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10 CFR 50.90

July 13, 2001
5928-01-20169

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

Dear Sir or Madam:

SUBJECT: THREE MILE ISLAND, UNIT 1 (TMI UNIT 1)
OPERATING LICENSE No. DPR-50
DOCKET No. 50-289
ADDITIONAL INFORMATION - LICENSE CHANGE APPLICATION
NO. 291 – ONCE THROUGH STEAM GENERATOR (OTSG) SURVEILLANCE
SPECIFICATIONS APPLICABILITY FOLLOWING CYCLE 13

On December 6, 2000, AmerGen Energy Company, LLC (AmerGen) submitted TMI Unit 1 License Change Application No. 291, requesting an amendment to the TMI Unit 1 Technical Specifications (TS) Surveillance Requirements for inservice inspection of the Once Through Steam Generators regarding inspection and repair of tubes having volumetric Inside Diameter Intergranular Attack (ID IGA) degradation. The proposed repair criteria for ID IGA are necessary to allow continued safe operation of TMI Unit 1 following OTSG inspection outages while preventing undue financial hardship, significantly increased radiological exposures, and unnecessary increases in outage duration due to repairs of ID IGA flawed tubes that meet these conservative criteria.

A public meeting was held between AmerGen and representatives of the NRC staff on April 25, 2001 to discuss the AmerGen request for amendment regarding TMI Unit 1 ID IGA. At this meeting, responses to questions by members of the NRC staff were discussed. Subsequent telephone calls were held on May 8, 11, and 15, 2001 to further discuss question from the NRC staff during the public meeting. The NRC's requests for additional information (RAI) was issued in a letter dated May 23, 2001.

Enclosure 1 provides the AmerGen response to the NRC's RAI. Enclosure 2 is AmerGen Engineering Report, ECR No. TM 01-00328, "Three Mile Island Unit 1, Management Program for Volumetric Inside Diameter Intergranular Attack (ID IGA) in the Once-Through Steam Generators." Enclosure 3 provides a hand markup of the TS pages including a summary listing of all of the changes to the TS pages affected by LCA No. 291. Enclosure 4 is a revision of the no

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significant hazards consideration provided with our December 6, 2000 submittal of LCA-291 to incorporate the additional changes included with this letter.

Since the TMI Unit 1 Refueling Outage 1R14 has been rescheduled to begin in early October, AmerGen requests NRC support in approval of LCA No. 291 by August 31, 2001.

If any additional information is needed, please contact Bob Knight at (717) 948-8554.

Very truly yours,

George Gellrich

Mark E. Warner
Vice President, TMI Unit 1

MEW/mrk

Enclosure:
1) TMI Unit 1 Response to NRC Request for Additional Information (RAI)
2) Engineering Report, EEC EER 01-00328, "Three Mile Island - Unit One, Management Program for Volumetric Inside Diameter Intergranular Attack (ID IGA) in the Once-Through Steam Generators"
3) Affected TMI Unit 1 Technical Specification Pages
4) Revised No Significant Hazards Consideration Evaluation

cc: H. J. Miller, Administrator, USNRC Region I
T. G. Colburn, USNRC Senior Project Manager, TMI Unit 1
J. D. Orr, USNRC Senior Resident Inspector, TMI Unit 1
D. Allard, Director, Bureau of Radiation Protection – PA Department of Environmental Resources
Chairman, Board of County Commissioners of Dauphin County
Chairman, Board of Supervisors of Londonderry Township
File No. 00120

AMERGEN ENERGY COMPANY, LLC

THREE MILE ISLAND, UNIT 1

Operating License No. DPR-50
Docket No. 50-289
Additional Information – License Change Application No. 291

COMMONWEALTH OF PENNSYLVANIA)
) SS:
COUNTY OF DAUPHIN)

This additional information is submitted in support of Licensee's request to change the Technical Specifications for Three Mile Island, Unit 1 (TMI Unit 1). All statements contained in this submittal have been reviewed, and all such statements made and matters set forth therein are true and correct to the best of my knowledge.

AmerGen Energy Company, LLC

By: [signature] for MEW.
Vice President, TMI Unit 1

Sworn and Subscribed to before me

this 13th day of July 2001.

[signature]
Notary Public

Notarial Seal
Suzanne C. Miklosik, Notary Public
Londonderry Twp., Dauphin County
My Commission Expires Nov. 22, 2003
Member, Pennsylvania Association of Notaries

ENCLOSURE 1

ADDITIONAL INFORMATION - LICENSE CHANGE APPLICATION NO. 291

TMI Unit 1 Response to NRC Request for Additional Information (RAI)

TMI Unit 1 Response to NRC Request for Additional Information on Technical Specification Repair Criteria for Volumetric Inner Diameter (ID) Intergranular (IGA) Attack Degradation

NRC RAI No. 1:

AmerGen stated in their submittal dated December 6, 2000 that "AmerGen has concluded that the inside diameter intergranular attack (ID IGA) indications are not growing in either size or depth." This statement is an apparent contradiction to the inspection findings listed in the following two paragraphs. These paragraphs indicate because tubes are being plugged, ID IGA indications are indeed growing. If eddy current analyst or technique uncertainty is the primary reason for apparent indication "growth", provide the NRC with information on how you confirmed this to be the case as opposed to real indication growth. If you have measured analyst uncertainty, please provide the results of that study to the NRC staff.

"In 1997, 100 percent of the in-service steam generator tubes were inspected with bobbin coil eddy current probes. While a number of tubes were plugged as a result of ID IGA indications that exceeded the 40% through-wall [TW] criterion, no ID IGA indications were found which exceeded the 0.52" circumferential extent criterion, and only one tube was found with an indication that required repair as a result of exceeding the 0.25" axial extent criterion."

"In 1999, 100% of the in-service steam generator tubes were inspected with bobbin coil eddy current probes. No ID IGA indications were found which exceeded the 0.52" circumferential extent criterion; three ID IGA indications were found that exceeded the 0.25" axial extent criterion. Two ID IGA indications were removed from service based on bobbin probe depth estimates of 40% and 43% through-wall."

TMI Response to RAI No. 1:

<u>SUMMARY</u>

The fact that tubes are being repaired by plugging under the subject criteria does not contradict the conclusions to date that the volumetric ID IGA indications are not growing. Repair of tubes with volumetric ID IGA indications has occurred, and will continue to occur, under the proposed permanent repair criteria. Eddy current analyst uncertainty is not the singular reason for apparent indication "growth." The primary reasons for apparent indication "growth" are:

1) Increases in eddy current examination scope,
2) Changes in the repair criteria for the ID IGA,
3) Eddy current test variability, and
4) Improvements in eddy current equipment and its deployment.

More than 40,000 steam generator eddy current examinations have been conducted during each of the last two plant outages; the small number of tube repairs is not indicative of growth of volumetric ID IGA. TMI-1 has reviewed examination results (i.e., performed "look backs") of previous examination raw data and has not identified growth of volumetric ID IGA indications.

TMI-1 eddy current analysts are tested to ensure proficiency in review of bobbin data for volumetric ID IGA indications. MRPC analysis uncertainty is addressed in the following section entitled "Analyst Uncertainties." TMI-1 has reviewed analyst variabilities and has determined that volumetric ID IGA is being conservatively dispositioned.

REASONS FOR REPAIRS

TMI-1's volumetric ID IGA indications have been in service since the plant's restart in 1985. In accordance with the plant's Technical Specifications, eddy current exams of the steam generator tubes have been conducted during each of the plant outages since 1985. Table 1, below, provides a list of bobbin probe eddy current scopes for the TMI-1 plant outages since the plant's restart:

Table 1
TMI-1 Steam Generator Tubes Inspected Using Bobbin Probes

Refueling Outage	Year	OTSG Tubes Inspected by Bobbin	Percent of Inservice Tubes Inspected by Bobbin
5M	1986	2,732	~ 9%
6R	1986	6,218	~ 20%
7R	1988	4,126	~ 13%
8R	1990	3,202	~ 10%
9R	1991	2,209	~ 7%
10R	1993	2,642	~ 9%
11R	1995	6,821	~ 23%
12R	1997	29,415	100%
13R	1999	29,367	100%

As depicted in Table 1, Outage 12R (in 1997) was the first recent TMI-1 outage in which full length bobbin coil examinations of all in-service tubes were conducted. (This was also the first TMI-1 outage during which the plant's Technical Specifications included axial and circumferential extent repair criteria for the ID volumetric IGA indications.) During the Outage 12R examinations a number of ID IGA volumetric indications were detected in tubes which had not been examined in recent outages. Some of those indications were plugged on the basis of estimated throughwall depth, axial extent or circumferential extent. This increase in the number of ID IGA indications requiring plugging was expected as a result of the large increase in tube bobbin coil examination scope, and the new repair criteria. During Outage 13R (1999) a second 100% bobbin coil examination was conducted of all in-service tubes.

In addition to the increases in bobbin coil examination scope, increases in MRPC examination scopes have also occurred. TMI-1 committed, for its technical specification repair criteria for ID IGA, to perform MRPC examinations of all bobbin coil indications of ID degradation. In addition, a large number of MRPC examinations have been performed in the upper tubesheet kinetic expansions. The following table depicts the number of MRPC examinations of TMI-1 tubing for each of the last three plant outages:

Table 2
TMI-1 Steam Generator Tubes Inspected Using MRPC Probes

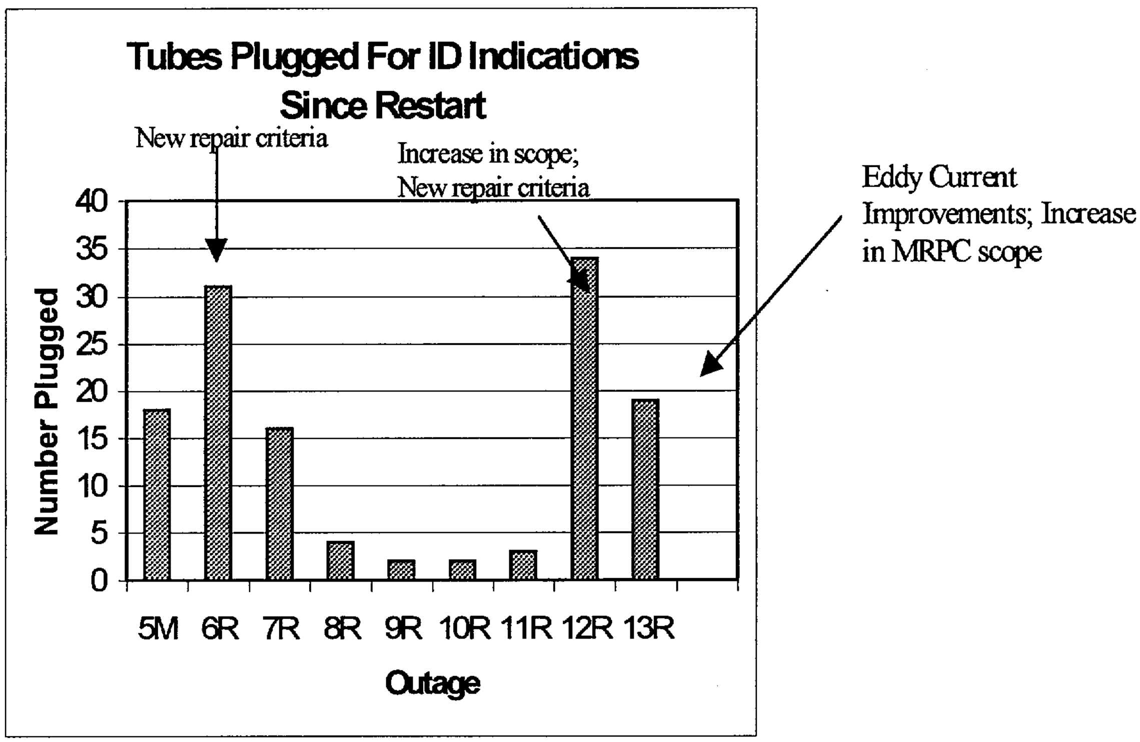
Refueling Outage	Year	OTSG Tubes Inspected by MRPC	Tubes Receiving First MRPC Examination
11R	1995	731	638
12R	1997	8,330	8,056
13R	1999	13,220	11,085

Improvements in eddy current examination equipment and its deployment have also accounted for some of the changes in examination data and resulting tube repairs. For example, the 1997 (12R) Outage was the first outage in which the Plus-Point coil and the 0.080" HF pancake coil were used at TMI-1. The 12R Outage eddy current data provided additional data for use in the 1999 (13R) Outage training and testing of the eddy current data analysts. A number of other changes were made for the 1999 examinations: MRPC probe pull directions were modified for more consistent probe axial speeds; the number of axial data samples of the MRPC coils was changed from a minimum of 25 to a minimum of 30 samples per inch of tubing.

The net result of the increase in bobbin coil and MRPC examination scopes, along with the increased sensitivity of eddy current electronic equipment, since 1981 has been an increase in identified volumetric ID IGA indications in the TMI-1 generators. The large increase in MRPC examination scopes also contributed to the number of tubes plugged for ID IGA indications during Outages 12R and 13R.

In addition, the axial extent and circumferential extent repair criteria for volumetric ID IGA was not a part of the plant's Technical Specifications until 1997. Therefore, the 1997 outage resulted in the plugging of a number of tubes as a result of these concurrent changes. The following bar chart (Figure 1) depicts the repair of tubes after the 1981 ID degradation occurred, and tube repairs performed during the 1997 (12R) and 1999 (13R) Outages.

Figure 1



The inherent variability of the eddy current process will likely cause additional volumetric ID IGA indications to exceed the repair criteria in future outages.

Increase in eddy current examination scope, along with the variability of the eddy current examination process, has resulted in repair by plugging of several tubes with indications exceeding the conservative Technical Specification repair criteria. Given the number of examinations conducted, and the population of indications detected during those examinations, plugging of a small number of tubes is expected and is not indicative of volumetric ID IGA indication growth.

ANALYST UNCERTAINTIES

ID IGA indications at TMI-1 are generally not associated with interfering deposits or support structures which complicate voltage measurement. The typical ID IGA indication at TMI-1 occurs in the freespan and is a very fast signal (the short axial extent produces a signal that occurs over a very short period of time), which also minimizes influences from undesirable sources. Analyst actions have very little influence over measurement of this type of signal (only flaw signal is present for voltage measurement). This is in contrast to eddy current analysis of some of the other industry tube damage mechanisms, such as measurement of ODSCC at support plates, which require the analyst to adjust the flaw viewing window in order to remove a support plate residual signal from the flaw signal for voltage measurement. For depth sizing estimates provided for some of the volumetric ID IGA indications using the bobbin coil probe, the TMI-1 site-specific eddy current analyst test for TMI-1 has required that all resolution analysts estimate ID IGA depth using the bobbin coil probe within 10% TW RMSE with respect to the test's truth answers. A minimum of sixteen flaws are used in these analyst tests. Given the above, AmerGen believes that the analyst uncertainty for the bobbin coil probe techniques used to examine volumetric ID IGA flaws in the tubing is acceptable.

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.

NRC RAI No. 2:

AmerGen provided the staff with a table that compared eddy current results from the outage 13R inspections with results from previous inspections. This table, Table III-4 "Average Growth for ID IGA Indications", was contained in the January 7, 2000 "Report on the 1999 Outage 13R Eddy Current Examinations of the Three Mile Island Unit 1 (TMI-1) Once-Through Steam Generator (OTSG) Tubing."

The staff discussed this table with the licensee during a January 12, 2001 conference call. The licensee indicated that during 12R and 13R, they performed a 100% bobbin probe examination with follow-up motorized rotating pancake coil (MRPC) examinations of all the ID IGA identified by the bobbin probe. In previous outages, the licensee performed less than 100% examination of all ID IGA flaws by MRPC.

Please confirm that Table III-4 contains the subset of indications that have a measured voltage or length from a previous outage for comparison. Please discuss why the number of observed axial and circumferential extent indications for 12R and 13R was higher than the number of indications used to compare bobbin volts for the same period. Please discuss how the number of indications listed as bobbin volts compares with the list of indications listed as bobbin %TW. Please discuss the reasons for finding MRPC indications that do not have an associated bobbin indication.

In general, it is difficult for the staff to determine from the information submitted for this license amendment and information submitted previously if the total number of ID IGA indications are increasing in each successive outage, or if the number is relatively stable. Because the information presented in the table is divided into subsets of what has been detected in each outage by eddy current inspection, the staff cannot assess the population of ID IGA indications found each outage.

In order for the staff to evaluate the numbers of new indications found each outage, in comparison to the previously detected ID IGA indications, the staff needs the data presented in a different manner. For outages 11R to 13R, please provide the total number of ID IGA indications found below the kinetic expansion region of the steam generators during each outage in a table, separated into 0.2V (as measured by bobbin) bins. In addition to the number of indications, please provide the number of tubes that contain ID IGA indications found below the kinetic expansion region of the steam generators during each outage in a table. Please provide the number of tubes with known ID IGA indications and total number of ID IGA indications taken out of service by plugging for each outage listed above.

TMI Response to RAI No. 2:

<u>BACKGROUND</u>
TMI-1's ID IGA indications may be categorized into one of several "groups" based on how individual indications were identified during an eddy current examination. The examination process and scope plays an important role in this categorization process, and change in

indication population or parameters in a given group can be evaluated to help assess the generators.

The normal examination process for TMI-1 bobbin coil examinations is that a steam generator tube is examined with a 0.510" mid frequency bobbin coil probe. If an ID degradation indication is identified during the 0.510" bobbin coil exam (i.e., flaw indications ≤ 30 degrees and ≥ 5 degrees) the tube is re-examined using a 0.540" high frequency bobbin coil probe. Tubes that in previous outages required evaluation with a 0.540" bobbin coil probe are "pre-scheduled" for examination with the 0.540" bobbin coil probe to minimize radiation exposure and radioactive waste. The 0.540" bobbin coil probe provides the data for final bobbin coil disposition of ID IGA indications in accordance with the site's analysis guidelines.

It should be noted that the data from the bobbin coil examinations is only evaluated between the lower tubesheet roll transition to the upper tubesheet kinetic expansion transition. The kinetic expansions are not evaluated because their expanded condition does not allow proper examination data quality using a bobbin coil probe (due to a slight rippled effect remaining on the tube surfaces.) For this reason MRPC surface-riding coils are presently used to examine kinetic expansion and their transitions.

The 0.540" bobbin coil ID flaw indications (≤ 30 degrees and ≥ 5 degrees) are assigned a percent through wall depth estimate if their measured signal is ≥ 0.4 volts or has a signal-to-noise ratio (S/N) of ≥ 3:1. ID flaw indications measuring < 0.4 volts and < 3:1 S/N are not assigned an estimated through wall extent (due to insufficient signal) and are assigned the three letter code "BVC". Therefore, the bobbin coil examinations yield two different types of indications, those with bobbin percent through wall estimates and BVCs. All of the "BVC" and percent through wall indications were examined with MRPC probes during Outages 12R (1997) and 13R (1999). Prior to these outages bobbin coil probe ID indications were examined with MRPC probes only if there was a new not previously identified indication or if an indication had possible change based on its bobbin coil probe signal (e.g. the indication changed from a BVC to a percent through wall disposition).

The MRPC probe examination results for bobbin coil probe indications are used, along with the bobbin coil results, to disposition the volumetric ID IGA indications. ID IGA indications measured as ≥40% TW by the bobbin coil probe (0.540" diameter) and confirmed by MRPC are plugged. Indications exceeding either the Technical Specification-defined axial length or circumferential length are plugged, regardless of the bobbin coil probe through wall measurement. Indications that are detectable with both the bobbin coil probe and the MRPC probe are generally considered the most degraded subset of ID IGA indications--based on their detection with both probes. In some cases a bobbin coil flaw indication is not confirmed by the subsequent MRPC probe exam and these bobbin indications are not considered to be flaws.

In other cases ID IGA indications are detected only with the MRPC probe (i.e., not detected by a bobbin coil probe). This situation occurs because a flaw is so small that only the MRPC probe can detect it (an MRPC probe has a smaller field of view and is more sensitive than a bobbin coil probe) or the indication is located at an area of reduced sensitivity for the bobbin coil probe (e.g., kinetic expansion transition). This situation accounts for the large difference in the number of bobbin coil ID indications and the number of MRPC ID IGA indications in a given outage.

In recent outages some of the volumetric ID IGA indications have been detected by MRPC probes only, while other volumetric ID IGA indications have been detected by both bobbin and MRPC probes. Thus, there is more MRPC data (i.e., axial and circumferential extents) than bobbin coil data (i.e., bobbin voltages and depth estimates) for the volumetric ID IGA indications. Also, since all bobbin coil indications of volumetric ID IGA are assigned voltages, but only those bobbin coil indications with sufficient signal are provided a depth estimate, the number of bobbin coil voltage values exceeds the number of bobbin coil estimated depths. Therefore, for recent outages the number of axial and circumferential extent data points exceeds the number of bobbin coil voltage data points, which, in turn, exceeds the number of bobbin coil depth estimate data points. It is for this reason that the number of axial and circumferential extent comparisons in recent outages exceeds the number of indications used for bobbin voltage or throughwall comparisons.

ID volumetric indications are evaluated with respect to the Technical Specifications criteria whether they are detected by the bobbin coil probe and confirmed by MRPC or if they are detected only by the MRPC probe. (ID IGA indications detected with the MRPC probe only are dispositioned based on Technical Specification 4.19 defined axial and circumferential length limits only; no through wall measurement is assigned).

As described in the response to Question 1, the number of tubes in the examination scope has also played a large part in determining the number of indications detected during a TMI-1 outage. Prior to Outage 11R the bobbin coil examination scope was smaller compared to the plant's recent outages. (Refer to Table 1 in the response to RAI Question No. 1). The Outage 11R and 12R bobbin coil examination scope resulted in a large number of tubes being examined with the bobbin coil probe for the first time since 1985. Table 1 of RAI Response No. 1 provides information on the examination scope. Table 1 of this RAI Response provides the number of tubes that, during Outages 11R and 12R, received their first bobbin examination since 1985.

The MRPC examination scope has gone through, and will continue to go through, an "inspection transient." MRPC examination scope was limited prior to Outage 12R. Prior to Outage 12R MRPC examinations were generally only performed on bobbin coil "NQI" (Non-Quantifiable Indication; sometimes referred to as "I-Code" indications) type indications, those ID bobbin coil indications that were newly detected or classified as changed, and at limited, specific areas such as the sleeve border region. The MRPC examination scope during TMI-1's Outages 12R and 13R increased very substantially. During Outage 12R MRPC examinations were performed on all "I-Code" indications, miscellaneous other bobbin coil indications, all bobbin coil percent throughwall and "BVC" indications, and about 20% of the kinetic expansions (the latter area included the required fully expanded area, the expansion transition, and about one inch of unexpanded tubing below the expanded region). During Outage 13R MRPC examinations were performed on all "I-Code" indications, miscellaneous other bobbin coil indications, all bobbin coil percent throughwall and "BVC" indications, and about 40% of the kinetic expansions. See Table 2 of the response to RAI Question No. 1 for the MRPC examination scope for Outages 11R, 12R, and 13R. As more areas of tubing are examined for the first time with the MRPC probe, newly defined ID IGA indications, detectable only with the MRPC probe, are expected.

AmerGen continues to believe these newly defined indications are attributable to the 1981 sodium thiosulfate intrusion because "look-ups" performed on newly defined bobbin coil indications are traceable back to eddy current data from the 1981 to 1985 examinations. Newly defined MRPC ID IGA indications cannot be traced to the same time frame because MRPC technology was not available for production examinations during the 1981 to 1985 time period.

Answers to Specific Questions/Requests

Please confirm that Table III-4 contains the subset of indications that have a measured voltage or length from a previous outage for comparison.

Table III-4 does contain the subset of individual ID IGA indications that have a measured voltage or length and could be compared to previous outages.

Please discuss why the number of observed axial and circumferential extent indications for 12R and 13R was higher than the number of indications used to compare bobbin volts for the same period.

Many ID IGA indications are detectable only with the MRPC probe as discussed above.

Please discuss how the number of indications listed as bobbin volts compares with the list of indications listed as bobbin %TW.

AmerGen has evaluated bobbin coil ID indication growth using both voltage change and measured through wall change. Because some of the indications evaluated only have a recorded voltage ("BVC" indications) and do not have a percent through wall estimate, there is a difference in the number of indications for which voltages could be compared and the number of indications for which percent through wall estimates could be compared.

Please discuss the reasons for finding MRPC indications that do not have an associated bobbin indication.

As discussed above, the MRPC probe has a smaller field of view and is more sensitive than a bobbin coil probe. The MRPC probe can examine the kinetic expansion transition region while the bobbin coil probe cannot.

For outages 11R to 13R, please provide the total number of ID IGA indications found below the kinetic expansion region of the steam generators during each outage in a table, separated into 0.2V (as measured by bobbin) bins.

Figures 1 through 3, which follow, provide binned voltage plots of 0.540" diameter bobbin coil indications that were ID in nature and were recorded as "BVC" or a measured through wall extent, regardless of whether the indication was confirmed by MRPC. The 0.540" bobbin coil indications are all below the kinetic expansion region. The 0.540" bobbin coil is not used in the kinetic expansion or the kinetic expansion transition regions.

In addition to the number of indications, please provide the number of tubes that contain ID IGA indications found below the kinetic expansion region of the steam generators during each outage in a table. Please provide the number of tubes with known ID IGA indications and total number of ID IGA indications taken out of service by plugging for each outage listed above.

Table 1, which follows, contains the number of indications located below the kinetic expansion that are considered ID IGA (ID volumetric indications) as determined by MRPC. Table 1 also provides the number of known ID IGA indications and total number of ID IGA indications removed from service by plugging during Outages 11R through 13R.

Table 1
ID IGA Indications Identified

	Outage 11R 1995[1]	Outage 12R 1997	Outage 13R 1999
Bobbin Scope (Tubes)	6,821	29,415	29,367
Bobbin BVC and ID %TW indications (indications/tubes/ID IGA indications confirmed by MRPC)[2]	471/235/NA	582*/284/480	422/254/373
Tubes receiving first bobbin coil examination since 1985	3,690	14,356	0
MRPC scope (tubes)	731	8,330	13,220
ID IGA MRPC indications recorded during outage (indications/tubes)[3]	70/40	970/383	1,385/607
ID IGA MRPC indications remaining inservice after repairs (indications/tubes)	66/37	871/349	1,123/578
ID IGA indications removed from service (indications/tubes)	4/3	99/34	262/29

* Note: This "582" quantity was "581" in Slide 10 of the April 25, 2001 meeting. Slide 12 of the April 25, 2001 meeting reflected the correct binning of 582 indications.

[1] MRPC ID IGA counts for Outage 11R are based on "SVI" signals with a corresponding ID phase plane phase angle and corresponding bobbin coil ID phase plane signal. ID IGA indications confirmed by MRPC were not evaluated because very few of the indications were examined with the MRPC probe during Outage 11R.

[2] These are all indications/tubes with 0.540" diameter bobbin coil signals <31 degrees and recorded as "BVC" or as a percent through wall.

[3] Includes bobbin probe indications confirmed as ID IGA by MRPC and ID IGA indications detected by the MRPC probe only.

Figure 1

Outage 11R 0.540" Bobbin Coil Probe ID Indication Flaw Distribution
(Note: 11R data has been converted to the current voltage normalization values)

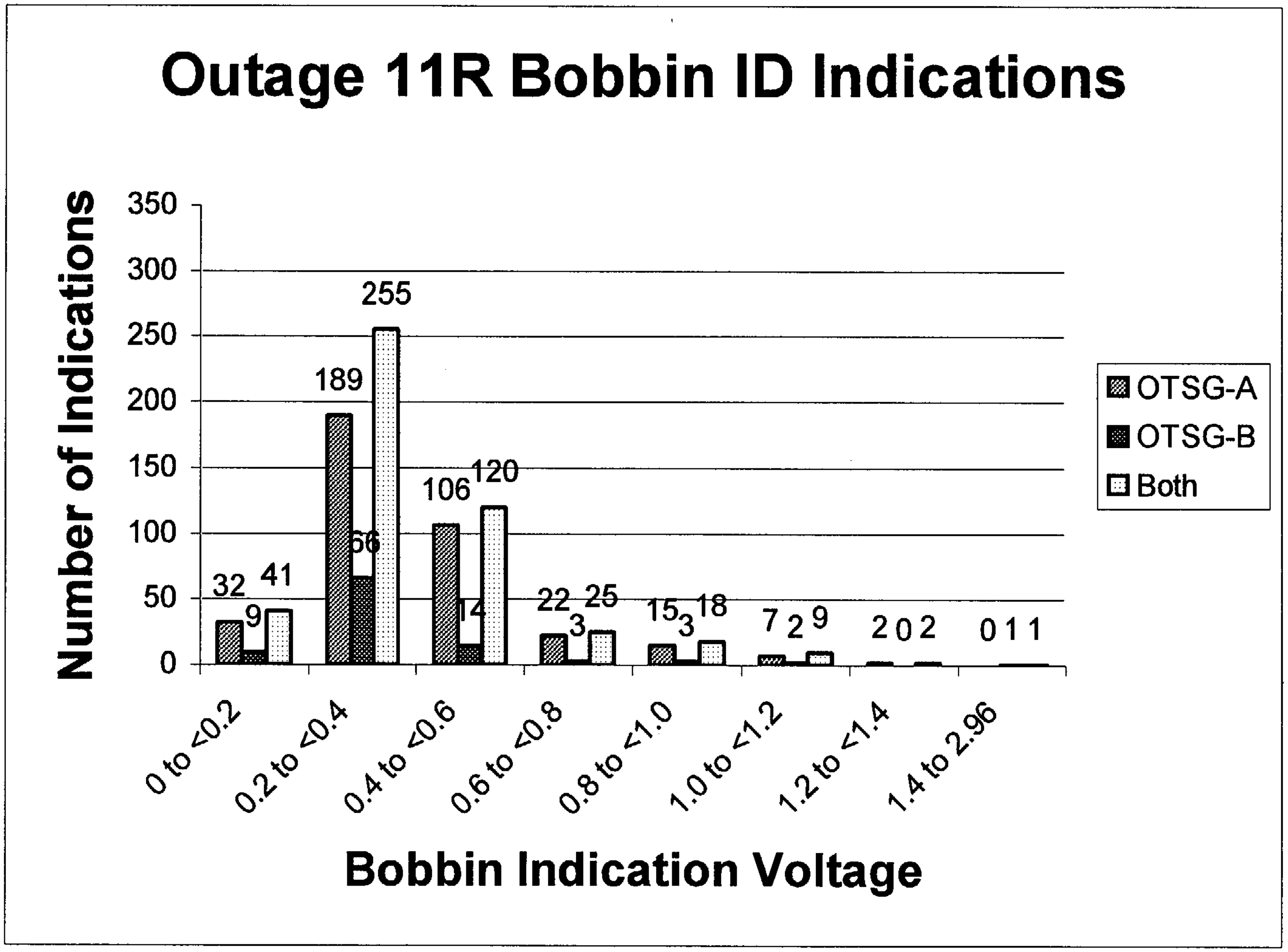


Figure 2

Outage 12R 0.540" Bobbin Coil Probe ID Indication Flaw Distribution
(Note: 12R data has been converted to the current voltage normalization values)

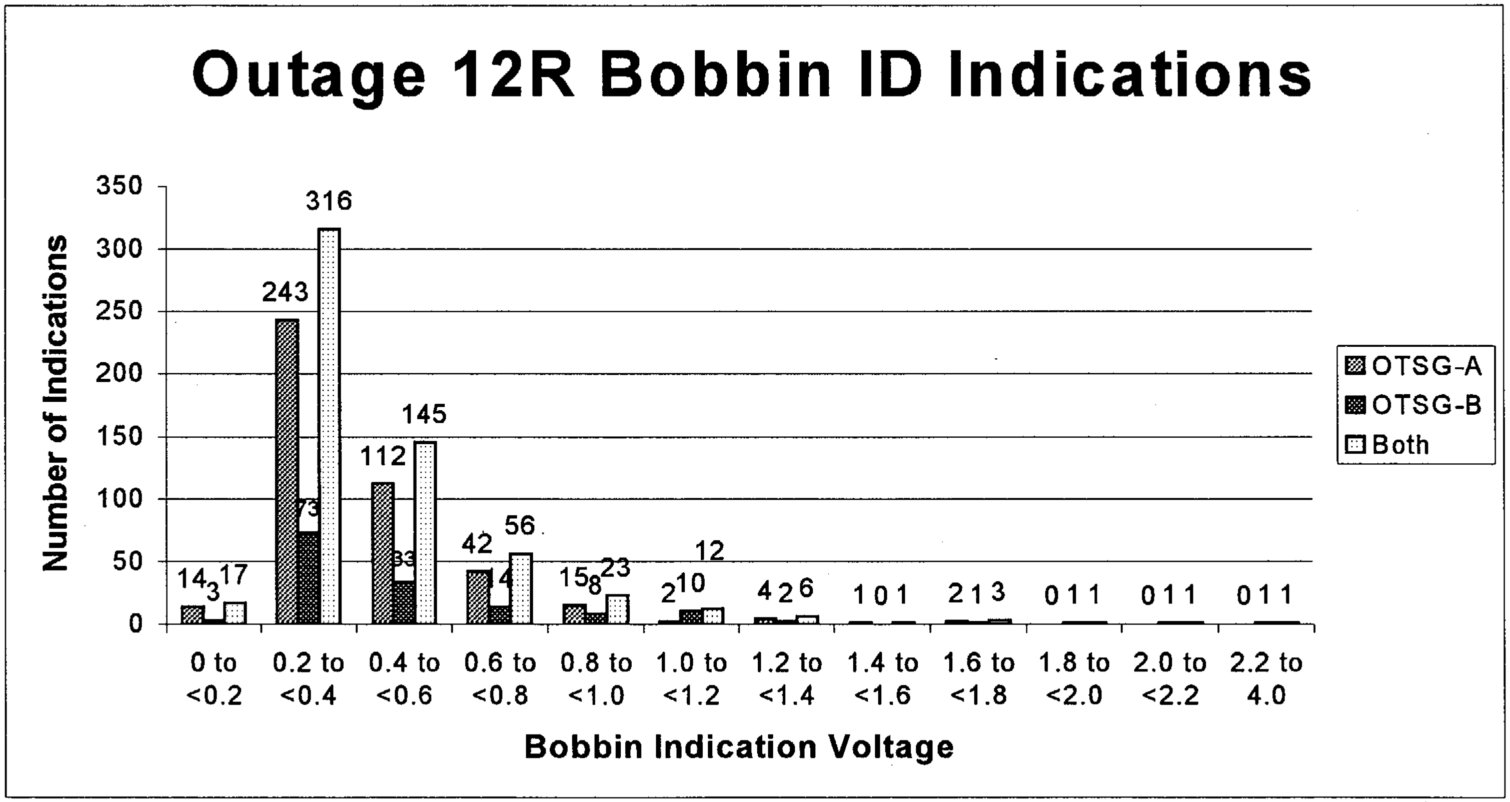
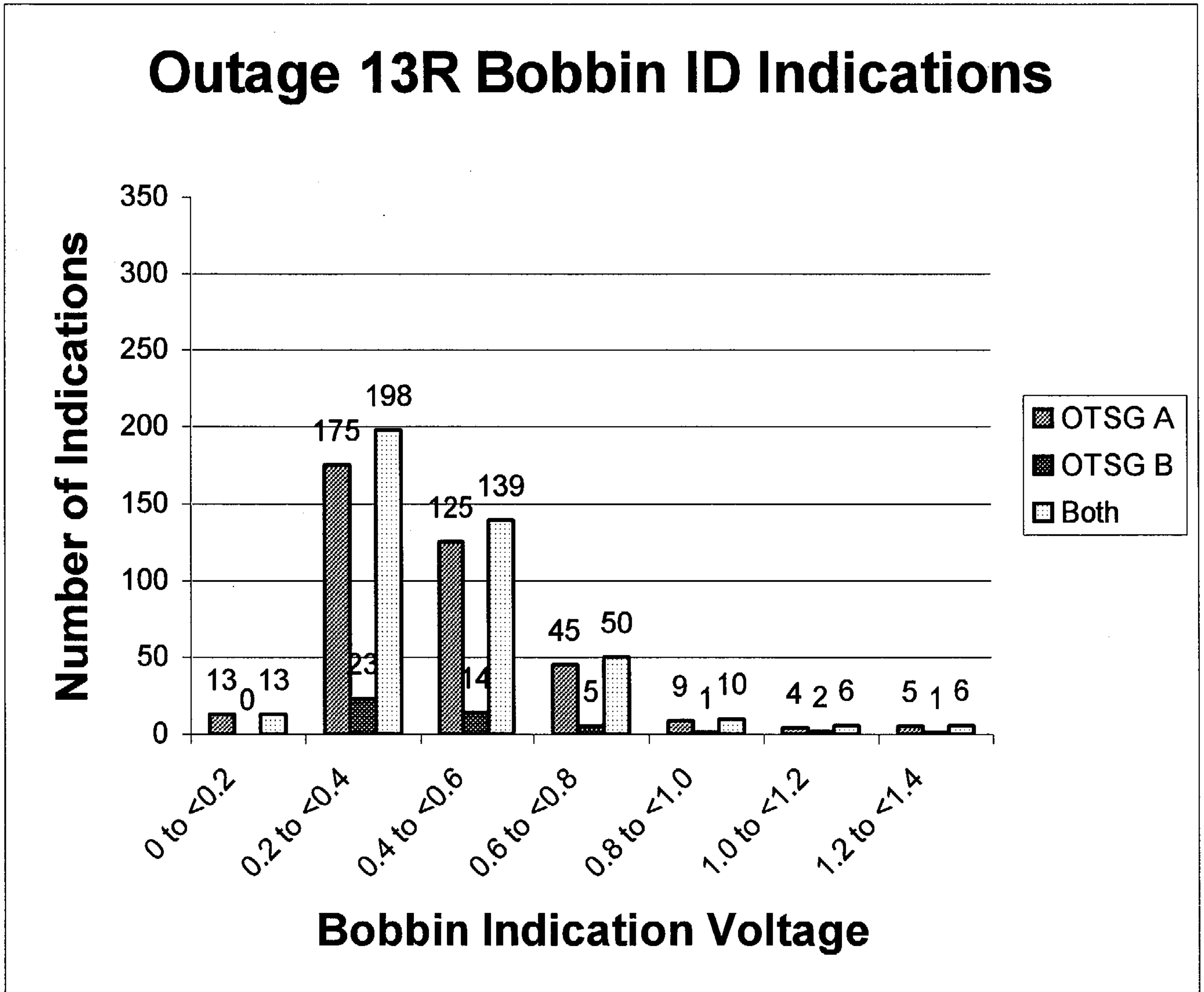


Figure 3

Outage 13R 0.540" Bobbin Coil Probe ID Indication Flaw Distribution



NRC RAI No. 3:

In a September 15, 1997 response to an NRC Request for Additional Information Regarding Technical Specification Change Request No. 268, the licensee stated that a growth study of ID IGA indications using MRPC data would be performed (question # 4). The licensee indicated that approximately 100 indications would be used, comparing 10R and 11R MRPC data with 12R MRPC data. In Table III-4 "Average Growth for ID IGA Indications", which was contained in the January 7, 2000 "Report on the 1999 Outage 13R Eddy Current Examinations of the TMI-1 OTSG Tubing, only 11 indications (10 in OTSG A and 1 in OTSG B) are used from 10R for the growth study. How were the other indications dispositioned?

TMI Response to RAI No. 3:

Table III-13 below, from the 1997 Outage 12R Steam Generator Examination Report, indicates that during Outage 12R there were actually 77 Outage 12R indications compared to the Outage 10R and 11R examinations. (This is the sum of the 63 10R and 14 11R indications listed in the table.)

Table III-4 below, from the 1999 Outage 13R Steam Generator Examination Report, had a large enough flaw population that it was possible to separate ID IGA data into kinetic expansion and non-kinetic expansion populations. A review of Table III-4 shows that 36 Outage 13R non-kinetic expansion indications were compared to Outage 10R and 11R indications. (This is the sum of the 25 and 11 values in the "Both SGs" column, for indications below the kinetic expansions.)

Seventy-seven (77) Outage 10R and 11R indications were compared in Outage 12R (1997); in Outage 13R (1999) 36 indications were available for comparison. During Outage 13R the data for the other 41 indications were not available for comparison because the indications were in tubes previously plugged, the indications were not recordable during Outage 13R, or the area was not examined with the MRPC probe. (Indications that were not previously considered degraded due to axial or circumferential length as defined by Technical Specification 4.19 and had no associated bobbin coil indication recorded during Outage 13R were not required to be examined per the Technical Specifications.)

[Reprinted from Outage 12R Report]
Table III-13

ID IGA Average Change in Length/Width Measurements

Outages	Number of Indications	Average Change in Circumferential Extent	Average Change in Axial Extent
10R → 11R	2	-0.02 in.	-0.09 in.
11R → 12R	14	0.01 in.	-0.01 in.
10R → 12R	63	0.03 in.	-0.02 in.

[Reprinted from Outage 13R Report]
Table III-4

(Note: The 11R and 12R bobbin voltages in this table have been adjusted to account for the voltage normalization change that was implemented for Outage 13R.)

Average Growth for ID IGA Indications

TMI-1 Outage 13R Compared to Outages 10R Through 12R

	NDE Measurement	Operating Period	SG A		SG B		Both SGs	
			No. of Inds	Avg. Change	No. of Inds	Avg. Change	No. of Inds	Avg. Change
Bobbin ID IGA Indications	Bobbin Volts	12R to 13R	313	0.004 V	43	0.010 V	356	0.005 V
		11R to 13R	237	0.030 V	32	0.090 V	269	0.037 V
	Bobbin %TW	12R to 13R	146	0.3%	24	-3.8%	170	-0.3%
		11R to 13R	86	0.7%	9	-5.9%	95	0.1%
ID IGA Below Kinetic Expansion (MRPC)	Axial Extent	12R to 13R	572	0.011"	43	0.018"	615	0.011"
		11R to 13R	25	-0.013"	0	NA	25	-0.013"
		10R to 13R	10	-0.032"	1	0.00"	11	-0.029"
	Circ Extent	12R to 13R	572	0.005"	43	0.003"	615	0.005"
		11R to 13R	25	-0.013"	0	NA	25	-0.013"
		10R to 13R	10	-0.016"	1	0.030"	11	-0.012"
ID IGA In Kinetic Expansions (MRPC)	Axial Extent	12R to 13R	128	0.003"	20	0.006"	148	0.003"
		11R to 13R	1	-0.04"	1	-0.01"	2	-0.025"
		10R to 13R	0	NA	0	NA	0	NA
	Circ Extent	12R to 13R	128	-0.012"	20	-0.005"	148	-0.012"
		11R to 13R	1	-0.06"	1	-0.01"	2	-0.035"
		10R to 13R	0	NA	0	NA	0	NA

NRC RAI No. 4:

In the one-cycle License Amendment No. 209 issued April 13, 1999, the NRC identified areas of weakness in the licensee's ID IGA growth rate study. A number of variables were identified which were not specifically addressed in the growth rate studies and are as follows: (1) bobbin probe wear, (2) calibration practices and standards, (3) differences in data acquisition hardware, and (4) data analyst uncertainty.

Please provide the staff with a discussion as to how each of the above listed variables have been addressed in the growth rate studies. This discussion should include any procedural changes that were made, what hardware was affected, and acceptance criteria for the above variables. For example, how will the probes, techniques, and analyst guidelines to be used in the outages to follow be consistent with the above variables.

In the April 25, 2001, meeting between AmerGen and the NRC staff, you discussed a pre-13R study of examination techniques and analyst variability. Have the results of this study been previously provided to the NRC staff? If not, please provide the results.

TMI Response to RAI No. 4:

BACKGROUND

Attachment 1 provides a detailed comparison of examination parameters used for Outages 11R through 13R and those planned for forthcoming Outage 1R14. Notes following the table provide more information for areas where differences are listed. The table indicates that changes will not adversely effect flaw growth studies because procedures are implemented to assure consistency. Where changes in the examination technique have occurred, efforts to compensate are utilized as appropriate to allow a meaningful comparison (e.g., growth studies with 0.115" Mid-Range Frequency (MR) pancake coil axial and circumferential length measurements permit a comparison with older data where data from the newer techniques do not exist).

Eddy current examinations for detection and evaluation of TMI-1's Inside Diameter (ID) Intergranular Attack (IGA) occur generally in the following sequence:

1. The tube is examined with a 0.510" diameter bobbin coil probe for initial flaw detection only. If bobbin coil ID IGA indications are already known to exist in a tube, this step is omitted and the tube examination is started at step 2.

2. The tube is examined with a 0.540" diameter bobbin coil probe for flaw detection and evaluation of ID IGA. Indication voltage and percent through wall are assigned using the data acquired from this examination. (A percent through wall estimate is not assigned if voltage and S/N are insufficient.)

3. ID IGA indications detected in step 2 are examined with a Motorized Rotating Pancake Coil (MRPC) probe. Plus Point data is used for detection, determining flaw morphology (i.e., axially-oriented, circumferentially-oriented or volumetric), and whether the flaw is ID or Outer Diameter (OD) initiated. The 0.080" High Frequency (HF) shielded pancake

coil data is used for evaluating volumetric ID IGA axial and circumferential lengths. Any 0.115" MR probe axial and circumferential length measurements that may be required for flaw growth studies to compare with older 0.115" probe data are normally made subsequent to the other required analyses.

4. Evaluate the acceptability of all examination results for continued service.

BOBBIN COIL PROBE WEAR

Bobbin coil probe wear is monitored for examinations where ID IGA is being evaluated (0.540" diameter HF bobbin coil probe examinations). This practice was implemented for Outages 12R and 13R, and will be used again during future outages. The probe wear calibration standard utilizes four 100% through wall (TW) 0.052" diameter holes separated axially and located at 90° increments around the standard in a helical pattern. A summary of the normal steps in evaluating bobbin coil probe wear is as follows:

1. Normalize voltage as required by the analysis guidelines.

2. Measure the 400 kHz differential voltage response from each of the four 100% TW holes of the probe wear standard during initial calibration and record the average (each acceptable calibration pull will be measured) of the measurements for later use.

3. Measure the 400 kHz differential voltage response from each of the four 100% TW holes of the probe wear standard during final calibration and record for comparison with the initial calibration results.

4. Evaluate the voltage responses from Step 3 against the averages recorded in Step 2 and calculate the percent difference between each measurement. If any measured final calibration voltages vary by more than ± 15% from the initial calibration voltage average for the same hole, the probe is considered out of tolerance. Any ID IGA indications evaluated with an "out of tolerance calibration group" are re-examined and evaluated with a new probe controlled in a similar manner. (That is, if a 0.540" probe is found to be out-of-calibration, the data from that probe is voided and the tubes are reexamined.)

CALIBRATION STANDARDS AND PRACTICES

Calibration standards used for examination at TMI-1 are designed to meet the requirements of ASME Section XI 1986 Edition with no Addenda and EPRI PWR Steam Generator Examination Guidelines, Revision 5. Future examinations will utilize calibration standards that comply with the applicable versions of ASME Section XI and the EPRI PWR Steam Generator Examination Guidelines. Any future required changes to calibration standards will be evaluated and included in growth analysis evaluations as appropriate. Bobbin coil probe voltages are further controlled by normalizing all voltage measurements equivalent to 4 volts from the four 20% TW holes in the B&W Owners Group (BWOG) "Mother" ASME standard (thereby minimizing subtle voltage differences between calibration standards).

DATA ANALYST UNCERTAINTIES

Prior to Outage 12R (1997) and Outage 13R (1999), a study was performed to quantify the expected analyst uncertainty for length measurements of ID IGA flaws using an MRPC probe. The results of these studies have not been previously provided to the NRC and are described in the response to RAI Question No. 1, above. 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.

SUMMARY

AmerGen concludes that the probes and techniques used are appropriate, consistent with industry standards, and are implemented carefully to assure conservative detection and sizing of ID IGA volumetric degradation at TMI.

Changes to examination technique essential variables will be evaluated prior to implementation to determine the effect on examination performance and the appropriate effects will be accounted for in future flaw growth studies. AmerGen will obtain NRC approval, prior to use, of any examination techniques that involve changes in probe types used for evaluation of ID IGA.

Bobbin probe wear, calibration standard usage, acquisition hardware changes, and eddy current analytical uncertainties have been factors considered in previous growth rate studies of, and dispositioning criteria for, the volumetric IGA indications. Probe wear monitoring, as described above, has been addressed in the TMI-1 examinations by requiring that all 0.540" probes show a voltage change of not more than 15% in response to holes in a calibration standard. Data obtained from probes not meeting the wear standard voltage requirement is voided and the affected tubes are re-examined. This helps to decrease voltage variations between examinations of volumetric ID IGA with new or "worn" probes, and to therefore decrease the uncertainty of the subsequent growth evaluations.

Calibration standards for eddy current probes used to examine volumetric ID IGA indications are normalized with respect to a single BWOG "mother standard." This helps minimize any changes in voltage caused by calibrating examination equipment to different calibration standards. The use of a mother standard over consecutive outages allows for a more accurate assessment of voltage changes for a given indication, such as those performed in growth studies. Use of a mother standard has decreased the uncertainty of growth studies performed subsequent to examinations.

Acquisition hardware changes have been assessed by the TMI-1 staff prior to their implementation, and after their implementation, to ensure that the volumetric ID IGA indications are being appropriately monitored. In some cases volumetric ID IGA examination data is even being acquired with older equipment (e.g. 0.115" pancake coil vice 0.080" pancake coil), in addition to examination with newer equipment, to allow comparison of old data and new data for growth study. Changes in acquisition hardware, identified in

Attachment 1, have been evaluated to ensure that the ID IGA examination data is not adversely affected.

Attachment 1
TMI-1 ECT Examination Techniques - Outages 11R through 1R14

Characteristic	Used During Outage 11R	Used During Outage 12R	Used During Outage 13R	Planned for Outage 1R14	Comment
Remote Data Acquisition Unit	Zetec MIZ-30	Zetec MIZ-30	Zetec MIZ-30	Zetec MIZ-30	No Difference
Drive Gain and Voltage	Gain Times 2 and Voltage Set to 12 Volts for All Flaw Detection Channels	Gain Times 2 and Voltage Set to 12 Volts for All Flaw Detection Channels	Gain Times 2 and Voltage Set to 12 Volts for All Flaw Detection Channels	Gain Times 2 and Voltage Set to 12 Volts for All Flaw Detection Channels	No Difference
Bobbin Coil Flaw Detection Probe, Lengths	Zetec 0.510" Diameter High Frequency, 83' and 100'	Zetec 0.510" Diameter High Frequency, 100'	Zetec 0.510" Diameter Mid Frequency, 100'	Zetec 0.510" Diameter Mid Frequency, 100'	Note 1
Bobbin Coil ID IGA Flaw Evaluation Probe: Lengths	Zetec 0.540" Diameter High Frequency, 83' and 100'	Zetec 0.540" Diameter High Frequency, 100'	Zetec 0.540" Diameter High Frequency, 100'	Zetec 0.540" Diameter High Frequency, 100'	Note 1
Bobbin Coil Detection/ Evaluation Channels	400 kHz in the freespan or 400/200 kHz Mix at support structures	400 kHz in the freespan or 400/200 kHz Mix at support structures	400 kHz in the freespan or 400/200 kHz Mix at support structures	400 kHz in the freespan or 400/200 kHz Mix at support structures	No Difference
MRPC Probe	Zetec 3-Coil Head with 0.115" MR Pancake, Axial, and Circ Coils	Zetec 3-Coil Head with 0.115" MR Pancake, + Point MR, and 0.080" HF (shielded)	Zetec 3-Coil Head with 0.115" MR Pancake, + Point MR, and 0.080" HF (shielded)	Zetec 3-Coil Head with 0.115" MR Pancake, + Point MR, and 0.080" HF (shielded)	Note 2
Extension Cables	Zetec-50' Shielded Low Loss	Zetec-50' Multipurpose	Zetec-50' Multipurpose	Zetec-50' Multipurpose	Note 3
Slip Ring	Zetec	Zetec	Zetec	Zetec	No Difference
Bobbin Coil Sample Rate	>30 Samples per Inch of Tubing	>30 Samples per Inch of Tubing	>30 Samples per Inch of Tubing	>30 Samples per Inch of Tubing	No Difference
MRPC Minimum Sample Rate	> 30 Samples/Inch Circ and > 25 Samples/Inch Axial	> 30 Samples/Inch Circ and > 25 Samples/Inch Axial	> 30 Samples/Inch Circ and > 30 Samples/Inch Axial	> 30 Samples/Inch Circ and > 30 Samples/Inch Axial	No Difference between 1R14 and 13R
MRPC Evaluation Channel	300 kHz Pancake or 300/100 kHz Pancake Mix for Detection. 300 kHz Axial and Circ for Morphology.	300 kHz + Point or 300/100 kHz + Point Mix for Detection and Morphology.	300 kHz + Point or 300/100 kHz + Point Mix for Detection and Morphology.	300 kHz + Point or 300/100 kHz + Point Mix for Detection and Morphology.	Note 4

Attachment 1 (Cont'd)
TMI-1 ECT Examination Techniques - Outages 11R through 1R14

Characteristic	Used During Outage 11R	Used During Outage 12R	Used During Outage 13R	Planned for Outage 1R14	Comment
MRPC Axial and Circ Length Measurement Channel for Volumetric ID IGA	Not Performed for Tube Dispositioning. 300 kHz 0.115" Pancake for Flaw Growth Studies.	600 kHz 0.080" HF Coil for Tube Dispositioning. 300 kHz 0.115" Coil for Flaw Growth Studies.	600 kHz 0.080" HF Coil for Tube Dispositioning. 600 kHz 0.080" HF Coil for Flaw Growth Studies (Where 0.080" Data is Available). 300 kHz 0.115" Coil for Flaw Growth Studies (Where 0.115" Data is Available).	600 kHz 0.080" HF Coil for Tube Dispositioning. 600 kHz 0.080" HF Coil for Flaw Growth Studies (Where 0.080" Data is Available). 300 kHz 0.115" Coil for Flaw Growth Studies (Where 0.115" Data is Available).	Note 5
Bobbin Coil Voltage Normalization	Set the 400 kHz Differential Response to 10 Volts From the Four ASME 20% TW Holes in Each Standard and Store to All Other Channels.	Set the 400 kHz Differential Response Equivalent to 10 Volts From the Four 20% TW Holes in the BWOG Mother ASME Standard and Store to All Other Channels.	Set the 400 kHz Differential Response Equivalent to 4 Volts From the Four 20% TW Holes in the BWOG Mother ASME Standard and Store to All Other Channels.	Set the 400 kHz Differential Response Equivalent to 4 Volts From the Four 20% TW Holes in the BWOG Mother ASME Standard and Store to All Other Channels.	Note 6
Bobbin Coil Phase Rotation (0.510" and 0.540" Diameter)	Set the ASME 0.052" 100% TW Hole Response to 30° on the 400 kHz and 400/200 kHz Mix Channels.	Set the ASME 0.052" 100% TW Hole Response to 30° on the 400 kHz and 400/200 kHz Mix Channels.	Set the ASME 0.052" 100% TW Hole Response to 30° on the 400 kHz and 400/200 kHz Mix Channels.	Set the ASME 0.052" 100% TW Hole Response to 30° on the 400 kHz and 400/200 kHz Mix Channels.	No Difference

Attachment 1 (Cont'd)
TMI-1 ECT Examination Techniques - Outages 11R through 1R14

Characteristic	Used During Outage 11R	Used During Outage 12R	Used During Outage 13R	Planned for Outage 1R14	Comment
MRPC Voltage Normalization	Set the ASME 100% TW Hole 300 kHz Pancake Coil Response to 10 Volts and Store to All Other Channels	Set the ASME 100% TW Hole 300 kHz Pancake Coil Response to 10 Volts and Store to All Other Channels Except +Point. Set the ASME 100% TW Hole 300 kHz + Point Response to 10 Volts and Store to All Other + Point Channels.	Set the EPRI Guidelines 100% TW Axial Notch 300 kHz Response for Each Axial and Pancake Coil Channel to 20 Volts and Store to All Other Axial Channels With That Coil. Set the EPRI Guidelines 100% TW Axial Notch 300 kHz Response for Each Circumferential Channel to 20 Volts and Store to All Other Circumferential Channels. If the 100% TW Notch Response Saturates, Set the EPRI Guidelines 60% TW ID Notch 300 kHz Response for That Channel to 7 Volts and Store to All Other Channels Using the Same Coil.	Set the EPRI Guidelines 100% TW Axial Notch 300 kHz Response for Each Axial and Pancake Coil Channel to 20 Volts and Store to All Other Axial Channels With That Coil. Set the EPRI Guidelines 100% TW Axial Notch 300 kHz Response for Each Circumferential Channel to 20 Volts and Store to All Other Circumferential Channels. If the 100% TW Notch Response Saturates, Set the EPRI Guidelines 60% TW ID Notch 300 kHz Response for That Channel to 7 Volts and Store to All Other Channels Using the Same Coil.	Note 7
MRPC Phase Rotation	Set Probe Motion Horizontal and Flaw Response Forming in the Up Direction on All Channels.	Set EPRI Guidelines 40% TW ID Axial Notch Response to 15° on Raw Frequency Channels. Set + Point Circ Sensitive Process Channel Response Rotated 180° From Raw Frequency Channel Above.	Set EPRI Guidelines 40% TW ID Axial Notch Response for Axial and Pancake Coil Channels to 15° on Raw Frequency Channels. Set EPRI Guidelines 40% TW ID Circumferential Notch Response for Circumferential Detection Channels to 15° on Circumferential Detection Channels.	Set EPRI Guidelines 40% TW ID Axial Notch Response for Axial and Pancake Coil Channels to 15° on Raw Frequency Channels. Set EPRI Guidelines 40% TW ID Circumferential Notch Response for Circumferential Detection Channels to 15° on Circumferential Detection Channels.	Note 8

Attachment 1 (Cont'd)
TMI-1 ECT Examination Techniques - Outages 11R through 1R14

Notes

1. 83' and 100' probe cable lengths were used during Outage 11R. 100' probe cable lengths were used during Outages 12R and 13R and are planned for future outages. This practice provides more consistency during the later outages. An 83' probe cable length could potentially provide a slightly larger signal than that provided by a 100' probe cable length. To avoid this effect and assure consistency, the displayed signal size is "normalized" during calibration where the signal is related to a specific flaw and a voltage value is assigned to that response regardless of signal size. Voltages are set using the entire examination system to eliminate any voltage variations due to cabling differences between the 83' and 100' cable length probes. This change does not effect flaw growth studies.

   TMI Unit 1 has evaluated in-steam generator ID IGA flaw responses for both the mid frequency and high frequency 0.510" bobbin coil probes and determined that the probes provide equal ID IGA flaw detection capability. TMI Unit 1 changed to the mid frequency 0.510" bobbin coil probe to use the same coil as the other OTSG design plants.

2. The + Point probe is recognized for providing better quality data for initial flaw detection and information for determining the flaw morphology (i.e., determining whether a flaw is axially or circumferentially oriented, volumetric, and whether the surface of origin is ID or OD), without the need for other coils. Studies performed for AmerGen Energy determined that the 0.080" HF shielded coil probe provides the most accurate, yet conservative, axial and circumferential length measurements for ID IGA type flaws. This sizing conservatism was also confirmed by destructive tests performed on a tube pulled during the 12R Outage.

3. Both cable designs use wire of the same impedance values. The difference between the two is that the multipurpose cable has more leads to allow using one cable for several different probe designs. This change does not affect eddy current data acquisition or analysis; nor does it affect the flaw growth studies.

4. The + Point probe is recognized as a probe that provides better quality data for initial flaw detection and provides information for determining flaw morphology (i.e., determining whether a flaw is axially or circumferentially oriented, volumetric, and whether the surface of origin is ID or OD), without the need for other coils.

5. See Note 2. The most accurate, yet conservative, method (0.080" HF shielded pancake) was used for estimating axial and circumferential flaw length for tube repair decisions during Outage 12R and 13R and will be used again during future outages. Flaw growth studies are best performed using the same equipment and procedures. Outage 12R was the first outage where 0.080"

Attachment 1 (Cont'd)
TMI-1 ECT Examination Techniques - Outages 11R through 1R14

HF coil data was obtained. Where only 0.115" MR pancake coil data exists (e.g. Outage 11R) flaw growth will be evaluated with the 0.115" MR pancake coil data.

6. The change from 10 volts normalization to 4 volts normalization requires voltage correction for comparisons of old and new data as discussed in the response to RAI No. 5. For flaw growth studies, flaw voltage measurements from the 1997 and previous outages will be normalized by multiplying the previous measured value by 0.4. The "BWOG Mother Standard" normalization removes subtle calibration standard voltage differences by correcting all calibrations to be equivalent to 4 volts on the four 20% TW holes in one standard.

7. This voltage normalization change will not affect any of the growth data because MRPC voltage is not typically used for flaw growth studies at TMI-1. The Outage 13R change was made to comply with Revision 5 of the EPRI PWR Steam Generator Examination Guidelines. The alternate setting using the 60% notch provides a setting equivalent to 20 volts on the 100% TW notch. Saturated flaw signals should not be used for setting voltage values because in that case the entire flaw signal is not used for setting the calibration value. This change has no affect on flaw length measurement or flaw disposition based on eddy current measurements. This change requires that Outage 12R Plus Point voltages be multiplied by 0.342 to produce an equivalent later outage voltage when plus point voltage is considered for in-situ pressure testing.

8. The Outage 12R and later rotation settings provide a setup which essentially sets probe motion horizontal, assures more consistent setup between analysts (i.e., all analysts are using the same response for setup), and assures that ID and OD flaws are visible on the lissajous and terrain displays.

Attachment 2

Table 2
Comparison of Field Eddy Current Estimated and Laboratory Determined ID IGA Axial Extents of TMI-1 Pulled Tube Flaws

TMI-1 Tube A 52-34 Flaw Type (as called by MRPC)	Location (Field)	Field Axial Length (by MRPC)	Maximum Laboratory Axial Length (How Determined.)	Ratio of Field Axial Length to Lab Axial Length
ID Volumetric IGA	7 + 36.8"	0.11"	0.024" (Radial Grinding / Photo Exam)	4.6
ID Volumetric IGA	13 + 23.1"	0.16"	0.033" (Radial Grinding / Photo Exam)	4.8
ID Volumetric IGA	14 + 12.8"	0.16"	0.054" (Radial Grinding / Photo Exam)	3.0
ID Volumetric IGA	14 + 31.9"	0.16"	0.042" (Radial Grinding / Photo Exam)	3.8
ID Volumetric IGA	15 + 14.7"	0.10"	0.029" (Radial Grinding / Photo Exam)	3.4
ID Volumetric IGA	15 + 24.9"	0.10"	0.030" (Radial Grinding / Photo Exam)	3.3
ID Volumetric IGA	UTS + 0.06"	0.20"	0.040" (Radial Grinding / Photo Exam)	5.0
ID Volumetric IGA	13 + 2.9"	0.10"	≅ 0.066" (By longitudinal grind at 1 of 2 fracture surfaces* / Photo exam)	≅ 1.5
ID Volumetric IGA	15 + 38.2"	0.10"	≅ 0.020" (By longitudinal grind at 1 of 2 fracture surfaces* / Photo exam)	≅ 5

* These two flaws were located at the fracture surfaces resulting from the laboratory burst testing. The flaws were torn in half during the testing and one of the two fracture surfaces was ground to determine the flaw morphology.

A similar degree of conservatism was noted for the circumferential extents as was seen for the axial extents. The following table compares the circumferential extent of the flaws in the TMI-1 pulled tube as called by field MRPC eddy current with the subsequent metallographic findings from the laboratory for the same flaws:

Attachment 2 (Cont'd)

Table 3:
Comparison of Field Eddy Current Estimated and Laboratory Determined ID IGA Circumferential Extents of TMI-1 Pulled Tube Flaws

TMI-1 Tube A 52-34 Flaw Type (as called by MRPC)	Location (Field)	Field Circumferential Width (by MRPC)	Maximum Laboratory Circumferential Width (How Determined)	Ratio of Field Circ Width to Lab Circ Width
ID Volumetric IGA	7 + 36.8"	0.11"	0.022" (Radial Grinding/Photo Exam)	5.0
ID Volumetric IGA	13 + 23.1"	0.11"	0.020" (Radial Grinding/Photo Exam)	5.5
ID Volumetric IGA	14 + 12.8"	0.19"	0.025" (Radial Grinding/Photo Exam)	7.6
ID Volumetric IGA	14 + 31.9"	0.11"	0.019" (Radial Grinding/Photo Exam)	5.8
ID Volumetric IGA	15 + 14.7"	0.06"	0.018" (Radial Grinding/Photo Exam)	3.3
ID Volumetric IGA	15 + 24.9"	0.11"	0.018" (Radial Grinding/ Photo Exam)	6.1
ID Volumetric IGA	UTS + 0.06"	0.14"	0.025" (Radial Grinding/Photo Exam)	5.6
ID Volumetric IGA	13 + 2.9"	0.11"	≅ 0.032" (By longitudinal grind at 1 of 2 fracture surfaces*/Photo exam)	≅ 3.4
ID Volumetric IGA	15 + 38.2"	0.06"	≅ 0.016" (By longitudinal grind at 1 of 2 fracture surfaces*/Photo exam)	≅ 3.8

* As mentioned above, these two flaws were located at the fracture surfaces resulting from the laboratory burst testing. The flaws were torn in half during the testing and one of the two fracture surfaces was ground to determine the flaw morphology. The circumferential extent listed in Table 3 for these two flaws were estimated by doubling the circumferential extent that was determined for one of the two fracture surfaces.

NRC RAI No. 5:

The December 6, 2000, submittal states that the results of the growth assessments showed no statistically significant growth in the ID IGA, and that the changes were less than the statistical uncertainty of the measurement techniques. Please discuss the methodology used for assessing growth in each outage. What statistical tests are being used to make this growth assessment, and what [are] the acceptance criteria?

The best measure of growth in any tube is the change in measured indications between inservice inspections. What statistical tests will be carried out on the data set of all such changes? How will the results of the tests above be used to draw a conclusion about growth in the ID IGA population? How sensitive is the procedure used to determine the hypothetical growth in the ID IGA population? What is the probability of detecting significant growth if it occurs, i.e., what is the power of the tests? What statistical outlier tests will be performed and how will the results be interpreted? Has this statistical methodology been used on data from previous outages? If so, provide the results of this analysis.

If you provide numbers of indications detected with the bobbin probe from previous outages to show the change in measured indications between inservice inspections, please provide the bobbin inspection scope for the previous outages cited.

TMI Response to RAI No. 5:

Answers to Specific Questions/Requests

Please discuss the methodology used for assessing growth in each outage. What statistical tests are being used to make this growth assessment, and what [are] the acceptance criteria?

TMI-1 has monitored the volumetric ID IGA indications for growth in all outages since the plant's restart in 1985. (As described in the responses to RAI Questions Nos. 1 and 2, some of the ID IGA indications have been in Technical Specification-defined degraded tubes, and therefore have been examined during plant outages since 1985.)

Eddy current examinations have increased significantly in scope and technical complexity since 1985, and the computer tools with which to analyze examination results have improved significantly. TMI-1 has deliberately retained a .540" bobbin probe as a "reference" probe by which ID IGA indications may be measured. (Refer to Response to Question No. 2.) This probe continues to provide a standard probe from which to assess the growth of the ID IGA indications. All of the bobbin growth data provided for the volumetric ID IGA indications over the 1985 through 1999 outages is based on 0.540" bobbin data.

Comparisons of individual indications, and the population of indications, from outage-to-outage have been used to assess growth. Individual indication voltage changes from outage-to-outage have been evaluated. Individual indication throughwall depth estimates have been monitored from outage-to-outage. For example, Table III-6 of the 1995 11R Outage report provided information on outage-to-outage comparisons of the degraded tubes performed between 1984 and 1995. That table's information is provided and reprinted in the following Table 1. Note that the 1999 13R Outage TMI-1 examination included a voltage normalization change which was incorporated into the Technical Specifications. To aid in evaluating the following Table, revised voltages in terms of today's current voltage normalization have been added to the table. 1999 voltage changes are 0.4 times (i.e., 40 percent of) voltages from earlier outages.

[Reprint of Table III-6 from 1995 11R Outage Report]
Table 1
A Comparison of Indications in Degraded Tubes

Period	Number of Indications	Mean Change (%TW)	Std Deviation (% TW)	Mean Change (Volts) / 1999 voltage	Std Deviation (Volts) / 1999 voltage
1984 to 1986 (Outage 5M)	152	-2.6	6.1	-0.2 / -0.08	0.3 / 0.12
1986 (5M) to 1986 (6R)	118	+1.1	6.6	+0.0 / +0.0	0.2 / 0.08
1986 (6R) to 1988 (7R)	119	+2.6	5.5	+0.2 / +0.08	0.3 / 0.12
1988 (7R) to 1990 (8R)	291	-0.2	7.43	-0.25 / -0.10	0.35 / 0.14
1990 (8R) to 1991 (9R)	229	-2.0	6.96	+0.07 / +0.03	0.31 / 0.12
1991 (9R) to 1993 (10R)	207	-0.6	6.62	+0.16 / +0.06	0.28 / 0.11
1993 (10R) to 1995 (11R)	197	+0.9	6.39	-0.26 / -0.10	0.4 / 0.16

The bobbin coil inspection scopes for the outages listed in the above table are provided in Table 2 below:

Table 2
TMI-1 Steam Generator Tubes Inspected Using Bobbin Coil Probes

Refueling Outage	Year	OTSG Tubes Inspected by Bobbin	Percent of Inservice Tubes Inspected by Bobbin
5M	1986	2,732	~ 9%
6R	1986	6,218	~ 20%
7R	1988	4,126	~ 13%
8R	1990	3,202	~ 10%
9R	1991	2,209	~ 7%
10R	1993	2,642	~ 9%
11R	1995	6,821	~ 23%
12R	1997	29,415	100%
13R	1999	29,367	100%

In the 1980's 8 x 1 probes were used to assess the circumferential extents of the indications. Extents from 8x1 probe examinations were evaluated to assess whether growth may or may not be occurring. In the 1990's new surface-riding MRPC probes with smaller eddy current coils, along with advances in computers, has allowed individual indication voltages, through wall estimates (if assigned), as well as axial extents and circumferential extents to be assessed.

As described in the Response to Question Nos. 1 and 2, from 1981 to 1999 the scope and sensitivity of the TMI-1 tube exams has been increasing, and there has been a commensurate increase in the number of ID IGA indications detected. During each outage since 1981 TMI-1 has assessed the dormancy of the ID IGA mechanism. TMI-1 has:

- assessed whether newly detected indications are consistent with the locations, voltages, and throughwall estimates of previously identified indications.

- assessed whether, on the average, the voltages and percent throughwall estimates of individual ID IGA indications have increased (for the ID IGA indications that could be compared).

- (using MRPC data in the more recent outages) assessed whether, on the average, the circumferential extents or axial extents of individual ID IGA indications have increased (for the ID IGA indications that could be compared.)

- created data scatter plots to visualize the data so as to assess whether the indication population has exhibited growth, help identify outliers, and review distributions of data.

The assessments concluded that the ID IGA population is not growing. During the 1985 through 1999 outages, engineering evaluations did not find:

- a significant number of new ID IGA indications at different locations (with similar eddy current probes),

- a significant number of ID IGA indications exhibiting growth based on reviews of prior outage eddy current data, or

- any statistically-significant increase in the average voltage change, percent through wall change, axial extent change, or circumferential extent change of individual ID IGA indications when compared outage-to-outage.

Any of the above evaluation findings, had they occurred, would have been a sign of potential growth.

What statistical tests will be carried out on the data set of all such changes? How will the results of the tests above be used to draw a conclusion about growth in the ID IGA population?

For future outages, TMI-1 has included, in its Engineering Report ECR No. TM 01-00328, performance of sign tests and paired t-tests in statistical analyses to evaluate growth data. These tests are required by a report that is referenced in the proposed Technical Specifications, and will provide additional assurance that growth of the volumetric ID IGA indications is evaluated. Refer to the Engineering Report for additional information about these tests.

How sensitive is the procedure used to determine the hypothetical growth in the ID IGA population? What is the probability of detecting significant growth if it occurs, i.e., what is the power of the tests?

The statistical tests that will be conducted under Engineering Report, ECR No. TM 01-00328 will be applied at the widely used level of sensitivity equal to a 5% chance of error. Therefore, there exists a 95% confidence level that detection of the hypothetical growth in the IDIGA population can be accomplished without error. The sign and paired-t statistical tests evaluate the possibility of a Type I error, i.e., the probability of erroneously concluding that there is growth when there is actually no growth.

The possibility of a Type II error was evaluated for paired-t tests performed as described in Engineering Report ECR No. TM 01-00328 using historical data from Steam Generator A for the outage interval 12R to 13R at a level of sensitivity equal to a 5% chance of error. The Type II error in this case is the failure to detect growth when there actually is growth. The power of this statistical test is represented by 1 minus the probability of a Type II error. For the purposes of this Type II error evaluation, the basis of the acceptance criteria for evaluating the upper bound associated with this error was not to exceed a cycle growth corresponding to separate reference values equal to one-half of the technical specification degraded tube dimensions for ID IGA indications, i.e., 0.1 V for bobbin voltage; 10% TW for bobbin through wall extent; and 0.13 inch for MRPC circumferential extent. The calculated mean difference for each parameter was less than the growth ranges that are required to detect growth with 95% probability because the differences were small. The actual growth range that is necessary to detect growth with 95% probability was, however, within the acceptance criteria for each parameter so that the conditions for the power test for the Type II error were conservatively satisfied. Differences as large as the acceptance criteria would have been detected.

What statistical outlier tests will be performed and how will the results be interpreted?

Engineering Report, ECR No. TM 01-00328 includes a screening of outage eddy current data for extreme values to be performed prior to sign tests and paired t-tests. Refer to the attached Engineering Report.

Has this statistical methodology been used on data from previous outages? If so, provide the results of this analysis.

The sign and paired-t statistical tests included in Engineering Report, ECR No. TM 01-00328 have been performed on "A" Steam Generator data from the last three TMI-1 refueling outages, and the results have shown that no growth of the volumetric ID IGA indications has occurred. (The TMI-1 "A" Steam Generator has a much larger population of volumetric ID IGA indications than does the "B" Steam

Generator.) Sign and paired t-tests were performed using bobbin voltage, bobbin percent through wall, and circumferential extent data for the period 12R to 13R. Sign and paired t-tests were performed using bobbin percent through wall and circumferential extent data for the period 11R to 13R. (11R Outage bobbin voltage data was not included since the ASME mother standard was not used until the 12R outage.)

NRC RAI No. 6:

In the License Amendment No. 209 which also approved a one-cycle Alternate Repair Criteria (ARC) for ID IGA, the NRC staff strongly encouraged the licensee to pursue the development of a qualified eddy current technique which can reliably depth size ID IGA in accordance with the original 40-percent tube repair limit. The NRC staff stated that if this path were pursued, further technical specifications (TS) amendments would not be required to address this mode of degradation.

In response, AmerGen indicated in the December 6, 2000, submittal that they have developed a bobbin coil examination technique for depth sizing inside diameter IGA/IGSCC (intergranular stress corrosion cracking) indications that provide an eddy current signal of sufficient strength and clarity. Further, AmerGen stated that ID IGA that can be reliably depth sized using the bobbin coil probe will be depth sized with the site qualified bobbin coil technique and repaired if it measures greater than or equal to 40-percent TW or is measured to exceed either the circumferential- or axial-length criteria.

Please provide information on the Electric Power Research Institute (EPRI), Appendix H, qualification of this bobbin coil technique, especially the data that supports a 0.89 POD (probability of detection) at 42-percent TW for freespan ID IGA with the bobbin coil probe. Discuss the specifics of how the data set that supports this qualification is representative of the conditions at TMI-1 (e.g., noise levels, signal-to-noise ratios, flaw signal characteristics, etc.). Describe the data set in detail. Describe in detail the performance demonstration techniques applied to ID IGA removed from TMI-1 OTSGs and the results of the performance demonstration. Discuss how sizing of indications is relied upon to assure leakage integrity.

TMI Response to RAI No. 6:

TMI-1 has a site-qualified eddy current technique for depth sizing volumetric ID IGA indications detected during bobbin coil examinations. However, volumetric ID IGA flaws that are too small to induce sufficient response from the bobbin coil probe, where voltages and signal-to-noise ratios are too small, cannot be reliably depth-sized with the technique. In addition, other volumetric ID IGA flaws are so small they are not detectable by the bobbin coil probe and are only detected by more sensitive MRPC probes. TMI-1 requests the proposed Technical Specification revisions to avoid dispositioning larger flaws that can be depth-sized as suitable to remain in service while smaller flaws that cannot be depth-sized are removed from service.

The Appendix H bobbin coil qualification for depth sizing ID IGA is a TMI-1 specific qualification based on two laboratory produced crack specimens and twenty eight flaws from TMI-1 pulled tubes with the sodium thiosulfate-induced damage. Since the tubes were pulled from the TMI-1 steam generators, the tube geometry, signal-to-noise ratios, deposits, and other parameters affecting eddy current are similar to the in-service tubes. This qualification has been reviewed by independent Qualified Data Analysts (QDAs) as required by the EPRI PWR Steam Generator Examination Guidelines, Revision 5, Volume 1, Section 6.2.1. The data set includes both cracks and IGA damage. Table 4 below provides information on the specimens used in this qualification. The examination eddy current data was acquired using high frequency bobbin coil probes of 0.510" diameter and 0.540" diameter. The 0.540" diameter probe is expected to provide more accurate sizing data than the 0.510" diameter probe because of increased fill factor, so sizing error estimates are considered conservative since some data was acquired using the less accurate 0.510" diameter probe. All data was acquired using the Zetec MIZ-12 data acquisition instrument except for tube 52-34, which was acquired using the MIZ-30 instrument in 1997. The examination frequencies were 400 kHz differential raw and 400/200 kHz differential mix-regardless of the instrument (i.e., MIZ-12 or MIZ-30) used. The MIZ-30 instrument is considered superior to the MIZ-12 instrument based on its later design and more rigorous performance specifications. The data was evaluated in accordance with Attachment 3.

Table 4
TMI-1 ID IGA/SCC Flaw Detection and Sizing Data Set

% TW ECT Depth	Flaw Type	DE Depth % TW	Count	Tube/Row	Data Location	Probe Size	Bobbin Detected
77	IGSCC	100	1	10-29	Tape 12, uts +16.3	0.51	Y
84	IGSCC	100	2	11-66	Tape 55, uts +12.3	0.51	Y
93	IGSCC	100	3	146-6	Tape 40, uts +15.8	0.51	Y
67	IGSCC	66	4	112-7	Tape 33, uts +13.4	0.51	Y
93	IGSCC	100	5	133-74	Tape 44, 015 +39.7	0.51	Y
90	IGSCC	100	6	133-74	Tape 44, 015 +38.2	0.51	Y
85	IGSCC	100	7	13-63	Tape 11, 015 +44.0	0.51	Y
81	IGSCC	70	8	146-8	Tape 40, uts +20.8	0.51	Y
50	IGSCC	70	9	24-94	Tape 230, uts +11.8	0.51	Y
95	IGSCC	100	10	24-94	Tape 230, 015 +37.6	0.51	Y
27	IGSCC	20	11	111-13	Tape 33, 010 +3.4	0.51	Y
86	IGSCC	100	12	112-5	Tape 33, uts +16.2	0.51	Y
63	IGSCC	100	13	112-5	Tape 33, uts +17.9	0.51	Y
88	IGSCC	100	14	112-5	Tape 33, uts +18.3	0.51	Y
20	IGA	48	15	8-45	Tape 1, 015 +39.4 (See note 1)	0.54	Y
36	IGA	16	16	35-83	Tape 1, 015 +35.7 (See note 1)	0.54	Y
26	IGA	42	17	141-3	Tape 1, 015 +30.3 (See note 1)	0.54	Y
41	IGSCC	38	18	Sample 23 (LAB)	Archive measurements and graphics were used	0.54	Y
51	IGSCC	54	19	Sample 24 (LAB)	Archive measurements and graphics were used	0.54	Y
37	IGA	49	20	52-34	Cal 364, 013 +23.1	0.54	Y
50	IGA	30	21	52-34	Cal 364, 013 +2.9	0.54	Y

Table 4
TMI-1 ID IGA/SCC Flaw Detection and Sizing Data Set

% TW ECT Depth	Flaw Type	DE Depth % TW	Count	Tube/Row	Data Location	Probe Size	Bobbin Detected
BVC (Note2)	IGA	19	22	52-34	Cal 364, 015 +38.3	0.54	Y
BVC (Note2)	IGSCC	100	23	112-5	Tape 33, uts +20.0	0.51	Y
BVC (Note2)	IGSCC	100	24	112-5	Tape 33, uts +20.5	0.51	Y
BVC (Note2)	IGA	32	25	52-34	Cal 364, 014 +31.9	0.54	Y
BVC (Note2)	IGA	32	26	52-34	Cal 364, 015 +14.7	0.54	Y
BVC (Note2)	IGA	43	27	53-34	Cal 364, 015 +24.9	0.54	Y
INR	IGA	32	28	52-34	Cal 364, 007 +36.3	0.54	N
INR	IGA	38	29	52-34	Cal 364, 014 +12.8	0.54	N
NDD	IGA	38	30	52-34	Cal 364, UTS +0.0	0.54	N
Note 1:	The results from the outage in which these tubes were pulled are used for RMSE calculations. The data on tape 1 cannot be recovered sufficiently for meaningful recording to optical disk. Data for these tubes from an outage 6 months prior is on tapes as follows:						
	tube 8-45		tape 3			0.54	
	tube 35-83		tape 7			0.54	
	tube 141-3		tape 2			0.54	
Note 2	Data analysis guidelines would require MRPC examination and subsequent evaluation with 0.540" probe for final disposition. The BVC indications are not included in the RMSE sizing calculation. Flaw count number 22 was had an estimated field eddy current through wall measurement of 17% prior to destructive analysis as transmitted to the NRC in GPUN Letter #1920-98-20653). For purposes of this qualification it was not included in the depth sizing evaluation because it could be categorized as a BVC indication in accordance with the ETSS.						
Note 3:	All data is TMI-1 pulled tube data except for Counts 18 and 19.						

Table 4 above is the basis for a conclusion of a 0.89 POD at the 90% confidence level. Attachments 4 and 5 provide information on the depth sizing performance for the 400 kHz differential and 400/200 kHz mix, respectively.

Sizing of indications is performed to disposition the volumetric ID IGA indications per the Technical Specifications' repair criteria and degraded tube criteria. The repair criteria, including limits on axial length, circumferential length, and bobbin percent throughwall depths, were based on conservative analyses to minimize the probability of indication leakage during plant transients. In addition, bobbin coil voltage measurements are also incorporated into the plant's Technical Specifications to help identify larger indications to be tracked under the degraded tube definition. Thus, sizing of indications is utilized to ensure that larger indications are removed from service and maintain generator tube integrity. To provide further assurance of leakage integrity of the volumetric ID IGA indications, TMI-1 has included in its Engineering Report, ECR No. TM 01-00328, the performance of in situ pressure testing of a number of volumetric ID IGA indications, as necessary to statistically demonstrate with 95% confidence that leakage from these indications during a hypothetical Main Steam Line Break from the limiting steam generator is less than allowable.

Attachment 3
ID IGA Qualification Analysis ETSS

Examination Technique Specification Sheet

ETSS # 1 - BOBBIN PROBE		Page: 1 of 2

Data Analysis

Calibration Differential Channels

Channel & Frequency	Ch 1 600 kHz	Ch 3 400 kHz	Ch 5 200 kHz	Ch 7 45 kHz
Phase Rotation	100% TWH 40° ± 3°	100% TWH 30° ± 3°	100% TWH 40° ± 3°	Broach TSP 270°
Span Setting Minimum	100% TWH 6 divisions	See Note 1	100% TWH 6 divisions	Broach TSP 5 divisions

Calibration Absolute Channels

Channel & Frequency	Ch 2 600 kHz	Ch 4 400 kHz	Ch 6 200 kHz	Ch 8 45 kHz
Phase Rotation	Probe Motion Horiz. Flaws Up	Probe Motion Horiz. Flaws Up	Probe Motion Horiz. Flaws Up	Broach TSP 270°
Span Setting Minimum	100% TWH 3 divisions	100% TWH 3 divisions	100% TWH 3 divisions	Broach TSP 5 divisions

Calibration Process and Other Channels

Channel & Frequency	P1 (Ch 3/5) 400/200 kHz Diff	P2 (Ch 3/5) 400/200 kHz Diff	P3 (Ch1/5) 600/200 kHz Diff	P4 (Ch 3/5/1) 400/200/600kHzDiff
Configure & Adjust Parameters	Suppress Broach TSP	Suppress Drilled TSP	Suppress Broach TSP	Save 100, 60, 20 Suppress Drilled TSP, Kinetic Expansion (see note 2)
Phase Rotation	100% TWH @ 30°	100% TWH @ 30°	100% TWH @ 40°	100% TWH @ 40°
Span Setting Minimum	See Note 1	See Note 1	100% TWH 5 divisions	100% TWH 5 divisions

Voltage Normalization				**Calibration Curves**		
CH	Signal	Set	Normalize	Type	CH	Set Points
3	4X20% FBH	Note 2	All	Phase	1, 3, 5, P1, P2	100, 60, 20 FBH

Data Screening

Left Strip Chart	Right Strip Chart	Lissajous
P1	Ch 6	Ch 3

Reporting Requirements

Condition/Region	**Report**	**Ch.**	**Comment**
ID Freespan	%TW	3 Vp-p	All indications ≥ 5° - ≤ 30° Ch3 and either ≥ 0.4 volt or ≥ 3:1S/N
ID Freespan	BVC	3 Vp-p	All indications ≥ 5° - ≤ 30° Ch3 and both < 0.4 volt and < 3:1S/N
Broached TSP	%TW	3 or P1 Vp-p	All indications ≥ 5° - ≤ 30° Ch3 and either ≥ 0.4 volt or ≥ 3:1S/N
Broached TSP	BVC	3 or P1 Vp-p	All indications ≥ 5° - ≤ 30° Ch3 and both < 0.4 volt and < 3:1S/N
Drilled TSP or TS Crevice	%TW	3 or P2 Vp-p	All indications ≥ 5° - ≤ 30° Ch3 and either ≥ 0.4 volt or ≥ 3:1S/N
Drilled TSP or TS Crevice	BVC	3 or P2 Vp-p	All indications ≥5°- ≤ 30° Ch3 and both < 0.4 volt and < 3:1S/N

Attachment 3 (Cont'd)
ID IGA Qualification Analysis ETSS

Examination Technique Specification Sheet		
ETSS # 1 – BOBBIN PROBE		Page: 2 of 2
Special Instructions		

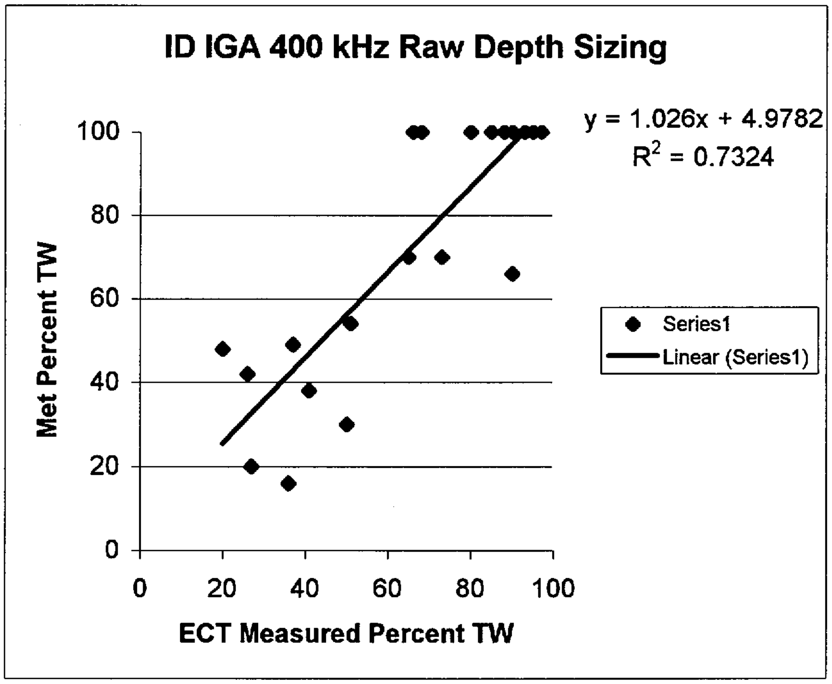
1. Adjust the span so the 100% TW hole is 7.5 divisions. Note the span setting and divide it by 2. This will approximate a 1 v/div display and will be the data screening setting.
2. Each Calibration Standard will have its own normalization value based on ARC transfer calculations. These values will be provided and shall be used as the voltage normalization setting. This setting will be equivalent to 4 volts in the BWOG mother standard.
3. Use the single 100%TW hole next to the 60%TW hole for setting rotation.
4. Zoom the strip charts to 8 (or equivalent setting based on window size) for increased visibility of small amplitude indications.
5. Scroll each tube between LTS and UTS with channel 3.
6. Scroll each open crevice tubesheet with channel P1 and P2 for mid frequency probes and P2 and P3 for high frequency probes.

   Note: You are not required to analyze the data above the upper tubesheet kinetic expansion (ETL) to the upper tube end (UTE) with the bobbin coil probe.
7. Review each broached TSP with channel P1.
8. Review each drilled TSP with channel P2.
9. Monitor the 200 kHz absolute strip chart for positive drift and evidence of possible loose parts.
10. When an indication reported with a 510HF probe is re-examined with a 540HF probe and the 540HF indication does not meet any reporting requirement the 540HF indication shall be reported as INR.

Attachment 4
TMI-1 ID IGA/SCC 400 kHz Bobbin Coil Sizing Performance

% TW ECT Depth	Flaw Type	DE Depth % TW	Count	Tube/Row	Data Location	Probe Size
80	IGSCC	100	1	10-29	Tape 12, uts +16.3	0.51
68	IGSCC	100	2	11-66	Tape 55, uts +12.3	0.51
85	IGSCC	100	3	146-6	Tape 40, uts +15.8	0.51
90	IGSCC	66	4	112-7	Tape 33, uts +13.4	0.51
93	IGSCC	100	5	133-74	Tape 44, 015 +39.7	0.51
90	IGSCC	100	6	133-74	Tape 44, 015 +38.2	0.51
85	IGSCC	100	7	13-63	Tape 11, 015 +44.0	0.51
65	IGSCC	70	8	146-8	Tape 40, uts +20.8	0.51
73	IGSCC	70	9	24-94	Tape 230, uts +11.8	0.51
95	IGSCC	100	10	24-94	Tape 230, 015 +37.6	0.51
27	IGSCC	20	11	111-13	Tape 33, 010 +3.4	0.51
66	IGSCC	100	12	112-5	Tape 33, uts +16.2	0.51
97	IGSCC	100	13	112-5	Tape 33, uts +17.9	0.51
88	IGSCC	100	14	112-5	Tape 33, uts +18.3	0.51
20	IGA	48	15	8-45	Tape 1, 015 +39.4	0.54
36	IGA	16	16	35-83	Tape 1, 015 +35.7	0.54
26	IGA	42	17	141-3	Tape 1, 015 +30.3	0.54
41	IGSCC	38	18	Sample 23	Raw data was not available. Archive measurements and graphics were used for the ECT depth value.	0.54
51	IGSCC	54	19	Sample 24	Raw data was not available. Archive measurements and graphics were used for the ECT depth value.	0.54
37	IGA	49	20	52-34	Cal 364, 013 +23.1	0.54
50	IGA	30	21	52-34	Cal 364, 013 +2.9	0.54
Root Mean Square Error					16.93 %TW	
Correlation Coefficient					0.86	
Standard Error of Regression					13.63 %TW	
Standard Error of Regression @90/50 Confidence Level					17.45 %TW	

Attachment 4
TMI-1 ID IGA/SCC 400 kHz Bobbin Coil Sizing Performance

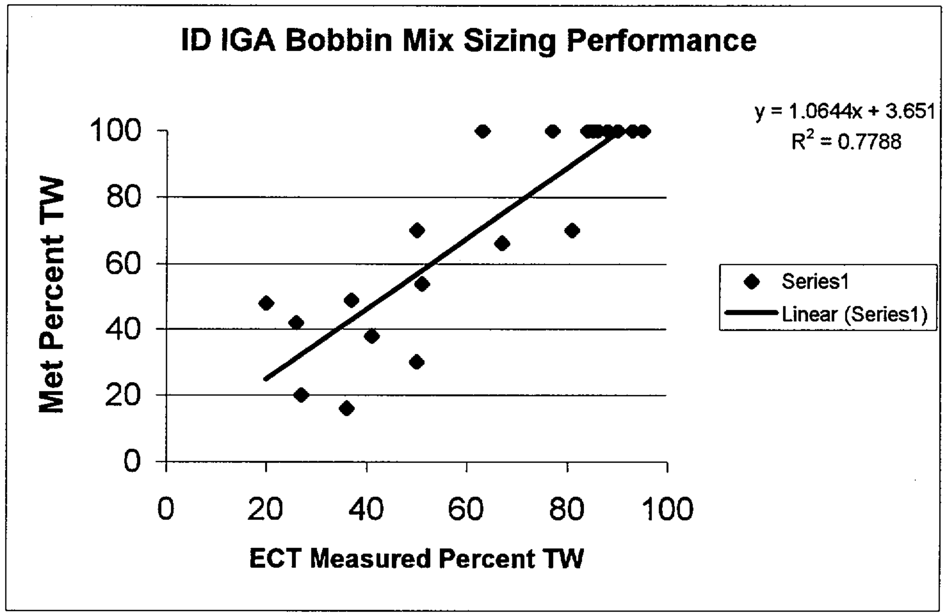


Attachment 5
TMI-1 ID IGA/SCC 400/200 Mix kHZ Bobbin Coil Sizing Performance

% TW ECT Depth	Flaw Type	DE Depth % TW	Count	Tube/Row	Data Location	Probe Size
77	IGSCC	100	1	10-29	tape 12, uts +16.3	0.51
84	IGSCC	100	2	11-66	tape 55, uts +12.3	0.51
93	IGSCC	100	3	146-6	tape 40, uts +15.8	0.51
67	IGSCC	66	4	112-7	tape 33, uts +13.4	0.51
93	IGSCC	100	5	133-74	tape 44, 015 +39.7	0.51
90	IGSCC	100	6	133-74	tape 44, 015 +38.2	0.51
85	IGSCC	100	7	13-63	tape 11, 015 +44.0	0.51
81	IGSCC	70	8	146-8	tape 40, uts +20.8	0.51
50	IGSCC	70	9	24-94	tape 230, uts +11.8	0.51
95	IGSCC	100	10	24-94	tape 230, 015 +37.6	0.51
27	IGSCC	20	11	111-13	tape 33, 010 +3.4	0.51
86	IGSCC	100	12	112-5	tape 33, uts +16.2	0.51
63	IGSCC	100	13	112-5	tape 33, uts +17.9	0.51
88	IGSCC	100	14	112-5	tape 33, uts +18.3	0.51
20	IGA	48	15	8-45	tape 1, 015 +39.4	0.54
36	IGA	16	16	35-83	tape 1, 015 +35.7	0.54
26	IGA	42	17	141-3	tape 1, 015 +30.3	0.54
41	IGSCC	38	18	Sample 23	Raw data was not available. Archive measurements and graphics were used for the ECT depth value.	0.54
51	IGSCC	54	19	Sample 24	Raw data was not available. Archive measurements and graphics were used for the ECT depth value.	0.54
37	IGA	49	20	52-34	Cal 364, 013 +23.1	0.54
50	IGA	30	21	52-34	Cal 364, 013 +2.9	0.54

Root Mean Square Error	16.21 %TW
Correlation Coefficient	0.88
Standard Error of Regression	12.32 %TW
Standard Error of Regression @90/50 Confidence Level	15.77 %TW

Attachment 5
TMI-1 ID IGA/SCC 400/200 Mix kHZ Bobbin Coil Sizing Performance



NRC RAI No. 7:

AmerGen has concluded in previous submittals that MRPC and Plus Point are able to conservatively assess the axial and circumferential extents of TMI-1 IGA flaws. However, AmerGen stated in the December 6, 2000, submittal that it may be possible for AmerGen to use probes other than bobbin and MRPC to conservatively assess the morphology and extents of the ID IGA flaws. For this ARC, the NRC staff will review bobbin and rotating pancake coil (RPC)/Plus Point qualification data. Use of any other probes for this ARC would require additional approval from the NRC staff.

TMI Response to RAI No. 7:

TMI-1 understands that the probes approved for use to detect and size TMI-1 ID IGA indications are those described in Section 4.3 of Engineering Report ECR No. TM 01-00328. Use of other probes will require NRC approval prior to use for detection and sizing of ID IGA.

NRC RAI No. 8:

Discuss how in-situ testing is relied upon to assure leakage integrity. Discuss, as applicable, the statistical evaluation of in-situ testing as it relates to the confidence it provides to ensuring tube integrity. Were the 12R in-situ tests still bounding for the 13R outage in the context of ID IGA? Are the selection criteria consistent with the latest revision to the EPRI Steam Generator In-Situ Pressure Test Guidelines? Please provide the inspection data for the bounding 12R in-situ test, and compare with the bounding values found for the 13R inspection data.

TMI Response to RAI No. 8:

In situ pressure testing has been performed to help ensure the leakage integrity of the TMI-1 steam generator tubes. During 1997's Outage 12R 2 tubes were in situ pressure tested in the TMI-1 "A" OTSG and 5 tubes were in situ pressure tested in the "B" OTSG. In 1999's Outage 13R, 3 tubes were in situ pressure tested in the "B" OTSG. To date 6 volumetric ID IGA indications have been in situ pressure tested during these outage tests.

The following tables provide information about the 12R Outage in situ pressure testing. (These tables are excerpted from similar tables in the TMI-1 12R and 13R Outage Reports previously submitted to the NRC staff.) The indications whose orientations are described as "ID VOL" in the tables are volumetric ID IGA indications.

Table 1 – "A" OTSG In Situ Pressure Test Results from Outage 1997's 12R

TUBE AND EDDY CURRENT INFORMATION										
Region	Tube Information				Plus Point Data			Bobbin Data		Comments
	Row	Tube	Location	Length (in.)	Volts	Est.% TW	Orientation	Volts	Est.% TW	
Upper Tubesheet	93	119	UTS + 1.50	0.25C	17.15	87%	ID SCI	2.39	93%	Upper Tubesheet Circ
	93	119	UTS +1.93	0.21A x 0.25C	9.2	N/A	ID VOL	2.39	93%	UTS Volumetric
	93	119	UTS +0.55	0.24A x 0.27C	3.69	N/A	ID VOL	0.95	40%	UTS Volumetric
	107	120	ETL – 0.49	0.27A x 0.25C	2.36	N/A	ID VOL	NDD	N/A	KET Volumetric
	107	120	ETL – 2.85	0.12A x 0.19C	3.81	N/A	ID VOL	1.47	27%	UTS Volumetric
	107	120	ETL – 3.95	0.16A x 0.16C	2.42	N/A	ID VOL	1.44	13%	UTS Volumetric

Table 2 - "B" OTSG In Situ Pressure Test Results from Outage 1997's 12R

TUBE AND EDDY CURRENT INFORMATION										
Region	Tube Information				Plus Point Data			Bobbin Data		Comments
	Row	Tube	Location	Length (in.)	Volts	Est.% TW	Orientation	Volts	Est.% TW	
Upper Tubesheet	58	13	UTS – 0.17	0.29C	6.99	N/A	ID SCI	4.28	67%	UTSF Circ
	134	19	UTS – 0.20	0.14A x 0.30C	6.04	N/A	ID VOL	2.88	60%	UTSF Volumetric
	118	38	UTS + 1.74	0.51C	5.11	N/A	ID SCI	9.88	43%	UTS Circ
Freespan	79	58	15 + 40.30	0.86A x 0.50C	1.39	N/A	OD VOL	1.38	13%	Freespan NQI
Freespan	79	60	15 + 41.57	0.69A x 0.39C	3.5	N/A	OD VOL	4.77	28%	Freespan NQI

Table 3 - "B" OTSG In Situ Pressure Test Results from Outage 1999's 13R

Region	Tube Information			Plus Point Data					Bobbin Data			Comments
	Row	Col	Location	Axial Length	Circ Length	Volts	Est.%	Orientation	Ind	Volts	Est.%	
Upper TS	61	19	ETL – 0.31		0.31	4.51	94	ID SCI	NDD			UTS Circ
Freespan	80	50	15S +29.05 to +33.79	4.74		0.46		OD SAI	NQI	0.37	47	Freespan Ax
	113	2	14S +27.94 to +29.07	1.13		0.43		OD SAI	NQI	0.67	67	Freespan Ax

No leakage was observed during the 12R and 13R Outage in situ pressure tests.

The 12R in situ tests bounded the population of ID volumetric indications detected in 13R. During Outage 13R, volumetric ID IGA indications were tracked and compared to previously-in-situ-tested indications on the basis of voltages, estimated depths, axial extents, and circumferential extents.

The highest bobbin voltage of volumetric ID IGA indications detected during 13R was 1.39 volts. This voltage was bounded by 12R in situ pressure testing performed in tubes B58-13, B118-38, and B79-60. [Note that 12R bobbin voltages must be multiplied by 0.4 to account for the voltage normalization change undertaken at TMI-1 during 13R. For example, the indication in tube B58-13 had a 12R bobbin voltage of 4.28 Volts. This would equate to a voltage of 1.71 Volts (i.e., 4.28 x 0.4) in 13R.]

The highest MRPC voltage of volumetric ID IGA indications detected during 13R was 5.1 volts. This voltage was bounded by 12R in situ pressure testing performed in tube A93-119. [Note that 12R plus point voltages must be multiplied by 0.342 to account for the voltage normalization change undertaken at TMI-1 during 13R.]

The highest bobbin estimated throughwall depth of volumetric ID IGA indications detected during 13R was 43% TW. This estimated depth was bounded by 12R in situ pressure testing performed in tubes A93-119, B58-13, B134-19, as well as 13R in situ pressure testing performed in tubes B80-50 and B113-2.

The longest axial extent of volumetric ID IGA indications detected during 13R was 0.36 inches. This axial extent was bounded by 12R in situ pressure testing performed in tube B79-58, B79-60, as well as 13R in situ pressure testing performed in tubes B80-50 and B113-2.

The longest circumferential extent of volumetric ID IGA indications detected during 13R was 0.39 inches. This circumferential extent was bounded by 12R in situ pressure testing performed in tube B118-38.

During the 13R Outage, AmerGen used Revision 1 of the EPRI In-Situ Pressure Test Guidelines (TR-107620), which was current at that time. (These guidelines and their selection criteria have since been revised by interim guidance from EPRI.) The TMI-1 12R and 13R Outage in situ pressure tests were performed with low pressurization rates and relatively long hold times.

No statistical criterion was used by AmerGen to select ID IGA volumetric indications for in situ pressure testing during either Outage 12R (in 1997) or 13R (in 1999). As described above, 13R indications were selected for testing based on their voltage, estimated depth, extents, and the revision of the EPRI In Situ Pressure Test Guidelines that was in effect in the fall of 1999.

It is important to note that laboratory pressure tests have been used, in addition to in situ pressure tests, to help test the integrity of the TMI-1 volumetric ID IGA indications. The most recent tube pull in 1997 included a tube with several ID IGA indications, including indications detected by both field bobbin and field MRPC probes, and indications not detected by field bobbin coil probes but detected by field or lab MRPC Probes. Several of the volumetric ID IGA flaws from this tube were subjected to laboratory leak and burst tests. These tests were undertaken to supplement the in-situ pressure testing of ID IGA flaws that was performed in the generators during Outage 12R. The results of the laboratory leak and burst testing were provided to the NRC in Reference 1 and are discussed in Engineering Report ECR No. TM 01-00328. None of the ID IGA flaws leaked at pressures simulating up to 3 times the normal operating delta P, with applied axial loads simulating those calculated for a hypothetical Main Steam Line Break (MSLB). No internal flaw bladders or supports were used for any of these leak or burst tests. Pressurization rates for these laboratory leak tests were relatively slow. The tube sections were pressurized to NOP, MSLB, and 3xNOP pressures at a rate of 1500 to 2000 psi/minute. Pressure was held at these three points for 5 minutes. The burst pressures of the tube sections containing ID IGA indications that were tested were above 10,000 psig, indicating that substantial structural margin exists for these flaws. These burst pressures are nearly equal to those of non-defective virgin tubing; recent burst tests of three non-defective virgin OTSG tube lengths had an average burst pressure of 11,216 psig.

In all 19 volumetric ID IGA indications have been leak tested since 1986, including both laboratory and in situ pressure tests. None of the 19 flaws has leaked or burst at hypothetical Main Steam Line Break delta pressure or three times the normal plant operating delta pressure. Note that for additional conservatism TMI-1 has included in Engineering Report, ECR No. TM 01-00328, performance of in situ pressure testing on a sufficient number of volumetric ID IGA indications to statistically demonstrate with 95% confidence that leakage from these indications during a hypothetical Main Steam Line Break from the limiting steam generator is less than allowable limits.

NRC RAI No. 9:

How is ID IGA evaluated for the condition monitoring and operational assessment for the TMI-1 steam generators? If ID IGA degradation is not found to be dormant, how will the leakage and structural integrity be assessed for the upcoming cycle?

TMI Response to RAI No. 9:

TMI-1's steam generator program requires that condition monitoring and operational assessment analyses be performed. During 1999's Outage 13R volumetric ID IGA was evaluated, along with eddy current indications of other degradation mechanisms, in the steam generator condition monitoring analysis and operational assessment. The observed degradation of the 13R Outage was evaluated in a manner consistent with the revisions of NEI 97-06 and EPRI Guidelines that were in effect at that time. The condition monitoring analysis concluded that the volumetric ID IGA indications detected during the outage were not of sufficient axial extent, circumferential extent, or estimated throughwall depth to challenge the structural limits or pose leakage concerns, even if conservative uncertainties were considered.

Conservative uncertainties were also used in the operational assessment. As an additional conservative measure, the operational assessment performed during 13R assumed that the throughwall growth rate of the volumetric ID IGA indications was 5% throughwall per operating cycle. This growth rate was assumed even though the eddy current data from the volumetric ID IGA examinations gave no appearance of growth in depth, axial extent, or circumferential extent. Even with this additional growth conservatism, at the end of the forthcoming cycle the projected volumetric ID IGA degradation had negligible impact on tube integrity calculations, and the projected MSLB leak rate for the volumetric ID IGA indications was zero.

The basis of TMI-1's Technical Specifications change requests to date has been that the volumetric ID IGA degradation mechanism is dormant, and the volumetric ID IGA indications are not growing in either depth, circumferential extent, or axial extent.

TMI-1 will continue to perform operational assessments to assess the volumetric ID IGA indications' impact on future operability of the generators. (TMI-1's existing steam generator program requires that operational assessments be performed to assess operability for forthcoming cycles.) If growth of the volumetric ID IGA population is detected, operational assessments would then have to consider the impact of this increased growth on tube leakage and burst integrity. Note that increased tube repair, in situ pressure testing and/or tube pulls may be required to support, or as a result of, operational assessment in this case.

Engineering Report, ECR No. TM 01-00328, requires in situ pressure testing of the volumetric ID IGA indications to the extent where, with 95% statistical confidence, projected leakage from the population of untested indications is less than the plant's allowable limits. If growth of the volumetric ID IGA indications is detected (which is based on their eddy current measurements), Engineering Report, ECR No. TM 01-00328, requires TMI-1 to create a cycle-specific growth model to be used in the plant's operational assessment. The proposed Technical Specifications require a report to the NRC, within 90 days of the end of the outage that includes the results of the growth studies. In addition, Engineering Report, ECR No. TM 01-00328, requires that a license amendment, with a revision to the report, be submitted to the NRC well ahead of the subsequent outage, following the outage for which growth of the indications is calculated.

NRC RAI No. 10:

From the "Report on the 1999 Outage 13R Eddy Current Examinations of the TMI-1 OTSG Tubing", you identified five tubes that had outer diameter (OD) volumetric "Patch-Like" IGA typical of OD volumetric IGA found in other OTSG's. Discuss whether this is an active mechanism, and in which outages it has been detected. Where has OD IGA been found, and what was the root cause for this degradation? How was the OD IGA detected? Discuss detection capability of OD IGA. Discuss how tubes with OD IGA indications are dispositioned. Discuss how OD IGA is addressed in condition monitoring and operational assessments, including the case of OD and ID IGA occurring at the same location.

TMI Response to RAI No. 10:

TMI-1 has detected some OD volumetric IGA indications similar to those detected in other B&W OTSG plants. At TMI-1, all OD degradation other than wear at tube support plates is "plugged on detection".

TMI-1 presently considers OD volumetric IGA an active mechanism in its degradation assessment and indications of this degradation have been identified during the recent TMI-1 outages. The following is a table of indications/tubes detected with OD volumetric indications from the last three TMI-1 outages:

Table 1
TMI-1 OTSG OD Volumetric Indications from Recent TMI-1 Outages

Outage (Year)	"A" OTSG OD volumetric IGA indications (Indications / Tubes)	"B" OTSG OD volumetric IGA indications (Indications / Tubes)	Total OTSG OD volumetric IGA indications (Indications / Tubes)
13R (1999)	3 / 3	3 / 2	6 / 5
12R (1997)	4 / 4	0 / 0	4 / 4
11R (1995)	0 / 0	1 / 1	1 / 1

OD volumetric degradation has been present in the TMI-1 steam generators in outages prior to 11R. The tube that was plugged for an OD volumetric indication in 11R was a degraded tube from the 10R examinations. As another example, tubes A35-83 and A13-63 were among the tubes pulled during Outage 6R (in 1986); these tubes had small isolated patches and pits of OD IGA that were very shallow (i.e., less than 5% TW as measured in the laboratory). These small OD volumetric IGA flaws are well below the detection threshold and were not detected by eddy current. No mechanism was speculated to be the cause of the secondary side IGA since the laboratory efforts to determine the mechanism were inconclusive.

OD volumetric IGA has been detected at various locations along the axial lengths of TMI-1 steam generator tubing, as described in Table III-7 of the 13R Outage report to the NRC.

The root cause of the OD volumetric IGA degradation at TMI-1 is not conclusively known. Numerous tubes were pulled from the TMI-1 generators in order to help identify the causes of the 1981 ID IGA. No TMI-1 tube to date has been selected for a tube pull as a result of OD volumetric IGA indications. As described above, tubes with (shallow, undetected) OD volumetric IGA were pulled in 1986, but no root cause for the degradation was determined. Sulfur intrusion in the secondary system is the usual cause to which OD volumetric IGA is attributed at the other OTSG plants.

Examination of the TMI-1 steam generator tubes to detect OD-initiated degradation has been performed using the same eddy current probes (and exams) as are used for detecting ID-initiated degradation. Bobbin coil examinations are conducted at frequencies at which both ID and OD degradation will be detected. In addition, the surface riding pancake and Plus-Point coils on the MRPC are capable of detecting volumetric flaws on either the ID or OD surfaces of the tubing. (Note that the physics of eddy current at the frequencies used in steam generator tube examinations are such that, since ID-surface initiated flaws are closer to the eddy current coils inside a tube, an ID-initiated flaw of a given morphology will generally create a larger voltage response during an eddy current examination than an equally-sized OD-initiated flaw of the same morphology.) In summary, TMI-1's eddy current examination procedures and guidelines examine the condition of both the ID and OD surfaces of the steam generator tubing.

Bobbin coil probes are used to provide TMI-1's capability to detect OD IGA. (After initial detection with a bobbin probe MRPC probes are used to confirm indication surface of origin and morphology.) Table II-1 of the TMI-1 13R Outage Report describes the qualification documents and parameters for the bobbin coil examinations. The examination techniques used have demonstrated minimum detection capabilities for flaws $\geq$ 60% TW of at least 80% POD at a 90% lower confidence level.

TMI-1 steam generator condition monitoring and operational assessments are now performed in accordance with NEI 97-06. OD IGA (both volumetric and axial) is addressed in these assessments.

It is possible that an ID volumetric IGA flaw could be located at the same axial location along a tube wall opposite an OD-initiated flaw. (This is not likely since both the OD and ID indications are very small in comparison to the overall length of the tubes, and the likelihood of near perfect alignment along both the axial length and circumferential location is very small.) If this situation were to hypothetically occur, the plant's eddy current techniques should be able to detect the presence of the opposing flaws (i.e., the presence of the ID flaw should not mask the presence of an OD flaw; the presence of an OD flaw should not mask the presence of an ID flaw). Note that assessing the integrity of a tube with such coincident flaws would likely require in situ pressure testing.

TMI Unit 1 Response "Other Issues" as Referred to in NRC May 23, 2001 Letter

During the May 8, 11, and 15, 2001, conference calls, discussions were held regarding other issues which the NRC staff wishes AmerGen to address. The NRC staff discussed proposed changes to the TMI-1 TSs in the following areas:

1) Defining the region of the tube to be inspected and dispositioned under the alternate repair criteria to which you proposed to add a new paragraph as TS 4.19.2.c to discuss the scope and the region of the inspection;"

   AmerGen Response:
   TS 4.19.2.c has been added. See the additional TS pages in Enclosure 2 which include a new TS 4.19.2.c which defines the region of the tube to be inspected and dispositioned under the repair criteria proposed by LCA No. 291.

2) Defining the inspection methodology that will be used to identify and disposition the ID IGA to which you proposed some modifications, following discussions with the NRC staff, to the proposed TS changes in your December 6, 2000, application, that would be included as part of your response;"

   AmerGen Response:
   Refer to RAI Questions No. 2, 4 and 7. Inspection methodologies to be used in future outages are now stipulated in Engineering Report, ECR No. TM 01-00328. In addition, a commitment to request NRC approval prior to utilizing any new probes is now provided in Engineering Report ECR No. TM 01-00328.

3) Defining the acceptance criteria for growth rate, and actions if the criteria were exceeded to which you indicated that a stand-alone reference document would be included with your response that would be used for referencing the growth rate acceptance criteria in the TSs; and,"

   AmerGen Response:
   Acceptance criteria for statistical tests to be used for growth rate are now provided in Engineering Report, ECR No. TM 01-00328, which is a stand-alone document now referenced in the proposed Technical Specifications. Actions to be taken if these criteria are exceeded (i.e., use of a cycle-specific growth rate in the plant's operational assessment; submittal of a revised Engineering Report well ahead of the next outage) are also stipulated in the Engineering Report.

4) Reporting requirements to which you indicated that some modifications may be made to the current reporting requirements to eliminate the verbal reporting requirement of TS 4.19.5.a and include those with the 90-day reporting requirement of TS 4.19.5.b. You indicated that to the extent practical, many of the TS changes you would make to respond to the above issues would be similar to those approved recently for Arkansas Nuclear One, Unit No. 1 on March 28, 2001. Additionally, you indicated that the

table in the 90-day report required by TS 4.19.5.b would include those indications found by MRPC, but not by bobbin.

AmerGen Response:
Reporting requirements were revised to eliminate the verbal reporting requirements and include the information in the 90-day reporting requirement.

The text of the proposed TMI-1 Technical Specifications, as well as the format and content of the Engineering Report now referenced in the proposed Technical Specifications, are similar to those approved recently for Arkansas Nuclear One (ANO) Unit 1.

The text of TS 4.19.4.a(9) and 4.19.5.b have been revised to require that the 90-day report include the volumetric ID IGA indications found only by MRPC, as well as the bobbin ID IGA indications.

TMI Unit 1 Response to NRC Questions/Comments on the April 25, 2001, Meeting Handout

1) **Draft question 1 discussion:**

Referring to page 29 of the April 25, 2001, meeting handout, have you measured analyst uncertainty? If so, please provide the results of that study to the NRC staff.

AmerGen Response:
See Response to RAI Question No. 1.

2) **Draft question 2 discussion:**

Referring to page 10 of the April 25, 2001 handout, please revise the second line in the table to reflect that the row refers to all volumetric ID IGA indications found with bobbin coil inspection.

AmerGen Response:
The subject table now appears in the response to RAI Question No. 2. The phrase "ID IGA" has been added to second row of the table to clarify, along with the text which precedes the table, that the row refers to all volumetric ID IGA indications found with the bobbin coil inspections.

3) **Draft question 3 discussion:**

Referring to page 16 of the April 25, 2001, meeting handout, please discuss the difference in the numbers of indications listed in the table with those provided on page 10 of the handout.

AmerGen Response:
Page 10 provided the number of indications detected during three outages, while Page 16 provided the numbers of indications that could be compared between different outages.

These numbers are not the same. For example, if a tube is plugged, the eddy current indications in that tube are not able to be compared to eddy current data in future outages. As another example, a small indication may be recorded by both bobbin coil and MRPC examinations in one outage, and then be recorded only by MRPC examination in a subsequent outage.

4) **Draft question 4 discussion:**

Referring to page 30 in the April 25, 2001, meeting handout, please indicate that probe wear is assessed for 0.540" bobbin probe only. Please revise the last bulleted statement to reflect your practice of reexamining tubes with a probe that has passed calibration.

AmerGen Response:
This information is now provided in the response to RAI Question No. 4.

5) **Draft question 4 discussion:**
Referring to page 32 in the April 25, 2001, meeting handout, provide reference for the pre-13R study. If the results of this study have not previously been provided to the NRC staff, please provide the results.

AmerGen Response:
This information is now provided in the response to RAI Question No. 1 and in Engineering Report, ECR No. TM 01-00328.

6) **Draft question 5 discussion:**
Referring to page 21 in the April 25, 2001, meeting handout, please provide the percent of bobbin scope for each of the rows (each outage from 5M [mid-cycle] to 11R).

AmerGen Response:
This information is now provided in the responses to RAI Questions Nos. 1 and 5.

7) **Draft question 6 discussion:**
Referring to page 42 and 43 in the April 25, 2001, meeting handout, please correct the tabular information given under the graphs. Please discuss how IGSCC is representative (or bounding) the ability of the technique to size ID IGA.

AmerGen Response:
The graphs and tabular information are now provided in the response to RAI Question No. 6.

The tabular information on Page 42 of the April 25, 2001, meeting handout was correct.

The tabular information on Page 43 of the April 25, 2001, meeting handout was not correct. (The information from Page 42 was inadvertently repeated on Page 43.)

Both ID-initiated IGSCC and IGA were used in the TMI-1 bobbin coil qualification data set, as described in the response to RAI Question No. 6. The volumetric ID IGA and IGSCC included in the qualification were both caused by the sodium thiosulfate intrusion in 1981. The IGSCC included in the TMI-1 specific qualification was determined to be generally circumferential in nature. In laboratory examinations microscopic corrosion "fingers" (small, jagged, randomly oriented areas of grain separation or grain dropout) were identified to extend sideways from the main crack providing a more volumetric nature to the damaged tube wall. Those same types of fingers were found during microscopic examinations of many of the volumetric ID IGA pulled tube samples.

The eddy current responses from the IGA and IGSCC flaws are similar in formation, voltage, and time (i.e., short axial extent). Eddy current examination relies upon an interruption in the eddy current flow (a discontinuity that impedes the flow of eddy currents) to produce a signal indicative of a flaw. The eddy current flow direction for the bobbin coil probe is circumferential in direction (parallel to a circumferential IGSCC crack) so the main circumferential crack body does not substantially impede the flow of eddy currents in the tube wall and, by itself, produces little, if any, eddy current signal. From an eddy current theory perspective the microscopic volumetric fingers should be the predominant contributor to eddy current flow interruption in both the circumferential crack and volumetric ID IGA situation, so similar responses and sizing errors are expected.

ENCLOSURE 2

ADDITIONAL INFORMATION - LICENSE CHANGE APPLICATION NO. 291

AMERGEN ENGINEERING REPORT, ECR No. TM 01-00328

ENGINEERING REPORT

Three Mile Island – Unit One
Management Program for Volumetric Inside Diameter Intergranular Attack (ID IGA) in Once Through Steam Generators

EXECUTIVE SUMMARY

During its last two operating cycles TMI-1 has used an NRC-approved, one-cycle repair criteria for eddy current indications of volumetric inside diameter intergranular attack (ID IGA) found during the examinations of the plant's steam generator tubing. TMI-1 has requested NRC approval to use the conservative criteria on a permanent basis. This report documents the technical justification and bases to implement a permanent steam generator defect-specific management program for volumetric ID IGA in the steam generator tubes, including:

1. The conclusion that ID IGA does not compromise the integrity of the plant's steam generators,
2. Methods to be used in future plant cycles to examine the tubing and monitor the ID IGA population,
3. Methods to be utilized to demonstrate that hypothetical accident leakage from the ID IGA population is much less than that previously analyzed for the plant,
4. The methods to be utilized in future plant cycles to assess growth of the ID IGA population, and
5. Actions to be taken if growth is identified.

Volumetric ID IGA is defined as three-dimensional grain boundary corrosion that initiated at the inside surface of the tube. Volumetric ID IGA has been present in the TMI-1 Once Through Steam Generators (OTSGs) since 1981. The cause of the inside diameter degradation was determined to be the intrusion of sulfur into the plant's primary system while the plant was shutdown. The source of this sulfur, the sodium thiosulfate storage tank used in the Reactor Building Spray System, has been removed from the plant design.

Since 1981 a large number of laboratory and engineering analyses have been performed to assess the TMI-1 ID IGA and evaluate eddy current (EC) indications of ID IGA. The resulting analytical data, laboratory data, and examination data is sufficient to develop a management program based on performing specific EC inspections and in situ leak testing in the future.

Structural evaluation of the volumetric ID IGA included assessments of the plant's limiting loading conditions. The resulting Technical Specification repair criteria include limits on the circumferential extent, axial extent, and estimated throughwall depths of the volumetric ID IGA in order to prevent leakage from, or rupture/burst of, the flaws. Potential growth of the ID IGA population is statistically evaluated and monitored to ensure the degradation remains dormant. In situ pressure tests are specified to ensure that volumetric ID IGA indications remain capable of withstanding plant transients. Additionally, an inspection of a defined region is required each outage to monitor the population of ID IGA indications. With these provisions, leaving tubes in service with volumetric ID IGA does not result in any significant reduction in the structural integrity of the TMI-1 steam generator tubes.

EXECUTIVE SUMMARY (Cont'd)

This report documents how TMI-1 will manage the ID IGA flaws to ensure that they do not leak in excess of 1 gpm during the limiting plant accident, a postulated Main Steam Line Break (MSLB). TMI-1 has evaluated MSLB-induced theoretical primary-to-secondary leakage and calculated resulting offsite doses that are within 10CFR Part 100 limits. To date, leak testing of defects that bound the sizes of volumetric ID IGA found in the TMI-1 steam generators has resulted in no predicted primary-to-secondary leakage under simulated accident conditions. Even ID IGA eddy current indications with very deep throughwall estimates (> 90%TW) did not develop leaks at bounding accident condition differential pressures. Additional in situ pressure tests to further demonstrate that ID IGA does not impact the integrity of the tubes are performed under this management program.

The TMI-1 volumetric ID IGA management program is designed to ensure that OTSG tubes with volumetric ID IGA meet the structural and leakage performance criteria both at the time of inspection and at the end of the next cycle of operation. The assessment process requires performing EC inspections of the defined region and performing EC sizing estimation of the indications characterized as volumetric ID IGA. A number of allowable indications that might theoretically leak, and still meet the allowable leakage criteria is determined through statistical analysis. Based on this number of allowable indications that might leak in an OTSG, the required number of indications that must be in situ leak tested to statistically demonstrate, with confidence, that the remaining population of inservice indications will not leak, is calculated. In situ leak testing is performed as necessary to demonstrate accident condition leakage of less than the allowable leakage limit from volumetric ID IGA indications.

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ACRONYMS AND ABBREVIATIONS

ASTM	American Society for Testing and Materials
B&W	Babcock & Wilcox
BOC	beginning of cycle
CFR	Code of Federal Regulations
DE	destructive examination
DNB	departure from nucleate boiling
EC	eddy current
EDM	electrical discharge machining
EFPY	effective full power years
EOC	end of cycle
EPRI	Electric Power Research Institute
GPM	gallons per minute
ID	inner diameter
IGA	intergranular attack
IGSCC	intergranular stress corrosion cracking
LTL	lower tolerance limit
LTS	lower tubesheet secondary face or lower tubesheet
MRPC	motorized rotating pancake coil
MSLB	main steam line break
NDE	non-destructive examination
NRC	Nuclear Regulatory Commission
OD	outer diameter
OTSG	once through steam generator
POD	probability of detection
RC	rotating coil technology, such as RPC or Plus-Point coil
RPC	rotating pancake coil
SBLOCA	small break loss of coolant accident
SCC	stress corrosion cracking
SEM	scanning electron microscopy
SG	steam generator
SGDSM	steam generator defect-specific management
TS	tubesheet
TSP	tube support plate
TW	through wall
UTS	upper tubesheet secondary face

1.0 INTRODUCTION

The steam generator tubes in pressurized water reactors are an integral part of the reactor coolant pressure boundary. In order to ensure that the tubes are capable of performing their intended safety functions, the effects of degradation mechanisms on SG tube integrity must be addressed. Steam generator defect-specific management (SGDSM) is an integrated strategy designed to ensure that tubes degraded by a specific damage mechanism will continue to meet established performance criteria. The performance criteria used to measure acceptance include peak accident leakage limits, normal operating leakage limits, and structural limits. SGDSM strategies include a program for conducting in-service inspections and methodologies for conducting condition monitoring and operational assessments against repair criteria.

Although the cumulative effect of all degradation mechanisms in the TMI-1 Once Through Steam Generators (OTSGs) must be considered, this report specifically addresses volumetric Inside Diameter Intergranular Attack (ID IGA) and provides the methodology for performing the condition monitoring and operational assessments for this mechanism.

1.1 Purpose

The purpose of this engineering report is to present a permanent SGDSM program for volumetric ID IGA indications in the TMI-1 OTSGs. This program includes continuation of the present ID IGA repair criteria in the Technical Specifications of 0.52" circumferential extent, 0.25" axial extent, and 40% through wall (TW) depth estimate. Volumetric ID IGA indications are removed from service if any one of these three repair criteria are exceeded. The repair criteria ensure that the steam generator performance criteria are maintained and are based on eddy current (EC) inspections, growth evaluations, and in situ leak testing.

1.2 Background

In November 1981 primary-to-secondary leakage was detected in both TMI Unit 1 OTSGs. Subsequent eddy current examinations revealed many defective tubes. Laboratory examination of portions of removed tubes confirmed that the tube degradation initiated from the primary side (ID) of the tubes, principally in the form of circumferential intergranular cracks at the upper tube sheet (UTS). The active chemical impurity which caused the tube damage was sulfur in reduced forms, which had been inadvertently introduced into the RCS. The vast majority (approximately 95 percent) of the defects occurred within the top 2 to 3 inches of the 24-inch thick UTS since the inter-granular attack occurred most rapidly at the air/water interface during lay up. The air/water interface was located within the UTS during a significant portion of the 1981 post-hot-functional shutdown period. To repair the defective OTSG tubes within the UTS, GPU Nuclear (the owner of TMI Unit 1 at that time) applied a kinetic expansion tube repair technique. The GPU Nuclear repair of TMI Unit 1 Once Through Steam Generator (OTSG) tubing was reviewed and approved by the NRC in the Safety Evaluation Report (SER) that accompanied License Amendment No. 103, dated December 21, 1984, entitled "NUREG-1019, Supplement No. 1, Safety Evaluation Report by the Office of NRR - Three Mile Island Nuclear Station, Unit 1 (TMI-1) - Steam Generator Tube Repair and Return to Operation," (Reference 2.1).

The kinetic expansion repair technique applied in the early 1980s addressed the existence of repairable defects located within the UTS. However, a limited population of the tubes contained degradation located below the kinetic expansion transition or below the UTS secondary face that could not be repaired by the kinetic expansion technique. During plant outages from 1985 through 1999, GPU Nuclear inspected the OTSG tubing for this type of degradation (along with other types of degradation pertinent to the OTSGs). Based on these examinations and pulled tube exams, GPU Nuclear confirmed that the ID IGA degradation due to the chemical intrusion was inactive.

Because of the uncertainty in sizing the depth of small amplitude ID IGA degradation that was not previously repaired, the NRC and GPU Nuclear agreed in 1997 that the Technical Specification tube repair criteria should be amended to specifically address the tubes identified with this mode of degradation. TMI Unit 1 License Amendment No. 206 (Reference 2.2) provided a set of surveillance criteria under which the volumetric ID IGA indications could remain in service for the 12R Outage and Cycle 12 operation. In 1999 License Amendment No. 209 (Reference 2.3) extended the applicability of these criteria one additional operating cycle, through Cycle 13 which is scheduled to end during the Fall of 2001. License Change Application (LCA) 291, submitted by AmerGen, the present owner of the plant, proposes that those criteria which have been approved for the previous two cycles be approved for future outages. This report supports the LCA 291 submittal.

This report documents a continued approach in specifying inspection techniques, in situ pressure tests, and growth tests using statistical models to ensure that the ID IGA is proven to be dormant.

2.0 REFERENCES

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2.3 NRC Letter dated April 13, 1999, from Timothy Colburn to James W. Langenbach, "Three Mile Island Unit No. 1– Issuance of Amendment Re: Once – Through Steam Generator Inspection Criteria for the Cycle 13 Refueling Examinations (TAC No. MA4234)," Amendment No. 209 to Facility Operating License No. DPR-50.

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2.14 Natrella, Mary G., "Experimental Statistics, National Bureau of Standards Handbook 91"; Issued August 1, 1963, reprinted October 1966 with corrections.

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3.0 DESCRIPTION OF THE TMI-1 OTSGS

The TMI-1 nuclear power plant contains two Babcock and Wilcox model 177FA OTSG's. The plant began commercial operation in 1974.

3.1 Functional Description

The OTSG is a straight-tube, straight-shell, vertical, counter-flow, once through heat exchanger with shell side boiling. By nature of its design, the OTSG eliminates the need for steam separating equipment.

In the TMI-1 OTSGs, shown in Figure 1, primary fluid from the reactor enters through an inlet nozzle in the top head, flows down through the tubes, is collected in the bottom head and exits through two primary outlet nozzles. The feedwater enters through a series of spray nozzles near the top of the annular feedwater heating chamber. Here the feedwater is heated to saturation temperature by direct contact with high quality or slightly superheated "bleed" steam. The resulting saturated feedwater enters the tube bundle through ports near the bottom of the tube bundle. Nucleate boiling starts immediately upon contact with the hot tubes. Steam quality increases as the secondary fluid flows upward between the tubes in counterflow to the primary fluid inside the tubes. The departure from nucleate boiling occurs at about the 348-inch level at design conditions. The mode of heat transfer then changes from nucleate to film boiling; steam quality continues to increase but at a slower rate. After 100% quality is reached, the steam becomes superheated, leaves the tube bundle at the upper tubesheet, flows down the steam annulus, and exits through two steam outlet nozzles.

3.2 Design Information

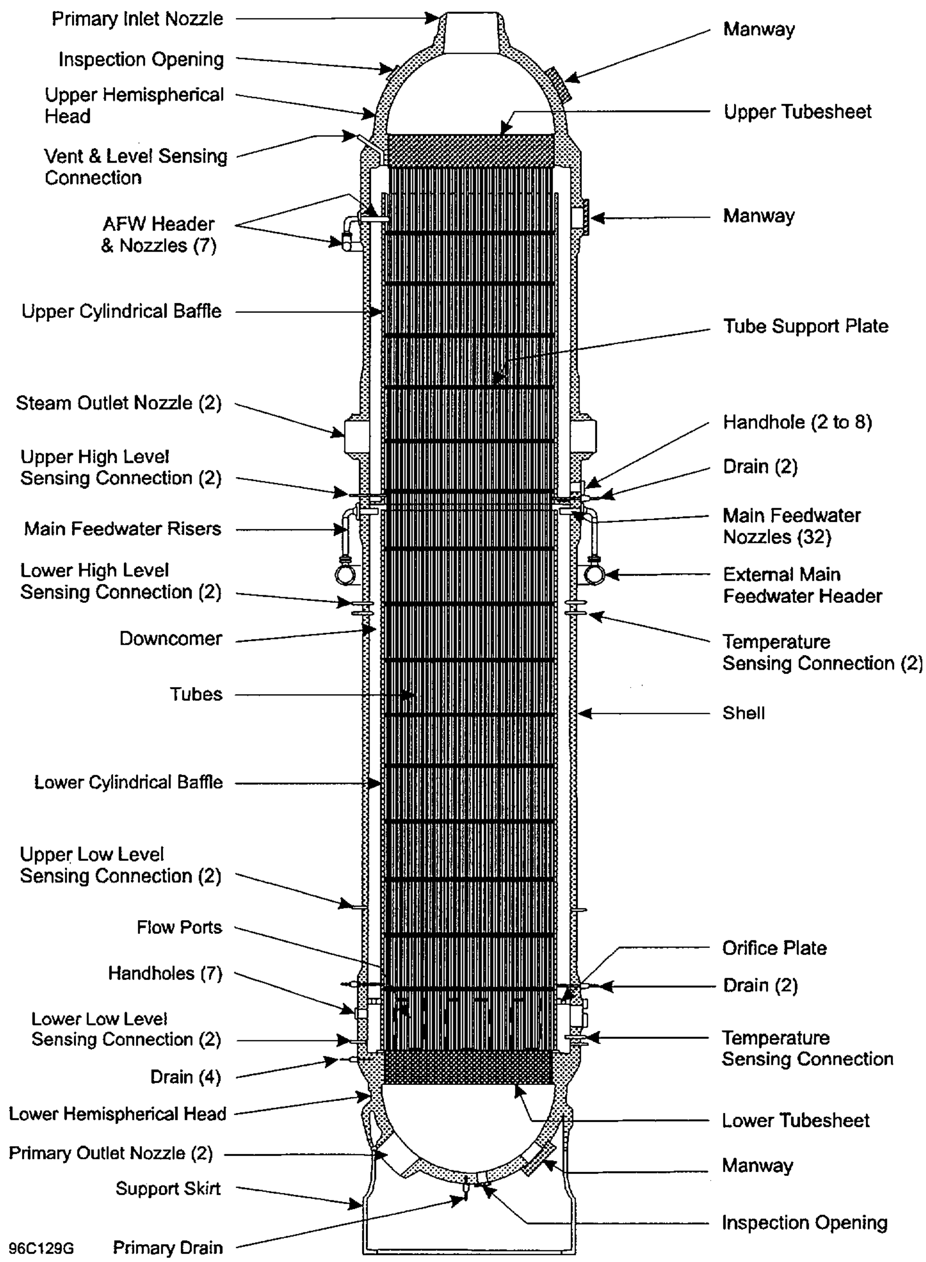
The TMI-1 plant has two steam generators. Each TMI-1 steam generator has 15,531 triangularly-spaced Inconel alloy 600 tubes. The tubes are 0.625 inch OD x 0.037 inch nominal wall x 673.375 inches long. In the lower tubesheet the tubes are partially roll expanded (1 inch minimum) and attached to the tubesheet by fillet welds. In the upper tubesheet, as described previously, the tubes originally had tube-to-tubesheet joints identical to the lower tubesheet, but inservice tubes now have 17" long or 22" long kinetic expansions. The use of straight tubes results in almost pure counterflow with resulting improved secondary flow distribution and primary-to-secondary temperature differentials. This design also has the benefit of placing the tubes in compression during normal operating conditions. This is mainly due to the fact that the alloy 600 tubes have a thermal coefficient of expansion slightly greater than that of the carbon steel steam generator shells. This compressive load tends to inhibit the initiation and propagation of stress related damage mechanisms. Proper lateral spacing of the tubes is maintained by fifteen tube support plates (TSPs). They are fabricated from 1-1/2 inch thick carbon steel plate, drilled and broached to provide surface contact and support along three axes for each tube at each tube support plate. An exception is the 15th TSP periphery at which the tube holes are not broached; this uppermost tube support plate is drilled rather than broached at the peripheral tube locations. The support plates are not uniformly spaced within the generators along the axial tube bundle length so as to prevent tube vibration.

3.3 Tube Material

The TMI-1 OTSG tube material is Inconel alloy 600 (ASTM SB163). The tube material was thermally treated at 1100°F to 1150°F for a minimum of 11 hours during the full furnace stress relief of the completed steam generators. As a result, the installed tubes are both sensitized and stress relieved. This resulted in improved resistance to stress corrosion cracking, but some susceptibility to intergranular attack.

Figure 1 OTSG

Longitudinal Section



4.0 DEFINITION OF VOLUMETRIC ID IGA

This section discusses the Eddy Current (EC) characteristics of ID IGA and defines the region of the steam generators where the SGDSM will be applied. This SGDSM will only be applied to the defined region as specified in Section 4.4.

4.1 Operating History

As described in Section 1.2, inside diameter degradation occurred in the TMI-1 steam generators as a result of a sulfur intrusion in 1981. During the 1981-1985 shutdown of the plant sections of 19 tubes were pulled to characterize the tube degradation, and optimize eddy current techniques that could detect the degradation. Eddy current examination methods and dispositioning criteria were developed, and were used during repeated examinations of the tubing to remove those tubes from service which might have insufficient integrity to withstand hypothetical plant accidents. After extensive examinations and repairs, the restart of the plant (with new kinetic expansion joints of the tubing in the upper tubesheets) was approved in 1985.

After the restart of the plant, samples from three TMI-1 "A" steam generator tubes containing volumetric ID IGA flaws were pulled in 1986. Three volumetric ID IGA "patches" were examined in the laboratory and compared to eddy current results at that time. (During the 1986 Outage, tubes were examined with the bobbin coil, and 8 x 1 probes were used to estimate circumferential extents. Motorized rotating pancake coils (MRPC) were not used.) The following is a summary of the slides presented to NRC at a meeting held May 21, 1987 (Reference 2.4) regarding the nature of the pulled volumetric ID IGA flaws and the ability of eddy current to detect those flaws:

Table 1
1986 Pulled Tube Eddy Current and DE Results

Tube ID	8 x 1 Eddy Current Coil Circ. Extent Estimate	Metallurgical Circ. Extent Estimate (from lab)	Bobbin Eddy Current Coil TW Depth Estimate	Metallurgical TW Mean Depth Estimate (from lab)	Metallurgical TW Max Depth Estimate (from lab)	Metallurgical Axial Extent Estimate (from lab)
A8-45	< 0.300"	0.076"	20%	18%	48%	0.060"
A35-83	< 0.300"	0.064"	36%	7%	16%	0.017"
A141-3	< 0.300"	0.063"	26%	21%	42%	0.047"

The above Table illustrates the ability of the 1986 dual eddy current processes (i.e., bobbin and 8 x 1) to detect small volumetric ID IGA flaws in the TMI-1 generators. (Note that the

8 x 1 probe, which used 8 surface riding pancake coils arranged circumferentially around a probe body to detect flaws, could only estimate flaw circumferential lengths in relatively large increments by today's standards.)

More recently tube samples containing volumetric ID IGA flaws were pulled from the TMI-1 steam generators during the September, 1997 outage (Outage 12R). A tube containing multiple volumetric ID IGA eddy current indications was pulled from the TMI-1 "A" OTSG. Tubing exams performed in 1997 at TMI-1 also utilized a dual probe approach: both bobbin coils and MRPC probes were used to examine the tubing. The results of that tube pull were forwarded to the NRC and were included in submittals requesting the continued one-cycle use of the conservative volumetric ID IGA repair criteria for the present cycle.

Appendix A is an excerpt from Technical Specification Change Request (TSCR) No. 277, (Reference 2.5). The Outage 12R pulled tube results described in TSCR No. 277 demonstrated that the evaluation results of TMI volumetric ID IGA flaw extents using the MRPC probe are conservative.

4.2 Morphology

The results of the various destructive exams performed since 1981 have typically shown an elliptical, "thumbnail" cross section (also described as "patch-like" or "pit-like") for the TMI-1 volumetric ID IGA. Volumetric ID IGA is defined as three-dimensional grain boundary corrosion initiating from the inside surface of the tube. The ID IGA can occur in isolated patches or at multiple initiation sites encompassing a given area. Typically, the ID IGA exhibits the thumbnail profile.

As an example of the thumbnail morphology of the TMI-1 ID IGA, the following laboratory metallography data is from one of the ID IGA flaws pulled in the 1997 Outage. As the inside surface of the tube containing a volumetric ID was incrementally ground, measurements of the axial and circumferential extent of the flaw were made:

Table 2
Example of TMI-1 Volumetric ID IGA Morphology/Measurements
(Tube A52-34, Mount Number 18-B98)

Depth of Grind into ID Surface (mils) and (%Throughwall)	Axial Length of Flaw (mils)	Circumferential Extent of Flaw (mils)
1 mil / 3% TW	29	18
2 mils / 5% TW	25	18
4 mils / 11% TW	22	17
6 mils / 16% TW	21	17
8 mils / 22% TW	15	13
10 mils / 27% TW	8	11
12 mils / 32% TW	0 (i.e., not present)	0 (i.e., not present)

4.3 Eddy Current Characteristics

During in-service tube inspections, bobbin examinations are performed to detect potential ID IGA indications. These indications are then examined with surface-riding rotating coils to characterize the indication as a specific type of indication (eg. ID-initiating, OD-initiating, crack-like, etc). The bobbin examinations screen the tubes for potential ID IGA indications. The MRPC probe rotating coil examination is then used to estimate the size of the flaw and whether or not the indication is volumetric ID IGA. The close proximity of the TMI-1 volumetric ID IGA to bobbin coil and surface-riding eddy current probes inside the tubing facilitates its detection and disposition.

TMI-1 uses the following eddy current examination coils for examination of volumetric ID IGA in the steam generator tubes:

- 0.510" bobbin is used as general screening coil
- 0.540" bobbin is used for evaluating ID Volumetric IGA indications
- 0.080" HF (Shielded Coil) Pancake Coil on MRPC probe is used for axial and circumferential extent measurement

- 0.115" Pancake Coil on MRPC probe is used for axial and circumferential extent measurement for comparison to previous .115" coil measurements, if available
- Plus-Point Coil on MRPC probe is used for determination of surface of initiation and volumetric morphology

TMI-1 has used the 0.540" bobbin coil for evaluating its volumetric ID IGA indications in all outages since 1985. This probe serves as a benchmark with which past eddy current data for a given indication may be compared with more current data. All ID flaw indications found with a 0.510" bobbin coil probe are given an additional examination with the 0.540" probe. Tubes known to contain ID IGA indications from previous exams, such as those meeting the Technical Specification definition for degraded tubes, are scheduled for a 0.540" bobbin coil exam (i.e., the 0.510" bobbin examination is not performed since the tube is already known to require a 0.540" bobbin examination.)

Many of the TMI-1 volumetric ID IGA indications are too small to be detected using a bobbin probe. These indications are detected only with more sensitive, surface riding MRPC probes. The bobbin coil probes detect the larger indications.

4.4 Defined Region

The application of this program, and its repair criteria, is limited to volumetric ID IGA indications located in the unexpanded tubing, both within and between the upper and lower tubesheets, of the TMI-1 steam generators. Indications located in the upper tubesheet kinetic expansion transitions are included in this program. Indications located in the lower tubesheet roll expansion transitions are not included in this program (since there are no known volumetric ID IGA indications at these lower tubesheet locations.)

This program, and its repair criteria, is also applicable to volumetric ID IGA indications located in the lower 5" length of inservice upper tubesheet kinetic expansions within a limited population of tubes having 22" long kinetic expansions and which are in the center of the tube bundles. The program is applicable to these tubes because the TMI-1 MSLB analysis for tubes with 22" kinetic expansions conservatively takes no credit for the presence of the tubesheet at the lower end of these kinetic expansions. The dispositioning criteria conservatively assumes that during a MSLB upper tubesheet flexure at the center of an affected generator is sufficient to relieve contact pressure between the tubing and the tubesheet along the lower 5" length of the expansion. Since the tubesheet is assumed to have no influence on the tubing at these locations, repair criteria for unexpanded, freespan tubing are also applicable to this length of tubing. (The program's ID IGA repair criteria are more conservative for the unexpanded, freespan tubing than the repair criteria applied to kinetically expanded tubing captured within the upper tubesheets. TMI-1 has applied the conservative Technical Specification "freespan" volumetric ID IGA dispositioning criteria, in addition to conservative kinetic expansion dispositioning criteria, to the lower lengths of this small subset of kinetic expansions during its last two 12R and 13R Outages. Under this program, the application of the freespan criteria to this subset of kinetic expansions will continue.)

Note that the program and criteria are not applicable to the majority of the plant's kinetic expansions, which are 17" long. The program is only applicable to the lower lengths of 22" long expansions in the center of the tube bundles. The radius of the upper tubesheets is 59.344"; the program is applicable only to tubes with 22" expansions at a radial location within 47" of the center of the tubesheet. There are only 466 22" long kinetic expansions currently in service in the two steam generators, and only 79 of these 466 are located within these center areas of the tube bundles.

This program and criteria are not applicable to tube sleeves nor the parent tubing spanned by the sleeves. TMI-1's tube sleeves are made of Inconel alloy 690 and were installed several years after the inside diameter degradation occurred. The sleeves were installed as a preventive measure to prevent tube leakage as a result of a high-cycle fatigue mechanism. The parent tubing spanned by the sleeve has been removed from service, and no attempt will be made to restore that spanned tubing to service under this program.

5.0 STRUCTURAL EVALUATION

In 1997 the results of structural evaluations were utilized to derive the conservative repair criteria for TMI-1's ID IGA. The three Technical Specification repair criteria (i.e., 40% throughwall estimate, 0.25" axial extent, and 0.52" circumferential extent) were based on conservative structural evaluations performed to determine the impact of bounding design conditions on tubes containing volumetric ID IGA. Due to the design of the OTSG, tensile loads can be developed within the tubes during certain accident and cool-down events. The effect of the ID IGA on the ability of the tube to carry these loads was also evaluated.

The 40% throughwall estimate criterion has remained a part of the plant's Technical Specifications since prior to the 1981 tube damage. This criterion was retained for the volumetric ID IGA indications. The 0.540" bobbin coil is the probe used to provide throughwall estimates to disposition the tube with respect to the 40% throughwall repair criterion. Throughwall estimates are not attempted for very small ID IGA indications whose signal-to-noise ratio is insufficient for bobbin coil response evaluation. TMI-1 does estimate throughwall depth of ID IGA indications whose 0.540" bobbin coil response is sufficient. The plant's eddy current guidelines stipulate that 0.540" bobbin coil depth estimates are to be provided for ID IGA indications having bobbin coil responses whose voltage is ≥0.4 V and/or signal-to-noise ratios ≥3:1.

The 0.25" axial extent criterion is based upon a Reg. Guide 1.121 analysis performed for the Crystal River-3 plant's OTSGs and accepted for use at TMI-1. This criterion was accepted in 1997 by the GPU Nuclear (former owner of the TMI-1 plant) and the NRC in Reference 2.2. (This length is based upon a Reg. Guide 1.121 analysis that assumed a 100% throughwall axial flaw of 0.25" extent was present in a tube.)

The 0.52" axial extent criterion is based upon GPU Technical Data Report #423, Revision 1, wherein the maximum permissible throughwall circumferential 100% throughwall crack for an MSLB was reported. This criterion was accepted in 1997 by the GPU Nuclear (former owner of the TMI-1 plant) and the NRC in Reference 2.2.

The axial and circumferential extent criteria are very conservative since they are based on the assumption that an indication is 100% throughwall over its entire measured length, and no credit is taken for the propensity for the MRPC coils to overestimate the length of the flaws. (As discussed in Section 4.1, the MRPC probes significantly overcall the extents of the small ID IGA flaws. Eddy current examination interrogates a volume of tubing larger than the coil itself, having the effect of overestimating the extents of these defects.)

5.1 Loading Conditions

Two loading conditions necessary for prescribing pressures for in situ pressure testing of ID IGA indications are the limiting normal operating conditions and the limiting accident conditions. The limiting 100% power steady state and accident conditions are discussed in this section.

5.1.1 Limiting Pressure Differentials

The normal operating primary-to-secondary pressure (NOP) differential associated with 100% steady state power conditions is 1,305 psi. Application of the safety factor of three in accordance with draft RG 1.121 results in a (3xNOP) primary-to-secondary pressure differential of 3,915 psi.

The limiting primary-to-secondary pressure differential associated with accident conditions is the safety relief valve setpoint of 2,575 psi. This condition is associated with a MSLB condition and includes a 3% allowance for setpoint tolerance. (Application of the safety factor of 1/0.7 (in accordance with RG 1.121 results in a limiting primary-to-secondary pressure differential of 3,679 psi. Therefore, the 3xNOP condition described in the above paragraph exceeds this value and is normally used to determine maximum pressures for in situ pressure testing.)

Note that the above pressures are not used directly for in situ pressure tests. Additional increases to these pressures are made, in accordance with the EPRI Report, "In-Situ Pressure Test Guidelines" (Reference 2.6), to account for other uncertainties such as the test pressure instrumentation error and changes in material strength properties of the tubing at operating temperatures relative to the test temperature. For example, 4,400 psid has been used for recent TMI-1 testing performed to assess tube integrity for 3xNOP pressure differentials.

5.1.2 Limiting Tensile Tube Loads

Tensile tube loads may develop in the OTSG during cool-down events. During these events, the tubes cool faster than the surrounding shell, resulting in tensile tube loads. The primary component of these tube loads are thermal loads, which are displacement limited. This results in the majority of the tensile load being associated with secondary stresses that do not require the ASME faulted condition safety factor of 1/0.7.

The 0.52" circumferential extent limit for the volumetric ID IGA indications presently in the TMI-1 Technical Specifications was based upon a worst case hypothetical Main Steam Line Break tensile tube load of 3,140 lbs. This is a very conservative load used to derive the 0.52" structural limit; a more recent analysis of the TMI Unit 1 MSLB accident determined that the maximum tube tensile load is 1310 lbs.

5.1.3 Limiting Cross Flow Loading

Cross flow loads occur in the upper and lower spans of OTSG tubing due to the radial flow of water and steam in these regions. The limiting case for cross flow loading is the MSLB, and the amount of cross flow load is related to the size, location, and "un-zip time" of the hypothetical break in the steam pipe. Cross-flow evaluations, stress analyses, and laboratory leak testing which have been performed do not indicate that cross flows have a measurable effect on the structural integrity of OTSG tubing (beyond the pressure and tensile loads described above). There are, therefore, no repair criteria or limitations associated with cross flow loads.

5.2 Tube Rupture Evaluation

5.2.1 Burst Strength

As described in Section 4.1, sections of three TMI-1 OTSG tubes containing volumetric ID IGA were pulled in 1986. One of these sections was subjected to burst testing in the laboratory. The following is a summary of the burst test results and eddy current indications:

Table 3
Summary of TMI-1 1986 6R Outage Pulled Tube Laboratory Burst Test

Tube/Section	Indications and Their Field Eddy Current Results	Burst Pressure of Section
A35-83 / Piece 2	Eddy Current Result: ID indication with 36% TW estimate by 0.540" bobbin; < 0.300" circumferential extent estimated by 8X1 absolute coil examination Metallurgical Result: ID Volumetric with extents 0.064" circ x 0.017" axial x 16%TW	11,700 psig

Sections of another TMI-1 OTSG tube containing volumetric ID IGA were pulled in 1997 and subjected to laboratory leak and burst testing. This tube would have been plugged under the subject criteria because it had a flaw with an estimated throughwall penetration by bobbin exceeding 40%. The leak/burst test results were forwarded to the NRC in Reference 2.7. The burst pressures of the tube sections containing ID IGA indications that were tested were above 10,000 psig, indicating that substantial structural margin existed for these flaws. (These burst pressures were nearly equal to those of non-defective virgin tubing which averaged 11,216 psig.) Tests were performed on tube sections containing flaws that were detected by bobbin coil examinations as well as sections containing flaws detected only by MRPC probe examinations. The following Table is similar to that in Reference 2.7 and describes the flaws that were tested:

Table 4
Summary of TMI-1 1997 12R Outage Pulled Tube Laboratory Burst Tests

Tube/Section	Indications and Their Field Eddy Current Results	Burst Pressure of Section (psig)
A52-34 / Section 12	0.10" circ x 0.10" axial; not detected by bobbin 0.11" circ x 0.11" axial; not detected by bobbin 0.11" circ x 0.11" axial; not detected by bobbin 0.10" circ x 0.10" axial; not detected by bobbin	11,200
A52-34 / Section 18	0.09" circ x 0.14" axial; not detected by bobbin 0.11" circ x 0.10" axial; 50% TW estimate by bobbin	10,950
A52-34 / Section 21	0.19" circ x 0.16" axial; INR by bobbin 0.06" circ x 0.05" axial; BVC by bobbin 0.14" circ x 0.10" axial; BVC by bobbin 0.09" circ x 0.14" axial; not detected by bobbin 0.11" circ x 0.16" axial; BVC by bobbin	10,800
A52-34 / Section 23	0.06" circ x 0.10" axial; 17% TW estimate by bobbin 0.14" circ x 0.20" axial; not detected by bobbin	10,800

In summary, thirteen eddy current-detected ID IGA defects pulled in 1997 were burst tested in a laboratory with burst pressures above 10,000 psig. The burst pressures exceeded the hypothetical MSLB or 3xNOP delta pressures by a considerable margin. These tube sections were also water leak tested at 1,500, 2,900 and 4,400 psig (corresponding to NOP, MSLB, and 3xNOP delta pressures with additional conservatisms), with no leakage detected. Leak tests were performed with an applied axial load of 1,402 lbs on the tube sections since 1402 lbs was the B&W plant MSLB-induced axial load at that time. Burst test axial loads exceeded 1,402 lbs. Pressurization rates during the laboratory testing were relatively slow; rates of increase from 0 psig to 3xNOP were 1500-2000 psi/minute, with 5 minute hold times at NOP, MSLB, and 3xNOP differential pressures. Pressurization rates from 3xNOP to burst were 200-2000 psi/second. No bladders, foils, or tubing supports were utilized for any of the burst or leak tests.

The above burst test results are consistent with other burst tests performed on steam generator tubing. Small pits or small IGA patches have a relatively small effect on the burst pressure of a steam generator tube, since a large fraction of the original, undegraded tube remains to maintain the integrity of the tubing under pressure loads. Typically, tubes must exhibit a uniform thinning of approximately 70% throughwall over a large area (i.e., only 30% of a tube wall remains intact) before the 3,915 psid (3xNOP) burst criterion is approached. Considering that the TMI-1 ID IGA indications are small in size, and the Technical Specification criteria require that they are removed from service when small in size, it is highly improbable that the TMI-1 indications will adversely influence burst pressures of the tubing with respect to the 3xNOP burst criterion.

5.3 Tensile Rupture Evaluation

Tensile rupture is defined as the complete severance of the tube due to tensile loads. The resistance of the OTSG tubing to tensile rupture is a function of its ultimate tensile strength. The OTSG tubes are subjected to tensile loads during certain cool-down transients and accident scenarios. To develop a criterion for tensile rupture, the tensile failure load of OTSG tube samples with volumetric degradation was correlated to the remaining cross-sectional area. The remaining cross-sectional area was then correlated to an allowable circumferential extent assuming the defect is 100%TW. These two relationships are then used to determine the maximum allowable circumferential extent of a 100%TW volumetric defect that will not result in tensile rupture of the tube under the limiting accident condition axial tube loads with the appropriate safety margins.

As previously described in Section 5.0, the allowable circumferential extent for the TMI-1 ID IGA indications of 0.52" was incorporated into the plant's Technical Specifications in 1997. This dimension assumes that a defect is 100% throughwall, and was based on an analysis that was performed in GPU Technical Data Report No. 423, Revision 1 (See Reference 2.2). This is a conservative result considering that analyses have shown that tubes with 100% TW flaws with circumferential extents of up to 140 degrees have sufficient tensile strength to withstand the OTSG's hypothetical tensile loads. OTSG steam generator tubes have outer diameters of 0.625" and a nominal wall thickness of 0.037". A 140 degree circumferential flaw would have a circumferential extent of 0.76" at a tube's outside wall. (TMI-1's eddy current circumferential extent estimates are made with respect to the outside diameter arc length dimension. Using the tube's OD surface as reference for arc length measurement provides an additional, conservative, overestimation for ID or mid-wall indications.) The use of the 0.52" dimension is also conservative because it neglects the fact that, as previously described, eddy current examinations tend to overestimate the circumferential extents of the ID IGA flaws.

5.4 Fatigue Evaluation

Fatigue loading on OTSG tubes can be classified as either high-cycle or low-cycle. Tube degradation due to high cycle fatigue has been observed in OTSGs at the 15th (uppermost) TSP and at the secondary face of the upper tubesheet. The resulting flaw morphology is a circumferential fatigue crack that propagates rapidly around the tube once initiated. In

OTSGs the affected tubes are located adjacent to the open tube lane, where secondary side cross flow velocity is high. This damage mechanism was first identified in the late 1970's and confirmed through examinations of tube pull samples from B&W plants. It was concluded that the flaws were initiated at sites of localized corrosion, and then were propagated into fatigue cracks by flow induced vibrations associated with the relatively high secondary steam cross flows.

High cycle fatigue has been addressed in B&W OTSGs by preventively sleeving the susceptible tubes. The lack of B&W plant tube leaks attributed to fatigue in recent operating cycles supports the adequacy of the defined sleeving zone in bounding the susceptible area. The installed sleeves span the entire upper tubesheet and top span of the generator tubes; this program will not be applied to the sleeved area of these parent tubes. The TMI-1 sleeves were installed in outages after the sulfur intrusion that caused the original ID-initiated degradation; the program will not be applied to the sleeves. Given the success of the sleeving repairs in the B&W plants, addressing the effects of high cycle fatigue is not necessary.

Fatigue due to low cycle loading results primarily from mechanical, thermal, and pressure cycling during normal plant operation. If volumetric ID IGA flaws were to propagate due to low cycle fatigue, this would be evident as a change in the EC response of the flaw from one cycle to the next. Therefore, performing evaluations for potential growth addresses any historical effects of low cycle fatigue on ID IGA. Since ID IGA growth will continue to be regularly monitored during implementation of the program, and flaws will be repaired prior to becoming a leakage or structural concern, a separate repair limit for low cycle fatigue is not necessary.

5.5 Repair Criteria

The Technical Specification repair criteria are the result of the evaluations described in sections 5.2 through 5.4, and are summarized in Table 5. The evaluations show that volumetric ID IGA, due to its limited size, has very little effect on the structural performance of the tubing. Burst of the ID IGA flaws is highly unlikely; laboratory burst tests of pulled flaws have shown that they have little influence on burst pressure. Tensile rupture of tubes with ID IGA is highly improbable based on the results of tensile testing on OTSG tubes with uniform thinning and 100%TW holes. Preventive sleeving and evaluating ID IGA for growth mitigates the potential consequences of fatigue. Finally, cross flow loads during MSLB conditions will not influence OTSG tube leakage and burst testing. Note that the Table 5 repair criteria, while based on the conservative assumption that the flaws are 100% throughwall cracks, are implemented only after the ID surface of initiation and volumetric morphology of ID IGA are confirmed by rotating coil probes.

Table 5
Repair Criteria

Condition	Repair Criteria	Comments
Burst Rupture	Tech Spec Repair criteria: EC measured circumferential extent >0.52", or EC measured axial extent > 0.25", or EC estimated throughwall depth ≥ 40%, if estimated.	Burst at delta P's less than 3xNOP highly unlikely based on pulled tube tests, in situ tests, and small size of flaws. Axial and circumferential extents conservatively assume 100%TW.
Tensile Rupture	Tech Spec Repair criteria: EC measured circumferential extent > 0.52".	Circumferential extent conservatively assumes 100%TW.
High Cycle Fatigue	None	Addressed through preventive sleeving.
Low Cycle Fatigue	None	Addressed through flaw characterization and growth monitoring.
Cross Flow Loads	None	Analyses/testing show no structural impact for these loads.

6.0 LEAKAGE EVALUATION

In addition to removing volumetric ID IGA indications from service based on their axial extent, circumferential extent, or estimated throughwall depth, TMI-1 will perform additional in situ tests on the ID IGA indications to evaluate the leakage integrity of tubes with ID IGA.

6.1 In situ and Laboratory Leak Testing

As part of the 12R Outage in-service tube examinations in 1997, six (6) volumetric ID IGA indications were in situ leak tested. No leakage was detected during any of the tests. This data was forwarded to NRC in the 12R Outage Report (Reference 2.8). The tubes were pressurized to a representative normal operating primary-to-secondary differential pressure (NOPD), MSLB differential pressure (MSLB), and three times the normal operating primary-to-secondary differential pressure (3xNOP). All tests were conducted in accordance with the revision of the EPRI Report, "In-Situ Pressure Testing Guidelines," in effect at the time. None of the indications tested under any of these conditions exhibited any leakage.

No volumetric ID IGA indications were in situ pressure tested during Outage 13R in 1999. However, indications with circumferential extents, axial extents, and percent throughwall depth estimates exceeding those of the volumetric ID IGA population were tested with no leakage. These results were forwarded to the NRC in the 13R Outage report to NRC (Reference 2.9).

As described in Section 5.2 of this report, thirteen (13) volumetric ID IGA indications were leak tested (and burst tested) from a tube pulled in 1997. Given the six volumetric ID IGA indications in situ leak tested during Outage 12R, and thirteen indications leak tested in the laboratory after Outage 12R, the total number of volumetric ID IGA indications that have successfully undergone leak testing to date is nineteen (19). (As described in Section 5.2.1, an additional ID IGA flaw pulled in 1986 was subjected to burst testing; no leak test was performed on that ID IGA flaw.)

6.2 Predicted Leakage Condition

As discussed in the previous sections, no TMI-1 volumetric ID IGA indications leaked under any of the pressurized water conditions tested in laboratory leak tests or in situ pressure tests. Pressures in excess of 10,000 psi have been necessary to burst the flaws tested in laboratories. Based on the lack of leakage and the following observations, it is concluded that ID IGA patches will not leak in their current state. Since volumetric ID IGA indications have not leaked, it is necessary to predict some leakage condition to be used to assess the steam generators tubing for hypothetical leakage from these flaws. Crack formation must be assumed to occur if a volumetric ID IGA defect is assumed to leak.

Volumetric ID IGA is three-dimensional corrosion of the grain boundaries, but not the grains themselves. As volumetric ID IGA progresses deeper into the tube wall, it tends to increase in circumferential and axial extent (measured at the ID initiation surface). As a theoretical volumetric ID IGA flaw approaches 100% TW, the local stresses in the remaining, surrounding tubing cross-sectional area increase. During normal operating conditions the tube is subjected to a small compressive load and a primary-to-secondary pressure differential, resulting in a positive hoop stress. In a predicted scenario, at some point before the ID IGA can progress to 100% TW, the cross section of the degraded tube will reach a critical stress needed for crack initiation. This crack may then progress to 100%TW. (Note that crack-like forms of degradation must be repaired under the subject program; in addition to the repair criteria, confirmation of volumetric morphology is required for an indication to remain in service.)

6.2.1 Predicted Mode of Leakage

For purposes of postulating leakage, it is therefore assumed that the ID IGA must form a crack in order to have the potential for leakage. Evaluation of the normal operating conditions results in the conclusion that leakage from an axial crack is more probable than leakage from a circumferential crack. This is based on the fact that the OTSG tubes are in compression during steady-state operation, which inhibits the formation of a circumferential crack, and hoop stresses caused by primary-to-secondary pressure differential favor the formation of an axial crack. Therefore, for purposes of estimating the theoretical leakage from ID IGA indication, it is concluded that the most probable means of developing leakage is by axial cracking during normal operation.

6.2.2 Predicted Length of Leak Path

As described previously, laboratory leak tests of 13 volumetric ID IGA flaws pulled in 1997, and 6 indications in situ pressure tested in 1997, have shown no leakage at differential pressures of up to 3xNOP.

As described in Section 4.2, the volumetric ID IGA has a generally elliptical profile. For purposes of predicting a leak path length, the elliptical profile will be assumed to be maintained as a flaw theoretically grows to a depth necessary to initiate an axial crack. Some fraction of a flaw's length must be assumed to completely penetrate the tube wall. When calculating theoretical population leak rates for this program, the assumed individual indication leak rates will be conservatively calculated based on a 100%TW crack whose length is 33% of the total measured axial extent of the IGA patch. This 33% term is based on the pulled tube analysis results illustrating that, as previously described, axial extents of the patches measured by MRPC are approximately three to five times larger than the actual extents of the patches.

Based on the lack of any leakage during the historical leak testing discussed in Sections 6.1 and 6.2, and lack of any significant reduction in structural strength as discussed in Section 5, this approach is deemed very conservative.

6.3 Leakage Criteria

For indications in the defined region, TMI-1 must provide assurance that the potential primary-to-secondary leakage rate during the limiting accident condition for leakage (MSLB) does not exceed 1 gpm for the affected SG. (Larger amounts of leakage have been analyzed for theoretical leakage from flaws in the kinetic expansions.) This criteria will be met each outage through the SG program requirements/procedures. A portion of the 1 gpm limit is designated for the volumetric ID IGA. The other degradation mechanisms are addressed separately under the SG Program requirements and are combined with the volumetric ID IGA leakage value to ensure the design requirements are met.

To provide a reasonable assurance that the leak rate will not be exceeded, MSLB primary-to-secondary leak rates must be determined as a function of the axial extent of the assumed crack (see discussion in Section 6.2). PICEP (Reference 2.10) was used to calculate the fluid flow rates through axial cracks in OTSG tubes subjected to bounding MSLB conditions. The crack opening displacement was calculated based on the EPRI/ZAHOOR Model (Reference 2.11). The effect of the tensile load, which would act to close an axial crack opening during an MSLB, was conservatively omitted in these calculations. The MSLB conditions assumed in this analysis were a primary-to-secondary pressure differential of 2575 psi, and the tube and primary fluid temperatures were assumed to be 600°F. Based on these conditions, the predicted leak rates are presented as a function of 100%TW crack length in Table 6.

Table 6

Predicted MSLB Leak Rate for Assumed Axial Cracks

Volumetric ID IGA EC Axial Extent (in)	Assumed 100% TW Crack Length (in)	PICEP Leak Rate @ 600°F (gpm)
0.09	0.03	0.0002
0.12	0.04	0.0004
0.15	0.05	0.0009
0.18	0.06	0.0013
0.21	0.07	0.0020
0.24	0.08	0.0028
0.27	0.09	0.0040
0.30	0.10	0.0054
0.33	0.11	0.0074
0.36	0.12	0.0102
0.39	0.13	0.0139
0.42	0.14	0.0186
0.45	0.15	0.0246
0.48	0.16	0.0323
0.51	0.17	0.0419
0.54	0.18	0.0539
0.57	0.19	0.0688
0.60	0.20	0.0877
0.63	0.21	0.1094
0.66	0.22	0.1368
0.69	0.23	0.1685
0.72	0.24	0.2069
0.75	0.25	0.2524

To implement the program, a maximum number of volumetric ID IGA indications that might theoretically leak in a generator, and still meet the leakage criterion, must be evaluated. This maximum number will then be used to determine a number of in situ pressure tests, with no leaks, that must be performed to statistically demonstrate that remaining indications will not leak in excess of the allowable leakage limit. This will be performed by analysis of the eddy current data for the volumetric ID IGA indications, evaluating the theoretical leak rate of those indications using Table 6, summing the leak rate from the indications, and comparing that summed leak rate to the leakage limit. For example, data from the plant's most recent 13R Outage was evaluated, and a theoretical leak rate was determined for each indication, assuming that 33% of each indication's measured axial extent was 100% TW. An average leak rate per indication per generator was calculated by dividing the total leak rate by the number of indications in each generator. The maximum allowable number of indications that might theoretically leak may then be calculated by dividing the leak rate limit for volumetric ID IGA by the average leak rate per indication. For various allowable leakage rates, the maximum allowable number of indications for Steam Generator A is shown in the following Table:

Table 7

Example: 13R Outage Steam Generator A – Maximum Allowable Number of Indications Determination

Crack Length Adjustment Factor	Leakage per indication (gpm)	Maximum Allowable Number of Indications		
		0.1 gpm	0.25 gpm	1.0 gpm
33%	9.516×10^{-4}	105	262	1050

Sections 8.0 and 9.0 of this report describe how in situ pressure tests will be performed as necessary to demonstrate that fewer than the maximum allowable number of indications, as described above, are present in the TMI-1 OTSGs.

7.0 EDDY CURRENT EXAMINATIONS OF TMI-1 VOLUMETRIC ID IGA

7.1 Examination Techniques and Analyses of ID IGA

7.1.1 Indication Population

As described earlier, the TMI-1 ID IGA degradation occurred in 1981. Numerous eddy current examinations were conducted while the plant was shutdown from 1981 to 1985; the upper tubesheet kinetic expansion repairs were made during this time period.

TMI-1's volumetric ID IGA indications have been in service since the plant's restart in 1985. In accordance with the plant's Technical Specifications, eddy current exams of the steam generator tubes have been conducted during each of the plant refueling outages since restart. Table 8, below, provides a list of bobbin probe eddy current scopes for the TMI-1 plant refueling outages since restart.

Table 8
TMI-1 Steam Generator Tubes Inspected Using Bobbin Probes

Refueling Outage	Year	OTSG Tubes Inspected by Bobbin	Percent of Inservice Tubes Inspected by Bobbin
5M	1986	2,732	~ 9%
6R	1986	6,218	~ 20%
7R	1988	4,126	~ 13%
8R	1990	3,202	~ 10%
9R	1991	2,209	~ 7%
10R	1993	2,642	~ 9%
11R	1995	6,821	~ 23%
12R	1997	29,415	100%
13R	1999	29,367	100%

As depicted in Table 8, Outage 12R (in 1997) was the first recent TMI-1 outage in which full length bobbin examinations of all inservice tubes were conducted. (This was also the first TMI-1 outage during which the plant's Technical Specifications included axial and circumferential extent criteria for the ID volumetric IGA indications.)

In addition to the increases in bobbin examination scope, increases in MRPC examination scopes have also occurred. TMI-1 committed, for its single-cycle Technical Specification changes for ID IGA, to perform MRPC examinations of all bobbin coil indications of ID degradation. In addition, a large number of MRPC examinations have been performed in the upper tubesheet kinetic expansions. The following Table depicts the number of MRPC examinations of TMI-1 tubing for the last three plant refueling outages:

Table 9
TMI-1 Steam Generator Tubes Inspected Using MRPC Probes

Refueling Outage	Year	Number of Tubes Inspected by MRPC	Number of Tubes Receiving First MRPC Examination
11R	1995	731	638
12R	1997	8,330	8,056
13R	1999	13,220	11,085

The net result of the increase in bobbin coil and MRPC examination scopes, along with the increased sensitivity of eddy current electronic equipment, since 1981 has been an increase in identified volumetric ID IGA indications in the TMI-1 generators. At the end of the last outage, 1,123 MRPC-confirmed volumetric ID IGA indications remained in service in the TMI-1 OTSGs. Of those 1,123 indications, 373 were detected with the bobbin probe. As additional MRPC examinations are performed in the TMI-1 OTSGs, and the sensitivity of eddy current electronic equipment continues to increase over time, it is projected that more small volumetric ID IGA indications will be identified.

7.1.2 Historical Growth Evaluations

Inspection of TMI-1 ID IGA indications allows characterization of their size and change in size in terms of bobbin coil voltage, bobbin coil depth estimates, axial length, and circumferential extent. Apparent changes in a particular examination result, for example bobbin voltage, may be calculated from the difference in voltage measured from two inspections for each flaw. The resulting empirical distribution of change in the examination result provides an indication of how the entire population of detected flaws are behaving as they continue in service. Uncertainties in the eddy current exam process, and changes in eddy current examination methods, must be considered when assessing the potential growth of the population.

There are several methods that have been used to assess the growth of individual ID IGA indications during the 1981-1999 outages. These assessments have considered both newly detected and previously detected ID IGA indications. Population comparisons of the recorded indications have been used to assess whether changes in the indication population have occurred. For example, population comparisons of the rate of occurrence have been made each outage. (OTSG "A" has a higher rate of occurrence than does OTSG "B".) Location of the defects has also been used as a comparison method from outage-to-outage. The ID IGA indications tend to be located in the upper part of the tube bundles in each of the generators (closer to the air/water interface during the 1981 thiosulfate intrusion.) In OTSG "A" the indications tend to be more toward the periphery of the tube bundle, while in OTSG "B" the indications tend to be more uniformly distributed over the cross-section of the generator.

Population comparisons on the basis of voltages and through-wall estimates (–if available) have also been utilized. The ID IGA indications overall tend to be low in voltage and part through wall.

In addition to population comparisons, comparisons of individual indications from outage-to-outage have also been used. Individual indication voltage changes from outage-to-outage have been evaluated. Individual indication throughwall depth estimates have been monitored from outage-to-outage. For example, Table III-6 of the 1995 11R Outage report (Ref. 2.12, Attachment 1, Page 26) provided information on outage-to-outage comparisons of the degraded tubes performed between 1984 and 1995. That Table's information is provided, along with updated voltage normalization information, and is reprinted in the following Table 10:

Table 10
A Comparison of Bobbin Indications in Degraded Tubes
[Reprint of Table III-6 from 1995 11R Outage Report]

Period	Number of Indications	Mean Change (%TW)	Std Deviation (% TW)	Mean Change (Volts) / 1999 Voltage*	Std Deviation (Volts) / 1999 Voltage*
1984 to 1986 (Outage 5M)	152	-2.6	6.1	-0.2 / -0.08	0.3 / 0.12
1986 (5M) to 1986 (6R)	118	+1.1	6.6	+0.0 / +0.0	0.2 / 0.08
1986 (6R) to 1988 (7R)	119	+2.6	5.5	+0.2 / +0.08	0.3 / 0.12
1988 (7R) to 1990 (8R)	291	-0.2	7.43	-0.25 / -0.10	0.35 / 0.14
1990 (8R) to 1991 (9R)	229	-2.0	6.96	+0.07 / +0.03	0.31 / 0.12
1991 (9R) to 1993 (10R)	207	-0.6	6.62	+0.16 / +0.06	0.28 / 0.11
1993 (10R) to 1995 (11R)	197	+0.9	6.39	-0.26 / -0.10	0.4 / 0.16

* This column has been revised to show voltage values under both the previous and the current normalization. The first number is for a 10 volt normalization and the second number is for a 4 volt normalization. In 1999 Outage 13R TMI-1 changed its bobbin coil voltage normalization method from 10V to 4V peak-to-peak voltage on a 20% TW hole on the ASME calibration standard.

In the 1980's 8x1 probes were used to assess the circumferential extents of the indications. Extents from 8x1 probe examinations were evaluated to assess whether growth may or may not be occurring. In the 1990's new surface-riding MRPC probes with smaller eddy current coils, along with advances in computers, have allowed individual indication voltages, through wall estimates (if assigned), axial extents, and circumferential extents to be assessed.

As described above, from 1981 to 1999 the scope and sensitivity of the TMI-1 tube exams has been increasing, and there has been a commensurate increase in the number of ID IGA indications detected. During each outage since 1981 TMI-1 has assessed the continuing dormancy of the ID IGA mechanism. TMI-1 has:

- assessed whether newly detected indications are consistent with the locations, voltages, and throughwall estimates of previously identified indications.

- assessed whether, on the average, the voltages and percent throughwall estimates of individual ID IGA indications have increased (for the ID IGA indications that could be compared).

- (using MRPC data in the more recent outages) assessed whether, on the average, the circumferential extents or axial extents of individual ID IGA indications have increased (for the ID IGA indications that could be compared.)

- created data scatter plots to visualize the data so as to assess whether the indication population has exhibited growth, help identify outliers, and review distributions of data.

Section 8.0 of this report provides a revised procedure by which the growth of volumetric ID IGA indications will be evaluated, including procedures for assessing the statistical significance of any apparent changes in the population of these flaws. The revised procedure provides guidance for condition monitoring analyses.

7.1.3 Examination Uncertainties

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 (Reference 2.13) so as to incorporate the data from the volumetric ID IGA flaws 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 each of 23 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 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 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 1999 study determined that the measured combined variability for the examination technique and analyst variability at the 95% Lower Confidence Level for ID volumetric indications was 0.047" for axial length and 0.048" for circumferential length. These variabilities are inconsequential considering that MRPC probes consistently overestimate the actual lengths of the volumetric ID IGA flaws. 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." (Reference 2.13) 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.

8.0 PROCEDURE FOR MONITORING VOLUMETRIC ID IGA GROWTH

8.1 Introduction

This section provides a procedure for monitoring volumetric ID IGA growth in the TMI-1 steam generators. The procedure is a multi-step process including statistical tests to detect changes in the apparent growth distributions. The procedure consists of screening the data for extreme values, followed by two tests that will be applied to bobbin voltage measurements, bobbin percent throughwall estimates, and circumferential length measurements from the ID IGA inspection data. The two tests will be the application of a sign test and a paired t-test. These two tests will be applied to each of the three variables. If all tests are passed (that is, if all six tests demonstrate that the ID IGA growth rate is less than a small positive value), it will be concluded that the ID IGA population is not growing. If these tests are unsuccessful in demonstrating that growth is less than a small positive value, a cycle-specific growth model is required.

8.2 Capability of Statistical Tests to Detect a Change in Mean Growth

Increases in bobbin voltages, bobbin percent throughwall estimates, and other eddy current parameters for the TMI-1 ID IGA do not necessarily indicate actual growth of the flaws as they also reflect the NDE uncertainties associated with sizing these relatively small flaws (as discussed earlier in this report). The validity of classical statistical tests for no growth depends strongly on the assumption that the data are normally distributed. Departures from normality such as excessive peakedness or skewness effect the results of the tests and may lead to incorrect conclusions (for example, concluding that flaw dimensions have changed when, in fact, they have not). While generally similar to normal distributions, the TMI-1 IGA field data do exhibit some deviations from the ideal shape of both the central portion of the distributions as well as the tails. Therefore, the shape of these distributions may adversely affect future assessments of changes in the flaw dimensions. The methods described in this report may be applied even if the data does not have a normal distribution. Generally, large datasets tend to be normally distributed; so the risk of error is not substantial.

8.3 Procedure for Assessing ID IGA Growth

A statistical procedure will be used to assess ID IGA growth. Step I of the procedure consists of initial screening the data for extreme values, followed by two statistical tests that will be applied to bobbin voltages, bobbin percent throughwall estimates, and circumferential length measurements from the ID IGA inspection data:

(1) Sign test
(2) Paired t-Test

These two tests will be applied to each of the three variables (i.e., 6 tests). If all tests are passed (that is, if all test statistics calculated from the ID IGA growth data are statistically insignificant), it will be concluded that the ID IGA population is not growing. In this case, Step I is successful and one proceeds directly to determining the in situ requirements for operational assessments as described in Section 9.0.

If the Step I test results are unsuccessful, then some evidence exists in the apparent growth data that the population of ID IGA may have changed. At this point, Step II calls for the development of a cycle-specific growth model that should be applied in the operational assessment.

An outline of the procedure follows:

Step I. Perform Extreme Value Screening and Perform Statistical Tests for Change in ID IGA Flaw Population

Extreme Value Screening

1. Sign Test
2. Paired t-Test

Because of the limited data population in the "B" OTSG, data from the two steam generators will be combined for these tests. Data from individual indications will be compared back to the prior outage.

Step II. Develop A Cycle-Specific Model for the Volumetric ID IGA Flaw Population

[This step will not be performed if the Step I tests are successful.] A cycle-specific growth model will be developed by evaluating the changes in the mean, variability, and extremes of apparent growth, and will be required as a basis for a cycle-specific growth allowance for operational assessments. It may be necessary to re-verify the analyst-to-analyst variability that is applicable to the field data at hand and to evaluate the components of variability so that an accurate model of actual growth can be obtained.

8.3.1 Step Ia. Extreme Value Tests for Largest Growth Rates

An extreme value analysis will be used as an initial screening for indications that may be outliers in the datasets. For example, if an indication is mis-analyzed or mis-characterized as volumetric ID IGA (in either the current outage or a previous outage), the extreme value screening will help identify the indication. Similarly, if an indication were to grow by a large amount, this test will help to identify it. The extreme value screening serves to identify (mathematically) those indications that might also be found by visual inspection of a scatter diagram of the data for outliers.

Samples from normal distributions yield extreme (in this case maximum apparent growth) values that are described (for large sample sizes) by the so-called Type I Extreme Value distribution. Since the number of volumetric ID IGA flaws in the TMI-1 steam generators is relatively large, the Type I distribution is expected to provide a good representation of the expected frequency of extreme growth values. This screening is performed by comparing the largest observed growth value with the 5% critical value. If the largest growth value is less than the critical value, it will be concluded that the IGA growth data extreme value is not statistically significant.

If the extreme value screening identifies indications with erroneous data, the erroneous data will be corrected prior to using that data in the subsequent screenings, or subsequent Sign and Paired t statistical tests. If the extreme value screening identifies indications with large apparent growth rates, and are not due to erroneous results, these indications will be used in the subsequent statistical tests.

The extreme value analysis will be performed to identify possible outliers or erroneous data. Additionally, it will identify indications for consideration for in situ pressure testing.

8.3.2 Step Ib. Perform Sign Tests for Change in ID IGA Population

The Sign test is a statistical test for detecting differences in the median of a binomial distribution from a reference value. This test will be used to identify the presence of statistically significant (i.e., positive) change in the ID IGA flaws based on three eddy current measurements: measurements of bobbin voltage, bobbin percent through wall estimates, and circumferential length. This approach will not require that the data be normally distributed.

The Sign tests will determine if the growth of the ID IGA indications is bounded by the following small, positive reference values between examinations: 0.05V bobbin voltage increase, 1% throughwall bobbin depth estimate increase, and 0.01" circumferential extent increase. (The use of small positive values will reduce the possibility that random process error alone could result in mistakenly concluding that actual physical growth has occurred. The small depth and extent values are very small in comparison to the repair criteria.) The maximum Type I error (i.e., the probability of erroneously concluding that there is growth when there is actually no growth) is 5%.

The variables for the Sign tests are:

α = the significance level of the test = 0.05 for a one sided test

m_o = the standard = volts, % through wall, or inches (for bobbin voltage, percentage through-wall or circumferential length, respectively)

X_i = each observation (change in inspection parameter for each indication) for a given parameter, from 1 to n_{total}

n_{total} = the total number of indications for which there is data or observations for a given parameter

X = average of X_i

r = the number of observations less than the standard

r_{crit} = critical value of "r" for the sign test which is taken from Table A-33 in Reference 2.14

Note that the significance level of the test has been chosen to be equal to 0.05 which is a generally accepted value within industry. The significance level of the test, as well as the number of observations, affects the probability of making a correct determination.

If r is greater than r_{crit}, it is concluded that there is no reason to believe the measured parameter change is different from zero and therefore, there is no reason to believe the defects were growing in the given outage interval.

8.3.3 Step Ic. Perform Paired t-Tests for Change in ID IGA Population

The Paired t-test is a standard statistical test for hypothesis testing as regards the significance of differences in sample means. The standard paired t-test will be used to further evaluate whether growth is indicated by this classic parametric test. For this application, again the null hypothesis is that the mean change (growth) in the ID IGA flaws is bounded by the following small, positive reference values between examinations: 0.05V bobbin voltage increase, 1% throughwall bobbin depth estimate, and 0.01" circumferential extent. (As in Step Ib, the use of small positive values will reduce the possibility that random process error alone could result in mistakenly concluding that actual physical growth has occurred.)

α = the significance level of the test = 0.05 for a one sided test

m_o = the standard = volts, % through wall, or inches (for bobbin voltage, percentage through-wall or circumferential length, respectively)

X_i = each observation (change in inspection parameter for each indications) for a given parameter,

X = average of X_i

n = the total number of defects for which there is data or observations for a given parameter

u = difference between the observed average and the standard = X - m_o

$t_{1-\alpha/2}$ = percentile of the t distribution, taken from Table A-4 of Reference 2.14, as a function of level of significance, α and degrees of freedom, df

$$u_{crit} = t_{1-\frac{\alpha}{2}} \frac{s}{\sqrt{n}}$$

s = standard deviation

df = degrees of freedom = n - 1

If u is less than u_{crit}, it is concluded that there is no reason to believe the measured parameter change is different from zero and there is no reason to believe the defects were growing in the given outage interval. If u is greater than u_{crit}, it is concluded that the defects were growing in the given outage interval.

8.3.4 Step II. Develop Cycle Specific Growth Model

If Step I, above, is successful in demonstrating the lack of statistically significant growth in the ID IGA population, Step II is not necessary. However, in the event that future TMI-1 ID IGA field data indicates that growth is greater than a small positive value change from the historical population, or apparent growth as evidenced by the inability to demonstrate statistically insignificant growth via the procedures in Step I, it will be necessary to develop a cycle-specific model of growth. It may also be necessary to perform additional in situ tests of the larger flaws. This growth model will characterize changes in the mean, variability and extremes of apparent growth and will be important as a basis for a cycle-specific growth allowance to be used in operational assessments for forthcoming cycles.

It may be necessary to re-verify the analyst-to-analyst variability that is applicable to the field data at hand and to evaluate the components of variability so that an accurate model of actual growth can be obtained. Any growth analysis performed using the cycle specific growth model described here will require a revision to this report to include information substantiating the growth conclusions reached and the basis for the conclusions. The revised report will be submitted in a license amendment to the NRC well ahead of the subsequent refueling outage with any actions to address potential growth.

9.0 VOLUMETRIC ID IGA MANAGEMENT PROGRAM

The volumetric ID IGA management program is designed to ensure that OTSG tubes with volumetric ID IGA meet the repair criteria of Section 5.5 and the leakage criteria of Section 6.3 at the time of inspection and at the end of the next cycle of operation. The assessment process involves performing EC inspections of the defined region and then performing EC defect sizing of the indications characterized as volumetric ID IGA. Even if all in situ pressure tests of ID IGA indications result in no leakage, conservative statistical methods are used to predict a number of ID IGA indications that might remain in service and leak under hypothetical conditions. The allowable number of indications that might theoretically leak is determined based on calculated leak rates using the EC sizing information (as described in Section 6.3). Based on that number allowable, the required number of indications that must be in situ leak tested is calculated based on the limiting SG. Additional in situ leak testing is then performed as necessary to demonstrate compliance with the accident condition leakage criteria.

9.1 SG Tube Inspection

During each outage in which the management program is utilized, a 100% bobbin coil inspection of the defined region (Section 4.4) of in-service tubes will be conducted in accordance with the requirements of the TMI-1 steam generator tube inspection guidelines. All ID indications of tube degradation reported as a result of this bobbin coil inspection will then be inspected with an MRPC probe.

During each outage in which the management program is utilized a 100% MRPC inspection of the defined region (Section 4.4) of the lower 5" length of 22" kinetic expansions in in-service tubes at a radial location within the tube bundle of ≤ 47.00" will be conducted in accordance with the requirements of the TMI-1 steam generator tube inspection guidelines. (Bobbin coil probe examinations are not used to detect flaws in the upper tubesheet kinetic expansions since bobbin is not qualified for detection in this area of the tubing. The kinetic expansions are examined with more sensitive, surface-riding MRPC probes.)

During each outage in which this management program is utilized, an MRPC examination of all known volumetric ID IGA indications in the upper tubesheet kinetic expansion transitions will be conducted in accordance with the requirements of the TMI-1 steam generator tube inspection guidelines. (Bobbin coil probe examinations are not used to detect flaws in the upper tubesheet kinetic expansion transitions since the bobbin probe is not qualified for detection in this area of the tubing. The kinetic expansion transitions, like the kinetic expansions themselves, are examined with more sensitive, surface-riding MRPC probes.)

If the morphology of an indication as determined by MRPC is characterized as:

- ⇒ ID-initiated and volumetric, then the indication will be treated as volumetric ID IGA.

⇒ OD-initiated, or crack-like, or mixed mode, then the indication will be treated as a mechanism other than volumetric ID IGA and will be repaired.
⇒ no defect, then it will be assumed that the bobbin or MRPC indication is not a defect.

The number of bobbin indications that are confirmed volumetric ID IGA, plus any additional volumetric ID IGA indications not reported by the bobbin examinations but detected during the MRPC examinations are considered to make up the detected population for each steam generator each outage.

9.2 Sizing of Volumetric ID IGA

All indications dispositioned as volumetric ID IGA will then be assigned estimated sizes. Sizing includes determining a bobbin voltage (if possible), a bobbin estimated throughwall depth (if possible), an axial extent, and a circumferential extent for each volumetric ID IGA patch. The NDE techniques used to perform these measurements are the best available methods and equipment, and are chosen such that a viable comparison can be made with the previous inspection's EC data. (Refer to Section 4.3 of this report for a description of the eddy current probes/coils to be used for the inspections conducted under the program.)

If new eddy current practices are used in an inspection that affect comparison to prior volumetric ID IGA data, then the EC data from the previous inspection(s) will be re-analyzed to provide an equivalent measurement comparison. If the new eddy current practices involve a different coil, or some other change that makes direct comparison with the previous outage impossible, then prior NRC approval is required.

9.3 Probability of Detection

Detection of the TMI-1's volumetric ID IGA with the bobbin coil is enhanced by its proximity to the probe coils (i.e., inside diameter probes for inside diameter flaws). The bobbin coils are capable of detecting ID IGA that might impact the integrity of the steam generator tubing or have a reasonable probability for leakage.

As described earlier in this report, the majority of the identified, inservice, volumetric ID IGA indications were small indications detected with more sensitive MRPC probes, and are not detectable by bobbin. At the end of the 13R Outage in 1999, approximately one third of the identified volumetric ID IGA indications in the TMI-1 generators were detected by bobbin; the other two thirds were "first detected by MRPC probes." Thus, there is no need to mathematically increase the number of bobbin indications of volumetric ID IGA to account for a bobbin POD. For the purpose of this management program, it will be assumed that the population of indications detected in the defined area, including those found by bobbin and those found by MRPC, constitute the population of indications with any chance of leakage.

9.4 New Indications

As discussed in Section 4.1, the volumetric ID IGA is attributed to sulfur ingress while the plant was shutdown in 1981. Given the small physical size of the ID IGA, however, as EC techniques and equipment continue to improve, indications not previously reported may be found. When a bobbin indication not previously reported is found, the EC inspection history will be reviewed to determine whether or not the indication was present previously. All newly identified volumetric ID IGA indications will be reviewed to determine if they meet or exceed the repair criteria; if not, they will be added to the plant's steam generator degradation database and monitored for growth.

9.5 EC Measurement Repair Limits

Repair limits are established in the plant's Technical Specifications (shown below in Table 11). Four EC measurements are performed on the volumetric ID IGA indications as discussed in Section 9.2. These measurements include a bobbin voltage (if possible), a bobbin estimated throughwall depth (if possible), an axial extent, and a circumferential extent. Repair limits are provided in the plant's Technical Specifications for bobbin estimated throughwall depth (if determined), axial extent, and circumferential extent. Bobbin voltage is a prescribed limit in the plant's Technical Specifications to identify degraded tubes with IDIGA indications requiring examinations in future outages.

The Technical Specification axial extent and circumferential extent repair limits are set at 0.25 and 0.52 inches, respectively, based on the analyses discussed in Section 5.0. These limits are considered conservative based on the fact that, in application, the limits will be compared against EC measurements that typically overestimate the flaw extents. A repair limit of 40% is also stipulated in the Technical Specifications for bobbin percent throughwall estimate.

Table 11
EC Measurement Repair Limits

Axial Extent (inches)	Circumferential Extent (inches)	Bobbin Coil Percent Throughwall Estimate
> 0.25	> 0.52	≥ 40%

9.6 Condition Monitoring Assessment

Condition monitoring is the assessment of the "as found" condition of the tubing relative to the steam generator performance criteria. The "as found" condition refers to the condition of the tubes during a SG inspection outage, prior to any plugging or repair of tubes.

Growth evaluations and in situ pressure testing, where necessary, will be used to assess the condition of the volumetric ID IGA indications with respect to the performance criteria.

9.6.1 Apparent Growth Evaluation

The growth evaluation is performed using the process outlined in Section 8.0 and is considered an apparent growth evaluation (because it is based on the relative change in numerous EC measurements as opposed to direct physical measurements). For the purposes of growth analyses, the number of indications includes all volumetric ID IGA indications detected and sized both at the beginning of the cycle (BOC) and the end of the cycle (EOC).

If the assumption of no growth continues to be supported based on the statistical tests prescribed in Section 8.0, then it is assumed that the volumetric ID IGA is not changing or growing. This allows the use of past tube destructive examination data, laboratory leak testing results, and in situ testing results to be used for assessing the condition of the volumetric ID IGA indications.

For instance, Sections 5.2.1 and 6.1 of this report illustrate that in 1997 19 volumetric ID IGA defects were leak tested either in a laboratory or in situ. None of these tests resulted in any leakage at 3xNOP pressures. Growth evaluations (including Sign tests and Paired t-tests per Section 8.0 for the "A" Steam Generator) performed using data for the 1995-to-1999 and 1997-to-1999 inspection intervals supported no growth and therefore, if no growth continues to be supported during future inspections, this data could be credited in the leakage assessments.

9.6.2 Population Size Defined

As described earlier, TMI-1 will in situ pressure test a sufficient number of volumetric ID IGA indications to demonstrate that potential leakage from indications remaining in service will be less than the allowable limit. The detected population is defined as all indications characterized by EC to be volumetric ID IGA during the current inspection (Section 9.1).

If the conclusion of the apparent growth evaluation (Section 8.3.1) is no growth, then previous leak testing data may be applied to the population (per Section 9.6.1). In other words, if it is concluded that the population is not changing, leak testing performed during an earlier inspection may be treated as though it were being performed during the current outage.

9.6.3 Determination of In Situ Pressure Test Sample Size

To provide an additional assessment of the volumetric ID IGA, a program involving in situ pressure testing will be utilized to monitor the current condition of the tubes and assess their future operability. The purpose of the in situ pressure testing is to provide a means of validating the premise that leaving tubes with volumetric ID IGA in service will not cause MSLB primary-to-secondary leakage rates in excess of allowable limits. The testing will be conducted to demonstrate that the limiting SG with the greatest number of ID IGA indications will meet the leakage criteria at the end of the next cycle of operation. Therefore, TMI-1 will determine the number of volumetric ID IGA patches that must be tested to provide a high level of confidence (95% confidence level) that any theoretical primary-to-secondary leakage through ID IGA patches left in service is less than the amount allocated.

9.6.3.1 Determine Allowable Number of Potential Leaking Indications

The first step will be to define the allowable MSLB leakage rate for the population of ID IGA indications. Based on the condition of the generators, the portion of the 1 gpm allowable leakage rate allocated to volumetric ID IGA indications may change from inspection to inspection and is therefore not set in this report. (Section 6.3 of this report describes the methods by which the allowable number of volumetric ID IGA indications that might leak will be calculated based on the leakage rate allocated.)

9.6.3.2 Determine Required Number of In Situ Tests

After each outage, a statistical assessment will be utilized to determine the number of in situ tests. For this assessment, the hypergeometric distribution is appropriate since it gives the probability of finding B number of successes (leaking indications) in a sample (taken without replacement) of n trials out of a total population of N. The total number of leaking indications in the population can then be determined with a specified degree of confidence (e.g., 95%). For the subject assessment at TMI-1, the binomial approximation of the hypergeometric distribution will be used (see Reference 2.15).

The statistical analysis performed under the program will make the assumption that all the volumetric ID IGA indications have an equal probability of leaking. The program's statistical analysis will also assume that all the volumetric ID IGA indications have an equal probability of leaking irrespective of the generator in which they are located. (Both of the generators share a common primary coolant system, and they were both damaged simultaneously by the sulfur intrusion into the primary system in 1981.) Therefore, TMI-1 may conduct in situ pressure testing on ID IGA indications in one generator in order to assess the integrity of indications in the other generator. (By having the ability to perform in situ testing in either generator, the TMI-1 staff will save time, money and worker radiation dose.)

After calculating the allowable number of indications that might leak in the generators, TMI-1 will calculate the number of in situ pressure tests that must be performed, with no leaks, to be statistically certain (95% one-sided confidence interval) the allowable number of untested indications remaining in service will leak less than the allowable leakage limit. The goal of this evaluation will be to determine the test sample size, n, that must be tested and found with a certain number of through-wall indications such that the number of potentially leaking indications in the entire population does not exceed the maximum allowable limit and that the total leak rate limit is not exceeded.

For instance, assume that it is determined that a steam generator has a volumetric ID IGA population of 1,395 indications. Further, assume that the allowable leakage rate is set to

0.1 gpm, resulting in an allowable number of potentially leaking indications equal to 105. [Refer to Section 6.3 for a description of the calculation of the allowable number of potentially leaking indications.] Also, in this example the analysis assumes that zero leaking throughwall indications are expected during the in situ pressure tests. With these assumptions, the final sample size to be tested is equal to 39. That is, if in situ pressure tests were performed on these 39 indications, with no leaks, the expected number of leaking indications in the total population of indications is less than 105, and the expected leakage from the generator during an MSLB for the ID IGA indications is less than 0.1 gpm with 95% confidence.

9.6.4 In situ Leak Testing

As described above, the purpose of the in situ pressure testing is to provide a means of validating the premise that leaving tubes with volumetric ID IGA in service will not cause MSLB primary-to-secondary leakage rates in excess of the plant technical specification allowable. The testing will be conducted to demonstrate that the limiting SG with the greatest number of ID IGA indications will meet the leakage criteria at the end of the next cycle of operation. As discussed in Section 6.3, the most probable cause of leakage is through the development of an axial crack in the volumetric ID IGA during plant operation. Therefore, leak tests will be conducted at the MSLB pressure differential of 2,575 psig (with additional allowance for temperature correction and test instrumentation error) without a specific axial load in order to maximize the hoop stress in the tube.

Upon completion of the leak testing, the hypergeometric distribution assumptions (Section (9.6.3.2) will be verified. If the assumptions have changed such that a 95% confidence level is not achieved, then more samples will be tested in order to reach the 95% confidence. If the assumption about the number of leaking indications found during in situ pressure testing proves to be non-conservative, then the procedure of Section 9.6 must be repeated with the reduced population. The mathematical procedures are repeated using the population of indications that have not yet been tested and more tests are performed as necessary to achieve 95% confidence. In this case, however, previous testing performed in accordance with Section 9.6 will not be credited.

APPENDIX A

(Excerpt from: Technical Specification Change Request No. 277, Enclosure 1, Page 10 of 18)

During Outage 12R, a tube (A 52-34) was pulled from the "A" TMI-1 steam generator that contained several volumetric ID IGA flaws. (This tube would have been repaired under the subject criteria as it contained an ID IGA flaw that was estimated as 50 percent through wall by bobbin coil examination. Essentially the "full length" of the tube was pulled; the upper and lower tube sheet expansions of the tube were not pulled.) The purpose of the tube pull was to reconfirm the ability of bobbin eddy current to identify the important flaws, to confirm the ability of rotating probe eddy current to determine the morphology and conservatively estimate the extents of the flaws in the field, and to perform chemical and metallurgical tests on these flaws. Several of the volumetric ID IGA flaws from this tube were subjected to laboratory leak and burst tests. These tests were undertaken to supplement the in situ pressure testing of ID IGA flaws that was performed in the generators during Outage 12R. The results of the laboratory leak and burst testing were provided to the NRC in Reference 5. None of the ID IGA flaws leaked at pressures simulating up to 3 times the normal operating delta P, with applied axial loads simulating those calculated for a hypothetical Main Steam Line Break (MSLB). No internal flaw bladders or supports were used for any of these leak or burst tests. The burst pressures of the tube sections containing ID IGA indications that were tested were above 10,000 psig, indicating that substantial structural margin exists for these flaws. These burst pressures are nearly equal to those of non-defective virgin tubing; recent burst tests of three non-defective virgin OTSG tube lengths had an average burst pressure of 11,216 psig.

The Outage 12R pulled tube laboratory results demonstrated that the MRPC probes are conservative in their evaluation of TMI-1's volumetric ID IGA axial and circumferential extents. For example, Table 1 compares the axial extents of the flaws in the TMI-1 pulled tube, as called by field MRPC eddy current, with the subsequent metallographic findings from the laboratory for those same flaws.

Table 1:
Comparison of Field Eddy Current Estimated and Laboratory Determined ID IGA Axial Extents of TMI-1 Pulled Tube Flaws

TMI-1 Tube A 52-34 Flaw Type (as called by MRPC)	Location (Field)	Field Axial Length (by MRPC)	Maximum Laboratory Axial Length (How determined.)	Ratio of Field Axial Length to Lab Axial Length
ID Volumetric IGA	7 + 36.8"	0.11"	0.024" (Radial Grinding / Photo Exam)	4.6
ID Volumetric IGA	13 + 23.1"	0.16"	0.033" (Radial Grinding/ Photo Exam)	4.8
ID Volumetric IGA	14 + 12.8"	0.16"	0.054" (Radial Grinding / Photo Exam)	3.0
ID Volumetric IGA	14 + 31.9"	0.16"	0.042" (Radial Grinding / Photo Exam)	3.8
ID Volumetric IGA	15 + 14.7"	0.10"	0.029" (Radial Grinding / Photo Exam)	3.4
ID Volumetric IGA	15 + 24.9"	0.10"	0.030" (Radial Grinding / Photo Exam)	3.3
ID Volumetric IGA	UTS + 0.06"	0.20"	0.040" (Radial Grinding / Photo Exam)	5.0
ID Volumetric IGA	13 + 2.9"	0.10"	≅ 0.066" (By longitudinal grind at 1 of 2 fracture surfaces* / Photo exam)	≅ 1.5
ID Volumetric IGA	15 + 38.2"	0.10"	≅ 0.020" (By longitudinal grind at 1 of 2 fracture surfaces* / Photo exam)	≅ 5

* These two flaws were located at the fracture surfaces resulting from the laboratory burst testing. The flaws were torn in half during the testing and one of the two fracture surfaces was ground to determine the flaw morphology.

A similar degree of conservatism was noted for the circumferential extents as was seen for the axial extents. The following Table compares the circumferential extent of the flaws in the TMI-1 pulled tube as called by field MRPC eddy current with the subsequent metallographic findings from the laboratory for the same flaws:

Table 2:
Comparison of Field Eddy Current Estimated and Laboratory Determined ID IGA Circumferential Extents of TMI-1 Pulled Tube Flaws

TMI-1 Tube A 52-34 Flaw Type (as called by MRPC)	Location (Field)	Field Circumferential Width (by MRPC)	Maximum Laboratory Circumferential Width (How Determined)	Ratio of Field Circumferential Width to Lab Circumferential Width
ID Volumetric IGA	7 + 36.8"	0.11"	0.022" (Radial Grinding/ Photo Exam)	5.0
ID Volumetric IGA	13 + 23.1"	0.11"	0.020" (Radial Grinding/ Photo Exam)	5.5
ID Volumetric IGA	14 + 12.8"	0.19"	0.025" (Radial Grinding/ Photo Exam)	7.6
ID Volumetric IGA	14 + 31.9"	0.11"	0.019" (Radial Grinding/ Photo Exam)	5.8
ID Volumetric IGA	15 + 14.7"	0.06"	0.018" (Radial Grinding/ Photo Exam)	3.3
ID Volumetric IGA	15 + 24.9"	0.11"	0.018" (Radial Grinding/ Photo Exam)	6.1
ID Volumetric IGA	UTS + 0.06"	0.14"	0.025" (Radial Grinding/ Photo Exam)	5.6
ID Volumetric IGA	13 + 2.9"	0.11"	≅ 0.032" (By longitudinal grind at 1 of 2 fracture surfaces*/Photo exam)	≅ 3.4
ID Volumetric IGA	15 + 38.2"	0.06"	≅ 0.016" (By longitudinal grind at 1 of 2 fracture surfaces* /Photo exam)	≅ 3.8

* As mentioned above, these two flaws were located at the fracture surfaces resulting from the laboratory burst testing. The flaws were torn in half during the testing and one of the two fracture surfaces was ground to determine the flaw morphology. The circumferential extent listed in Table 2 for these two flaws were estimated by doubling the circumferential extent that was determined for one of the two fracture surfaces.

Tables 1 and 2 indicate that the MRPC probes are able to conservatively assess the axial and circumferential extents of the TMI-1 ID IGA flaws. In general, eddy current measurements of volumetric IGA axial and circumferential flaw length are typically conservative because of a combination of field effect and the degradation morphology. An eddy current coil interrogates a volume of tube material that is larger than the physical dimensions of the coil. Because a coil's electromagnetic field extends beyond the coil dimensions, inspection probes have the ability to detect degradation before and after the coil passes over the actual tube degradation. This has the effect of extending the measured bounds of tube degradation beyond the actual bounds of the degradation. As illustrated in Tables 1 and 2, this was the case for the pulled tube during Outage 12R. The ability to detect degradation before passing a coil over the affected tube areas also depends, in part, on the geometry of the degradation. The three-dimensional morphology of TMI-1's ID IGA tube degradation facilitates its detection by eddy current methods.

The TMI-1 ID IGA flaws that remain in service were inspected with the same MRPC probes and techniques as the pulled tube. Thus, it is reasonable to assume that axial and circumferential extents of the ID IGA flaws remaining in service were also conservatively evaluated with the MRPC probes used in Outage 12R.

Three of the ID IGA flaws in the Outage 12R pulled tube were detected by the bobbin probe and assigned through wall estimates based on phase angle analysis prior to their removal from the generator. The following Table compares the through wall extent of those flaws in the TMI-1 pulled tube as called by bobbin coil phase angle analysis versus the subsequent metallographic findings from the laboratory for the same flaws. The depths in the Table that were determined by radial grinds are prefaced by a less than ("<") sign. These signs are due to the fact that the some of the flaws were incrementally ground from the inside surface of the tubing until the flaws were no longer present. The depth of the flaws was then assigned as less than the grind depth at which the flaw is no longer present in the tube wall.

Table 3:
Comparison of Field Eddy Current Estimated and Laboratory Determined ID IGA Depths of TMI-1 Pulled Tube Flaws

TMI-1 Tube A 52-34 Flaw Type	Location (Field)	Field Depth based on Bobbin Coil Phase Angle Analysis (in percent through-wall)	Maximum Laboratory Depth In percent through-wall based on 0.037" wall thickness and in inches (How Determined)
ID Volumetric IGA	13 + 23.1"	37%	< 49% < 0.018" (Radial Grinding / Photo Exam)
ID Volumetric IGA (fracture surface at burst location)	13 + 2.9"	50%	30% 0.011" (By longitudinal grind at 1 of 2 fracture surfaces / Photo exam)
ID Volumetric IGA (fracture surface at burst location)	15 + 38.2"	17%	19% 0.007" (By longitudinal grind at 1 of 2 fracture surfaces / Photo exam)

Nine (9) ID IGA flaws from the pulled tube were examined in a laboratory to determine morphology (length, width, and depth). Tables 1 and 2 provided the axial and circumferential extent data on the nine flaws. Table 3, above, provided the depth data for the three (3) flaws that were assigned a depth estimate by the bobbin probe prior to pulling the tube. Table 4 provides the laboratory depth data for the other six (6) flaws, which had insufficient bobbin coil eddy current signal to be given depth estimates using the bobbin probe, or were not detected by the bobbin coil probe. It is noteworthy that none of the flaws represented in Table 4 (i.e., flaws that were not provided with estimated depths in the field) were deeper than the deepest flaw represented in Table 3.

Table 4:
Laboratory Determined ID IGA Depths of TMI-1 Pulled Tube Flaws without Field Eddy Current Depth Estimates

TMI-1 Tube A 52-34 Flaw Type	Location (Field)	Maximum Laboratory Depth in percent through-wall based on 0.037" wall thickness and in inches (How Determined)
ID Volumetric IGA	7 + 36.8"	< 32% < 0.012" Radial Grinding / Photo Exam
ID Volumetric IGA	14 + 12.8"	< 38% < 0.014" Radial Grinding / Photo Exam
ID Volumetric IGA	14 + 31.9"	< 32% < 0.012" Radial Grinding / Photo Exam
ID Volumetric IGA	15 + 14.7"	< 32% < 0.012" Radial Grinding / Photo Exam
ID Volumetric IGA	15 + 24.9"	< 43% < 0.016" Radial Grinding / Photo Exam
ID Volumetric IGA	UTS + 0.06"	< 38% < 0.014" Radial Grinding / Photo Exam

Tables 3 and 4 illustrate that many of the TMI-1 volumetric ID IGA flaws are too small to be detected with the bobbin coil probe, or may be too small to be assigned a through-wall extent using bobbin coil phase angle analysis. The very small eddy current signal, and the resulting low signal-to-noise ratio, of many of these small flaws precludes reliable detection and/or through-wall extent estimates using the bobbin coil probe. The bobbin coil is, however, able to detect the larger ID IGA flaws; thus, the bobbin probe provides a screen with which the most significant flaws are detected. GPU Nuclear performed laboratory leak and burst testing on pulled tube flaws detected by the bobbin probe, as well as flaws that were not detected by the bobbin probe. Reference 5 reported the laboratory leak and burst test results to the NRC. All of the ID IGA flaws that were tested met the structural requirements required by Draft Regulatory Guide 1.121 (Reference 7), and demonstrated no leakage at 3 times normal operating delta P.

ENCLOSURE 3

ADDITIONAL INFORMATION - LICENSE CHANGE APPLICATION NO. 291

AFFECTED TMI UNIT 1 TECHNICAL SPECIFICATION PAGES

(Includes summary change for LCA-291 as affected by this submittal)

Summary change for LCA-291 as affected by this RAI Response

The following lists the changes on each of the affected pages:

Page 4-78

A new Section 4.19.2.c is added which reads as follows:

"c. Implementation of the repair criteria for Inside Diameter (ID) Inter-Granular Attack (IGA) requires 100% bobbin coil inspection of all non-plugged tubes in accordance with AmerGen Engineering Report, ECR No. TM 01-00328 during all subsequent steam generator inspection intervals pursuant to 4.19.3. ID IGA indications detected by the bobbin coil probe shall be characterized using rotating coil probes, as defined in that report."

Page 4-80

TS 4.19.4.a.3 is revised in the definition of a degraded tube, regarding the criteria for ID IGA indications, to delete the restriction of applicability only to Cycle 13. The phrase, "(for operation through Cycle 13 only)," is deleted.

Page 4-81

1. Section 4.19.4.a.6 is revised in the definition of "repair limit" to remove the phrase "...For operation through Cycle 13 only,..." so that the criteria (pertinent to ID IGA indications) are made permanent.

2. Section 4.19.4.a.9 is revised to replace the words, "a bobbin coil" with the word "an" so that the volumetric ID IGA repair criteria are applied to rotating coil indications in the defined regions (as shown above), and rotating coil indications of volumetric ID IGA are reported to the NRC in the written report submitted in accordance with TS 4.19.5.b.

3. Section 4.19.5.a is deleted and the subject notifications (verbal reports) are moved to 4.19.5.b to be included in the written report submitted 90 days after completion of the inspections and repairs.

Page 4-82

1. Section 4.19.5.b.3 has been revised to require bobbin coil depth estimate data, if determined, to be included in the written report submitted 90 days after completion of inspections and repairs. This is an editorial clarification to reflect that not all ID IGA flaws are detected with the bobbin coil.

2. Section 4.19.5.b is revised to include the items moved from Section 4.19.5.a.

Page 4-83

1. Several references to "the 13R Outage" and "Cycle 13 operation" in the Bases are deleted.

2. The words "does not show growth greater than expected ECT repeatability variations" are deleted and replaced with the words "meets the requirements of AmerGen Engineering Report, ECR No. TM 01-00328." This change is made to incorporate in the Bases the more prescriptive growth assessment requirements required by the report.

each inservice inspection shall include at least 3% of the total number of tubes in all steam generators; the tubes selected for these inspections shall be selected on a random basis except:

a. The first sample of tubes selected for each inservice inspection (subsequent to the preservice inspection) of each steam generator shall include:

1. All nonplugged tubes that previously had detectable wall penetrations (>20%).

2. At least 50% of the tubes inspected shall be in those areas where experience has indicated potential problems.

3. A tube inspection (pursuant to Specification 4.19.4.a.8) shall be performed on each selected tube. If any selected tube does not permit the passage of the eddy current probe for a tube inspection, this shall be recorded and an adjacent tube shall be selected and subjected to a tube inspection.

4. Tubes in the following groups may be excluded from the first random sample if all tubes in a group in both steam generators are inspected. No credit will be taken for these tubes in meeting minimum sample size requirements.

   (1) Group A-1: Tubes in rows 73 through 79 adjacent to the open inspection lane, and tubes between and on lines drawn from tube 66-1 to tube 75-15 and from 86-1 to 77-15.

   (2) Group A-2: Tubes having a drilled opening in the 15th support plate.

b. The tubes selected as the second and third samples (if required by Table 4.19.2) during each inservice inspection may be subjected to a partial tube inspection provided:

1. The tubes selected for these second and third samples include the tubes from those areas of the tube sheet array where tubes with imperfections were previously found.

2. The inspection includes those portions of the tubes where imperfections were previously found.

c. Implementation of the repair criteria for Inside Diameter (ID) Inter-Granular Attack (IGA) requires 100% bobbin coil inspection of all non-plugged tubes in accordance with AmerGen Engineering Report, ECR No. TM 01-00328 ~~Revision~~ during all subsequent steam generator inspection intervals pursuant to Section 4.19.3. ID IGA indications detected by the bobbin coil probe shall be characterized using rotating coil probes, as defined in that report.

The results of each sample inspection shall be classified into one of the following three categories:

Category	Inspection Results
C-1	Less than 5% of the total tubes inspected in a steam generator are degraded tubes and none of the inspected tubes are defective.

4.19.3 Inspection Frequency (Continued)

c. Additional, unscheduled inservice inspections shall be performed on each steam generator in accordance with the first sample inspection specified in Table 4.19-2 during the shutdown subsequent to any of the following conditions:

1. A seismic occurrence greater than the Operating Basis Earthquake.
2. A loss of coolant accident requiring actuation of engineering safeguards, or
3. A major main steam line or feedwater line break.

d. After primary-to-secondary tube leakage (not including leaks originating from tube-to-tube sheet welds) in excess of the limits of Specification 3.1.6.3, an inspection of the affected steam generator will be performed in accordance with the following criteria:

1. If the leak is above the 14th tube support plate in a Group as defined in Section 4.19.2.a.4(1) all of the tubes in this Group in the affected steam generator will be inspected above the 14th tube support plate. If the results of this inspection fall into the C-3 category, additional inspections will be performed in the same Group in the other steam generator.
2. If the leaking tube is not as defined in Section 4.19.3.d.1, then an inspection will be performed on the affected steam generator(s) in accordance with Table 4.19-2.

4.19.4 Acceptance Criteria

a. As used in this Specification:

1. Imperfection means an exception to the dimensions, finish, or contour of a tube from that required by fabrication drawing or specifications. Eddy current testing indications less than degraded tube criteria specified in a.3 below may be considered imperfections.
2. Degradation means a service-induced cracking, wastage, wear or general corrosion occurring on either inside or outside of a tube.
3. Degraded Tube means a tube containing :
   (a) an inside diameter (I.D.) IGA indication with a bobbin coil indication $\geq$ **0.2** volt or $\geq$ 0.13 inches axial extent or $\geq$ 0.26 inches circumferential extent ~~(for operation through Cycle 13 only)~~ or
   (b) imperfections $\geq$ 20% of the nominal wall thickness caused by degradation.
4. % Degradation means the percentage of the tube wall thickness affected or removed by degradation.

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4.19.4 Acceptance Criteria (Continued)

5. Defect means an imperfection of such severity that it exceeds the repair limit. A tube containing a defect is defective.

6. Repair Limit means the extent of degradation at or beyond which the tube shall be repaired or removed from service because it may become unserviceable prior to the next inspection.

This limit is equal to 40% of the nominal tube wall thickness. ~~For operation through Cycle 13 only,~~ Inside diameter IGA indications shall be repaired or removed from service if they exceed an axial extent of 0.25 inches, or a circumferential extent of 0.52 inches, or a through wall degradation dimension of ≥ 40% if assigned.

7. Unserviceable describes the condition of a tube if it leaks or contains a defect large enough to affect its structural integrity in the event of an Operating Basis Earthquake, a loss of coolant accident, or a steam line or feedwater line break as specified in 4.19.3.c., above.

8. Tube Inspection means an inspection of the steam generator tube from the bottom of the upper tubesheet completely to the top of the lower tubesheet, except as permitted by 4.19.2.b.2, above.

9. Inside Diameter Inter-Granular Attack (IGA) Indication means an ~~a bobbin coil~~ indication initiating on the inside diameter surface and confirmed by diagnostic ECT to have a volumetric morphology characteristic of IGA.

b. The steam generator shall be determined OPERABLE after completing the corresponding actions (removal from service by plugging, or repair by kinetic expansion, sleeving, or other methods, of all tubes exceeding the repair limit and all tubes containing throughwall cracks) required by Table 4.19-2.

4.19.5 Reports

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a. ~~After the completion of each inservice inspection of steam generator tubes, prior to exceeding a reactor coolant system (RCS) temperature of 250 °F, the NRC shall be notified of the following:~~

5) ~~1)~~ The number of tubes repaired or removed from service in each steam generator,

6) ~~2)~~ An assessment of growth of inside diameter IGA degradation, and

7) ~~3)~~ Results of in-situ pressure testing, if performed.

MOVE TO 4.19.5 (b), on next page.

4.19.5 Reports (Continued)

b. The complete results of the steam generator tube inservice inspection shall be reported to the NRC within 90 days following completion of the inspection and repairs **(main generator breaker closure)**. The report shall include:

1. Number and extent of tubes inspected.

2. Location and percent of wall-thickness penetration for each indication of an imperfection.

3. Location, bobbin coil depth estimate (if determined), bobbin coil amplitude, and axial and circumferential extent (if determined) for each inside diameter IGA indication, and

4. Identification of tubes repaired or removed from service.

INSERT 5, 6, 7 from previous page here.

c. Results of steam generator tube inspections which fall into Category C-3 require notification in accordance with 10 CFR 50.72 prior to resumption of plant operation. The written follow-up of this report shall provide a description of investigations conducted to determine the cause of the tube degradation and corrective measures taken to prevent recurrence in accordance with 10 CFR 50.73.

Bases

The Surveillance Requirements for inspection of the steam generator tubes ensure that the structural integrity of this portion of the RCS will be maintained.

The program for inservice inspection of steam generator tubes is based on modification of Regulatory Guide 1.83, Revision 1. In-service inspection of steam generator tubing is essential in order to maintain surveillance of the conditions of the tubes in the event that there is evidence of mechanical damage or progressive degradation due to design, manufacturing errors, or inservice conditions. Inservice inspection of steam generator tubing also provides a means of characterizing the nature and cause of any tube degradation so that corrective measures can be taken.

The Unit is expected to be operated in a manner such that the primary and secondary coolant will be maintained within those chemistry limits found to result in negligible corrosion of the steam generator tubes. If the primary or secondary coolant chemistry is not maintained within these chemistry limits, localized corrosion may likely result.

The extent of steam generator tube leakage due to cracking would be limited by the secondary coolant activity, Specification 3.1.6.3.

The extent of cracking during plant operation would be limited by the limitation of total steam generator tube leakage between the primary coolant system and the secondary coolant system (primary-to-secondary leakage = 1 gpm). Leakage in excess of this limit will require plant shutdown and an unscheduled inspection, during which the leaking tubes will be located and repaired or removed from service.

Bases (Continued)

Wastage-type defects are unlikely with proper chemistry treatment of the primary or the secondary coolant. However, even if a defect would develop in service, it will be found during scheduled in-service steam generator tube examinations. For tubes with ID IGA indications, additional conservatism is being applied ~~through Cycle 13 operation,~~ to evaluate circumferential and axial dimensions for determining final disposition of the tube. For ID IGA indications through wall dimension will continue to be assigned to those indications where amplitude response permits measuring through wall dimension. Steam generator tube inspections of operating plants have demonstrated the capability to reliably detect degradation that has penetrated 20% of the original tube wall thickness.

Removal from service by plugging, or repair by kinetic expansion, sleeving, or other methods, will be required for degradation equal to or in excess of 40% of the tube nominal wall thickness. ~~For operation through Cycle 13 only,~~ tubes with I.D. initiated intergranular degradation may remain in service without % T.W. sizing if the degradation morphology has been characterized as not crack-like by diagnostic eddy current inspection and the degradation is of limited circumferential and axial length to ensure tube structural integrity. Additionally, serviceability for accident leakage under the limiting postulated Main Steam Line Break (MSLB) accident will be evaluated by determining that this I.D. initiated degradation mechanism is inactive (e.g. comparison of the ~~13R~~ outage examination results with the results from past outages ~~does not show growth greater than expected ECT repeatability variations~~) and by successful ~~13R~~ in-situ pressure testing of a sample of these degraded tubes to evaluate their accident leakage potential **when in-situ pressure tests are performed.**

(meets the requirements of AmerGen Engineering Report ECR No. TM 01-00328)

Where experience in similar plants with similar water chemistry, as documented by USNRC Bulletins/Notices, indicate critical areas to be inspected, at least 50% of the tubes inspected should be from these critical areas. First sample inspections sample size may be modified subject to NRC review and approval.

Whenever the results of any steam generator tubing inservice inspection fall into Category C-3 on the first sample inspection (See Table 4.19.2), these results will be reported to NRC pursuant to the requirements of Specification 4.19.5.c. Such cases will be considered by the NRC on a case-by-case basis and may result in a requirement for analysis, laboratory examinations, tests, additional eddy current inspection, and revision of the Technical Specifications, if necessary.

Note: The eddy current examination voltages referred to in this section (section 4.19) are based on a normalization procedure that sets the bobbin coil prime frequency peak-to-peak response from the four 20% through-wall holes of an ASME calibration standard to 4 volts.

ENCLOSURE 4

ADDITIONAL INFORMATION - TMI UNIT 1 LICENSE CHANGE APPLICATION NO. 291

REVISED NO SIGNIFICANT HAZARDS CONSIDERATION EVALUATION

This revision of the No Significant Hazards Evaluation provided by AmerGen with its December 6, 2000 submittal of TMI Unit 1 License Change Application No. 291 reflects the additional TS change needed in response to the NRC Requests for Additional Information dated May 23, 2001. The changes are indicated by margin bar.

No Significant Hazards Consideration

The Commission has provided standards for determining whether a significant hazards consideration exists as stated in 10 CFR 50.92. A proposed amendment to an operating license for a facility involves no significant hazards consideration if operation of the facility in accordance with a proposed amendment would not: (1) involve a significant increase in the probability or consequences of an accident previously evaluated; or (2) create the possibility of a new or different kind of accident from any accident previously evaluated; or (3) involve a significant reduction in a margin of safety. A discussion of these standards as they relate to this change request follows.

1. Operation of the facility in accordance with the proposed amendment will not involve a significant increase in the probability or consequences of an accident previously evaluated.

   The proposed flaw disposition strategy, based on measurable eddy current parameters of axial and circumferential extent for Inside Diameter (ID) Initiated Inter-Granular Attack (IGA), will continue to provide high confidence that unacceptable flaws that do not have the required structural integrity to withstand a postulated MSLB are removed from service. The axial and circumferential length limits for eddy current ID degradation indications meet the Draft Regulatory Guide 1.121 (Reference 9) acceptance criteria for margin to failure for MSLB-applied differential pressure and axial tube loads. The capability for detection of flaws is unaffected; and the identification of tubes that should be repaired or removed from service is maintained. The operation of the OTSGs or related structures, systems, or components is otherwise unaffected. Therefore, neither the probability nor consequences of a Steam Generator Tube Rupture (SGTR) is significantly increased either during normal operation or due to the limiting loads of a MSLB accident. Revision of the reporting requirements is administrative in nature and would have no effect on any accident previously evaluated.

   Therefore, operation of the facility in accordance with the changes included in LCA No. 291 will not involve a significant increase in the probability or consequences of an accident previously evaluated.

2. Operation of the facility in accordance with the proposed amendment will not create the possibility of a new or different kind of accident from any accident previously evaluated.

   The proposed changes do not create the possibility of a new or different kind of accident from any accident previously evaluated because there are no hardware changes involved nor changes to any operating practices. These changes involve only the OTSG tube inservice inspection surveillance requirements, which could only affect the potential for OTSG primary-to-secondary leakage which has been analyzed and is subject to Technical Specification requirements not affected by these changes. The proposed changes continue to impose flaw length limits for ID IGA to assure tube structural and leakage integrity. Revision of the reporting requirements is administrative in nature and would have no potential for creation of an accident scenario different from any previously evaluated.

Therefore, operation of the facility in accordance with the changes included with LCA No. 291 will not create the possibility of a new or different kind of accident from any accident previously evaluated.

3. Operation of the facility in accordance with the proposed amendment will not involve a significant reduction in a margin of safety.

The margins of safety defined in Draft Regulatory Guide 1.121 (Reference 9) are retained. The probability of detecting degradation is unchanged since the bobbin coil eddy current methods will continue to be the primary means of initial detection and the probability of leakage from any indications left in service remains acceptably small. The strategy for dispositioning ID-initiated IGA indications will continue to provide a high level of confidence that tubes exceeding the allowable limits for tube integrity are repaired or removed from service. Revision of the reporting requirements is administrative in nature and would not affect any safety margin.

Therefore, operation in accordance with the changes included in LCA No. 291 will not involve a significant reduction in a margin of safety.

Based on the negative responses to these three criteria, AmerGen has concluded that the requested change does not involve a significant hazards consideration.