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April 11, 1985

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In the Matter of
Metropolitan Edison Company, Et Al.
(Three Mile Island Nuclear Station, Unit No. 1)
Docket No. 50-289-OLA (Steam Generator Repair)

Dear Administrative Judges:

Enclosed for the Appeal Board's information are two documents entitled "Evaluation of the 1984 Required Technical Specification Examination for the TMI-1 OTSG" (TDR-652) and "Adequacy of TMI-1 OTSG Return to Service Safety Assessment After 1984 Technical Specification ECT Examination" (TDR-666) which have just been released. The documents were submitted to the staff on April 11, 1985.

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During the oral arguments heard on April 3 in this proceeding, a number of questions were posed by the Appeal Board to counsel. In reviewing the transcript, it appears that it might be helpful to the Appeal Board in some instances to provide specific references to documentation pertinent to those questions:

1. Cause of 1984 ECT indications (Tr. 29-32): TDR-638 at 11-24; TDR-666 at 4-6; TDR-652 at 25-47; January 10, 1985 Affidavit of F. Scott Giacobbe (Answer to Motion to Reopen), ¶¶ 3-13. See also TR-008 at 7-15, 21-28; February 24, 1984 Affidavit of F. Scott Giacobbe (Motion for Summary Disposition), ¶¶ 4-51.

2. Long-term corrosion test program reflected reactor conditions during layup, hot functional testing, and future operation through the first refueling cycle after restart, including stresses, temperatures, and reactor coolant chemistry (Tr. 30-32): TR-008 at 26-27; TDR-638 at 11-19; February 24, 1984 Giacobbe Affidavit, ¶¶ 120-124; January 10, 1985 Giacobbe Affidavit (Answer to Motion to Reopen), ¶ 4; Testimony of Don K. Croneberger and F. Scott Giacobbe on Contention 1.D at 4-9; Testimony of Conrad E. McCracken and Paul C. S. Wu on Contention 1.A at 11-13; Hearing Transcript at 345-346 (Croneberger); 359-361, 366-368 (Giacobbe); 369-370 (Giacobbe, Croneberger).

3. Fiberscopic examination of IGA (Tr. 32-33): TDR-638 at 20, 23; January 10, 1985 Giacobbe Affidavit, ¶ 11; February 24, 1984 Giacobbe Affidavit, ¶¶ 131-148.

4. The hot functional testing and cooldown and the kinetic expansion occurred after the 1982 100% baseline ECT and prior to the 1984 100% ECT. (Tr. 33-34): TDR-638 at 6, 7, 23; TDR-652 at 25-27, 34.

5. Threshold of ECT detectability without grain dropout is below critical crack size for tube rupture during main steamline break accident (Tr. 42-44, 47-50): TDR-666 at 5, 7-9; TDR-652 at 47; TR-008 at 78-89.

6. Axial stresses during hot functional testing and cooldown (Tr. 47-49): TDR-638 at 23; TR-008 at 85, 119; February 24, 1984 Affidavit of David G. Slear (Motion for Summary Disposition), ¶ 45(g).

7. Tensile, fatigue and other properties of tubes unaffected (Tr. 67-69): TR-008, ¶ b, at 10; Hearing Transcript at 346-347, 349 (Giacobbe); 527-534, 546-548, 572-575 (Slear, Giacobbe); 668-669 (McCracken).

Respectfully submitted,

Bruce W. Churchill

Bruce W. Churchill
Counsel for Applicant

Enclosures

cc: Service List (attached)

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

Before the Atomic Safety and Licensing Appeal Board

In the Matter of	)	
	)	
METROPOLITAN EDISON COMPANY, ET AL.	)	Docket No. 50-289-OLA
	)	(Steam Generator Repair)
(Three Mile Island Nuclear Station,	)	
Unit No. 1)	)	

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Office of Nuclear Reactor Regulation
Attn: J. F. Stolz, Chief
Operating Reactors Branch No. 4
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D. C. 20555

Dear Mr. Stolz:

TMI-1 Steam Generators
1984 Eddy Current Examination

In accordance with the TMI-1 Technical Specification 4.19, an eddy current examination of the steam generator tubes was conducted in November and December 1984. An initial report on the results of the examination was contained in LER 84-007-00, submitted on December 17, 1984. GPU Nuclear Corporation identified in LER 84-007-00 that supplemental information would be provided as available.

GPUN has recently completed TDR-652 entitled "Evaluation of the 1984 Required Technical Specification Examination of the TMI-1 OTSG", a copy of which is provided as Attachment 1. Also provided, as Attachment 2, is TDR-666 "Adequacy of TMI-1 OTSG Return to Service Safety Assessment After 1984 Technical Specification ECT Examination," which summarizes our analyses and conclusions with respect to the eddy current test results.

Sincerely,

for. R. F. Wilson
Vice President
Technical Functions

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RELATED CORRESPONDENCE

GPU Nuclear

TECHNICAL DATA REPORT

TDR NO. 652	**REVISION NO.** 1
BUDGET ACTIVITY NO. 123125	**PAGE** 1 **OF** 60
DEPARTMENT/SECTION Quality Assurance	
RELEASE DATE 3/6/85	**REVISION DATE**

PROJECT: TMI Unit 1 OTSG Eddy Current Program

DOCUMENT TITLE: Evaluation of the 1984 Required Technical Specification Examination for the TMI-1 OTSG

ORIGINATOR SIGNATURE	DATE	APPROVAL(S) SIGNATURE	DATE
G. E. Rhedrick *Gregory E Rhedrick*	3/1/85	R. O. Barley/s/	3/1/85
M. T. Torborg/s/	3/1/85	N. C. Kazanas *NCKazanas*	3/1/85
D. Langan/s/	3/1/85		
		APPROVAL FOR EXTERNAL DISTRIBUTION	**DATE**
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ABSTRACT: Statement of Problem

The results of the 1984 eddy current examination performed on the TMI-1 steam generator tubing had identified 328 tubes with confirmed indications of ≥ 40% through wall penetration. These indications were not identified in previous eddy current examinations performed prior to mechanical thermal and hydraulic loading evolutions which took place in the steam generators.

Technical Approach

Knowing the locations of the 1984 confirmed indications, a review of the 1983 and 1982 examinations have confirmed the earlier presence for a majority of these indications. A characterization of the 1984 indications by defect location, signal amplitude, percent through wall and circumferential extent was performed and compared to the 1982 examination results. A growth sample study on a random selection of tubes was performed after the detection of the 1984 indications in order to determine if evidence of an active mechanism was occurring.

Findings

It was observed that the 1984 indications were located in the same affected axial and radial areas previously identified during 1982 examination. The 1984 indications were predominately shorter in circumferential extent. The review of 1984, 1983 and 1982 examination results revealed that the percent through wall determination showed no change. 90% of the new indications were of size at or near the threshold of GPUN standard differential technique sensitivity of detection. The results of the growth sample study showed no evidence of an active mechanism occurring during the period of observation.

Conclusion

The 1984 examination identified indications that were already present in the tubes in 1982 but because of their weak signal amplitude were masked by background noise. The mechanical, thermal and hydraulic loads imposed on the OTSG since 1982 examination may have enhanced the eddy current detection of small indications by increasing the signal amplitude but without evidence of increase to percent through wall.

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SUMMARY

During the 1984 Technical Specification required eddy current examination, performed on the once through steam generator tubing at TMI Unit 1, a number of new relevant indications were detected in the "A" and "B" steam generator tubes. These new indications were not detected back in November 1982 when a full length eddy current examination was conducted on all the inservice "A" and "B" steam generator tubes. During both inspection periods the same eddy current examination technique was employed.

Since the 1982 eddy current examination both steam generators had undergone mechanical loading due to kinetic expansion tube repair and thermal/hydraulic loading due to two hot functional tests.

GPUN first determined that a new corrosion mechanism was not active. This was determined through repeat eddy current examinations on a controlled group of tubes in 1984 after initial detection of the new indications. This revealed that no growth or change in given eddy current signals occurred for the time period studied.

The 1984 indications were characterized as to size, location, depth and then compared to the 1982 examination results. GPUN concluded that the 1984 indications are a smaller additional subset of those detected in 1982 examination. The percent through wall and circumferential extent for 90% of the

1984 indications are of a size that approximates the threshold of detection for the measured sensitivity curve using the GPUN qualified standard differential eddy current examination process.

Detailed analysis of the new 1984 indications reveal, that by knowing the specific location of the indication the majority can be found in the 1982 eddy current tapes. The indications that could be measured in the 1982 tapes including the in service inspection tubes reveal that:

(1) No new indications were detected in the ISI subset (one exception explained)

(2) The percent through wall assignments, as determined by phase angle measurement remain constant from 1982 to 1984

(3) For indications not previously identified in 1982, the amplitude of the eddy current signal has substantially increased in the 1984 tapes which would result from some increase in the discontinuity volume. Presumably the latter is a reflection of the mechanical/thermal working of the tubing.

(4) For indications not previously identified in 1982 the increase in the amplitude of the indications in 1984 contributed to our ability to detect the small indications which now revealed themselves above the surrounding background noise. The latter combined with the low amplitudes associated with the signals from the indications prevented earlier detection.

Implicit within this fact, is that the earlier undetected indications were in fact very small. This is substantiated by the characterization studies for the 1984 indications which show them to be smaller percent through wall and circumferential extent than the 1982 indications. Additionally, the 1984 indications are located in areas which identify closely to intergranular stress assisted corrosion cracking revealed earlier in the 1981-1982 examinations.

I. INTRODUCTION

In November of 1984, eddy current examination was performed on the TMI - Unit 1, once through steam generator (OTSG) tubing in accordance with Technical Specification, 4.19. The examination ultimately included 14,615 tubes in the "A" OTSG and approximately 6,500 tubes in the "B" OTSG. This examination was concluded with a total count of 328 tubes with confirmed indications having tube wall degradation measuring 40 percent through wall or greater. This is a criterion that requires engineering disposition. There were another 319 tubes that had confirmed indications with a measured through wall degradation less than 40 percent. Those tubes with 20-40% through wall indication are classified "degraded" tubes and are required to be monitored for change at futu. examinations. In addition, those tubes which contain indications of 40% through wall or greater but do not meet the approved plugging criteria will also be monitored.

Since the last complete eddy current examination (1982 baseline) performed on the OTSG in 1982, the OTSG tubes have been subjected to mechanical loading due to kinetic expansion repairs and thermal and hydraulic loadings due to the two hot functional tests. The eddy current examinations performed subsequent to these loadings have resulted in the detection of indications not seen previously.

The analysis performed herein has the following purposes:

1. To characterize and report the indications identified during the 1984 examination and compare these characteristics with indications reported during the 1982 baseline examination. The purpose of this comparison is to evaluate the pattern of defect distribution and to determine if the affected areas correspond to the previously affected areas.

2. Determine the correlation of the kinetic expansion and subsequent hot functional test to the detection of indications not detected prior to these loading events. And, evaluate the impact from a chronological perspective.

3. Review the data from the 1984 Growth Program and evaluate the results to determine if evidence of continued tube degradation existed.

II. METHOD OF EXAMINATION

The eddy current examinations performed in November of 1984 utilized both standard differential and absolute eddy current examination techniques. This dual examination method was developed by GPUN to specifically detect and confirm small volume but predominately circumferentially oriented inner diameter defects. (See Appendix A).

The dual examination method involved first examining the tubing with a high gain standard differential technique using a .540" diameter eddy current probe. If no indications are detected the examination is complete and the tube is considered acceptable. Tubes found to have standard differential indications were examined a second time using the absolute 8x1 technique which used a probe having 8 independent coils. The absolute 8x1 examination determines the circumferential extent of the defect and also determines if the indications are relevant or non-relevant. A relevant indication is a flaw that has been confirmed by absolute 8x1 examination.

This dual examination method is the same method GPUN qualified and used for the 1982 baseline eddy current examination of the TMI-1 OTSG tubing (Ref. 1)

III. SCOPE OF EXAMINATION

The initial set of tubes for the 1984 eddy current examinations was a 3% sample selected in accordance with the requirements of Technical Specification 4.19. As required by 4.19, this set included all tubes remaining in service which were classified "degraded tubes." These tubes had previously reported indications of 20-40% through wall and are referred to as the ISI tubes. Approximately 50% of the 3% sample was from the high defect area (outer periphery) with the remaining 50% being located randomly throughout the generators.

The examination of the initial sample identified some discontinuities which exceeded the 40% through wall technical specification limit. As a result of these discontinuities, the examination scope was increased to include 100% of the tubes in the affected area of both OTSGs. This increased scope included 100% of the tubes in OTSG "A" and 100% of the tubes in the outer periphery of OTSG "B". This outer periphery is defined as the area outside the outer tie rod circle and includes approximately 6500 tubes.

The November 1984 examination was not continued into the center of the "B" generator because no confirmed indications ≥40% through wall were found in this area during the random examination. The indications reported in the "B" generator were at a significantly lower frequency than reported in the "A" generator. And their distribution declined sharply with distance from the outer perimeter and was bounded by the outer tie rod circle.

As part of the expanded scope, a selected 100 tube sample, designated the "A" Growth Program, was monitored in order to determine if there was an active mechanism initiating the 1984 eddy current indications. This sample was also comparatively evaluated against the eddy current tapes from the 1982 examination.

Examinations discussed within this report included the full length of the unexpanded region of the tubes. Expanded portions of the tubes cannot be effectively examined and evaluated with the standard differential technique and are therefore not included in the tubing examinations.

IV. RESULTS OF 1984 EXAMINATIONS

A. INDICATIONS REPORT

As a result of expanding the scope of the examinations, 14,615 tubes in OTSG "A" and approximately 6500 tubes in OTSG "B" were examined. Of these tubes, 298 in OTSG "A" and 30 in OTSG B were identified as having relevant indications 40% through wall or greater. In addition, 274 tubes in OTSG "A" and 45 tubes in OTSG "B" were identified as having confirmed indications from 20-40% through wall and are classified as "degraded tubes". These tubes and any tubes with confirmed indications 40% through wall or greater which do not meet the approved plugging criteria will be monitored during future examinations as "ISI tubes".

B. ISI TUBES

The subset of ISI tubes included 28 tubes in OTSG A and 56 tubes in OTSG B which had indications of 20-40% through wall penetration identified and recorded during previous examinations.

These ISI tubes were examined as a subset and an in depth evaluation and comparison of the 1984 data to the previous data was performed. The purpose of this evaluation and comparison was to determine if the previously identified indications had "grown".

The criteria used to establish growth addressed significant changes in percent through wall determinations, changes in signal voltage or changes in arc length of the monitored indication. When performing evaluations of this type, it must be noted that changes of about 10% through wall can be caused by a change of only 3 degrees in the phase angle measurement of the standard differential reponse signal. When addressing small voltage signals, measurement errors of this type can be expected. For the absolute 8x1, the orientation of the coils to the defect may change the number of coils an indication appears on by 1 additional coil during repeat examinations. The evaluations must therefore factor in these limitations on repeatability.

ISI Tubes in the "A" Generator

From the "A" generator 28 of the 28 ISI tubes showed no evidence of growth for any of the previously identified indications.

Two tubes, A-2-9 and A-88-128, had indications previously identified as being <40% through wall which were subsequently reported as $\geq$40% through wall in 1984. These indications were compared by the data

analyst on a one-to-one basis to the previous data and it was determined that the change in the percent through wall determinations were caused by variations in the repeatability of the overall eddy current process and not by the physical changes in the tube. (See Table 1).

ISI Tubes in the "B" Generator

In OTSG "B" there was no indication of "growth" for 56 of the 56 tubes. One tube B-98-5 did have an indication reported as greater than 40% through wall and required further evaluation. The details for this tube are shown in Table 1.

The 1984 and previous data for this tube was re-evaluated by the data analyst to compare the eddy current signal's shape. The analyst determined the variation in the percent through wall determinations was attributed to distortion of eddy current signals caused by multiple indications and was not a result of physical changes in the tube.

Status of ISI Tubes

A number of tubes previously placed in the ISI category during the 1982 baseline examination were determined to have non-relevant indications as a result of the 1984 absolute 8x1 examination.

These tubes, 13 in "A" OTSG and 27 in "B" OTSG, had non-relevant indications as determined by absolute 8x1 in 1982 but were placed on

the ISI list for monitoring purposes in order to verify the precision of the absolute 8x1 confirmation exams during future dual examination exercises. With the completion of the 1984 examination and the consistency of reporting the same standard differential indication as non-relevant, these tubes were removed from the ISI list.

The number of ISI tubes has increased as 264 tubes in OTSG A and 20 tubes in OTSG B had confirmed indication from 20-40% through wall in 1984 which were not previously identified. This puts the present population of ISI tubes between 20-40% through wall at 274 tubes in "A" and 45 tubes in "B".

Table 1

ISI Confirmed Indications
Greater Than 40% Through Wall in 1984

Gen	Row Tube	Indication Elevation	Origin	April 1983 Post KE Data % T.W.	April 1983 Post KE Data Volts	Nov. 1984 Post HFT Data %	Nov. 1984 Post HFT Data Volts
A	2 - 9	US+06*	ID	40%	1.7	45%	1.6
A	88 - 128	12+05	ID	<20%	0.9	31%	1.4
		13-09	ID	<20%	0.6	<20%	0.6
		US-11	ID	23%	1.9	41%	2.5
B	98 - 5	US+07*	ID	37%	2.3	48%	4.0
		US+01	ID	<20%	1.9	<20%	2.0
		US+04	ID	<20%	2.3	21%	3.5

*immediately below expanded area

C. CHARACTERIZATION OF INDICATIONS

The indications detected during the 1984 examinations were characterized by the location and extent of degradation based on the eddy current response signal. Details, listing the data in support of this section are included in Appendix B.

The characterization is further defined by comparing the 1984 indications with those reported in 1982. For this comparison GPUN used the 1984 data described previously and the 1982 standard differential high gain data base. The 1982 data base included all tubes examined using the GPUN dual examination method prior to 1984. This data base was previously used to disposition the OTSG tubes for the kinetic expansion process and subsequent tube plugging. This data base contains the 1982 baseline results which are summarized in TDR 442. (See Ref. 2).

Both the standard differential and absolute techniques are used to furnish these characterization as described below.

Standard differential response signal offers the following:

a. Amplitude (this relates to the defects geometry and volume, and is reported as a voltage reading).
b. Percent through wall (this relates to the response signal's phase angle and is measured in degrees).

c. Axial locations are reported by distance from the tube support plates that are spaced at known elevations in the generators.

Absolute 8x1 signal offers the following:

a. Number of coils (this relates to the defect's circumferential extent). The maximum circumferential extent is 8 coils and represents a defect circumferential arc length that could be as much as 360 degrees.

NOTE: Amplitude, phase and axial location are also recorded on the absolute 8x1 results; however, these results are used only to confirm the standard differential indications.

1. RADIAL DISTRIBUTION

The indications detected during the 1984 examination were located in essentially the same areas of the OTSGs as those discovered in 1982. The indications were located predominately towards the outer periphery of both OTSG A and B. In addition to the indications located in the periphery there was also a smaller number of indications present in the center of OTSG A. No indications greater than or equal to 40% through wall were reported in the center of OTSG B. (See Figures 1a and 1b).

2. AXIAL DISTRIBUTION

The axial location of the 1984 indications can be characterized as being towards the top of the OTSGs. For OTSG A, 79 percent of the indications during the 1984 examination are located in or above the 15th span with 57 percent of the indications in OTSG B located in this region. This corresponds with 82 percent in "A" generator and 74 percent in "B" generator for the 1982 examination.

In order to compare the 1982 and 1984 axial distributions, it must be noted that the majority of the indications detected during 1982 were within the upper tube sheet area and were captured by the kinetic expansion process. As a result of the expansion process and the coining of the tube wall against the tube sheet an examination of the coined area was not possible using the standard differential probe. Only the area of the tube below the expansion zone could be examined using the standard differential technique.

With the exception of the upper tube sheet region, the overall distribution of the indications in 1984 closely resembles the 1982 distribution. This distribution shows the indications are concentrated towards the uppermost regions of the OTSGs and the frequency of occurrence decreases sharply at the lower regions. (See Figures 2a and 2b).

3. SIGNAL AMPLITUDE

The majority of the discontinuities detected in 1984 were small volume as indicated by the amplitude of the standard differential signal. In OTSG A, 93 percent of the 1984 indications detected were 2 volts or less in amplitude, while in OTSG B 74 percent of the indications were in this category.

This voltage distribution corresponds to approximately 93 percent of the 1982 indications in OTSG A and 78 percent of the indications in OTSG B as being 2 volts or less. (See Figures 3a and 3b).

To establish a reference volume for the discontinuities in this range, a comparison can be made to the responses from the calibration standard. This standard has a 100% through wall 0.052" diameter drilled hole which produces a 15 volt response signal for calibration purposes. This indicates that the discontinuities present in the OTSGs are of a significantly smaller volume than the calibration standard.

4. PERCENT THROUGH WALL

The 1984 eddy current examination results have shown that a considerable number of the reported indications measured less than 40% through wall penetration. The 1984 examination reported 572

tubes in "A" and 75 tubes in "B" with confirmed indications. In the "A" generator the indications in 48% of the 572 tubes were less than 40% through wall and in the "B" generator the indications in 60% of the 75 tubes were less than 40% through wall.

For the 1982 examination, the results indicated higher percent through wall degradation. In the "A" generator, 50% of the indications reported were 90% through wall penetration or greater while 3% of the reported indications were less than 40% through wall. In the "B" generator, 16% of the indications reported were 90% through wall penetration or greater and 40% of the reported indications were less than 40% through wall. (See figures 4a and 4b).

The contrast between the 1982 and 1984 examination results for percent through wall comparison must consider that most of the tubing within the upper tubesheet region could not be examined in 1984. This region accounted for 63% in "A" and 61% in "B" of the reported indications in the 1982 examination. This comparison serves as an approximation only, since an improved inner diameter conversion curve was used for the November 1984 examinations (Ref. 3).

5. CIRCUMFERENTIAL EXTENT

To confirm the relevancy of the reported standard differential indication an absolute 8x1 examination is performed. The number of coils that respond to a relevant indication provides an estimate of the indication's circumferential extent. The 1984 examination results showed that the confirmed indications ranged from 1 to 3 coils. The circumferential extent for a one coil indication is from the threshold of detection to 0.194". A two coil indication is from 0.024" to 0.413" whereas a three coil indication is from 0.219" to 0.632". (Ref. 4). For the "A" generator approximately 90% of the confirmed indications were 1 coil, approximately 10% were 2 coils, and only 2 indications were 3 coils of which one was outer diameter. For the "B" generator 79% of the confirmed indications were 1 coil, 20% were 2 coils, and only one was 3 coils.

For the 1982 examination the results showed that the confirmed indications ranged from 1 to 8 coils. For the "A" generator 66% of the confirmed indications were 1 coil, and for the "B" generator 50% of the confirmed indications were 1 coil. A greater number of 2 coil and greater indications were confirmed by absolute 8x1 during the 1982 examination than in the 1984 examination. (See figures 5a and 5b).

D. SUMMARY OF INDICATION CHARACTERIZATION

The eddy current examinations performed in 1982 and 1984, both utilized the GPUN qualified examination program using a combination of standard differential high gain .540" probe and absolute 8x' probe. This dual examination method was developed to detect intergranular stress assisted cracking, predominately circumferentially oriented and initiated on the tube's inner diameter wall.

The 1982 eddy current examinations prior to the kinetic expansion repair were full length examinations performed on all in service tubes in both "A" and "B" generators. The 1984 examination were also full length however the kinetic expanded area could not be examined.

Some tubes could not be examined with the S.D. .540" probe below the center of the lower tubesheet due to ligament distortion from adjacent explosive plugs.

The comparison of the 1982 to 1984 data showed both similarities and differences in the characterization of the indications reported. The characterization of the axial and radial distribution showed the indications occurred in the same regions of the OTSGs in both 1982 and 1984. The amplitudes of the indications also appears to be similar in 1982 and 1984. The differences between the two sets of data appear in the percent through walls, which are significantly lower in 1984 than in 1982 and in the circumferential extent which is also smaller in 1984 than in 1982

This characterization and comparison would suggest the 1984 indications are a smaller additional subset of those detected during the 1982 examination.

To determine how the size of the new 1984 indications reflect on the given sensitivity curve established in TDR 401 and 423, the maximum size of the new indications detected was established and compared to the above. It was determined that approximately 90% of the indications are a maximum of one coil. (Note: a one coil indication if not preferentially oriented could give a two coil response). Additionally, approximately 90% of the new indications were determined to be between 20-60% through wall. Using this data against the sensitivity curve shown in TDR 423, the new indications appear to predominately reveal themselves at or near the threshold of detection of the given sensitivity curves.

It was determined that approximately 10% was from a population that has $\geq$60% through wall determination. For indications $\geq$60% through wall all were 1 or 2 coils with the exception of one indication in tube B-97-5. The indication (76% through wall, 3 coils) was located at the upper tube sheet lower face region. It is expected that the sensitivity for detection is suppressed during the eddy current probe passage into and out of (0.5" distance) this region. (Ref. 1).

The two other 3 coil indications in tubes A-84-131 and A-79-1 had <20% and 52% through wall determinations respectively.

The three, 3 coil circumferential extent indications, and the ≥60% through wall indications are of dimension below those analyzed to withstand the main steam line break loadings (See Figure 6).

The following is the breakdown of the 1982 and 1984 characterization:

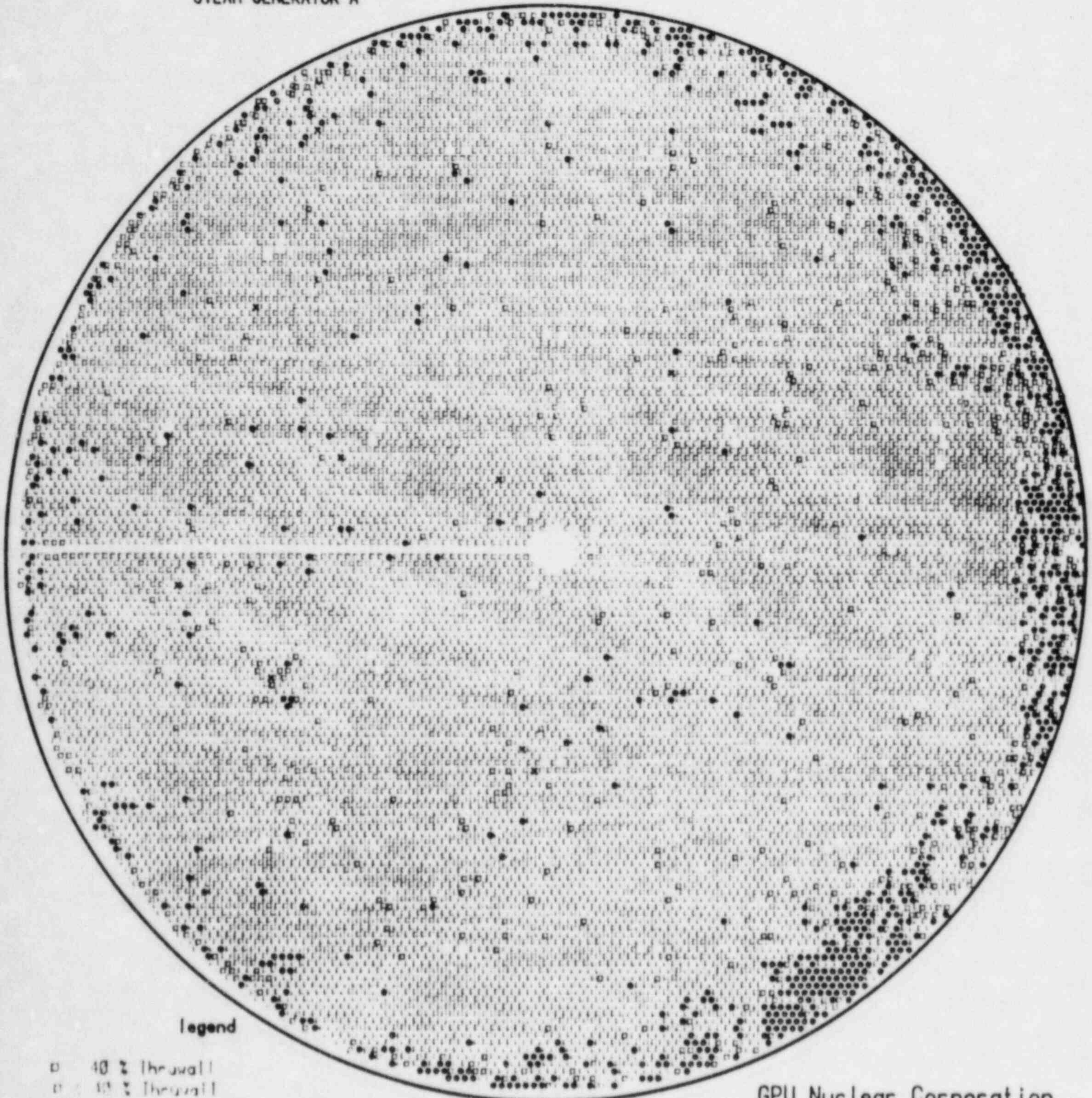
		1982	1984
1.	Radial Distribution	Predominately in the outer periphery of both "A" & "B" (significantly fewer in "B")	Predominately in the outer periphery of both "A" & "B" (significantly fewer in "B")
2.	Axial Distribution	Predominately in the UTS Region ≃63%, and 16th span ≃14%	Most in UTS Region ≃50%. Some in 16th span ≃19%
3.	Amplitude (Voltage)	76% less than 2 volts in "A" and 51% less than 2 volts in "B"	75% less than 2 volts in "A" and 47% less than 2 volts in "B"
4.	Percent Through Wall	50% greater than 90% T.W. and 96% greater than 40% T.W. in "A". 16% greater than 90% T.W. and 60% greater than 40% T.W. in "B"	2% greater than 90% T.W. and 40% greater than 40% T.W. in "A". 1% greater than 90% T.W. and 27% greater than 40% T.W. in "B"

		1982	1984
5.	Circumferential Extent	The indications ranged from 1 to 8 coils in both "A" and "B". For "A" more than 90% of the indications were 1 and 2 coils (66% - 1 coil and 30% - 2 coils). For "B" more than 90% of the indictations were 1, 2, 3 coils (50% -1, 34% -2 coils and 8% - 3 coils)	The indications ranged from 1 to 3 coils in both "A" and "B". For "A" 90% of the indications were 1 coil. For "B" more than 90% of the indications were 1 and 2 coils (79% - 1 coil and 20% - 2 coils). There was a total of 3 indications with 3 coils 2 were inner diameter and 1 was outer diameter

FIG. 1A

THREE MILE ISLAND NUCLEAR GENERATING STATION

UNIT 1
STEAM GENERATOR A



legend

- ▫ 40 % Thruwall
- ▫ [illegible] % Thruwall
- ▫ No Detectable Discontinuity
- o Plugged Tube
- x Not Inspected

GPU Nuclear Corporation
20-FEB-85

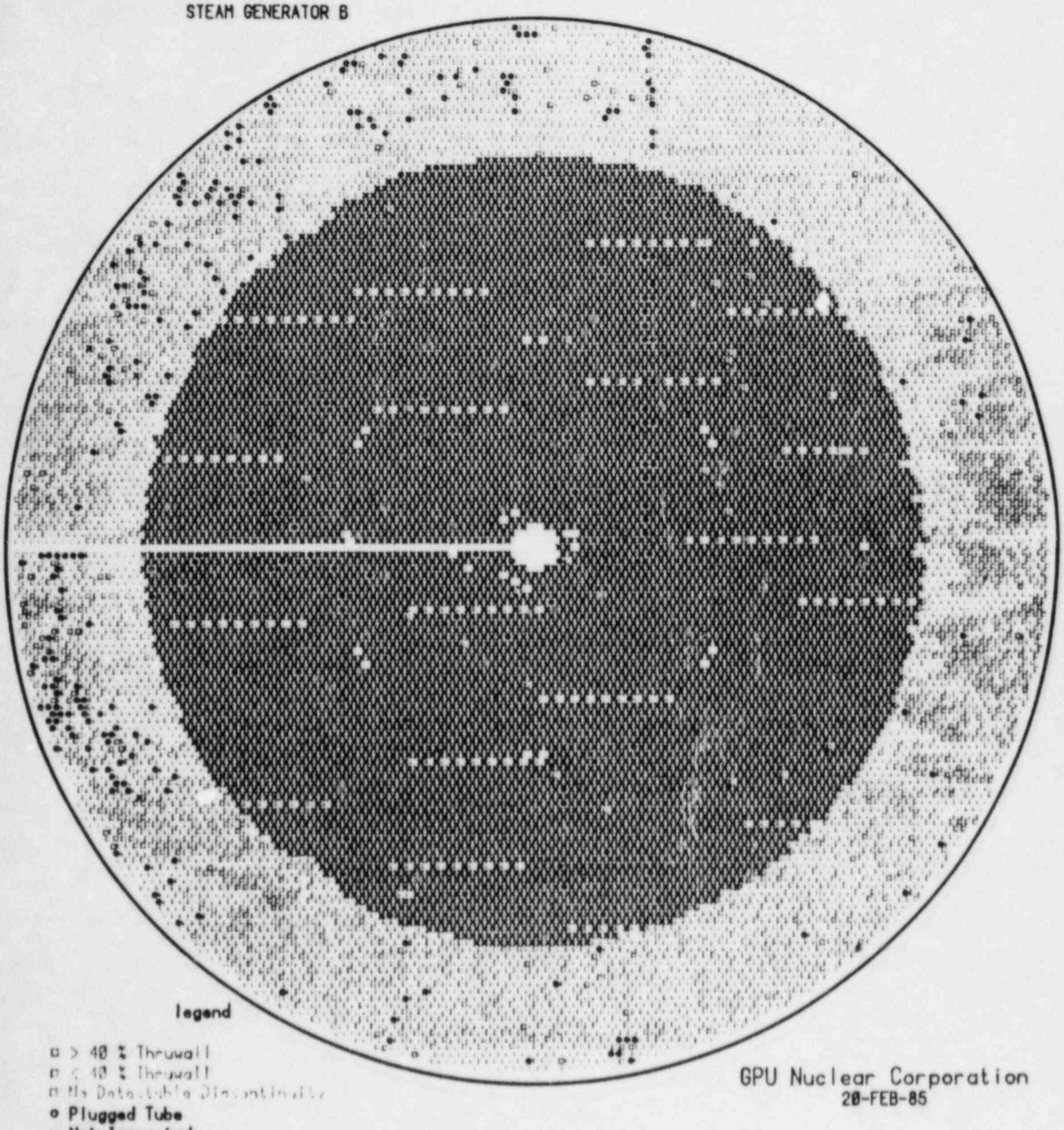
FIG. 1B

TDR-652

THREE MILE ISLAND NUCLEAR GENERATING STATION

UNIT I

STEAM GENERATOR B



legend

□ > 40 % Thruwall
□ < 40 % Thruwall
□ No Detectable Discontinuity
o Plugged Tube
x Not Inspected

GPU Nuclear Corporation
20-FEB-85

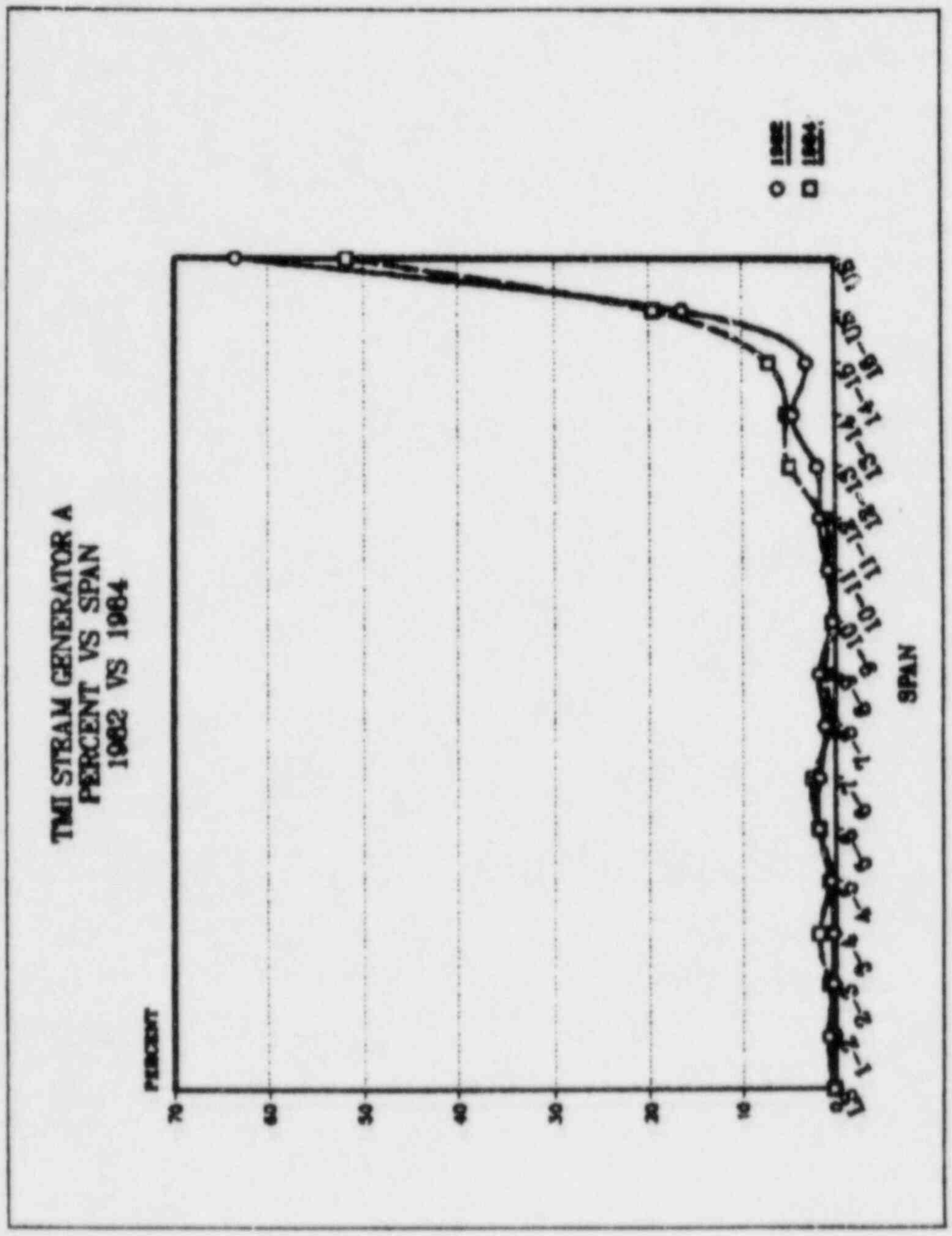

TMI STEAM GENERATOR A
PERCENT VS SPAN
1982 VS 1984
PERCENT
70
60
50
40
30
20
10
0
SPAN
1982
1984

FIGURE 2B

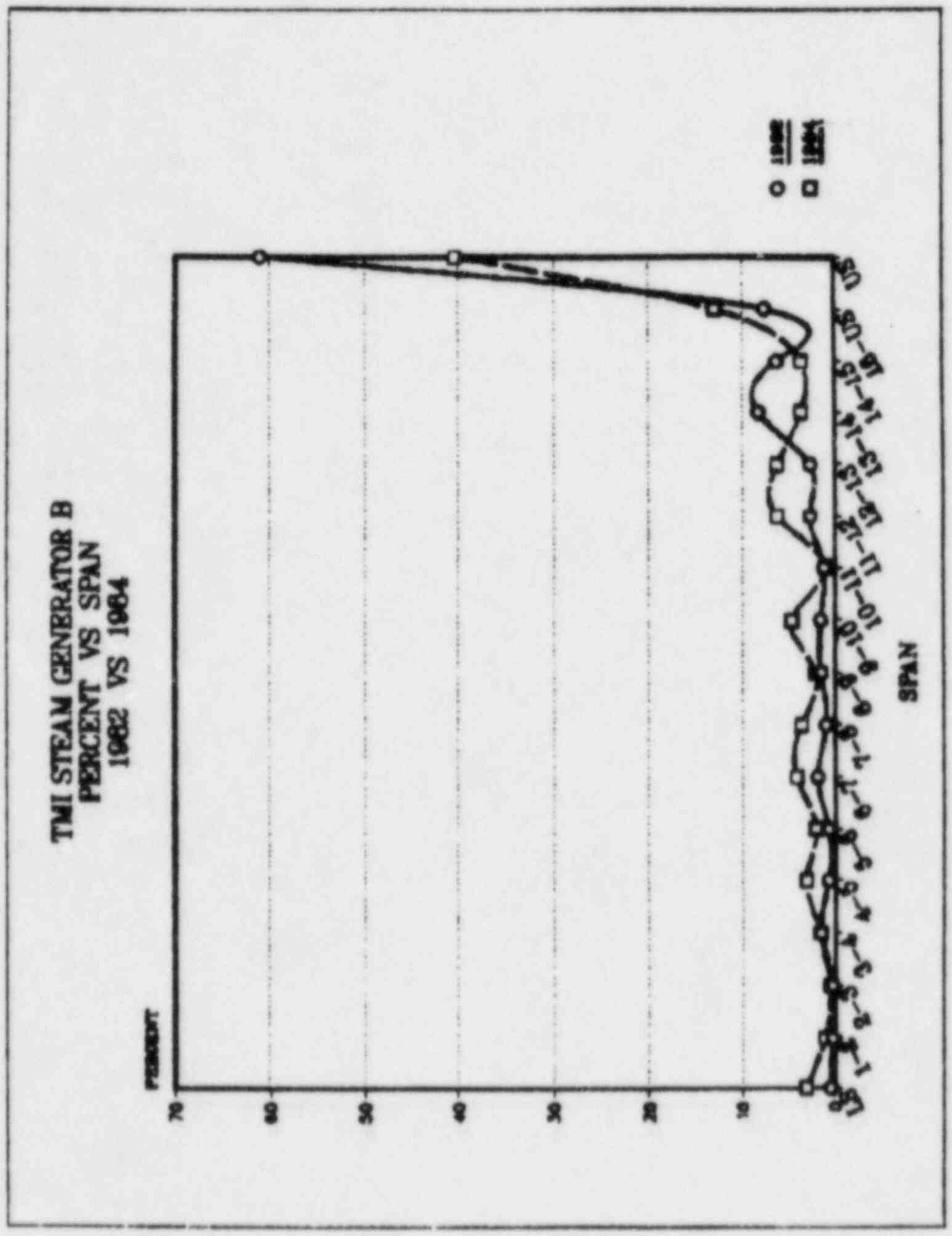

TMI STEAM GENERATOR B
PERCENT VS SPAN
1982 VS 1984
PERCENT
SPAN
70
60
50
40
30
20
10
0

FIGURE 3A

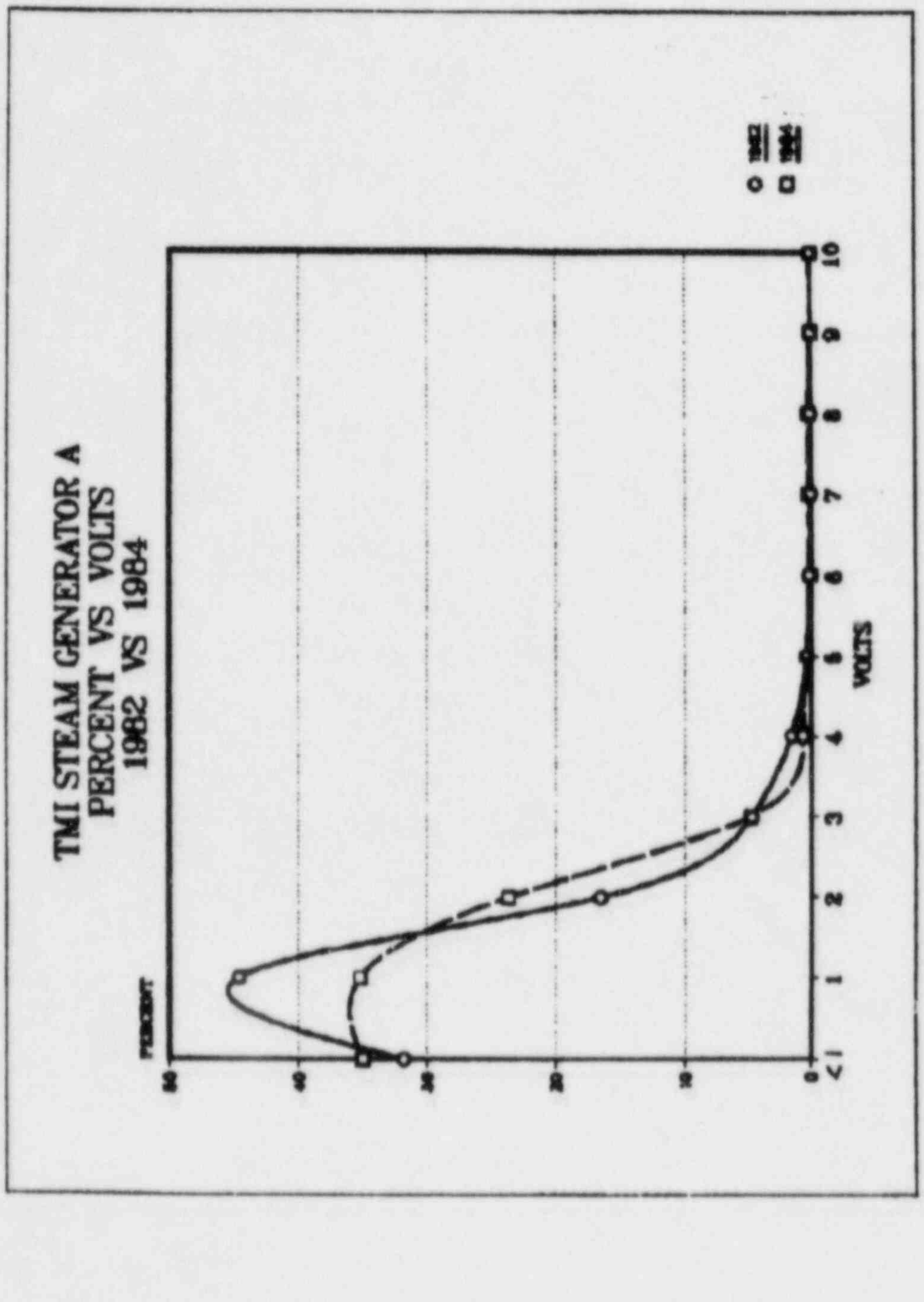

TMI STEAM GENERATOR A
PERCENT VS VOLTS
1982 VS 1984
PERCENT
VOLTS

FIGURE 3B

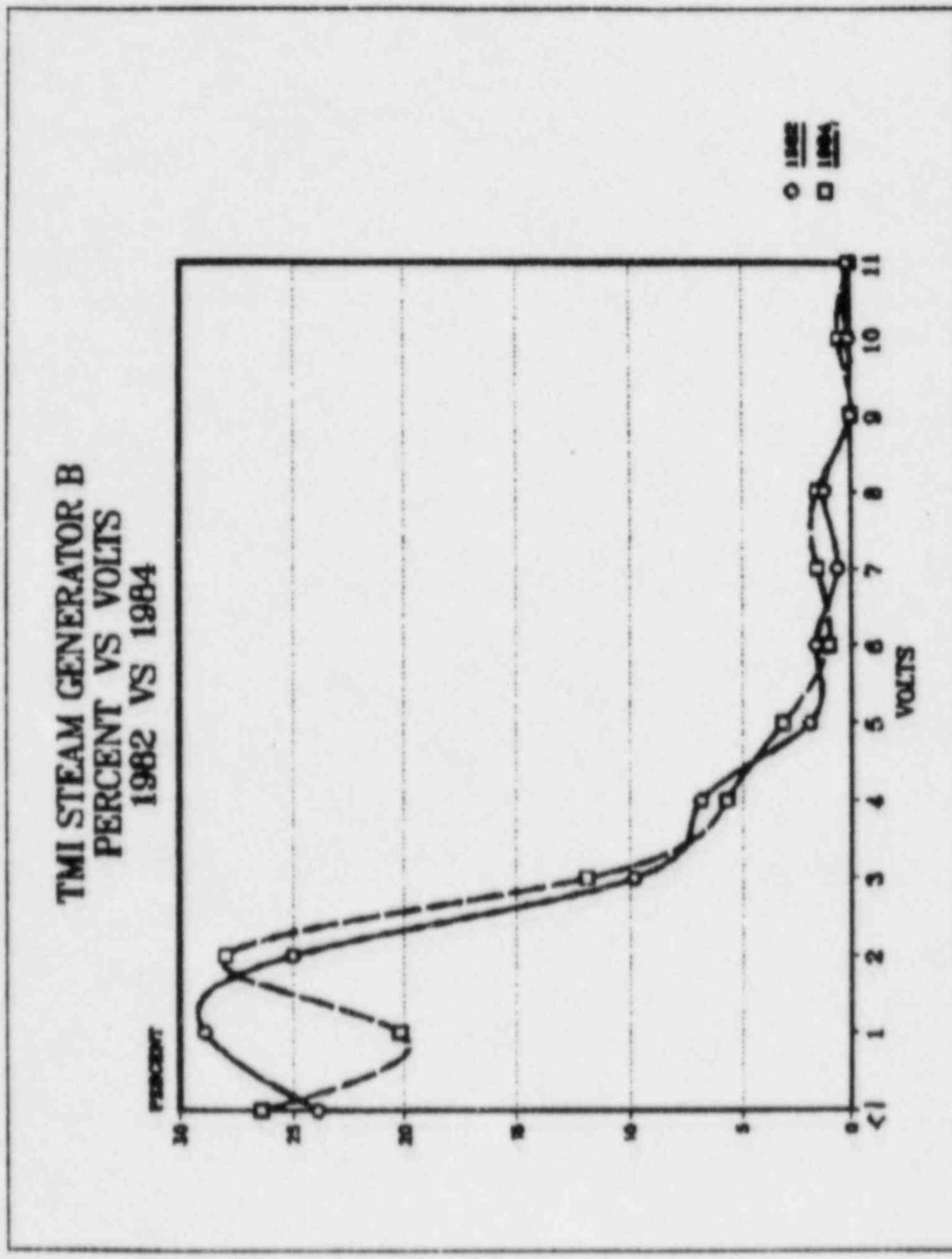

TMI STEAM GENERATOR B
PERCENT VS VOLTS
1982 VS 1984
PERCENT
VOLTS
1982
1984

FIGURE 4A

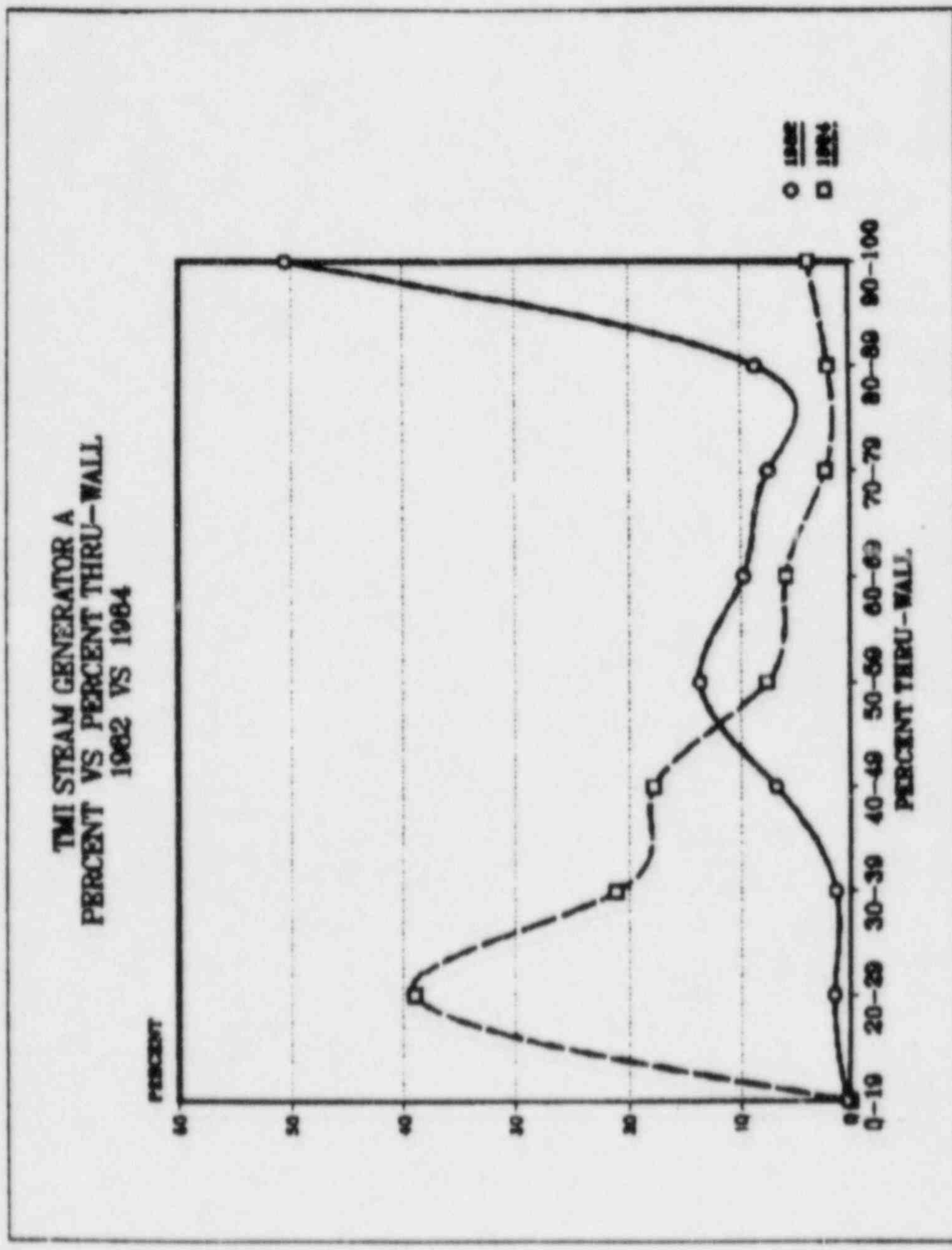

TMI STEAM GENERATOR A
PERCENT VS PERCENT THRU-WALL
1982 VS 1984
PERCENT
PERCENT THRU-WALL
0-19
20-29
30-39
40-49
50-59
60-69
70-79
80-89
90-100

FIGURE 4B

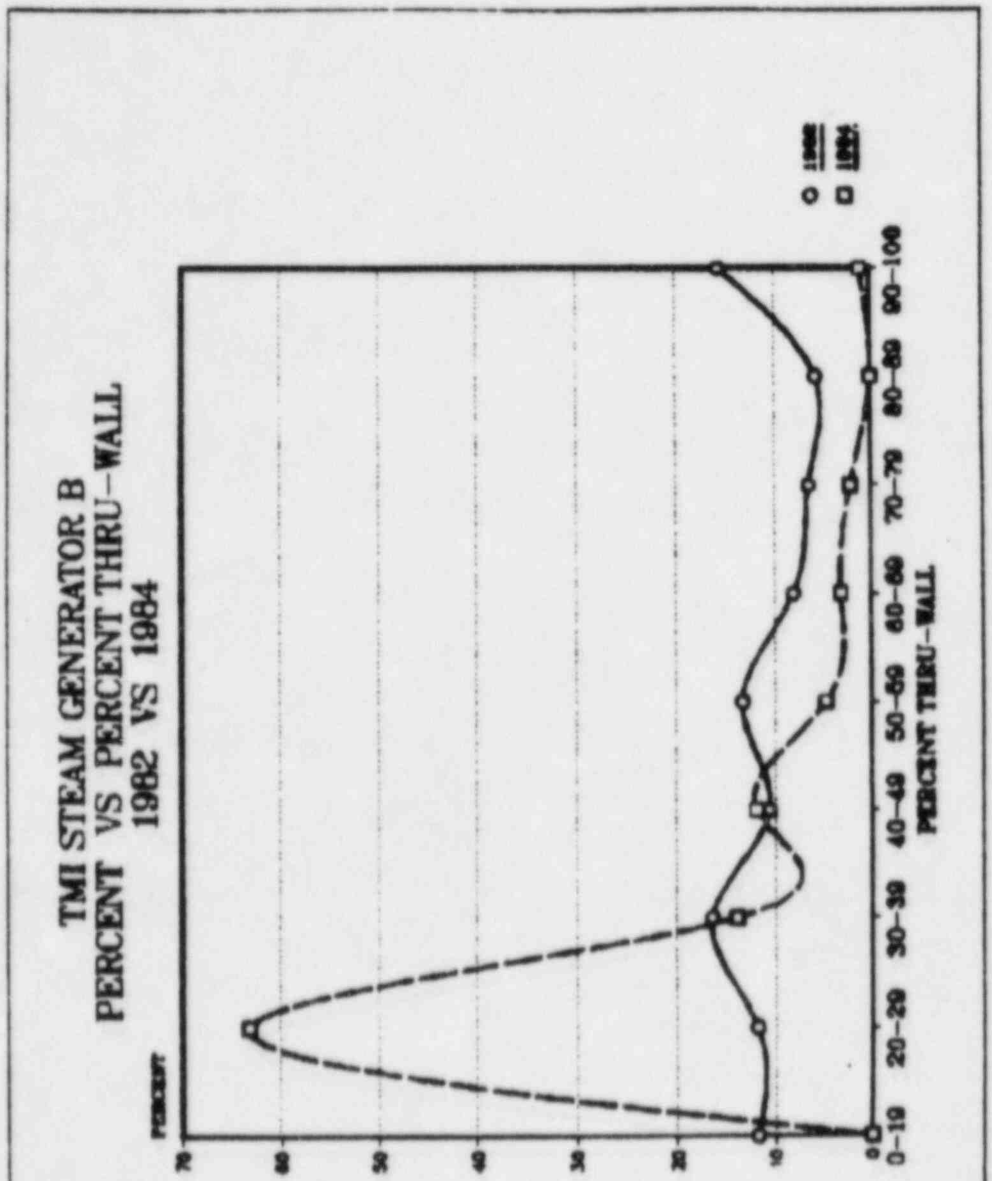

TMI STEAM GENERATOR B
PERCENT VS PERCENT THRU-WALL
1982 VS 1984
PERCENT
PERCENT THRU-WALL
0-10
20-29
30-39
40-49
50-59
60-69
70-79
80-89
90-100
0
10
20
30
40
50
60
70

FIGURE 5A

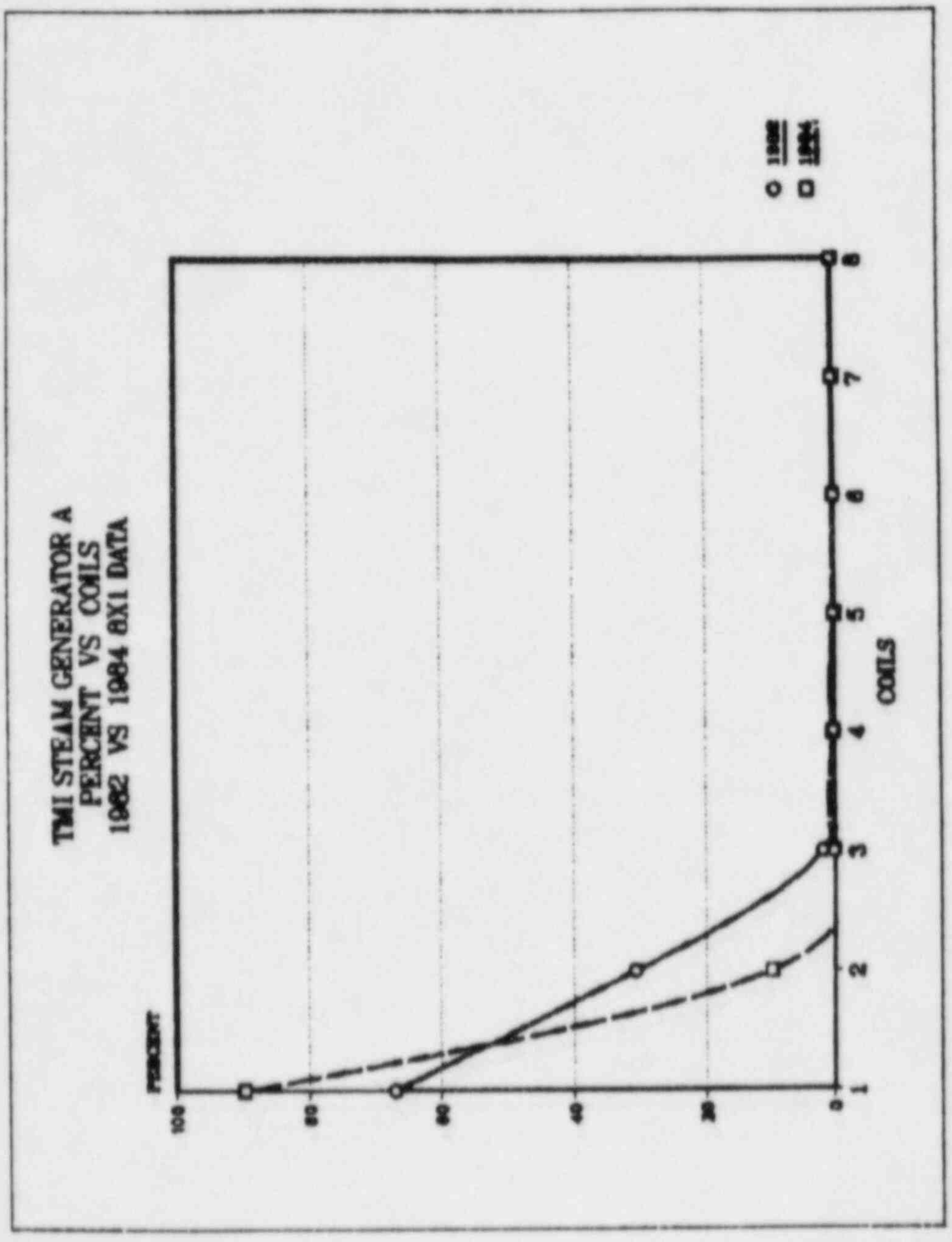

TMI STEAM GENERATOR A
PERCENT VS COILS
1982 VS 1984 8X1 DATA
PERCENT
100
80
60
40
20
0
1
2
3
4
5
6
7
8
COILS

FIGURE 5B

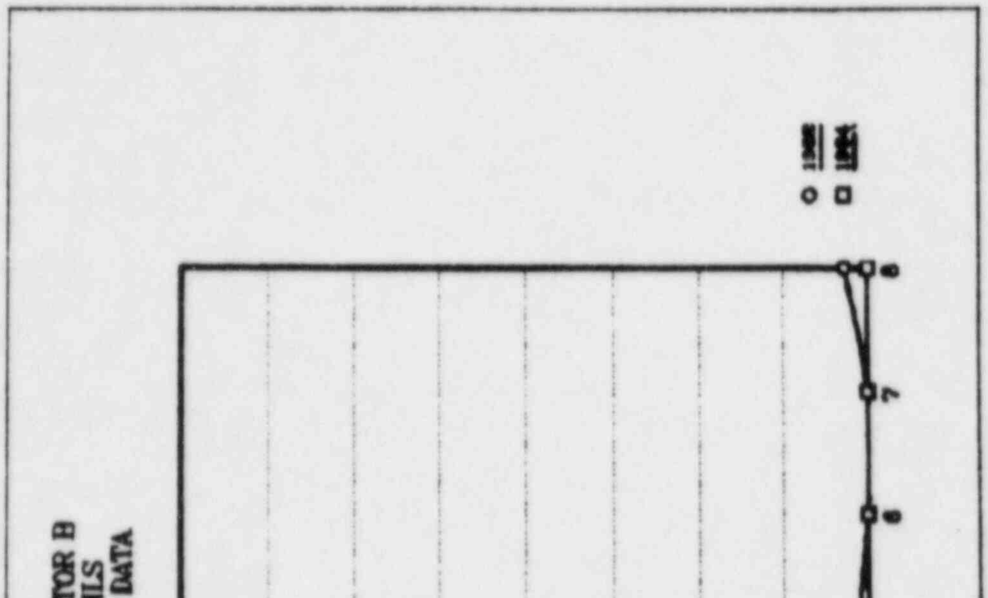
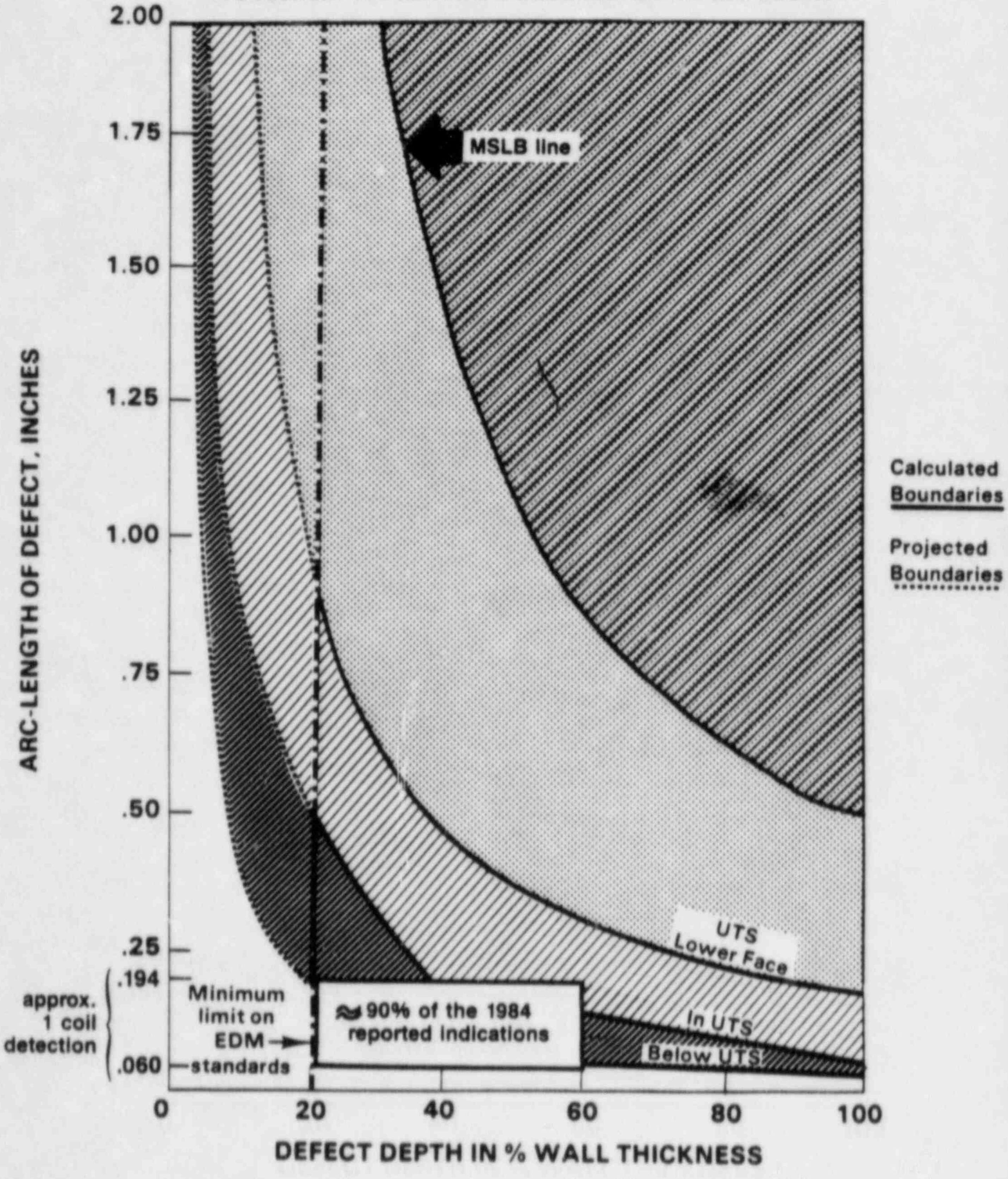

TMI STEAM GENERATOR B
PERCENT VS COILS
1982 VS 1984 8X1 DATA
PERCENT
COILS

FIGURE 6

ESTABLISHED MINIMUM SENSITIVITY FOR THE HIGH GAIN .540 S.D. EXAMINATIONS BELOW UPPER TUBESHEET (300 MV) WITHIN UPPER TUBESHEET (1 VOLT) AND TUBESHEET ENTRY (3.3 VOLTS)



V. REVIEW OF PRE KINETIC, POST KINETIC & POST HOT FUNCTIONAL EXAMINATION DATA

A. OVERVIEW

GPUN performed a 100% Examination of the OTSG tubes in 1982. This examination is referred to as the 1982 baseline.

Since performing this examination GPUN has reexamined a select number of the OTSG tubes to monitor the effects of the kinetic expansion repair (KE) and the subsequent hot functional testing (HFT).

These examinations revealed the presence of indications which were not previously identified during the 1982 baseline examinations. To more fully understand the appearance of these indications GPUN performed detailed evaluations of the available eddy current data to determine if the indications had been present but could not be detected on previous examinations or if the indications were in previously unaffected areas of tubing.

Included in these evaluations were data sets of:

1982 In Process Examinations for Kinetic Expansion (October, 1982)

Purpose: Determine the effects of kinetically expanding the OTSG tubes.

This data set consisted of examining 437 tubes in OTSG A and B after the tubes were expanded. The data was then compared to the 1982 baseline.

1983 Post KE Examinations (April, 1983)

Purpose: Determine the effects of the complete kinetic expansion process on the OTSG tubes.

This data set consisted of examining 477 tubes in OTSG A & B after the kinetic expansion repair was completed. The data was then compared to the 1982 baseline. This data set includes the ISI tubes.

1984 Post HFT Examinations (November, 1984)

Purpose: Determine the cumulative effects of the kinetic expansion repair and subsequent HFT on the condition of the OTSG tubes.

A data set of 375 tubes was identified from the November 1984 population which remained in service for which GPUN had 1983 post kinetic expansion data. This data set includes the ISI tubes. This data was then compared to the 1983 post kinetic expansion and the 1982 baseline data.

Also included in the review were 45 tubes with indications identified as ≥40% through wall, during the 1984 examinations. These tubes were selected from tubes included in the 1984 flaw growth program. Since no 1983 post KE data was available, the evaluation results were compared to the 1982 baseline.

B. METHOD OF EVALUATION

During the evaluations, the data analyst reviewed the magnetic tapes of the previous eddy current data for tubes with newly detected indications. This review was accomplished by isolating the specific area of interest and performing a detailed review of the eddy current signals. By isolating the known area of interest, the data analyst was able to perform an intense analysis of the eddy current signals at a higher level of sensitivity than allowed by production analysis techniques. This intense focus permitted the data analyst to identify the possible presence of low level eddy current signals which may be masked by background noise during production analysis.

Once the signal was identified and isolated, the analyst then measured and recorded the signals amplitude, which indicates the volume of the discontinuity, and the phase angle, which indicates the depth of the discontinuity.

The amplitudes and phase angles of the signals were then characterized to determine the relative size of the discontinuities. The evaluations from the successive examinations were then compared to establish when the signals were first detectable by eddy current. This also characterized any changes which made the signal detectable by production eddy current techniques.

C. RESULTS OF EVALUATIONS

As a result of the evaluations performed on these data sets GPUN concluded that:

1. Knowing the exact location of a reported indication, most of the indications could be identified in previous examination data. This indicated the discontinuities were previously present but not detectable due to their low amplitude.

2. As a result of the kinetic expansion and the hot functional testing the amplitude of previously unidentified signals increased making the signal response more detectable. This was typically a 100-200% increase in amplitude which brought the signals above the threshold of detection. This can be attributed to an increase in the volume of the discontinuity.

   Example: 1984 data shows 1.5 volt signal in 0.5 volt noise, re-review of 1982 data shows 0.5 volt signal in 0.5 volt noise at the same location.

3. Although the amplitude of the signals increased, the phase angle of the signals did not show a corresponding increase for the indications first detected in 1984. This would indicate that, although the volume of the discontinuity changed, the percent through wall penetration remained constant.

4. The new (1984) indications which were reviewed are located at the upper elevations of the OTSGs. This corresponds to the previously affected areas of the OTSGs identified during the 1982 examinations.

D. DETAILS OF EVALUATIONS PERFORMED

The following is a brief description of the evaluations performed and the details of the data sets utilized. The data sets are presented in chronological order to demonstrate the cumulative effects of the various OTSG activities upon the tubes since the 1982 baseline. This chronology is also contained in Table 2.

1982 In Process Examinations for Kinetic Expansion (October, 1982)

Purpose: Determine the effects of kinetically expanding the OTSG tubes.

In order to monitor the effects of the kinetic expansions GPUN examined 437 tubes. The tubes selected for these examinations were the first tubes to be expanded, located in rows 1-8, in both OTSGs.

This examination identified discontinuities which were not previously recorded in 15 of the 437 tubes examined (3.5%). An evaluation was performed at that time to determine why the indications were not identified previously.

This evaluation is documented in TDR 401 (Ref. 4) and TR-008 (p. 44-45) (Ref. 5) and concluded that:

1. The indications were not initiated by the kinetic expansion process nor was there any evidence of detectable propagation of existing indications.

2. The defects were small (threshold) type indications that had either been masked by the high background noise levels in the upper tube sheet regions or were sufficiently tight that significant metal removal was not present to permit detection. Kinetic expansion may have altered these areas to make them more detectable.

1983 Post Kinetic Expansion Examinations (April, 1983)

Purpose: Determine the effects of the Kinetic Expansion Repair and associated Tube Plugging Activities

GPUN examined a sample of 477 tubes in OTSGs A and B using the dual examination method. This sample was selected to determine if the kinetic expansion process had significantly altered the condition of the OTSG tubes.

The sample was based on the requirements of GPUN specification SP-1101-22-014 which is summarized in TR-008 Appendix A (p. 109-113). The sample requirements are summarized below:

(a) All tubes with <40% through wall indications which remained in-service. (ISI Tubes)

(b) All tubes adjacent to 10 selected simply plugged tubes with defects in the 15th, 10th and 1st spans. (10 tubes each OTSG).

(c) All tubes adjacent to 10 selected simply plugged tubes, in the periphery of each OTSG.

(d) 50 tubes in high plugging density areas in each OTSG.

(e) All tubes adjacent to 5 plugged tubes in each OTSG with >3 volt signals in the lower part of the OTSGs.

(f) In addition to (a) through (e) above, all tubes identified as leaking during the post repair drip and or bubble tests were included.

The examination of the above sample of tubes provided an evaluation of the "worst case" areas of the OTSGs. The examination resulted in the identification of indications $\geq$40% through wall which were not previously recorded in 35 tubes (7.5%). In addition, 1 of the indications previously identified as being <40% through wall in OTSG A appeared as $\geq$40% and required further dispositioning. The comparison of the tube status prior to and after the kinetic expansion process is summarized in Table 3 and in TR-008, Appendix A (p. 109-113).

In its 1983 evaluation GPUN reviewed the 1982 baseline to establish the cause of the newly detected indications. This review concluded that:

1. The majority of the indications could be detected during detailed reviews of specific areas of the 1982 baseline data. These reviews showed the indications had typically been present at low amplitudes and signal to noise ratios of 1 to 1 or less.

2. The kinetic expansion process apparently caused the amplitude and corresponding signal to noise ratio of the indications to increase thereby making them more detectable.

3. The indications were located near the top of the OTSG. Twenty eight (28) of the 35 (80%) of the indications ≥40% through wall which had not previously been detected were located within the upper tube sheet. This would be the area most affected by the kinetic expansion process.

4. The phase angles of the indications reported in 1983 did not show a relevant increase in the percent through wall when compared to the 1982 baseline data.

GPUN also reviewed the 1982 baseline and 1983 post KE data to determine if the indication (ISI tube in 1982) previously identified as being <40% through wall in 1982, and then reported as greater than 40% through wall in 1983, indicated a change in the status of the tube. A detailed review of this tube and prior associated indications revealed that they were outside diameter originated and are therefore not part of this evaluation for primary side attack. Its disposition was covered by the TMI Unit 1 technical specifications requirements and the tube was removed from service.

1984 Pos* Hot Functional Testing Examinations (November, 1984)

Purpose: Determine the cumulative effects of the kinetic expansion repair and subsequent hot functional testing on the condition of the OTSG tubes.

Following the hot functional testing (HFT) performed after the kinetic expansion repairs (KE) GPUN performed the 1984 examinations of the TMI OTSGs. These examinations provided a basis for determining the cumulative effects of the kinetic expansion repair and subsequent hot functional testing of the OTSG tubes. These examinations identified indications not recorded in previous examinations. To characterize the newly recorded indications and determine when they could first be detected, GPUN performed extensive reviews of the historical data for 2 data sets. These data sets are discussed in (A) and (B) below.

(A) The first data set selected for evaluation from the November, 1984 data set was 375 tubes for which post kinetic expansion data was available. This data set included:

(1) All tubes remaining in service in OTSG A which were previously examined during the 1983 post KE examination. This consisted of 163 tubes with no previously recorded indications and 28 tubes previously identified as having 20-<40% through wall indications (ISI Tubes).

(2) All tubes in the outer periphery of OTSG B which remained in service following the 1983 post KE examinations. This consisted of 128 tubes with no previous indications and 56 tubes previously identified as having 20-<40% through wall indications (ISI Tubes).

As a result of these examinations, 14 of the 291 (5%) tubes with no previous indications were identified as having indications ≥40% through wall. Of the 84 previous ISI tubes, 3 tubes had indications reported in 1984 which had not been previously identified in 1983. These 14 tubes with no previous indications and the 3 ISI tubes are discussed separately below. The results of the examinations are summarized in Tables 4 and 5.

Tubes With No Previous Indications

For the 14 tubes with indications ≥40% through wall which were not previously recorded, a complete evaluation of the historical data was performed. The review characterized the indications and determined if they had been present during the previous examinations. This evaluation concluded that:

1. During the review of the 1983 post KE data, 14 of the 14 indications were detectable but were low amplitude signals within the noise. During the review of the 1982 baseline

data, 9 of the 14 indications could be identified. This would suggest that both the kinetic expansion and hot functional testing increased the detectability of the indications.

2. The amplitude of the indications increased from the 1983 post KE examination to the 1984 post HFT examinations making them more detectable from the surrounding noise.

3. The indications recorded during the 1984 Post HFT examinations have a small circumferential extent as shown by the 8x1 absolute probe. Of the 14 indications having ≥40% through wall penetrations, 13 appear as 1 coil and 1 appears as a 2 coil indication. A 360° indication would appear as an 8 coil indication.

<u>ISI Tubes</u>

For the three previous ISI tubes which have indications ≥40% through wall, which were not previously identified and reported in 1983, the evaluations are as follows:

One tube A-120-106 showed an additional indication which was identified as being 95% through wall and 4.0 volts and was located at the edge of the 15th support plate.

Upon a re-review of the 1983 Post Kinetic Expansion Data it was determined that the indication was present at approximately 55% through wall and 2.1 volts but the signal was masked by the signal from the tube support plate. The effects of the support plate signal also distorts the phase angle of the eddy current signal making an accurate percent through wall determination impractical.

This particular tube support is a drilled support and cannot be "mixed out" using the multifrequency eddy current techniques used to examine the broached supports located throughout the remainder of the OTSGs. This creates a zone of reduced sensitivity (approximately .5" above and below the edges of the support plate) at the drilled support locations. The 1983 signal at 2.1 volts is below the 3.3 volt threshold of detection for the drilled support plate as established in TDR 423.

This zone of reduced sensitivity applies to the edges of both the upper and lower tubesheets and the drilled hole in the 15th support plate. The drilled holes are located only in the extreme outer periphery of the 15th support plate. The remainder of the 15th support plate and the other 14 support plates are the "broach" design and do not have this zone of reduced sensitivity.

The other two tubes, A-3-31 and A-149-14, had indications greater than 40% through wall reported in 1984 which had not been previously identified. In the re-review of the 1983 data at the specified location, the indications were identified and compared to the 1984 data. This comparison showed the indications were low amplitude signals masked by noise in the 1983 data. (See Table 5).

(B) The second data set selected for evaluation from the November 1984 data set was 46 tubes with indications first identified during the 1984 examinations. This data set included:

(1) 12 tubes with indications less than 40% through wall and 34 tubes with indications greater than 40% through wall. The tubes selected for this evaluation were previously included in the 1984 Growth Program. The tubes were located in the outer periphery of the OTSG A.

The indications were characterized and compared to the 1982 baseline data. The results of the evaluation conclude that:

1. Knowing the exact location of the 1984 indications, the corresponding indications could be identified during a review of the 1982 baseline data for 32 (70%) of the tubes. This would indicate the areas had been affected prior to the 1982 baseline examinations.

2. A comparison of the 1982 to 1984 data shows the average amplitude increased from 0.6 volts in 1982 to 1.5 volts in 1984. This demonstrates the amplitude of the indications increased during this time period making them more detectable.

3. The comparison of the 1982 to 1984 percent through wall determinations showed a slight downward trend of approximately 11 percent through wall (equivalent to a 3° phase angle change). Based on this phase angle evaluation, no significant trend of through wall growth can be established.

Table 2

Chronology of Steam Generator Evolutions and Corresponding Eddy Current Examination

Steam Generator		Eddy Current Examination		
Event	Duration	Data Sets	Results > 40% T.W.	
			A	B
Start-up & Test 131 tubes leak	Oct-Nov 1981	July-Sept 1982 (1982 baseline)	885	273
Kinetic Expansion Repair	Oct-Dec 1982	Oct-Nov 1982 (in process)	9	6
		April-May 1983 (Post)	22	14
Hot Functional Test	Aug-Oct 1983 May 1984		- -	- -
Leak Test	June 1984	July 1984	0	1
Dry Lay up	June-Nov 1984		-	-
Tech Spec 4.19	Nov-Dec 1984	Nov-Jan 1984	298	30

Table 3

Results of 1983 Post Kinetic Expansion Examinations

Status Prior to Kinetic Expansion (1982 Baseline)

OTSG	Tubes Examined	Tubes NRI	Tubes <40% (ISI Tubes)	Tubes ≥40%	** ISI Tubes Preventivel Plugged
A	215	200	14	0	1
B	263	212	51	0	0
TOTALS	478	412	65	0	1

Status After Kinetic Expansion (1983 Examinations)

OTSG	Tubes Examined	Tubes NRI	Tubes <40% (ISI Tubes)		Tubes ≥40%		** ISI Tubes Preventivel Plugged
A	214	163	28	(12 previous ISI) (16 previous NRI)	22	(1* previous ISI) (21 previous NRI)	1
B	263	193	56	(51 Previous ISI) (5 Previous NRI)	14	(0 previous ISI) (14 Previous NRI)	0
TOTALS	477	356	84		36		1

NRI - No Relevant Indications

NOTES: * In 1 tubes, indications reported as <40% through wall in 1982 were reported as ≥40% through wall in 1983. These indications are outside diameter initiated and are not considered relevant to the present evaluations.

** These ISI tubes were preventively plugged in accordance with engineering dispositioning based on location (axial and/or radial) of <40% thru wall indications.

Table 4

Results of Post Hot Functional Testing Examinations

Status of Tubes Prior to H.F.T.

OTSG	Tubes Examined	Tubes NRI	Tubes <40% (ISI Tubes)	Tubes >40%
A	191	163	28	0
B	184	128	56	0
Total	375	291	84	0

Status of Tubes After H.F.T.

OTSG	Tubes Examined	Tubes NRI	Tubes <40% (ISI Tubes)	Tubes >40%
A	191	133	39 (23 previous ISI) (16 previous NRI)	19 (5 previous ISI) (14 previous NRI)
B	184	127	56 (55 previous ISI) (1 previous NRI)	1 (1 previous ISI) (0 previous NRI)
Total	375	260	95	20

NRI = No Relevant Indications

Table 5

ISI Confirmed Indications

Greater Than 40% Through Wall in 1984

				April 1983 Post KE Data		Nov. 1984 Post HFT Data	
Gen	Row Tube	Indication Elevation	Origin	% T.W.	Volts	%	Volts
A	3 - 31	13+0	ID	33%*	1.1	33%	1.5
		13+04	ID	27%**	0.8	<20%	1.3
		13+05	ID	33%**	1.3	36%	3.3
		13+08	ID	40%**	0.6	45%	1.5
		13+15	ID	30%**	0.3	2831%	0.8
A	149 - 14	14-06	ID	86%**	0.4	76%	0.6
		15-16	ID	80%**	0.5	69%	0.7
		US+04	ID	20%	1.0	Not Detected	
A	120 - 106	12+09	ID	40%**	0.5	41%	1.4
		13-08/15-08	ID	50%**	0.4	48%	0.7
		15+0	ID	55%**	2.1	95%	4.0
		US+02	ID	20%	1.1	20%	1.2

* Represents re-evaluation of 1983 data.

** Indications not previously identified during production examinations, indications first identified during 1984 review of 1983 data.

VI. GROWTH PROGRAM

GPUN initiated a growth program during the examinations in November 1984 to determine if a growth mechanism was active during the current (July-Nov 1984) period of extended dry layup of the TMI-1 OTSGs. This sample included a population of 100 tubes in 'A' and 50 tubes in 'B'. The tubes for both generators were selected from high defect areas of the generators and were examined full length using the GPUN dual examination method.

OTSG A GROWTH PROGRAM

The growth program in the 'A' OTSG consisted of examining a population of 100 tubes 3 times at approximately 2 week intervals. Initially, these tubes were examined as part of the production eddy current program in Mid-November 1984. The tubes were subsequently examined a second time in late November 1984 and a third time in Mid-December 1984. Results of the 3 examinations of each tube were then compared for changes in the number of indications and for changes in signal response voltage or percent through wall determinations.

The 100 tubes in the 'A' Growth Program included 55 tubes with confirmed indications and 45 with no relevant indications. The comparisons of the repeat examinations were performed by evaluating the signal amplitudes and percent through wall determinations. These evaluations revealed essentially no change in the voltage or percent through wall determinations. These results indicate that there was no continued degradation during the three examinations from November to December, 1984.

OTSG B GROWTH PROGRAM

The Growth Program in 'B' consisted of a Mid-November 1984 examination of 50 tubes which were previously examined in July 1984. These 50 tubes were selected from the high defect area for full length examination in July 1984 during a limited scope examination performed when primary to secondary leakage was detected.

The July and November 1984 Eddy Current results were then compared and no previously undetected indications were found to exist in the November 1984 results. There was no evidence of continued degradation in these tubes between July and November 1984.

GROWTH PROGRAM CONCLUSIONS

The Growth Program evaluations indicate there was no significant change in the condition of the tubes from July to November 1984 in the 'B' OTSG or from Mid-November to Mid-December in 1984 for the 'A' OTSG. This information does not indicate any correlation between extended dry lay-up and identification of previously undetected indications.

VII. CONCLUSIONS

Based on the characterization of the 1984 indications, a review of the 1982, 1983 and the growth program data, GPUN was able to draw the following conclusions for the 1984 examination results.

1. The characterization of the 1984 indications by axial and radial locations, and their correlation to the indications reported in the 1982 baseline, suggest that the 1984 indications are an additional subset of the 1982 indications.

2. The re-evaluation of previous data suggests that the indications identified in 1984 were already present during the 1982 examination but were within the background noise.

   The kinetic expansion repair and hot functional testing may have increased the amplitude of these previously existing indications and made them detectable during production examinations. There was no trend of through wall growth associated with this amplitude increase.

3. Based on the evaluation of the Growth Program, there is no evidence of continuing tube degradation since the OTSGs were placed in dry layup in July 1984.

4. The characterization of the 1984 indications shows that approximately 90% of the indications are 20-60 percent through wall and 1 coil. These indications are at or near the threshold of detection for the previously established sensitivity curve.

5. Approximately 10% of the indications are higher percent through wall (≥60%) with a circumferential extent of 1 or 2 coils. There is a total of three (3) coil circumferential extent indications. All of these indications are between the threshold for detection and the most conservative curve for critical crack size. (Main Steam Line Break).

VIII. REFERENCES

1. GPUN TDR 423, Rev. 1, R. Barley, J. Janiszewski, G. Rhedrick, M. Torborg, "Three Mile Island - Unit 1 OTSG Tubing Eddy Current Program Qualification," 3/15/84.

2. GPUN TDR 442, Rev. 0, G. Rhedrick, "Eddy Current Examination Results of Three Mile Island Unit 1 OTSG," 8/29/83.

3. GPUN TDR 642, Rev. 0, M. Torborg, G. Rhedrick, "Qualification of Conversion Curve for Inner Diameter Discontinuities," 1/29/85.

4. GPUN TDR 401, Rev. 0, G. Rhedrick, "Report on Eddy Current Indications Found Subsequent to Kinetic Expansion of TMI-1 Steam Generator Tubes," April 1983.

5. GPUN Topical Report 008, Rev. 3, T.M. Moran, "Assessment of TMI-1 Plant Safety for Return to Service After Steam Generator Repair", August 19, 1983.

APPENDIX A

ABSTRACT ON THE DEVELOPMENT OF THE DUAL INSPECTION TECHNIQUE AND PERCENT THROUGH WALL CALIBRATION CURVE

Prior to the 1982 OTSG tubing inspection, GPU Nuclear had always performed its OTSG tubing examinations with the standard differential eddy current technique for detecting indications that normally originated on the outer diameter of the tube wall. The eddy current inspection system was operated at normal gain and the probes used for these inspections measured 0.510" diameter. These parameters traditionally were considered acceptable for inspecting the OTSG tubing which has a nominal inner diameter of 0.557".

After 131 tubes leaked upon start-up and test in November 1981, eddy current examinations were immediately performed with the standard differential (S.D.) .510" technique and some of the leaking indications were not detected. A subsequent examination was performed with a multi-coil absolute eddy current technique and indications were identified in the roll transition of the leaking tubes. In addition, other indications which had not been detected by the previous S.D. .510" examination were identified. The defects discovered in the OTSG tubing were metallurgically evaluated as inner diameter initiated, very tight, and orientated around the circumference of the tubes. It was then recognized that the S.D. .510" technique was not sensitive enough for detecting all of the new inner diameter discontinuities.

GPU Nuclear modified and improved the sensitivity of its standard differential technique by increasing the probe's diameter to 0.540", and increasing the operating gain. This modification improved the standard differential's sensitivity for detection of predominately circumferential, I.D. initiated indications by approximately 175% over the older technique. The disadvantage of using the high gain and improved fill factor is that the standard differential examination becomes overly sensitive to surface anomalies.

The absolute technique used to confirm the standard differential inspection results was also modified and improved. The development of the 8X1 Absolute probe with eight pancake shape coils placed around the probe body provided 360 degrees coverage on the circumference of the tube wall. This design permitted a single pass of the probe in the tube during an examination as compared to multiple passes when fewer coils are used. The eight coils also provided a fair estimate of the arc length of an indication because the response signal from each coil represents its proximity to the indication.

Using the improved S.D. .540" high gain and absolute 8x1 techniques, GPU Nuclear developed a dual method eddy current inspection technique. The initial examination was performed by the S.D. .540" high gain technique. If the examination by S.D. .540" showed no evidence of a defect, its examination became the final inspection of record.

If the S.D. .540" examination reported an indication, a second examination was performed using the absolute 8x1 technique. The absolute 8x1 examination determined if the reported indication was relevant or non-relevant. For those indications determined to be relevant, the absolute 8x1 result was used to estimate the arc length and also confirm the origin (I.D./O.D.) and axial location of the indication.

During a standard differential eddy current examination the percent through wall penetration of a flaw is determined by measuring the response signal's phase angle and converting that measurement to the percent through wall. A

calibration for this conversion is established by setting up the standard differential equipment and testing a known standard. The phase angle for the eddy current response signal is adjusted to a specified measurement which generally is 40 degrees for a 100 percent through wall by .052" diameter hole standard. This calibration is done in accordance with the ASME Section XI code. The traditional conversion curve for phase angle measurement to inner diameter initiated percent through wall is determined by the values that are extrapolated from the 40 degree phase angle-100 percent through wall (given by the .052" diameter hole standard) to zero degree phase angle--zero percent through wall.

The estimated percent through wall that is extrapolated from the conversion curve tends to overcall the actual percent through wall of a small volume flaw. This over calling is considered conservative eddy current evaluation and was instituted in the 1982 dual inspection technique.

It had always been acknowledged that this traditional curve overcalled small volume inner diameter discontinuities. The presence of smaller inner diameter initiated cracks in the TMI-1 OTSG's had required GPUN to develop a more accurate means of assigning the percent through wall penetration. Therefore, the traditional inner diameter conversion curve was enhanced by using supplemental data from EDM with various known depths. This data was used to develop a conversion curve which more accurately represented small volume, inner diameter initiated discontinuities and this accuracy was verified through metallurgical correlations using actual intergranular stress assisted crack samples.

APPENDIX B

1982, 1984 EDDY CURRENT STATISTICS

TMI STEAM GENERATOR A AXIAL LOCATIONS OF CONFIRMED
INDICATIONS 0-100% THROUGH WALL
PERCENT VS SPAN
1982 VS 1984

	1982		1984	
Support	Frequency	%	Frequency	%
LP-1	6	.19	1	.090
1-2	23	.717	2	.181
2-3	8	.249	8	.726
3-4	8	.249	19	1.725
4-5	17	.53	7	.635
5-6	58	1.808	19	1.725
6-7	34	1.714	26	2.361
7-8	55	1.060	5	.458
8-9	34	1.714	12	1.1
9-10	11	.343	4	.367
10-11	24	.748	8	.726
11-12	54	1.683	13	1.181
12-13	63	1.964	54	4.900
13-14	146	4.551	57	5.177
14-15	97	3.024	78	7.084
15-US	530	16.521	217	19.70
US-UP	2040	63.591	571	51.861
TOTAL	3208		1101	

Note: (1) 1984 data includes the length of tubing below the kinetically expanded zone. (Approximately US+7 and below).

(2) 1982 data includes the length of tubing from US+15 and below.

(3) Data taken from 1982 and 1984 data bases as of 2/15/85.

TMI STEAM GENERATOR B AXIAL LOCATION OF CONFIRMED
INDICATIONS 0-100% THROUGH WALL
PERCENT VS SPAN
1982 VS 1984

	1982		1984	
Support	Frequency	%	Frequency	%
LS	6	.468	6	3.109
1-2	3	.234	2	1.036
2-3	4	.312	1	.518
3-4	20	1.561	3	1.554
4-5	9	.703	6	3.109
5-6	9	.703	4	2.072
6-7	24	1.874	8	4.145
7-8	12	.937	7	3.627
8-9	19	1.483	4	2.072
9-10	20	1.561	9	4.663
10-11	15	1.171	2	1.036
11-12	34	2.654	12	6.218
12-13	34	2.654	12	6.218
13-14	106	8.275	7	3.627
14-15	81	6.323	7	3.627
15-US	98	7.650	25	12.953
US	787	61.144	78	40.414
TOTAL	1281		193	

Note: (1) 1984 data includes the length of tubing below the kinetically expanded zone. (Approximately US+7 and below).

(2) 1982 data includes the length of tubing from US+15 and below.

(3) Data taken from 1982 and 1984 data bases as of 2/15/85.

TMI STEAM GENERATOR A VOLTAGE DISTRIBUTION FOR CONFIRMED
INDICATIONS 0-100% THROUGH WALL
PERCENT VS VOLTS
1982 VS 1984

1982		1984	
Volts	Percent	Volts	Percent
0	31.807	0	34.968
1	44.653	1	35.15
2	16.595	2	23.615
3	4.702	3	4.814
4	1.537	4	.636
5	.338	5	.363
6	.184	6	.091
7	.061	7	.182
8	.092	8	.182
9	0	9	0
10	.031	10	0

Note: (1) 1984 data includes the length of tubing below the kinetically expanded zone. (Approximately US+7 and below).

(2) 1982 data includes the length of tubing from US+15 and below.

(3) Data taken from 1982 and 1984 data bases as of 2/15/85.

TMI STEAM GENERATOR B VOLTAGE DISTRIBUTION FOR CONFIRMED
INDICATIONS 0-100% THROUGH WALL
PERCENT VS VOLTS
1982 VS 1984

1982 Volts	1982 Percent	1984 Volts	1984 Percent
0	23.878	0	26.425
1	28.897	1	20.207
2	25.019	2	27.979
3	9.810	3	11.917
4	6.844	4	5.699
5	1.901	5	3.109
6	1.597	6	1.036
7	.608	7	1.554
8	1.217	8	1.554
9	0	9	0
10	.076	10	.518
11	.152	11	0

Note: (1) 1984 data includes the length of tubing below the kinetically expanded zone. (Approximately US+7 and below).

(2) 1982 data includes the length of tubing from US+15 and below.

(3) Data taken from 1982 and 1984 data bases as of 2/15/85.

TMI STEAM GENERATOR A CONFIRMED PERCENT THROUGH WALL
DISTRIBUTION FOR CONFIRMED INDICATIONS 0-100% THROUGH WALL
PERCENT VS PERCENT THROUGH WALL
1982 VS 1984

1982 % Thru-Wall	%	1984 % Thru-Wall	%
0-19	.281	0-19	0
20-29	1.434	20-29	39.055
30-39	1.309	30-39	21.163
40-49	6.827	40-49	17.802
50-59	13.685	50-59	7.629
60-69	9.757	60-69	5.904
70-79	7.512	70-79	2.186
80-89	8.635	80-89	1.907
90-100	50.561	90-100	3.724

Note: (1) 1984 data includes the length of tubing below the kinetically expanded zone. (Approximately US+7 and below).

(2) 1982 data includes the length of tubing from US+15 and below.

(3) Data taken from 1982 and 1984 data bases as of 2/15/85.

TMI STEAM GENERATOR B CONFIRMED PERCENT THROUGH WALL
DISTRIBUTION FOR CONFIRMED INDICATIONS 0-100% THROUGH WALL
PERCENT VS PERCENT THROUGH WALL
1982 VS 1984

1982 % Thru-Wall	%	1984 % Thru-Wall	%
0-19	11.788	0-19	0
20-29	11.866	20-29	63.212
30-39	16.472	30-39	13.99
40-49	10.617	40-49	11.917
50-59	13.349	50-59	4.663
60-69	8.041	60-69	3.109
70-79	6.401	70-79	2.073
80-89	5.699	80-89	0
90-100	15.769	90-100	1.036

Note: (1) 1984 data includes the length of tubing below the kinetically expanded zone. (Approximately US+7 and below).

(2) 1982 data includes the length of tubing from US+15 and below.

(3) Data taken from 1982 and 1984 data bases as of 2/15/85.

CIRCUMFERENTIAL EXTENT FOR CONFIRMED INDICATIONS

GENERATOR A

Coils	1982 Frequency	%	Coils	1984 Frequency	%
0	270	(N/A)	0	321	(N/A)
1	655	66.973	1	1111	89.959
2	301	30.777	2	122	9.878
3	18	1.840	3	2	0.162
4	1	0.102	4	0	0
5	1	0.102	5	0	0
6	0	0	6	0	0
7	1	0.102	7	0	0
8	1	0.102	8	0	0
TOTAL	978			1235	

GENERATOR B

Coils	1982 Frequency	%	Coils	1984 Frequency	%
0	361	(N/A)	0	321	(N/A)
1	147	50.000	1	102	79.069
2	102	34.694	2	26	20.155
3	26	8.843	3	1	.775
4	7	2.381	4	0	0
5	4	1.360	5	0	0
6	0	0	7	0	0
7	0	0	8	0	0
8	8	2.721	9	0	0
TOTAL	294			129	

Note: (1) 1984 data includes the length of tubing below the kinetically expanded zone. (Approximately US+7 and below).

(2) 1982 data includes the length of tubing from US+15 and below.

(3) Data taken from 1982 and 1984 data bases as of 2/15/85.

GPU Nuclear	**DOCUMENT NO.** TDR-652

TITLE Evaluation of the 1984 Required Technical Specification Examination for the TMI-1 OTSG

REV	SUMMARY OF CHANGE	APPROVAL	DATE
1	The number of confirmed indications ≥ 40% thru wall in "A" Once Through Steam Generator has changed to 298 tubes from 297 tubes. The total number of tubes with indications ≥ 40% for both "A" & "B" has increased by one to 320. Pg. 12 add subtitle "Status of ISI Tubes." Revised Table 1, % T.W. & Volts 1983 & 1984. Revised Table 2, quantity of tubes in "A" OTSG with indications ≥ 40% to 22 from 20 and to 298 from 297. Revised Table 3, add column to report ISI tubes that were preventively plugged. Revised Table 4, revised quantity of tubes examined and tubes NR I to be in agreement with revision made to Table 3. Revised Table 5, % T.W. & Volts - 1983 & 1984.	[signature] 3/26/85 RDB 3/26/85 NCK 3/27/85	

RELATED CORRESPONDENCE

GPU Nuclear
TECHNICAL DATA REPORT

TDR NO. 666	REVISION NO. 0	
BUDGET ACTIVITY NO. 123125	PAGE 1 OF 18	
PROJECT: TMI-1 OTSG REPAIRS	DEPARTMENT/SECTION E&D/Mech. Comp.	
	RELEASE DATE	REVISION DATE

DOCKETED USNRC '85 APR 12 P12:14

DOCUMENT TITLE: Adequacy of TMI-1 OTSG Return to Service Safety Assessment After 1984 Technical Specification ECT Examination

ORIGINATOR SIGNATURE	DATE	APPROVAL(S) SIGNATURE	DATE
T. A. Richter *T. A. Richter*	3/18/85	B. D. Elam *B. Elam*	3/20/85
		G. R. Capodanno *G. Capodanno*	3/25/85
		APPROVAL FOR EXTERNAL DISTRIBUTION	**DATE**
		D. K. Croneberger *D. K. Croneberger*	3-28-85

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ABSTRACT:

Statement of the Problem

The safety assessment of the return to service of the TMI-1 OTSG's was made in 1983 (TR-008) and encompassed the examination, evaluation and repair of defects known up to that time and the prevention of reoccurrence. The 1984 technical specification eddy current examination reported further indications in both OTSG's.

Summary

The examinations done in 1984 have identified enhanced visibility of pre-existing indications on the threshold of detectability as the most probable and reasonable explanation for the new indications.

It was concluded that the corrosive failure mechanism identified in 1983 is still the correct description of what the OTSG's have undergone. The precautions taken to prevent reoccurrence have been adequately observed and are effective; no new material attack has occurred.

Conclusion

The safety assessment as originally performed in TR-008 remains valid and the 1984 inspection results neither call into question, nor invalidate, nor require a revision to the assessment.

*COVER PAGE ONLY

1.0 INTRODUCTION

The safety assessment of the results of the TMI-1 OTSG repairs was originally done in Reference (1) and encompassed the examination, evaluation, and repair of the defects known up to the reports' release date and the subsequent testing and examination of those repairs. Recent examination in support of TMI-1 Technical Specification requirements in 1984 has uncovered additional indications. These indications may be generally characterized as follows (Ref. 3, page 23-24):

1. They are predominantly located within the outer periphery of both OTSG's. Some indications appear entirely across OTSG-1A; none of greater than 40% through wall penetration appear in the core region of OTSG-1B.

2. They are mostly (approximately 50%) in the upper tubesheet and (approximately 20%) in the 16th tube span area.

3. They predominantly exhibit voltages below 2 volts.

4. They are, in the majority, of less than 50% through-wall penetration.

5. They exhibit circumferential extent by 8 x 1 absolute ECT of predominantly 2 coils or less (90% of all indications).

This report reviews the 1983 evaluation for accuracy in light of the 1984 examination results. Discussion will center on the information contained in References 2 & 3 as it pertains to the logic and conclusions of Reference 1.

2.0 METHOD

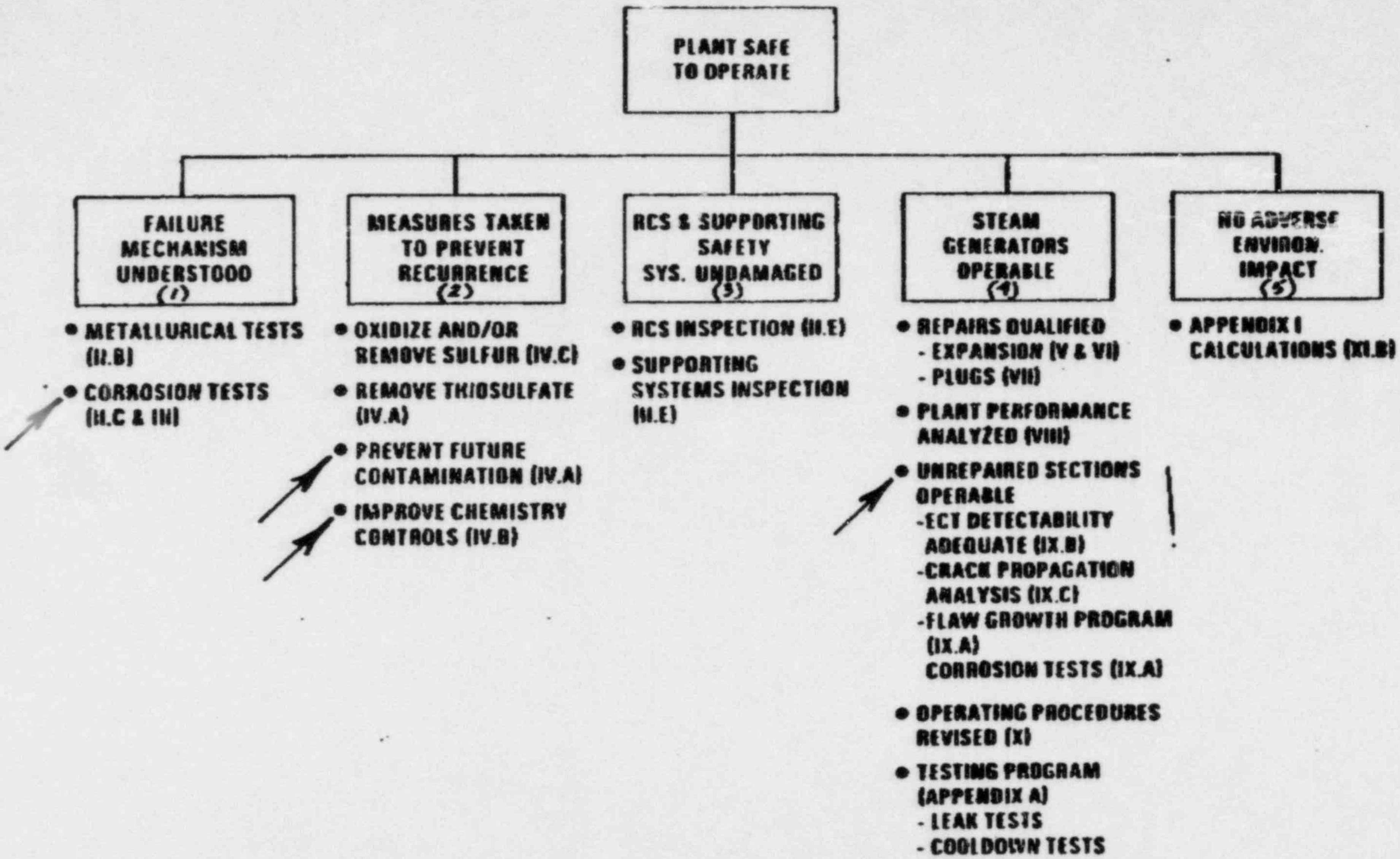
The logic of the safety evaluation done in TR-008 is set forth in Section ID and describes the points to be demonstrated and assured by the repair program to allow OTSG return to service. This logic is graphically captured in Figure 1-7 (attached) and stated in ID (1) through (5) as follows (Ref. 1, Section ID, page 3):

"1. The failure mechanism is understood well enough to define the root cause of the steam generator damage;
2. Other components in the RCS and supporting safety systems were not visibly damaged by the failure mechanism;
3. The plant can be operated such that this failure mechanism is arrested and will not recur;
4. The Steam Generators can be repaired and operated within the design basis;

5. The plant can be operated with some tube leakage without adversely impacting the environment."

FIGURE 1-7

PLANT RETURN TO SERVICE SAFETY EVALUATION OVERVIEW



( ) - CORRESPONDING PARAGRAPH NUMBERS ADDED

↗ - EMPHASIS ADDED

The issues raised by the results of the 1984 inspection principally impact points (1), (2) and (4), specifically:

(1) Have the inspection results indicated the presence of a failure mechanism different than that set forth in TR-008?

(2) Have the steps taken under the assurance of preventing reoccurrence been followed accurately and proven effective?

(4) Has the confidence in ECT detectability been compromised by the discovery of new indications in the period Sept. 1982 to Jan. 1984 and has the lack of flaw growth and non-reoccurrence predicted by TR-008 been supplanted by the latest observations?

Each of these issues will be addressed in turn and the evidence to support or refute the positions set forth in TR-008 examined.

3.0 RESULTS

3.1 Issue (1): Failure Mechanism Identification

The discussion of failure mechanism is contained in Section II B and C and III in TR-008 (Ref. 1, Section IIB, 2g, page 11). Succinctly put, the OTSG tubing was found to have undergone intergranular stress-assisted cracking (IGSAC) producing predominantly circumferential cracking under the influences of a reduced sulphur species and axial stresses. In conjunction with cracking, intergranular attack (IGA) was observed. The cracking appeared to initiate and propagate in the presence of the thiosulphate agent, oxygen, and ambient temperatures.

Since the writing of TR-008, the results of the Long Term Corrosion Test (LTCT) have become available. The test followed conditions comparable to plant operation and confirmed that "in the absence of the intentionally added aggressive sulphur species, normal operations would not cause corrosion of TMI-1 OTSG tubing" (Ref. 2, Pg 12). Some IGA was noted in the LTCT samples that was not detectable by ECT (Ref. 2, page 12) most reasonably due to its superficial wall penetrations. Additionally, the ECT indications seen in 1982 were characterized as to voltage, percentage through-wall penetration, circumferential extent and spatial distribution. The comparison of recent ECT results with those of the 1982 examinations is accomplished in detail in Reference 3 (Section IVC, page 15). Here note was made that the amplitude and distribution of the total population of indications below the kinetic expansion zone appeared similar in 1982 and 1984, and both the through-wall

penetration and the circumferential extent seen in 1984 were lower than those seen in 1982. For the smaller population of indications that are reported in 1984 but only seen on re-review of 1982 tapes, the amplitudes have generally increased while the through-wall penetration has not. This is indicative of newly reported but previously existing indications formerly below the threshold of reportability.

Hot Functional Testing (HFT) provided mechanical loading necessary to cause enhanced detectability, in degrees which varied according to the severity of loading. All tubes at each elevation saw flow loads both inside and out. Lateral loads due to buffeting and cross-flow were present at varying elevations, and heat-up and cool-down axial loads in excess of those generated by normal operations were experienced by all OTSG tubes. The axial load varies from a maximum on peripheral tubes to a minimum on core tubes; both the ISGAC defects found previously and the 1984 indications reflected this radial bias. The kinetic expansion (KE) process produced loads significant enough to enhance detectability as well. Additionally, larger IGA areas would be more susceptible to enhancement after mechanical loading, and smaller areas are structurally insignificant. Fourteen (14) tubes with no previous history of indications were identified in this 1984 ECT examination (Post - HFT) as having indications of over 40% through-wall penetration. A review of the 1983 ECT (Post - KE) tapes identified all 14 indications as marginally detectable but of low amplitude. One of the 14 indications could be seen in the review of the 1982 examination, which preceded both hot functional testing and kinetic expansion. The amplitude increase in these indications is demonstration of increased detectability with "...no trend of through-wall growth associated with this amplitude increase." (Ref. 3, page 46).

These observations and appreciations support the plausibility of enhanced visibility of pre-existing indications on the threshold of detectability as the most probable and reasonable explanation for the new indications. The failure mechanism identified in 1983 is still the correct description of what the OTSG's have undergone.

3.2 <u>Issue (2): Prevention of Re-occurence</u>

The steps to be taken to prevent the reoccurrence of the 1981 IGSAC incident were outlined in Reference 1, Section IV. These involved four areas: physical removal of the source of contamination, chemical removal of the existing contaminant, introduction of strict administrative controls on the use of

other potential contaminants, and the revision of allowable RCS chemistry limits. The first two steps had been accomplished and were discussed in Reference 1.

The administration of the last two of these steps was reviewed for the period of time between 1982 and 1984. It was stated that a 95% adherence to the imposed limits was achieved; excursions were for brief periods and the environment remained protective (Ref. 2, pg. 16). It was therefore concluded that the adherence to the measures taken was adequate to prevent re-initiation of primary side corrosion.

The consideration of the ECT techniques used in 1982 to detect defects in the OTSG tubes is discussed in Reference 1, Section IX, as is the argument against recurring defects. Taking the last point first, the arguments against re-initiation are threefold:

"a) Cracking will not occur unless an active reduced species of sulfur is present and cracks in SG tubing will not propagate in the present chemical environment.

b) Sulfur induced cracking requires an oxidizing potential which does not exist under normal hot operating conditions.

c) Lithium hydroxide is an effective inhibitor of the cracking mechanism."

The results of both the short term corrosion tests (Reference 1, Section IIID) related in TR-008 and the Long Term Corrosion Tests (Ref. 2, pg. 11) bear out the accuracy of the original assessment.

Additional assurance of non-reoccurrence is obtained from the absence of flaw growth (Ref. 1, III) or the development of significant leaks since the 1982 inspections. The cracking mechanism is rapid, propagating up to 1 millimeter through-wall per day, and if the mechanism were still active the period of time past would have allowed the development of many severely leaking tubes. The bubble test of both OTSG's in Oct. 1984 showed 8 tubes in the lane area exhibiting minor leakage above the bottom of the kinetic expansion; the leakage was stopped by rolling the tubes. The leakage was via the kinetic expansion joint and in no way indicative of flaw growth in the tubes and as such had no safety impact. The most recent bubble test (3/11/85) showed no bubbling at all.

3.3 Issue (4) - Eddy Current Testing Limits of Detectability as It Impacts OTSG Operability

This leaves the question of why ECT found defects in 1984 that were not seen in 1982. Three possible classes of undetected defects were outlined in Reference 1 (IXC page 81):

"1) Local intergranular attack (IGA)

2) Below the detection limits of ECT

3) Detectable by ECT but missed through random error"

These causes were deemed to present no significant hazard because local shallow surface IGA results from the manufacturing process and is only 1-2 grains deep. Its long term behavior would be assessed by the Long Term Corrosion Testing. Additionally, small cracks below eddy current detectability will not propagate by chemical means in the absence of active corrodants and are far smaller than the crack size above which mechanical loading will cause propagation (Ref. 1 Section IXC page 82).

Taking the last point first, protection against randomly occurring failure to correctly read test results has been provided by Quality Assurance overview and the use of permanent magnetic tape records, allowing call-up and review of inspection results at any date. Additional protection is afforded by the GPUN practice of having a second data analyst separately review all tape records for missed or incorrectly analysed indications.

Subsequent to the release of TR-008 the observations obtained from the outcome of the Long Term Corrosion Tests and failure analysis are now seen to support the presence of local IGA which may not be visible to the standard .540 differential probe but have the potential to be exercised into visibility by mechanical loadings (Ref. 2, pg. 22). This presence is further suggested by the distribution of new indications (in tubes of higher mechanical loading) and the results of fiberscope observations in OTSG tubes in which rounded dark areas consistent with IGA in appearance were seen at locations where ECT reported indications (See Figures 3a and 3b).

The new indications can in fact be IGA that interacts with the ECT probe in a manner similar to IGSAC. This reflects the different geometries of IGA and IGSAC and the qualification method for ECT which employs constant width EDM slots more characteristic of IGSAC than IGA in as much as IGSAC implies significant depth of wall penetration for a given volume while IGA does not.

Consider the difference between IGSAC and IGA: Inter-Granular Stress-Assisted Cracking is characterized by sharp-edged, tight cracks running between metal grains and not visible optically prior to straining. It can be propagated under mechanical loading; the rate and threshold of this propagation has been determined in detail for the OTSG tubes and this knowledge was used to formulate the plugging and stabilizing criteria employed to determine which tubes must be removed from service, and how they shall be removed. Since circumferentially-oriented IGSAC posed the chief threat to the OTSG tubes, the examination methods were appropriately tailored to finding and measuring it accurately. Hence, ECT calibrations were done on electro-discharge machined slots in which the principal contributions to defect volumes were through-wall penetration and circumferential extent, not crack width.

Inter-Granular Attack, however, is characterized as roughly hemispherical pits penetrating as much as 50% of the tube wall, as seen in both the failure analysis (Ref. 8, Section IV, page 4, Fig. 17) and the Long Term Corrosion Test; the circumferential extent of an IGA pit of this size would be approximately .035". Two methods by which these pits of metal grains could become visible under mechanical loading were identified in Reference 2 (page 22) as:

"(1) Crea ion of a uneven grain boundary separation within the IGA islands as was seen in the LTCT...., or

(2) Disconnected grains dropping out and leaving pits."

It is important to note that this addresses the enhancement of visibility, and not propagation; the pit depth (to sound metal) remains the same. It has been demonstrated that IGA pits up to 83% through-wall do not significantly reduce tube burst strength (Ref. 4). Cracks originating in patches ("islands") of IGA would show no distinct orientation preference in the absence of loading and would not grow because the metal surrounding this IGA pit maintains its original ductility and would blunt the crack tip. Additionally, in the absence of an aggressive corrodant the pit will not grow chemically. Therefore tube damage done by IGA is already accomplished and is static; it remains only to evaluate the extent of that damage.

Nonetheless, for conservatism all 1984 indications have been dispositioned as if they were defects capable of active mechanical propagation in service (cracks). When this was done it could be seen that none of the defects individually challenged the Main Steam Line Break criteria for peripheral tubes. This is depicted on Figure 1 (a thru c), where the effects of through-wall penetration uncertainty and absolute ECT probe coil overlaps are used to show each defect as a probability area

rather than a point. The indications plotted in Figure 1 (a thru c) include all the worst combinations of through-wall penetration and circumferential extent for single defects (See Table 1). These tubes have all been removed from service in 1985. Three tubes exhibited defects of large circumferential extent but lesser penetration: 3 coil signals coupled with 20-50% through-wall penetration, with one showing 75% through-wall but located within the upper tubesheet. These extreme cases are also plotted and they nonetheless did not approach the MSLB line for peripheral tubes. It should be noted that, minority extremes aside, the great majority of all 1984 ECT indications fall below or in the immediate vicinity of the limits of ECT detectability (See Figure 2).

It can be seen from Figure 1a-c that the maximum possible size characterization of several indications both extend above the ECT detectability curve and include areas above curve A. Areas above curve A represent crack sizes which will propagate through-wall in service. Nonetheless, assuming the worst confluence of events (1- the indication is truly at the maximum extent of its characterization range, and 2- the defect is a crack and not an IGA pit) there is still no unanticipated hazard. Degradation in this range will be by through-wall penetration before tube rupture (Leak Before Break) and OTSG leak detection systems and procedures will enable operators to deal with the leaking tubes safely.

Many of these defects were nonetheless used as justification for removal of a tube from service. This arose from considering these pits as behaving like cracks and therefore capable of propagative interaction. Additionally, circumferential extent was characterized solely by the maximum number of ECT probe coils signalling; no credit was taken for the overlap of coils (See Figure 1a thru c) whereby a defect only slightly larger than one-half of one-coil sensitivity would register as a two-coil defect. These are inherent conservatisms which should not be used to mask the actual appreciation of the comparatively benign nature of these defects.

4.0 CONCLUSION

To recapitulate, TR-008 postulated a failure mechanism, a plan to prevent reoccurrence, and an assurance of the detectability of potential flaws before they propagate to tube failure. The results of the 1984 inspections (Ref. 2 and 3) indicate no alternative failure mechanism, general adherence to preventative guidelines, and reassurance of flaw detectability. There is nothing in the 1984 inspection results which invalidates, calls into question, or necessitates a revision to TR-008.

5.0 REFERENCES

1) GPUN TR-008 Rev. 3, "Assessment of TMI-1 Plant Safety in Return to Service After Steam Generator Repair", T.M. Moran, 9/3/83.

2) GPUN TDR 638, "Evaluation of Eddy Current Indications Detected During TDR 1984 Tech. Spec. Inspection", J. A. Janiszewski, 1/11/85.

3) GPUN TDR 652, "Evaluation of the 1984 Tech. Spec. Inspection for TMI-1 OTSG" - G. Rhedrick.

4) NUREG 1063 - "Steam Generator Operating Experience Update, 1982 - 1983".

5) GPUN TDR 388, "Mechanical Integrity Analysis of TMI-1 OTSG Unplugged Tubes", S. D. Leshnoff, 5/11/83.

6) GPUN TDR 401, 'Task IV Report on Eddy Current Indications Found Subsequent to Kinetic Expansion of TMI-1 Steam Generator Tubes", G. Rhedrick, 4/8/83.

7) GPUN TDR 423 Rev. 1, "TMI Unit 1 OTSG Tubing Eddy Current Program Qualification", R. Barley, 3/15/84

8) A. K. Agrawal, W. N. Stiegelmeyer, and W. E. Berry, "Final Report on Failure Analysis of Inconel 600 Tubes from OTSG A and B of Three Mile Island Unit 1", Battalle Columbus Laboratories, June 30, 1982

9) GPUN TDR 642, "Qualification of Conversion Curve For Inner Diameter Discontinuties", M. T. Torborg, 1/24/85.

TABLE 1

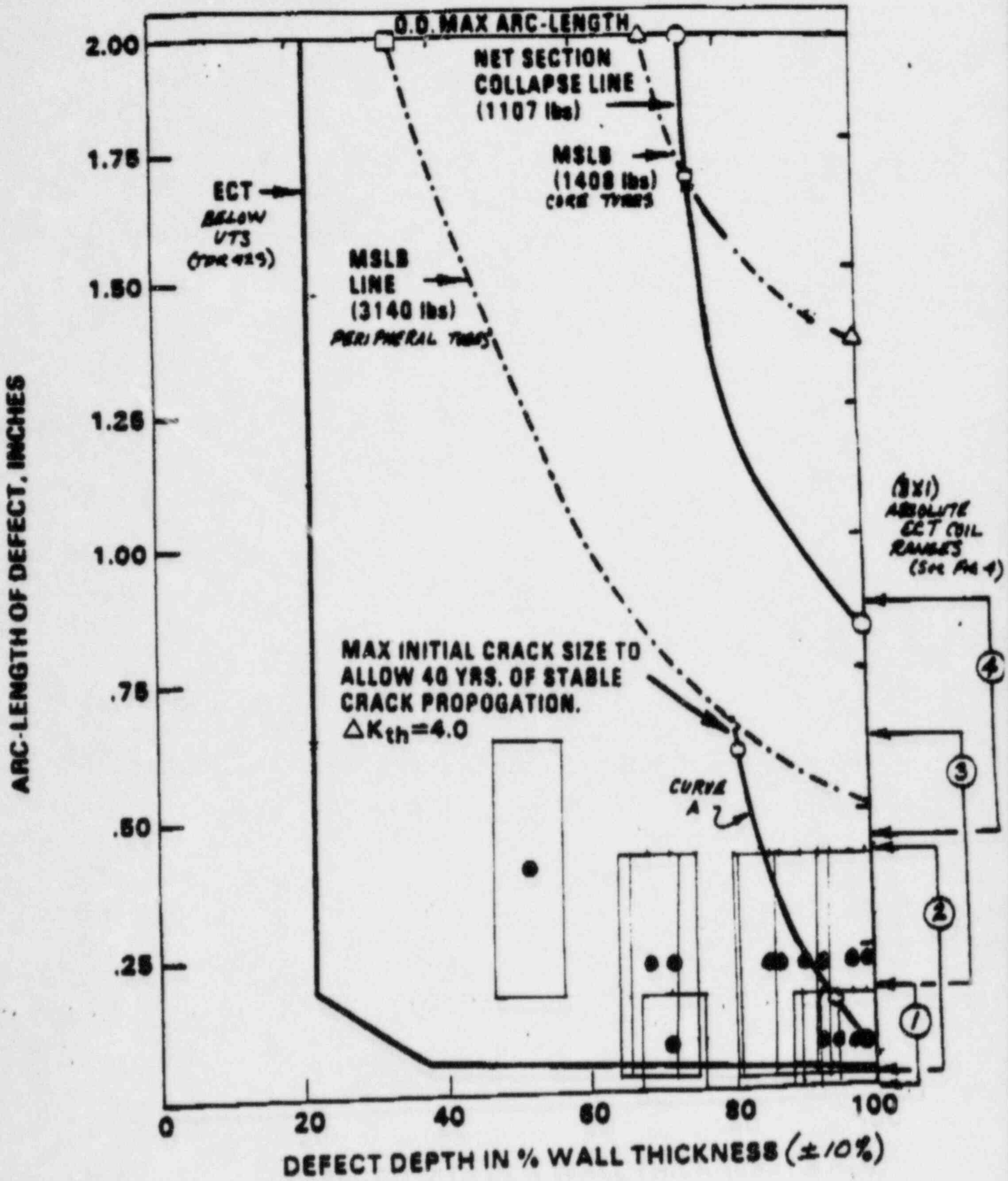
Major 1984 ECT Indications

OTSG	ROW/TUBE	ELEVATION	% THRU-WALL (540SD)	COIL-CALL(S) (8X1 ABS)
A	2-13	15 + 17	97	2
A	9-1	9 + 11	97	2
A	12-4	15 + 11	87	2
A	13-2	06 - 9	90	2
A	15-3	US + 0	97	1
A	16-3	15 + 6	97	1
A	57-1	03 - 13	99	1
A	57-128	15 + 43	95	1
A	63-127	US + 2	90	2
A	92-5	US + 5	99	2
A	111-113	15 - 13	93	1
A	112-117	10 + 14	99	2
A	115-110	US - 4	90	2
A	115-114	11 + 2	93	2
A	117-2	13 + 04	99	1
A	120-106	15 + 0	97	2
A	127-97	14 + 07	97	1
A	133-2	15 + 31	93	1
A	134-72	15 + 13	99	1
A	135-1	US - 14	97	1
A	138-64	US - 03	92	2
A	139-65	US - 03	86	2
A	139-73	US + 01	97	2
A	142-1	07 - 11	93	2
A	142-50	US - 08	97	2
A	143-31	US - 03	97	1
A	147-4	15 + 27	98	2
A	147-45	US + 01	99	2
A	149-14	15 - 17	99	1
A	151-8	15 + 00	86	2
A	9-4	15 + 26	72	1
A	63-127	US - 1	76	2
A	64-126	US + 6	86	2
A	78-126	US - 4	69	2
A	96-125	US + 1	72	2
A	115-110	US + 3	90	2
B	65-1	15 + 32	72	2
B	88-5	US + 1.1	66	2
B	97-5	US + 0	76	3
A	147-4	15 + 22	98	2

0838d

FIGURE 1 a

MAJOR INDICATIONS BELOW THE UTS LOWER FACE (±1")



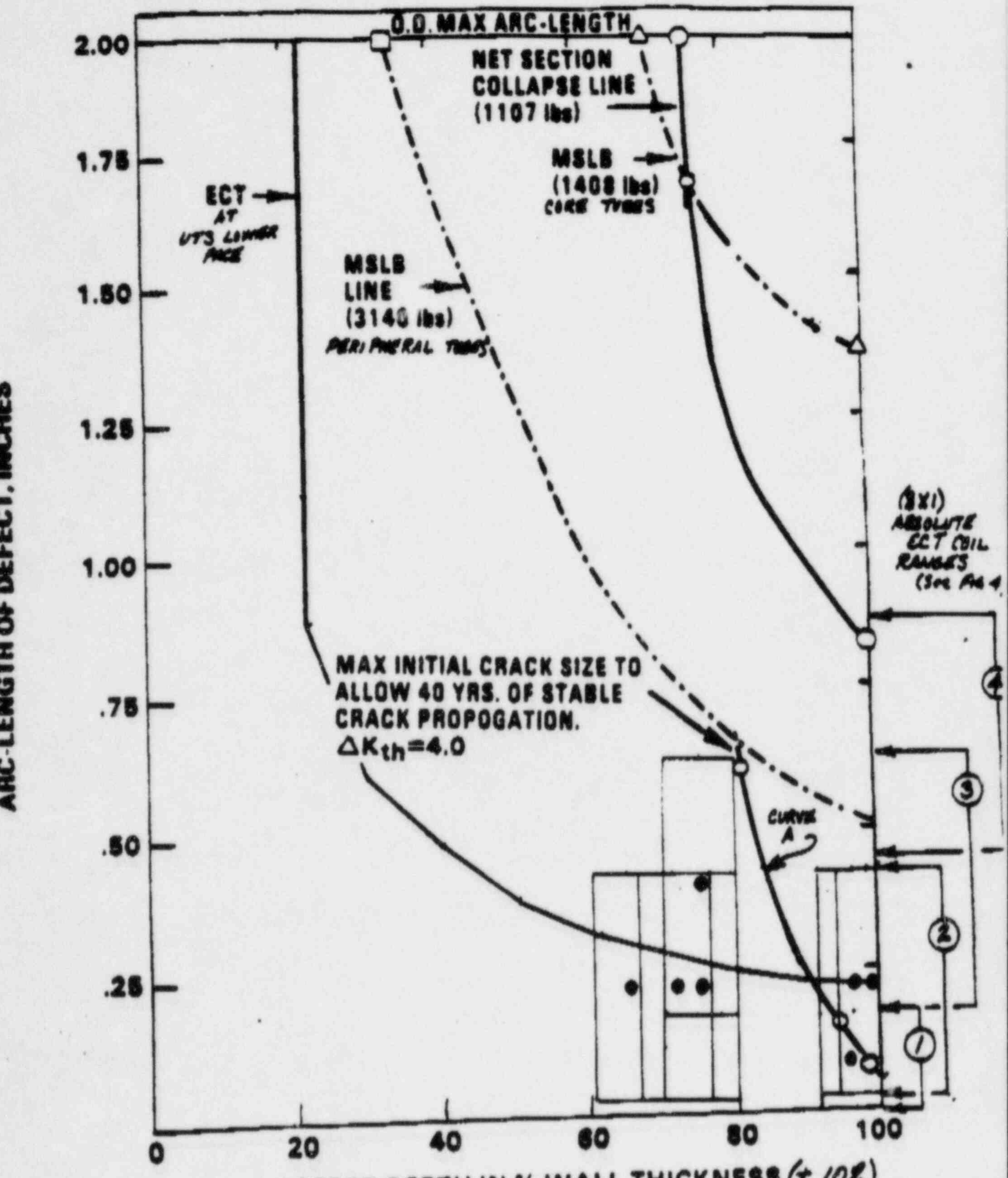
□ - PROBABILITY AREA OF INDICATION (REF 3, APP D, PG D22)

● - MOST PROBABLE INDICATION CHARACTERIZATION

(from TDR ...)

FIGURE 1b

MAJOR INDICATIONS AT THE UTS LOWER FACE (±1°)

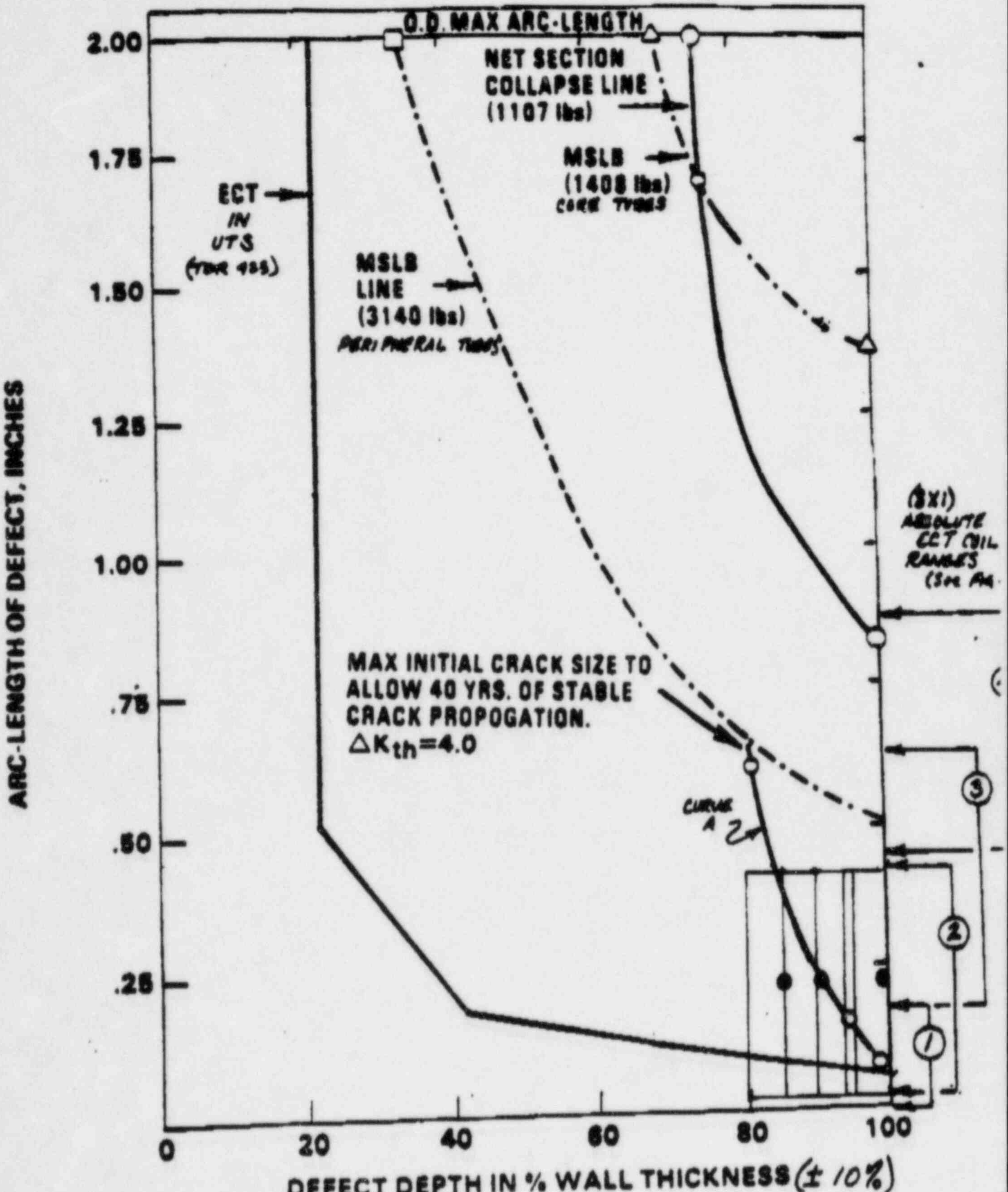


▯ - PROBABILITY AREA OF INDICATION (REF 3, APP O, PA DER)

● - MOST PROBABLE INDICATION CHARACTERIZATION

FIGURE 1c

MAJOR INDICATIONS INSIDE THE UTS (±1")



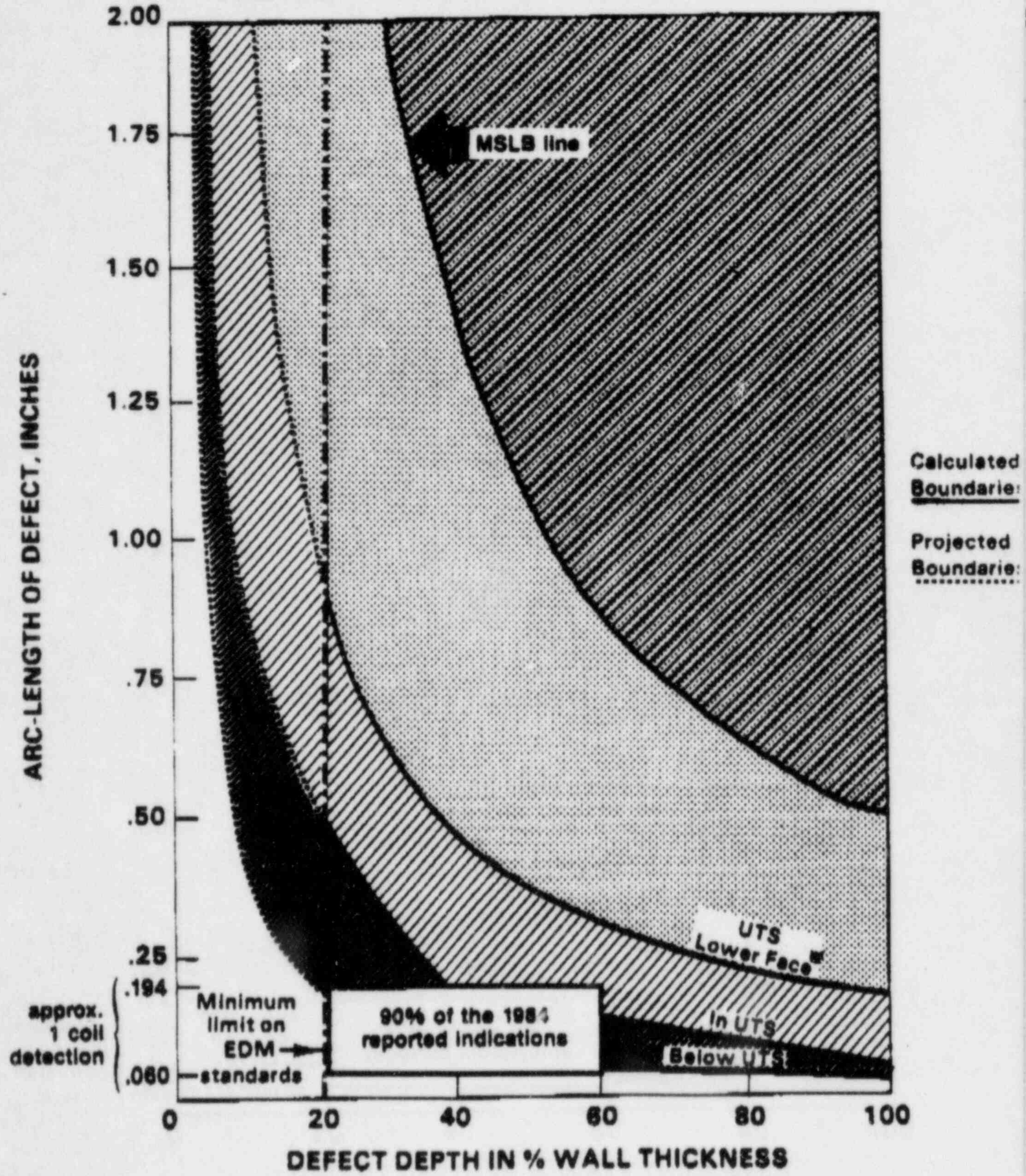
□ - PROBABILITY AREA OF INDICATION (REF 9, APRD, PG D22)

● - MOST PROBABLE INDICATION CHARACTERIZATION

FIGURE 2

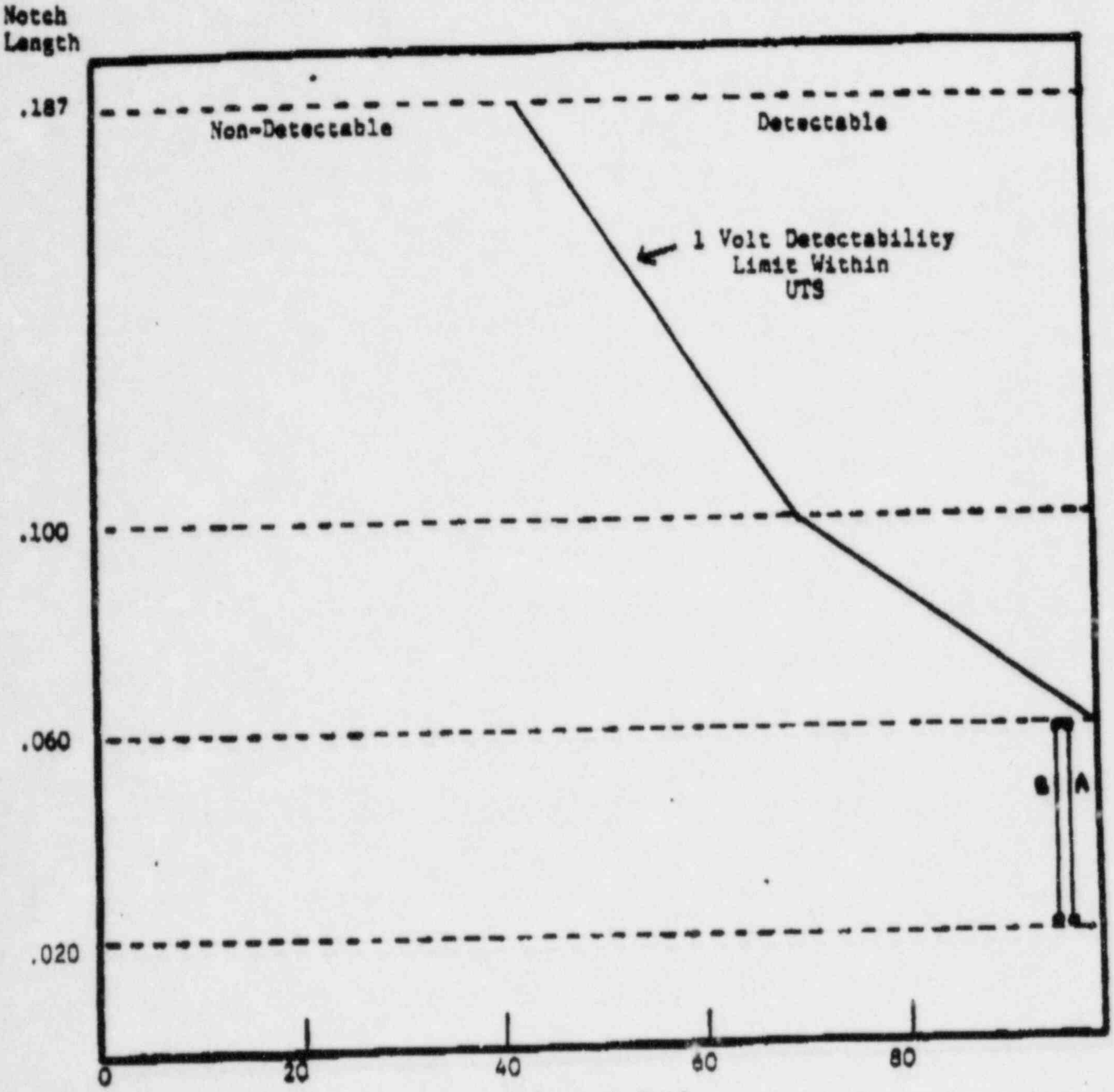
(WAS FIGURE 6 of TDR 652)

ESTABLISHED MINIMUM SENSITIVITY FOR THE HIGH GAIN .540 S.D. EXAMINATIONS BELOW UPPER TUBESHEET (300 MV) WITHIN UPPER TUBESHEET (1 VOLT) AND TUBESHEET ENTRY (3.3 VOLTS)



*UTS+0±1/4"

Figure 3a - Within - Tubesheet Fiberscope Indications Compared to Detectability Limit

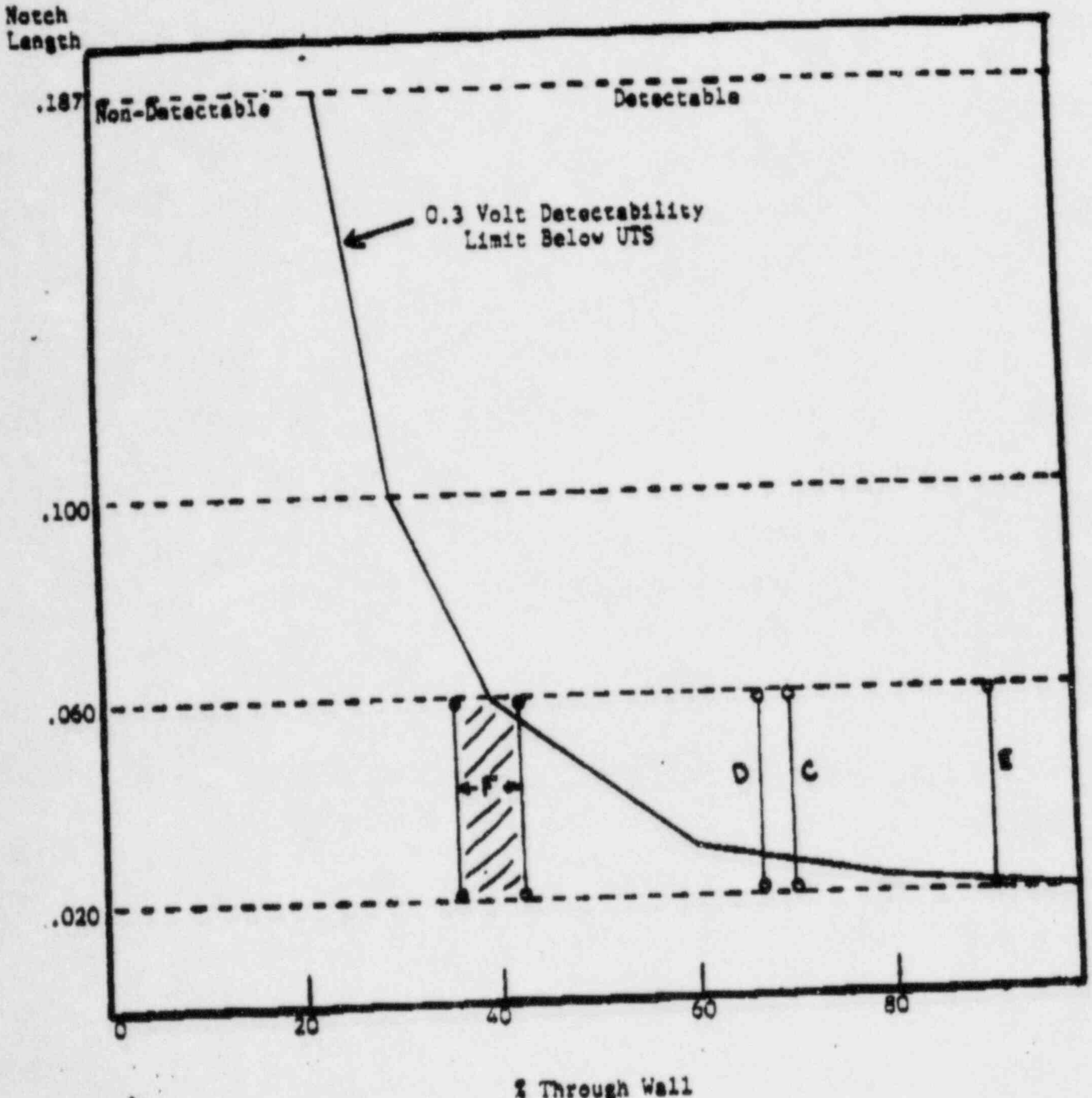


(BASED ON PRELIMINARY 1984 DATA)

Tube Identification

A A-89-124
B A-76-119

Figure 3b - Below - Tubesheet Fiberscope Indications Compared to Detectability Limit



(BASED ON PRELIMINARY 1984 DATA)

Tube Identification

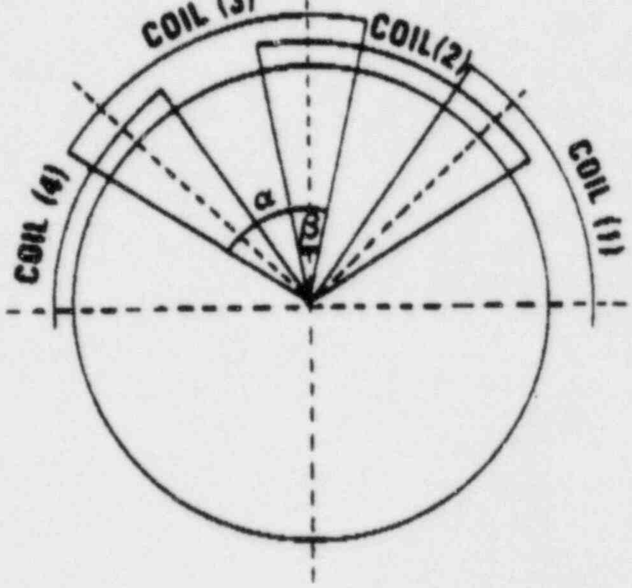
C	A-66-129
D	A-61-123
E	A-57-128
F	A-60-126

(from TDR 401 Rev. 0)

FIGURE 4

(WAS Figure 8-1)

Tube OD	.625
Min. wall X (2)	.068
Tube ID	.557
Circumf ID	1.75
Coil dia.	.187
1 volt peak calibration	
.300 volt response	
50° coverage per coil	α
5° overlap	β



COILS	MAXIMUM		MINIMUM	
			Threshold of	Detection
1	< 40°	.194"	|5°|	.024"
2	< 85°	.413"	> 45°	.219"
3	<130°	.632"	> 90°	.438"
4	<175°	.851"	>135°	.656"
5	<220°	1.07"	>180°	.875"
6	<265°	1.29"	>225°	1.09"
7	<310°	1.51"	>270°	1.31"
8	360°	1.75"		

(BASED ON TESTING WITH .060" x 80% TW x .005" EDM NOTCH)