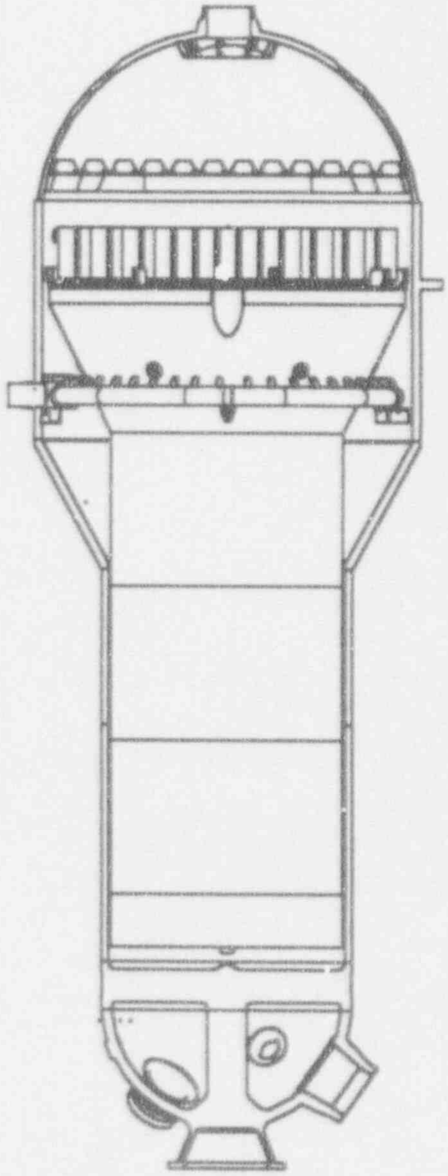
Evaluation of Foreign Objects in the SONGS Unit 3 Steam Generators



SOUTHERN CALIFORNIA EDISON

December 1993

EXECUTIVE SUMMARY

During the San Onofre Unit 3 Cycle 7 refueling outage, foreign objects were detected in both steam generators as a result of Eddy Current Tests (ECT). Several of these objects had interacted with the steam generator tubing resulting in detectable tube wear, one of which was through-wall. The objective of this report is to assess the foreign object/steam generator tube interactions based on the configuration and orientation of the objects as inferred from the ECT results, known steam generator geometry, and analytical and laboratory flow data. The evaluation also considers the safety implications associated with leaving the objects in the steam generators through at least the next operating cycle.

The evaluation concludes that the continued presence of the identified foreign objects in the Unit 3 steam generators is not a safety concern and does not constitute an unreviewed safety question. A total of seven known loose parts are located in the outer five rows of the San Onofre Unit 3 steam generators secondary side. The parts have been evaluated to have originated during the 1990 time period from erosion of the steam generator feedwater distribution box and distribution feedring. Five of these parts have resulted in measured tube wear and therefore, plugging and staking of the affected tubes is required to minimize any impact on primary boundary integrity. The remaining parts have not caused tube wear to date and plugging of the affected tubes was not warranted.

The loose parts were originally discovered in May 1990. At this time, SCE conducted a thorough inspection of the feedrings, the downcomer annulus, the tube bundle periphery of the tubesheet and the blowdown lane. Loose parts that were accessible were removed. A safety evaluation was conducted for the remaining parts. The safety evaluation concluded that the predicted tube wear rate from the identified debris, which could not be removed, would be sufficiently low such that any degraded tubes would be identified prior to exceeding the allowable wear limits. It also recognized that a loose part could wear through a tube and cause a tube leak; however, the unit would be shut down well before exceeding Technical Specification leakage limits. Based on the Cycle 7 data, a loose part did cause a tube leak and SCE identified and monitored the leakage prior to the outage. A forced outage was not required as the leak remained acceptably small.

All seven Unit 3 steam generator loose parts will most likely remain in their existing locations during the next operating cycle. Leaving the objects in place creates the potential for continued wear of adjacent tubes. Using a wear model, developed by ABB-CE and benchmarked with current data from San Onofre Unit 3, the calculated operating cycle wear of tubes with adjacent loose parts is less than the conservative structural acceptance criteria for wall thinning. Therefore, a steam generator tube rupture from loose parts is not credible for the next Unit 3 operating cycle.

Based on San Onofre Cycle 7 ECT inspection of the inner steam generator bundle region, it is highly unlikely that any significant (loose part of sufficient

size to cause wear) loose parts currently exist. All tubes in the outer five rows were inspected by ECT so the locations of all loose parts in this region have been quantified. Should the loose parts in the outer (five rows) region become dislodged or break into smaller pieces, the parts would most likely migrate to a position of lower flow within the bundle. Tube wear in the new location would be bounded by the acceptable wear predictions for the tubes in the outer five rows of the steam generators and would be identified by future ECT prior to a steam generator tube leak.

In the unlikely event that a leak develops as a result of wear from loose parts, the leak would be detected early, and would remain stable during normal (or postulated accident) conditions, and therefore allow for a timely, controlled shutdown well before reaching Technical Specification 3.4.5.2 limits. The leak detection and leak response capabilities at San Onofre provide as close as possible real time information on the rate of increasing leakage. Operations procedures are currently in place at San Onofre to identify and respond to the potential development of steam generator tube leaks.

Therefore, SCE has concluded there is no safety concern associated with operating Unit 3 with the potential loose parts.

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FIGURES (Cont.)

1.0 PURPOSE

The purpose of this evaluation is to assess the consequences of foreign objects identified in the San Onofre Unit 3 steam generators via Eddy Current Testing (ECT) conducted during the Cycle 7 Refueling Outage. The focus of this report will be to evaluate the safety significance of leaving the objects in the steam generators through the next operating cycle. The evaluation includes an assessment of all potential foreign object/steam generator tube interactions, and considers the safety implications associated with their effects over the next operating cycle. The report also provides a background summary of Unit 3 loose parts detection and removal techniques.

2.0 BACKGROUND

2.1 STEAM GENERATOR DESIGN

Each San Onofre Nuclear Steam Supply System (NSSS) Unit utilizes two steam generators (E088 and E089) which are vertical U-tube and shell heat exchangers approximatelv 65 feet in height with a steam drum diameter of 22 feet. The steam generator arrangement is shown in Figure 2.1-1.

The steam generator is constructed of carbon and alloy steel pressure containing members and Inconel 600 tubing. The primary or high-pressure parts of the unit are the hemispherical head, the tube sheet, and the tubes. A divider plate with tongue and groove construction separates the head into inlet and outlet chambers. A 42-inch nozzle provides entrance of reactor coolant into the steam generator which passes through the heat transfer tubes and exits through two 30-inch outlet nozzles. The unit is supported by a skirt attached to the bottom head.

The secondary side of the steam generator consists of two cylindrical shells joined by a conical section and a hemispherical head. The tube bundle is enclosed by a baffle (shroud) which forms the downcomer annulus just inside the shell. The top of the baffle serves to support the steam separator deck.

The tube bundle consists of 9350 3/4-inch tubes of various lengths. The tubes are arranged in rows with all tubes in a given row having the same length. The rows are staggered giving a triangular pitch arrangement as shown in Figure 2.1-2. The shorter tubes, which have 180° bends, are at the center of the bundle in the first 18 rows. The vacant space (approximately 4-1/4 inches) between tubes in the first row is called the tube lane which is open through the tube bundle. The tube lane is the boundary between the hot leg side and the cold leg side of the secondary side of the steam generator. Longer tubes in the outer rows have double 90° bends.

The tube support design provides protection from tube damage resulting from vibrations or seismic and accident conditions while offering minimum restriction to steam/water flow in the tube bundle. There are seven tube supports in the straight tube portion of the evaporator section of the steam generator which is the ABB/CE "eggcrate" design. The outer rings of each eggcrate are welded to wedge blocks which are in turn welded to the baffle. Flow deflector plates, shown in Figure 2.1-3, are installed on alternate full eggcrates and all partial eggcrates. These flow deflector plates prevent fluid bypass outside the tube bundle by closing the annulus between the outer perimeter of the tube bundle and the baffle.

The San Onofre steam generators are natural circulation units which are designed to produce low moisture steam at approximately 900 psia. The flow paths for the secondary fluid are shown in Figure 2.1-1. Feedwater enters through the feedwater nozzle and flow distribution ring where it

mixes with separated water and flows down the downcomer. The subcooled mixture enters the tube bundle at the tubesheet (Figure 2.1-4) and flows upward. Saturation conditions are attained in the first few feet, and nucleate boiling occurs as the secondary fluid flows upward through the tube bundle continually increasing in steam quality.

Unitized steam-water separators mounted on a deck plate at the top of the tube bundle baffle separate the steam from the two-phase mixture by centrifugal action. The steam continues to flow upward through a secondary stage of steam-water separators (steam dryers) and leaves the steam generator as essentially dry steam. Water removed by the steam separators returns to the downcomer where it mixes with the feedwater to complete the circulation loop.

The force of gravity which results from the difference between the density of the fluids in the downcomer (down flow) and the evaporator (up flow) portions of the circuit produces flow in natural circulation steam generators. Circulation increases with increased heat input (increase in load and steam output) until a point where maximum fluid flow is reached. This point is illustrated in Figure 2.1-5 where downcomer flow is plotted versus load.

Figure 2.1-1

General Arrangement of San Onofre Steam Generators

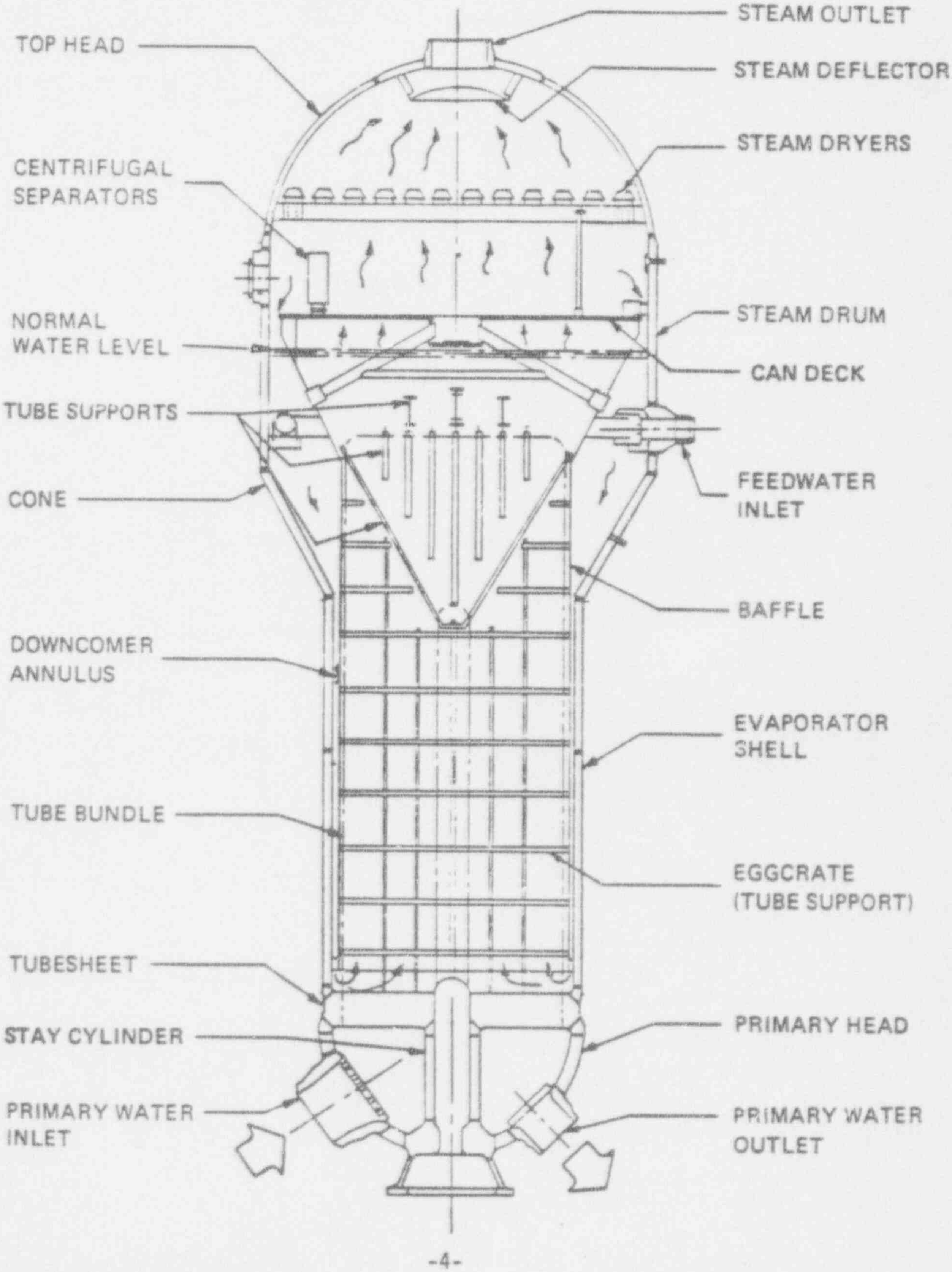


Figure 2.1-2

General Arrangement of Steam Generator Tubes

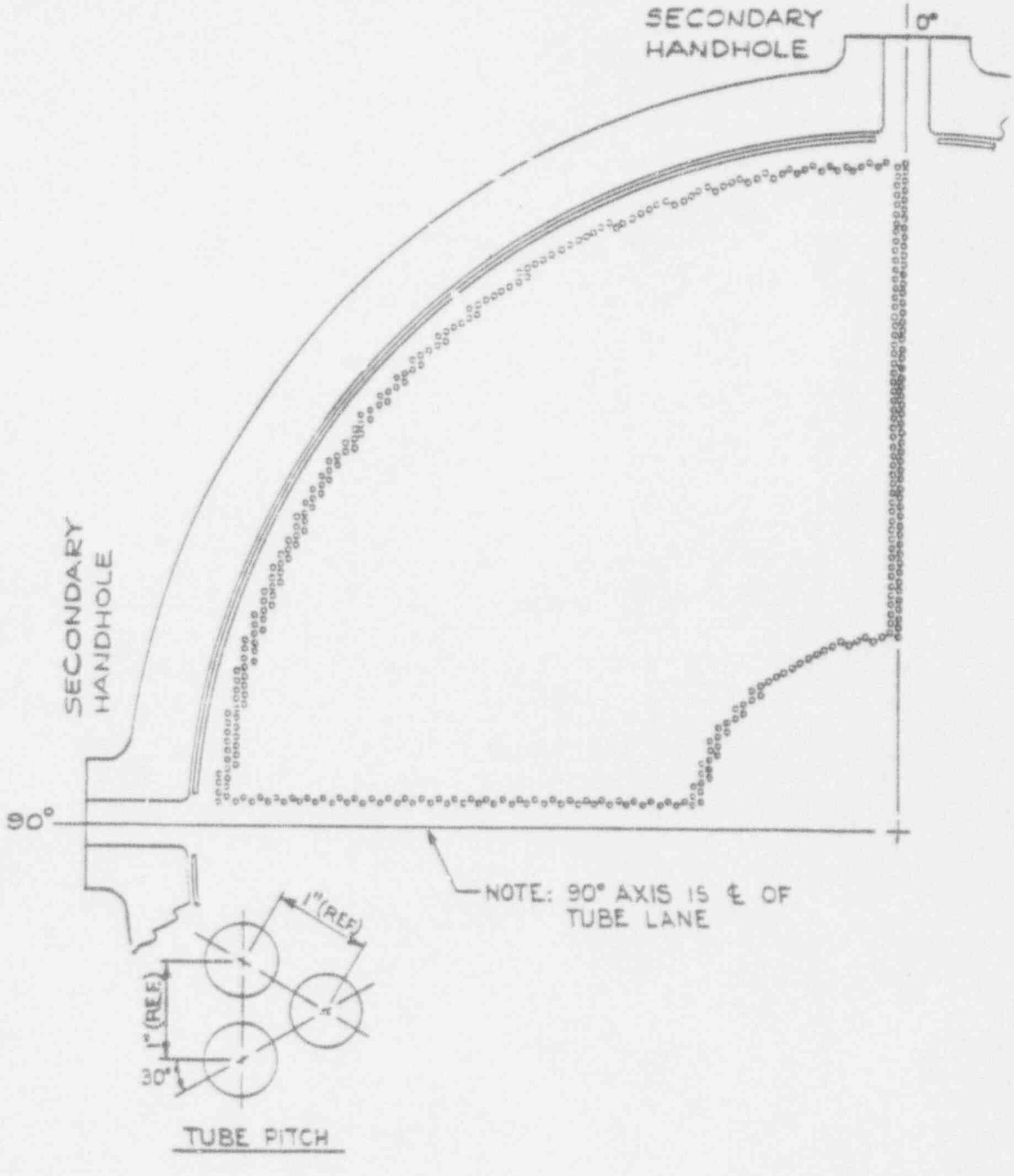


Figure 2.1-3

Baffle-Eggcrate Assembly with Deflector Plate

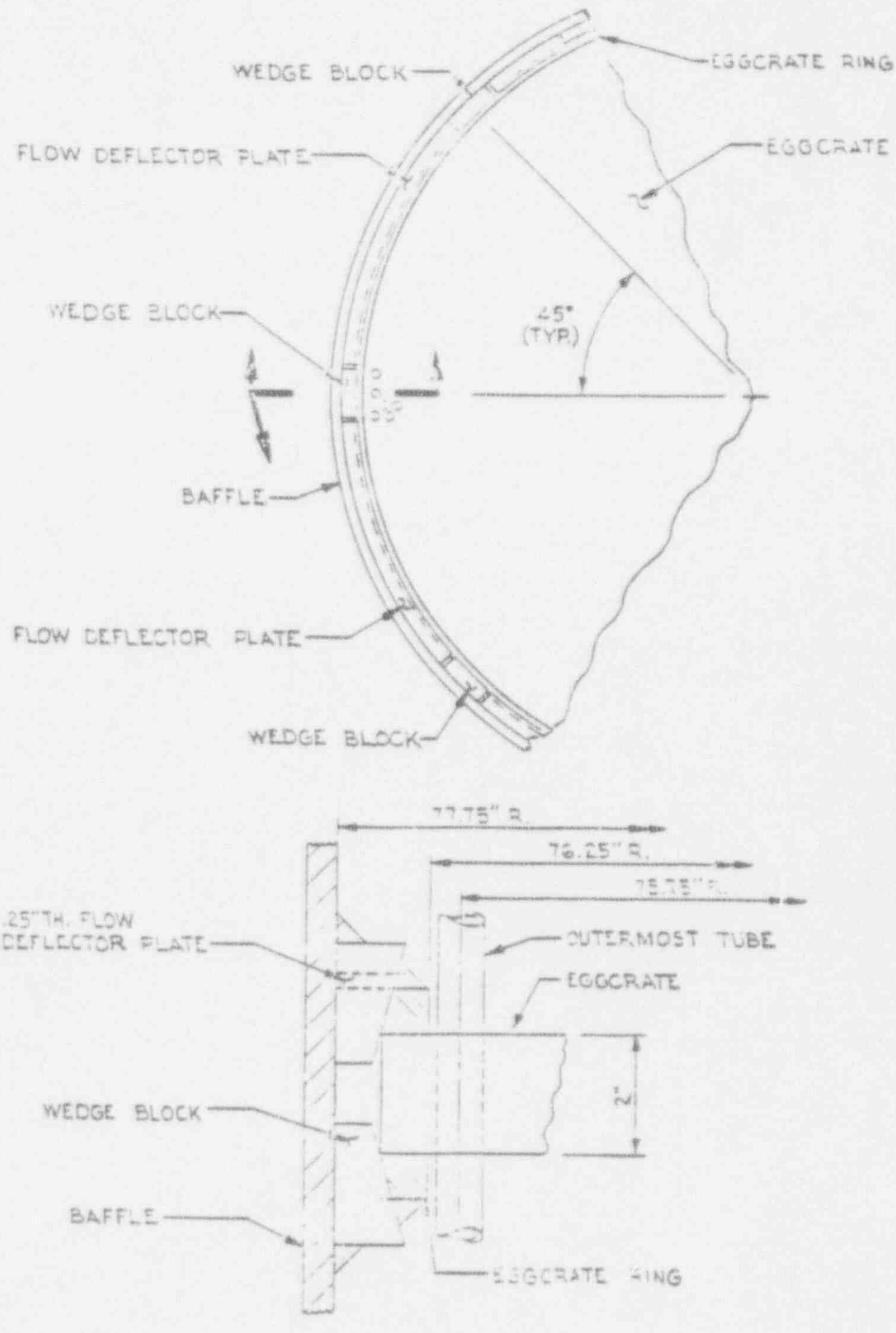


Figure 2.1-4

Downcomer Entrance to Tube Bundle

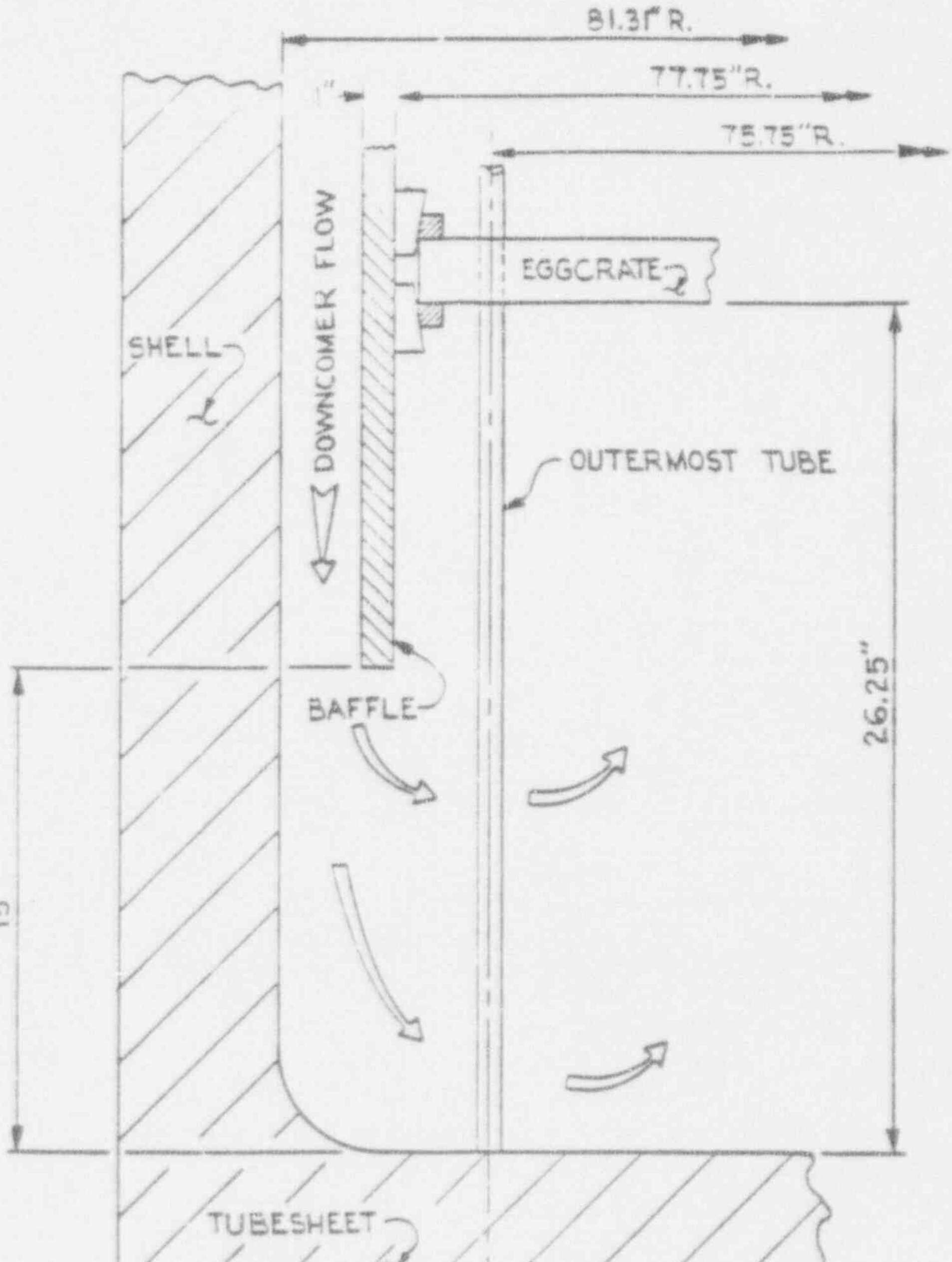
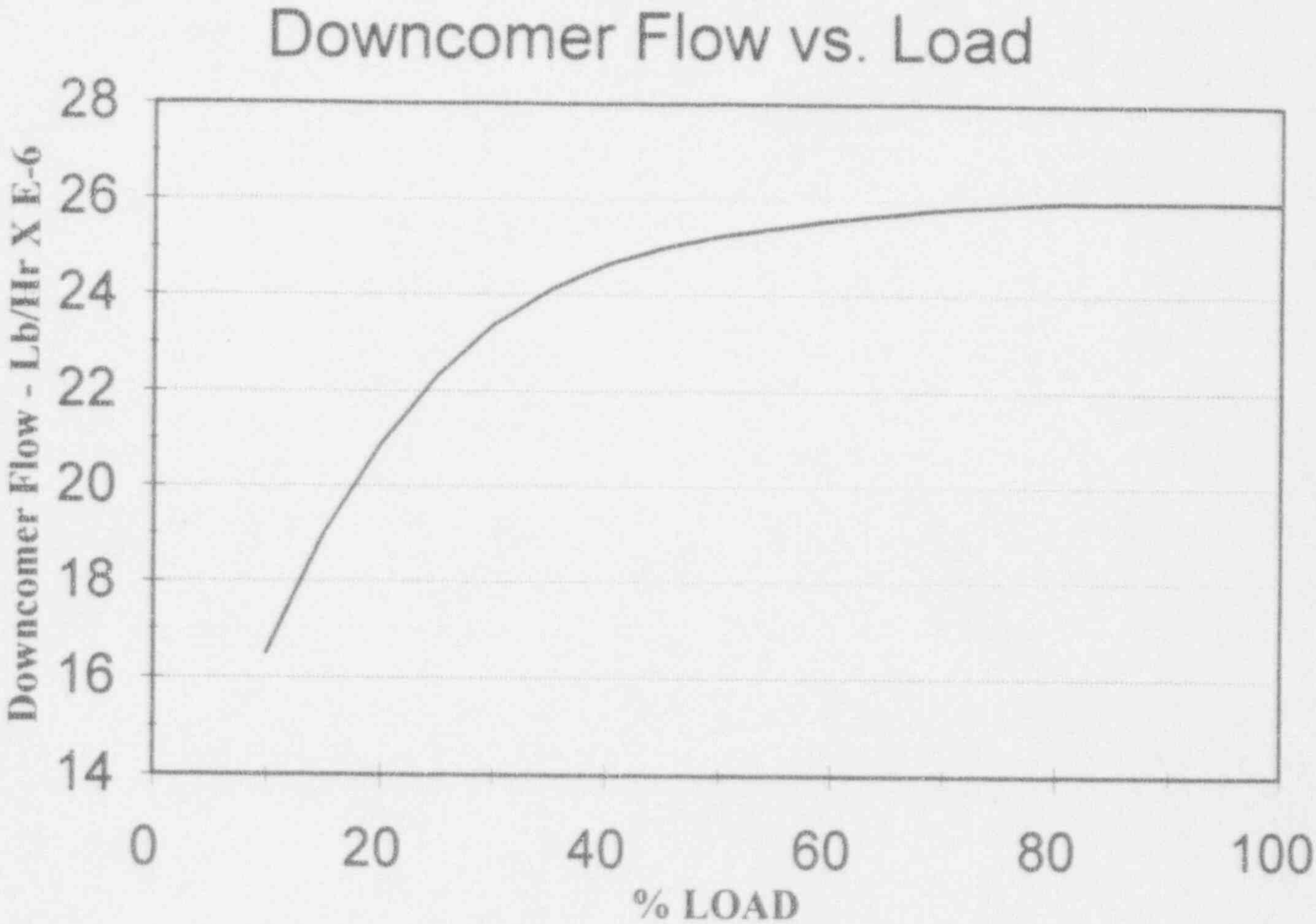


Figure 2.1-5


Downcomer Flow vs. Load
Downcomer Flow - Lb/Hr X E-6
28
26
24
22
20
18
16
14
0
20
40
60
80
100
% LOAD

2.2 REGULATORY REQUIREMENTS

In Generic Letter 85-02, "Staff Recommended Actions Stemming From NRC Integrated Program For The Resolution of Unresolved Safety Issues Regarding Steam Generator Tube Integrity," the NRC provided recommended actions for assuring steam generator tube integrity and for steam generator tube rupture mitigation. This letter was the result of a study documented in NUREG-0844, "NRC Integrated Program for the Resolution of Unresolved Safety Issues A-3, A-4, and A-5 Regarding Steam Generator Tube Integrity."

One of the areas of concern in Generic Letter 85-02 and NUREG-0844 was the prevention and detection of loose parts and foreign objects in steam generators. This concern was due to the fact that two steam generator tube rupture events were caused by foreign objects on the secondary side of the steam generators. The Generic Letter recommended that visual inspections be performed on the steam generator secondary side in the vicinity of the tube sheet, both along the periphery of the tube bundle and along the tube lane. This would serve to identify loose parts or foreign objects on the tubesheet and possible external damage to peripheral tubes just above the tube sheet.

SCE's response to Generic Letter 85-02 was dated June 26, 1985. This response indicated that visual inspections were completed at Unit 2 in December 1984 and would be conducted at Unit 3 during the first refueling in August 1985. After the initial baseline inspections, future inspections for detection of loose parts will be conducted when appropriate, such as after significant repairs or modifications to the steam generator secondary side internals. SCE's letter also described the operator's response to a steam generator tube rupture ev[illegible] in addition to safety injection signal reset and coolant iodine [illegible]ity limits.

In July 1990, during the Unit 3 Cycle 5 refueling outage, a routine inspection of the tubesheet of the steam generators identified metal debris on the secondary side of both steam generators. The sources of the debris were determined to be from both the feedring at its intersection with the feedwater inlet distribution box and the "T" vent assembly attached to each feedwater inlet distribution box. In July 1990, Unit 2 was shut down for steam generator secondary side inspections and similar but much less severe conditions were found. This condition was reported in Licensee Event Report 90-005, Revision 1, dated November 16, 1990.

In addition to the repair of the feedring and distribution boxes, considerable efforts were made to inspect the generator and remove accessible debris from both Units 2 and 3 steam generators. Only one piece (located in Unit 3 steam generator 3E089) caused wear of adjacent tubes (this piece was removed). Although the wear of these tubes was not sufficiently deep to require plugging, as a precautionary measure, these tubes were plugged and staked. At the time, it was concluded that the predicted tube wear rate from the identified debris which could not be removed would be sufficiently low such that any degraded tubes would

2.2 REGULATORY REQUIREMENTS (Continued)

be identified prior to exceeding the allowable wear limits. It was also recognized that, should the loose parts cause wear, the effect would be a tube leak which would cause the unit to be shutdown before exceeding Technical Specification leakage limits. This actually occurred during the last portion of Unit 3 Cycle 6 where SCE identified, closely monitored, and evaluated the slowly increasing primary-to-secondary leakage. A plant shutdown prior to the outage was not required due to the low leakage rates.

2.3 FEEDRING EROSION HISTORY

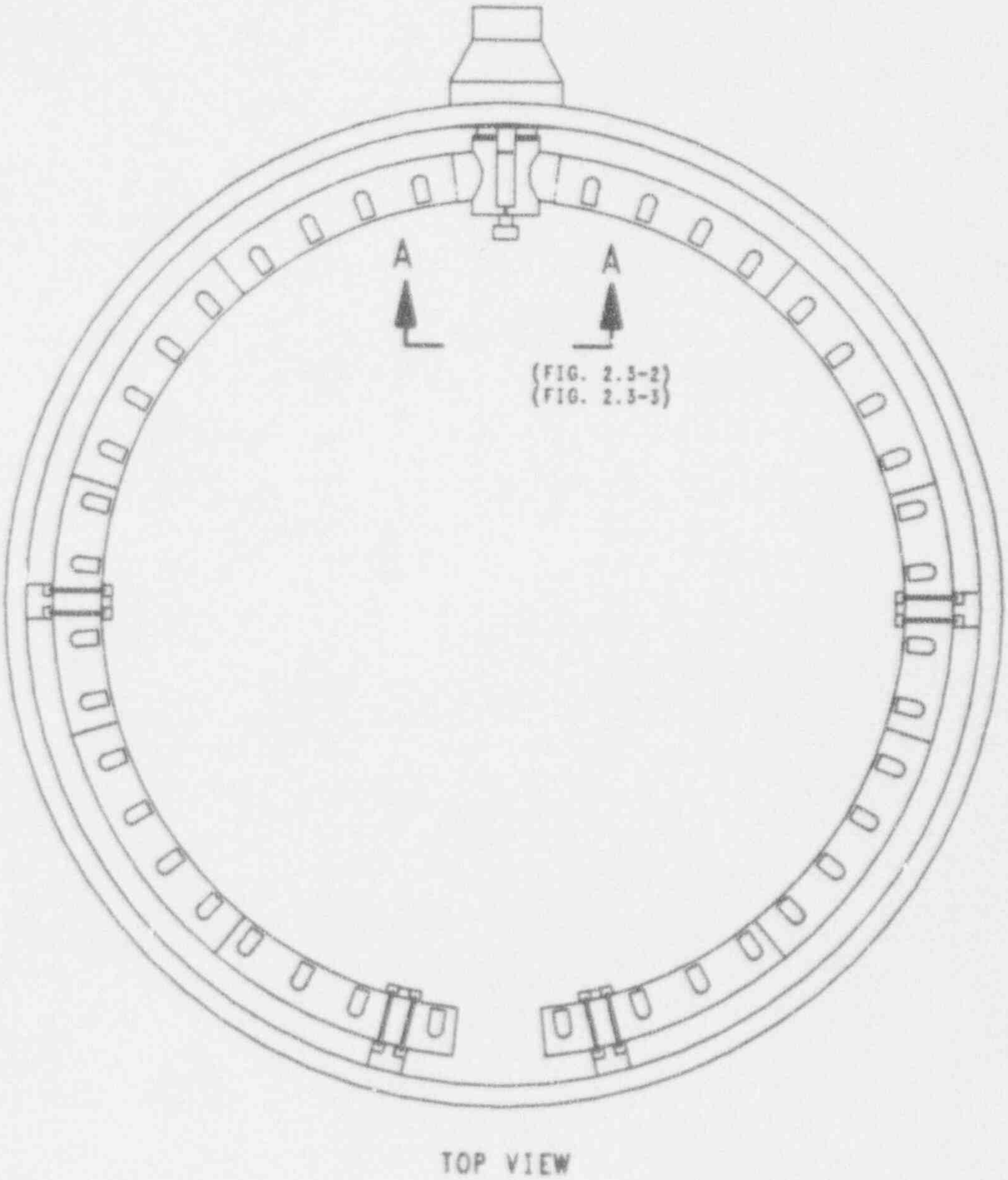
In May 1990, during the San Onofre Unit 3 Cycle 5 refueling outage, a few pieces of carbon steel metal were found in the secondary side of Steam Generator 3E089. A detailed visual inspection was subsequently conducted of both Unit 3 steam generator secondary internals. The inspection revealed that the bottom portions of three of the four pipe stubs (Schedule 40 pipes approximately 9 inches long connecting the Schedule 120 feedring and the center distribution box) were missing and the other was cracked. The 3 inch vents on the distribution box were also missing.

The failure of the feedring resulted in through-wall cracking at the welded connection of the distribution box, excessive metal thinning and finally sparger debris being generated.

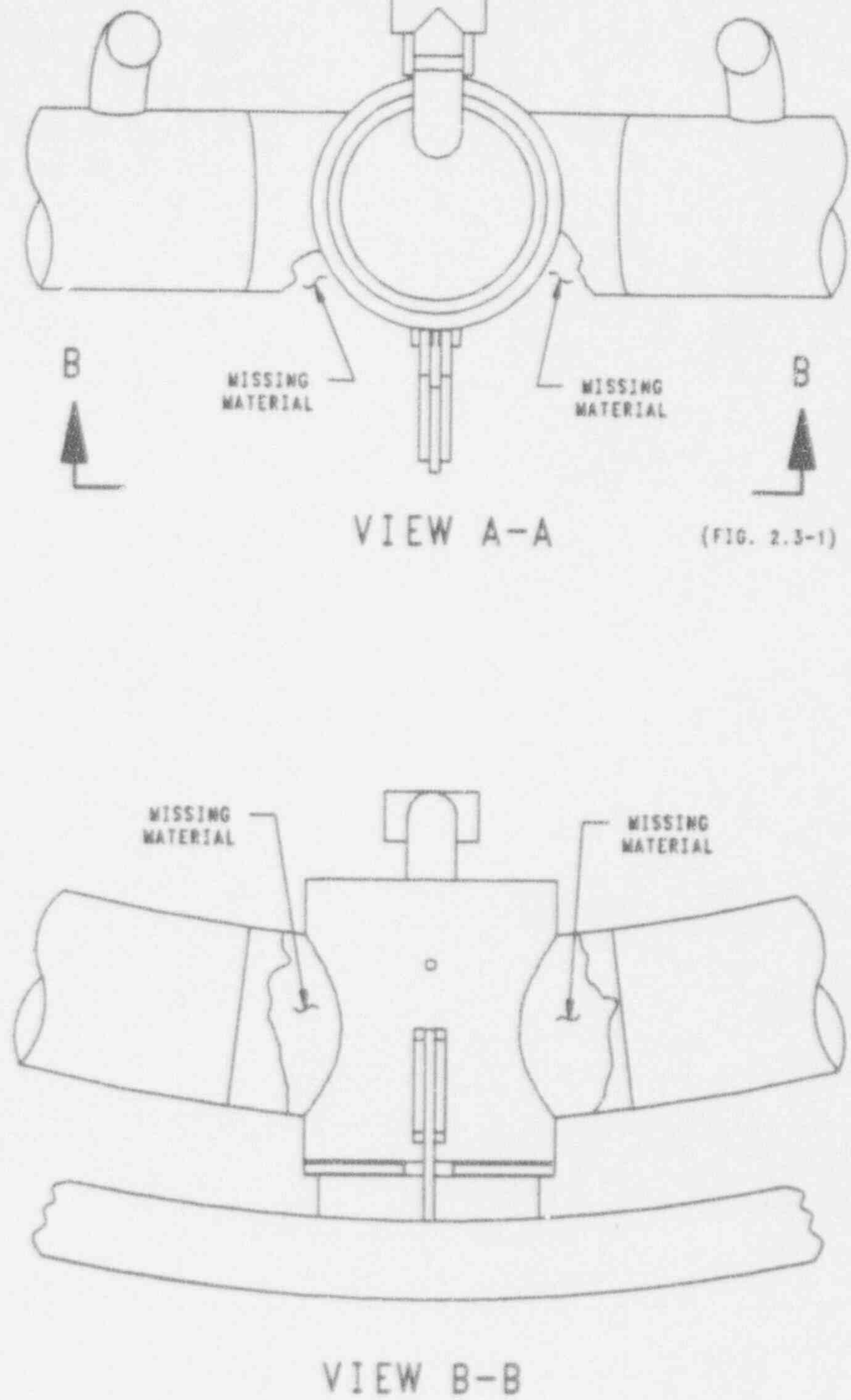
The failure of the vents and distribution box resulted in excessive metal loss inside the distribution boxes and separation of the vents from the distribution box due to severe erosion.

Repair of the feedring and distribution box was completed as part of the Cycle 5 Refueling Outage. However, the material removed from the feedring and vents was not all accounted for, resulting in the potential for loose parts to remain in the steam generators.

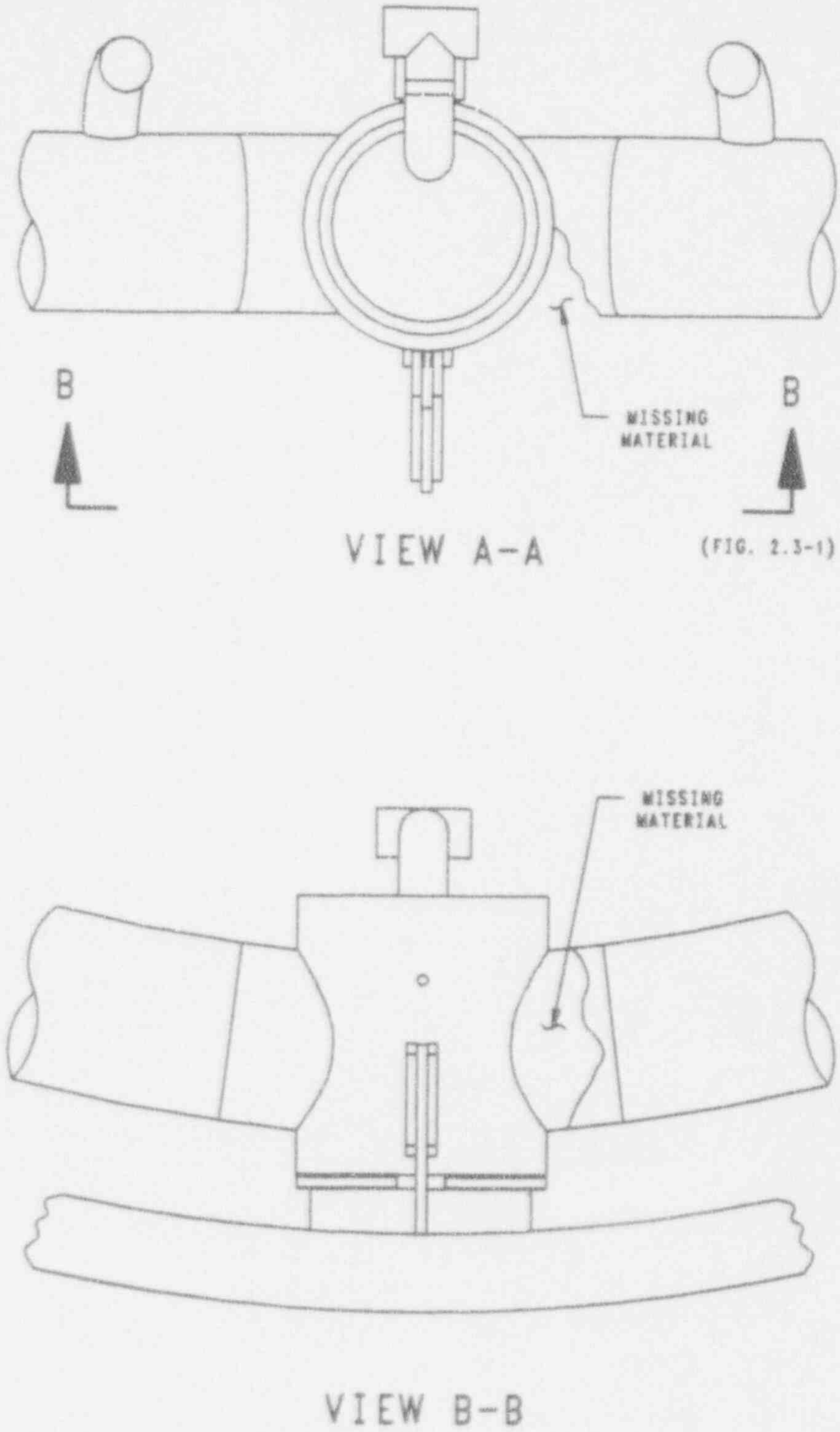
The configuration of the feedring in the steam generator is shown in Figure 2.3-1. The locations of missing material in steam generators 3E088 and 3E089 are shown in Figures 2.3-2 and 2.3-3, respectively. Approximately 81 sq. in. of material was missing from the right pipe stub and 69 sq. in. was missing from the left pipe stub in 3E088. In 3E089, 52 sq. in. of material was missing from the left pipe stub. In addition, approximately 80 sq. in. of the vent tee in each steam generator was missing. Loose part retrieval prior to the 1993 outage accounted for about 120 sq. in. of the missing material in 3E088 and 108 sq. in. of the missing material in 3E089. In 1993, 8 sq. in. of additional material was removed from 3E088. As of the end of the Unit 3 Cycle 7 refueling outage, 60% of the missing material in 3E088 and 93% in 3E089 had been accounted for. The inventory balance of loose parts has not significantly changed from the original inspections which is an indication that the significant pieces have been accounted for and identified. It is judged that erosion of the base metal of the feedring and distribution box prior to and after failure accounts for the remainder of the material from these components.



San Onofre Steam Generator Feedring
Figure 2.3-1



3E088 Feedwater
Distribution Box Erosion (1990)
Figure 2.3-2



3E089 Feedwater
Distribution Box Erosion (1990)
Figure 2.3-3

2.4 PRIMARY-SECONDARY LEAK MONITORING

As stated in Section 3 of this report, the worst case scenario considered as a result of leaving the existing foreign objects in the Unit 3 steam generators is a small, stable detectable tube leak. The NRC has issued IE Notice 91-43 regarding incidents involving rapid increases in primary-to-secondary leak rates. The IE Notice identified three recent events where steam generator tube leaks escalated from very low levels to more than 500 gallons per day in time periods of one to six hours. It should be noted that these events were not a result of fretting type wear. The events were due to rapidly propagating cracks in steam generator tubes. However, it is the position of the Staff that an effective approach to minimizing the frequency of SGTR events can be achieved by obtaining, as close as possible, real time information on the rate of increasing leakage. The purpose of this section is to review the administrative and system capabilities present at San Onofre for the detection and response to primary-to-secondary leakage.

San Onofre leakage detection methods are described within Updated Final Safety Analysis Report (UFSAR), Section 5.2.5 "Reactor Coolant Pressure Boundary Leakage Detection Systems." These detection methods are consistent with recommendations of NRC Regulatory Guide 1.45 "Reactor Coolant Pressure Boundary Leakage Detection Systems." The leakage detection methods described in the UFSAR are implemented through plant Technical Specifications and San Onofre Station Procedures. The Operations and Chemistry Divisions are responsible for implementing these requirements. Leakage detection methods are summarized in Table 3.4-1. The escalating steps for increased leakage are as follows:

- Blowdown is sampled every 72 hours; air ejector is sampled once per week.
- Upon indication of tube leakage, chemistry leak rate determinations increase to every 72 hours.
- Upon exceeding 10 gpd leakage, chemistry leak rate determinations increase to daily.
- Upon reaching the Air Ejector Alarm Setpoint (30 gpd), Operations begins logging RE-7870 readings.
- If RE-7870 indicates leakage has increased by more than 60 gpd in any 1-hour period, verify the monitor response is real and sustained (by checking blowdown). If valid, then commence a rapid shutdown at 1% to 5% power per minute.
- For large leaks, EOIs are utilized. A Mihama-type of tube rupture event was run last year in simulator training. All 15 crews isolated the affected generator within 32 minutes.
- As necessary, a portable Nitrogen-15 monitor can be used as a steam generator leakage diagnostic tool to differentiate active tube leakage from tube plug leakage.

2.4 PRIMARY-SECONDARY LEAK MONITORING (Continued)

Prior to shutdown for the Unit 3 Cycle 7 refueling outage, a small gradually increasing tube leak existed in steam generator 3E088 as shown in Figure 2.4-1. Following shutdown, one tube was identified as leaking and the cause of leakage was determined to be wear from a foreign object. Eddy current testing was later used to identify the presence of other foreign objects. That testing is described in Section 3.2.

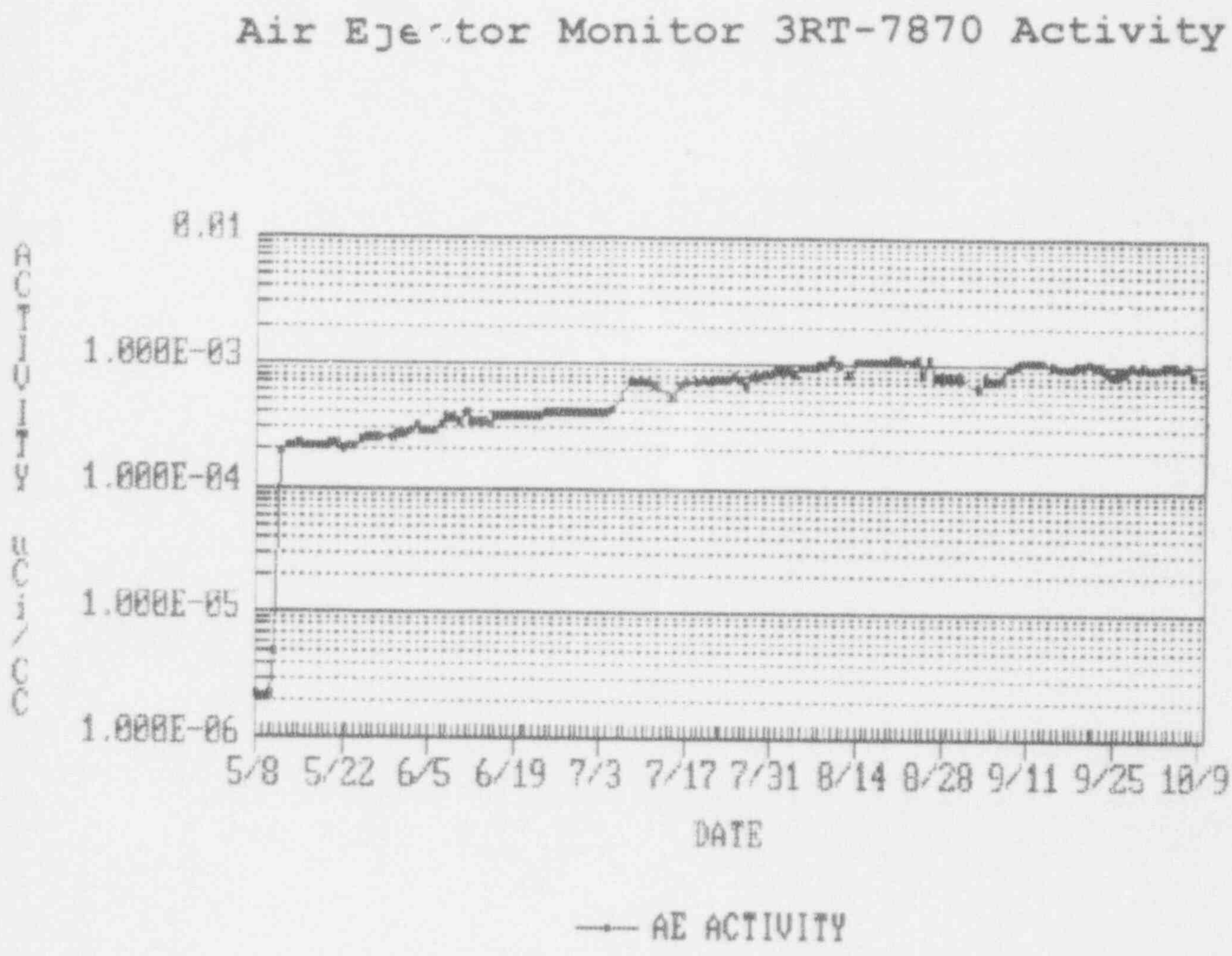
TABLE 2.4-1

STEAM GENERATOR TUBE LEAKAGE MONITORING

LOCATION	TYPE	FREQUENCY	LLD *
Air Ejector	Monitor	Continuous	<5 gpd
Air Ejector	Alarm	Continuous	30 gpd
Air Ejector	Grab	Weekly	~0.5 gpd
Blowdown	Monitor	Continuous	~25 gpd
Blowdown	Alarm	Continuous	~1000 gpd
Blowdown	Grab	Every 72 Hours	<5 gpd
Steamline	N-16	As needed (new)	~1 gpd
Steamline	Monitor	Continuous	~3000 gpd
Feedwater	Tritium	As needed	~0.3 gpd

* Based on expected Unit 3 RCS Activity.

Figure 2.4-1



Air Eje-tor Monitor 3RT-7870 Activity
ACTIVITY uCi/CC
0.01
1.000E-03
1.000E-04
1.000E-05
1.000E-06
5/8 5/22 6/5 6/19 7/3 7/17 7/31 8/14 8/28 9/11 9/25 10/9
DATE
AE ACTIVITY

2.5 LOOSE PARTS REMOVAL

Foreign object search and retrieval (FOSAR) is routinely performed during refueling outages at San Onofre. Additionally, consistent with the expectations expressed by the NRC in Generic Letter 85-02, a FOSAR examination is performed following maintenance or repair activities that could lead to generation of foreign objects. Specifically, during the Unit 3 Cycle 7 refueling outage, two FOSAR efforts were completed, one in conjunction with sludge lancing and another following repairs to the feedring.

The FOSAR technique used during the Unit 3 Cycle 7 outage consists of a remotely operated transporter assembly. The assembly can be maneuvered to any location in the steam generator periphery for examination and retrieval of foreign objects. Retrieval is accomplished using either a manipulator arm, a pick attachment, or an electromagnet.

Following identification of the foreign object-initiated tube leak, SCE concluded the existing FOSAR apparatus was not capable of retrieving the object which caused the leakage and perhaps not capable of retrieving the other objects identified by ECT. Special retrieval tools were developed which were ultimately used to recover three of the foreign objects. These tools and the procedures developed for their use assured that no loose parts were pushed further into the tube bundle.

The seven remaining objects could not be recovered. SCE concluded that the existing equipment and techniques were not capable of retrieving these parts, hence the conclusion was that further removal efforts require addition of a retrieval port, similar to a handhole, at each part location.

After considering the difficulties involved in the installation of several retrieval ports, SCE chose to plug and stabilize tubes with wear (and adjacent tubes) to prevent further damage and to prepare a safety-evaluation for those parts which did not cause wear.

3.0 ENGINEERING EVALUATION

3.1 POTENTIAL SOURCES OF FOREIGN OBJECTS

In Generic Letter 85-02 and NUREG-0844, the NRC Staff addresses the need to ensure that effective mechanisms are in place to preclude the introduction of foreign objects into the secondary and primary side of steam generators. Specifically, the introduction or presence of loose parts is attributed to construction and/or modification of the steam generators or interfacing systems. The Staff recommends that procedures be in place which include detailed accountability of all tools and equipment used during the work effort, cleanliness requirements, and controls on personnel-related foreign objects such as film badges, eye glasses etc.

A summary of significant industry experience follows:

Southern California Edison

The most extensive and thorough analysis was performed during the initial fabrication of the San Onofre Units 2 and 3 steam generators and is detailed in Reference 1. During the steam generator tubing operation, a tube guide, which is attached to the end of the heat transfer tubes to facilitate installation, became dislodged and could not be located during subsequent search efforts. They were presumed to be in the steam generators and extensive analysis and testing were performed by ABB/CE to verify that the tube guide would not affect the safety and performance of the steam generator during its 40-year lifetime.

Northeast Utilities

During modification of a tube support plate at Millstone Unit 2, it was postulated that plate slivers from a cutting process may not have been completely removed from the steam generator. ABB/CE performed an evaluation and concluded that the tubes would not sustain any loss of structural integrity resulting from the potential loose objects.

Florida Power & Light

During sludge lancing of the Turkey Point Unit 4 steam generators, the camera light bracket on the spray unit came off inside generator "C". The bracket was subsequently located and retrieved from the tube lane but three round head screws which attached the bracket to the camera housing could not be found. As a result, ABB/CE performed an analysis to support the continued operation with the loose objects in the secondary side of the steam generator.

A review of an industry database to determine typical foreign object introduction revealed that the majority of objects identified in the domestic generators are a result of construction or outage related activities:

3.1 POTENTIAL SOURCES OF FOREIGN OBJECTS (Continued)

Plant	Foreign Object	Identification Technique
Ginna	3.5 lb orifice plate, cut during downcomer modification	Visual (Fiber-optic) (a)
Prairie Island	Spring from sludge lance tool	Visual (Fiber-optic) (a)
San Onofre Units 2 and 3	Tube Guide (Construction)	Inventory Deviation (c)
St. Lucie 1	Weld rod, weld slag	Eddy Current (b,c)
South Texas 1	Metal shavings	Eddy Current (b)
Indian Point	Plate, pipe tap, weld rod, wire	Visual, Eddy Current (c)
Millstone II	Slag, Rim Plate Mod slivers	Visual, Postulated (c)
Palo Verde 1	Shim Bar	Eddy Current (c)

NOTES:

a. Part visually identified after tube rupture event

b. Part identified by Eddy Current examination and subsequently verified visually

c. Evaluation performed to leave the foreign object in the steam generators.

SCE has identified two (2) cases of foreign object introduction from an operational source or event. These are:

Plant	Foreign Object	Identification Technique
Turkey Point	Check Valve pin	Visual (Fiber-optic)
St. Lucie 1	Broken Feedring U-Bolt (a)	Visual (Fiber-optic)

NOTE:

a. Root cause evaluated to be water hammer during feedwater initiation.

Based on the industry and regulatory review results indicating that foreign object ingress can be a result of either maintenance activities or process system transport, SCE evaluated the administrative and physical mechanisms in place at San Onofre to preclude the introduction of foreign material into the steam generators.

3.1 POTENTIAL SOURCES OF FOREIGN OBJECTS (Continued)

Foreign Material Exclusion (FME)

In response to INPO SOER 82-12 and IE Notice 88-06, "Foreign Objects in Steam Generators", SCE has reviewed procedures and training programs concerned with modifications and maintenance activities involving the steam generators and interfacing systems. The program in effect at San Onofre has been determined to meet the recommendations of these documents.

Introduction of Foreign Material via Operational Sources

SCE has reviewed the potential for foreign object introduction into the steam generators (SGs) by transport from interfacing process systems. The most likely transport medium is the feedwater system. The Feedwater System (FW) supplies the water to the SGs during normal operation. Auxiliary feedwater supplies the water to the SGs during start-up and emergency conditions. Two trains of feedwater pumps and feedwater heaters supply feedwater to the Steam Generators. Several gate valves are installed in the feedwater heater trains for maintenance isolation. With regard to design, maintenance and operating frequency, these valves are not expected to add any foreign pieces into the feedwater lines.

Steam Generator Internals

Feedwater enters the steam generators through the feedwater nozzle, feedwater distribution box, feedring, and discharge elbows. As discussed in Section 3.1, in 1990 there was significant erosion of the feedring - in particular there were large holes in the feedwater distribution box-to-feedring pipe stubs. The material composition (chemistry) of the parts removed from steam generator 3E088 during the Unit 3 Cycle 7 outage is very similar to the pieces removed in 1990 as provided in Table 3.1-1. Additionally, the shape and size of the pieces appear to be feedring material. Although a search for missing pieces of pipe stubs was conducted in 1990, not all of the missing area could be accounted for. SCE has concluded that the current PLP indications are likely caused by pieces of these pipe stubs.

Summary

Based on a review of the plant systems and programs at San Onofre, it is judged that the parts present in the Unit 3 steam generators were not transported via the feedwater system or auxiliary feedwater system. Although parts of the size described in this engineering evaluation are capable of passing through the interferences present in the feedwater components or the steam generators, it is more likely that the loose parts are a result of the 1990 feedring erosion.

Table 3.1-1

COMPARISON OF MATERIAL COMPOSITION

Year	Sample	Elements Analyzed (Wt.%)								
		Mn	P *	Si	Cr	Ni *	Mo	Cu	Al	V
1993	88-5	0.61	0.035	0.22	<0.01	0.03	0.02	0.01	0.038	<0.01
1993	88-4	0.57	0.034	0.21	0.02	0.21	0.02	0.03	0.041	<0.01
1993	88-3	0.61	0.040	0.23	0.03	0.10	0.02	0.04	0.051	0.01
1990	88 A	0.66	0.011	0.19	0.05	0.07	0.01	N/A	0.016	N/A
1990	88 C	0.65	0.008	0.20	0.02	0.05	0.02	0.02	0.031	<0.01
1990	88 D	0.63	0.008	0.18	0.02	0.04	0.02	0.01	0.024	<0.01
1990	88 E	0.63	0.009	0.19	0.02	0.05	0.02	0.01	0.025	<0.01
1990	89 A	0.62	0.008	0.18	0.02	0.04	0.02	0.01	0.024	<0.01
1990	88 Vent	0.84	0.010	0.20	0.05	0.05	0.02	0.03	0.023	<0.01

* The variances in Ni and P wt. % are not considered significant.

3.2 POTENTIAL LOOSE PART (PLP) EVALUATION

Eddy current testing (ECT) used for inservice inspection of steam generator tubes can result in indications of potential loose parts (PLPs). These indications, identified by the use of low frequency (20 kHz) ECT show the contact (or near contact) of a conductive material with a steam generator tube. These signals can be interpreted as to the material causing the indication, however, there is some ambiguity. Specifically, it is very difficult to determine the difference between a piece of scale (mostly magnetite) in contact with a tube at one point from a piece of steel in contact with the tubes at a point. In order to be conservative, it is assumed that the indications are a result of metal contact; however, the nature and effect of scale can explain how a PLP indication can be present in one inspection and not present at the next inspection.

ECT with multi-frequency bobbin coil and rotating pancake coil (RPC) probes during the current Unit 3 Cycle 7 refueling outage revealed the presence of foreign objects in both steam generators. A bobbin coil ECT examination of the full length of 60% of the tubing was conducted in all regions of both steam generators, with a 100% RPC ECT exam of the hot leg tubesheet region. In addition, a five-tube wide region (~2500 tubes) in all periphery and tube lane areas were inspected full length with bobbin coil ECT. In all, 72% of the tubes were inspected full length with bobbin coil ECT. All the bobbin coil data was specifically screened to detect the presence of loose parts using a 20 kHz absolute frequency. An RPC exam was then performed on any tubes with PLP indications and/or degradation in adjacent tubes. Additionally, data from previous ECT examinations were reviewed for the presence of similar indications.

For loose part characterization and orientation, SCE utilizes information provided by the RPC examination. The RPC examination technique uses a single or multiple wound coil that is mounted in a probe for characterization of defects. These coils are surface riding and are sensitive to tube degradation problems. Through the use of computers, software, and trained analysts, a tube profile can be determined. The RPC coils are wound so the orientation of degradation can be determined. Wear orientation, loose part length and position are typical characteristics which can be evaluated with RPC techniques. Based on the ECT data from the three loose parts removed from steam generator 3E088, SCE is confident that the ECT results provide adequate information to allow for foreign object characterization.

During the 1990 and 1993 refueling outages (Cycle 5 and Cycle 7, respectively) for San Onofre Unit 3, ECT results included PLP indications. These results were used as a basis for the PLP evaluations. The reports of these results are provided in Appendix A. The ECT results in 1992 (Cycle 6) did not identify any PLP indications.

PLP Evaluation

The first step of the evaluation of the PLP indications listed in Appendix A was to screen the indications to eliminate those that are not loose parts or are not significant. For example, as a result of analyzing the 1990 data using 1993 ECT Analysis Guidelines, several tubes were determined to not have PLP indications. In addition, all tubes which are separated (isolated) from other tubes with PLP indications are considered to not have a loose object in contact with the tube. The results of this screening are contained in Tables 3.2-1 and 3.2-2 for steam generators 3E088 and 3E089, respectively.

The next step in the evaluation was to characterize the objects that could be causing the significant PLP indications as listed in these tables. Table 3.2-3 is a list of these objects and their geometric characteristics. Table 3.2-4 describes the current disposition of these objects.

Summary of Indicated Loose Parts

As a result of the previously described evaluations, SCE has concluded that two loose objects remain in 3E088 and five loose objects remain in 3E089. Appendix B shows the location of these objects in the steam generators, and their orientation.

Two of the seven objects are in contact with tubes that remain in service. These two objects have not caused any detectable degradation to any tubes. All of the tubes in contact with the remaining five objects have been plugged and all but one of the plugged tubes were staked. Five other loose objects (designated 89-6, 89-7, 88-6, 88-7, and 88-8) identified in the evaluation based on 1990 data, but determined to not be present in 1993 are described and dispositioned in Tables 3.2-3 and 3.2-4, respectively.

The above conclusions are based on a review of 1990, 1992 and 1993 ECT data as discussed and tabulated in detail below.

Steam Generator 3E088

A total of 27 tubes at the start of the Cycle 7 outage had ECT indications of potential loose parts. Three loose parts were removed from the vicinity of a leaking tube (143-85) and manual cleaning was performed between the tubes in the surrounding area to verify the elimination of all loose objects near these tubes. After removal of the three loose objects, cleaning of the affected area and evaluation of the ECT data, PLP indications for 22 of the 27 tubes were eliminated. The five remaining tubes with valid PLP indications have been evaluated and two loose objects were identified. These objects, designated 88-1 and

88-2, are described and dispositioned in Tables 3.2-3 and 3.2-4, respectively.

The removed loose objects, designated 88-3, 88-4, and 88-5, are also described and dispositioned in Tables 3.2-3 and 3.2-4. Figure 3.2-1 shows the location and orientation of these parts prior to cleaning. Figure 3.2-2 provides the location of remaining ECT PLP indications subsequent to cleaning. As a result of the cleaning, all of these PLP indications were determined to not be valid.

Steam Generator 3E089

Based on a review of inspection data for 3E089 from 1990, 1992 and 1993 nineteen tubes have been identified as potentially being in contact with loose parts. No objects were removed associated with these tubes. The tubes with valid PLP indications have been evaluated and five loose objects were identified. These objects, designated 89-1 through 89-5 are described and dispositioned in Tables 3.2-3 and 3.2-4, respectively.

Tube Plugging

The criteria used for plugging tubes with PLP indications was as follows:

- All tubes associated with a single object were plugged and staked if any one tube had a wear indication. Tube 115-37 was plugged but not staked.

- Tubes with PLP indications where none of the tubes showed wear were placed on a list to be monitored during subsequent inspections.

Tables 3.2-5 and 3.2-6 list the tubes that were plugged due to ECT PLP indications, ECT wear (in vicinity of tubes with PLP indications) and visual observations during the Unit 3 Cycle 7 (1993) refueling outage.

TABLE 3.2-1

STEAM GENERATOR 3E088 PLP INDICATIONS

TUBE	1990	%	1992	%	1993	%	COMMENTS
22-4	N/A	N/A	N/A	N/A	PLP	SV1	
21-5	N/A	N/A	N/A	N/A	PLP	NDD	
137-67	N/A	N/A	NPLP	NDD	PLP	NDD	STPLP
142-72	PLP	NDD	NPLP	NDD	NPLP	NDD	NPLP 1993
144-72	PLP	NDD	NPLP	NDD	NPLP	NDD	NPLP 1993
144-74	PLP	NDD	N/A	N/A	NPLP	NDD	NPLP 1993
143-75	PLP	NDD	N/A	N/A	NPLP	NDD	NPLP 199[illegible]
145-75	PLP	NDD	N/A	N/A	NPLP	NDD	NPLP 1993
144-84	NPLP	NDD	N/A	N/A	PLP	NDD	PLP REMOVED
146-84	NPLP	NDD	N/A	N/A	PLP	NDD	PLP REMOVED
143-85	NPLP	NDD	N/A	N/A	PLP	82	PLP REMOVED
145-85	NPLP	NDD	N/A	N/A	PLP	SV1	PLP REMOVED
144-86	NPLP	NDD	N/A	N/A	PLP	41/<20	PLP REMOVED
146-86	NPLP	NDD	N/A	N/A	PLP	SVI	PLP REMOVED
141-87	NPLP	NDD	NPLP	NDD	PLP	NDD	PLP REMOVED
145-87	PLP	NDD	PLP	24	PLP	44/<20	PLP REMOVED
147-87	PLP	NDD	PLP	NDD	PLP	SVI	PLP REMOVED
141-89	NPLP	NDD	N/A	N/A	PLP	SVI	PLP REMOVED
144-92	NPLP	NDD	N/A	NDO	PLP	NDD	PLP REMOVED
142-88	NPLP	NDD	N/A	N/A	PLP	NDD	PLP REMOVED
144-88	PLP	NDD	N/A	N/A	PLP	40/SVI	PLP REMOVED
146-88	PLP	NDD	N/A	N/A	PLP	<20/SVI	PLP REMOVED
143-89	NPLP	NDD	N/A	N/A	PLP	NDD	PLP REMOVED
145-89	PLP	NDD	N/A	N/A	PLP	<20/SVI	PLP REMOVED
147-89	PLP	NDD	N/A	N/A	NPLP	NDD	NPLP 1993
138-90	N/A	NDD	PLP	NDD	NPLP	NDD	NPLP 1993
142-90	NPLP	NDD	N/A	N/A	PLP	NDD	PLP REMOVED

TUBE	1990	%	1992	%	1993	%	COMMENTS
139-91	NPLP	NDD	N/A	N/A	PLP	NDD	PLP REMOVED
141-91	NPLP	NDD	N/A	N/A	PLP	NDD	PLP REMOVED
3-91	NPLP	NDD	N/A	N/A	PLP	NDD	PLP REMOVED
145-91	NPLP	NDD	N/A	N/A	PLP	NDD	PLP REMOVED
136-106	NPLP	NDD	N/A	N/A	NPLP	NDD	RNPLP
138-106	NPLP	NDD	N/A	N/A	NPLP	NDD	NPLP 1993
141-105	NPLP	NDD	NPLP	NDD	PLP	NDD	
142-106	NPLP	NDD	N/A	N/A	PLP	SVI	
144-106	NPLP	NDD	N/A	N/A	PLP	NDD	
137-107	PLP	NDD	NPLP	NDD	NPLP	NDD	NPLP 1993
139-107	PLP	NDD	NPLP	NDD	NPLP	NDD	NPLP 1993
143-107	PLP	NDD	NPLP	NDD	NPLP	SVI	RNPLP
140-108	NPLP	NDD	NPLP	NDD	NPLP	NDD	RNPLP
142-108	NPLP	NDD	NPLP	NDD	NPLP	NDD	RNPLP
129-125	NPLP	NDD	N/A	N/A	NPLP	NDD	RNPLP
131-125	NPLP	NDD	N/A	N/A	NPLP	NDD	RNPLP

LEGEND:

- PLP - Potential loose part indication
- NPLP - Tube examined, no potential loose part indications
- N/A - Tube not examined
- SVI - Single Volumetric indication (not quantifiable)
- Number - % through-wall flaw penetration
- NDD - No detectable degradation near PLP indication
- TSH - Top of hot leg tubesheet
- STPLP - Single tube PLP, not considered to be valid PLP
- PLP Removed - Area cleared and all PLPs removed
- RNPLP - 1990 data reevaluated in 1993, no PLP indication

TABLE 3.2-2

STEAM GENERATOR 3E089 PLP INDICATIONS

TUBE	1990	%	1992	%	1993	%	COMMENTS
16-2	NPLP	NDD	NPLP	NDD	NPLP	NDD	NPLP 1993 RNPLP
22-2	NPLP	NDD	NPLP	NDD	NPLP	NDD	NPLP 1993 RNPLP
1-3	PLP	N/A	N/A	N/A	N/A	N/A	PLUGGED 1990
27-3	NPLP	<20	N/A	N/A	NPLP	NDD	NPLP 1993
115-37	N/A	N/A	NPLP	NDD	PLP	NDD	
117-37	N/A	N/A	NPLP	NDD	PLP	NDD	
116-38	N/A	N/A	N/A	N/A	PLP	NDD	
117-39	N/A	N/A	N/A	N/A	PLP	NDD	
1-55	PLP	NDD	N/A	N/A	NPLP	NDD	RNPLP
1-57	PLP	NDD	NPLP	NDD	NPLP	NDD	RNPLP
1-59	PLP	NDD	N/A	N/A	NPLP	NDD	RNPLP
1-63	PLP	NDD	N/A	N/A	NPLP	NDD	RNPLP
141-107	PLP	<20	N/A	N/A	N/A	N/A	PLUGGED 1990
143-107	PLP	32	N/A	N/A	N/A	N/A	PLUGGED 1990
142-108	PLP	<20	N/A	N/A	N/A	N/A	PLUGGED 1990
141-109	PLP	NDD	N/A	N/A	N/A	N/A	PLUGGED 1990
143-109	PLP	NDD	N/A	N/A	N/A	N/A	PLUGGED 1990
142-110	PLP	NDD	N/A	N/A	N/A	N/A	PLUGGED 1990
1-113	PLP	NDD	N/A	N/A	NPLP	NDD	RNPLP
1-115	PLP	NDD	N/A	N/A	NPLP	NDD	RNPLP
1-117	PLP	NDD	NPLP	NDD	NPLP	NDD	RNPLP
1-119	PLP	NDD	N/A	N/A	NPLP	NDD	RNPLP
1-123	PLP	NDD	N/A	N/A	NPLP	NDD	RNPLP
1-125	PLP	NDD	N/A	N/A	NPLP	NDD	RNPLP
1-127	PLP	NDD	NPLP	N/A	NPLP	NDD	RNPLP
1-129	PLP	NDD	N/A	N/A	NPLP	NDD	RNPLP
1-133	PLP	NDD	N/A	N/A	NPLP	NDD	RNPLP

TABLE 3.2-2 (Cont.)

STEAM GENERATOR E089 PLP INDICATIONS

TUBE	1990	%	1992	%	1993	%	COMMENTS
1-135	PLP	NDD	N/A	N/A	NPLP	NDD	RNPLP
118-136	NPLP	NDD	N/A	N/A	PLP	NDD	
1-137	PLP	NDD	NPLP	NDD	NPLP	NDD	RNPLP
117-137	N/A	N/A	NPLP	NDD	PLP	NDD	
119-137	N/A	N/A	NPLP	NDD	PLP	NDD	
1-139	PLP	NDD	N/A	N/A	NPLP	NDD	RNPLP
1-143	PLP	NDD	N/A	N/A	NPLP	NDD	RNPLP
1-145	PLP	NDD	N/A	N/A	NPLP	NDD	RNPLP
1-147	PLP	NDD	NPLP	NDD	NPLP	NDD	RNPLP
1-149	PLP	NDD	N/A	N/A	NPLP	NDD	RNPLP
69-163	N/A	N/A	N/A	N/A	PLP	NDD	
68-164	N/A	N/A	N/A	N/A	PLP	NDD	
65-165	N/A	N/A	N/A	N/A	PLP	NDD	
67-165	N/A	N/A	N/A	N/A	PLP	NDD	
64-166	N/A	NDD	N/A	N/A	PLP	NDD	

LEGEND:
- PLP - Potential loose part indication
- NPLP - Tube examined, no potential loose part indications
- N/A - Tube not examined
- SVI - Single Volumetric indication (not quantifiable)
- Number - % through-wall flaw penetration
- NDD - No detectable degradation near PLP indication
- TSH - Top of hot leg tubesheet
- STPLP - Single tube PLP, not considered to be valid PLP
- PLP Removed - Area cleared and all PLPs removed
- RNPLP - 1990 data reevaluated in 1993, no PLP indication

TABLE 3.2-3 - STEAM GENERATOR LOOSE OBJECT GEOMETRY

Loose Object No.	S/G	Location (deg)	Tubes Contacted	Angle (deg)	Max Dimensions		Max Weight (Oz.)	Min. Weight (Oz.)
					Width (in.)	Height (in.)		
88-1	88	170	141-105 142-106 144-106 143-107	120/ 300	2.5	1.0	1.30	0.19
88-2	88	260	20-4 22-4 21-5	60/ 240	2.5	1.0	1.30	0.19
89-1	89	120	69-163 68-164 65-165 67-165 64-166	60/ 240	4.0	1.75	3.63	0.52
89-2	89	150	118-136 117-137 119-137	60/ 240	1.5	1.0	0.78	0.11
89-3	89	220	115-37 117-37 116-38 117-39	120/ 300	2.5	1.0	1.30	0.19
89-4	89	165	141-107 143-107 142-108	120/ 300	1.5	5.0	3.89	0.56
89-5	89	165	142-108 141-109 143-109 142-110	60/ 240	2.0	2.25	2.33	0.34
88-3	88	000	143-85 145-85 144-86 146-86 145-87	60/* 240	2.4 **	2.6	*** 0.94	*** 0.94
88-4	88	000	145-87 147-87 142-88 144-88 146-88 143-89 145-89	120/* 300	2.1 **	1.3	*** 0.22	*** 0.22

TABLE 3.2-3 - STEAM GENERATOR LOOSE OBJECT GEOMETRY (Cont.)

Loose Object No.	S/G	Location (deg)	Tubes Contacted	Angle (deg)	Max Dimensions		Max Weight (Ozs)	Min Weight (Ozs)
					Length (in.)	Width (in.)		
88-5	88	000	142-90 139-91 141-91 143-91	0/* 180	2.0**	1.2	*** 0.18	*** 0.18
89-6	89	270	1-3	90/ 270	1.5##	0.7##	0.54	0.08
89-7	89	270	None	90/ 270	1.0##	0.7##	0.36	0.05
88-6	88	350	142-72 144-72	60/# 240	1.0	1.0	0.52	0.07
88-7	88	350	144-74 143-75 145-75	60/# 240	1.5	1.0	0.52	0.07
88-8	88	015	138-106 137-107 139-107	120/ 300	1.5	2.0	0.52	0.07

LEGEND:

* - Estimated

** - Irregular object

*** - Actual weight (measured)

- Various angles are possible

- Based on visual observations

TABLE 3.2-4 - STEAM GENERATOR LOOSE OBJECT* DISPOSITION

Item No.	S/G	Axial Loca-tion	Years Noted	Remarks
88-1	88	TSH	1993	Two tubes with wear in 1993. Four tubes plugged and staked in 1993.
88-2	88	TSH	1993	Two tubes with wear in 1993. Six tubes plugged and staked in 1993.
89-1	89	TSH	1993	No wear. Five tubes to be monitored in future inspections.
89-2	89	TSH	1993	No wear. Three tubes to be monitored in future inspections.
89-3	89	TSH	1993	One tube with wear in 1993. Three tubes plugged and staked in 1993. One tube only plugged.
89-4	89	TSH	1990 1992 1993	Four tubes plugged and staked in 1990. Visually verified all 3 years.
89-5	89	TSH +18	1990	Five tubes plugged and staked in 1990.
88-3	88	TSC	1993	Caused leak in tube 143-85 in 1993. Wear on four additional tubes in 1993. Some wear (24%) on tube 144-86 in 1992. Part removed in 1993, however, five tubes plugged.
88-4	88	TSC	1990 1992# 1993	Part removed in 1993. Wear on four tubes in 1993. Four tubes plugged. #Reanalysis of data from 1992 showed the part to be present.
88-5	88	TSC	1993	No wear. Part removed in 1993.

* Each item represents a group of tubes with PLP indications. More detailed information on each item is provided in Table 3.2-3

TABLE 3.2-4 - STEAM GENERATOR LOOSE OBJECT* DISPOSITION (Cont.)

Item No.	S/G	Axial Loca-tion	Years Noted	Remarks
89-6& 89-7	89	TSC/ TSH	1990 1992	Two parts along blowdown pipe were visually identified and seven tubes were plugged and staked in 1990. A small remnant of one part was visually identified in 1992.
88-6	88	TSC	1990	No wear.
88-7	88	TSC	1990	No wear.
88-8	88	TSC	1990	No wear.

* Each item represents a group of tubes with PLP indications. More detailed information on each item is provided in Table 3.2-3

TABLE 3.2-5
PLP TUBE PLUGGING LIST 3E088

TUBE LOCATION ROW-COLUMN	COMMENTS
22-2	Staked
21-3	Staked
23-3	Staked
20-4	Staked
22-4	Staked
21-5	Staked
143-85	Loose Part Removed
145-85	Loose Part Removed
144-86	Loose Part Removed
146-86	Loose Part Removed
145-87	Loose Part Removed
147-87	Loose Part Removed
144-88	Loose Part Removed
146-88	Loose Part Removed
145-89	Loose Part Removed
141-105	Staked
142-106	Staked
144-106	Staked
143-107	Staked

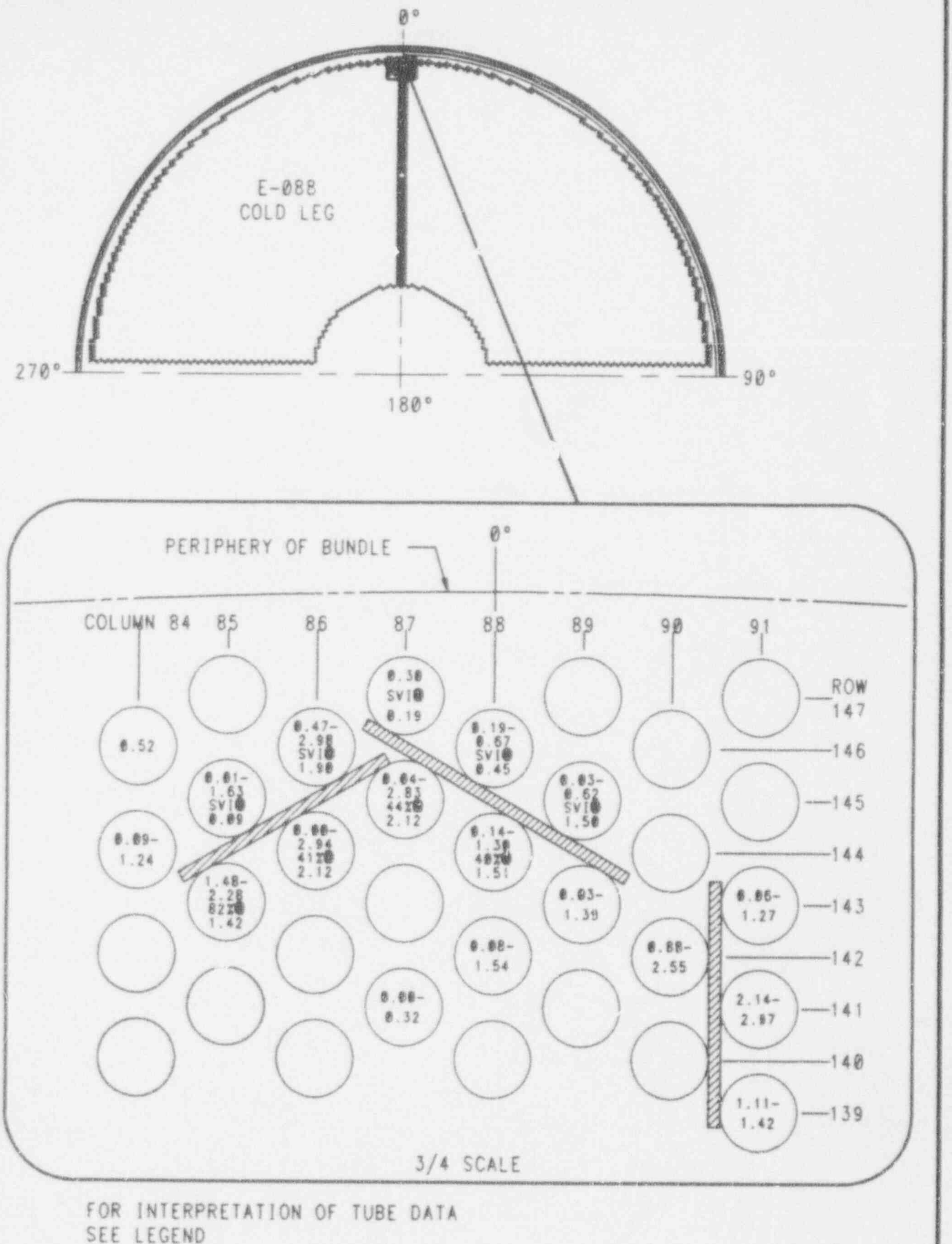
TABLE 3.2-6
PLP TUBE PLUGGING LIST 3E089

TUBE LOCATION ROW-COLUMN	COMMENTS
115-37	
117-37	Staked
116-38	Staked
117-39	Staked

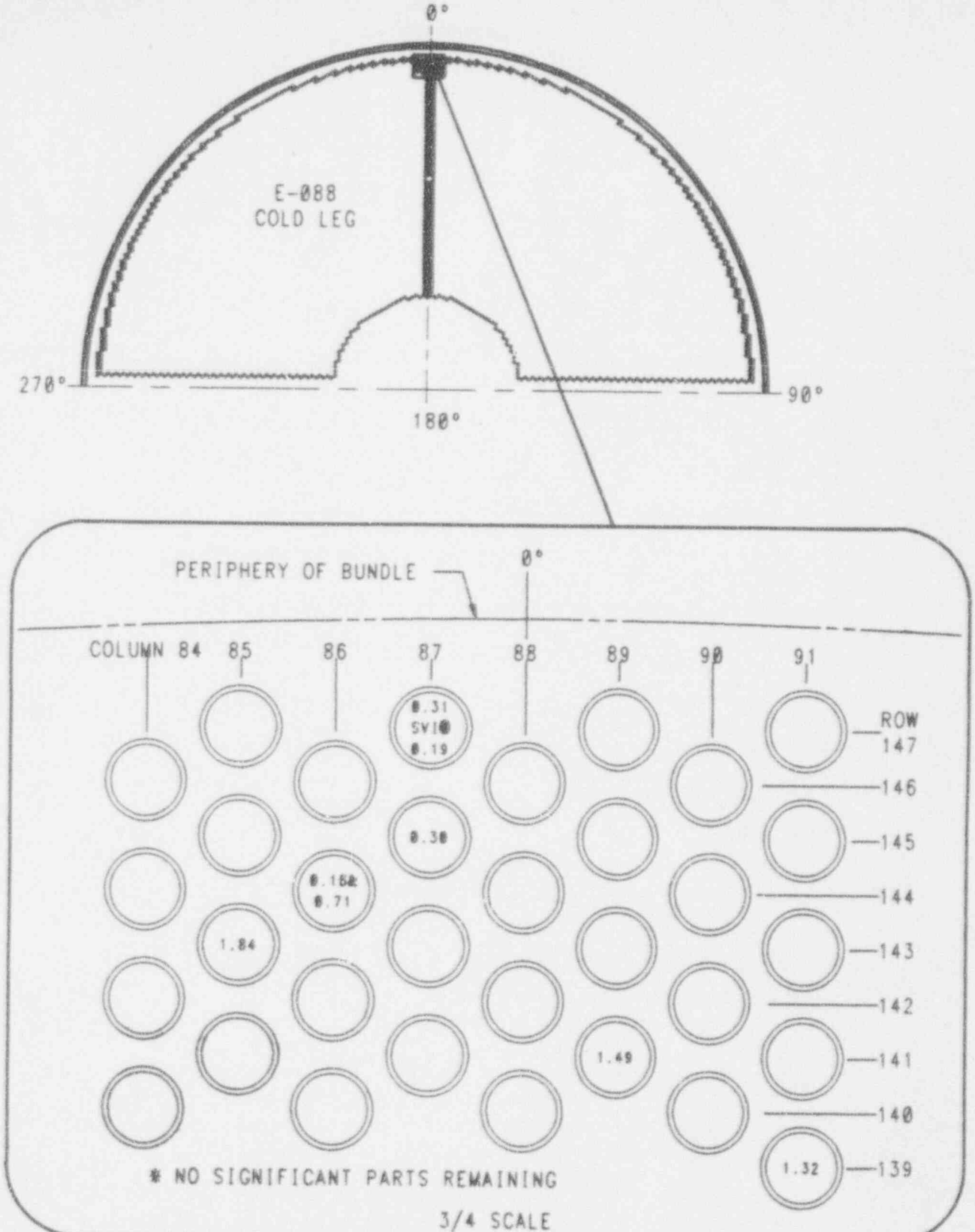
Legend for Figures 3.2-1 and 3.2-2

The following figures show the location and orientation of removed loose objects 88-3, 4 and 5 in the steam generator 3E088. Codes 1 or 2 can be combined with codes 3 or 4 if both PLP and wear occur. The legend for these maps is as follows:

Code No.	Code	Meaning
1.	xx- yy	Indicates the range of distance of loose objects from the top of the tubesheet, xx through the contact length, xx-yy
2.	xx	Indicates the point of contact of a loose object at xx from the top of the tubesheet
3.	SVI@ yy	Indicates the height of a Single Volumetric Indication (SVI) at YY from the tubesheet
4.	___% @xx	Indicates a flaw ___% through wall at xx from the top of the tubesheet
5.	PLUG	Indicates the tube was previously plugged



Location of Removed Loose Objects 88-3,4,5
Figure 3.2-1



FOR INTERPRETATION OF TUBE DATA
SEE LEGEND

Location of Removed Loose Objects 88-3,4,5
(After Parts Retrieval)
Figure 3.2-2

3.3 LOOSE PART/TUBING INTERACTIONS

In support of this report, ABB-CE has performed an evaluation (Reference 6) of each object considering its apparent size, shape and orientation as inferred from the Eddy Current Test (ECT) data and the local flow velocity profiles based on ABB-CE's Steam Generator flow distribution analyses.

It is ABB/CE's experience in evaluating potential loose objects in the secondary side of the steam generator that by the end of the fuel cycle (when the eddy current examinations are performed) the objects have found a preferred location. That is, the objects are probably wedged between tubes and/or have found a "stable" position where a static position balance exists between the size and weight of the object and the local flow fields. Therefore, the most likely scenario is that the objects will remain where they are and may continue to wear the same tubes once power operation is resumed.

Although loose objects generally find a preferred location and stay there, it is possible that the objects could dislodge or break into smaller pieces and migrate to other areas of the steam generator. As previously discussed, the outer rows (five tubes deep) of steam generator tubes were fully inspected for PLPs providing confidence that all loose parts have been identified in this region. A total of 60% of the remainder of the inner tubes were inspected for loose parts in the Cycle 7 outage. No loose parts were identified for the inner region of the bundle. For the Cycle 7 Outage, 6 of every 10 columns were inspected in the interior of the bundle. Two additional columns were tested in the last outage and the last two columns were tested in 1990. Therefore, all inner bundle tubes have been inspected over the last three outages.

There is a small chance that a loose piece has moved around within the inner bundle and gone undetected. To determine the confidence that no significant (parts that cause wear) parts are in the inner region, probability concepts were used to determine the random sample size needed to establish 95% confidence that no loose parts exist. Results show that a population sample of 3,000 tubes is required to ensure that 99.9% of the tubes have no loose parts with a confidence level of 95%. Approximately 4,000 inner tubes were inspected during the Cycle 7 Outage in each steam generator. Therefore, considering only the Cycle 7 inspection data, SCE concludes with high confidence that no significant loose parts exist in the inner bundle region. Nonetheless, to be conservative, the potential consequences associated with migration of the objects to other areas in the secondary side of the steam generator is included in this evaluation.

There are three possible scenarios which describe how loose objects have historically and experimentally interacted with the steam generator heat transfer tubes. These scenarios are described below:

3.3 LOOSE PART/TUBING INTERACTIONS (Continued)

3.3A Scenario 1

The object(s) become dislodged from their current location (in its current size or smaller pieces), reenters the flow field and randomly impacts tubes as it moves about in the steam generator.

In studies performed for San Onofre Units 2 & 3 and Millstone 2 (References 4 and 5) ABB-CE has performed prototypical laboratory tests simulating objects of various sizes and flow rates. The objects moved through the flow field impacting tubes on a random basis.

The first test was performed in 1976 and simulated a three ounce loose object which was allowed to remain in the secondary flow field for an extended period of time. The modeling criteria used for this test is specifically applicable to the San Onofre steam generators since the dynamic pressure (ρV^2) of the fluid in the downcomer annulus as well as the annulus itself was chosen such that they were specifically representative of the San Onofre steam generators. The tubes were 3/4" diameter and 0.048" thick. The loose object randomly impacted the peripheral tubes as it moved about in the flow field. This test simulated two years of continuous steam generator operation and was later extrapolated to cover the entire operational life of the steam generator.

As the loose object impacted the tubes, its volume gradually became smaller. It was estimated that at some point the object would eventually disintegrate and simply add to the steam generator sludge inventory.

At the conclusion of the test, the tubes were removed from the model and inspected. The portions of the tubes exposed to the loose object showed evidence of uniformly distributed impacts over the entire area susceptible to impact. It was concluded from this observation that the motion of the object in the flow field was random in nature. The tubes removed from the flow model were then examined for wear, hardness and general surface appearance.

Diameter and wall thickness measurements did not indicate any measurable difference between tubes impacted by the loose object and tubes shielded from the impacts. Examination of the tube wall microstructure showed a depth of deformation of only 1.0 mil (2%) to 1.5 mils (3%). Degradation of surface hardness was limited to this depth with the remaining wall having a hardness value characteristic of the unaffected metal. Hence, it was concluded that a three ounce loose object would have no adverse effect on a San Onofre-type steam generator over its entire operating life. Further details regarding this test can be found in Reference 4.

A test similar to the one described above was repeated in 1980. In this test, the three ounce object was replaced by a 20 ounce pipe cap moving in the downcomer flow adjacent to the tubesheet region. The downcomer flow field for this test was 12.5 ft/sec. Although this flow velocity resulted in a dynamic pressure slightly less than the San Onofre test, ABB-CE believes the results of the test are applicable to San Onofre (Reference 6).

Following this test, inspections of the tubes revealed very little differences from the previous test. Uniformly distributed impacts were evident on those tubes exposed to the loose object; however, no impact measurement exceeded 1 mil (2% wear).

In addition to inspection of the tubes, this test also used a Super 8 movie camera to record data concerning the motion of the pipe cap in the test model and to calculate the impact velocity of the cap on the tubes. The results of this study indicated that the 12.5 ft/sec downcomer flow velocity resulted in an impact velocity of approximately 1.5 ft/sec. Any object significantly heavier than 20 ounces would probably not be entrained in the flow field but would simply remain on the tubesheet and rock back and forth in response to the downcomer flow. Additional information regarding this test may be found in Reference 5.

Based on the preceding discussion, SCE and ABB-CE have concluded that the seven loose objects identified in the San Onofre steam generators will not cause any damage to the heat transfer tubes from Scenario 1.

3.3B **Scenario 2**

A loose object rocks in the flow field and repeatedly impacts a plugged tube which eventually loses its structural integrity and collapses. The collapsed (but plugged) tube becomes a whip and ruptures its unplugged neighboring tube.

This scenario is the "Ginna Incident" and requires a fairly heavy object located adjacent to a plugged tube and in a flow field capable of moving or rocking the object. Only plugged tubes are vulnerable to this failure mode because their internal pressure is atmospheric. An active tube has an internal pressure of 2250 psia to provide support against the repeated impacts by the rocking object.

The object inside the Ginna steam generator (later identified as an orifice plate cut during a downcomer modification) had a weight exceeding three pounds. Although there is no threshold weight above which one must be concerned with this failure mode, ABB-CE and SCE have concluded that the results from the prototype testing

3.3 LOOSE PART/TUBING INTERACTIONS (Continued)

described in Scenario 1 indicate that the weight of a loose object must significantly exceed the weight of any of the object currently identified in the San Onofre Unit 3 steam generators. Moreover, even if the object did cause a through-wall wear indication on a plugged tube, there would be an immediate equalization of pressure on the inside and outside of the tube. This pressure increase on the inside of the tube would significantly increase its structural integrity.

In addition to being too small to sever a plugged tube by the forces of impact, the Unit 3 PLPs are not of a sufficient thickness to sever an unstaked plugged tube by continuing to wear on the tube over many plant operating cycles. This is based on the following:

For a plugged tube to become completely severed by a loose part, the object must be large enough and have sufficient force applied to not only wear a hole into the plugged tube but to also completely wear through the tube. This would require that a continual force be applied throughout the severing process. However, as the plugged tube wears, the object will not be wedged as tightly to the plugged tube and the forces causing wear will diminish and/or the object will migrate to another location.

3.3C Scenario 3

The object(s) wear scars on active steam generator tubes.

Based on a review of 1990, 1992 and 1993 tube inspections and the three objects removed from steam generator 3E088 during the current Cycle 7 outage, the loose parts appear to be left over from the erosion failure of the feedwater distribution box to feedring pipe stub that was identified in 1990. This is based on the results of chemical analysis of the three parts removed from 3E088 (Section 3.1). The objects thus would consist of pieces of carbon steel piping that are irregular in shape, curved, and of variable thickness due to erosion. This is consistent with the three loose parts that were removed near the leaking tube.

ABB/CE conducted an analysis of the potential for known loose parts to migrate from the current locations in the outside portion of the steam generator tube bundle. The analysis considered the estimated parts sizes, locations, and flow velocities in the region of the SONGS steam generators. As discussed later, the results show that the known objects are likely to not move from their current positions over the next fuel cycle.

3.3 LOOSE PART/TUBING INTERACTIONS (Continued)

An evaluation was also completed by ABB-CE to determine a conservative allowable tube wall thinning for SONGS steam generators during both normal and accident conditions. Results show that 64% tube wall thinning is a conservative acceptance criteria that will maintain the tube structural integrity.

As discussed later, ABB-CE in Reference 6 has conducted a tube wear rate evaluation. First, the C-E tube wall degradation model was validated by comparison of predictions with actual tube data in 3E088. The model was then used to predict tube wall thinning for the known loose parts in the steam generators. Results indicate that the worst case predicted wear is 58% per plant cycle. This predicted wear is less than the 64% allowable tube degradation criteria. Therefore, it is not expected that tube wear will progress to leakage for the known loose parts over the course of one cycle of operation.

However in the unlikely event that a part does result in leakage, the leak would be expected to start out small and grow gradually over many days. This is based on the following:

Typically this type of debris is irregular in shape and slightly curved and thus results in sharp wear marks over a limited tube surface area. These parts will not wear over a large area. Should the debris end up causing a tube to fail it would be expected to create a leak that grows slowly with time rather than a sudden rupture. This is consistent with the leak and the wear marks on the tubes inspected during the Unit 3 refueling outage. The leak that occurred in tube 143-85 during cycle 6 started out at approximately 5 GPD (0.0035 gpm) and increased to approximately 40 GPD (0.028 gpm) over a five month period of time. In addition, San Onofre Units 1, 2 & 3 have had experience with tube leaks caused by tube vibration, fretting and wear against smooth steel support surfaces. In every case, the leaks have started out very small and grown gradually over many days.

This is further supported by leak/burst protype tests performed by CE for wear caused by batwing and vertical supports (References 6, 8, & 9). These tests validate stability of these leaks and therefore that rapid propagation of the leak is not expected.

During these tests, two types of tube defects were tested to simulate the type of wear one would expect from a tube support wearing on a tube. Both simulated defects were machined flat spots; one defect was one inch in length and one defect was 0.5 inches in length and are representative of the type of wear that could be expected from a potential loose object.

Three-quarter (3/4) inch OD, 0.048 inch wall Inconel 600 tubing was used to construct the specimens. A milling machine was used initially to achieve the desired wear condition. For those specimens that were leak tested, the last portion of material that was removed was done so with a file while the specimen was pressurized with water.

The results of the burst tests showed a minimum value of 5700 psig (on a 1 inch wear specimen) was required before bursting. This value is over twice the maximum differential pressure the steam generator tubes will experience during the most severe accident conditions. Thus, there is a high degree of confidence that tubes with as much as a 70% wall thickness degradation will still maintain their required pressure retaining capabilities.

The tubes with 100% through-wall defects were tested at differential pressures representative of normal operating conditions and accident (steam line break) conditions. The measured leak rates resulting from normal operating differential pressure measured a maximum of 0.63 GPM. The measured leak rates resulting from the accident differential pressure measured less than 1 GPM. These tests showed that a through-wall defect would not suddenly leak in an uncontrolled manner (Reference 8).

The possibility exists, however, that the objects could become dislodged or break apart and migrate to a new preferred location.

As objects move in the flow field they will eventually migrate to a region with a lower fluid velocity and become stagnant or less active than in their previous position. The highest flow fields are the entrance regions to the tube lane. Once an object enters the tube lane it either becomes lodged in place or moves inward to a lower velocity field.

This scenario is more difficult to evaluate since it assumes that the object is dislodged and again finds another location to initiate tube wear. In general, the object that is wearing on the steam generator tubes is itself undergoing wear damage. Although specific values (for the object as well as the tube) are difficult to predict and quantify, some critical characteristics such as the size and velocity profile can be bounded. That is, for the object to become dislodged from its current location it most likely has worked down to a smaller object or has broken into two or more pieces. Smaller objects are considered to be more favorable since they will have less potential for damage than the original object. In addition to the object being smaller, any movement of the object will almost surely be toward a lower velocity field. However, since these effects are difficult to quantify, the most

conservative approach in evaluating this scenario is to assume that the object retains its shape and weight, moves elsewhere in the system and starts a wear phenomenon similar to the original one.

In summary, it is unlikely that sufficient wear will occur during the next fuel cycle to produce a tube leak. If a leak were to occur, it would be a small stable leak that would be detected, monitored and should the leakage rate exceed acceptable limits, allow for an orderly shutdown of the plant.

3.4 MIGRATION AND DAMAGE ASSESSMENT

This section evaluates each loose part with regard to its ability to wear, migrate and cause further damage in the steam generator. This section also addresses the potential impact on the steam generator of loose parts that were detected in the 1990 inspection but were not identified again in the 1993 ECT inspection.

3.4A Estimate of Maximum Wear Rates

This section describes the method and assumptions utilized to determine the potential wear rates and associated maximum size of the defects on steam generator tubes adjacent to the loose objects at the end of the next plant operating cycle. It was conservatively assumed for this evaluation that the objects remained in their current locations.

The wear scars characterized by eddy current testing on the three tubes used to benchmark the wear calculation showed that the wear on the tubes were characteristic of both angle wear and flat wear. The eddy current traces for tubes 145-87 and 144-86 characterized the volume removed as ellipsoidal indicating that the wear on these tubes was characteristic of flat wear. The eddy current traces for tube 143-85 had slightly more of a "notch" effect indicating that the wear on this tube had a slight angle effect to it. As a conservatism, the wear associated with the potential loose objects was calculated for both flat wear and angle wear.

Angle wear provides the most conservative wear values and represents a measure of the propensity for wear to initiate a leak. Flat wear is less conservative in predicting a leak but is a more accurate measure of the broad wear necessary to induce a tube rupture.

The method used to determine maximum wear from the objects remaining in the steam generators was based on a quantified amount of wear caused by a known (i.e., removed) object. The amount of energy required to cause a known amount of volume loss (i.e., wear scars on tubes 143-85, 144-86, and 145-87 as shown in Appendix D) was calculated based on the size and position of the object, the local flow velocities and fluid densities, and the length of time spent in the flow field. By comparing similar properties in the locations of the other objects, a conservative estimate of the volume of metal removed from the tube wall was performed. The wear volume was then compared to Figure 5.4-1 (the "batwing" wear curve) of Reference 9 to determine the maximum wall degradation.

ABB-CE has determined that the batwing wear curve provides a conservative estimate of the depth of the defect because of the pattern of the wear scar it assumes. The batwings are fixed supports that produce a "notched" wear scar when they contact the

steam generator tubes. As a result, the wear scar is very deep on one end and gradually becomes shallower. This type of wear scar is more conservative than those observed on the tubes adjacent to the loose objects which are much more symmetrical in nature. Thus, the depth to volume ratio for a batwing wear scar will be larger than has been observed for the loose object wear scar.

It should be noted that the angle in which the batwing causes the wear scar is smaller than some of the angles assumed in this analysis and observed in the actual wear in 3E088. That is, to perform a truly rigorous calculation it would be necessary to construct a family of curves similar to batwing wear curve that represent the angle of each of the individual loose objects. However, after reviewing the manner in which the batwing curve was developed, and accounting for the conservative depth to volume ratios predicted by this curve, ABB-CE has concluded that the batwing wear curve is representative of the available data and provides a conservative estimate of the maximum defect.

To determine the amount of energy required to remove the known amount of metal, it was assumed that the wear was initiated during Cycle 5 and continued through all of Cycle 6. Although the precise time the wear can not be determined, a conservative estimate was made by the end of Cycle 6. By determining the volume removed during Cycle 5 and ratioing that value to the volume removed during Cycle 6 (where it was known to have been for the entire cycle as a result of being identified in the 1992 ECT inspection) the approximate time the wear began was developed. As a further conservatism when calculating wear during one cycle for the known remaining objects, it was assumed that all of the energy imparted by the object was absorbed by one tube, thereby maximizing the depth of the defect. Further, the maximum potential object size was evaluated and used in the wear calculation.

Appendix A to Reference 6 contains the specific calculations that were performed to conservatively estimate the amount of wear each potential loose object could cause on the affected tubes. The following table summarizes the calculated wear defects at the end of the next operating cycle.

Table 3.4-1
Calculated Wear for One Cycle

Object	88-1	88-2	89-1	89-2	89-3	89-4	89-5
Defect Size (Flat Wear)	17%	2%	30%	20%	29%	10%	0%
Defect Size (Angle Wear)	27%	3%	58%	31%	41%	43%	1%

3.4B **Potential Migration of Loose Objects**

ABB-CE has also evaluated the dynamic forces in the locations where the potential loose objects are located. This evaluation was performed to determine if there was enough energy in the fluid to dislodge the object and move it up the tube bundle (i.e., to initiate wear in another location on the same tube) or to a different location in the tube bundle (i.e., to initiate wear on a different tube). The minimum weights from Section 3.2 were used for this calculation. The results of this evaluation are summarized in Table 3.4-2:

Table 3.4-2
Calculated/Required Velocities for Migration

Object	Hor. Velocity Required	Calc. Hor Velocity	Vert. Velocity Required	Calc. Vert. Velocity
88-1	4.041	3.24	2.556	2.56
88-2	4.041	3.24	3.300	2.31
89-1	5.054	3.23	3.343	2.47
89-2	3.075	3.23	2.511	2.57
89-3	4.041	3.24	2.556	2.57
89-4	3.103	3.24	5.665	2.56
89-5	3.604	0.20	3.823	3.70

The preceding table shows that the calculated velocities where each potential loose object is located are adequate, in some cases, to move the object. The most likely scenario is that the objects are wedged in place and will remain in their current locations. However, should they become dislodged, movement of any object would be to a lower flow velocity field and therefore to an area with lower energy and associated lower wear rates. Thus, the potential defect sizes calculated previously bound wear that could occur should any of the objects migrate.

3.4 MIGRATION AND DAMAGE ASSESSMENT (Continued)

3.4C Summary Impact of the Identified Loose Parts

Loose Part Description

Two objects in 3E088 and five objects in 3E089 have been identified via Eddy Current Testing (ECT).

3E088

Both objects in 3E088 have created small volumetric indications of wear on tubes and are located within plugged and staked tubes. Loose objects 88-1 and 88-2 (located on the hot leg tube sheet) are currently each in contact with two tubes that did not previously have PLP indications in 1990. Both of these objects are not considered related to any objects previously identified in 1990.

3E089

Tubes surrounding three of the objects in 3E089 (89-3, 89-4, 89-5) were plugged and all but one of the tubes (in contact with 89-3) were staked. The other two objects in 3E089 (89-1 and 89-2) are in contact with inservice tubes and have not created any detectable tube degradation.

All five objects are located on the hot leg tube sheet except 89-5 which is located approximately 18 inches above the tube sheet. The largest of the five objects is estimated to weigh 3.89 oz.

89-1, 89-2 and 89-3 were not identified in 1990 and are not related to any objects previously identified in 1990. There is no indication that these objects have migrated to surrounding tubes.

Potential Damage

Previous sections have addressed the potential effects the loose objects may have on the steam generator tubes. The loose parts are too small to cause impact damage and thus impacts due to migration or creation of a Ginna type scenario are not a concern. As discussed earlier, the most likely event is that the objects will remain at their current locations and continue to wear the tubes they are in contact with. Assuming the affected tubes are not plugged, it is unlikely that the object will cause a through-wall defect and a primary to secondary leak during one cycle of operation based on the wear rates shown. It should be noted that although object 89-1 indicates a relatively high end of cycle wear defect size of 58%, this value is considered very conservative. Object 89-1 has not caused any detectable tube wear in its current location. Thus, it is unlikely that this object will cause any significant tube wear during the next operating cycle. Should a

wear scar result in a leak, the leak/burst testing performed by ABB-CE (as discussed in Section 3.3C) validates leak stability and therefore rapid propagation of a leak, should one occur, is not expected even under accident conditions. Further, should the objects become dislodged they would move to lower flow regions. Thus, wear would be expected to be less than their current location. As a consequence, should a leak occur as a result of a loose part fretting, a timely, orderly shutdown would result.

3.4D Missing Objects Previously Identified in 1990

Loose Part Description

Five objects (88-6, 88-7, 88-8, 89-6, 89-7) were identified in 1990 but were not located in the 1993 inspection. The 1993 inspection included a 100% inspection of the periphery of the bundle and 60% of the rest of the tubes in the steam generators. Thus, it is unlikely that these objects still remain in the steam generator. The parts are either too small to be detected, or are sufficiently small to have been removed from the steam generators via blowdown or sludge removal without being detected.

However, assuming the parts still remain in the steam generator, the largest of these potential objects (88-8) is estimated to be a maximum of 3.12 oz. However, only one object, 88-6, caused a small wear indication (< 20%) on tube 144-72. It should be noted that PLP 88-6 is estimated to have weighed less than 0.52 oz.

Potential Damage

These five objects are presumed to have eroded and broken up into smaller pieces and been carried to a location of less flow. Thus damage from impacts is not a concern (Scenarios 1 and 2).

The wear rates estimated for the seven known objects are considered bounding for these objects. It is anticipated that since the objects did not cause any significant wear in their previous locations that it is unlikely that their new preferred locations of lower flow would allow them to produce any significant wear on tubes in their new location.

However, if these parts are wearing on tubes, the impact of this wear would be bounded by the previously discussed impact of wear for the seven identified/located loose parts (i.e., a small stable leak would occur which would allow for early detection and a timely, orderly shutdown of the plant).

3.5 MARGIN OF SAFETY ASSESSMENT FOR TUBE 143-85

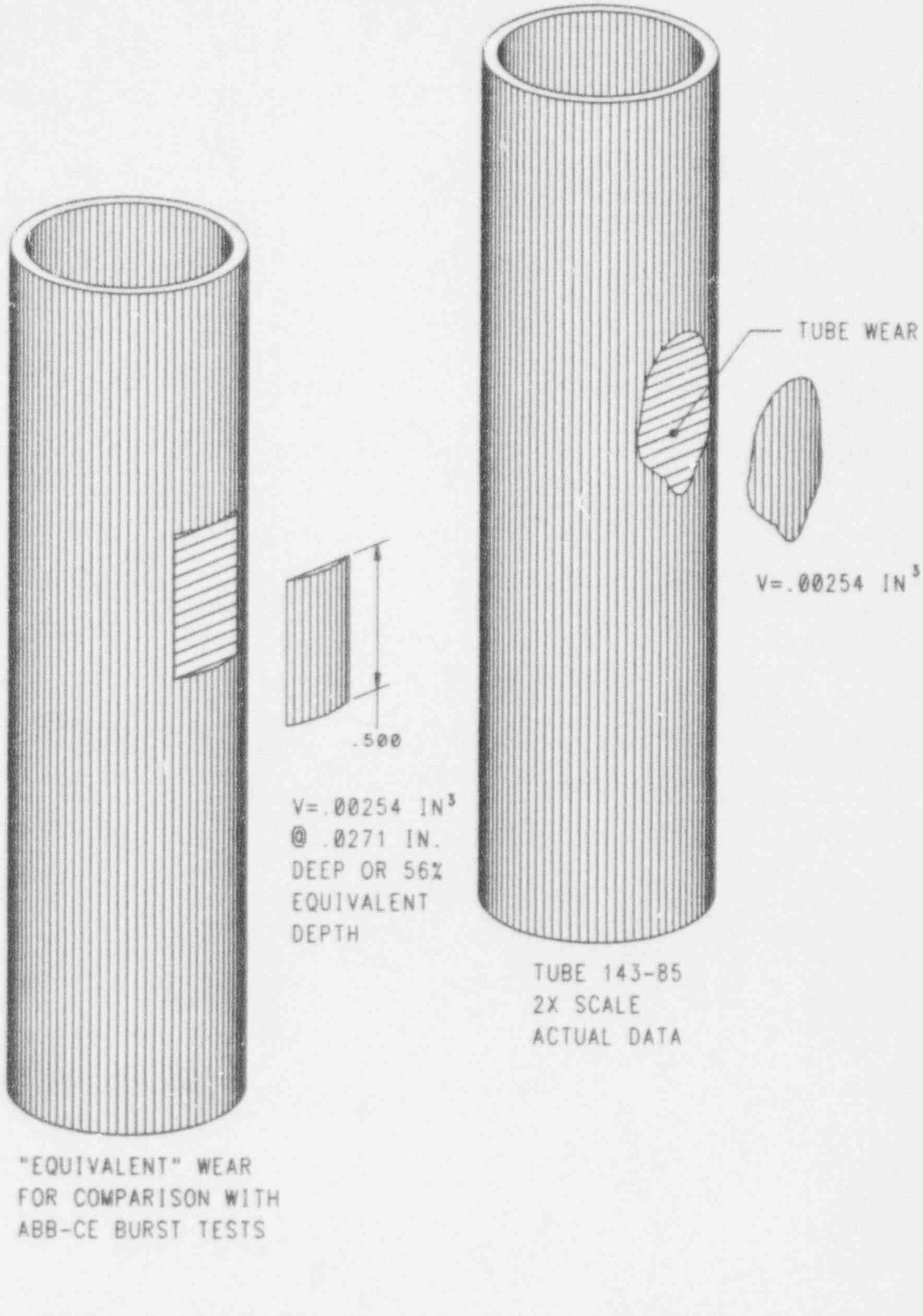
In the November 30, 1993 phone conversation between representatives of the NRC and SCE, a summary was provided of a Linear Elastic Fracture Mechanics model used to evaluate potential cracks in the steam generator tubes that can result from the loose objects. The results of this model are still preliminary and the methodology used in relating crack development to wear is still under development. Therefore, the results of this model have not been incorporated into this document.

A burst margin assessment has been completed for Tube 143-85 using steam generator leak and burst test data conducted by ABB-CE in 1985 [Reference 8]. The ABB-CE leak and burst tests were completed on a set of Inconel steam generator tube specimens with simulated wall wear. The tests consisted of two lengths of simulated wear (1/2 inch and 1 inch) that were uniformly cut into the test specimen tubes. For the burst tests, the simulated wear defect was 70% of the tube wall. This wear defect is very conservative in that the wall is uniformly "worn" over the entire wear length rather than the measured, irregular shapes typical of actual wear patterns. The long uniform wear patterns are more likely to rupture by a "fish mouth" opening.

To correlate the data from Tube 143-85, an "equivalent" uniform (flat wear) dimension is calculated for the tube as shown in Figure 3.5-1. The figure shows an enlarged view of the actual wear defect measured in Tube 143-85 and the calculated defect assuming the wear is uniformly distributed over the 1/2 inch axial length. This wear dimension approximates an average tube wall degradation over the axial wear mark of the tube. The resultant wear degradation is determined to be a 56% decrease in the wall thickness.

Based on the 1985 ABB-CE tests, the burst pressure of an Inconel steam generator tube with 70% flat wear over a 1/2 inch axial defect is 6700 psig. This burst pressure is conservatively used without accounting for the difference between a 70% wear defect of the test and a 56% equivalent wear defect of Unit 3 Tube 143-85.

Using this burst pressure, the calculated margin to burst (difference between burst pressure and delta pressure) for normal and accident conditions is 4.9 and 2.7, respectively. This margin is well within the tube design criteria.



Calculated Equivalent Wear Depth for Comparison of SCE Tube Degradation with ABB-CE Test Results
Figure 3.5-1

3.6 SAFETY EVALUATION

The purpose of this safety evaluation is to determine whether or not an unreviewed safety question would result from leaving known potential loose parts (PLP) in steam generators 3E088 and 3E089.

A total of seven loose objects have been identified during Eddy Current examinations of the San Onofre Unit 3 steam generators. Two of the objects are in steam generator 3E088 and five are in steam generator 3E089. All of the parts are located on or near the hot leg tube sheet. The largest object is estimated to be 1.5 inches x 5.0 inches and weighs 3.89 ounces.

The two objects in 3E088 caused detectable defects on tubes. All of the tubes in contact with these parts were subsequently plugged and staked.

Three of the five objects in 3E089 have caused detectable defects on tubes. All of the tubes in contact with these three parts have been plugged and all but one staked. The one tube that was not staked was the result of original inspection data interpretations that did not identify the PLP indication in adjacent tubes. The other two of the five objects in 3E089 remain in contact with a total of six inservice tubes and have not caused any detectable degradation of these tubes.

The objects have most likely found a "stable" position where a static position balance exists between the size and weight of the object and the local flow fields; therefore, the objects will probably remain stationary in their present position (Reference 6). However, the possibility exists that the parts will migrate to new locations and initiate wear on an inservice tube or an unstaked plugged tube.

All inservice tubes in contact with PLPs will be monitored for wear during all future refueling outages.

In addition, five parts in 3E088 were identified in 1990 as previously explained in Section 3.4D, but do not show up in the 1993 ECT inspections.

1. **May the proposed activity increase the probability of occurrence of an accident evaluated previously in the safety anaysis report?**

   NO

   The only accident in Chapter 15 that can potentially be initiated as a result of leaving potential loose parts in the tube bundle is a Steam Generator Tube Rupture (SGTR). In order to bound the potential for a loose part to cause a tube rupture the following three PLP/tube interaction scenarios were evaluated in Section 3.3A, 3.3B, and 3.3C for the objects that remain or could potentially have migrated in the San Onofre Unit 3 steam generators:

3.6 **SAFETY EVALUATION** (Continued)

1. Random Impact Under Influence Of Flow Stream
2. Repeated Impact On Plugged Tubes Causing Tube Collapse Per Ginna Scenario.
3. Wedged Part With Tube Wear

The results of this evaluation concluded the following:

1. Random impacts on tubes should parts migrate are bounded by ABB-CE prototypical lab studies. Insignificant tube wall degradation occurs.

2. Objects are too small to cause a Ginna type scenario.

3. A wedged part with tube wear will result in significant leakage prior to a tube rupture. Normal plant monitoring of steam generator tube leakage combined with actions required by Technical Specification 3.4.5.2 (Reference 3) ensure that the PLPs will not increase the probability of a SGTR via wedged wear.

Thus, evaluation of scenarios 1 and 2 for the loose parts indicate no potential for these objects to initiate a tube leak or rupture. Further, evaluation of scenario 3 for the loose parts indicates it is unlikely that these foreign objects would cause tube damage of a type that could not be controlled by normal refueling inspections and/or would result in a tube rupture without significant prior leakage.

The SGTR analysis in Chapter 15.6 of the FSAR assumes a double-ended guillotine break of one tube and an initial leak rate in excess of 300 gpm. The potential for a steam generator tube rupture event resulting from the damage identified by the loose parts is considered to be negligible based on the assessment of each part. The worst case event considered to be a result of leaving the objects in place is a small, detectable, and stable tube leak. Therefore, the probability of a SGTR accident as defined in Chapter 15 of the UFSAR is not increased.

2. **May the proposed activity increase the consequences of an accident evaluated previously in the safety analysis report?**

NO

Should tube wear from a remaining PLP result in a tube rupture, the consequences of this occurring would be bounded by existing analysis for the SGTR accident.

The SGTR analysis described in Chapter 15.6 of the San Onofre Final Safety Analysis Report (FSAR) assumes a double-ended guillotine break of one tube and an initial leak rate in excess of 300 GPM. Leak rates associated with through-wall wear defects have been shown to be less than 1 GPM even under accident conditions (differential pressures as high as 1760 psid).

Further, in the unlikely event that a small leak does develop, the leak detection and leak response capabilities of San Onofre provides as close as possible real time information on the rate of increasing leakage. Operations procedures are currently in place at San Onofre Units 2 & 3 to identify and respond to the potential development of steam generator tube leaks. The leakage monitoring program, as discussed in Section 2.4, further ensures that a leak will not propagate into a design basis SGTR event.

Thus, the presence of the potential loose objects on the secondary side of the steam generator will not increase the consequences of a SGTR as currently described in the FSAR.

3. **May the proposed activity increase the probability of occurrence of a malfunction of equipment important to safety evaluated previously in the safety analysis report?**

NO

PLPs remaining in the steam generator will not prevent the steam generator from performing its function to remove decay heat from the RCS for cooldown of the plant.

Should leakage occur, procedures are in place to prevent continued plant operation with excessive tube leakage. Thus, any leakage induced by these PLPs will not prevent the steam generators from performing their safety related function of removing decay heat.

Thus, leaving loose parts in the steam generator will not increase the probability of occurrence of a malfunction of equipment important to safety evaluated previously in the safety analysis report.

4. **May the proposed activity increase the consequence of a malfunction of equipment important to safety evaluated previously in the safety analysis report?**

NO

Leaving PLPs in the steam generator will not prevent the steam generators from performing their safety related function of removing heat generated in the RCS. Also, compliance with plant procedures and the Technical Specifications ensure that the plant will not be allowed to operate with excessive tube leakage. Further, the steam generators do not directly interact with other equipment important to safety.

Thus, leaving PLPs in the steam generator will not increase the consequences of a malfunction of equipment important to safety evaluated previously in the safety analysis report.

5. **May the proposed activity create the possibility of an accident of a different type than any evaluated previously in the safety analysis report?**

NO

The only impact that these PLPs can potentially have on plant operation is to induce steam generator tube leakage. The impact of this is bounded by the SGTR analysis. Also, as discussed below, the occurrence of a tube rupture concurrent with another previously analyzed accident or multiple tube ruptures is not credible.

Multiple tube ruptures are not considered credible based on the expectation of significant leakage occurring prior to a rupture as discussed in response to question 1 above. Further, because of the irregular shape of this debris, a range of wear patterns/rates would exist. The wear caused by the PLPs would thus be different for each tube/PLP interaction. Consequently, two or more tubes would not be expected to reach a condition that would allow for concurrent tube ruptures.

Per NUREG-0844, (Reference 10) all domestic SGTR events to date have involved a single tube. The report further states that it is highly improbable that two or more tubes could rupture simultaneously as a true "initiating" event during normal steady-state operation in view of random differences in flaw geometries, and therefore in pressure-retaining capabilities, which exist from tube to tube. Rupture of two or more tubes are credible only as a consequence of a plant transient or accident when the loading on the tubes becomes more severe.

However, consideration of a PLP creating a condition of tube wear that could rupture during the transient conditions of an accident (thus potentially causing a new or different accident than

previously analyzed) is not considered credible for the seven objects currently in the Unit 3 steam generators. This scenario is bounded by ABB-CE analysis (References 7 & 11). These analyses determined the allowable defect size for any tube in the steam generator after accounting for stresses that could occur in the tubes from a Loss of Coolant Accident (LOCA) or Main Steam Line Break (MSLB) accident conditions in combination with Safe Shutdown Earthquake (SSE) loads. Based on the results of these analyses, it was shown that for all the tubes in the San Onofre steam generators the allowable tube wall degradation is 64%.

As previously discussed in Section 3, the maximum predicted wear rate for a PLP in the steam generator is conservatively estimated to be less than 64%. All inservice tubes currently showing PLP indications do not have any detectable degradation. Thus, it is reasonable to assume that if wear should occur or if the part migrates and wear is initiated at a new preferred location that the wear rate would be less than the steam generator tube wall acceptance criteria for the next plant operating cycle. Therefore, a tube rupture as a result of wear from these loose parts concurrent with an accident is not considered credible and is bounded by the results of the ABB-CE analysis.

Further, as previously discussed in Section 3, ABB-CE has performed prototype laboratory testing to empirically determine the leak rate from defects that were intended to simulate wear defects produced by tube supports. The wear patterns produced by these supports is similar to the wear profiles seen from loose parts in steam generator 3E088. The results of these tests demonstrate that even once a small leak has been initiated the transient conditions of an accident will only result in a maximum leak rate of less than 1 gpm. Thus, once a leak has been initiated the defect will not result in significant leakage or tube rupture during transient conditions of an accident.

Therefore, operation of Unit 3 with the known loose parts will not create the possibility of an accident of a different type than any evaluated previously in the safety analysis report.

6. **May the proposed activity create the possibility of a malfunction of equipment important to safety of a different type than evaluated previously in the safety analysis report?**

NO

The only possible impact that the PLPs can have on operation of the steam generator is to create a steam generator tube leak. As discussed in response to Question 3, the PLPs will not impact the

ability of the steam generator to remove RCS heat nor impact the operation of any other equipment important to safety.

Therefore, leaving PLPs in the steam generators will not create the possibility of a malfunction of equipment important to safety of a different type than evaluated previously in the safety analysis report.

7. **Does the proposed activity reduce the margin of safety as defined in the basis for any technical specification?**

NO

Technical Specification 3.4.5.2c limits the total primary-to-secondary leakage through all steam generators to 1 gpm and 720 gallons per day through any one steam generator.

Leaving PLPs in the steam generator will not impact the leakage limits established by this specification nor will the PLPs impact any plant equipment used to monitor/measure primary-to-secondary steam generator leakage.

The wear rates anticipated are within the 64% design criteria as determined in Reference 11. The 64% criteria is the bases for the 44% tube plugging criteria discussed in TS 3/4.4.4 Bases (Reference 2).

Further, the PLPs will have no impact on the ability of the steam generators to remove heat generated in the RCS.

Therefore, leaving PLPs in the steam generator will not reduce the margin of safety as defined in the basis for any technical specification.

3.7 CONCLUSIONS

Based on the SCE and ABB-CE engineering evaluation and Eddy Current Testing results, SCE concludes that:

1. The foreign objects in the 3E088 and 3E089 steam generators are small with the largest part weighing less than four ounces.

2. The most likely effect of leaving the foreign objects in the SONGS steam generators is continued wearing in their current location. The predicted loose parts wear for the next operating cycle is less than the allowable tube degradation criteria.

3. Should the parts become dislodged, the most credible sequence of events would be movement to another "wear conducive" location, and initiation of new wear on active steam generator tubes. The tube wear in the new location would be bounded by the current wear predictions, and consequently, would be identified by future ECT prior to a steam generator tube leak.

4. In the unlikely event that a leak might develop, it would be detected early and would remain stable during normal and postulated accident conditions and would allow for a timely, controlled shutdown as required by Technical Specification 3.4.5.2.

5. It is unlikely that the five objects identified in 1990, but not seen in 1993, still remain in the steam generators. However, if they do, the wear would be bounded by the predicted wear of the current loose parts.

6. None of the objects are large enough to cause a Ginna-type failure.

7. Leaving the parts in the Unit 3 steam generators is not a safety concern and does not constitute an unreviewed safety question.

4.0 REFERENCES

1. UFSAR Section 15.6.3.2, "Steam Generator Tube Rupture"
2. Technical Specification 3/4.4.4, "Steam Generators and Bases"
3. Technical Specification 3/4.4.5, "RCS Leakage"
4. CENC 1278, "Investigation of the Effects of a Tube Guide in a San Onofre Steam Generator," dated December 10, 1976
5. CENC 1381, "Evaluation of Potential Loose Parts in the Millstone II Steam Generators," Revision 1 dated August 11, 1980
6. CR-9417-CSE93-1126, Draft "Evaluation of Potential Loose Objects On The Secondary Side of San Onofre Unit 3 Steam Generators".
7. CENC 1327, "San Onofre Steam Generator Pipe Break Accident Analysis," dated May 26, 1978
8. CENC 1698, "Leak Rate and Burst Tests of Steam Generator Tubes with a Simulated Wear Condition from Vertical Supports," dated July 1985
9. CEN-299(S), "SONGS Unit 2, Evaluation Of Steam Generator Tube And Diagonal Spacer Strip Interaction And Wear," dated March 1985
10. NUREG-0844, "NRC Integrated Program for the Resolution of Unresolved Safety Issues A-3, A-4, A-5 regarding Steam Generator Tube Integrity," September 1988
11. CENC 1645 "San Onofre Steam Generators Revised LOCA Tube Analysis," July 1984
12. NUREG-0916, "Safety Evaluation Report related to the restart of R.E. Ginna Nuclear Power Plant," May 1982
13. U2-MS-A72, "Evaluation of Foreign Objects in the PVNGS Unit 2 Steam Generators," dated December 17, 1991

APPENDIX A

EDDY CURRENT TEST RESULTS

Table A-1
1990 Eddy Current Test Potential Loose Part Results (3E088)

CUMULATIVE REPORT
04/90, SOUTHERN CALIFORNIA EDISON, SAN ONOFRE, UNIT 3

STEAM GENERATOR: 88
LOCATION: ALL
CRITERIA: PLP

PAGE: 1 OF 1
DATE: 05/22/90
TIME: 14:18:30

ROW	COL	HEAT#	LEG	EXAM EXTENT PROGRAM	EXAM EXTENT ACTUAL	REM	REEL	PROBE	LOCATION	CURRENT VOLTS	MIL	DEG	%	CH
142	72		C	TEC-TEH	TEC-TEH		049	580UL	TSC+ 1.7	3.7		191	PLP	8
144	72		C	TEC-TEH	TEC-TEH		049	580UL	TSC+ 1.6	1.5		178	PLP	8
144	74		C	TEC-TEH	TEC-TEH		049	580UL	01C+ 3.7	4.0		193	PLP	8
143	75		C	TEC-TEH	TEC-TEH		049	580UL	TSC+ 2.7	4.2		36	PLP	8
145	75		C	TEC-TEH	TEC-TEH		049	580UL	TSC+ 3.0	4.0		26	PLP	8
145	87		C	TEC-TEH	TEC-TEH		050	580UL	TSC+ 1.2	4.4		182	PLP	8
147	87		C	TEC-TEH	TEC-TEH		050	580UL	TSC+ 2.4	1.9		193	PLP	8
144	88		C	TEC-TEH	TEC-TEH		050	580UL	TSC+ 1.5	3.0		186	PLP	8
146	88		C	TEC-TEH	TEC-TEH		050	580UL	TSC+ 2.4	1.6		202	PLP	8
145	89		C	TEC-TEH	TEC-TEH		050	580UL	TSC+ 1.5	2.0		176	PLP	8
147	89		C	TEC-TEH	TEC-TEH		050	580UL	01C+ 9.9	1.5		94	PLP	8
136	106		C	TEC-TEH	TEC-TEH		019	580UL	TSC+ 1.0	1.4		163	PLP	8
138	106		C	TEC-TEH	TEC-TEH		019	580UL	TSC+ 1.9	2.9		192	PLP	8
137	107		C	TEC-TEH	TEC-TEH		052	580UL	TSC+ 1.7	3.0		189	PLP	8
139	107		C	TEC-TEH	TEC-TEH		052	580UL	TSC+ 1.1	2.8		171	PLP	8
143	107		C	TEC-TEH	TEC-TEH		052	580UL	TSC+ 3.7	3.6		187	PLP	8
140	108		C	TEC-TEH	TEC-TEH		052	580UL	TSC+ 1.6	1.6		345	PLP	8
142	108		C	TEC-TEH	TEC-TEH		052	580UL	TSC+ 3.5	3.5		202	PLP	8
129	125		C	TEC-TEH	TEC-TEH		054	580UL	TSC+ 15.6	3.5		330	PLP	4
131	125		C	TEC-TEH	TEC-TEH		054	580UL	TSC+ 15.2	1.4		306	PLP	7

NUMBER OF TUBES SELECTED FROM CURRENT OUTAGE: 20

NO TREND ANALYSIS REQUESTED

Table A-2

1993 Eddy Current Test Potential Loose Part Results (3E088)

CUMULATIVE REPORT

11/93, SOUTHERN CALIFORNIA EDISON, SAN ONOFRE, UNIT 3

STEAM GENERATOR : 88
OUTAGE DATA SET : CURRENT
SELECTION VARIABLES: Percent

DATE: 11/19/93
TIME: 09:52:27

				EXAM EXTENT						CURRENT				
ROW	COL	HEAT#	LEG	PROGRAM	ACTUAL	EXP	CAL	PROBE	LOCATION	VOLTS	MIL	DEG	%	CH
22	4		H	TSH-TSH	TSH-TSH		00024	600RC	TSH+ 0.00	1.06		352	PLP	11
			H	TSH-TSH	TSH-TSH		00032	600RC	TSH+ 0.10	1.33		63	PLP	11
21	5		H	TSH-TSH	TSH-TSH		00032	600RC	TSH+ 0.89	4.32		87	PLP	11
137	67		H	TSH-TSH	TSH-TSH		00050	600RC	TSH+ 0.37	1.86		62	PLP	11
144	84		C	TSC-TSC	TSC-TSC		00003	600RC	TSC+ 0.09to+ 1.24	4.17		0	PLP	11
146	84		C	TSC-TSC	TSC-TSC	6	00084	600RC	TSC+ 0.52	1.06		259	PLP	11
143	85		C	TSC-TSC	TSC-TSC	8	00094	600MR	TSC+ 1.84	2.63		219	PLP	11
			C	TSC-TSC	TSC-TSC	7	00092	600RP	TSC+ 1.59	1.76		44	PLP	11
			C	TSC-TSC	TSC-TSC		00003	600RC	TSC+ 1.48to+ 2.28	0.36		0	PLP	11
			C	TEC-TEH	TEC-TEH		00001	580UL	TSC+ 1.42	7.11		0	PLP	8
145	85		C	TEC-TEH	TEC-TEH		00001	580UL	TSC+ 1.21	0.87		0	PLP	8
			C	TSC-TSC	TSC-TSC	7	00092	600RP	TSC+ 0.03	0.36		73	PLP	11
			C	TSC-TSC	TSC-TSC		00003	600RC	TSC+ 0.01to+ 1.63	3.91		272	[illegible]	11
144	86		C	TEC-TEH	TEC-TEH		00001	580UL	TSC+ 1.13to+ 2.27	0.00		0	PLP	8
			C	TSC-TSC	TSC-TSC	8	00094	600MR	TSC+ 0.71	3.42		87	PLP	11
			C	TSC-TSC	TSC-TSC	8	00094	600MR	TSC+ 0.16	4.76		251	PLP	11
			C	TSC-TSC	TSC-TSC	7	00092	600RP	TSC+ 0.09	1.97		64	PLP	11
			C	TSC-TSC	TSC-TSC		00003	600RC	TSC+ 0.00to+ 2.94	3.82		279	PLP	11
146	86		C	TEC-TEH	TEC-TEH		00001	580UL	TSC+ 1.46to+ 2.27	0.00		0	PLP	8
			C	TSC-TSC	TSC-TSC		00003	600RC	TSC+ 0.47to+ 2.98	4.75		101	PLP	11
141	87		C	TSC-TSC	TSC-TSC		00003	600RC	TSC+ 0.00to+ 0.32	2.00		0	PLP	11
145	87		C	TEC-TEH	TEC-TEH		00001	580UL	TSC+ 2.09	1.81		0	PLP	8
			C	TEC-TEH	TEC-TEH		00001	580UL	TSC+ 0.76	1.45		0	PLP	8
			C	TSC-TSC	TSC-TSC	8	00094	600MR	TSC+ 0.30	2.63		71	PLP	11
			C	TSC-TSC	TSC-TSC	7	[illegible]	600RP	TSC+ 0.24	0.88		62	PLP	11
			C	TSC-TSC	TSC-TSC		00003	600RC	TSC+ 0.04to+ 2.83	3.73		85	PLP	11
147	87		C	TEC-TEH	TEC-TEH		00001	580UL	TSC+ 1.58	0.20		290	PLP	7
			C	TSC-TSC	TSC-TSC	8	00094	600MR	TSC+ 0.31	5.77		246	PLP	11
			C	TSC-TSC	TSC-TSC	7	00092	600RP	TSC+ 0.30	1.97		63	PLP	11
142	88		C	TEC-TEH	TEC-TEH		00001	580UL	TSC+ 1.00	2.42		0	PLP	8
			C	TSC-TSC	TSC-TSC		00003	600RC	TSC+ 0.08to+ 1.54	0.00		0	PLP	11
144	88		C	TEC-TEH	TEC-TEH		00001	580UL	TSC+ 1.51	0.38		0	PLP	8
			C	TSC-TSC	TSC-TSC	7	00092	600RP	TSC+ 1.51	0.49		84	PLP	11
			C	TSC-TSC	TSC-TSC		00003	600RC	TSC+ 0.14to+ 1.30	4.38		105	PLP	11
			C	TSC-TSC	TSC-TSC	7	00092	600RP	TSC+ 0.12to+ 0.76	0.64		274	PLP	11
146	88		C	TSC-TSC	TSC-TSC		00003	600RC	TSC+ 0.19to+ 0.67	3.52		0	PLP	11
			C	TSC-TSC	TSC-TSC	7	00092	600RP	TSC+ 0.18to+ 1.79	0.71		282	PLP	11
141	89		C	TSC-TSC	TSC-TSC	8	00094	600MR	TSC+ 1.49	4.29		91	PLP	11
143	89		C	TEC-TEH	TEC-TEH		00002	580UL	TSC+ 1.15	1.65		0	PLP	8
			C	TSC-TSC	TSC-TSC		00003	600RC	TSC+ 0.03to+ 1.39	0.00		0	PLP	11
145	89		C	TEC-TEH	TEC-TEH		00002	580UL	TSC+ 1.24	0.36		0	PLP	8
			C	TEC-TEH	TEC-TEH		00057	580UL	TSC+ 0.63	3.46		72	PLP	8
			C	TSC-TSC	TSC-TSC		00003	600RC	TSC+ 0.03to+ 0.62	0.00		0	PLP	11
142	90		C	TEC-TEH	TEC-TEH		00002	580UL	TSC+ 1.34	0.31		0	PLP	8
			C	TSC-TSC	TSC-TSC		00003	600RC	TSC+ 0.88to+ 2.55	0.00		0	PLP	11

Table A-2 (continued)
1993 Eddy Current Test Potential Loos‹ Part Results (3E088)

CUMULATIVE REPORT
11/93, SOUTHERN CALIFORNIA EDISON, SAN ONOFRE, UNIT 3

STEAM GENERATOR : 88
OUTAGE DATA SET : CURRENT
SELECTION VARIABLES: Percent

PAGE: 2 OF 2
DATE: 11/19/93
TIME: 09:52:27

ROW	COL	HEAT#	LEG	EXAM EXTENT PROGRAM	ACTUAL	EXP	CAL	PROBE	LOCATION	CURRENT VOLTS	MIL	DEG	%	CH
139	91		C	TSC-TSC	TSC-TSC	8	00094	600MR	TSC+ 1.32	0.95		78	PLP	11
			C	TSC-TSC	TSC-TSC		00003	600RC	TSC+ 1.11to+ 1.42	0.00		0	PLP	11
			C	TSC-TSC	TSC-TSC	7	00092	600RP	TSC+ 0.97to+ 1.41	0.53		330	PLP	11
141	91		C	TEC-TEH	TEC-TEH		00002	580UL	TSC+ 2.14	1.27		0	PLP	8
			C	TSC-TSC	TSC-TSC		00003	600RC	TSC+ 2.14to+ 2.97	0.00		0	PLP	11
143	91		C	TSC-TSC	TSC-TSC		00003	600RC	TSC+ 0.06to+ 1.27	0.00		0	PLP	11
			C	TSC-TSC	TSC-TSC	7	00092	600RP	TSC+ 0.00to+ 0.93	0.37		270	PLP	11
145	91		C	TSC-TSC	TSC-TSC	7	00092	600RP	TSC+ 1.29	1.99		86	PLP	11
144	92		C	TSC-TSC	TSC-TSC		00090	600RP	TSC+ 2.60	1.24		85	PLP	11
141	105		H	TSH-TSH	TSH-TSH		00062	600RC	TSH+ 0.17to+ 0.83	0.68		102	PLP	11
142	106		H	TSH-TSH	TSH-TSH		00061	600RC	TSH+ 0.22	1.13		94	PLP	11
144	106		H	TSH-TSH	TSH-TSH		00062	600RC	TSH+ 0.60	0.66		101	PLP	11

NUMBER OF TUBES SELECTED FROM CURRENT OUTAGE: 27
NUMBER OF DATA RECORDS SELECTED FROM CURRENT OUTAGE: 57

NO TREND ANALYSIS REQUESTED

DATA SELECTION CRITERIA:
Percent: PLP

REPORT OPTIONS:
Only examination results matching criteria are included

Table A-3
1990 Eddy Current Test Potential Loose Part Results (3E089)

CUMULATIVE REPORT
04/90, SOUTHERN CALIFORNIA EDISON, SAN ONOFRE, UNIT 3

STEAM GENERATOR: 89
LOCATION: ALL
CRITERIA: PLP

PAGE: 1 OF 1
DATE: 06/01/90
TIME: 10:01:38

ROW	COL	HEAT#	LEG	EXAM EXTENT PROGRAM	EXAM EXTENT ACTUAL	REM	REEL	PROBE	LOCATION	CURRENT VOLTS	MIL	DEG	%	CH
16	2		C	TEC-TEH	TEC-TEH		044	560SM	TSC+ 14.3	3.0		321	PLP	8
22	2		C	TEC-TEH	TEC-TEH		044	560SM	TSC+ 15.1	3.7		139	PLP	8
1	3		C	TEC-TEH	TEC-TEH		044	560SM	TEH+ 3.5	5.0		186	PLP	8
27	3		C	TEC-TEH	TEC-TEH		044	560SM	TSH+ 10.7	5.3		183	PLP	8
1	55		C	TEC-TEH	TEC-TEH		044	560SM	TSH+ 21.8	7.0		143	PLP	8
1	57		C	TEC-TEH	TEC-TEH		044	560SM	TSH+ 21.9	7.2		159	PLP	8
1	59		C	TEC-TEH	TEC-TEH		044	560SM	TSH+ 21.8	7.3		147	PLP	8
1	63		C	TEC-TEH	TEC-TEH		044	560SM	TSH+ 22.0	8.0		156	PLP	8
141	107		H	TEH-DBH	TEH-DBH		047	580UL	TSH+ 2.3	0.2		0	PLP	8
143	107		H	TEH-DBH	TEH-DBH		047	580UL	TSH+ 0.3 TO+ 5.0	13.5		304	PLP	8
142	108		H	TEH-DBH	TEH-DBH		047	580UL	TSH+ 0.6 TO+ 4.4	1.3		193	PLP	8
			H	TEH-DBH	TEH-DBH		047	580UL	TSH+ 17.2 TO+ 19.2	2.0		355	PLP	8
141	109		H	TEH-DBH	TEH-DBH		047	580UL	TSH+ 19.2	2.6		354	PLP	8
143	109		H	TEH-DBH	TEH-DBH		047	580UL	TSH+ 19.2	3.9		208	PLP	8
142	110		H	TEH-DBH	TEH-DBH		047	580UL	TSH+ 18.6	3.2		254	PLP	8
1	113		C	TEC-TEH	TEC-TEH		046	560SM	TSH+ 21.8	8.3		315	PLP	8
1	115		C	TEC-TEH	TEC-TEH		046	560SM	TSH+ 22.0	8.5		146	PLP	8
1	117		C	TEC-TEH	TEC-TEH		046	560SM	TSH+ 21.5	8.8		141	PLP	8
1	119		C	TEC-TEH	TEC-TEH		046	560SM	TSH+ 22.1	9.0		140	PLP	8
1	123		C	TEC-TEH	TEC-TEH		046	560SM	TSH+ 22.1	7.8		146	PLP	8
1	125		C	TEC-TEH	TEC-TEH		046	560SM	TSH+ 22.1	7.6		144	PLP	8
1	127		C	TEC-TEH	TEC-TEH		046	560SM	TSH+ 21.7	6.8		148	PLP	8
1	129		C	TEC-TEH	TEC-TEH		046	560SM	TSH+ 22.1	6.3		324	PLP	8
1	133		C	TEC-TEH	TEC-TEH		046	560SM	TSH+ 22.2	6.7		161	PLP	8
1	135		C	TEC-TEH	TEC-TEH		046	560SM	TSH+ 22.2	6.3		149	PLP	8
1	137		C	TEC-TEH	TEC-TEH		046	560SM	TSH+ 22.3	5.5		167	PLP	8
1	139		C	TEC-TEH	TEC-TEH		046	560SM	TSH+ 22.4	5.2		157	PLP	8
1	143		C	TEC-TEH	TEC-TEH		046	560SM	TSH+ 22.3	5.2		164	PLP	8
1	145		C	TEC-TEH	TEC-TEH		046	560SM	TSH+ 22.3	4.6		163	PLP	8
1	147		C	TEC-TEH	TEC-TEH		046	560SM	TSH+ 22.4	4.7		161	PLP	8
1	149		C	TEC-TEH	TEC-TEH		046	560SM	TSH+ 22.2	4.1		141	PLP	8

NUMBER OF TUBES SELECTED FROM CURRENT OUTAGE: 30

NO TREND ANALYSIS REQUESTED

Table A-4

1993 Eddy Current Test Potential Loose Part Results (3E089)

CUMULATIVE REPORT

11/93, SOUTHERN CALIFORNIA EDISON, SAN ONOFRE, UNIT 3

STEAM GENERATOR : 89
OUTAGE DATA SET : CURRENT
SELECTION VARIABLES: Percent

PAGE: 1 OF 1
DATE: 11/19/93
TIME: 09:54:08

ROW	COL	HEAT#	LEG	EXAM EXTENT PROGRAM	EXAM EXTENT ACTUAL	EXP	CAL	PROBE	LOCATION			CURRENT VOLTS	CURRENT MIL	CURRENT DEG	CURRENT %	CURRENT CH
115	37		H	TSH-TSH	TSH-TSH		00040	600RC	TSH+	0.03		3.53		76	PLP	11
117	37		H	TSH-TSH	TSH-TSH		00041	600RC	TSH+	0.09TO+	0.78	0.96		83	PLP	11
116	38		H	TSH-TSH	TSH-TSH		00041	600RC	TSH+	0.04to+	0.74	1.27		69	PLP	11
117	39		H	TSH-TSH	TSH-TSH		00041	600RC	TSH+	0.14TO+	0.76	1.19		74	PLP	11
118	136		H	TSH-TSH	TSH-TSH		00074	600RC	TSH+	0.42		2.77		0	PLP	11
117	137		H	TSH-TSH	TSH-TSH		00074	600RC	TSH+	0.68		3.44		259	PLP	11
119	137		H	TSH-TSH	TSH-TSH		00075	600RC	TSH+	0.52		2.02		82	PLP	11
69	163		H	TSH-TSH	TSH-TSH		00076	600RC	TSH+	0.47TO+	1.82	2.10		70	PLP	11
68	164		H	TSH-TSH	TSH-TSH		00077	600RC	TSH+	1.26		0.84		68	PLP	11
65	165		H	TSH-TSH	TSH-TSH		00076	600RC	TSH+	0.34		1.23		72	PLP	11
67	165		H	TSH-TSH	TSH-TSH		00076	600RC	TSH+	0.57		0.51		74	PLP	11
64	166		H	TSH-TSH	TSH-TSH		00076	600RC	TSH+	0.32TO+	1.03	0.35		67	PLP	11

NUMBER OF TUBES SELECTED FROM CURRENT OUTAGE: 12
NUMBER OF DATA RECORDS SELECTED FROM CURRENT OUTAGE: 12

NO TREND ANALYSIS REQUESTED

DATA SELECTION CRITERIA:
Percent: PLP

REPORT OPTIONS:
Only examination results matching criteria are included

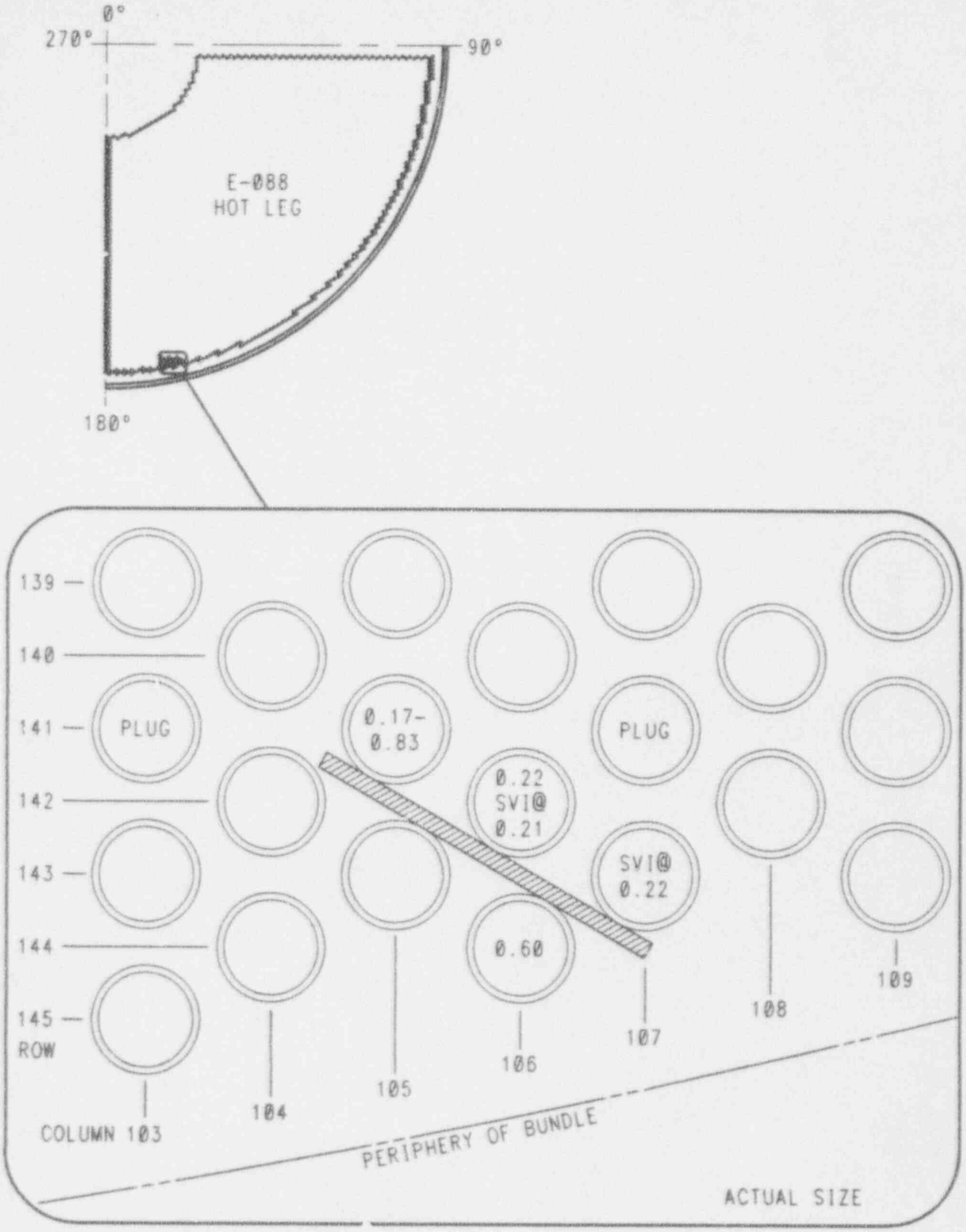
APPENDIX B

MAPS OF LOOSE PART LOCATIONS

Appendix B

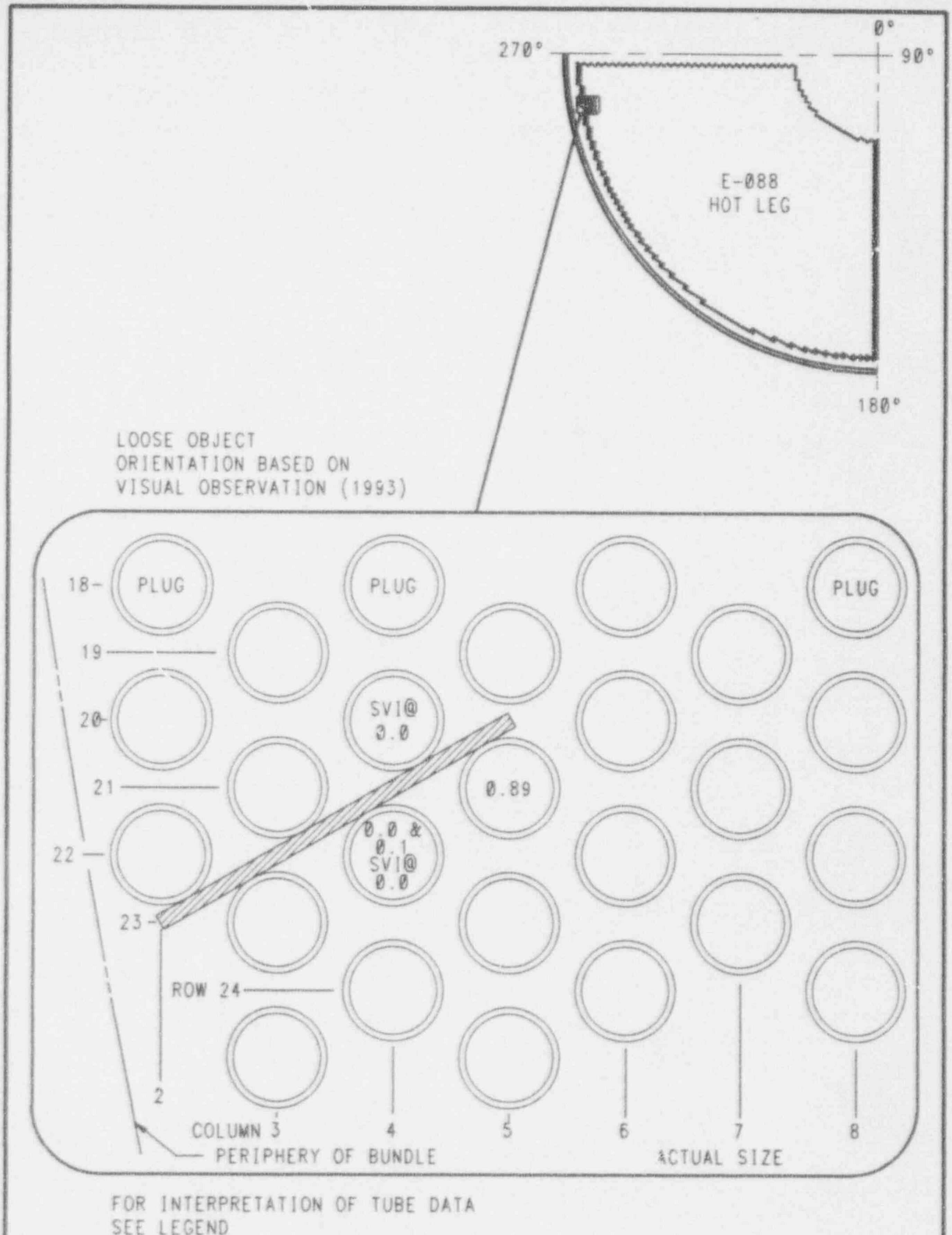
This appendix contains maps showing the location and orientation of loose objects in the steam generators. Codes 1 or 2 can be combined with codes 3 or 4 if both PLP and wear occur. The legend for these maps is as follows:

Code No.	Code	Meaning
1.	xx- yy	Indicates the range of distance of loose objects from the top of the tubesheet, xx, through the contact length, xx-yy
2.	xx	Indicates the point of contact of a loose object at xx from the top of the tubesheet
3.	SVI@ yy	Indicates the height of a Single Volumetric Indication (SVI) at YY from the tubesheet
4.	___% @xx	Indicates a flaw ___% through wall at xx from the top of the tubesheet
5.	PLUG	Indicates the tube was previously plugged

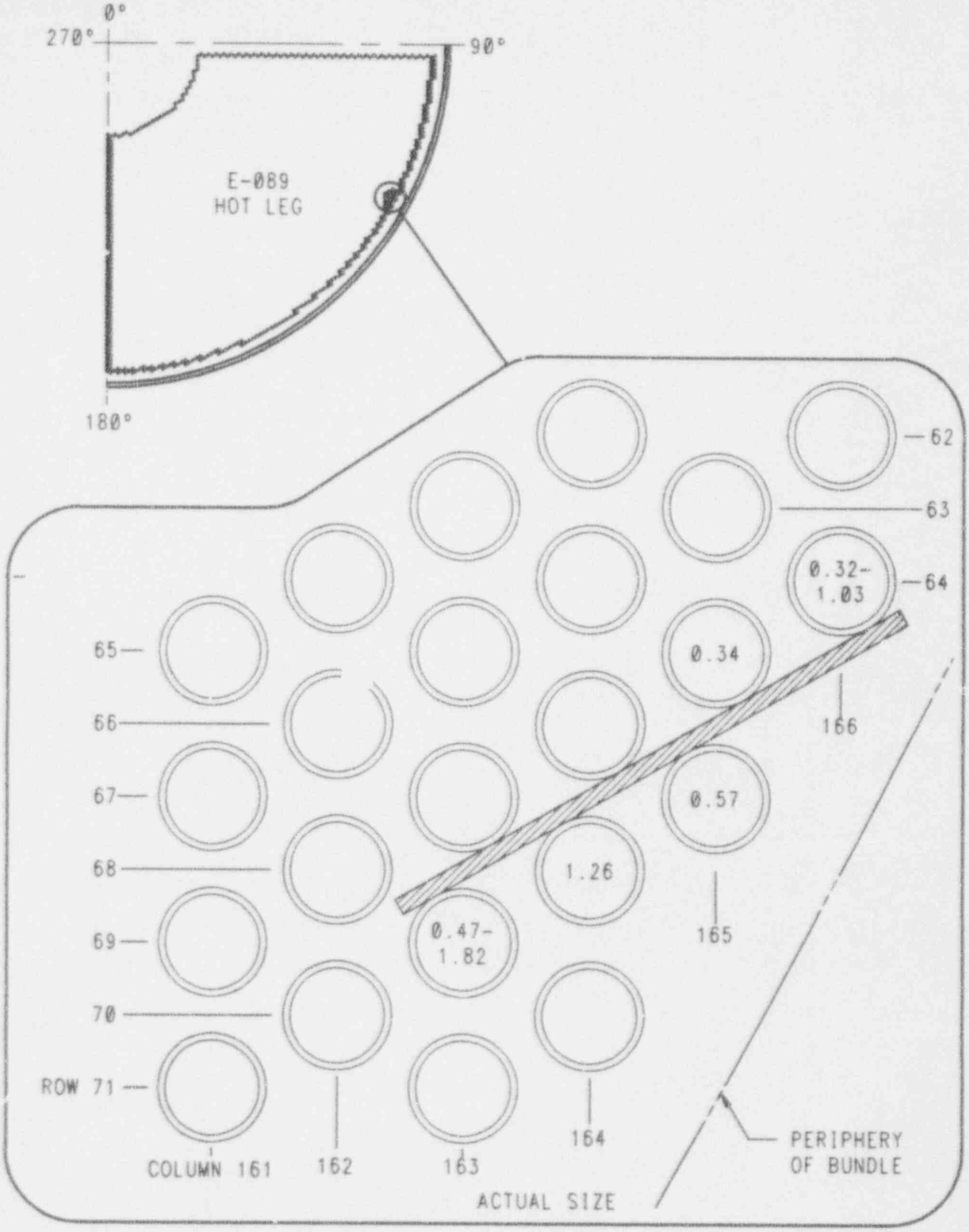


FOR INTERPRETATION OF TUBE DATA
SEE LEGEND

Location of Potent[illegible]l Loose Object 88-1
Figure B-1

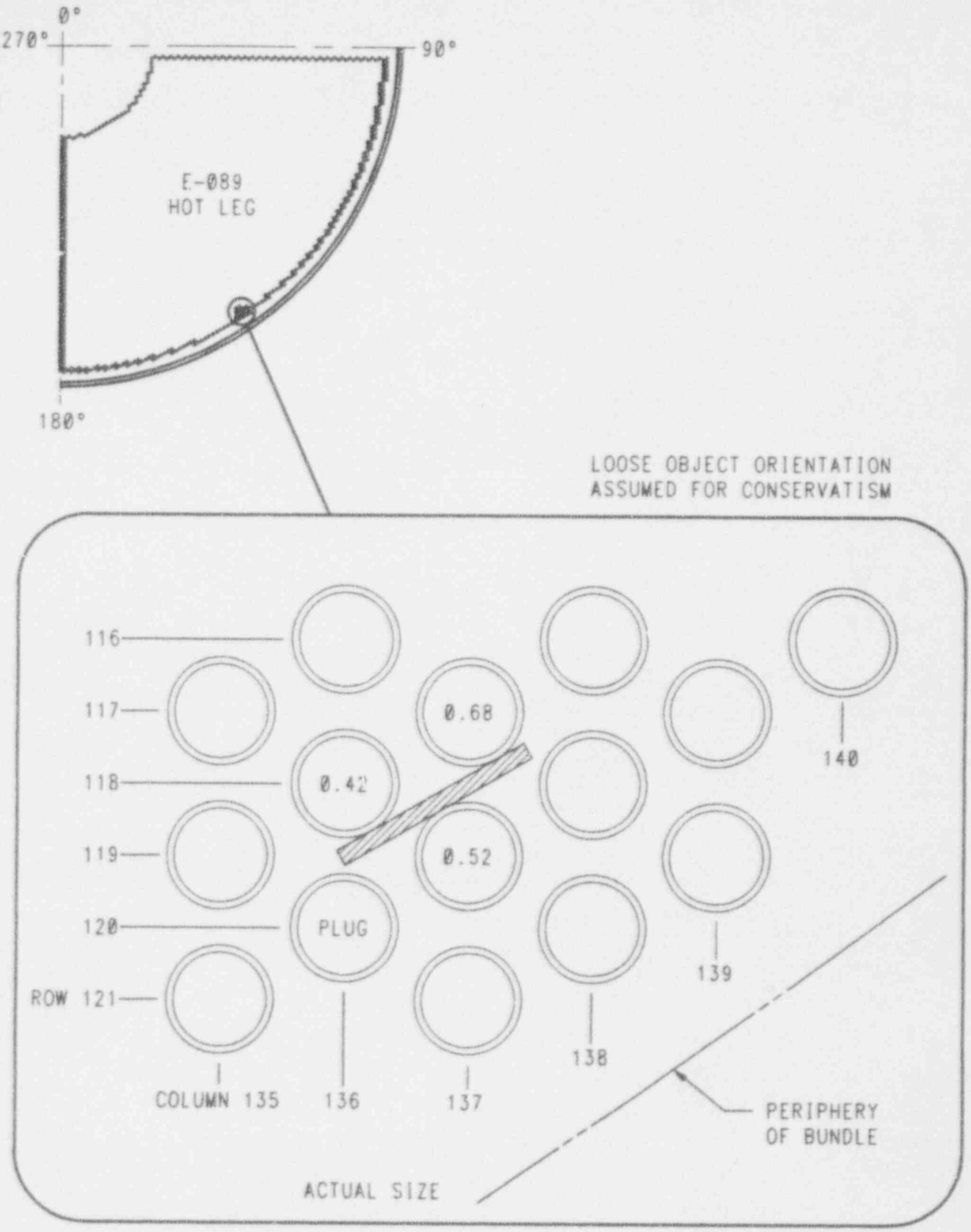


Location of Potential Loose Object 88-2
Figure B-2



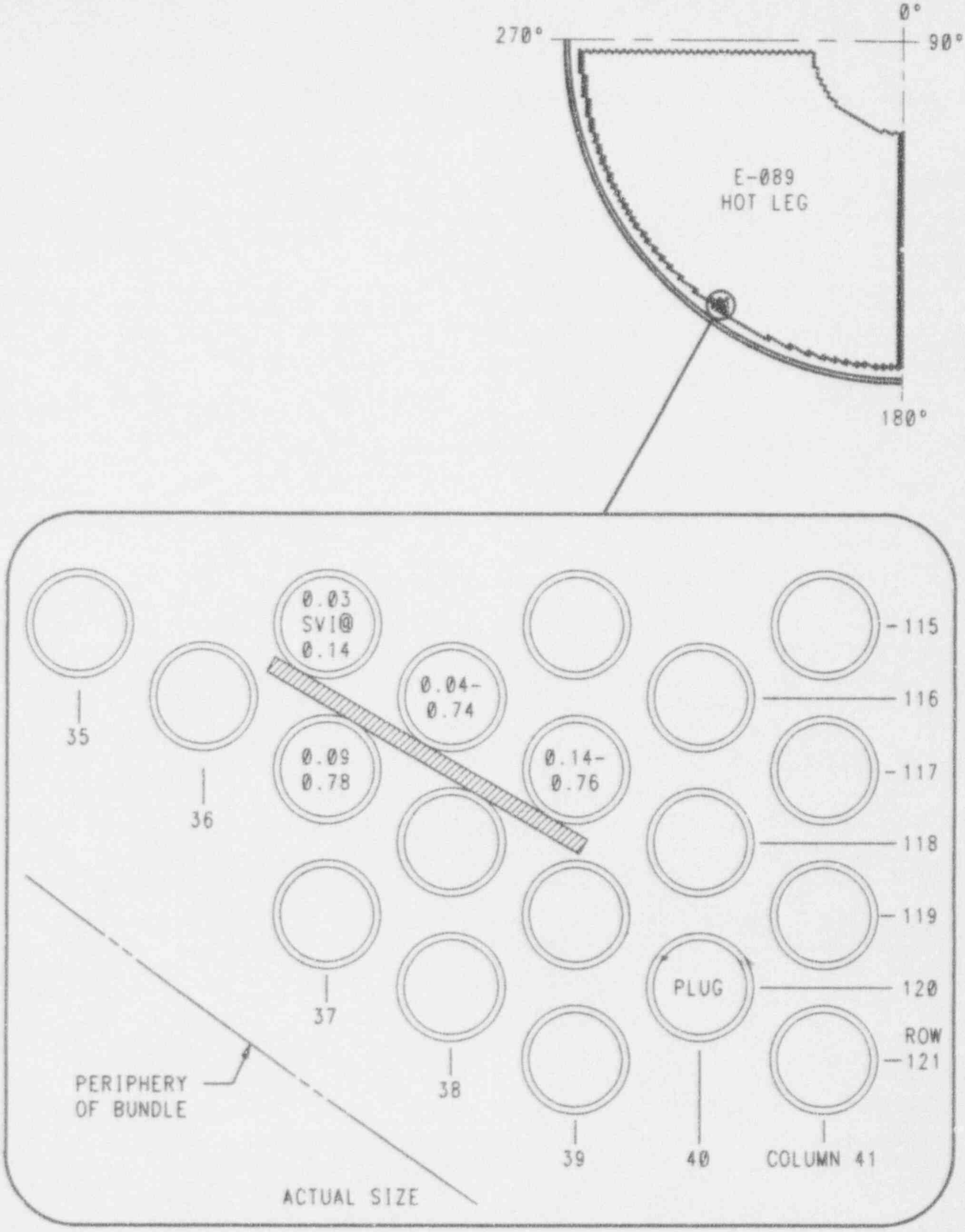
FOR INTERPRETATION OF TUBE DATA
SEE LEGEND

Location of Potential Loose Object 89-1
Figure B-3



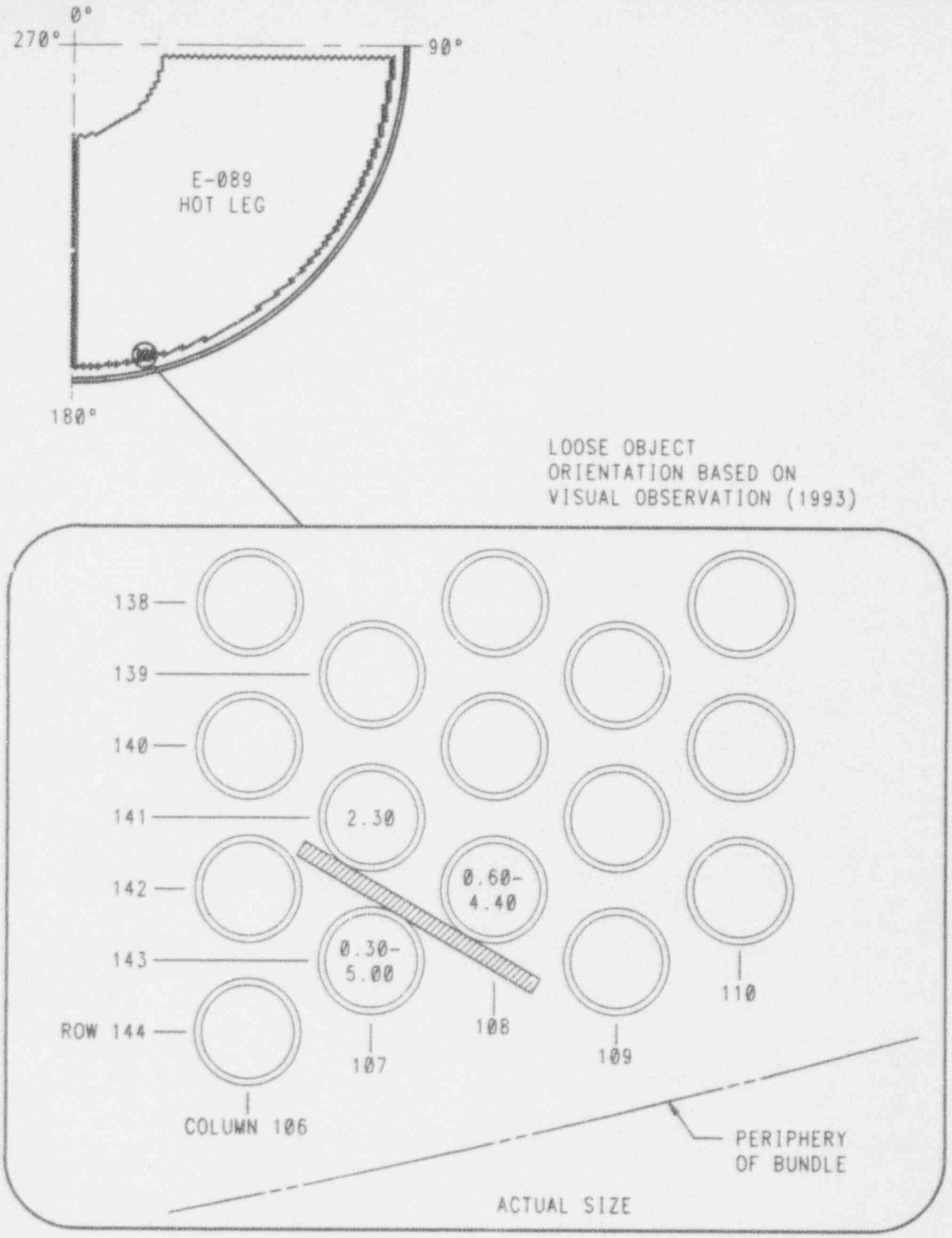
FOR INTERPRETATION OF TUBE DATA
SEE LEGEND

Location of Potential Loose Object 89-2
Figure B-4



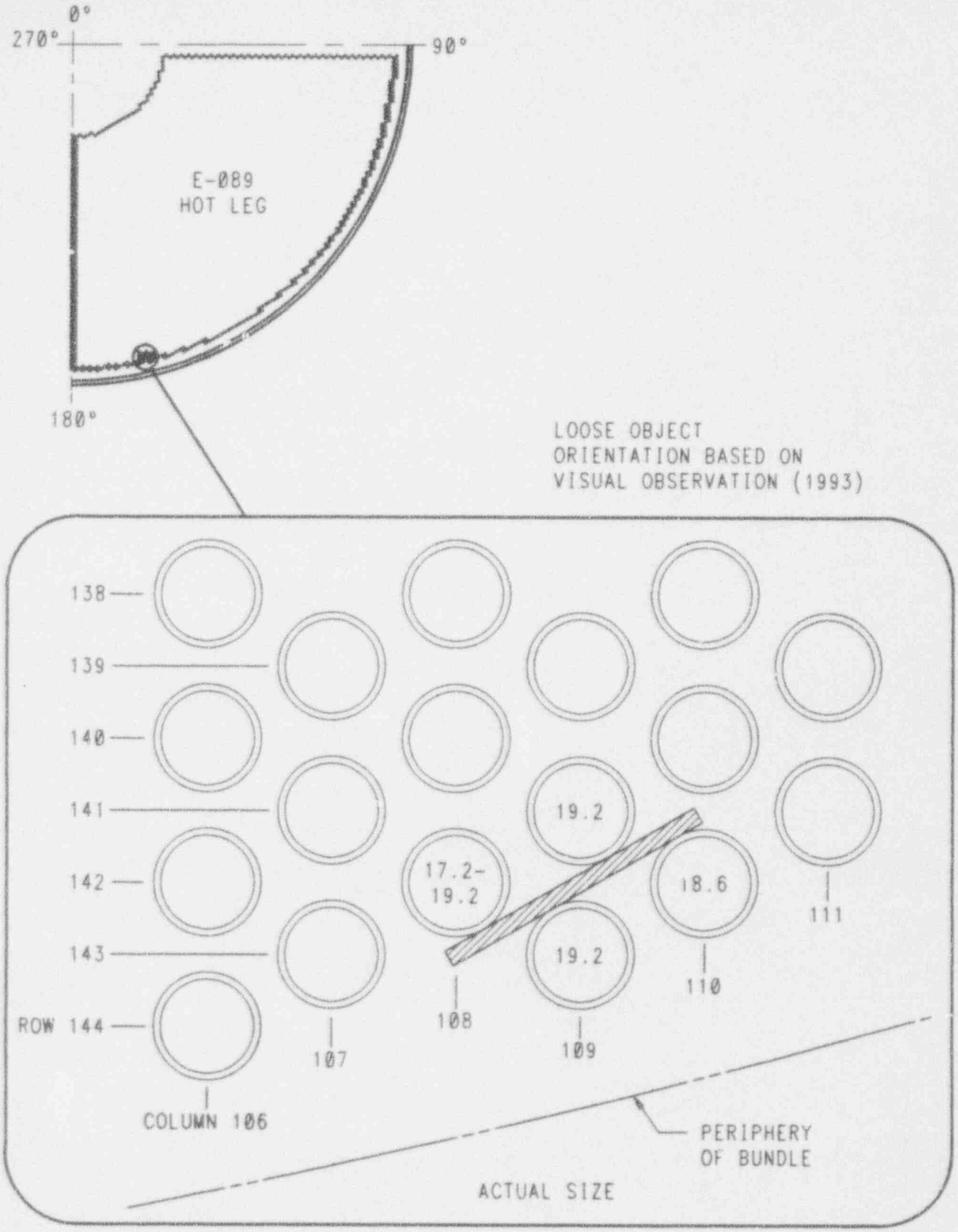
FOR INTERPRETATION OF TUBE DATA
SEE LEGEND

Location of Potential Loose Object 89-3
Figure B-5



FOR INTERPRETATION OF TUBE DATA
SEE LEGEND

Location of Potential Loose Object 89-4
Figure B-6



FOR INTERPRETATION OF TUBE DATA
SEE LEGEND

Location of Potential Loose Object 89-5
Figure B-7

APPENDIX C

EDDY CURRENT WEAR DATA

Figure C-1

C-Scan of RPC Pancake Data for Tube 143-85

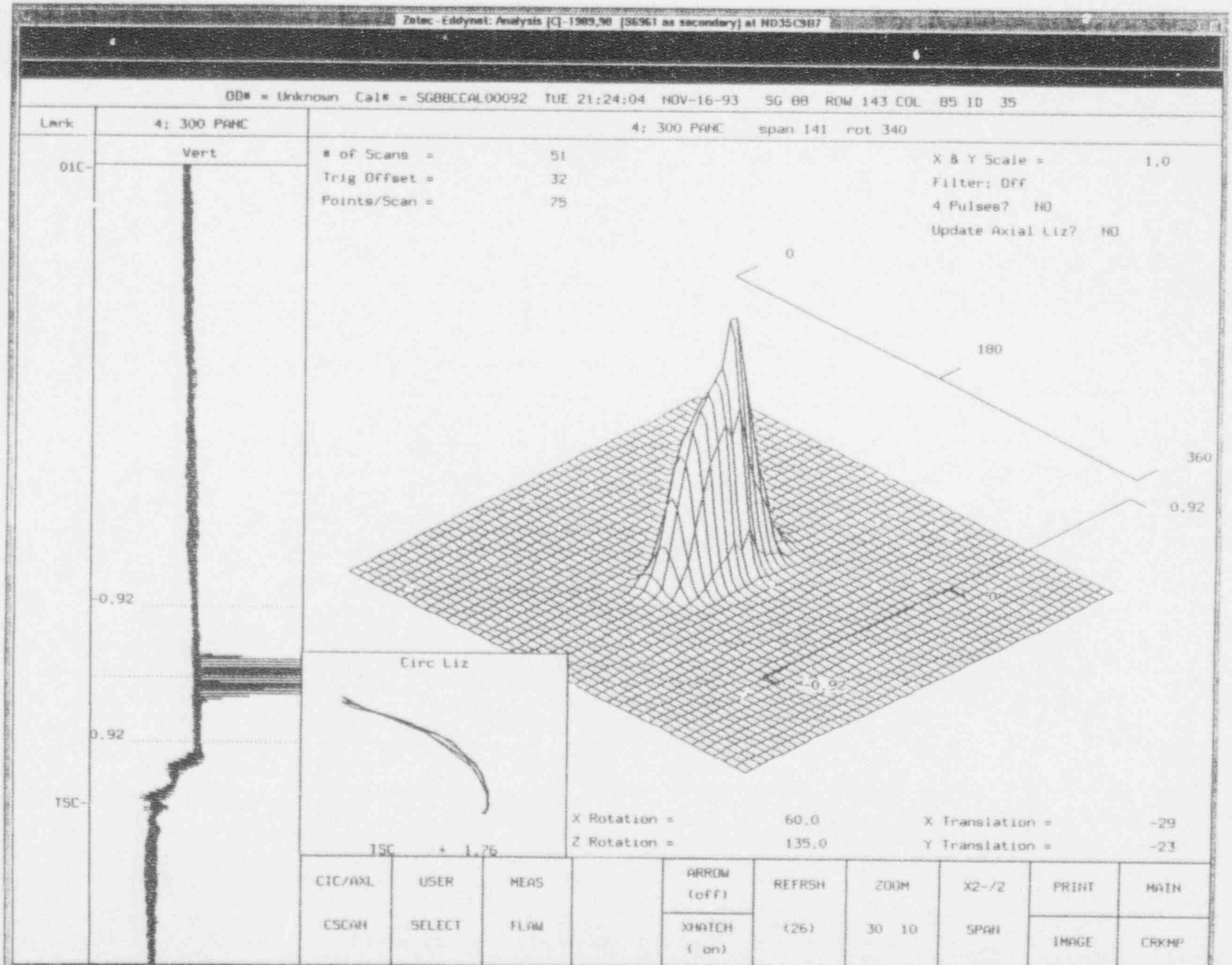


Figure C-2

Axial Profile of RPC Pancake Data for Tube 143-85

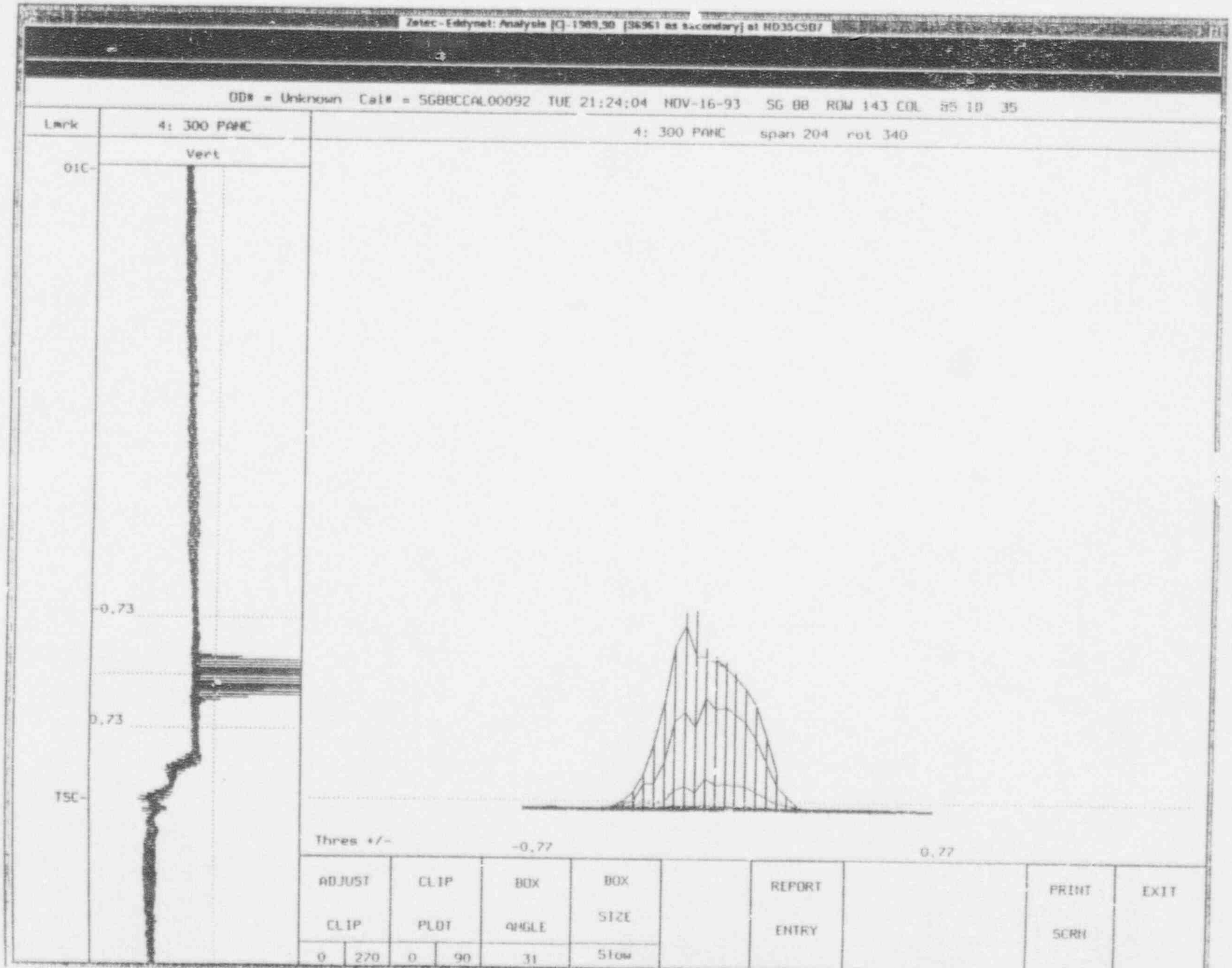


Figure C-3

C-Scan of RPC Pancake Data for Tube 144-86

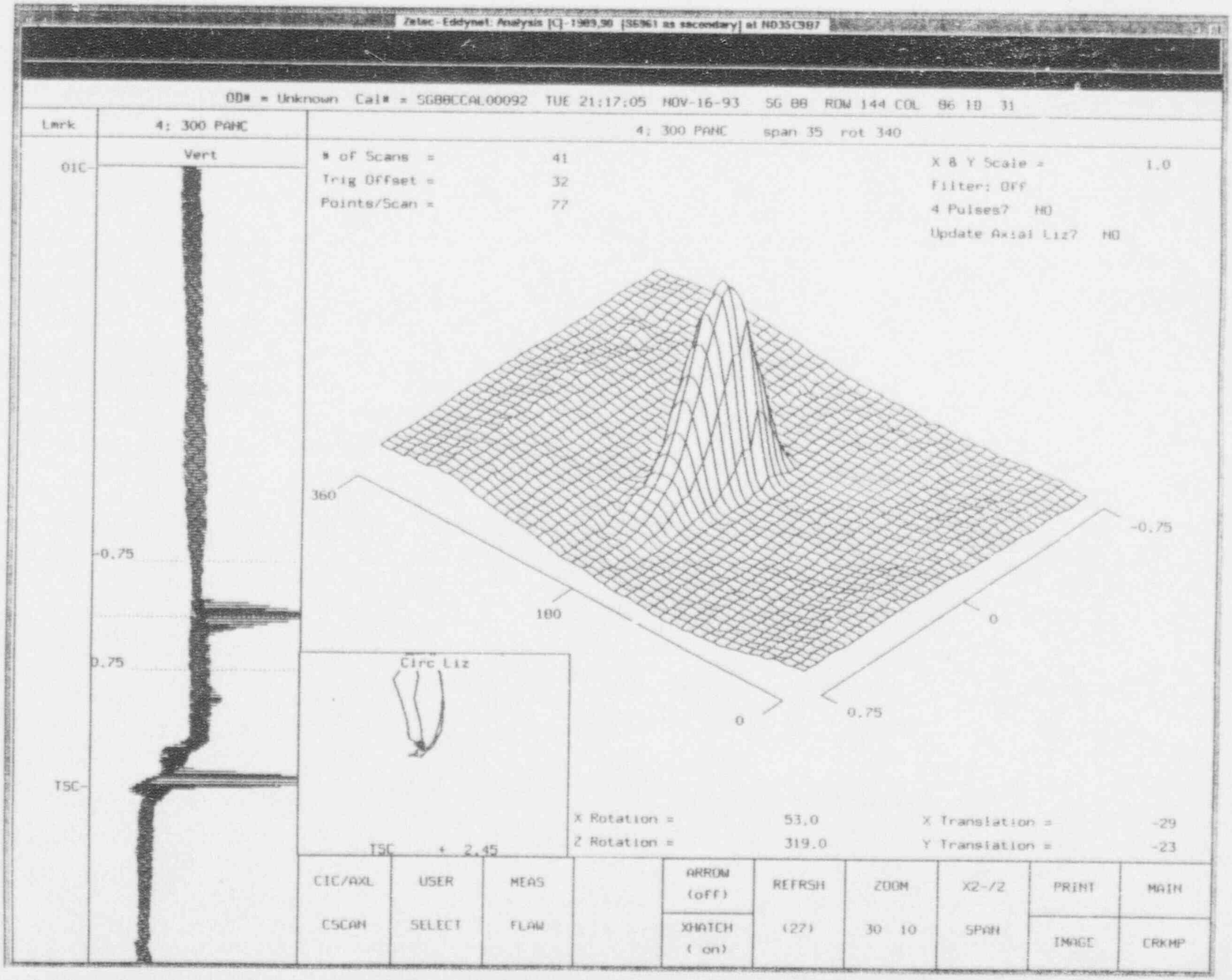


Figure C-4

Axial Profile of RPC Pancake Data for Tube 144-86

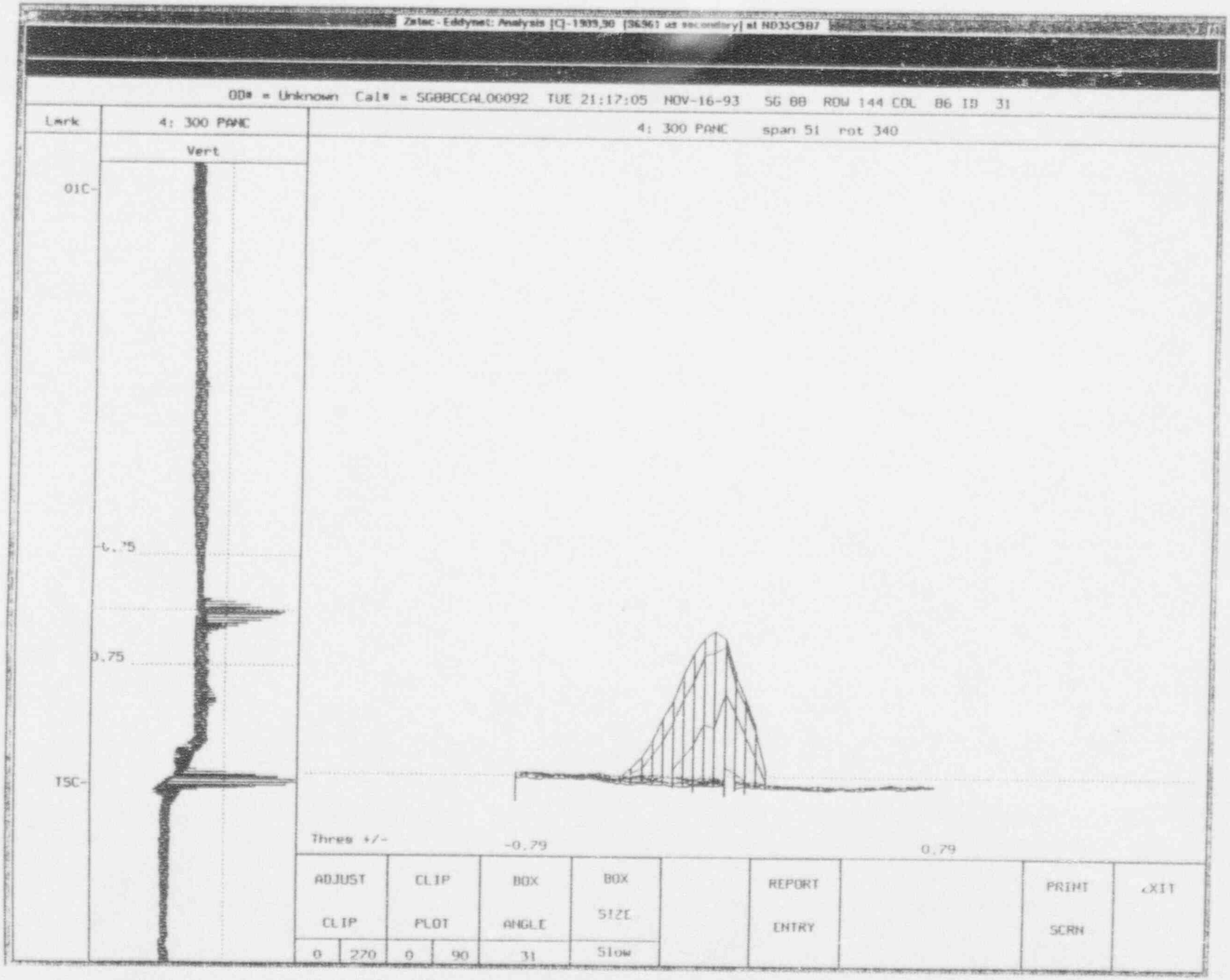


Figure C-5

C-Scan of RPC Pancake Data for Tube 145-87

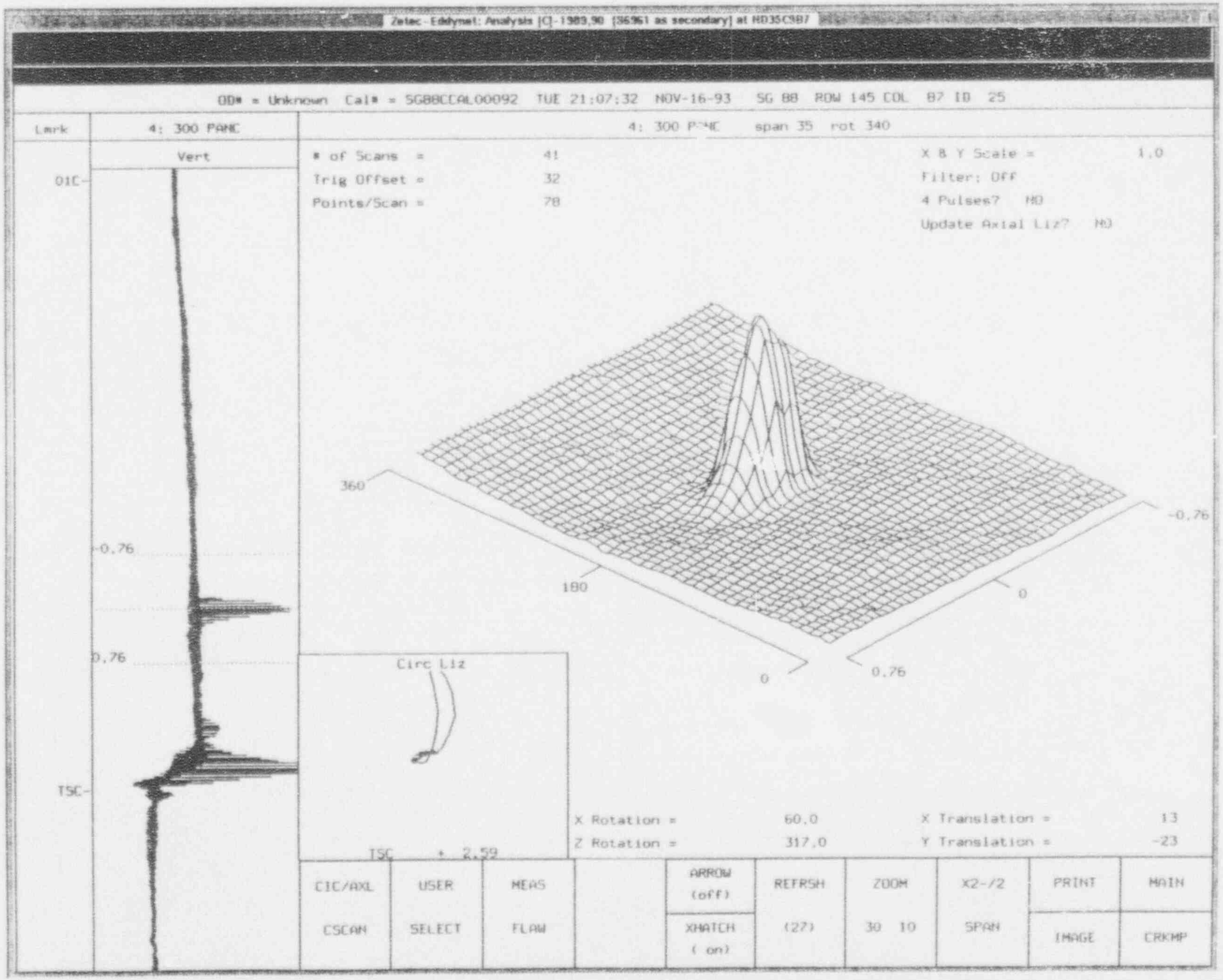


Figure C-6

Axial Profile of RPC Pancake Data for Tube 145-87

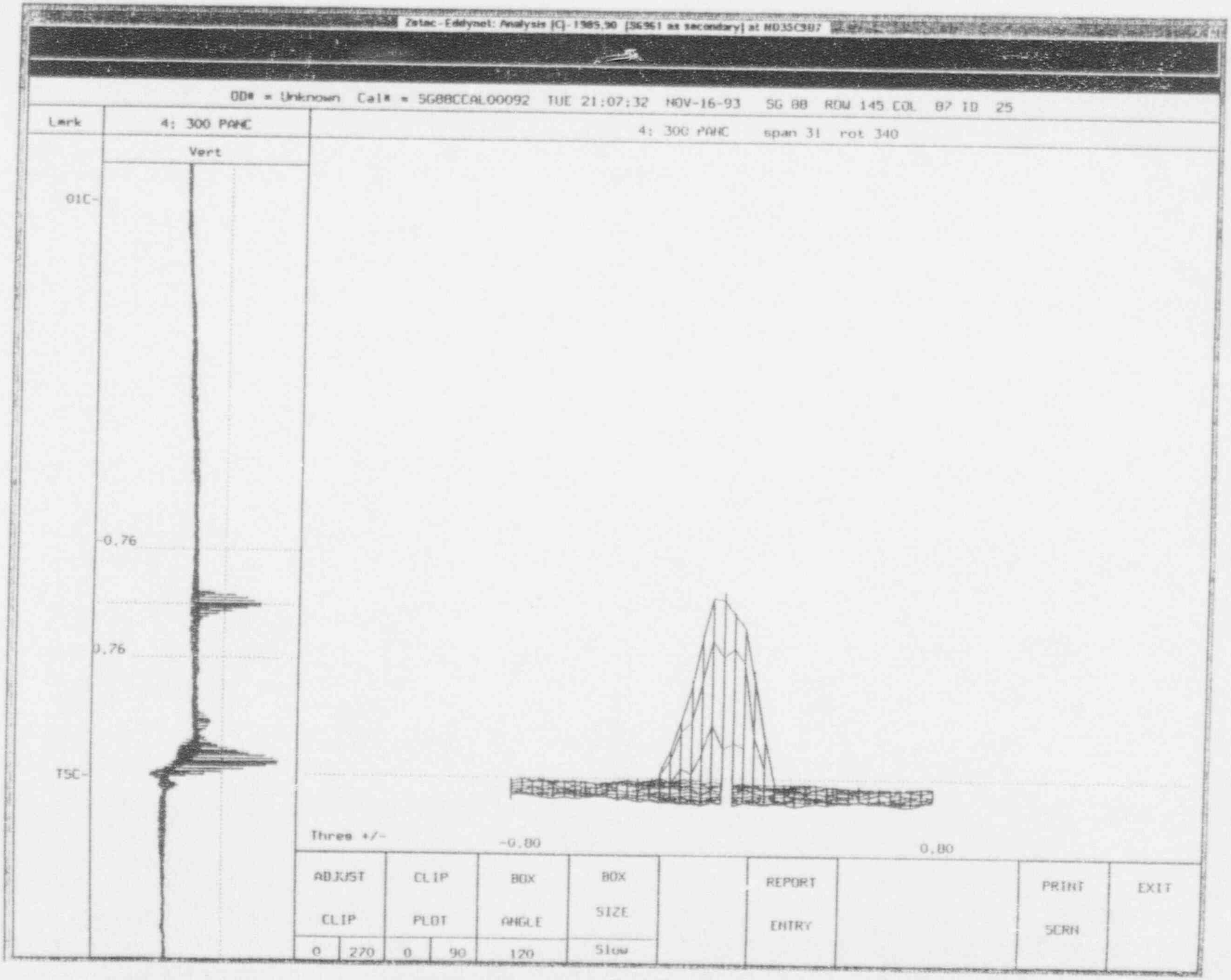


Figure C-7

C-Scan Of RPC Pancake Data for Tube 144-88

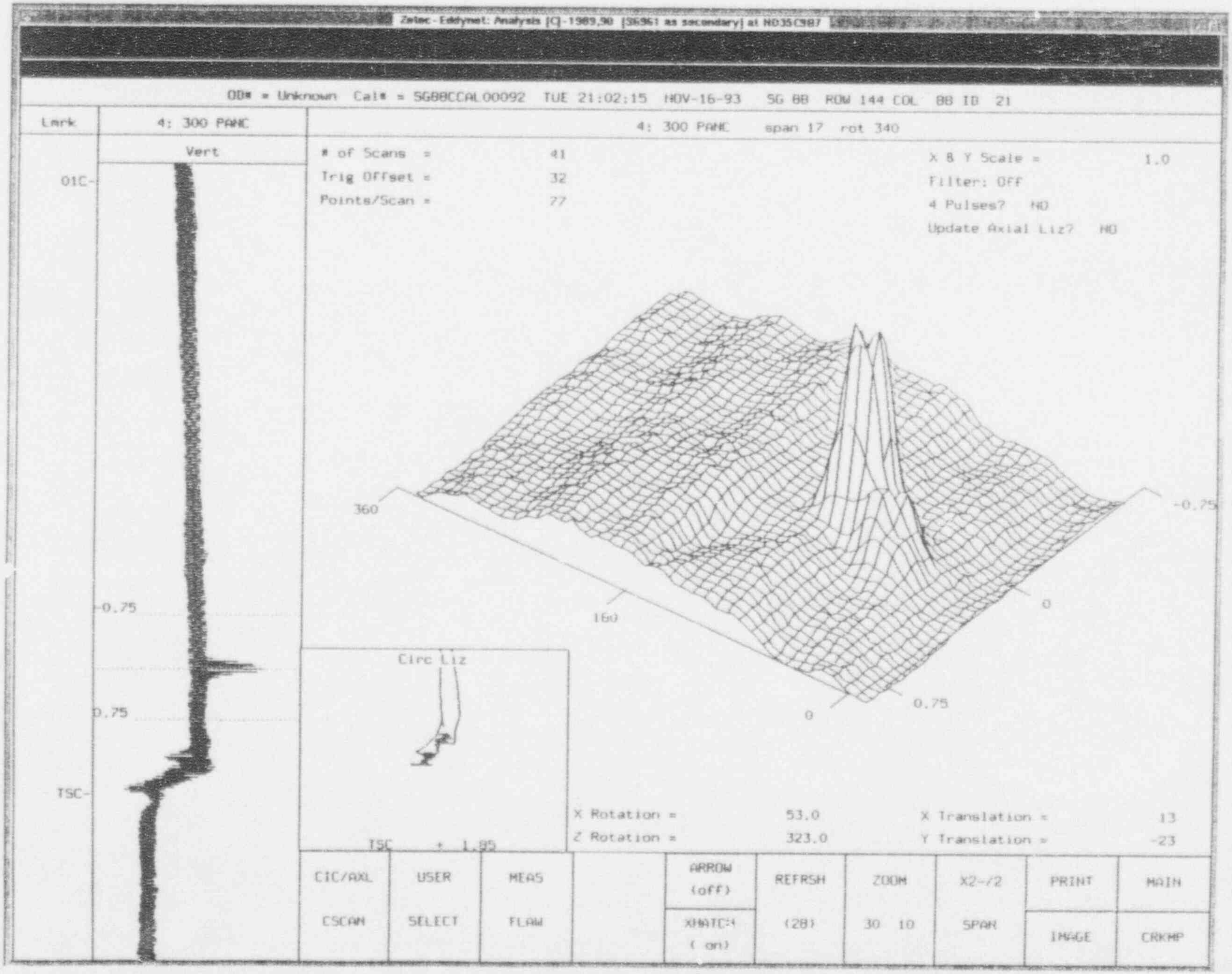


Figure C-8
Axial Profile of RPC Pancake Data for Tube 144-88

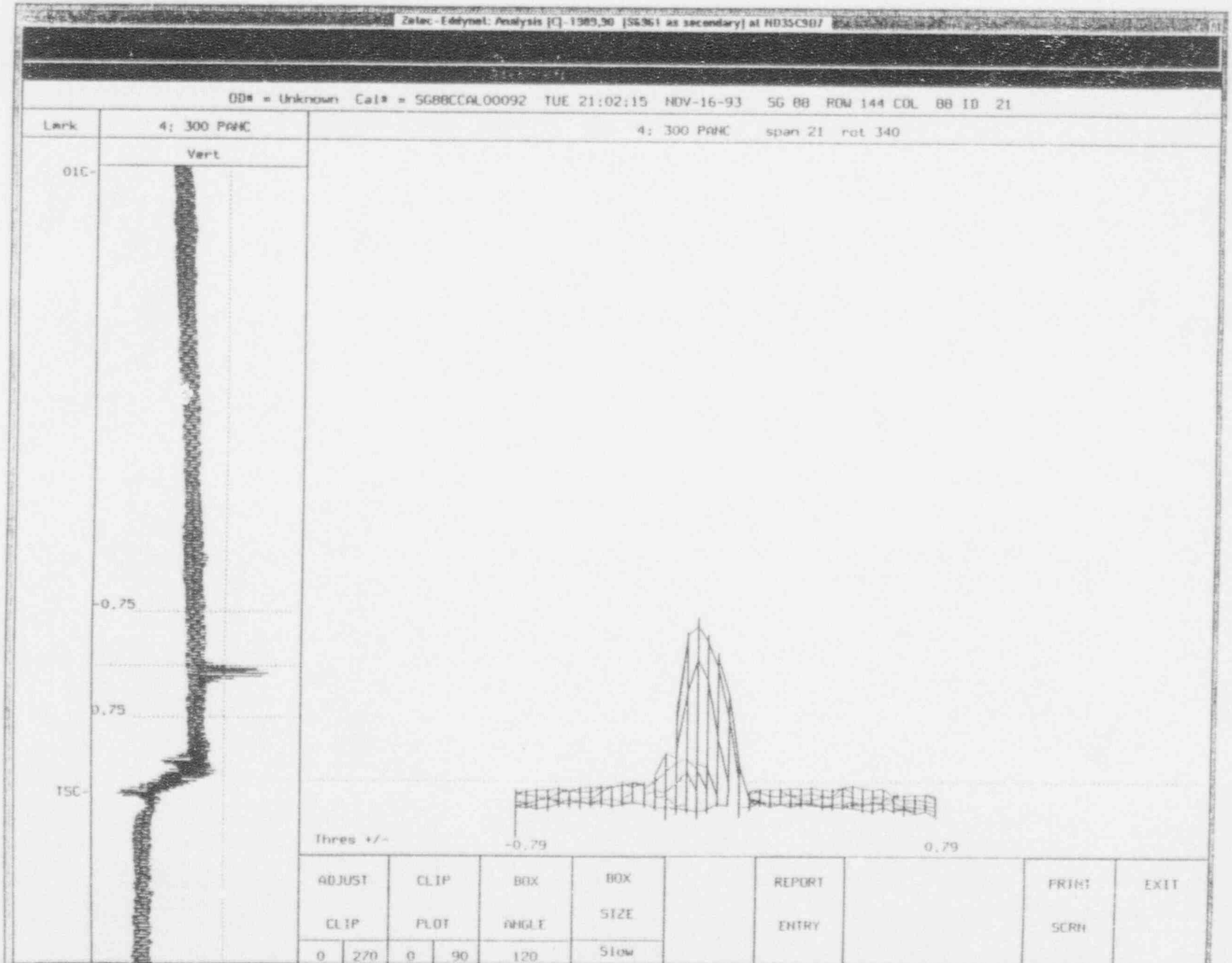


Figure C-9

C-Scan of RPC Pancake Data for 29% Wear Standard

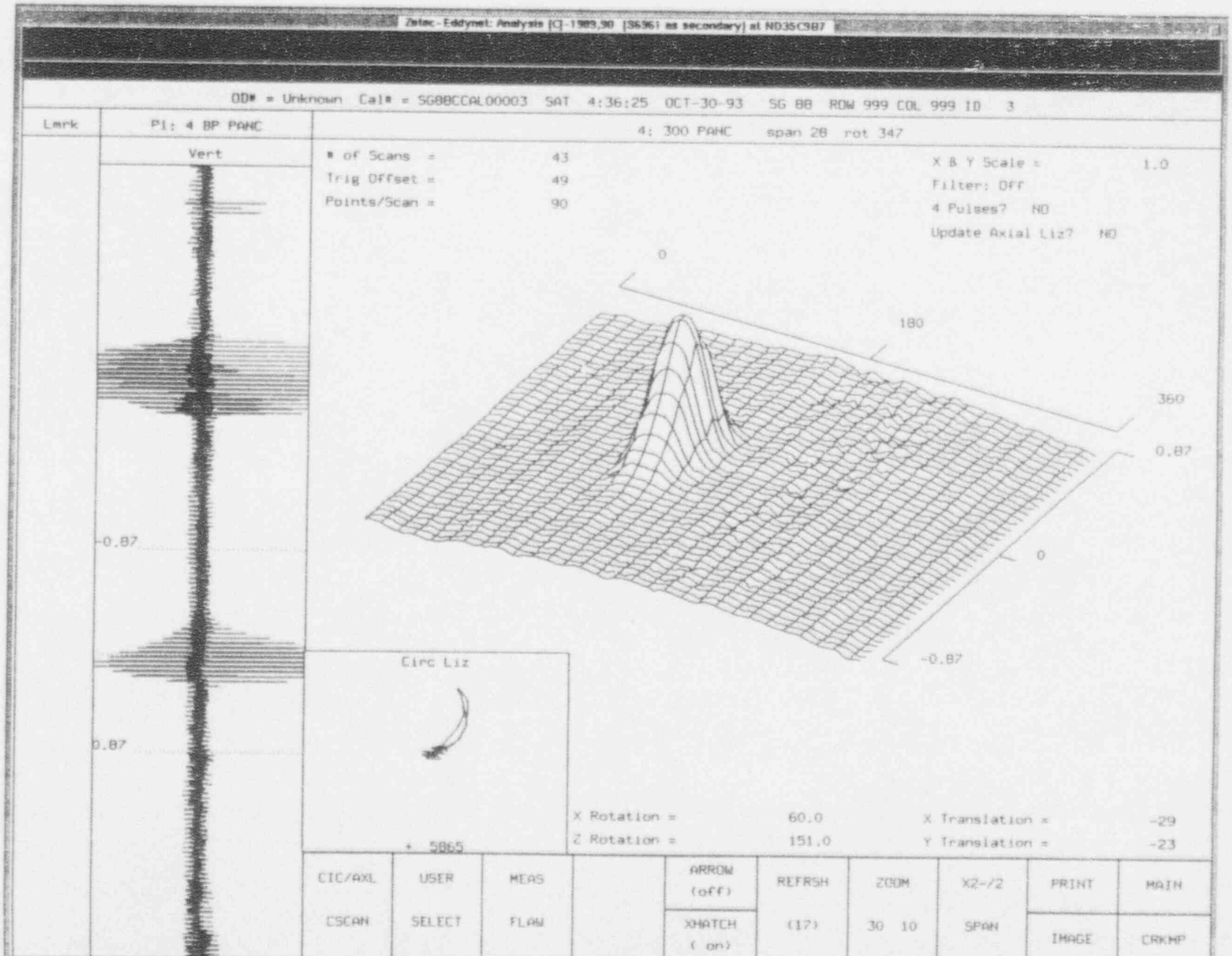


Figure C-10

Axial Profile of RPC Pancake Data for 29% Wear Standard

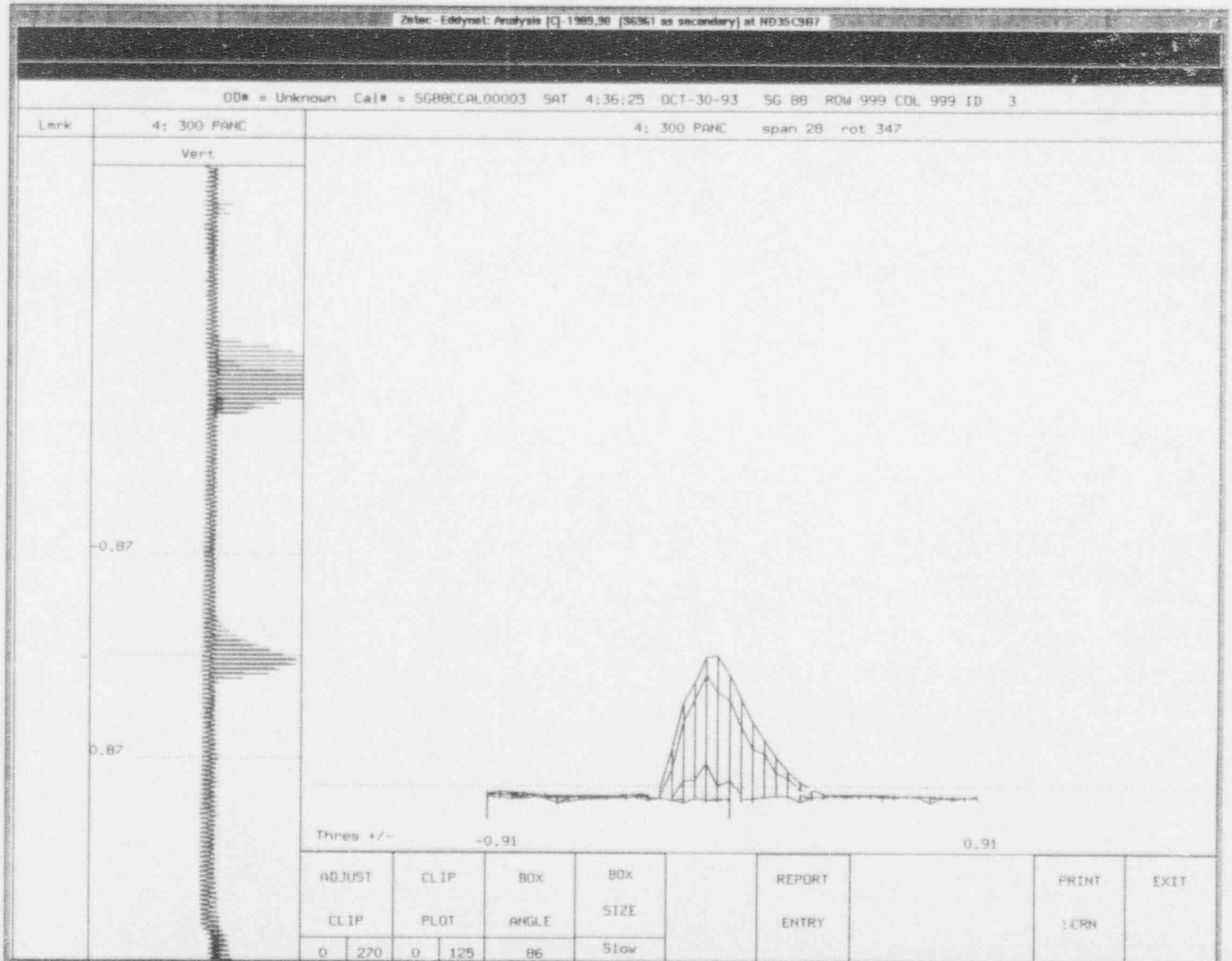
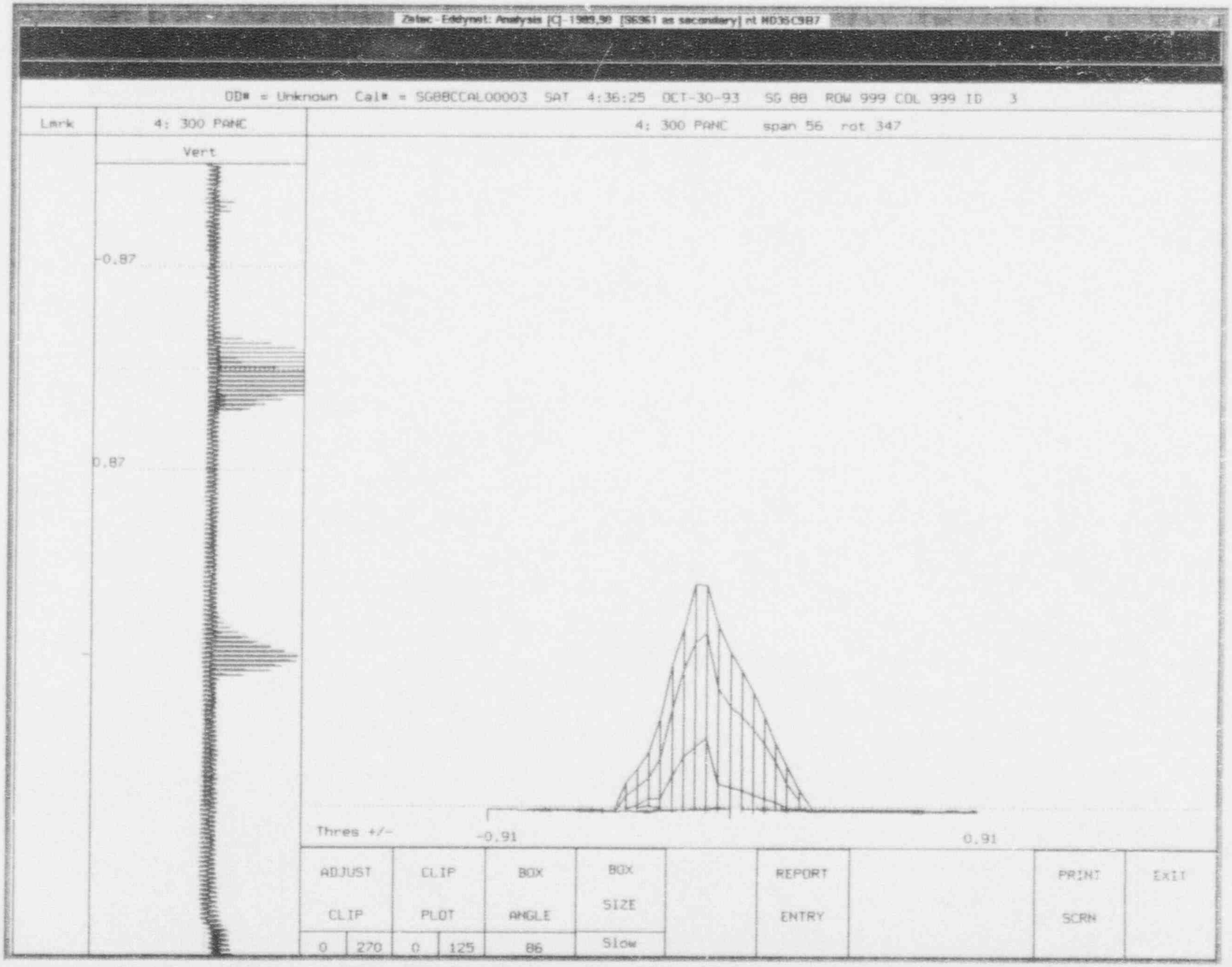


Figure C-11

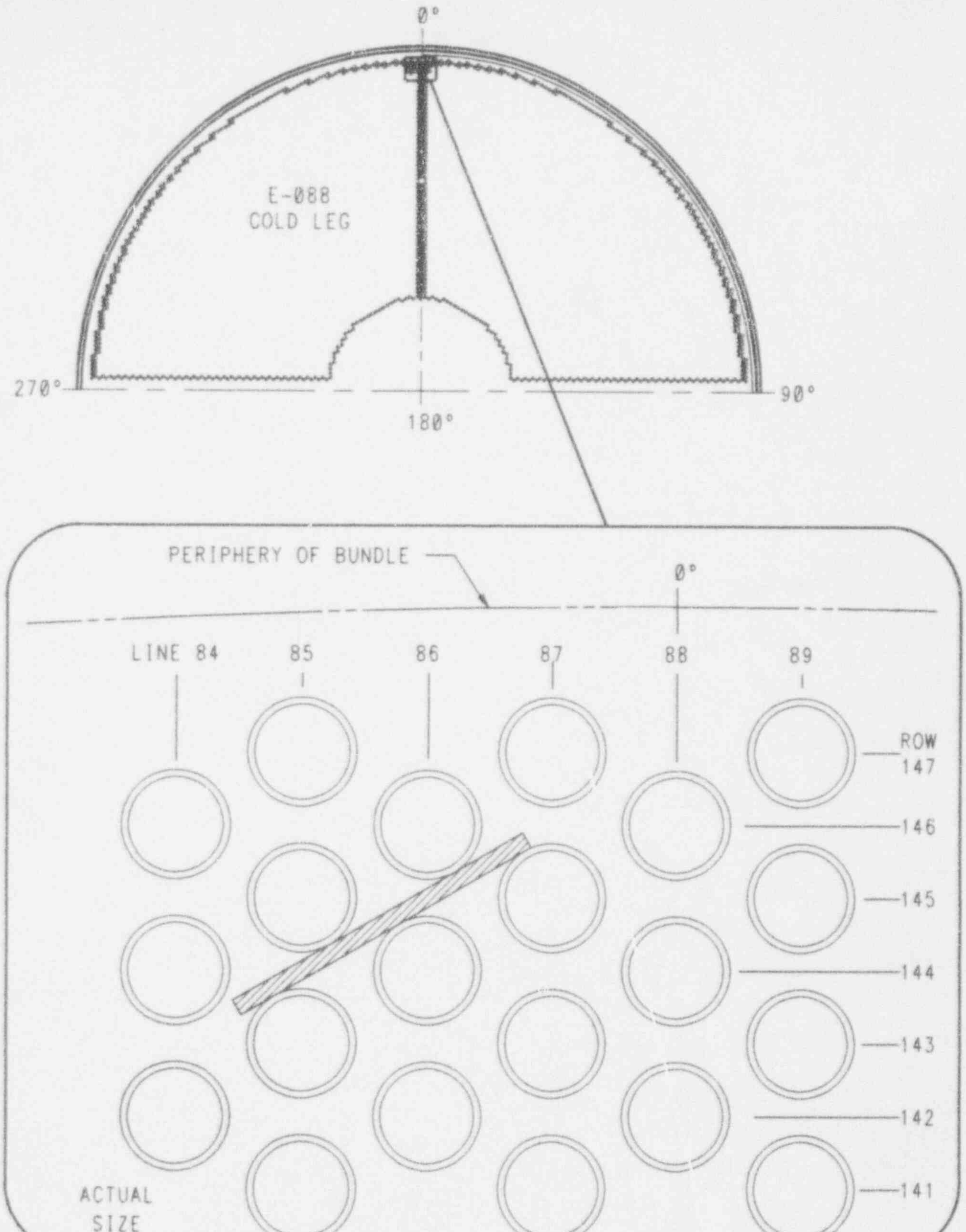
Axial Profile of RPC Pancake Data for 49% Wear Standard



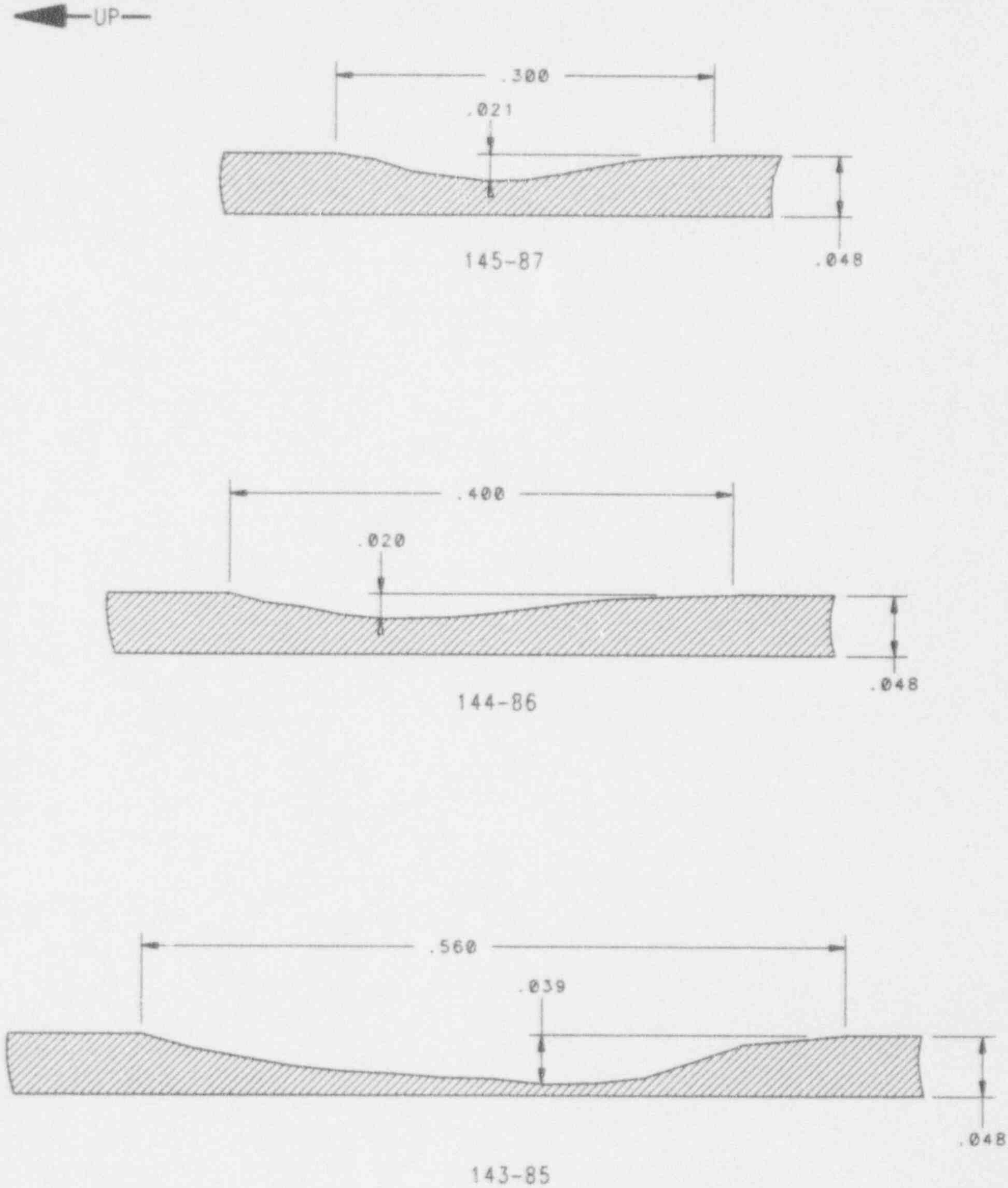
APPENDIX D

TUBE WEAR PROFILES FOR TUBES 143-85, 144-86, AND 145-87

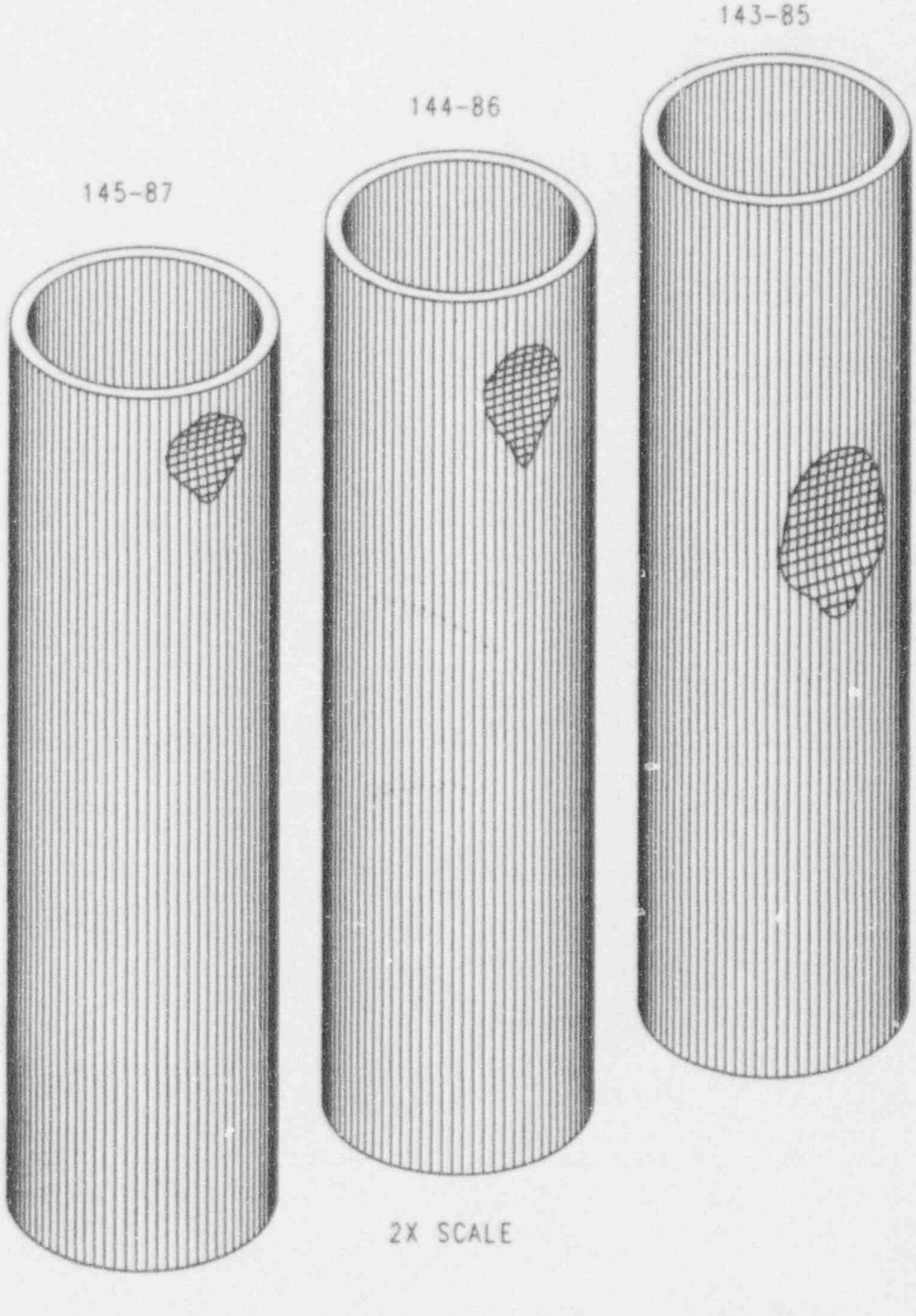
(LOOSE OBJECT 88-3)



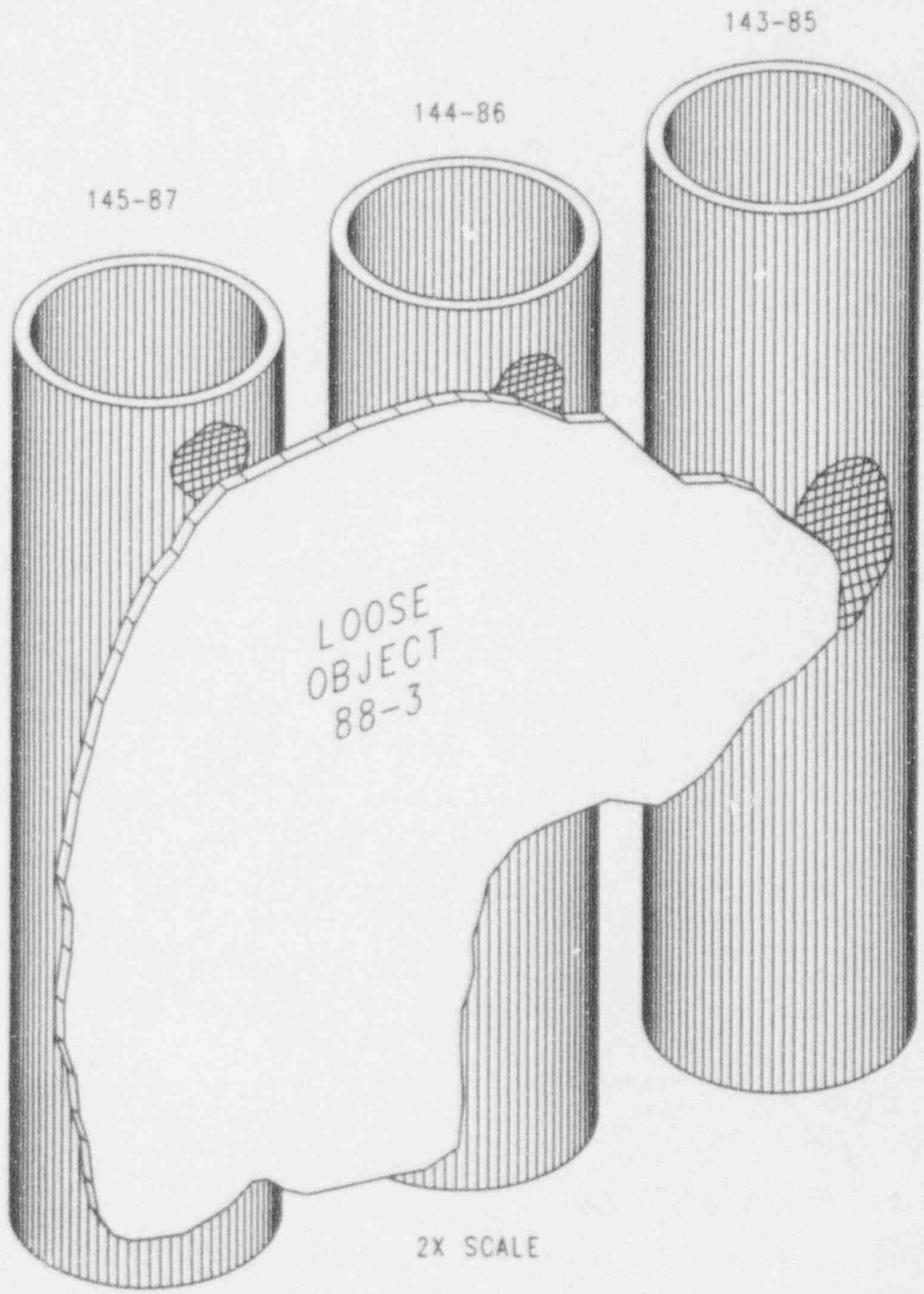
Location of Loose Object 88-3
Figure D-1



Tube Wear Profiles
Figure D-2



Wear Scars from Loose Object 88-3
Figure D-3



Loose Object 88-3 in Perspective
Figure D-4