McGuire Nuclear Station Unit 2
Review of Susceptibility to an Event like the
McGuire Unit 1 Tube R18C25 Rupture
and Justification for Return to Power

Addendum to McGuire Unit 1 Justification for Return to Power

August 1989

Duke Power Company

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Abstract

On March 7, 1989, a steam generator tube rupture occurred at McGuire Nuclear Station Unit 1. The rupture was caused by intergranular stress corrosion cracking (SCC) which initiated on the outside diameter of the tube. The degradation consisted of a network of small axial and circumferential cracks associated with and confined to an axially linear, shallow surface groove. The groove probably originated during tube manufacture. A local surface contaminant was identified within a region of high residual stress in the groove. This provided the conditions for crack initiation. Crack propagation then occurred at a slow rate over a long period of time. Laboratory and field data suggest that this rate is approximately 0.7 mil/month.

The McGuire Nuclear Station Unit 2 steam generators have been inspected for indications of the presence of conditions similar to that which led to the R18C25 McGuire Unit 1 tube rupture event. The subject inspections revealed no indications of similar conditions or evidence of cracking. As a result of these inspections and evaluations, the return to power of the McGuire Unit 2 steam generators does not represent an unreviewed safety question.

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1.0 INTRODUCTION

This report contains the evaluation of the McGuire Unit 2 steam generators for conditions like those which led to the rupture of McGuire Unit 1 tube R18C25, in March, 1989. This assessment includes 100% bobbin coil and diagnostic rotating pancake coil (RPC) eddy current inspection of the McGuire Unit 2 steam generators, a review of operating history and environment and an update of the laboratory examination of pulled tube R18C25 from McGuire Unit 1. These evaluations are used to assess the applicability of the ruptured tube degradation mechanism to the McGuire Unit 2 steam generator tubes.

Section 2 of this report provides the overall summary and conclusions. Background plant history and a description of the steam generators is given in Section 3. Updated information based on the McGuire Unit 1 pulled tube examinations is identified in Section 4. In Section 5, the results of the 1989 McGuire Unit 2 inspection are presented. A detailed review of operating chemistry data since startup was performed, as summarized in Section 6. The overall safety assessment for justification for return to power is given in Section 7. This assessment summarizes the McGuire Unit 2 evaluation relative to conditions that led to the McGuire Unit 1 tube rupture. In addition, this section assesses the potential safety impact of restrictions detected in the U-bend region of several tubes during the eddy current inspections of McGuire Unit 2. Finally, this section includes an assessment of the potential safety impact of operating of the McGuire Unit 2 steam generators with four unretrievable loose objects remaining in the secondary side of the steam generators.

The plug cracking issue was also addressed during the current outage. The locations of plugs and the heats which are potentially susceptible are given in a separate section of this addendum.

2.0 SUMMARY AND CONCLUSIONS

2.1 Background

The cause of the rupture in tube R18C25 in SG B of McGuire Unit 1 was determined to be intergranular stress corrosion cracking (SCC) which initiated on the outside diameter of the tube. The degradation consisted of a network of small axial and circumferential cracks associated with and confined to a linear groove on the OD surface. The groove probably occurred during tube manufacture. A local surface contaminant was identified to be present within the stressed region at the surface of the groove and acted as the site for crack initiation. Crack propagation then occurred at a slow rate. Laboratory and field data suggest that this rate is approximately 0.7 mil/month.

The ruptured tube had not been inspected since the baseline prior to the start of operation. If inspected, the crack degradation could have been detected by the conventional bobbin coil eddy current test before rupture. A second tube in McGuire Unit 1 SG B, which exhibited a linear indication upon EC inspection and which was of the same heat as the ruptured tube, was pulled for inspection. Destructive examination of tube R13C34 revealed no cracking. Nevertheless, 26 tubes were plugged in McGuire Unit 1 for free span indications exhibiting significant length.

2.2 McGuire Unit 2 Inspection

2.2.1 Eddy Current Inspections

All active tubes in the McGuire Unit 2 steam generators were examined full length using standard eddy current bobbin coils. In addition, RPC technology was used 1) to diagnose selected bobbin coil indications and 2) to examine a number of tubes in all four steam generators for evidence of incipient cracking of the type associated with the McGuire Unit 1 tube rupture. Neither the bobbin coil nor the RPC inspection identified any abnormal tube wall degradation characteristic of the McGuire Unit 1 tube rupture. All of the reported eddy current indications were within the boundaries of expected

Model D steam generator operating experience. One hundred and seventy-three (173) tubes were plugged in all four McGuire Unit 2 steam generators with a majority of the tubes (131) plugged for PWSCC within the F* region. Some tubes (29) with free span axial indication were identified and conservatively removed from service. The remaining tubes (13) were plugged for miscellaneous reasons, such as obstructed or overrolled conditions.

2.2.2 Additional Inspections

Restrictions to passage of a 0.610" probe were identified in the U-bend of a few row 46 tubes in SG B. Probes of 0.590" diameter were able to pass through the U-bends. A visual inspection from the secondary side of the U-bend was performed. No loose parts or abnormal visual indications on these tubes were observed. Conservatively, three tubes with U-bend tube ovality of less than 12%, as indicated by profilometry measurements, were removed from service by plugging.

The FOSAR examination identified two wire fragments which were not retrievable in SG A and B. It was also noted that a nut and washer were left in the steam generator following the secondary side, U-bend inspection. These loose objects have been evaluated for potential wear and found to be acceptable for Cycle 6 operation.

2.3 McGuire Unit 1 Pulled Tube Examination

As noted in the Reference 1 report, the metallurgical investigation of the ruptured tube from McGuire Unit 1 indicated that the degradation, which was OD-initiated stress corrosion cracking (SCC), initiated in and was confined to shallow axial groove that may have originated in the tube manufacturing rocessing. Detailed metallurgical examinations of additional sections of the subject tube, away from the anomaly, and of a second McGuire Unit 1 tube from the same heat indicated no SCC in surface regions.

The initial examinations of the pulled tubes from McGuire Unit 1 have been completed. The residual stress measurements by X-ray diffraction confirmed the existence of high (at or above normal yield strength) residual tensile stresses in both the axial and hoop directions at the surface of the groove in the ruptured tube. Additionally, the presence of a nickel-free, iron-chromium layer was identified at the surface of the groove. This metallurgical anomaly together with the residual stresses contributed to the SCC initiation. Overall, the metallurgical characteristics of the groove support a relatively unique anomalous tube condition.

2.4 McGuire Unit 2 Chemistry Summary

A review of chemistry data since initial startup indicates that McGuire Unit 2 has had generally good secondary chemistry. From the review of routine chemistry data, chemistry excursion data, and wet layup data, secondary chemistry shows no obvious trends toward a deleterious environment. The hideout return data does indicate the potential to form alkaline crevice conditions. However, no secondary side SCC has been detected in the McGuire Unit 2 steam generators. Therefore, it is felt that the normally good secondary chemistry combined with the appropriate power reductions following moderate to severe excursions have helped to prevent detectable corrosion to date.

2.5 Conclusions

The rupture of McGuire Unit 1 tube R18C25 was a unique event, resulting from the circumstances described in the McGuire Unit 1 report (Reference 1) and supplemented by Section 4 of this addendum. All tubes in the McGuire Unit 2 steam generators have been inspected and no indications of secondary side free span SCC have been found. Conservatively, tubes with free span, linear eddy current indications were plugged.

As a result of the inspection and evaluation, it is concluded that the unique circumstances associated with the McGuire Unit 1 tube rupture are not present in McGuire Unit 2. In light of the above, it is concluded that the return to power of McGuire Unit 2 does not represent an unreviewed safety question per 10 CFR 50.59 (a) (2) criteria.

3.0 BACKGROUND

3.1 McGuire Unit 1 Tube Rupture

In March, 1989, a large primary to secondary leak was detected in steam generator B of McGuire Unit 1. The first indication was an alarm from a steam line monitor. The leakage flow rate was estimated to be 540 gpm; this is consistent with the size of the opening found during the inspection of the ruptured tube (R18C25). Over the previous three months, the leak rate had varied between 5 and 30 gpd, with one determination of 45 gpd attributed to problems with air ejector flow.

3.2 Plant History

McGuire Nuclear Station Unit 2 is a 4-loop Westinghouse PWR, rated at 3425 MWt, equipped with Model D3 preheat steam generators (fabricated in 1973). The plant reached initial criticality in May 1983 and began commercial operation in March 1984. Prior to 1989, 743 tubes had been plugged, mostly for PWSCC in Row 1 U-bends (mainly preventive) and in the expansion zones of the hot-leg tubesheet. A few tubes have been plugged for wear. There is no evidence of systematic secondary side tube corrosion to date. The preservice base line inspection of 3% of the tubes was performed in December, 1978. Plugging to date is summarized in Table 5-2 of Section 5 of this report.

McGuire Unit 2 is equipped with an all-ferrous secondary system (no copper alloys) and full flow condensate polishers (FFCP). Since initial startup, the secondary water chemistry has been All Volatile Treatment (AVT). The operating chemistry record is summarized in Section 6.

3.3 Description of Steam Generators

The Model D3 steam generator is a vertical preheat steam generator with 4674 tubes, having an outside diameter of 0.750 inches and a wall thickness of 0.043 inches. The tube material is mill annealed Alloy 600. The general arrangement of these steam generators is shown in Figure 3-1. The arrangement of the preheater section is shown in Figure 3-2. The baffle plates and support plates are 0.75 inches thick, manufactured from carbon steel, with drilled holes, 0.766 inches in diameter. The Flow Distribution Baffle (FDB) holes are 0.828 inches in diameter. The partition plate separating the hot leg from the cold leg is one piece. Consequently, the hot leg FDB (Plate 1) and support plates 2, 3, and 4, in the lower part of the tube bundle, are half plates.

The McGuire Unit 1 Model D2 steam generators differ from the Model D3 design primarily in the use of an FDB in the Model D3.

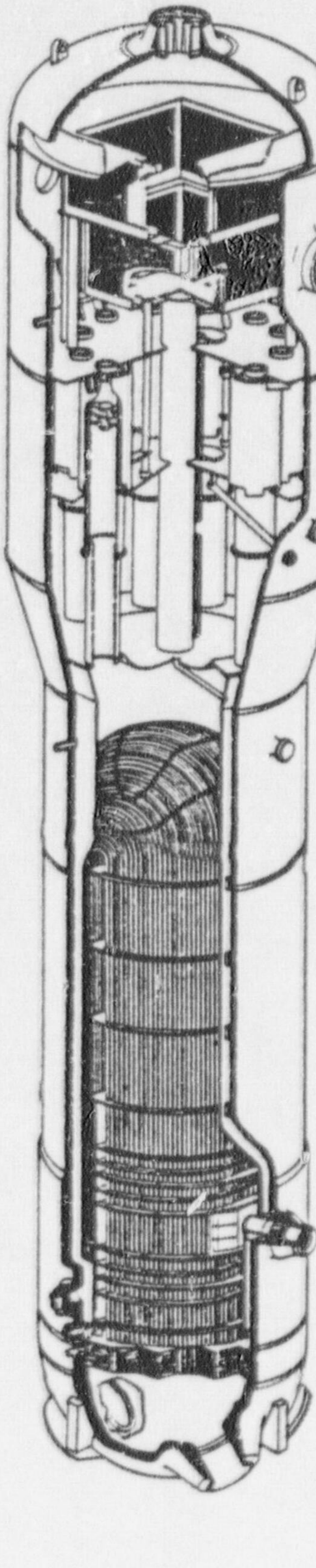

Figure 3-1. Model D3 Steam Generator

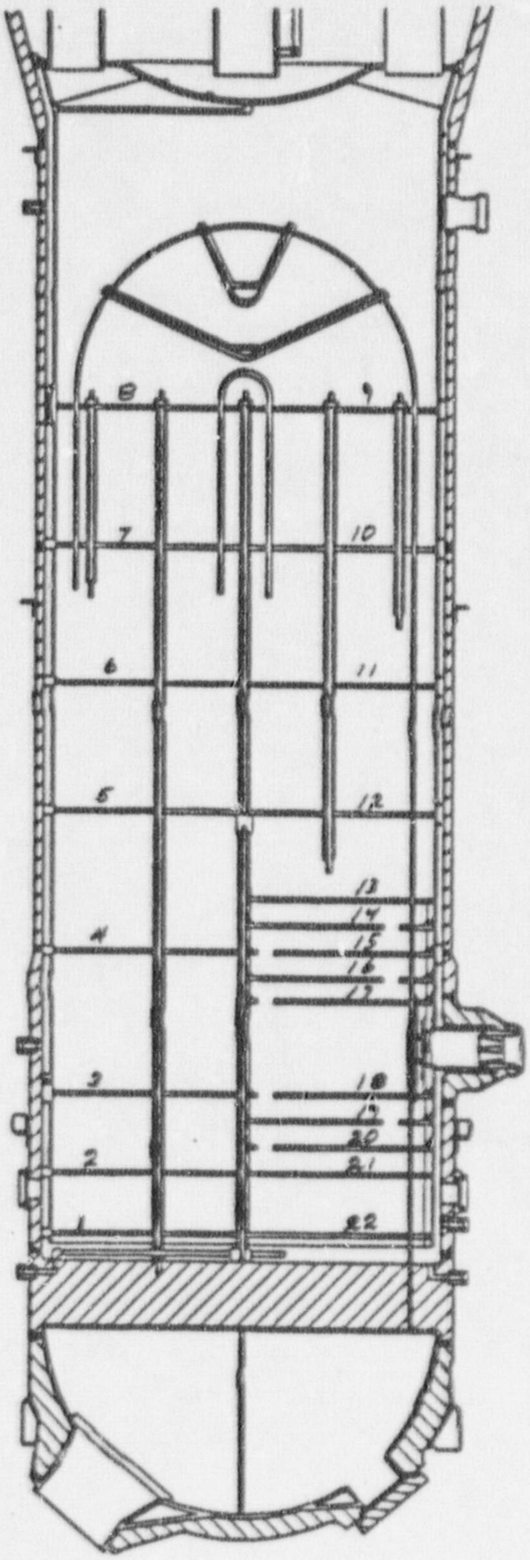

Figure 3-2. Model D3 TSP Nomenclature

4.0 MCGUIRE UNIT 1 TUBE EXAMINATION

The tube that ruptured in the leakage event at McGuire Unit 1 in March, 1989, was subjected to extensive metallurgical evaluation. The investigation established that the degradation occurred in a zone of unique surface conditions in the outer surface over limited axial distance. This zone consisted of a shallow (/0.6 mils deep), narrow axial groove.

The metallurgical investigation of the McGuire Unit 1 ruptured tube had clearly established that the degradation was OD initiated (secondary side) SCC in the narrow axial groove of the tube. Since the preparation of the McGuire Unit 1 Return-to-Power Report, additional metallurgical examinations of McGuire Unit 1 tubes have been performed. The principle new finding of the examination was the identification of a very thin, structureless-appearing zone of a metallic second phase at the surface of the groove. The composition of this second phase was nickel-free, iron-chromium (12%Cr). Although the structure of this second phase was not establishable, the composition indicates that the structure could be either ferritic or martensitic.

Further metallurgical investigation also included additional X-ray diffraction residual stress measurements. The additional measurements continued to verify the previously established high residual tensile stresses, both axial and hoop, that were locally present at and near the surface of the groove. Localized stresses in excess of the yield strength of the bulk material were observed.

The high residual stresses associated with the unrepresentative composition of this second phase acted as initiation sites for the SCC. The origin of the contaminant second phase appears to be associated with the tube manufacturing processing. The development of the degradation was therefore not associated with steam generator operations or conditions.

The extensive metallurgical investigations of the subject tube (R18C25) and a neighboring McGuire Unit 1 tube (R13C34) of the same Alloy 600 heat confirmed that the SCC crack initiation was confined only to the zone of irregular surface conditions of the ruptured tube. These observations indicate that the composition, microstructure, and mechanical properties of the heat of the ruptured tube were not peculiarly susceptible (outside of the groove) to ODSCC initiation processes. The absence of SCC initiation in other regions of the ruptured tube and in adjacent tubes of the same heat is also further confirmation of the general resistance of the Alloy 600 material to the secondary side environmental conditions present during the McGuire Unit 1 chemistry.

5.0 MCGUIRE UNIT 2 INSPECTION

5.1 Eddy Current Inspection

All active tubes in the McGuire Unit 2 steam generators were examined full length using standard bobbin coil. In addition, rotating pancake coil (RPC) technology was used in a twofold manner 1) to diagnose selected tubes with bobbin coil indications of interest and 2) to examine a number of tubes in all four steam generators for evidence of incipient cracking which was a precursor condition to the McGuire Unit 1 tube rupture. RPC technology is somewhat more sensitive to tube wall degradation than the bobbin coil and is useful in inferring the morphology of the signal source which in conjunction with knowledge of steam generator location can be used to provide a more reliable estimate of the damage mechanism.

Duke Power Eddy Current Analysis Guidelines were used to assure analysis consistency among data analysts. Demonstration of individual understanding of the guidelines and reporting criteria was accomplished by giving each analyst a site-specific practical examination. Only those analysts who successfully completed the examination were permitted to analyze McGuire Unit 2 production eddy current data.

Neither the bobbin coil nor the RPC inspection identified any abnormal tube wall degradation conditions. Some obstructed tubes were discovered during the course of the bobbin coil examination. Inspection results for these tubes are discussed in more detail in Section 5.2.

5.1.1 Bobbin Coil Examination

A summary of bobbin coil inspection results for all four generators is given in Table 5-1. Listed are the total number of indications attributed to a specific cause or degradation mechanism. Numbers in parentheses denote the number of tubes with similar types of indications identified during the previous (June 1988) refueling outage. The Table 5-1 reportable indications are grouped into two broad categories; 1) those due to steam generator operation and 2) those attributable to tube manufacturing (buff marks) or installation artifacts (axial indications), e.g., so called "free-span" indications. This latter class of indications is discussed in more detail in Section 5.1.2 and was basically present prior to plant operation. All the reported indications listed in Table 5-1 are within the bounds of expected Model D steam generator operating experience.

Tubesheet maps for the various operational degradation mechanisms are presented in Figures 5-1 through 5-8. Maps are shown for all four steam generators by hot-leg and cold-leg. A review of the maps shows that expansion zone PWSCC is randomly distributed throughout the tube bundle with most of the indications on the hot-leg as expected. AVB wear is considered a hot-leg degradation mechanism and tends to be distributed across all columns but is bounded by rows 20-45. Tube wear in the preheater section of the steam generator is for the most part confined to the outer two rows on the cold-leg side.

Tubesheet maps for "free-span" indications are shown in Figures 5-9 through 5-16. These maps include localized tube "buff marks" and axial indications which exhibit some significant length. All of the axial indications were plugged; SG D had the highest population of these indications.

A summary of tubes plugged during the McGuire Unit 2 July 1989 refueling outage is given in Table 5-2. The cumulative number of plugged tubes prior to the current refueling outage is also provided. Figures 5-17 through 5-20 show tubesheet maps of tubes removed from service prior to the July 1989 refueling outage for all four McGuire Unit 2 steam generators. Row-1 tubes returned to service in SG D are evident in Figure 5-20. McGuire Unit 2 tube plugging history has been dominated by PWSCC within the F* region and inner row U-bends.

TABLE 5-1

MCGUIRE UNIT 2 1989
BOBBIN COIL INSPECTION RESULTS

	SG A		SG B		SG C		SG D	
	HL	CL	HL	CL	HL	CL	HL	CL
Operational Degradation								
o PWSCC within F* region	48(20)	1(1)	24(16)	0(6)	28(28)	1(8)	25(9)	4(0)
o Wear								
- Preheater Wear	-	1(0)	-	23(12)	-	1(0)	-	14(5)
- AVB Wear	34(0)	-	16(0)	-	14(0)	-	26(1)	-
Total Tubes	82	2	40	23	42	2	51	18
Manufacturing Artifacts								
o Free Span Indications (1)	12	6	5	11	3	3	9	14
o Permeability	1	2	0	1	5	2	0	0
Total Tubes	13	8	5	12	8	5	9	14

Note: Numbers in parentheses denote number of tubes with indications attributable to operation identified during previous refueling outage. Some of these tubes were subsequently removed from service and were, therefore, not subject to further inspection.

(1) Includes localized buff marks and axial indications.

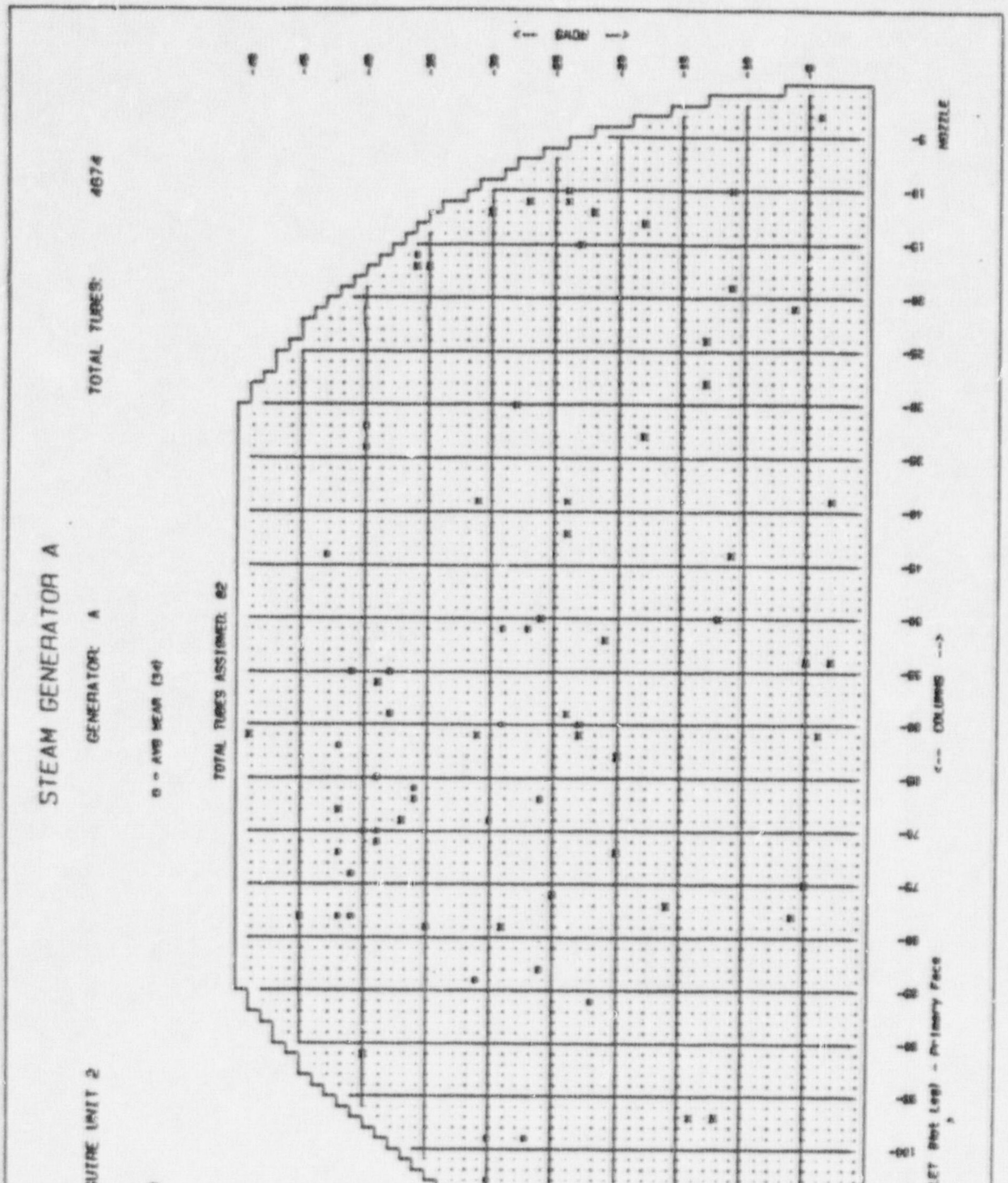

Figure 5-1. Steam Generator A Inlet - Operational Degradation

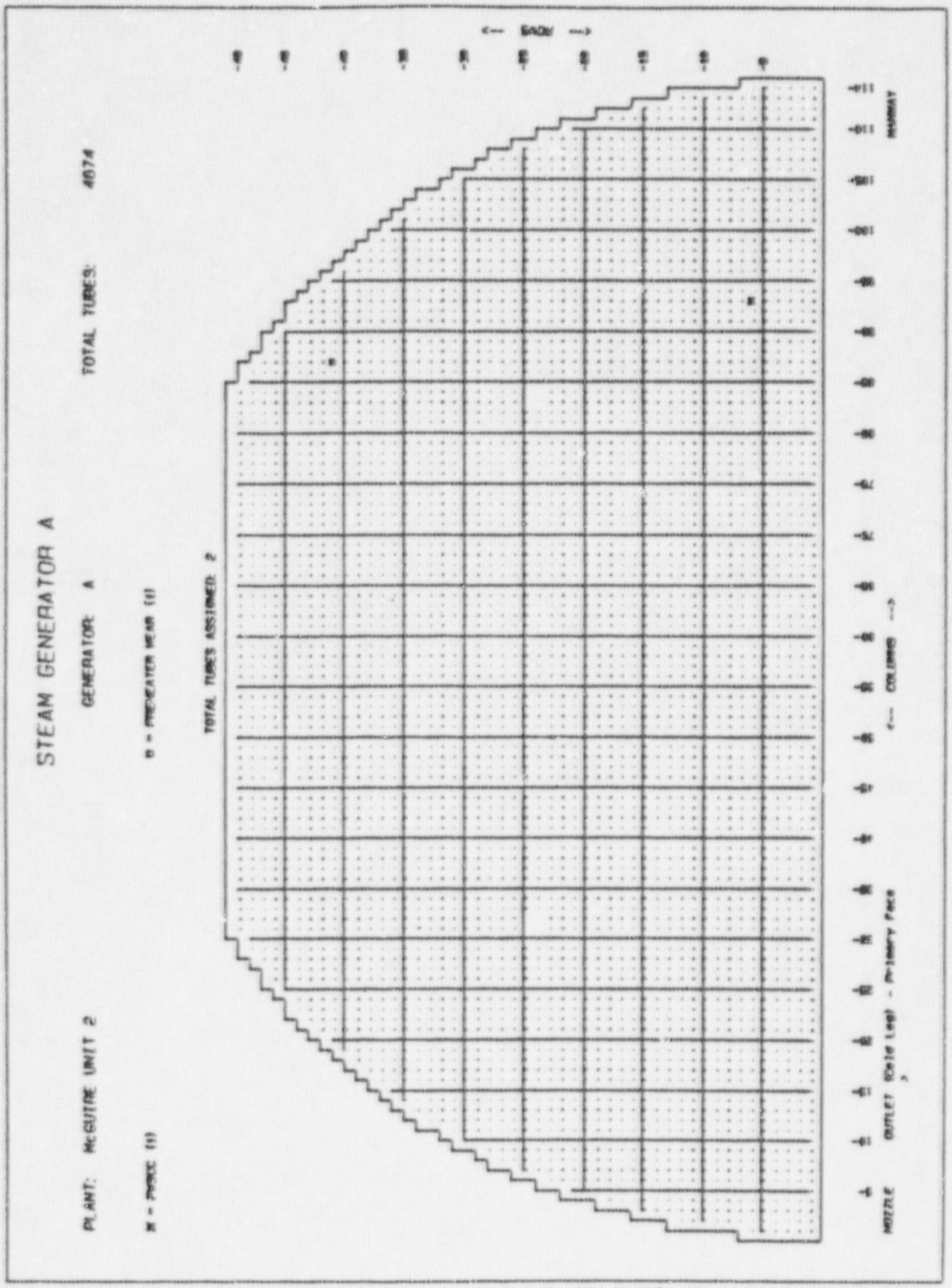

Figure 5-2. Steam Generator A Outlet - Operational Degradation

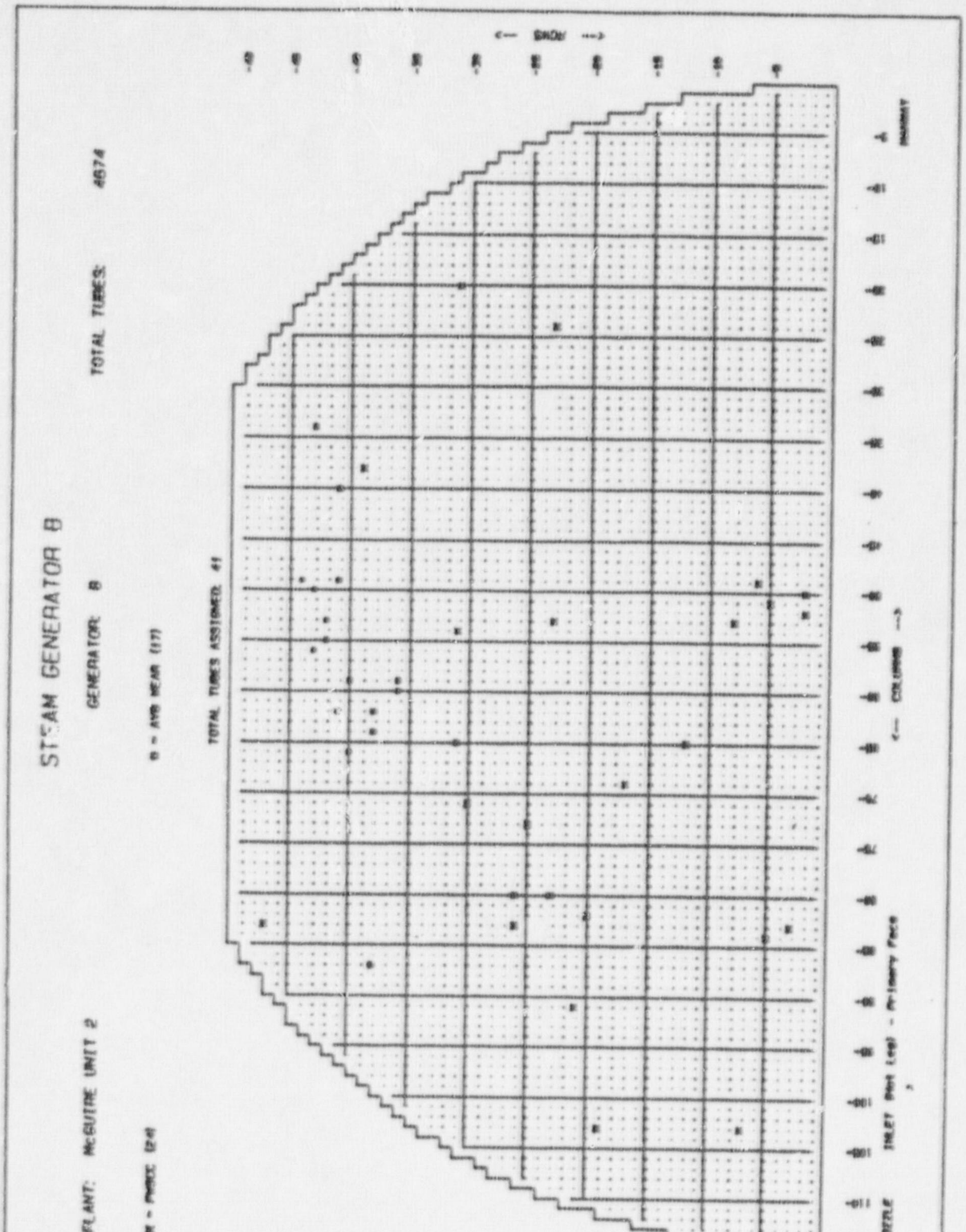

Figure 5-3. Steam Generator B Inlet - Operational Degradation

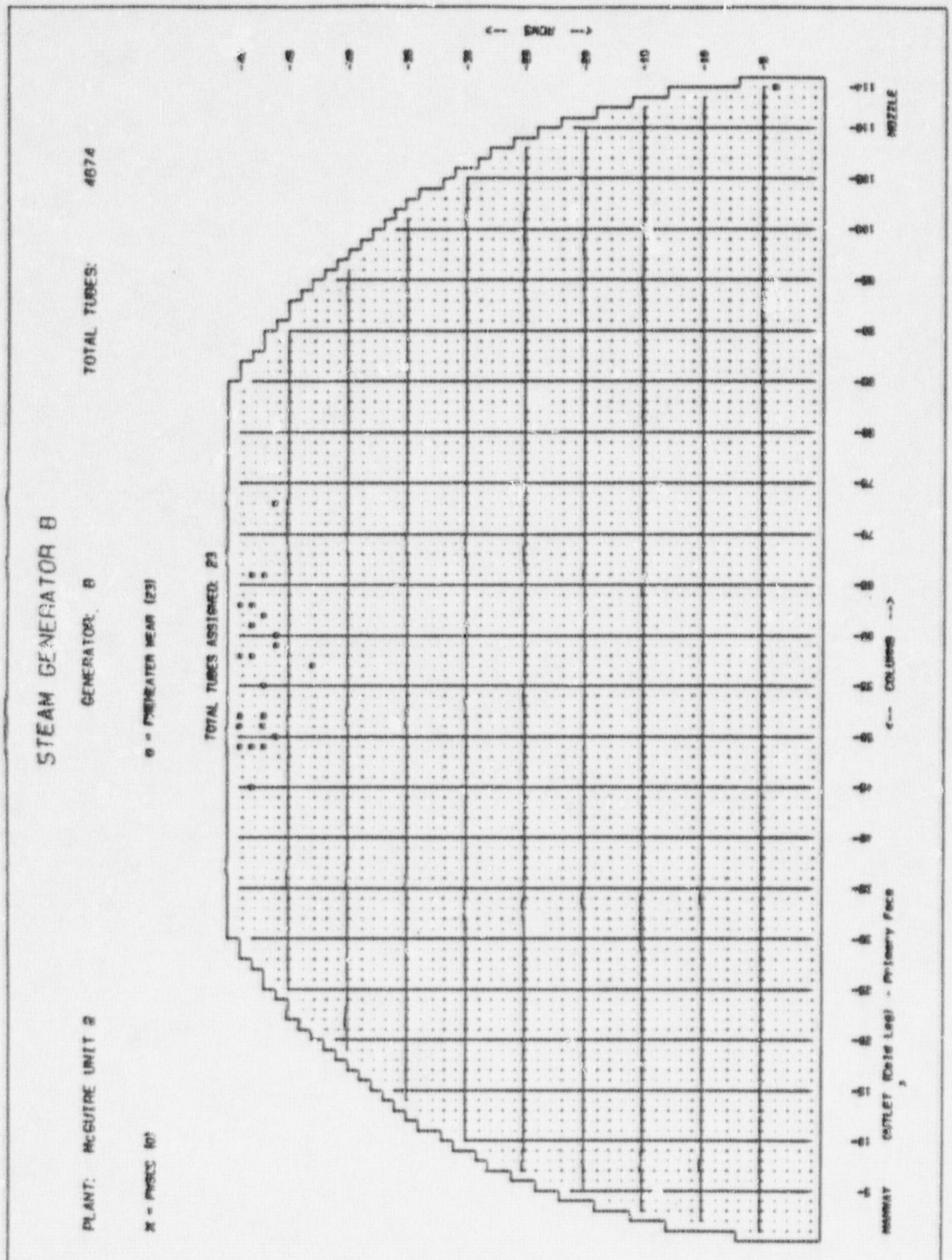

Figure 5-4. Steam Generator B Outlet - Operational Degradation

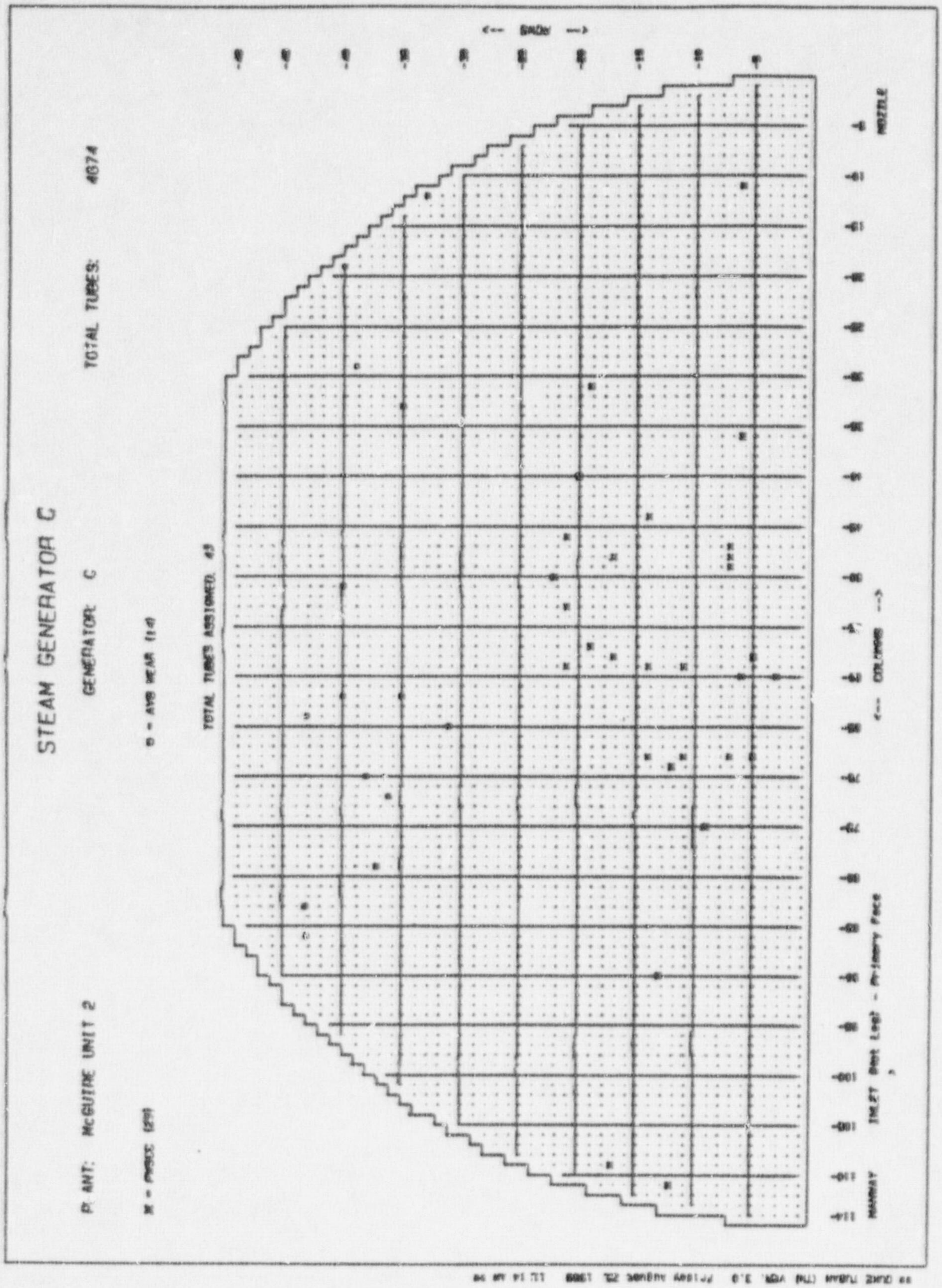

Figure 5-5. Steam Generator C Inlet - Operational Degradation

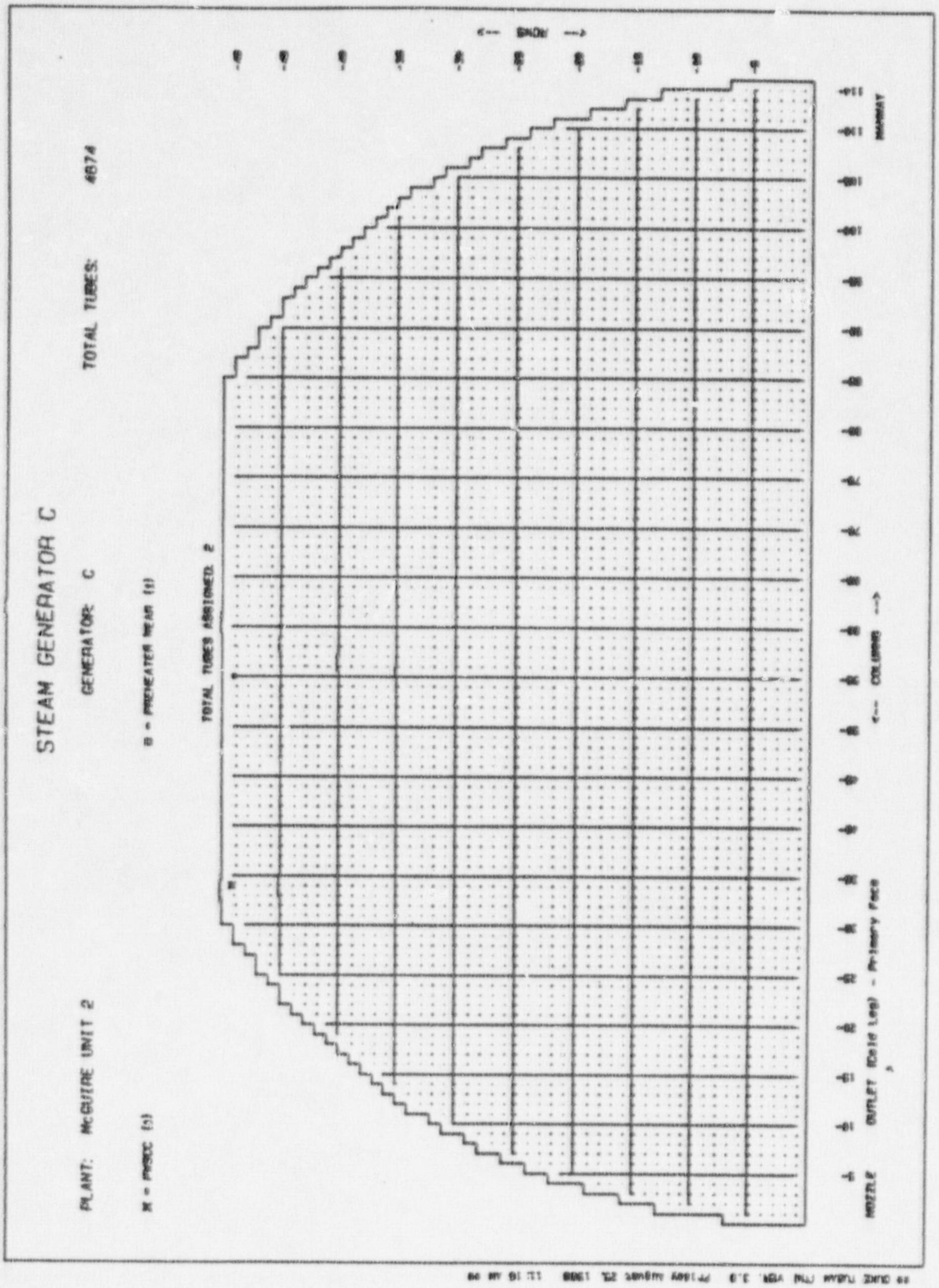

Figure 5-6. Steam Generator C Outlet - Operational Degradation

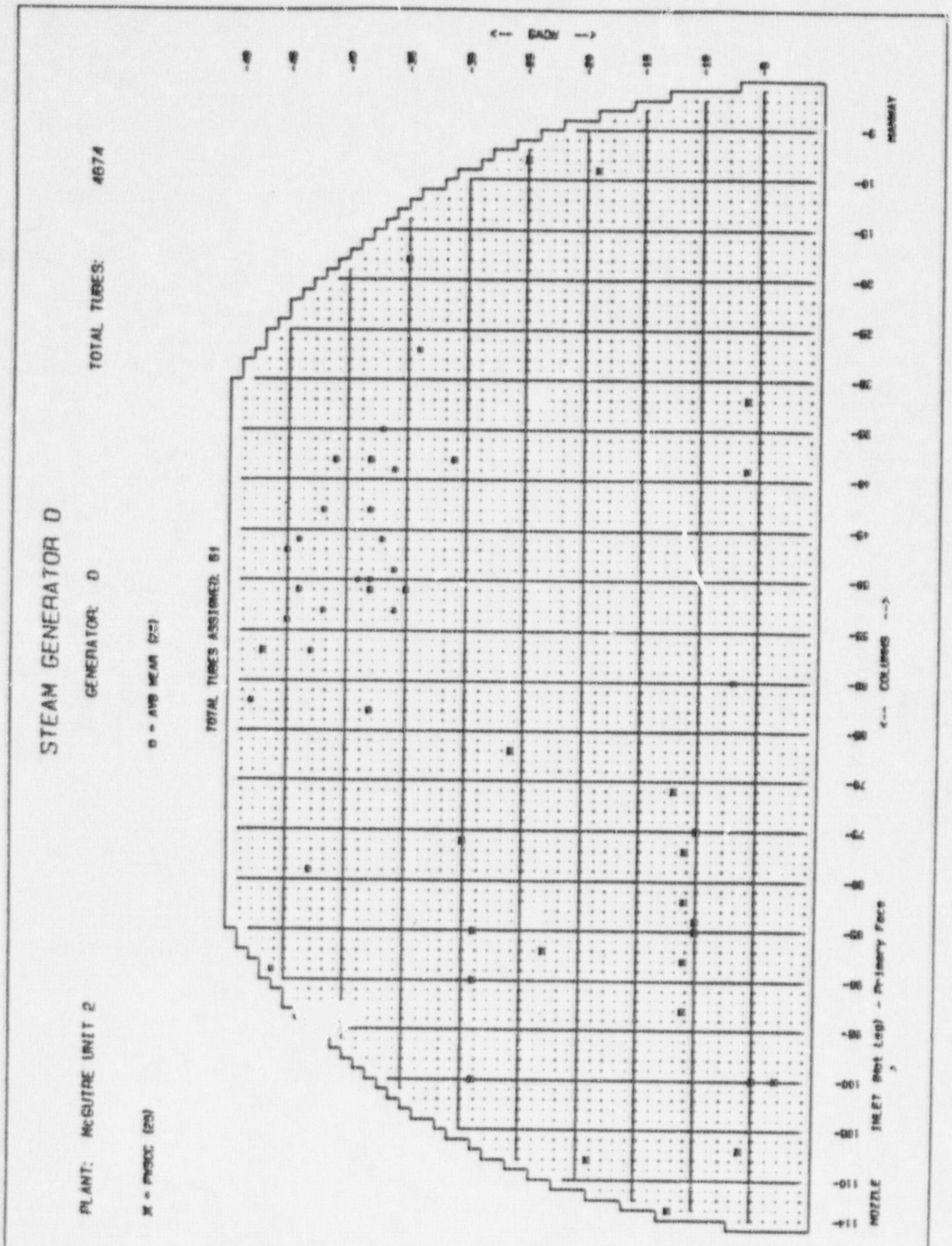

Figure 5-7. Steam Generator D Inlet - Operational Degradation

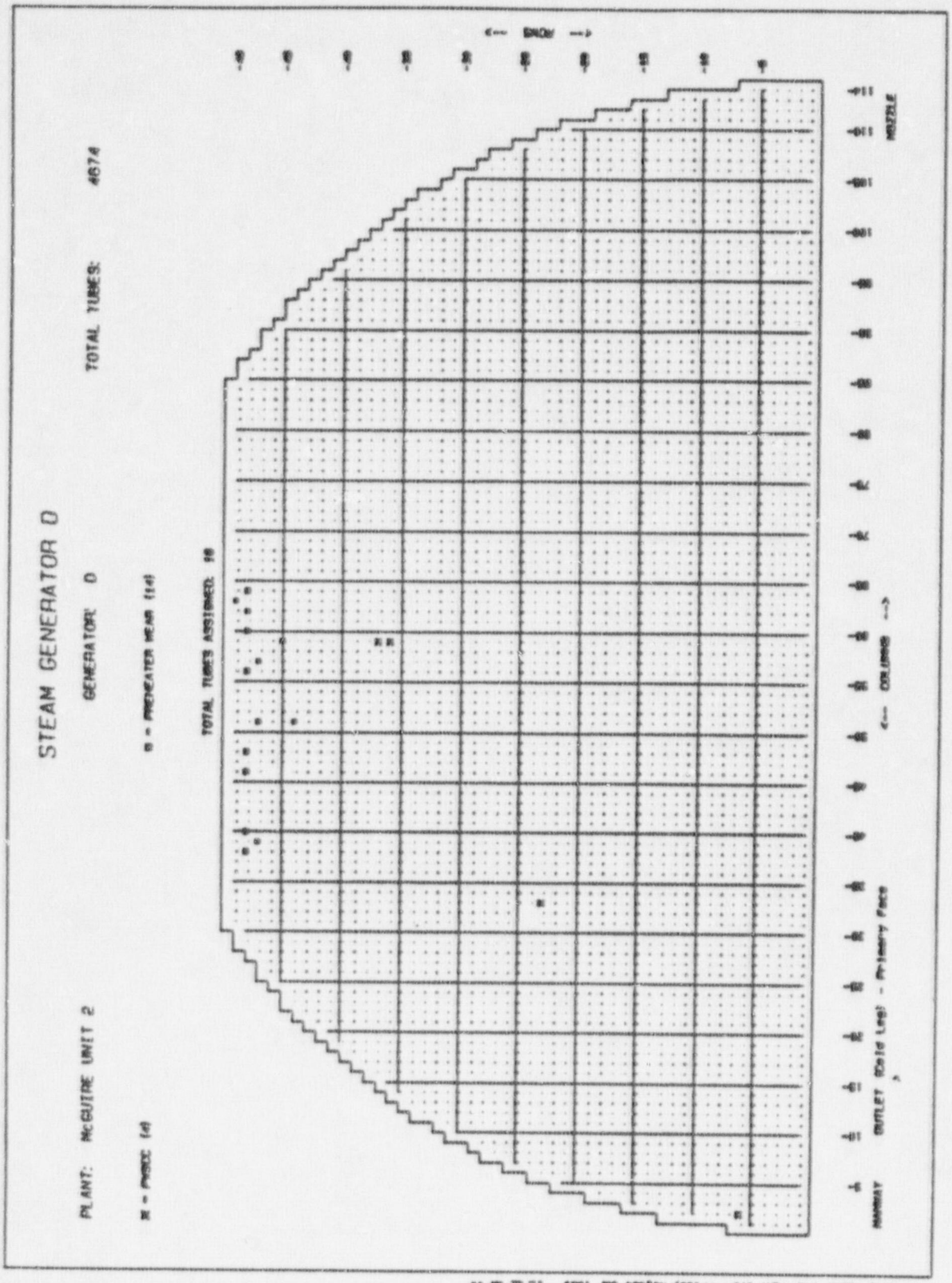

Figure 5-8. Steam Generator D Outlet - Operational Degradation

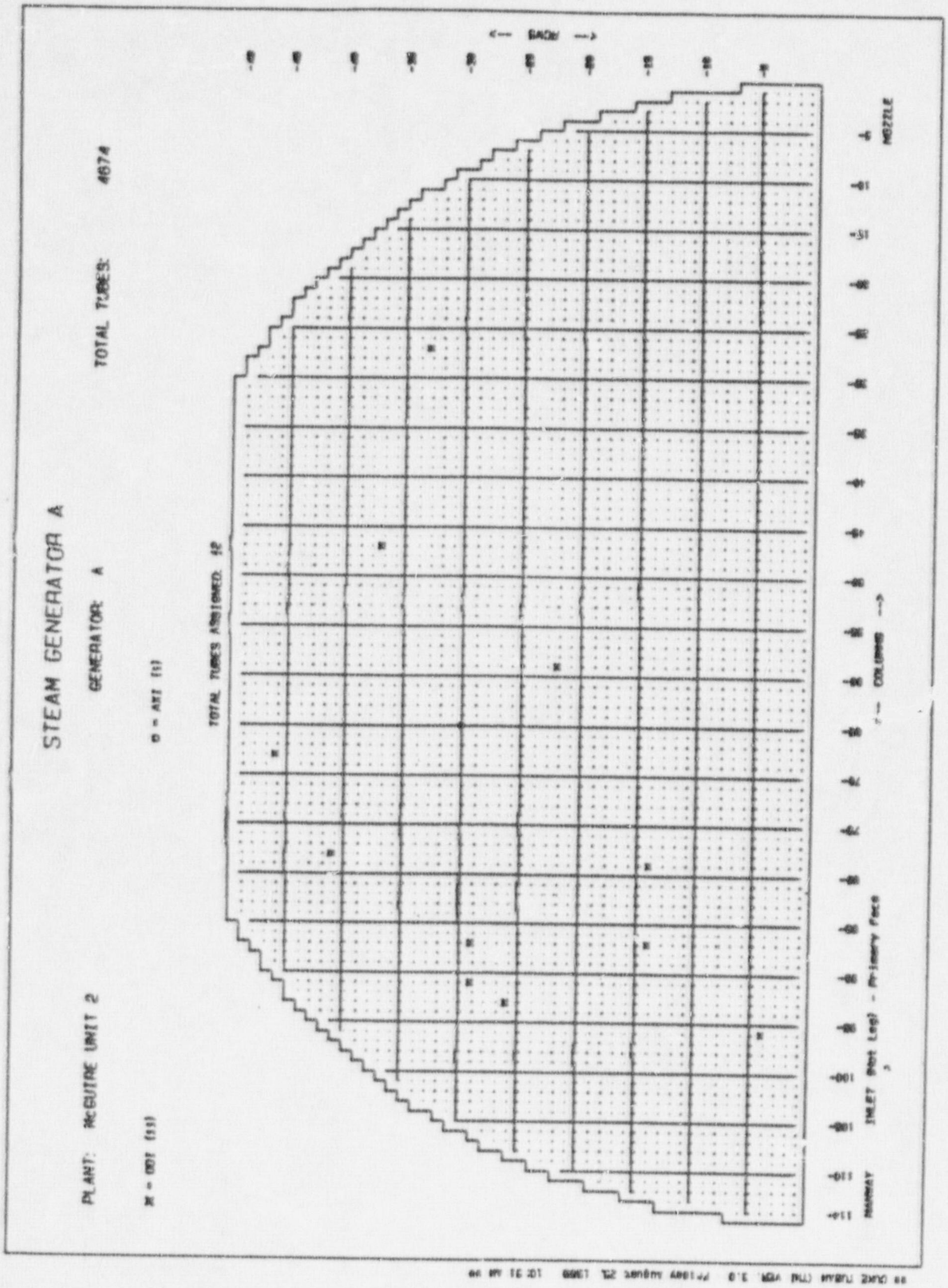

Figure 5-9. Steam Generator A Inlet - Free Span Indications

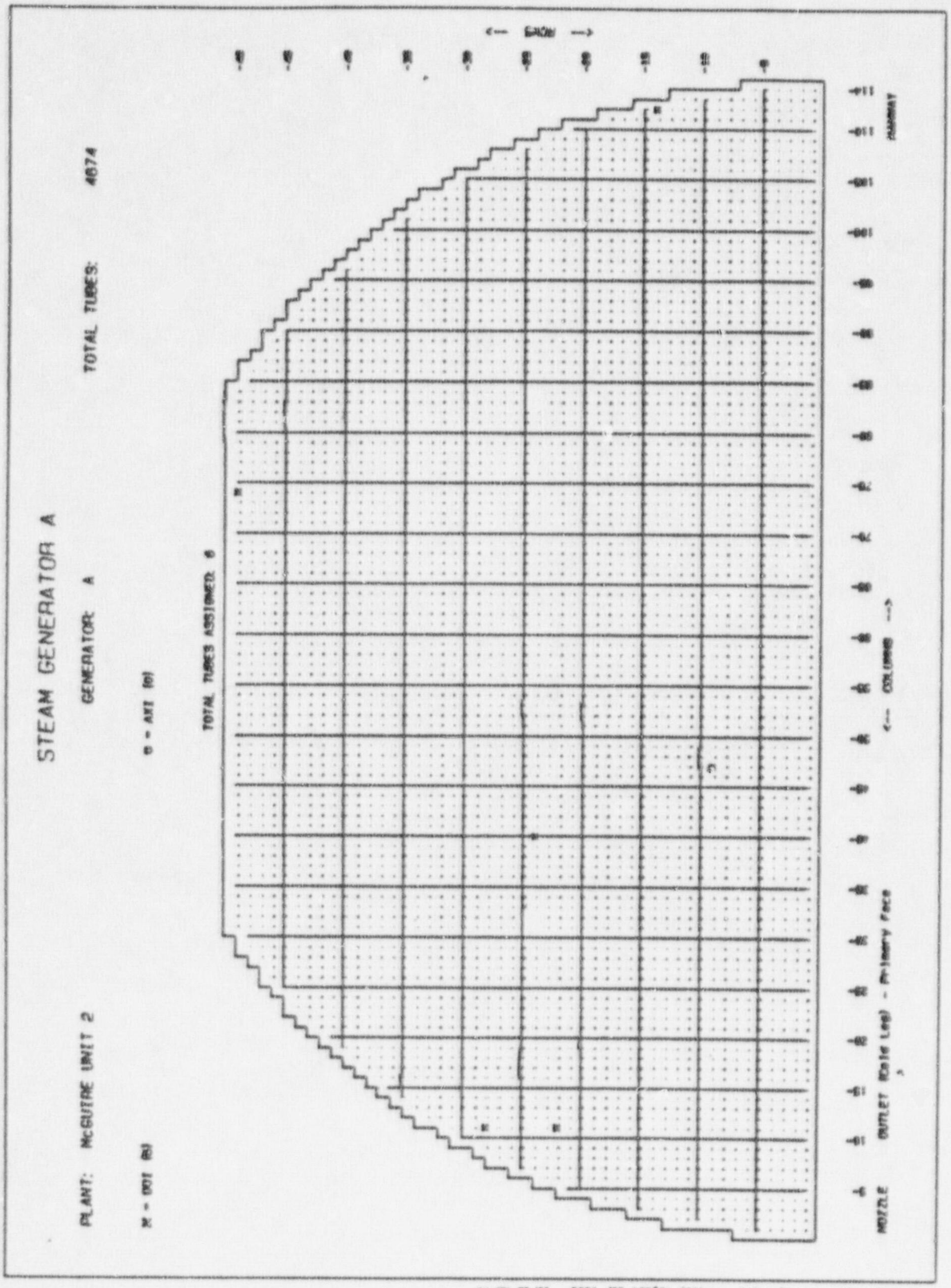

Figure 5-10. Steam Generator A Outlet - Free Span Indications

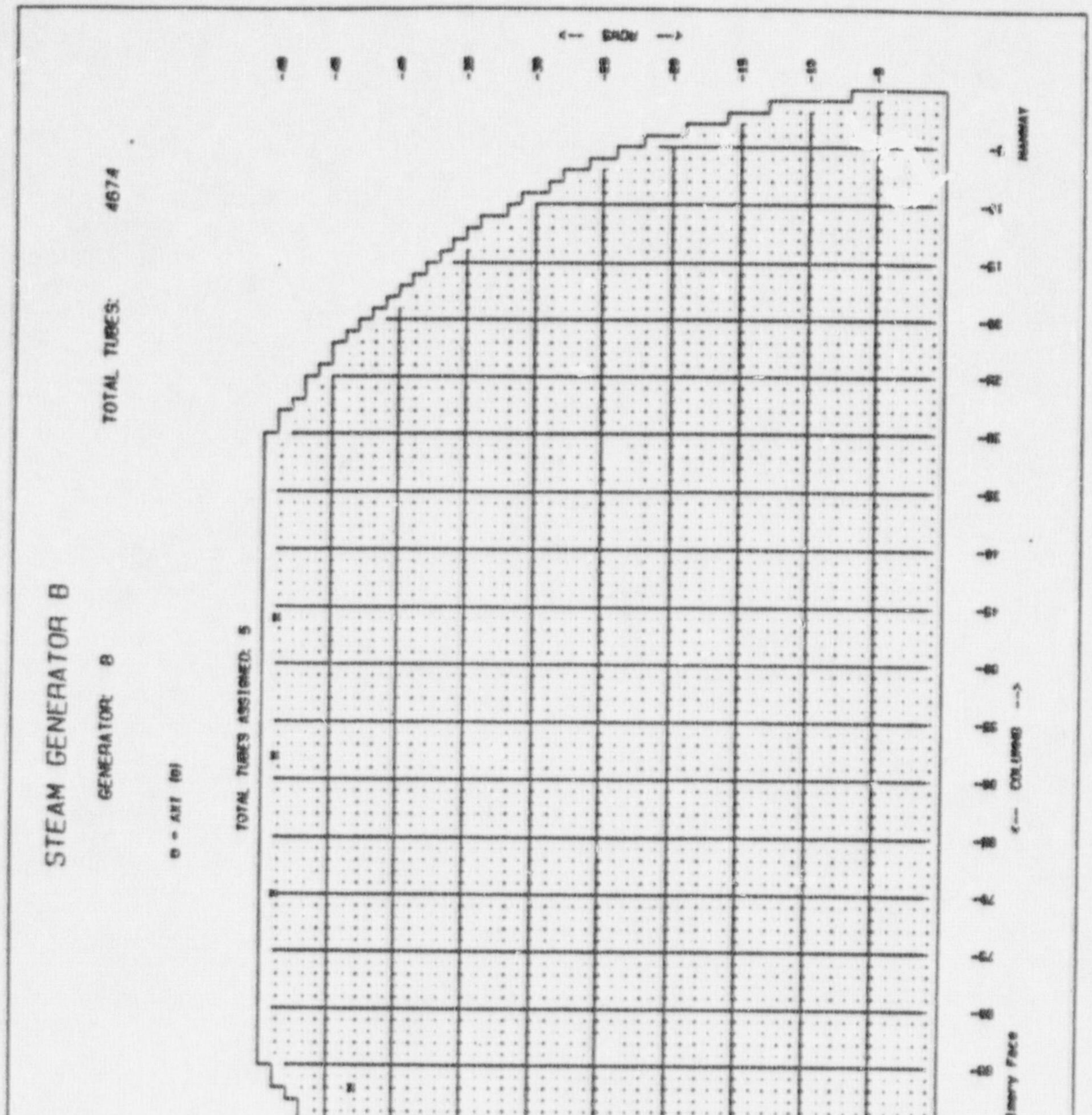

Figure 5-11. Steam Generator B Inlet - Free Span Indications

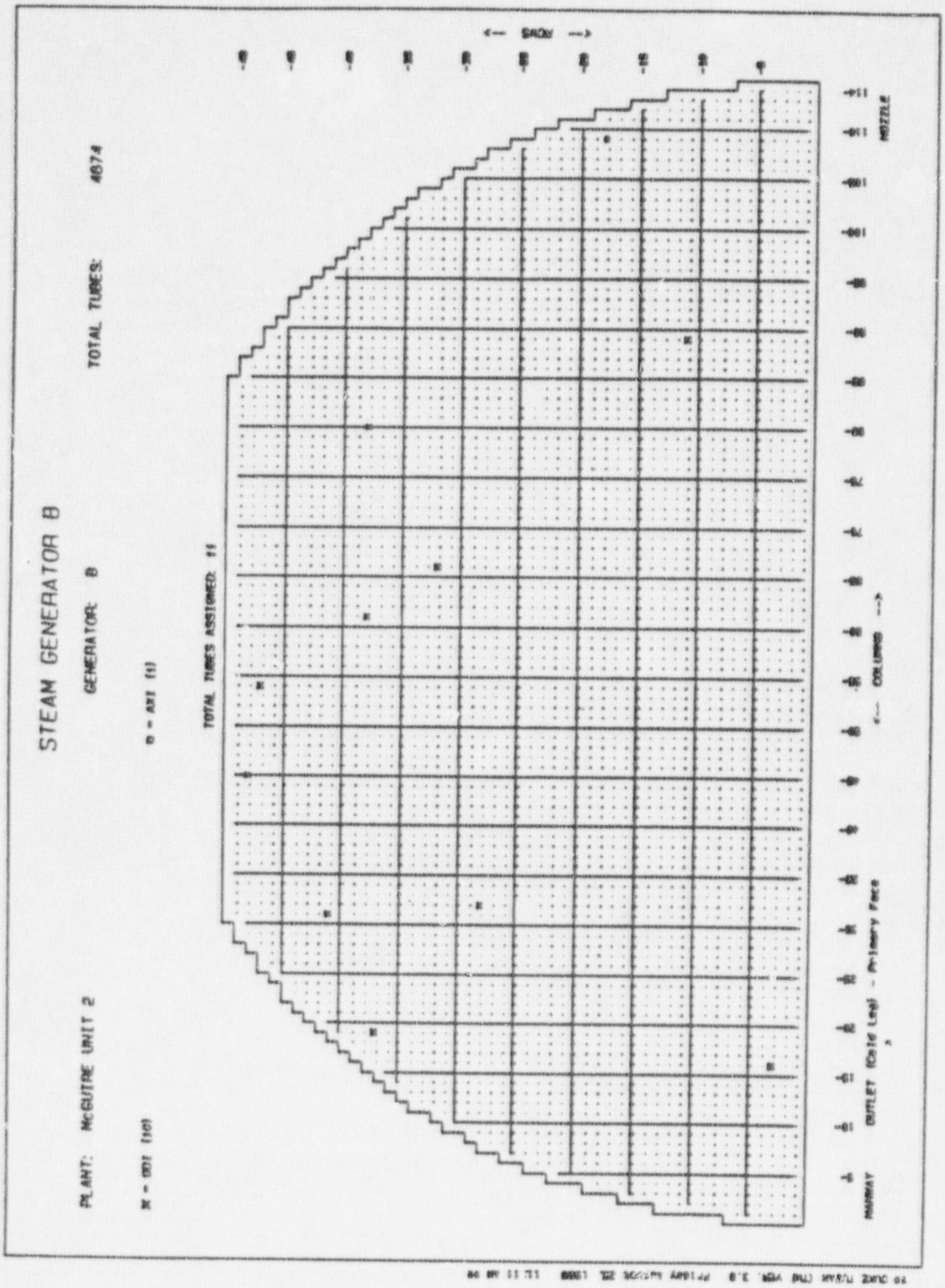

Figure 5-12. Steam Generator B Outlet - Free Span Indications

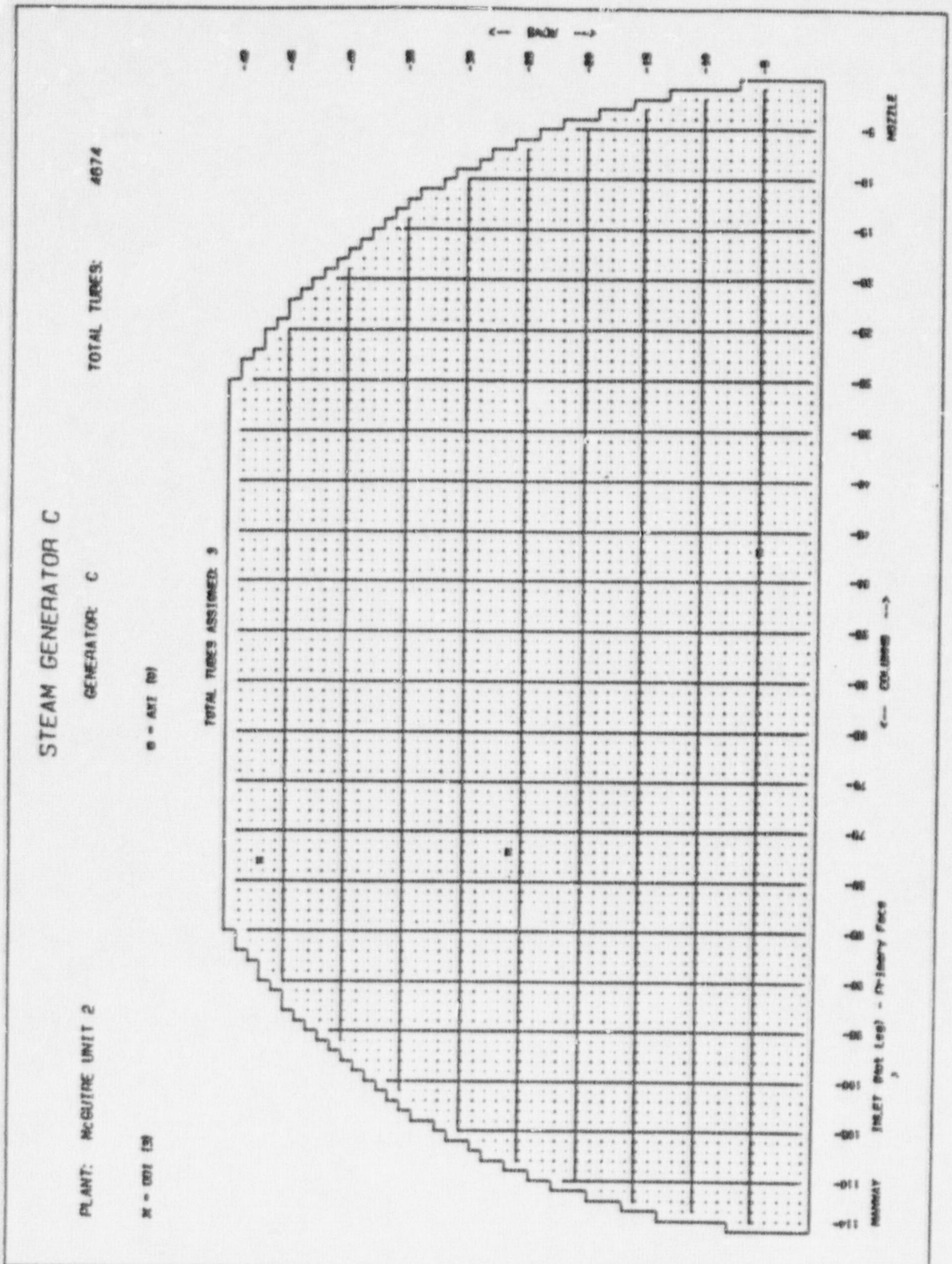

Figure 5-13. Steam Generator C Inlet - Free Span Indications

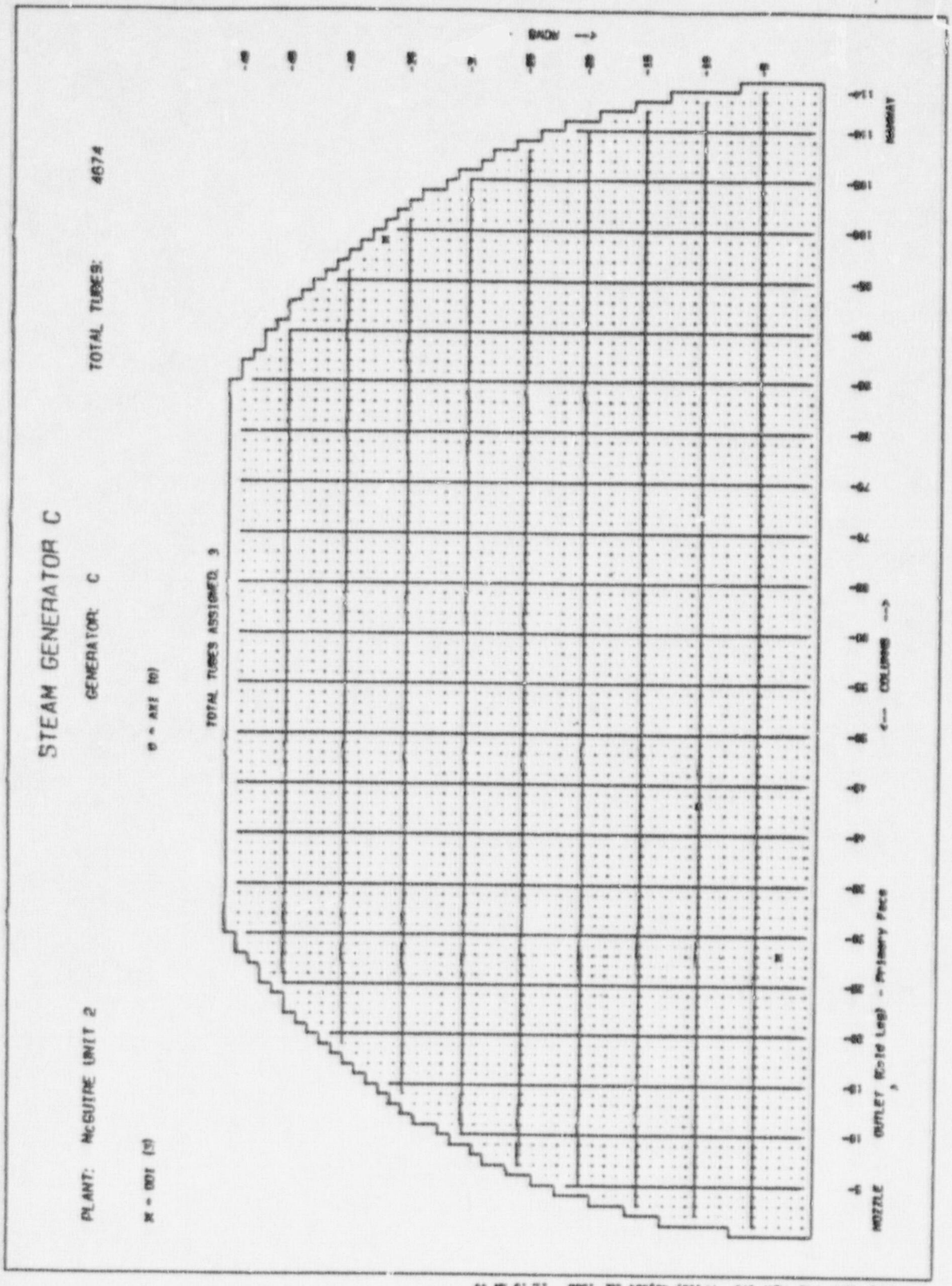

Figure 5-14. Steam Generator C Outlet Free Span Indications

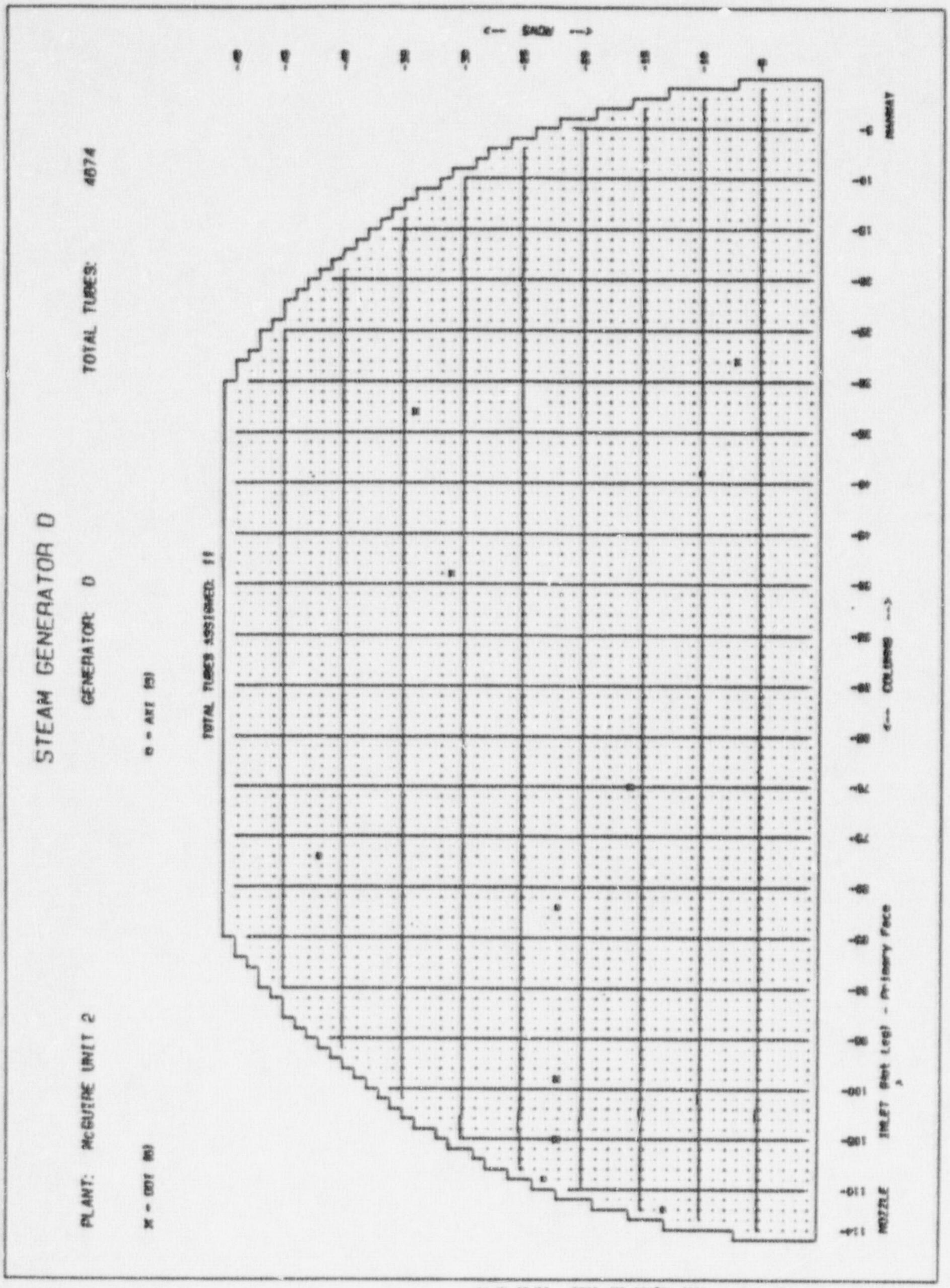

Figure 5-15. Steam Generator D Inlet - Free Span Indications

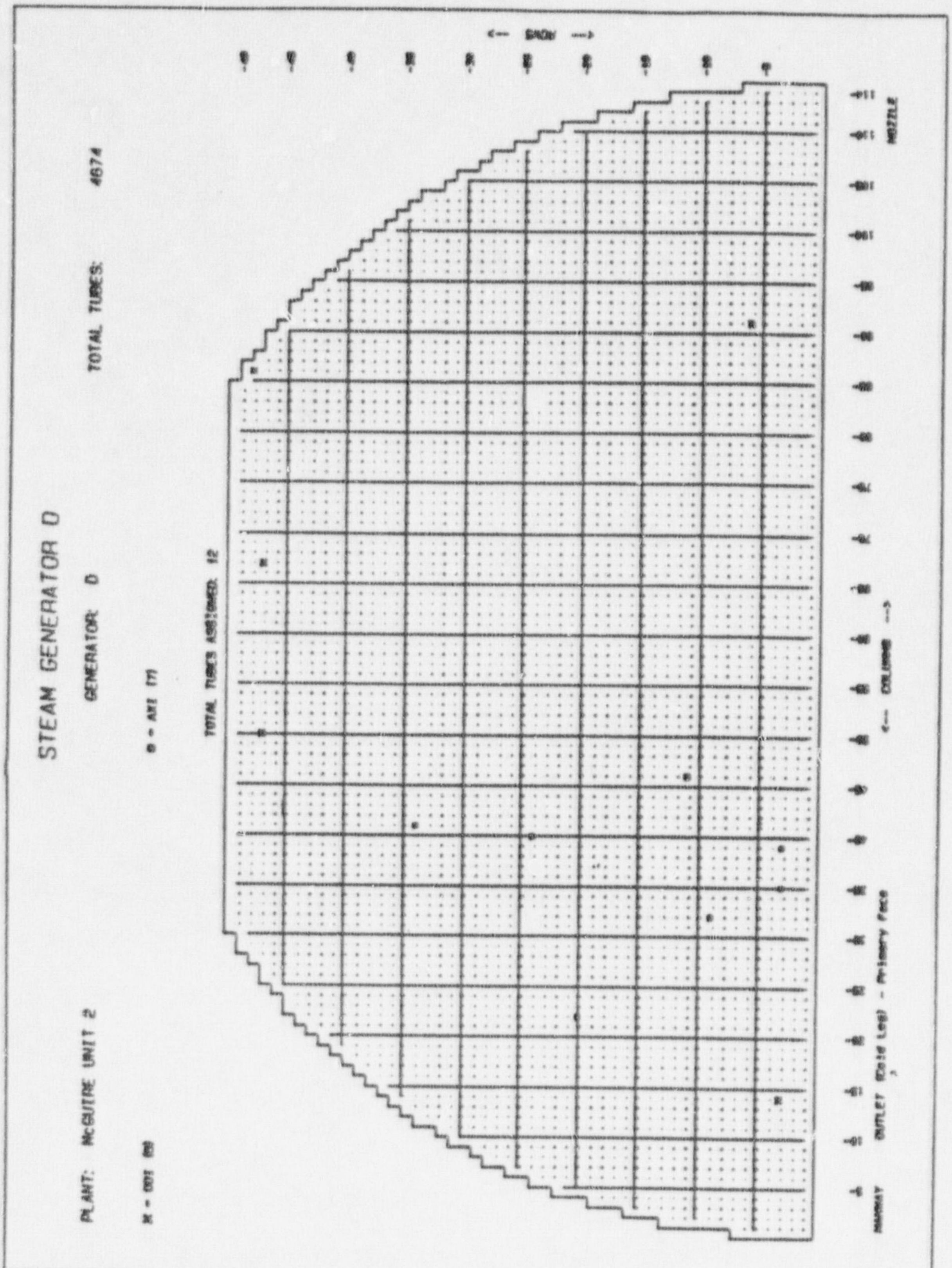

Figure 5-16. Steam Generator D Outlet- Free Span Indications

5.1.2 Rotating Pancake Coil Diagnostics

As was done during the McGuire Unit 1 forced outage, examples of all the different classes of bobbin coil indications were examined using RPC technology. In addition, numerous tubes from Heat 3835 (the heat of the ruptured tube) and tubes centered around R18C25 (corresponding to the McGuire Unit 1 tube that ruptured) were examined for evidence of abnormal tube conditions. These tubes were inspected on both the hot-leg and cold-leg side of the bundle, generally at the two lower support structures over a axial extent of -4" to +2" centered about the support structure of interest. The support structures of interest include the first, second, twenty-first and twenty-second tube support plates.

RPC data that was acquired during the refueling outage by steam generator and test objective is detailed in Table 5-3. The upper part of the table shows the number of bobbin coil indications by signal class that were further diagnosed using RPC. The special testing listed on the lower part of the table summarizes the number of tubes examined by steam generator leg for evidence of conditions similar to the McGuire Unit 1 ruptured tube. Approximately 371 tubes were tested during this special examination with no abnormal conditions observed.

Operational Degradation

Confirmed industry Model D preheater operating experience has included OD stress-corrosion cracking at support plates and the top of the tubesheet, tube wear at AVB's and at the cold-leg baffle plates within the preheater section, and PWSCC at roll expansions and the U-bend tangent point. All of these mechanisms have been experienced at McGuire Unit 2 with the exception of OD stress-corrosion cracking.

- Roll-Expansion PWSCC

  Typical RPC data from a bobbin coil indication identified within the F* region near the top of the tubesheet is shown in Figure 5-21. Review of the RPC isometric plot shows the presence of axially oriented linear indications in the roll expansion, characteristic of stress corrosion cracking.

TABLE 5-2

MCGUIRE UNIT 2
PLUGGED TUBE SUMMARY

	SG A	SG B	SG C	SG D
Previous Plugged Tubes (Total)(1)	(191)	(191)	(198)	(163)
Tubes Plugged During 1989 Refueling Outage				
o PWSCC (F* region)	49	24	29	29
c Wear				
- Preheater	0	2	0	0
o Manufacturing Artifacts				
- Free Span Indications(2)	7	1	3	18
o Other Reasons	2	6	1	2
Total Tubes	249	224	231	212

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1 Includes 114 Row 1 tubes preventively plugged in each steam generator except for SG D which had 12 Row 1 tubes returned to service.

2 Includes all axial indications.

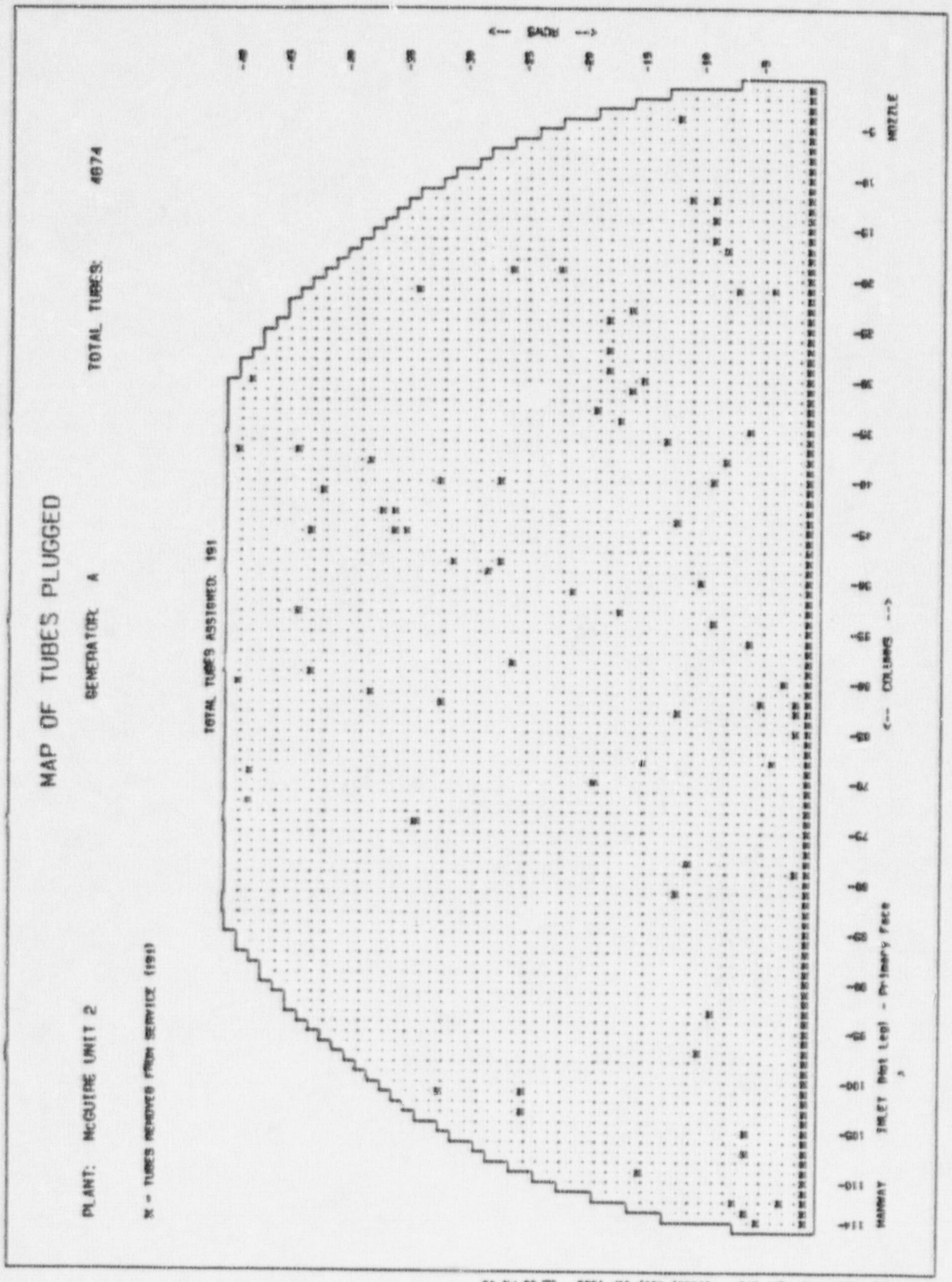

Figure 5-17. Steam Generator A Plugged Tubes - Prior to 1989

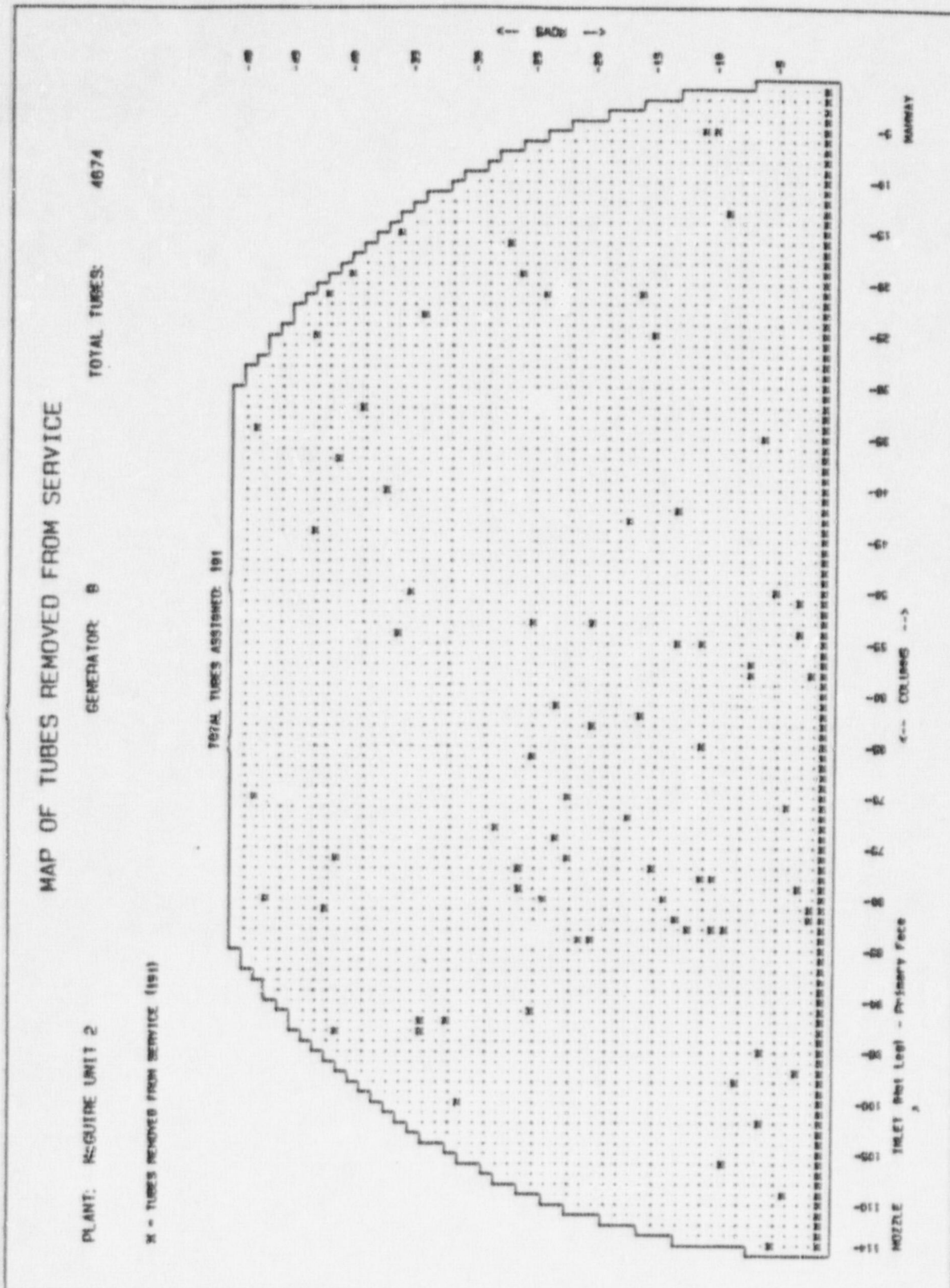

Figure 5-18. Steam Generator B Plugged Tubes - Prior to 1989

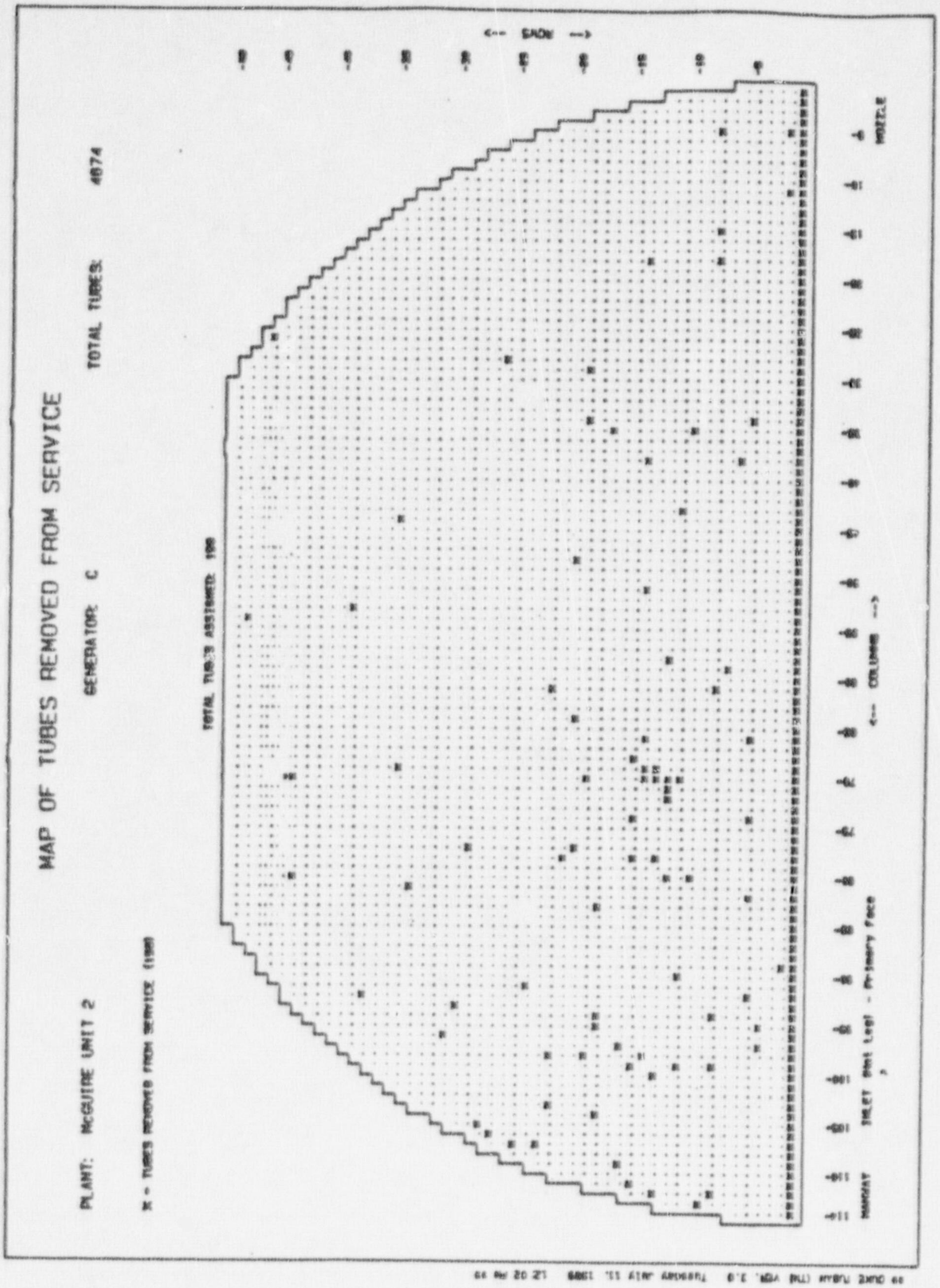

Figure 5-19. Steam Generator C Plugged Tubes Prior to 1989

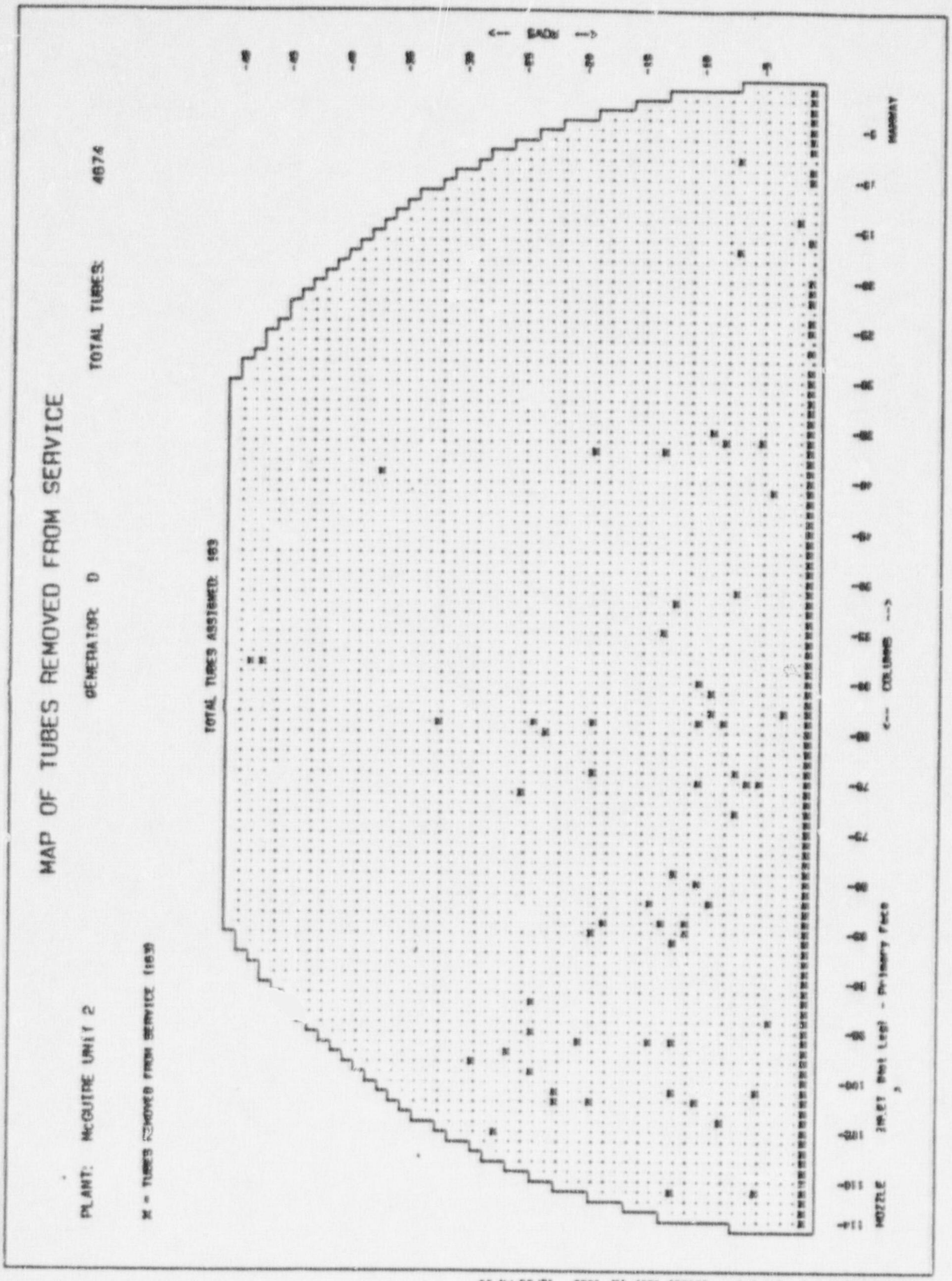

Figure 5-20. Steam Generator D Plugged Tubes - Prior to 1989

TABLE 5-3

MCGUIRE UNIT 2 1989

ROTATING PANCAKE COIL INSPECTION

General: Diagnostic Limited Length Inspection of Tubes Were Performed to Characterize Indications of Various Classes

	SG A		SG B		SG C		SG D	
	HL	CL	HL	CL	HL	CL	HL	CL
Operational Degradation								
o PWSCC within F* region	34	0	8	1	3	0	17	0
o Wear								
- Preheater Wear	-	2	-	3	-	1	-	
- AVB Wear		-		-		-		-
# of Tubes	34	2	8	4	3	1	17	0

Total - 69 Tubes

	SG A		SG B		SG C		SG D	
	HL	CL	HL	CL	HL	CL	HL	CL
Manufacturing Artifacts								
o Buff Marks	11	4	5	7	2	3	7	19
o Installation Marks	0	0	0	1	0	0	1	2
o Permeability	25	8	1	3	2	2	1	0
# of Tubes	36	12	6	11	4	5	9	21

Total - 104 Tubes

Special: Limited Length Inspection At Lower Support Plate Elevations on Heat Treat 3835 and Tubes Around R18C25

	SG A		SG B		SG C		SG D	
	HL	CL	HL	CL	HL	CL	HL	CL
# of Tubes	35	35	0	84	58	49	55	55

Total - 371 Tubes

- Preheater Wear

  An example of RPC data for tube wear within the preheater section is shown in Figure 5-22. Based on an extensive number of pulled tubes, these wear scars have been shown to be volumetric, sometimes tapered, and are bounded axially by the thickness of the support plate. As discussed in Reference 1, special wear scar standards are used to provide statistically conservative estimates of depth. The RPC data illustrated in Figure 5-22 is characteristic of volumetric wall loss of shallow depth, i.e. <20% through-wall, with axial tapering and an angular extent of approximately 90 degrees.

- AVB Wear

  RPC data for tube wear at an AVB was shown in Reference 1. Tube wear occurs as the result of the anti-vibration bars fretting against an adjacent tube. Tube wear can be both single-sided and two-sided. As discussed in Reference 1, special calibration standards are used for the bobbin coil sizing of AVB wear scar depth.

Tube Manufacturing/Installation Artifacts

Three additional classes of indications not attributed to operating related degradation were also observed during the McGuire Unit 2 inspection. As described in Reference 1, two of these classes are artifacts of tube manufacturing, e.g., buff marks and permeability variations, whereas the third class i.e., installation marks, is probably due to difficulties encountered during tube installation. All three signal classes are somewhat common in operating recirculating steam generators. All tubes reported to have axial indications were plugged.

- Manufacturing Buff Marks

  So called buff or burnish marks are generally localized cosmetic repairs made to the tube during manufacturing to remove small pits or tube discoloration. These indications are generally localized and have been

UTILITY: DUKE POWER COMPANY.........................
PLANT: MCGUIRE UNIT 2.........................
GEN: SG D INLET STRAIGHT TUBE INSPECTION.....
DATE: 7/29/89
TIME: 17:29: 5
ANALYST: B0690
TAPE: 1 record #20

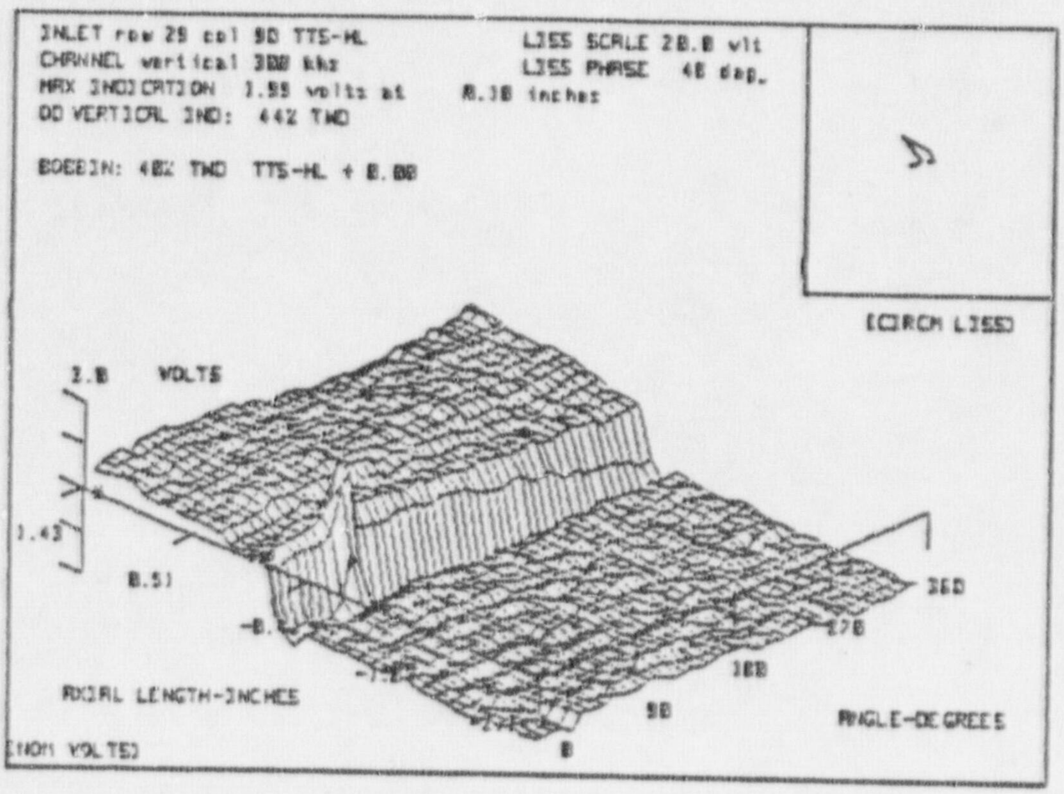

Figure 5-21. RPC Isometric of PWSCC at Roll Expansion

UTILITY: DUKE POWER COMPANY
PLANT: MCGUIRE UNIT #2
GEN: B S/G OUTLET STRAIGHT ET-360
DATE: 8/10/89
TIME: 6:16:47
ANALYST: B0690
TAPE: 4 record #57

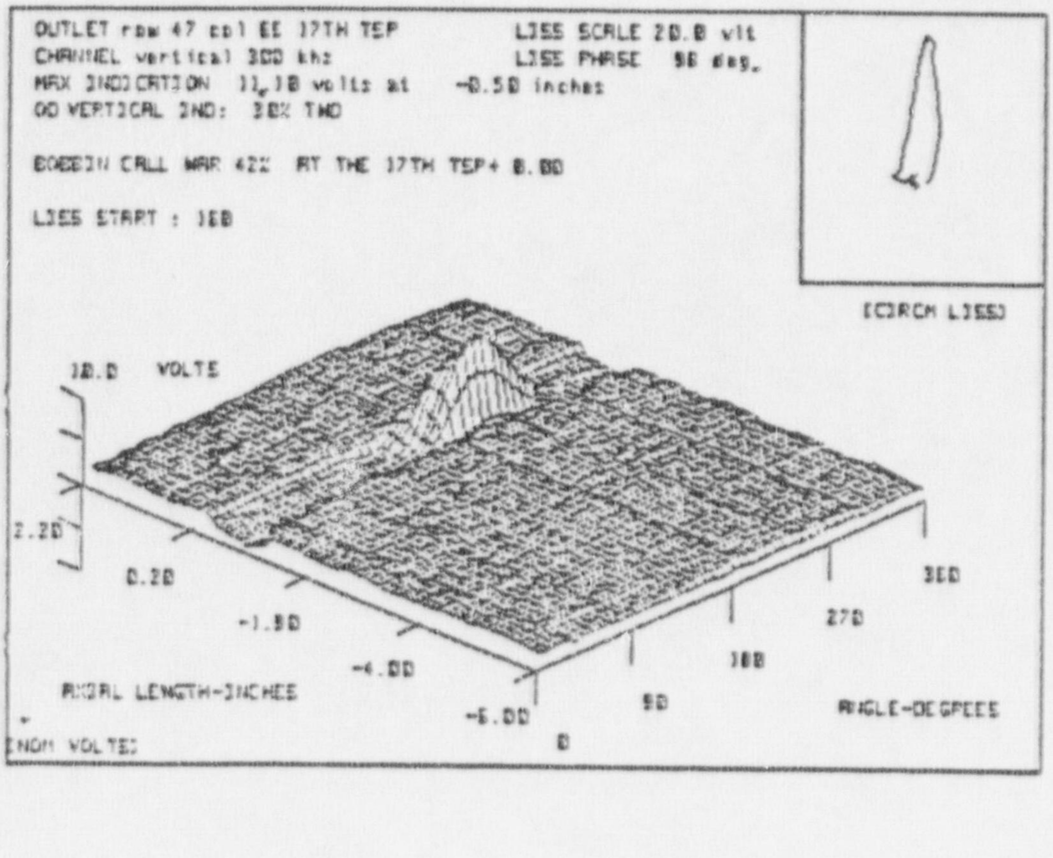

Figure 5-22. RPC Isometric of Preheater Wear Scar

observed in all regions of the steam generator; i.e., there is no preferred location for their occurrence. Depth estimates derived from absolute bobbin coil data show these types of discontinuities to be typically less then 20% through-wall; these depth estimates are supported by RPC data and by direct tube pull evidence, Reference 1. RPC data for a typical bobbin coil buff mark indication is shown in Figure 5-23. This particular indication was reported with the bobbin coil as <20% through-wall, located at the 22nd support plate +16.7 inches. Measured depth for this indication with the RPC was approximately 9% through-wall.

o Probable Tube Installation Marks

RPC eddy current data from a <20% through-wall "axial indication" identified in SG B using the bobbin coil is shown in Figure 5-24. This indication was reported on the cold-leg side at the 19th support plate +15.53" to 20.01". The RPC isometric shows a linear indication with significant axial length; estimated depth using RPC signal amplitude is approximately 5% through-wall. All reported axial indications were plugged.

o Permeability Variations

Probably the most common artifact eddy current indications related to tube manufacturing are "PV" signals; these signals are attributed to permeability variations within the tube wall. These indications sometimes exhibit signal features characteristic of tube wall degradation that has initiated from the tube inner surface. They can generally be distinguished from real tube wall degradation by the use of magnetic bias saturating coils which tend to suppress permeability variations. An example of RPC data from a permeability spot is shown in Figure 5-25.

5.2 Additional Inspections

5.2.1 U-bend Restrictions

During the inspection of steam generator "B", it was reported that tubes R46C35 and R46C36 were restricted to the passage of a 0.610" diameter probe between the #1 and #2 AVB's. A review of 1988 data from tube R46C35 using bobbin coil profilometry techniques revealed a signal similar to that exhibited by a reduction in the tube diameter. Data from the 1986 inspection revealed a similar type signal for R46C36. A subsequent review of the 1989 data by bobbin coil profilometry techniques indicated that R46C37 also exhibited the same type of profile trace as the aforementioned tubes in the same location. In addition, of 90 tubes reviewed in the same area of the steam generator, 9 tubes exhibited signals typical of a smaller reduction of tube diameter at the same location and 9 tubes showed similar signals between the #3 and #4 AVB's. These 18 tubes however exhibited very minor apparent diameter reductions as compared to tubes R46C35, 36 and 37. Profilometry with a rotating coil system (Profil 360) was performed on 7 tubes, R46C34 through C40; this showed ovality less than 12% on the three row 46 tubes, and only nominal ovality, less than 5% on the others. The secondary side visual examination revealed no obvious deformation of these tubes. Prior to tube plugging, a 0.590" probe was passed through tubes R46C35 and R46C36 when these tubes were hand probed, indicating that they were not severely deformed. These observations are consistent with regions of increased ovality in a portion of the U-bend and do not indicate the presence of a new pervasive damage mechanism. Tubes R46C35, R46C36 and R46C37 were conservatively plugged.

5.2.2 Foreign Objects

During the routine foreign object screening, two wire fragments were located in SG A and B. In addition, following the secondary side visual examination of the restricted tubes, a small nut and washer were left in the steam generator. These have been evaluated for further operation as described in Section 7.3.

UTILITY: DUKE POWER COMPANY
PLANT: MCGUIRE UNIT #2
GEN: B S/G OUTLET STRAIGHT ET-360
DATE: 8/10/89
TIME: 3:34: 9
ANALYST: B0690
TAPE: 4 record #39

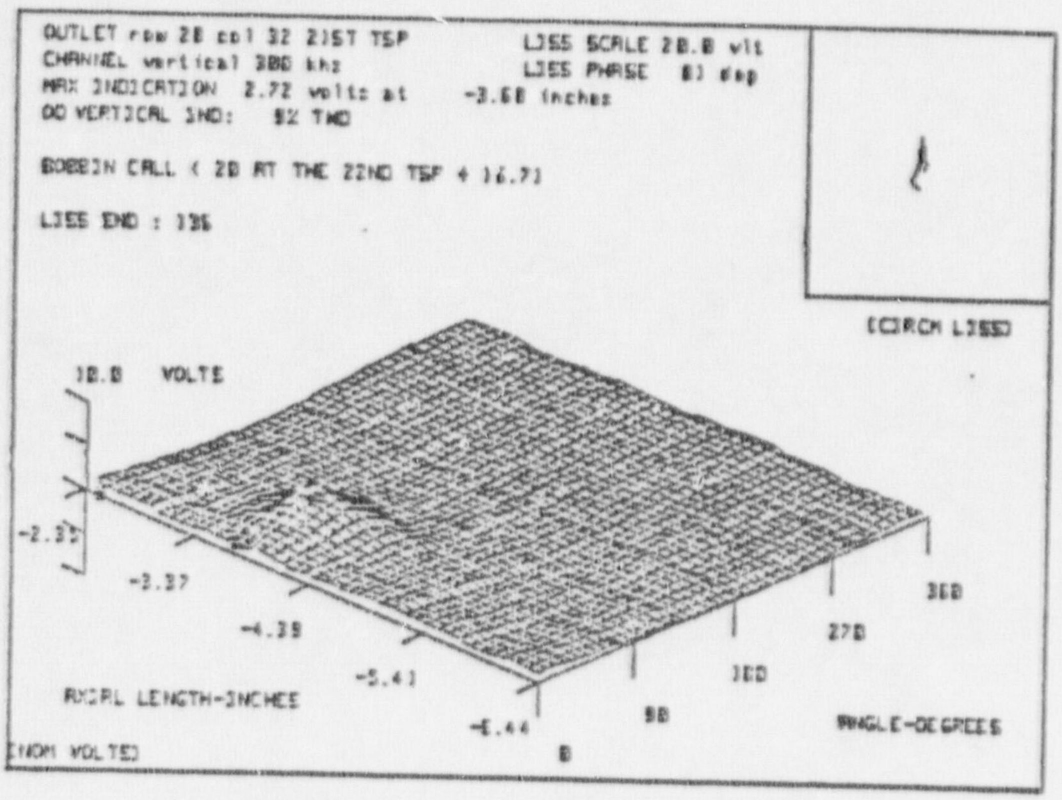

Figure 5-23. RPC Isometric of Free Span Buff Mark

UTILITY: DUKE POWER COMPANY
PLANT: MCGUIRE UNIT #2
GEN: B S/G OUTLET STRAIGHT ET-360
DATE: 8/10/89
TIME: 7:26:54
ANALYST: B0690
TAPE: 4 record #62

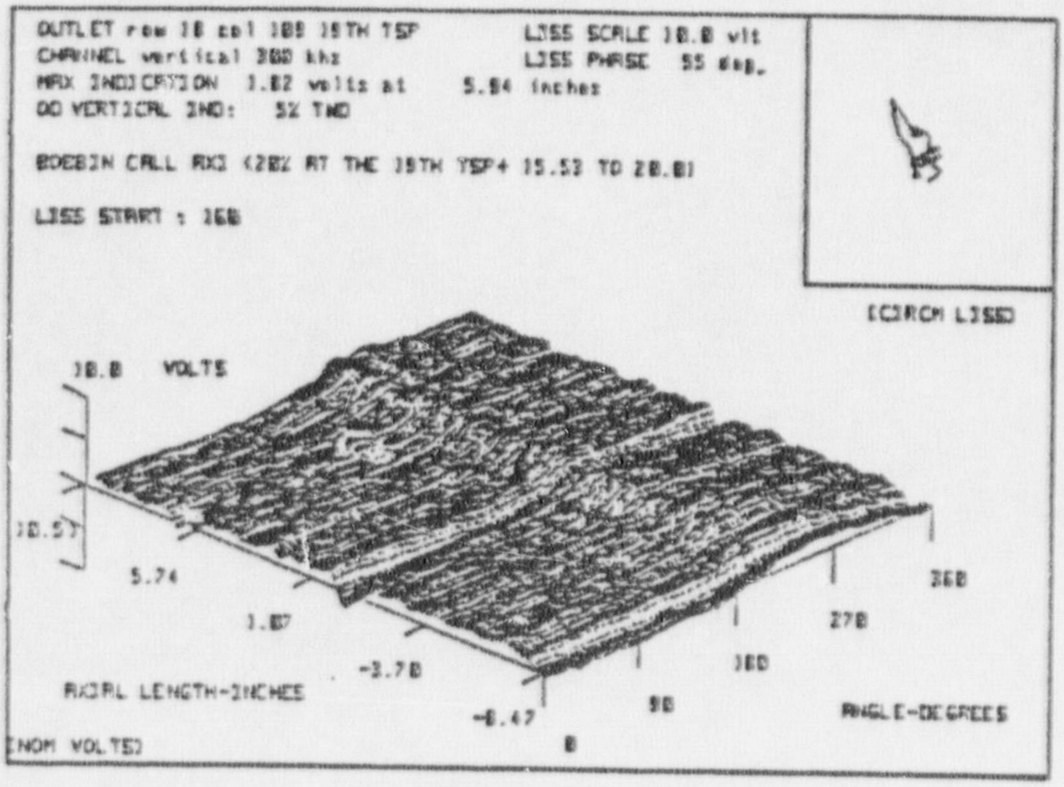

Figure 5-24. RPC Isometric of OD Axial Indications

UTILITY: DUKE POWER COMPANY
PLANT: MCGUIRE UNIT #2
GEN: B S/G OUTLET STRAIGHT ET-360
DATE: 8/10/89
TIME: 5:45:14
ANALYST: B0690
TAPE: 4 record #50

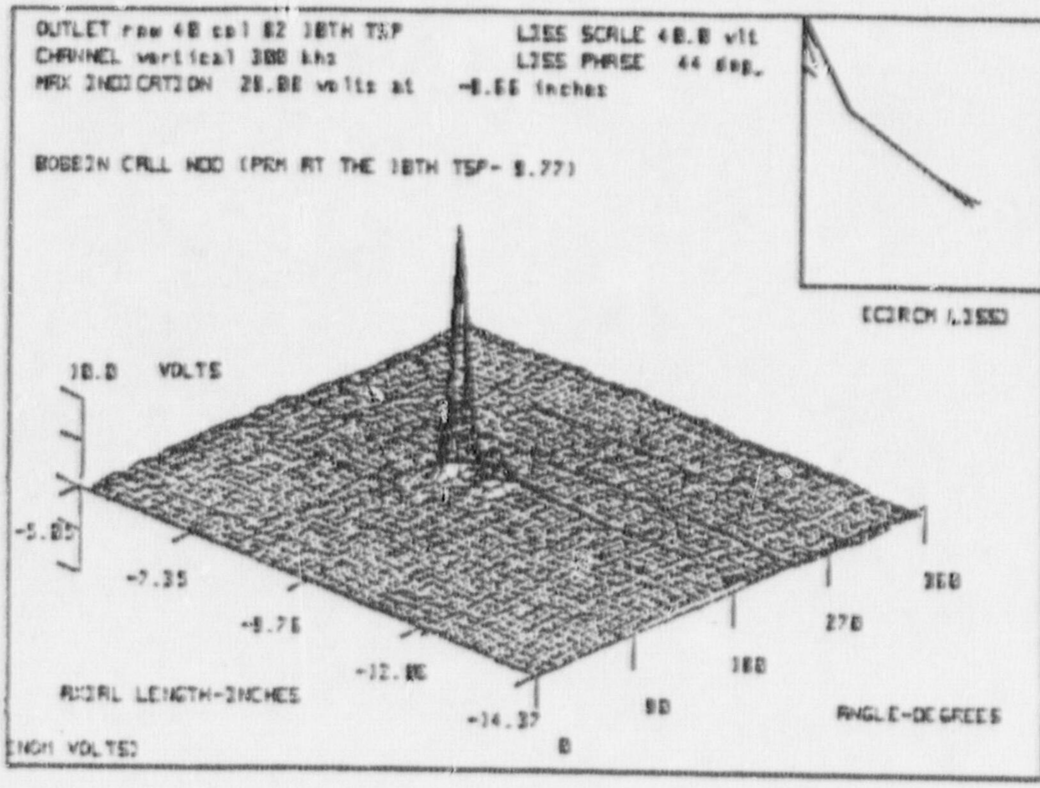

Figure 5-25. RPC Isometric of Permeability Indication

6.0 REVIEW OF OPERATING CHEMISTRY

A detailed review of McGuire Unit 2 secondary chemistry data was performed for use in a report on the status of the McGuire Unit 2 steam generators. This effort consisted of reviewing routine chemistry data, chemistry excursion data, wet layup data, and hideout return data since initial startup.

6.1 Routine Chemistry Data

Since initial startup in 1984, McGuire Unit 2 has had relatively good secondary chemistry as indicated by a statistical review of pertinent chemistry parameters. Table 6-1 summarizes data for key chemistry parameters on an annual basis, including steam generator cation conductivity, steam generator sodium, steam generator chloride, steam generator sulfate, condensate dissolved oxygen, and chemistry performance index (CPI).

Overall, McGuire Unit 2 secondary chemistry has not been quite as good as the secondary chemistry for McGuire Unit 1, which has generally been excellent. The reasons for this are: 1) McGuire Unit 2 receives a predominance of makeup water, and thus makeup water contaminants, as a result of normally supplying the auxiliary steam header, and 2) McGuire Unit 2 has had a problem with condenser leaks during the past several years.

While McGuire Unit 2 secondary chemistry has not been as good as McGuire Unit 1, it has been relatively good in a comparison with the industry. McGuire Unit 2's chemistry performance index of 0.195 in 1988 ranked it in the best quartile as reported in INPO's 1988 year-end report on performance indicators. The industry-wide best quartile value for chemistry performance index in 1988 was 0.20 and the median value was 0.24. In fact, McGuire Unit 2's chemistry performance index for each year since 1986 was better than the industry-wide best quartile value in 1988. Note that INPO just began using chemistry performance index as an performance indicator in 1988, and thus there is no information available for a year-by-year comparison with industry prior to 1988. It should be noted that the CPI is dependent upon the quantity but not the composition of the contaminants.

6.2 Steam Generator Chemistry Excursions

A review of steam generator chemistry excursions since initial startup indicates that McGuire Unit 2 has had a number of minor excursions, but has had relatively few moderate or severe excursions. Table 6-2 lists the steam generator chemistry excursions that have occurred. These excursions are grouped by severity in accordance with Action Level 1, 2, and 3 of the EPRI PWR Secondary Water Chemistry Guidelines.

The number of minor chemistry excursions that have occurred on McGuire Unit 2 is considered to be rather typical. Most have occurred during power escalation following trips or outages. It has generally been the practice at McGuire to hold at 30% power until Action Level 1 guidelines values have been met to minimize contaminant hideout. This is consistent with recommendations in the EPRI Guidelines.

During the first year of operation, blowdown isolation due to valve failures caused several chemistry excursions. This problem was essentially corrected by the end of 1984. During 1985 and 1986, condensate polisher resin leakage was a recurring problem which caused chemistry excursions. This problem was corrected in mid-1986 by replacing the original wire mesh polisher elements with smaller pore size sintered metal elements. During the past several years, condenser leaks have been the cause of several chemistry excursions. The cause of the condenser leaks was investigated during the current outage and was found to be the result of severe steam erosion caused by a leaking valve (i.e., turbine crossover bypass to condenser valve). The corrective actions implemented were to repair the leaking valve and plug tubes in the affected area, with a long term action of improving the condenser baffles.

ince initial startup, McGuire Unit 2 has had one Action Level 2 chemistry excursion (1-27-89) and one Action Level 3 chemistry excursion (10-31-88) while at full power. (Note that several parameters exceeded Action Level 2 values ring the 1-27-89 Action Level 2 event and the 10-31-88 Action Level 3 ent). Both of these excursions were due to condenser leaks. In response to the Action Level 2 excursion, power was reduced to 38% to minimize contaminant hideout. In response to the Action Level 3 excursion, the unit was shut down (<2% reactor power) to minimize hideout and to flush crevices.

In addition to the above excursions, five Action Level 2 excursions occurred during startups. No power reductions were made since the unit was already at low power when these occurred.

6.3 Steam Generator Wet Layup

A review of steam generator wet layup data for outages of one week or longer at cold shutdown conditions indicates that wet layup conditions were effectively implemented at the start of each of these outages. The following summarizes these outages and wet layup implementation for each:

Outage Start Date of 7-29-84
All Four Steam Generators in Wet Layup by 7-30-84

Outage Start Date of 1-25-85
All Four Steam Generators in Wet Layup by 1-27-85

Outage Start Date of 7-12-85
All Four Steam Generators in Wet Layup by 7-14-85

Outage Start Date of 12-11-85
All Four Steam Generators in Wet Layup by 12-13-85

Outage Start Date of 3-13-86
All Four Steam Generators in Wet Layup by 3-16-86

Outage Start Date of 10-28-86
All Four Steam Generators in Wet Layup by 10-31-86

Outage Start Date of 5-1-87
All Four Steam Generators in Wet Layup by 5-3-88

Outage Start Date of 5-27-88
All Four Steam Generators in Wet Layup by 5-30-88

Outage Start Date of 7-5-89
All Four Steam Generators in Wet Layup by 7-07-89

During the 7-29-84, 1-25-85, 5-1-87, 5-27-88, and 7-5-89 outages, the steam generators were drained for maintenance subsequent to placing them in wet layup.

6.4 Steam Generator Hideout Return Data

During refueling outage shutdowns, the steam generators are soaked at approximately 350° to promote hideout return. For each of the McGuire Unit 2 refueling outage shutdowns, chemistry data was taken during the cooldown and soak periods to assess hideout return.

The hideout return data for McGuire Unit 2 indicates the potential for alkaline crevice conditions when analyzed using EPRI's MULTEQ equilibrium chemistry computer model. This is not unexpected for a freshwater-cooled plant with condensate polishers. How alkaline the crevices are predicted to be by MULTEQ depends on the assumptions made regarding the influence of precipitates on crevice chemistry (i.e., whether the precipitates that are formed remain in contact with the crevice liquid or are continuously removed).

The first three refueling outage shutdowns for McGuire Unit 2 (1985, 1986 and 1987) were characterized by relatively small quantities of hideout return. MULTEQ analysis of the 1987 data indicated that any crevice solutions formed had the potential to be moderately alkaline.

During the most recent shutdowns (1988 and 1989), an increase in the amount of hideout return was observed for most contaminants. This increase in hideout return is believed to be due to the condenser leaks that were experienced during the period and the ingress of filtered water into the demineralized water header over an extended period of time at levels that were too low to detect with normal sampling. Even though the three most severe condenser leaks occurred during the most recent cycle, the quantity of return for this cycle was not as great as for the previous cycle. This is attributed to the cleanup effect of the three unit trips that occurred in March and April, 1989 during which substantial return was observed. Similar to the 1987 shutdown data, MULTEQ indicates the potential for moderately alkaline crevice solutions for the 1988 and 1989 shutdowns.

Caustic crevice conditions have been implicated in intergranular attack (IGA) and intergranular SCC of Alloy 600 tubing. In addition, mill annealed Alloy 600 tubing is reported to be susceptible to this type of cracking. However, in spite of hideout return data which indicates the potential for alkaline crevice conditions to occur and tubing reported to be susceptible to caustic-induced cracking, no secondary side SCC has been detected to date in the McGuire Unit 2 steam generators.

6.5 Conclusion

A review of chemistry data since initial startup indicates that McGuire Unit 2 has had generally good secondary chemistry. From the review of routine chemistry data, chemistry excursion data, and wet layup data, secondary chemistry shows no obvious trends toward a deleterious environment. The hideout return data does indicate the potential to form alkaline crevice conditions. However, no secondary side SCC has been detected in the McGuire Unit 2 steam generators. Therefore, it is felt that the normally good secondary chemistry combined with the appropriate power reductions during moderate to severe excursions have helped to prevent detectable corrosion to date.

TABLE 6-1

MCGUIRE UNIT 2 SECONDARY CHEMISTRY DATA
SUMMARY BY YEAR (1984-1989) (1)

Parameter	1984(2)	1985	1986	1987	1988	1989(3)	Guidelines(4)
Cat. Cond. (µmhos/cm)	.300	.264	.203	.192	.166	.160	≤ .8
Sodium (ppb)	4.5	6.7	2.4	2.2	5.1	4.3	≤ 20
Chloride (ppb)	4.0	2.6	1.9	2.2	3.2	3.6	≤ 20
Sulfate (ppb) (5)	7.0	7.0	3.8	2.0	3.7	2.5	≤ 20
HW DO (ppb) (6)	2.0	1.6	1.9	2.5	1.7	1.9	≤ 10
CPI (7)	.270	.261	.170	.162	.195	.182	N/A

Notes: (1) Pertinent secondary chemistry data as reported to INPO. With the exception of 1984, the data represents the average of daily maximum values for > 30% power operation.

(2) Data for 1984 represents typical values for power operation.

(3) Data for 1989 is for the period 1-1-89 to 6-30-89.

(4) EPRI PWR Secondary Water Chemistry Guidelines - Action Level 1.

(5) Sulfate was not routinely measured until late 1984.

(6) Dissolved oxygen measured at the discharge of the hotwell pumps.

(7) INPO Chemistry Performance Index for secondary chemistry.

TABLE 6-2

MCGUIRE UNIT 2 STEAM GENERATOR
CHEMISTRY EXCURSIONS (1984-1988) (1)

Minor Chemistry Excursions (Action Level 1)

Date	Parameter	Max. Value	Duration	Cause
04/13/84	Sodium	24 ppb	NR(2)	BB Isolated (3)
06/10/84	Sodium	24 ppb	NR	BB Isolated
07/03/84	Cat. Cond.	1.1 µmhos	NR	BB Isolated
07/03/84	Chloride	38 ppb	NR	BB Isolated
07/09/84	Cat. Cond.	1.0 µmhos	NR	Restart (4)
07/19/84	Cat. Cond.	1.9 µmhos	NR	BB Isolated
07/22/84	Chloride	24 ppb	NR	Cond. Coolers (5)
07/26/84	Cat. Cond.	0.9 µmhos	NR	BB Isolated
07/27/84	Chloride	23 ppb	NR	BB Isolated
10/26/84	Sulfate	25 ppb	NR	Restart
11/19/84	Sulfate	40 ppb	NR	Restart
05/13/85	Sulfate	40 ppb	NR	Resin Leakage (6)
05/18/85	Sulfate	35 ppb	NR	Resin Leakage
05/19/85	Sulfate	23 ppb	NR	Resin Leakage
05/20/85	Sulfate	35 ppb	NR	Resin Leakage
05/21/85	Sulfate	30 ppb	NR	Resin Leakage
07/03/85	Sulfate	35 ppb	NR	Resin Leakage
08/06/85	Sulfate	56 ppb	NR	Startup (7)
08/16/85	Sulfate	36 ppb	NR	Power Reduct.
11/03/85	Sodium	30 ppb	NR	Restart
01/16/86	Sulfate	27 ppb	9.1 hrs	Restart
03/12/86	Cat. Cond.	1.7 µmhos	2.9 hrs	Resin Leakage
03/12/86	Sulfate	90 ppb	12.8 hrs	Resin Leakage
06/28/86	Sulfate	91 ppb	14.3 hrs	Startup
06/29/86	Cat. Cond.	0.9 µmhos	5.5 hrs	Resin Leakage
07/24/86	Cat. Cond.	1.3 µmhos	3.3 hrs	Power Escl.
08/26/86	Sulfate	25 ppb	7.3 hrs	Restart
08/28/86	Cat. Cond.	0.9 µmhos	3.2 hrs	Power Escl.
08/17/87	Sulfate	23 ppb	2.3 hrs	Restart
09/30/87	Sodium	45 ppb	11.2 hrs	RN Ingress(8)
09/30/87	Chloride	26 ppb	8.4 hrs	RN Ingress
11/06/87	Sodium	30 ppb	3.5 hrs	Restart
11/21/87	Sodium	23 ppb	3.8 hrs	Condenser Leak
03/14/88	Sodium	24 ppb	4.7 hrs	CS Ingress (9)
05/14/88	Sodium	33 ppb	3.4 hrs	Power Reduct.
05/14/88	Sulfate	57 ppb	25.2 hrs	Power Reduct.
07/27/88	Sodium	25 ppb	6.6 hrs	Startup/BB Isol.
07/27/88	Sulfate	42 ppb	15.3 hrs	Startup/BB Isol.
07/28/88	Sulfate	27 ppb	4.6 hrs	Power Escl.
11/07/88	Sodium	73 ppb	18.6 hrs	Condenser Leak
11/07/88	Chloride	60 ppb	2.6 hrs	Condenser Leak
01/27/89	Sulfate	32 ppb	9.5 hrs	Condenser Leak
03/04/89	Cat. Cond.	1.5 µmhos	5.3 hrs	Restart
03/04/89	Chloride	28 ppb	2.7 hrs	Restart
03/04/89	Sulfate	99 ppb	16.8 hrs	Restart

TABLE 6-2 (Cont'd.)

Minor Chemistry Excursions (Action Level 1)

Date	Parameter	Max. Value	Duration	Cause
03/14/89	Cat. Cond.	1.0 µmhos	2.3 hrs	Restart
03/14/89	Sulfate	61 ppb	9.4 hrs	Restart
04/07/89	Cat. Cond.	1.2 µmhos	5.3 hrs	Restart
04/07/89	Sodium	82 ppb	8.6 hrs	Restart
04/07/89	Chloride	26 ppb	12.0 hrs	Restart

Moderate Chemistry Excursions (Action Level 2)

Date	Parameter	Max. Value	Duration	Cause
06/29/86	Sulfate	160 ppb	14.5 hrs	Startup/Res.Leak.
07/23/86	Sulfate	203 ppb	25.8 hrs	Restart
07/27/88	Cat. Cond.	2.3 µmhos	4.2 hrs	Startup/BB Isol.
10/31/88	Cat. Cond.	3.8 µmhos	10.8 hrs	Condenser Leak
10/31/88	Chloride	260 ppb	11.8 hrs	Condenser Leak
10/31/88	Sulfate	120 ppb	8.1 hrs	Condenser Leak
01/27/89	Cat. Cond.	2.6 µmhos	6.5 hrs	Condenser Leak
01/27/89	Sodium	183 ppb	13.5 hrs	Condenser Leak
01/27/89	Chloride	235 ppb	11.5 hrs	Condenser Leak
03/04/89	Sodium	115 ppb	7.2 hrs	Restart
03/14/89	Sodium	134 ppb	12.8 hrs	Restart

Severe Chemistry Excursions (Action Level 3)

Date	Parameter	Max. Value	Duration	Cause
10/31/88	Sodium	800 ppb	12.8 hrs	Condenser Leak

Notes:
(1) Pertinent steam generator chemistry parameters per the EPRI PWR Secondary Chemistry Guidelines for Mode 1 operation (pH and silica not included).
(2) No records available on the duration of excursions until 1986.
(3) Blowdown (BB) system isolated.
(4) Restart and power escalation after a trip or non-outage related shutdown.
(5) Condensate coolers valved into service.
(6) Resin leakage during condensate polisher manipulations.
(7) Startup and power escalation following an outage.
(8) Ingress of RN nuclear service water into auxiliary steam header during containment spray heat exchanger cleaning, with eventual ingress into the secondary system via the condensate storage tank.
(9) Ingress of Calgon CS corrosion inhibitor (sodium nitrite) into the secondary system via sample drain return to the condensate storage tank.

7.0 JUSTIFICATION FOR RETURN TO POWER

The information in the previous sections of this Addendum to the "McGuire Unit 1 Nuclear Power Station Evaluation of Degradation of tube R18C25 and Justification for Return to Power Report" supports the return to power of the McGuire Unit 2 steam generators. Significant areas addressed in this Addendum are summarized in this section, "Justification for Return to Power". Specifically, the impact on tube integrity with respect to the following has been considered:

- McGuire Unit 1 R18 C25 Tube Rupture
- U-bend Restriction
- Steam Generator Secondary Side Loose Objects

Evaluations in these areas, completed per 10 CFR 50.59 criteria, support the return to power of the McGuire Unit 2 steam generators.

7.1 McGuire Unit 1 Tube Rupture Issue

This section of the Addendum addresses the March 7, 1989, McGuire Unit 1, R18 C25, steam generator "B", tube rupture. The cause of the tube rupture was established by metallurgical investigation to be outer diameter initiated intergranular SCC. Specifically, the degradation consisted of a network of small axial and circumferential cracks which linked together. The network of cracks was associated with and confined to a linear surface groove. The degradation on tube R18C25 extended from just above the crevice region of the lowest cold-leg baffle plate of the preheater, through the crevice region and terminated approximately two and one-half inches below the baffle plate. Typically, SCC is expected to result in a relatively slow propagation of the crack based on previous experience with SCC in the cold leg of steam generator tubes. The presence of a nickel-free, iron chromium layer was identified at the surface of the groove. This metallurgical anomaly together with the residual stresses are judged to have contributed to the SCC initiation. Overall, the metallurgical characteristics of the groove support a relatively unique anomaly.

7.1.1 Frequency of Occurrence of Degradation

Indication of cracking of the type experienced in tube R18C25 has not been found in any other tube in any location in any of the steam generators at McGuire Units 1 and 2. It is expected that if the causative factors were widespread, a significant number of tubes would be affected. Consequently, such cracking would have been detectable by eddy current inspection in a broad population of tubes, particularly hot leg tubes. Furthermore, if the degradation mechanism was due to factors potentially impacting many tubes such as operating chemistry, thermal hydraulic conditions, or material microstructure, it is very unlikely that one tube (R18C25) would have extensive through wall cracking while all other tubes exhibited no detectable eddy current indications.

McGuire Unit 1, tube R13C34, which had a groove on the outer diameter surface of the tube, was examined metallurgically. This subject tube was from the same heat of material and operated in a similar thermal and hydraulic environment as the tube that ruptured (R18C25). The examination of R13C34 found no evidence of cracking, supporting the position that the mechanism which initiated the cracking was not widespread.

7.1.2 Degradation Growth Rate

The mechanism responsible for the growth of the degradation (i.e., stress corrosion cracking) would be expected to result in relatively slow propagation of the crack based on thermal activation considerations of SCC in hot leg tubes. The rate of propagation can be estimated independently of a defined mechanism for initiation of the degradation. For the McGuire Unit 1 type degradation, a growth rate has been evaluated for the postulated continued growth for the purposes of estimating a crack depth at the end of the current McGuire Unit 1 fuel cycle. The estimated growth rate is 0.7 mils (1.6% wall loss) per month. This growth rate is detailed further in Section 9.3 of Reference 1, "McGuire Nuclear Power Station Evaluation of Degradation of Tube R18C25 and Justification for Return to Power Report".

Previous experience with SCC in the McGuire Unit 1 and other steam generators has demonstrated that propagation of SCC has a significant temperature dependence and the rate of growth on the hot leg side of the tube bundle would be expected to be approximately a factor of four faster than for the cold leg location of the cracking in R18C25. The absence of evidence of similar cracking on the hot leg side of the tube bundle provides additional support for the position that the initiating condition for the degradation in R18C25 is not widespread.

7.1.3 Eddy Current Inspection

Correlation of eddy current data with metallographic results from tube R13C34 demonstrates that the bobbin probe eddy current may be sensitive to the presence of shallow outer diameter surface grooves on tubes remaining in service. None of the tubes with extended indications suggestive of grooves were found to have indications of cracking or other degradation within the groove via an RPC probe. Nevertheless, tubes with grooves of significant length have been conservatively plugged and removed from service. Given the absence of indications of cracking of any size, widespread tube degradation of the type found in the steam generator tube R18C25 is not considered a credible condition for the McGuire Units 1 and 2 steam generators.

Rotating pancake eddy current inspection results of 100 tubes in Unit 1 steam generator "B" of the same heat of material as tube R18C25 were reviewed for evidence of cracks between the top of the tubesheet and the first support plate on the hotleg and between the tubesheet and the second baffle plate on the cold leg. In McGuire Unit 2, 371 tubes including tubes from the heat of the ruptured tube, were examined by RPC at and near the lower two support plates. The results of the RPC examination confirm the findings of the bobbin probe examination that no tubes remain in service with indications of cracking or other tube degradation of the type found in R18C25.

In addition, a review of eddy current indications associated with other types of degradation present in active tubes found no significant change from previous inspections. Consequently, these findings support the conclusion that there is no significant widespread secondary side SCC mechanism adversely affecting the tubes in the McGuire Units 1 and 2 steam generators.

7.1.4 Operation Interval Determination

The maximum depth of a long crack which would meet all the analysis criteria of Regulatory Guide 1.121 (R.G. 1.121) has been established. The controlling value is the minimum wall thickness based on meeting a factor of safety of 3 against burst for normal operating differential pressure. The value for the minimum wall was determined to be 0.015 inch. The method used to calculate the minimum wall uses lower tolerance limit material strength properties and is typical of the method used by Westinghouse for other recent determinations of minimum wall per the R.G. 1.121 criteria.

The comparison of the depth of penetration to the maximum allowable wall loss for the McGuire Units as a percentage of tube wall thickness is tabulated below and demonstrates compliance with R.G. 1.121 criteria:

	Normal operation loadings	Accident condition loadings
Postulated initial depth	49%	49%
Estimated total growth *	19%	19%
PREDICTED DEPTH	68%	68%
MAXIMUM ALLOWABLE WALL LOSS	65%	67%

* 12 months at 0.7 mils per month

The postulated degradation depth at the start of the operating interval is just below the limit of detectability of 50% through wall and not dependent on an estimate of the depth based on an eddy current signal. Using a degradation growth rate of 0.7 (1.6% wall loss) mils per month and a postulated initial indication of 49% through wall results in a projected remaining wall thickness comparable to the controlling allowable wall loss for the McGuire Unit 2 steam generator tubes.

7.1.5 Leak Before Break Considerations

The leak before break rationale is to limit the maximum primary to secondary leak rate during normal operating conditions such that the associated crack length through which Technical Specification leakage occurs is less than the critical crack length corresponding to tube burst at a maximum postulated pressure condition loading (i.e., Feedline Break). Thus on the basis of normal operation, unstable crack growth is not expected to occur in the unlikely event of a limiting accident.

As noted in Reference 1, the cracking that occurred in tube R18C25 was contained within the groove. Consequently, special attention has been given to detecting scratches or grooves similar to those observed in R18C25 and R13C34. This resulted in plugging tubes which were interpreted to have signals with extended length even though only minimal tube wall penetration was evident. Therefore, it is expected that no tubes with detectable grooves remain in service in the McGuire Units 1 and 2 steam generators with a length that exceeds the length that, if a single crack were to occur in this location, would result in unstable crack growth during faulted condition loadings.

Additionally, the use of a leak rate monitoring policy consistent with the requirements of NRC Bulletin 88-02, which emphasizes both absolute leak rate measurement and rate of change and includes the initiation of action prior to reaching the Technical Specification limit of 0.35 gpm, yields additional safety margin.

7.1.6 Conclusions

In light of the above, it is judged that the McGuire Unit 1 steam generator tube R18C25 was a unique event resulting from the circumstances described above in this Addendum and in Reference 1. In support of the McGuire Unit 2 return to power, all of the McGuire Unit 2 steam generator tubes have been inspected. The results of this inspection have revealed no indications of secondary side SCC in the free span of the tubes. Nevertheless, tubes with secondary side, free span linear eddy current indications have been conservatively plugged.

As a result of the preceding inspections and evaluations, it is concluded that the unique circumstances associated with the March 7, 1989, McGuire Unit 1 steam generator tube rupture do not apply to McGuire Unit 2. Hence, it is concluded that the return to power of the McGuire Unit 2 steam generators does not represent an unreviewed safety question per 10 CFR50.59 (a) (2) criteria.

7.2 U-BEND RESTRICTION ISSUE

During the inspection of steam generator "B", it was reported that two tubes (R46C35 and R46C36) were restricted to the passage of a 0.610 inch probe between the first and second anti-vibration bar (AVB). Hence, this section of the Addendum addresses the McGuire Unit 2 U-bend restriction issue.

The McGuire Unit 2, steam generator "B", U-bend restriction was discovered during previous inspections and encountered again during the most recent eddy current inspections. A review of the June 1988 data from tube R46C35, using bobbin coil profilometry techniques, revealed a signal similar to that exhibited by a tube with a reduction in diameter. Data from the March 1986 inspection revealed a similar type signal for tube R46C36. A subsequent review of the August 1989 data indicated that R46C37 also exhibited a similar type profile trace in the same location as these tubes. In addition, eighteen (18) tubes in the vicinity of the subject tubes exhibited indications suggestive of a very small reduction of tube diameter in the affected location.

Although data from the 1986, 1988, and 1989 inspections showed the subject tubes to be restricted to the passage of a 0.610 inch probe in the U-bend region, a 0.590 inch probe did pass through the affected area of the U-bend region. Since the 0.590 inch probe did successfully pass through the region of the affected tubes during the 1986, 1988, and 1989 inspections, it is judged that no continuing tube deformation/restriction mechanism is present in the McGuire Unit 2 steam generators. This assessment is supported by the results of steam generator secondary side visual examinations of the U-bend region that found no loose objects in the vicinity of the subject tubes. In addition, this assessment is supported by existing eddy current inspection data that indicates the tubes are not severely deformed.

No causative reason for a tube diameter reduction, such as a secondary side loose object lodged between the subject tubes, is supported by the visual examination or available eddy current data. The eddy current inspection results of the McGuire Unit 2 tubes do not indicate the presence of a new pervasive damage or inner diameter (ID) tube reduction mechanism. Therefore, in light of the eddy current inspection results, the return to power for McGuire Unit 2 is judged to be acceptable.

The potential impact on the McGuire Unit 2 operating interval as a result of the U-bend restriction issue has been considered. As the affected steam generator has been operating since the detection of these restrictions (in March 1986) with no impact on steam generator structural integrity or operability, and with no apparent increase in severity of the restrictions, it is judged that the return to power for Cycle 6 and subsequent operation will not result in an unreviewed safety question.

7.2.6 Conclusions

The McGuire Unit 2 U-bend restrictions could be an as-built condition. Confirmation of this cannot be provided as these subject tubes were not included in the pre-service inspection sample. Nonetheless, the U-bend restrictions identified do not affect the return to power or subsequent operation of McGuire Unit 2.

7.3 SECONDARY SIDE LOOSE OBJECT EVALUATION CONSIDERATIONS

This section of the Addendum addresses the potential safety significance of the return to power and subsequent operation of the McGuire Unit 2 steam generators with irretrievable loose objects present in the secondary side of the steam generators. During the outage, various objects were discovered in the secondary sides of the McGuire Unit 2 steam generators. As a result, foreign object search and retrieval (FOSAR) efforts were implemented. The FOSAR successfully removed pieces of carbon steel flat stock associated with the steam generator "B" hatch cover. The FOSAR effort proved unsuccessful in removing some objects. An inventory of objects remaining in the McGuire Unit 2 steam generators is as follows:

LOOSE OBJECTS INVENTORY

OBJECT	DESCRIPTION/LOCATION
Wire Fragment	The wire fragment is approximately 2.5 inches in length by 1/16 inch in diameter. The wire is reported to be non-magnetic. The location of the wire is approximately 2.5 feet into the tube bundle of steam generator "A" resting on the tubesheet.

Wire Fragment	The wire fragment is approximately 3.5 inches in length by 1/16 inch in diameter. The wire fragment is located on top of the tubesheet in steam generator "B". Specifically, the wire fragment is located on the hot-leg side of the steam generator 16 tubes deep, one row to the left of the sludge lance port.
Hexagonal Head Nut	The hexagonal head nut is approximately 0.375 inch across the flats, 0.433 inch across the corners, and 0.225 inch thick. The location of the nut is reported as being on the tube bundle in steam generator "B" but is postulated to migrate to the top of the tubesheet during operation.
Flat Washer	The dimensions of the washer are reported as 0.500 inch outer diameter by 0.049 inch thick having an inner diameter of 0.219 inch. The washer is also located on the tube bundle in steam generator "B" but is postulated to migrate to the top of the tubesheet during operation.

It continues to be Duke Power's position, which is consistent with the current Regulatory Position (NUREG-0844, "NRC Integrated Program for the Resolution of Unresolved Safety Issues A-3, A-4, and A-5 Regarding Steam Generator Tube Integrity", USNRC, April 1985), that loose/foreign objects should be removed from the secondary side of steam generators. However, for the objects listed above, retrieval attempts using available technology proved unsuccessful. Consequently, this evaluation, completed in accordance with

Chapter 10 of the Code of Federal Regulations (10 CFR 50.59 criteria), supports Cycle 6 operation of the McGuire Unit 2 steam generators with the identified objects present in the secondary side of the steam generators.

7.3.1 Regulatory Basis

Loose parts and foreign objects have caused two of the six domestic steam generator tube rupture (SGTR) events to date. Consequently, the NRC staff has identified recommended industry actions within NUREG-0844 entitled, "NRC Integrated Program for the Resolution of Unresolved Safety Issues A-3, A-4, and A-5 Regarding Steam Generator Tube Integrity." These actions include:

- Visual inspection of the secondary sides of steam generators
- Quality assurance procedures governing all work within the steam generators
- Loose parts monitoring systems

It is the NRC staff position that loose parts or foreign objects which are found from the above actions should be removed from the steam generators. Tubes observed to have visible damage should be eddy current inspected and plugged if found defective. For objects that cannot be removed, the licensee should develop criteria addressing the maintenance of steam generator tube integrity during subsequent plant operation.

Hence, the purpose of this evaluation is to assess the potential safety impact of the aforementioned loose objects on McGuire Unit 2 steam generator tube integrity, and to provide documentation supporting return to power and subsequent operation.

Chapter 10 of the Code of Federal Regulations, Section 50.59 (10 CFR 50.59) allows the holder of a license authorizing operation of a nuclear power facility the capacity to evaluate a change to a plant, a change to plant procedures, tests or experiments not described in the FSAR, and changes to the plant technical specifications (Appendix A to the Operating License). Prior

Nuclear Regulatory Commission (NRC) approval is not required to operate, provided that the condition does not involve an unreviewed safety question or result in a change in the margin of safety as previously evaluated in the plant Technical Specifications incorporated in the license. It is, however, the obligation of the licensee to maintain a record of the change or modification to the facility, to the extent that such a change impacts the FSAR. 10 CFR 50.59 further stipulates that these records shall include a written safety evaluation which provides the basis for the determination that the subject condition (i.e., the return to power/subsequent Cycle 6 operation of the McGuire Unit 2 with the aforementioned objects present in the secondary side of the steam generators) does not involve an unreviewed safety question.

7.3.2 Evaluation

This evaluation addresses the potential safety significance of operating McGuire Unit 2 steam generators with the above inventory of loose objects present in the secondary side. Specifically, this evaluation postulates the objects to be located in limiting case orientations as fixity has not been established for the objects.

Tube Integrity Considerations

Wear calculations have been performed for the wire fragments, hexagonal nut, and flat washer. The wear calculations assume that the objects and tubes remain in contact in a "worst case" orientation and that impact/sliding wear occurs. Also, the wear calculations performed take into account the flow velocities, fluid densities, and resultant drag forces applicable to the McGuire Unit 2 Model D3 steam generators.

Although the wire fragments are resting on the top of the tubesheet, fixity has not been established. Therefore, the wire fragments are postulated to contact the tubes at an elevation of up to six (6) inches above the top of the tubesheet. The elevation assumption provides a conservative tube vibration amplitude and secondary flow velocity that bounds the critical evaluation parameters anywhere in the tubesheet region for these wear calculations. The bounding wear evaluation approximates the time expected for impact and sliding motion of the tubes in contact with the wire fragments to wear a tube wall to a minimum acceptable wall thickness. The hexagonal nut and the flat washer were inadvertently dropped onto the tube bundle during repair of the steam generator "B" hatch cover. Retrieval efforts also proved unsuccessful in removing these objects. It is conservatively assumed that these objects migrate from the top of the tube bundle to the top of the tubesheet (the location of higher cross flow velocities) during operation. Assuming these objects are located on top of the tubesheet, the bounding wear evaluations approximate the time expected for impact and sliding motion of the tubes in contact with the hexagonal head nut, flat washer and wire fragments to wear a tube wall to a minimum acceptable wall thickness.

Since the loose objects are not confirmed as being fixed or constrained in their current location and position in the steam generators, and could potentially migrate to a tube exhibiting wall thinning, and active tubes may be left in service with thinning of up to 40% through wall, the analysis conservatively uses an initial tube wall loss of forty (40) percent, or approximately 0.017 inches.

The McGuire Unit 2 Model D3 steam generator tubes are 0.750 inch outer diameter and have a nominal 0.043 inch tube wall thickness. The minimum acceptable tube wall thickness for the subject steam generators is determined on the basis of internal (burst) and external (collapse) pressures. Conservatively assuming a tube is thinned 360 degrees around its circumference for an axial extent of greater than 1.5 inches, a minimum tube wall thickness of approximately 0.015 inch is required to satisfy the burst and collapse requirements for normal, upset, and accident condition loadings.

The time required for the wire fragments, hexagonal nut, and flat washer in limiting case orientations, to wear into the tube to the minimum allowable tube wall thickness is estimated. Impact/sliding wear is postulated and the wear site is conservatively assumed to remain constant. The results of this evaluation indicate that tube integrity is expected to be maintained during normal operation and postulated accident condition loadings commensurate with

U.S. Nuclear Regulatory Commission Regulatory Guide 1.121 (U.S. RG 1.121) criteria during Cycle 6 operation. Hence, tube wear to minimum acceptable wall thickness is not expected to occur during Cycle 6 operation.

7.3.3 Conclusions

In light of the above, the return to power and subsequent Cycle 6 operation of McGuire Unit 2 with the identified wire fragments present in steam generators "A" and "B" and the hexagonal nut and flat washer in steam generator "B" is not expected to produce any previously unanalyzed accident or increase the probability of an analyzed accident. The presence of the objects on the secondary side of the steam generators is not expected to result in a multiple tube rupture event nor increase the probability that a single tube rupture event would occur. Additionally, the safety margin as defined in the Technical Specification Bases for the maintenance of reactor coolant pressure boundary integrity is not expected to be reduced. Steam generator tubes potentially experiencing localized wall thinning due to impact/sliding wear by a "loose object" should remain in compliance with R.G. 1.121 criteria.

Therefore, Cycle 6 operation of the McGuire Unit 2 steam generators with the loose objects present in the secondary side of steam generators is not expected to result in an unreviewed safety question pursuant to 10CFR50.59 (a) (2) criteria.

7.4 FUTURE ACTIONS

Eddy Current inspection to date has not revealed the occurrence of additional ODSCC in the McGuire Units 1 and 2. These results will be verified by the 100% full length bobbin coil inspection of McGuire Unit 1 in 1990. If the results of the McGuire Unit 1 inspection are similar to those of McGuire Units 1 and 2 then Duke Power plans on implementing an Eddy Current sample size consistent with the EPRI NDE Guidelines. These inspections would include a 20% random sample size inspection per cycle and an augumented inspection of special interest areas.

This position is more conservative than the current plant technical specifications.

7.5 CONCLUSIONS

In support of the return to power of McGuire Unit 2 the following issues potentially impacting the return to power of McGuire Unit 2 have been considered:

- McGuire Unit 1 Tube Rupture
- McGuire Unit 2 U-Bend Restrictions
- Secondary Side Loose Object Evaluation Considerations

The results of the McGuire Unit 1 tube rupture assessment concluded that the McGuire Unit 1 R18C25 tube rupture was a unique event and is not a representative condition of the steam generator tubes left in service at McGuire Units 1 and 2. In addition, the U-bend restrictions encountered in the McGuire Unit 2 steam generator "B" are not expected to impact adversely the structural integrity or operability of the subject steam generator. Furthermore, evaluations were completed addressing the potential safety significance of returning to power and subsequent operation of the McGuire Unit 2 steam generators with the wire fragments, hexagonal nut, and flat washer present in the secondary side of the steam generators. The results of these evaluations concluded that the return to power with the aforementioned loose objects present in the steam generators is acceptable.

Hence, the return to power of the McGuire Unit 2 steam generators does not represent an unreviewed safety question pursuant to 10 CFR 50.59 (a) (2) criteria.

REFERENCES

(1) McGuire Unit 1 Nuclear Power Station "Evaluation of Degradation of Tube R18C25 and Justification for Return to Power," Duke Power Company, May 1989.