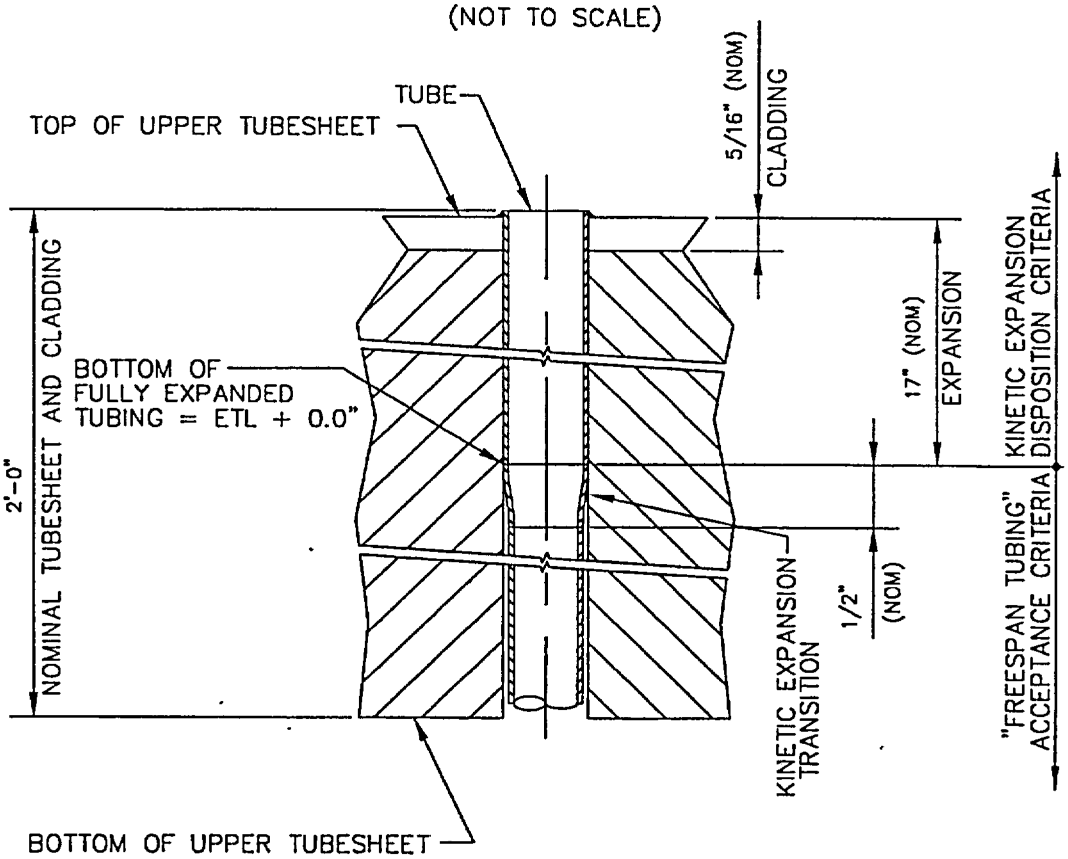


FIGURE 1

Question 7

Reference 1 states: *"Footnote (4) to Table 3-5, in MPR-1820, Revision 1, states that the inspection acceptance criteria are only applicable for the fully-expanded region from 0.5 inch to 6 inches above the bottom of the kinetic expansion joint. The staff identified two issues with this statement:*

The table identifies allowable defect length. Is the allowable defect length within the 6-inch distance or within the 5.5-inch distance. For example, the allowable defect length for an axial flaw in a tube in the periphery is 4.4 inches. Therefore, when applied in the field, is the "defect free" length 1.6 inches or 1.1 inches?

Do the criteria apply to the entire 6 inches if the inspection region does not include the expansion transition region (e.g., 22-inch kinetic expansion located in the mid-radius or center of the bundle)?"

Response

For the first issue identified above, with respect to the structural analysis model of the kinetic expansions, the "defect free" length is 1.1 inches. This length is based on structural analysis only and does not consider examination uncertainties. For the inspection acceptance criteria additional length was added to the dimensions calculated in MPR-1820, Revision 1 to conservatively account for the expected uncertainty in locating eddy current indications along the axial length of the kinetic expansion with respect to the ETL + 0.00" reference point, and the uncertainty in locating the ETL + 0.00" reference point itself. When applied in the field the minimum "defect free" length is 2.1" for a peripheral tube. TMI Unit 1 designated a "minimum axial kinetic expansion length" (AKELmin) for each tube in its generators based in part on MPR-1820, Revision 1. (These were submitted to the NRC in Reference 6 and are listed in Table 1, above.)

Regarding the second issue, the inspection of a kinetic expansion always includes a concurrent inspection of its transition. (This is required by the plant's eddy current guidelines and is also necessary to determine the location of the ETL+0.00" reference point as described above.) All kinetic expansion examination results are referenced to the ETL+0.00" reference point at the top of the expansion transition. All minimum axial kinetic expansion lengths (for both 17" and 22" expansions) are measured from the ETL+0.00" reference point.

Question 8

Reference 1 states, "*Based on several references in documented material, it is not clear if the inspection criteria apply to the 6 inches beginning at the bottom of the expansion transition region, or from the point beginning at which the tube is fully expanded. The licensee verbally stated that the structural criteria were developed with the 6 inches beginning at the bottom of the expansion transition region. However, in the field they conservatively measure the 6 inches beginning at the fully expanded region. The docketed information alludes to two different inspection areas; however, this distinction is not clearly identified.*"

Response

The kinetic expansion acceptance criteria apply only to tubing that has been fully kinetically expanded. As described above, the plant's analysis guidelines require that that point at which the tubing is fully expanded against the tubesheet bore is identified and is given the ETL + 0.00" reference point. This provides a reference point to locate any indications that may be present. (See Figure 1 above.) All kinetic expansion examination results are referenced to the ETL+0.00" reference point. All minimum axial kinetic expansion lengths are measured from the ETL+0.00" reference point.

The kinetic expansion transitions, since they are not expanded against the tubesheet bore and do not benefit from any compressive residual stresses such as those present in the expansions, are treated as "freespan" tubing under the plant's inspection criteria. For example, a small circumferentially-oriented indication may be left in service within a 17" long kinetic expansion if sufficient defect-free expansion is present to ensure the structural integrity of the expansion, while any circumferential indication detected in the kinetic expansion transition is removed from service.

Since the expansions and transitions are two distinctly different areas, AmerGen has clearly identified the distinction between the kinetic expansions and the kinetic expansion transitions in its inspection requirements and acceptance criteria.

Question 9

Reference 1 states, "*A statement is made in the August 8, 1997, submittal that requires clarification. On page 7 of 13, in Attachment 1, the licensee states: "The 6" qualification length of the 22" expansion at center and mid-radius locations does not contribute to slip resistance under postulated MSLB conditions due to the tubesheet bowing. Possible indications in the 6" qualification length of the 22" expansions in these locations will be dispositioned using more stringent free span criteria, since this length of expanded tubing loses contact with the tubesheet as a result of postulated tubesheet bow." This statement requires clarification because other docketed material implies that the bottom 5 inches of the 22-inch kinetic expansion does not contribute to slip resistance, not the bottom 6 inches as implied above.*"

Response

Clarification/correction of the subject statement is required: At 17" deep in the upper tubesheets (i.e., near the bottom of a 17" deep expansion, or 5" up into a 22" deep expansion) there is no physical difference between a 17" expansion and a 22" expansion located at the same radial location within the tube bundle in terms of calculated bow or dilation of the tubesheet. Thus, the plant's more stringent "freespan" eddy current extent limits for volumetric IGA indications (i.e., 0.25" axial or 0.52" circumferential) are invoked for only the lower 5" of the 22" expansions located near the center of the generators' tube bundles as measured from the ETL + 0.00" reference point—not the lower 6".

Note that TMI-1 ECR No. TM 01-00328 was incorporated into the plant's Technical Specifications in 2001 and includes a requirement to examine each outage the lower 5" lengths of 22" in-service kinetic expansions located at mid-bundle radial locations (Reference 4, 15).

Question 10

Reference 1 states, "*The licensee submitted a document, dated October 22, 1999, which corrected an error they identified in their July 30, 1999, submittal. The licensee stated that the July 30, 1999, submittal incorrectly noted an additional conservatism associated with the structural flaw acceptance criteria. The paragraph that was deleted read as follows: "Also, the practical implementation of the inspection acceptance criteria introduced another conservatism. The acceptance criteria were applied from the point of full expansion at the bottom of the expansion and above. The analytical model representation of the six-inch kinetically expanded region included the transition where it was less than fully expanded. The load carrying capacity given by the analytical model was based on a reduction to the six-inch qualification length equal to the length of the transition region (about 0.5"). The analysis model results depend on about 0.5" less than the full qualification length as contributing to the pull-out capacity due to the presence of this transition. Therefore, the implementation of the acceptance criteria required approximately 0.5" more defect free expanded tube length than was required analytically." This paragraph agreed with the NRC staff's understanding (based on verbal discussions with the licensee) of the analytical requirements versus implementation practices. Therefore, the reasoning behind the deletion of this paragraph is not understood.*"

Response

The paragraph could perhaps have been retained, but was deleted in 1999 to avoid any possible misunderstanding. Subsequent verbal discussions may have been clearer on this aspect of the implementation practices. As described above in this submittal, TMI-1 increased the minimum length of the kinetic expansions to be examined as part of the field implementation of the analytically-derived inspection criteria. The additional length was added to address uncertainties in the examination techniques and for conservatism.

[The analytical model was a 6" long kinetic expansion. However, only 5.5" of the 6" analytical model was assumed to be fully expanded tubing; the remaining 0.5" was assumed to be kinetic expansion transition having no tube-to-tubesheet contact.]

The paragraph was deleted at the time in order to avoid the possible misunderstanding that the analytically-derived necessary lengths of defect-free tubing could be decreased by 0.5".

Question 11

Reference 1 states, "*In the context of the preceding issues, the licensee needs to specify what actions would be taken if insufficient defect-free tubing is identified in the full qualification length. For example, would the inspection for sufficient defect-free tubing be allowed to continue higher in the tubesheet? The NRC staff requests that the licensee provide the technical basis for continued inspection or for other actions that would be taken.*"

Response

TMI-1 does not use the phrase "full qualification length" in its kinetic expansion acceptance criteria. As described in the above responses, kinetic expansion evaluations are performed beginning at the ETL + 0.00" location to verify that sufficient defect-free lengths are present.

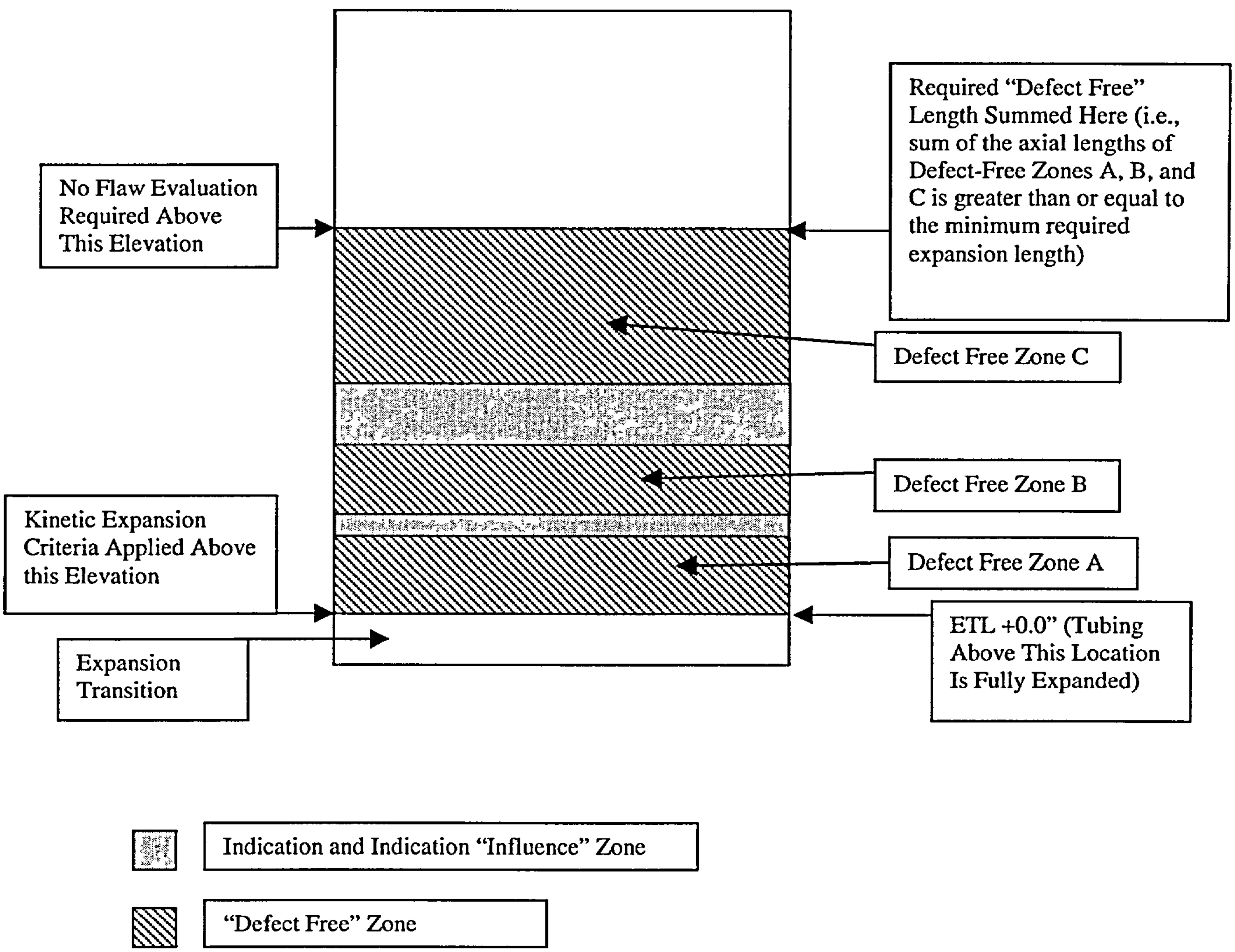
Structural evaluations of the kinetic expansions require that a kinetic expansion be removed from service if insufficient defect-free length is identified over its examined length. That is, if a defect (or a combination of defects) is detected that exceeds the allowable circumferential extent acceptance criterion, or an insufficient axial length of defect-free expansion is present, the expansion is removed from service. The inspection of a kinetic expansion may proceed farther (i.e., higher) in the tubesheet if flaws detected during the course of the examination within that expansion are within the conservative structural acceptance criteria. Figure 2, below, provides a visual presentation of the "defect-free" concept for a kinetic expansion with two indications.

MPR Report 1820, Rev 1., Table 3-5, describes the conservative criteria with which flaw indications in the kinetic expansions are evaluated. If a flaw is detected in a kinetic expansion the TMI-1 dispositioning criteria conservatively assume that the joint is not usable for structural purposes over the entire axial length of that flaw. For example, if a small volumetric flaw is detected with an eddy current-measured axial extent of 0.15", the entire 0.15" length of the expansion (360 degrees around the surface of the tube) is not credited in the evaluation of the joint structural integrity. In addition, no credit is taken for defect-free tubing along additional axial lengths of the joints adjacent to flaws (known as flaw "influence zones"). Even small circumferentially-oriented flaws, if present, are assigned axial lengths of flaw influence zone so that no credit is given for that axial influence zone length of the entire joint. In summary, sufficient defect-free tubing must be detected to verify the integrity of an expansion during an inspection; no credit is taken for the length of the kinetic expansion where any defect is present, or where any defect might influence joint integrity.

While these TMI-1 structural dispositioning criteria (described in MPR 1820, Rev. 1) are very conservative, there is no requirement that the defect-free joint length be "continuous". The kinetic expansions are flaw tolerant. (For example, burst is precluded due to the presence of the tubesheet; residual compressive stresses are present; bending stresses and vibration are limited; secondary side loose parts are prevented from impacting the tubing.) Small defects do not influence the reliability of the kinetically expanded joints. For example, a small volumetric ID IGA pit on the surface of a kinetic expansion will not impact the ability of defect-free tubing, located above or below that pit, to maintain the structural requirements of the joint (e.g., no tube parting, no joint pullout). Outside of the flaw influence zones a small ID-initiated axial crack present along the length of a kinetic expansion would not adversely affect the structural integrity of defect-free tubing located above or below that crack. From a structural standpoint, so long as no flaw or combination of flaws is present with a circumferential extent greater than 0.64", the defect-free tubing located above or below the flaw is an integral part of the kinetic expansion joint. (If the 0.64" circumferential extent value is exceeded prior to the required defect-free length being observed, the kinetic expansion is repaired, since the tube, conservatively assuming 100% throughwall degradation, could theoretically be parted under calculated accident-induced loads.) The expansion evaluations only "move higher into the tubesheet" if the examination data is available, and the repair criteria are not exceeded. The technical basis for this continued inspection (i.e., higher in the tubesheet) is provided in MPR 1820, Rev. 1.

FIGURE 2
"Defect Free" Concept

(Inside Surface of a Hypothetical Kinetic Expansion "Flattened" for this Sketch)
---Not to Scale---



Question 12

Reference 1 states: *"...Minimal details were provided by the licensee regarding their no-growth-rate assumption. The licensee should provide additional details regarding the basis for concluding that no defect growth has been observed and the statistical methods and criteria used to verify this assumption. The NRC staff's concerns regarding the reliability of the ECT technique for length and depth sizing (see Section 3.4) should be considered when responding to this issue. In addition, the NRC staff believes it is necessary that the licensee continue to monitor the no-growth-rate assumption supporting data each cycle to ensure that this assumption continues to remain valid. The licensee should summarize their plans in this regard...."*

Response

TMI-1 has monitored the growth of eddy current indications within the kinetic expansions for the past several outages (since MRPC inspections were started) and has reported these results to the NRC. Since the 1997 submittal TMI-1 has provided additional details regarding growth of indications in the TMI-1 steam generators. Reference 4 provided information regarding the methods with which TMI-1 has monitored the growth of the ID degradation found in the kinetic expansions, and as well as growth within the unexpanded tubing within the tubesheets. Indications are evaluated for changes in axial extent and circumferential extent over successive outages, and over multiple outages. Analysis of indication growth, and an assessment of that indication growth relative to the repair criteria, is required by the plant as part of operational assessments each outage.

Reference 4 provided information regarding the reliability of ECT techniques used for indication detection and sizing. TMI-1 has examined approximately one third of the population of inservice kinetic expansions during each of the last three plant refueling outages (Outages 12R, 13R and 1R14). MRPC eddy current examinations of each of the in-service kinetic expansions has now been completed. These examinations will serve as "benchmarking" or "baseline" MRPC examinations with which to compare future examination results.

TMI-1 will continue to monitor for growth of flaws in its steam generators, including flaws in the unexpanded tubing within the tubesheets and kinetic expansions. The plant's steam generator program requires growth monitoring for the purposes of operational assessment. The plant will continue to perform a significant number of kinetic expansion examinations each refueling outage. As described above, approximately one third of the plant's kinetic expansions have been examined during each of the plant's last three refueling outages. These samples have been sufficient to detect if significant growth of existing flaws in the kinetic expansions is occurring, or if any new degradation begins to appear within the kinetic expansions. The plant's steam generator program requires that condition monitoring assessments and operational assessments be performed based on the results of the outage examinations. The operational assessments must contain an evaluation of the potential for growth during the following operating cycle.

In addition, as a result of TMI's recent steam generator Technical Specification Amendment No. 237 (Reference 15), the TMI-1 Technical Specifications prescribe statistical tests to be utilized to evaluate the growth of ID volumetric IGA indications (-the predominant degradation mechanism noted to date in the kinetic expansions) following each steam generator inspection. These statistical tests are applied to ID volumetric indications noted in the unexpanded tubing and the kinetic expansion transitions, and the results of these statistical tests are reported to the NRC. These statistical tests, currently prescribed under the plant's Technical Specifications will provide a quantitative assessment of indication growth in tubing regions where growth is more probable than in the kinetic expansions. Monitoring of possible growth of freespan ID IGA using statistical criteria under the current Technical Specifications will provide a conservative representation of the growth potential for indications within the kinetic expansion. The tubing service stresses in the freespan are greater than those in the kinetic expansions. Higher service stresses constitute a more aggressive environment for the potential propagation of stress corrosion cracking (SCC). Circumferential stresses within the kinetic expansion are less than in the freespan due to the participation of the tubesheet ligament in reacting to internal pressure. In addition, residual contact pressure from formation of the kinetic expansion joint causes membrane hoop compression to counteract internal pressure. Axial tube loads in the kinetic expansion are diverted into the tubesheet ligaments due to the friction reaction as a result of residual contact pressure from the formation of the joint. Axial stresses in the kinetic expansion are reduced in proportion to the elevation within the repaired joint. In summary, the current Technical Specification requirements for statistical growth analyses for indications in unexpanded tubing and transitions also enable the plant to conservatively assess the potential for growth of kinetic expansion indications.

Question 13

Reference 1 states, *"Provide a rigorous basis for utilizing a lower contact pressure threshold (250 psi) than that used in the leakrate tests (500 psi)".*

Response

The leakrate test results indicated that there was almost zero correlation between leakage from tube flaws and changes in joint contact pressure at those flaws. Testing was performed at contact pressures of 500, 1500 and 3000 psi, and leak rates at each of these contact pressures were extremely low in comparison to the no contact pressure case. The results suggested that leakage would be reduced at any time where positive contact pressure existed between the tubesheet bore surface and the tube outside diameter surface (i.e., conditions where the tube remained in contact with the tubesheet). Intuitively, these results were logical because the presence of tube-to-tubesheet contact should significantly reduce the leakage in comparison to the case where no such contact is present.

Two hundred and fifty (250) psi was used as the threshold contact pressure at which to consider reduced leakage from the joints based upon the following:

> Two hundred and fifty (250) psi is a significant remaining contact pressure for the joint with respect to the zero contact pressure condition. (Since a positive contact pressure still exists, the expanded tube is still in close contact with, and pressed against, the tubesheet bore. Thus, any annular space between the expanded tube and the tubesheet bore that might create a leakage path should be very small.)
>
> Testing with the leaktest apparatus was very conservative because the test apparatus was not "pre-conditioned" by the kinetic expansion pressure to achieve mating surface-to-surface contact between the tube and mockup test block. In the TMI-1 steam generators, the inservice tubing was kinetically-expanded (with an explosive charge) so that the

tubing was plastically flattened against the inside surface of the tubesheet bore. Contact pressure greater than yield strength was achieved in the kinetically repaired joint. In-service pressures, which are much lower, are actually applied to these surfaces that have been plastically compressed or "flattened". No such effort to plastically expand the tubing against the tubesheet block was attempted for the lab leakrate tests. (The compressed surfaces of the kinetic expansions will remain compressed as the applied contact pressure is reduced--in the same manner that bolted, flanged joints remain leaktight until the bolt preload is exceeded by the applied load.) The demonstrated leak reduction capability of the test apparatus should be considerably less than the leak reduction capability of the kinetically repaired joint since the latter has the benefit of plastically compressed surfaces.

In addition, the results of the leakrate tests were conservatively applied to derive the leakage estimates for flaws in the tube-to-tubesheet joint. For example, peak axial tensile tube load was applied over the full duration of the laboratory leakrate tests. [The axial tube load causes Poisson contraction of the tube within the joint, which tends to decrease the joint contact pressure.] The leakrate test results were used to help estimate leakage from flaws over a postulated MSLB event of 23.5 hrs duration, while the calculated peak axial loads act upon the joint for approximately one minute. (Peak calculated tube load of 1310 lbs. is reached at t= 60 seconds; calculated loads are less than 1000 lbs. after t=115 seconds.) Thus, in implementing the leakage estimate a large amount of Poisson contraction was assumed over the entire course of the event, while this maximum amount should be present for a only relatively short time during an actual event.

An additional conservatism is that the 250 psi contact pressure was used only to derive a "minimum location" at which the Leakage Reduction Factor could be applied to project a leakage volume. The leak tests were conducted on flaws that were only 0.25" and 0.325" from the edge of a mockup tubesheet block (i.e., from the "freespan" condition). No credit was taken for additional leakage reduction that might have occurred for flaws that were a larger distance from the edge of the block. In implementing the leakage estimates for the as-found flaws during inspections this results in cases where flaws may have 2 or 3 inches of expanded tubing between the flaw and the transition, but the leakage estimate is the same that would be estimated if the flaw only had 0.25" of expanded tubing between the flaw and the transition.

In summary, the leakrate projection performed for flaws present in the kinetic expansions is conservative with the 250 psi contact pressure threshold.

Question 14

Reference 1 states: "*...The licensee stated that "the defect must be located at an elevation at which structural analysis results identify a remaining contact pressure at least equal to 250 psi and a leak path length of at least 0.25 inches from the expansion transition. Defects that are not clamped by at least 250 psi over a leak path of at least 0.25 inches were evaluated without a LRF." These two statements made by the licensee are not identical, and it is not clear which interpretation is intended (i.e., there must be a 0.25-inch leak path clamped at a minimum of 250 psi below the area where an LRF is applied, or the LRF is applied when there is a 0.25-inch leak* *path and a minimum of 250 psi in the area the LRF is being applied). This issue must be clarified. In addition, if the second interpretation is the one intended (i.e., a minimum of 250 psi is only necessary in the region the LRF is applied), provide the technical basis for this considering the laboratory tests maintained a 250 psi over the 0.25-inch leak path in addition to where the LRF is applied."*

Response

The interpretation that was intended is that both the location of the defect and the entire length of the 0.25" minimum leak path have a contact pressure of at least 250 psi. TMI-1 performed analyses which demonstrated that a minimum of 250 psi contact pressure was maintained throughout a 17" kinetic expansion at all times during a hypothetical MSLB event, and regardless of the radial location of a tube in the tube bundle. Thus, a 250 psi minimum contact pressure is maintained both at the location of the indication and along the length of the 0.25" minimum leakage path length.

(Note that above NRC text and AmerGen's response apply to the normal case for 17" kinetic expansions. Different lengths are used for the 22" kinetic expansions. Refer to Table 1, above.)

Question 15

Reference 1 states: "*...The licensee indicated that any leakage contribution due to possible defects located further into the expansion than the 'minimum required inspection distance' was considered negligible. The NRC staff verbally questioned during a conference call whether analysis or calculations were performed to determine the minimum-required length of tubing that would be required, such that any flaws located above this distance would contribute negligible leakage. This is of particular interest to the NRC staff because the 'minimum required inspection distance' is variable. (Section 3.1 provides more details on the 'minimum required inspection distance'.) The licensee indicated that analyses were not performed to determine the minimum-required length. Perform an analysis to determine the minimum-required length or provide a justification to explain why this is unnecessary. Provide an expanded discussion quantifying 'negligible' so that these values can be put in perspective."*

Response

The "minimum required inspection distances" for the various TMI-1 kinetic expansions are provided in the Table 1, above. This table was also submitted to the NRC in Reference 6.

Estimated leakage from flaws that are located above these AKELmin expansion lengths will be very small in comparison with flaws that are located nearer to the expansion transitions. In classical equations for laminar flow through a small annular orifice formed by concentric members with circular cross sections - a highly idealized representation of the kinetic expansions in which the tubing was expanded against a drilled tubesheet bore with explosive force - flow is inversely proportional to length of the orifice (Reference 3). Thus, if it was conservatively assumed that a kinetic expansion flaw's leakpath were a concentric annulus, expected leakage from a hypothetical flaw 3.0" into the expansion would be 10% of the expected leakage from an identical flaw located 0.3" into the expansion.

Laboratory leak testing that was performed for the kinetic expansion work demonstrated that even a small length (e.g. 0.25") of expansion, even with no contact pressure, will significantly decrease leakage over the "freespan" condition. (This is consistent with established calculational methods for leakage through cracks where leakage is inversely proportional to the length of the leak path, as described above. This is also consistent with leakage evaluations for other types of expanded tube-to-tubesheet joints where leakage resistance is increased with increased length of the joint.) The laboratory leak testing performed for the TMI-1 kinetic expansions also showed a 20% decrease in flaw leak rate with an additional 0.125" length of leak path—even with no applied contact pressure on the leaking flaws within a loose tubesheet mockup block.

The following discussion is also provided for perspective as to the small amount of leakage that might be expected from flaws located above the minimum expansion lengths in comparison to those flaws located near the kinetic expansion. For example, a flaw that is located 0.2" into the expansion (i.e., at ETL + 0.2") is conservatively treated as a "freespan" flaw, and this flaw has a relatively significant leakrate. If this same flaw were located further into the expansion, for example at 1 inch into the expansion at ETL+1.0", its assigned leakrate is reduced (from that expected at the ETL + 0.2" location) by the Leakage Reduction Factor (LRF) of 1/25th. If this same flaw were located above the "minimum inspection distance", there would be a minimum of 2.1" of defect free kinetic expansion between the flaw and the expansion transition (since the shortest minimum inspection distance is 2.1"). Considering that the kinetic expansion leakage tests showed that even a small length (0.25") of expansion will restrict leakage by more than a factor of 25 with minimal joint contact pressure, 2.1" of defect-free expansion (with installed contact pressures from the expansion process's plastic deformation of the tubing) should prevent additional leakage. Given the above, the estimated leakage from flaws above the minimum inspected lengths of the kinetic expansions should be very small in comparison to the projected leakrates calculated for flaws nearer to the kinetic expansion transitions. Defects that are located near (i.e., within 0.25" of) the expansion transition, and therefore whose leakage is not reduced by the Leakage Reduction Factor of 1/25, are the dominant contributors to the results of the leakage estimates.

Question 16

Reference 1 states, "*...The licensee stated that the circumferential and axial components of the volumetric inside diameter (ID) IGA are evaluated separately, and indicated that this is a conservative representation of a volumetric indication for the purposes of total leakage evaluation. The technical basis supporting this assumption is not clear.*

In addition, the licensee stated that the leakage flow for a given crack opening area (for a given crack) is determined by the PICEP computer code and that the code was validated with experimental data. The licensee should provide technical justification for the use of PICEP, a crack code, for IGA (crack and IGA typically have very different flaw morphologies). Describe the various inputs used for PICEP, if necessary, for this technical justification. In addition, the licensee should provide a brief summary of the PICEP code validation that was performed, including a brief description of the actual flaws that were used for the validation."

Response

It is very conservative to estimate the theoretical leakage from volumetric flaws in the kinetically expanded tubing by considering them as a combination of a 100% throughwall circumferential crack of length equal to the as-called circumferential extent of the volumetric flaw and a 100% throughwall axial crack of length equal to the as-called axial extent of the volumetric flaw. This treatment of the volumetric flaws is conservative for a number of reasons including:

- the fact that the tubing is expanded into the tubesheet and is unlikely to crack axially. (Expansion and deformation of the tube in the hoop direction are prevented by the constraint of the tubesheet.)

- pulled tube examination results from TMI-1 have demonstrated that the MRPC examinations tend to overestimate the extents of the ID volumetric IGA flaws (as a result of the "look-ahead/look behind" effect and the proximity of the ID flaws to the surface-riding coils),

- bending of the tubing is prevented by the presence of the tubesheet. (Crack formation is less likely since movement/displacement of the tubing is severely restricted.).

- the presence of the tubesheet prevents formation of a volumetric "hole"; thus only a tortuous flow path through an intergranular flaw surface (similar to a crack) would be expected.

The PICEP program was used to estimate the theoretical leakage from the axial, circumferential, and volumetric indications in the TMI-1 kinetic expansions. (As described above, volumetric indications were conservatively assumed to result in both a circumferential crack and an axial crack.) The PICEP program predicts the theoretical flow through straight cracks. The volumetric morphology of the ID IGA flaws, the predominant flaws within the kinetic expansions, is dissimilar to the morphology of straight cracks. However, given the constraint of the tubesheet, it is very conservative to predict leakage based on the assumption that each volumetric flaw will result in one circumferential, throughwall, straight crack and one axial, throughwall, straight crack. The PICEP program is described in EPRI NP-3596-SR (Reference 13).

Numerous inputs were required for the PICEP calculations to estimate the leakage from the kinetic expansion flaws:

- Tensile loads on the tube were set to zero for the axial cracks (since tensile loads tend to tighten these cracks and reduce leakage).

- Surface roughness was set to 0.0002 inches, a value of roughness typical for corrosion-induced cracks.

- No credit was taken for any tortuosity of the crack channel. (The number of 45 degree turns was set to zero for the computer code runs.)

- Minimum tube wall thickness of 0.034" was assumed.

Validation/benchmarking of the PICEP program was based on a large number of flaws and is described in Appendix C of EPRI NP-3596-SR. PICEP crack flow results were assessed using several sets of leak data including data from EPRI (Battelle Columbus and Wyle Laboratory), NRC (UC Berkeley), Canada (AECL), Italy and Japan. The types of cracks used for this validation work were varied. For example, PICEP results were compared with flow data from cracks formed by parallel plates, pipes with circumferential cracks, and rectangular slits. Among the test results with which PICEP was compared were those results described in NUREG/CR-3475, "Critical Discharge of Initially Subcooled Water Thru Slits". (The PICEP results showed good agreement with the NUREG's results.) Additional work to benchmark the PICEP code is described in EPRI NP-6897-L, "Steam Generator Tube Leakage Experiments and PICEP Correlations" (Reference 14). In that study the PICEP results were benchmarked against numerous steam generator tube laboratory leak tests. (48 leak tests were conducted on I-600 steam generator tube specimens with laboratory-generated flaws.)

Question 17

Reference 1 states, with respect to the kinetic expansion acceptance criteria, "*Four regions (A, B, C and D) were used above to describe the different methods used by the licensee to calculate leakage volume. Provide further information and/or support for the following:*

A - "Provide a more detailed discussion on the calculations, leakage values and supporting basis for flaws identified in this region. How does this leakage assessment methodology differ from that used for freespan flaws identified outside the tubesheet? The NRC staff assumes that the region where "calculations" are necessary encompasses the region from the secondary face of the upper tubesheet to the height indicated in each of the tables. Please indicate whether this assumption is correct."

Response

The assumption is not correct. The regions requiring "calculations" were referenced from the location at the top of the kinetic expansion transition location (ETL); they were not referenced from the secondary face of the upper tubesheet.

Region A is "below" the kinetic expansion and includes unexpanded tubing and the kinetic expansion transition. A table entry for this area was created (i.e., "Calculations Required") that would alert the plant's engineers that the kinetic expansion analyses did not apply in this area of the tubing. Since 1997, when the subject table was created, TMI-1 has used in situ pressure testing in lieu of calculations to assess the possible leakage of indications located in Region A. (When the table was created in 1997 TMI-1 had yet to perform any in situ pressure tests.) Since 1997 TMI-1 has in situ pressure tested many tubes to help assess leakage; in situ pressure testing has provided the plant with empirical data regarding the integrity of steam generator tube indications without the need for calculations.

Leakage assessment of indications in Region A is essentially no different than leakage assessment of indications identified in freespan tubing outside of the tubesheet. (Note that this is different than the situation for burst since burst is precluded for indications within the tubesheet.)

It should also be noted that the vast majority of the indications located in Region A are ID volumetric IGA indications. Therefore, the assessment of possible leakage from these indications during the last plant outage was performed in accordance with ECR No. TM 01-00328. This ECR was incorporated into the TMI-1 Technical Specifications prior to 2001's Outage 1R14 and requires a leakage assessment of the volumetric ID IGA indications. (This ECR is an attachment to Reference 4.) Thus, while Region A was first called out in the 1997 criteria (-to differentiate this region from the kinetically expanded region), volumetric ID IGA indications in this region are now addressed for leakage potential under ECR No. TMI 01-00328.

Question 18

Reference 1 stated the following as regards Region B of the table:

B - "Identify how the calculations performed to create the tables used in this region differ from the calculations used for region A. If the difference in calculational methods is due to the difference in contact pressure (i.e., no contact pressure in region A versus minimal contact pressure in region B), discuss the contact pressure that is utilized as it appears to vary from tube to tube depending on location within the tube bundle."

Response

As discussed in the above response, leakage calculations have not been used in Region A. (In situ pressure testing has been used.) Region B of the table includes the "first" (i.e., lowest) 0.25" length of a kinetic expansion. This region is fully expanded and is located at ETL + 0.00" to ETL + 0.25". To assess possible leakage from indications in Region B, the leakage tables provided in Table 7-1 of Reference 10 are used. These leakage tables assume no contact pressure as a result of the kinetic expansion. As discussed in the responses above, since Region B is within 0.25" of the kinetic expansion transition, no credit was taken for any contact pressure and the Leakage Reduction Factor of 1/25th is not used. In summary, neither Region A nor Region B is credited with any contact pressure in the leakage assessment.

The Reference 10 leakage tables were created from evaluations performed specifically for kinetically expanded tubing; therefore the tables of leakage values used for Region B are not used for Region A. (Region A tubing has not been kinetically expanded.) The Region B leakage tables, while they assume there is no joint contact pressure present, take credit for the fact that the tubesheet is present and will prevent deformation of a tube at the location of a leaking defect. In Region A the tube is not adjacent to the tubesheet.

Question 19

Reference 1 stated the following: "*...The attachment to the licensee's November 26, 1997, submittal, "GPU Nuclear Topical Report #116, Revision 0, Leakage Assessment Methodology For TMI-1 OTSG Kinetic Expansion Examination," November 6, 1997, provides the leakage assessment methodology. Page 33 of the topical report states that the "minimum inspection length was 1.8 inches from the transition for peripheral tubes." The basis for this statement is not clear, as it appears to conflict with the structural integrity inspection acceptance criteria".*

Response

The statement is no longer correct. TMI-1 revised its kinetic expansion inspection lengths so that the minimum inspection length is 2.1 inches. The minimum inspection length of 1.8" was never used. (Refer to Table 1 in Response #6 above, which delineates the minimum inspection lengths for the kinetic expansions.)

Question 20

Reference 1 stated the following: "*...The NRC staff has concerns whether the elimination of flaws from the leakage assessment methodology based on depth measurements is appropriate and conservative. This issue is further discussed in Section 3.4.*"

Response

TMI-1 has only used kinetic expansion indication depth measurements for estimates of accident-induced leakage. To implement the kinetic expansion structural criteria, which determine whether or not a tube needs repair, TMI-1 has conservatively assumed that all indications are 100% throughwall over their entire as-called eddy current extent(s).

For the leakage estimates TMI-1 has conservatively assumed that indications within the kinetic expansions whose estimated depth exceeds 67% T.W. will leak under hypothetical MSLB conditions. The derivation of this 67% T.W. figure was based on an evaluation of eddy current performance with machined, laboratory grown, and pulled tube flaws of known depth.

The 67% throughwall threshold is a very conservative criterion considering:

- the 33% TW eddy current accuracy (i.e., 100% minus 67%) is based on the results of the eddy current analysis with a 95% single tailed lower confidence level. A team of analysts was used for the study to evaluate error.

- the majority of the indications within the TMI kinetic expansions are ID volumetric IGA indications. In-situ pressure testing of ID volumetric IGA indications at TMI to date has not identified any indications that have demonstrated measurable leakage (i.e., leakage above detectable levels) at simulated normal operating or accident conditions. For example, 69 ID volumetric indications were in situ pressure tested, without leakage, during the plant's most recent refueling outage (Reference 8).

- A number of additional conservatisms are incorporated into the leakage assessment methodology. For example, volumetric indications are hypothesized to form both a circumferential crack and an axial crack, with the entire measured eddy current extent(s) used to calculate expected accident leakage.

The results of in situ pressure tests performed during recent refueling outages also provide some evidence that the depths of TMI-1 steam generator tube flaws are conservative. For example, during the most recent 1R14 Outage, seven TMI-1 tube indications whose estimated depth by Plus-Point was greater than 80% throughwall were insitu pressure tested. (Reference 8) None of these seven indications leaked at a delta pressure equivalent to three times the delta pressure during normal plant operation (i.e., 3NODP). One of these seven indications leaked at a rate of 0.014 gpm, a small leakrate, at a delta pressure of 6450 psi, approximately five times the delta pressure during normal plant operation. All seven of these indications had estimated depths greater than 67% throughwall and would have been assumed to leak at MSLB delta pressure, which is less than 3NODP delta pressure, under the kinetic expansion leakage criteria.

Question 21

Reference 1 states:"... *The licensee uses "ETL" to describe the location at which to apply different leakage assessment methodologies. This acronym in not defined in the docketed information.*"

Response

Refer to Figures 1 and 2, above. ETL is an acronym created by TMI-1 that stands for "Expansion Transition Location". ETL + 0.00" is that point at the top of the kinetic expansion transition where the tubing is fully expanded against the tubesheet bore. Indications in the TMI-1 kinetic expansions are located with respect to this point (e.g., one indication may be located at ETL + 3.45", while another indication might be located at ETL – 0.16".)

Establishing a reference point at the top of the expansion transition (--which is the bottom of the expansion) is important for the implementation of the inspection and dispositioning criteria. Basically, for the standard 17" deep kinetic expansions, the kinetic expansion dispositioning criteria is applicable to indications at "ETL plus" locations (i.e., ETL + some dimension), while indications at "ETL minus" locations (i.e., ETL – some dimension) are located below the expansions and are not dispositioned using the kinetic expansion criteria. Indications located at ETL+0.00" (i.e., on the boundary between the two regions) are dispositioned using the freespan criteria.

The ETL term was defined in Reference 7 (13R Outage Report, TR-135, Appendix III, Page 1), which was submitted to the NRC since the original kinetic expansion submittals. The ETL term is also defined in Reference 8, which was recently submitted to the NRC (1R14 Outage Report, TR-151, Page 12).

Question 22

Reference 1 states: *"The method used by the licensee to determine acceptability of the eddy current technique for use on the IDIGA identified at TMI-1 is not sufficiently rigorous for NRC staff's approval of an alternate repair criteria. There are inherent weaknesses in the information provided by the licensee. Resolution of this concern is crucial to the NRC staff's review of the proposed inspection criteria.*

Three examples of the weaknesses are as follows: the NRC staff does not typically accept machined notches as a substitute for corrosion-induced steam generator tube degradation for eddy current testing qualification purposes; flaws that are utilized in the data set should be shown to be representative of the IDIGA at TMI-1; discussion of the eddy current technique qualification which supports length sizing of flaws was not provided.

The NRC staff suggests the licensee develop a plant-specific performance demonstration which includes a statistically valid sample set shown to representative of TMI-1 IDIGA, and blind data acquisition and analysis. Alternatively, the licensee may consider documenting a convincing technical justification for why industry and TMI experience with IDIGA indicates that the current technique qualification and related uncertainties are bounding for TMI-1."

Response

Axial and circumferential extent of ID IGA indications is measured using the 0.080" shielded high frequency pancake coil. AmerGen's Reference 4, RAI Question 1, response provided to the NRC the following information concerning length and width sizing of ID IGA indications:

> "...TMI-1 has evaluated eddy current techniques and expected analyst uncertainties so as to assure that the dispositioning of the ID IGA indications using MRPC probes is conservative. Before 1997's Outage 12R, a study was performed to evaluate the acquisition, analysis, and technique errors expected during the MRPC examinations of the ID IGA indications. Volumetric flaws manufactured by EDM were used in the 1997 study. This study was updated before 1999's Outage 13R so as to incorporate the data from the ID IGA flaws in the tube samples pulled during the 1997 outage. A team of 5 production analysts and 1 senior (resolution) analyst was used in the study.
>
> "Acquisition variabilities were obtained by running three separate MRPC exams of the ID volumetric flaws. Comparison of the three separate exams by a single analyst enabled the acquisition errors to be evaluated. Since each flaw was a separate test, a pooled variance was used to combine the results. For the 0.080" HF pancake coil (the coil utilized by TMI-1 to measure the extents of the ID IGA indications), the acquisition pooled standard deviations were 0.0114" for axial length and 0.0084" for circumferential length.
>
> "Analysis variabilities were obtained by comparing the different analysis results of the six different eddy current analysts. For the 1999 study, this dataset included 23 EDM flaws and 9 flaws from the 1997 TMI-1 pulled tube, for a total of 32 volumetric flaws. For the 0.080" HF pancake coil (the coil utilized by TMI-1 to measure the extents of the ID IGA indications), the analysis pooled standard deviations were 0.022" for axial length and 0.031" for circumferential length.

"Technique variabilities were obtained by comparing the results of the eddy current analyses to the actual metallurgy of the flaws. Again, for the 1999 study, this dataset included the 23 EDM flaws and 9 flaws from the 1997 pulled tube, for a total of 32 volumetric flaws. For the 0.080" HF pancake coil (the coil utilized by TMI-1 to measure the extents of the ID IGA indications), the technique standard deviations were 0.039" for axial length and 0.033" for circumferential length. For the 0.080" HF pancake coil, the technique average errors were a 0.124" overestimate of axial extent and 0.127" overestimate of circumferential extent.

"The conclusion of the 1999 error analysis and performance evaluation is that "...the rotating coil techniques have demonstrated that axial and circumferential extents are consistently overestimated. Even when analysis and technique / equipment variability are applied at a 95% confidence level, the extents measured by eddy current are larger than the actual extents." The overestimation of axial and circumferential extents is of sufficient magnitude that no correction to the repair limits is necessary to account for eddy current acquisition, analysis, or technique uncertainty. Since the eddy current coils interrogate a volume of metal larger than the volume of the flaws themselves (i.e., "look ahead" and "look behind") the result is a consistent overestimate of flaw extents.

"Note that tube pull results from the 1997's Outage 12R demonstrated that the MRPC probe typically overestimates the axial extents of the ID IGA flaws by a factor of approximately three. This occurs due to the "look ahead" and "look behind" phenomena of eddy current coils used in steam generator tube examinations. Additional information on analyst uncertainty is provided in the response to RAI Question No. 4."

AmerGen's Reference 4, RAI Question 4, response provided to the NRC the following information concerning length and width sizing of ID IGA indications:

"...The analyst variabilities during the MRPC probe examinations are inconsequential considering that MRPC probes consistently overestimate the actual length of the volumetric ID IGA flaws as shown in Attachment 2. Tables 2 and 3 in the attachment are excerpts from a 1999 TMI Unit 1 submittal and provide Outage 12R eddy current measured length data prior to tube removal and laboratory destructive examination for a tube removed in 1997's Outage 12R."

Similar length sizing studies were performed for axially- and circumferentially-oriented indications prior to the 1997 and 1999 outages using 30 machined notches and 6 laboratory induced axially oriented PWSCC cracks. These measurements were made using the mid-frequency Plus Point coil similar to measurements made in the field. The results of these studies indicated that the Plus Point coil, like the pancake coils, overestimates crack length.

In the kinetic expansion region flaw depth measurements are made using the mid-frequency Plus Point coil. Prior to the 1997 and 1999 outages Plus Point coil depth sizing performance studies were performed in a manner similar to that described above for the length sizing studies. The 1999 study was performed using 68 total flaws that were comprised of 10 machined axial notches, 20 machined circumferential notches, 23 machined ID volumetric IGA like indications, 6 laboratory grown PWSCC indications in OTSG tubing, and 9 TMI pulled tube ID IGA indications. The studies indicated that the measured 95% lower confidence level (LCL) through wall measurement error is expected to be -28.1% through wall.

It should be noted that, as described in Reference 10, the measured eddy current through wall estimate is used for estimation of accident-induced leakage only. The eddy current measured axial and/or circumferential extent is assumed to be 100% through wall for evaluation of structural integrity (resistance to pull-out) as described in Reference 9. Based on the eddy current examination results, and in situ pressure tests of freespan indications performed at TMI to date (See response to question 20), accident-induced leakage from kinetic expansion indications remaining in service is expected to be very small.

In summary, the eddy current techniques used at TMI-1 are based on qualification datasets that included pulled tube samples from TMI-1 and other samples representative of TMI-1 ID degradation. Performance studies have demonstrated that eddy current sizing is conservative, and both pulled tubes and in situ pressure testing to date have demonstrated that the techniques used at TMI-1 are able to reliably disposition steam generator tube flaws.