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Steam Generator Group Project

Semiannual Progress Report
July - December 1982

Prepared by R. A. Clark, M. Lewis

Pacific Northwest Laboratory
Operated by
Battelle Memorial Institute

Prepared for
U.S. Nuclear Regulatory Commission

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Office of Nuclear Regulatory Research
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Washington, D.C. 20555
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Abstract

The Steam Generator Group Project (SGGP) is an NRC program joined by additional sponsors. The SGGP utilizes a steam generator removed from service at a nuclear plant as a vehicle for research on a variety of safety and reliability issues. This report is a semi-annual summary of progress of the program. Information is presented on positioning the generator into the Steam Generator Examination Facility, and examination of the secondary side to confirm pretransport generator condition. The report then presents radiological field mapping results and personnel exposure monitoring data. Radiation field reduction achieved in channel head decontamination efforts is reported. The results of a profilometry examination to determine the extent of denting are summarized. Plans for unplugging of selective explosively plugged tubes are discussed.

Abstract

The Steam Generator Group Project (SGGP) is an NRC program joined by additional sponsors. The SGGP utilizes a steam generator removed from service at a nuclear plant as a vehicle for research on a variety of safety and reliability issues. This report is a semi-annual summary of progress of the program. Information is presented on positioning the generator into the Steam Generator Examination Facility, and examination of the secondary side to confirm pretransport generator condition. The report then presents radiological field mapping results and personnel exposure monitoring data. Radiation field reduction achieved in channel head decontamination efforts is reported. The results of a profilometry examination to determine the extent of denting are summarized. Plans for unplugging of selective explosively plugged tubes are discussed.

Acknowledgement

The assistance of the Virginia Electric and Power Company (VEPCO) in obtaining the use of the research generator removed from service at their Surry Nuclear Station Unit 2 is hereby acknowledged. VEPCO has also provided valuable assistance with historical information on the generator's operation inspection and maintenance.

Progress Report

Steam Generator Group Project (SGGP)

July through December 1982

Introduction

This is the first in a series of semi-annual reports for participants of the SGGP. This report provides increased detail over the summary quarterly NUREG reports published with the PNL combined quarterly report for NRC programs. Since it is the first report, it will briefly review tasks completed before July 1, 1982. Details of those tasks will be found in the project annual report.

Through November, with completion of the channel head decontamination, the project was on schedule. Owing to the poor response to the Tube Unplugging RFP, the project has fallen behind, potentially 1-3 months. As of this writing the problem has not yet been solved, so it does not appear that the time will be made up this year. See Task 8 for a discussion of the problem.

Unexpected costs associated with Task 6, Channel Head Decontamination, have resulted in some reallocation of resources. Factors contributing to this task over-run were:

a) Extra crafts personnel to adapt the SGEF to accommodate subcontractor equipment, and to install that equipment.

b) Longer-than-expected around-the-clock operation, requiring extra engineers, technicians and radiation monitors.

c) Crafts people, often on overtime, to help subcontractor personnel repair failed equipment.

d) More complex and slower-than-expected waste transfer operations.

Because the successful bids for decontamination were so attractive, with each subcontractor offering much cost sharing, we decided to select separate subcontractors for each side of the channel head. With hindsight, we might have avoided the budget over-run if we had selected one subcontractor to apply one process to both sides.

Task 1 - Construction of the Steam Generator Examination Facility (SGEF)

This task was completed November 18, 1981 with acceptance by Battelle of the facility for the NRC from the construction contractor. The $1.7 million facility was completed within budget and on schedule. Additional NRC expense funds (~$200K) were spent during FY82 for outfitting and supplying the facility. This included voice and visual communications systems, radiation monitoring equipment, tools, welding apparatus, etc. Experience during the past year has shown that the SGEF is well-suited to the wide variety of tasks called for in the project program. Operations ranging from cutting and grinding in high radiation fields to wet chemical decontamination processes have been performed successfully. Modifications, often temporary, have been required for some operations, notably those utilizing specialized subcontractor equipment. After its first year of intensive use, however, the facility is fully functional, clean, and with good contamination control, and ready for follow-on tasks.

Task 2 - Position Generator in SGEF

This task was completed on January 11, 1982 when the relocation contractor moved the unit into the facility, and secured it in place. Figures 1 through 4 show specific phases of this operation. It was completed without mishap, also on schedule, under a favorable, fixed-price subcontract.

Task 5 - Reopen Preshipment Penetrations

All experimental work was completed during the second quarter of 1982. A preliminary oral report of the findings was made to the American Nuclear Society Annual Meeting in Los Angeles during June 1982 (Ref. 1). A complete topical report of Task 5 is in final stages of preparation for distribution to participants early in 1983. Basically, the conclusions of Task 5 are that (a) no significant dimensional changes occurred in moving the generator, (b) no change in corrosion product composition was found, and (c) the general condition of the generator is unchanged from its observed condition at Surry. The only exception was that inner row U-bend crack indications found at the Surry preshipment examination have opened up in two instances. Visual examination confirmed the existence of severe support plate damage, in the form of flow slot closure, throughout the generator. Inspection of the channel head through the reopened manways showed that numerous plugs were leaking water under gravity, as the generator again stands in its normal vertical operating position.

Task 3 - Health Physics

A health physics program was established to monitor all aspects of radiation exposure. The task provides tracking of all personnel exposure by individual, by occupation and by task. An environmental monitoring system has been established which measures radiation fields within the SGEF and at various locations about the SGEF perimeter. This task has also provided mapping of radiation fields along the generator, inside the generator and throughout the SGEF. Figure 5 shows radiation levels on the external surface of the steam generator shell, while Figure 6 shows the levels at three feet from the shell. Figure 7 is a typical map of radiation levels around the generator, in this case in the working area on the main floor of the SGEF tower. Table 1 shows radiation levels inside the tube bundle.

Neg. 8200094-22cn

FIGURE 1. Moving the Generator from Interim Storage to the SGEF (seen in background)

Neg. 8200094-83cn

FIGURE 2. Tilting the Generator into a Vertical Position

Neg. 8200094-97cr.

FIGURE 3. Lifting the Generator into the SGEF

Neg. 8200094-114cn

FIGURE 4. View of the Generator As It Entered the SGEF Through the Removable Roof Panel

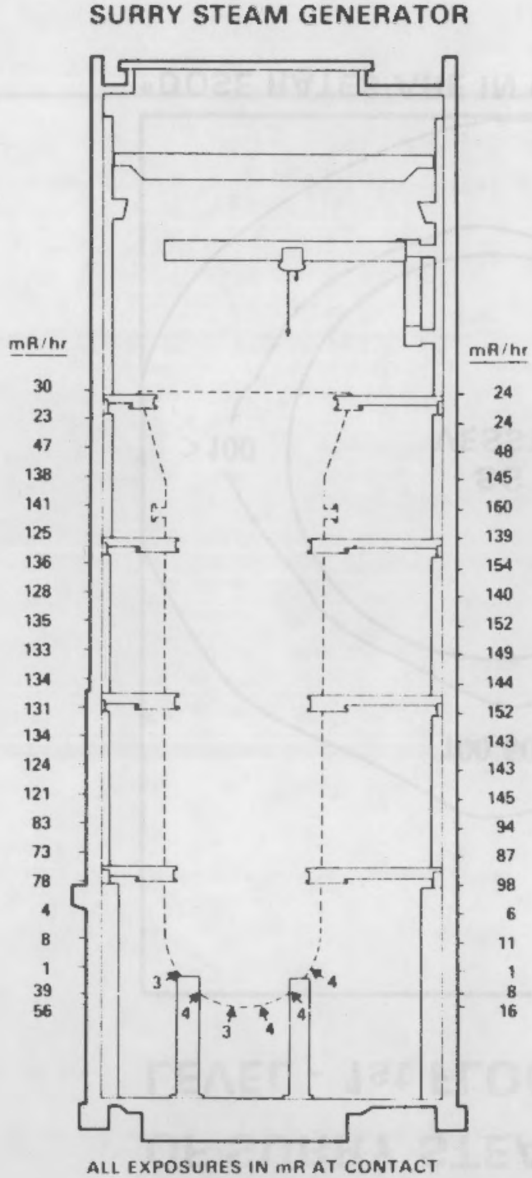


Figure 5. Radiation Levels at Contact of the Generator in the SGEF

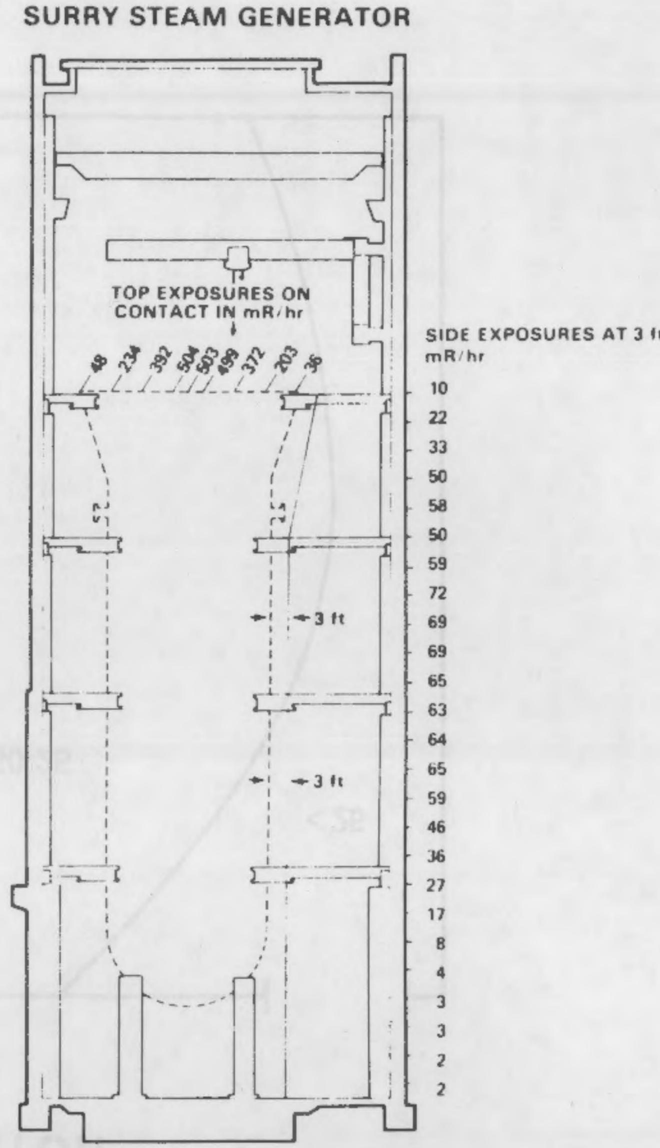
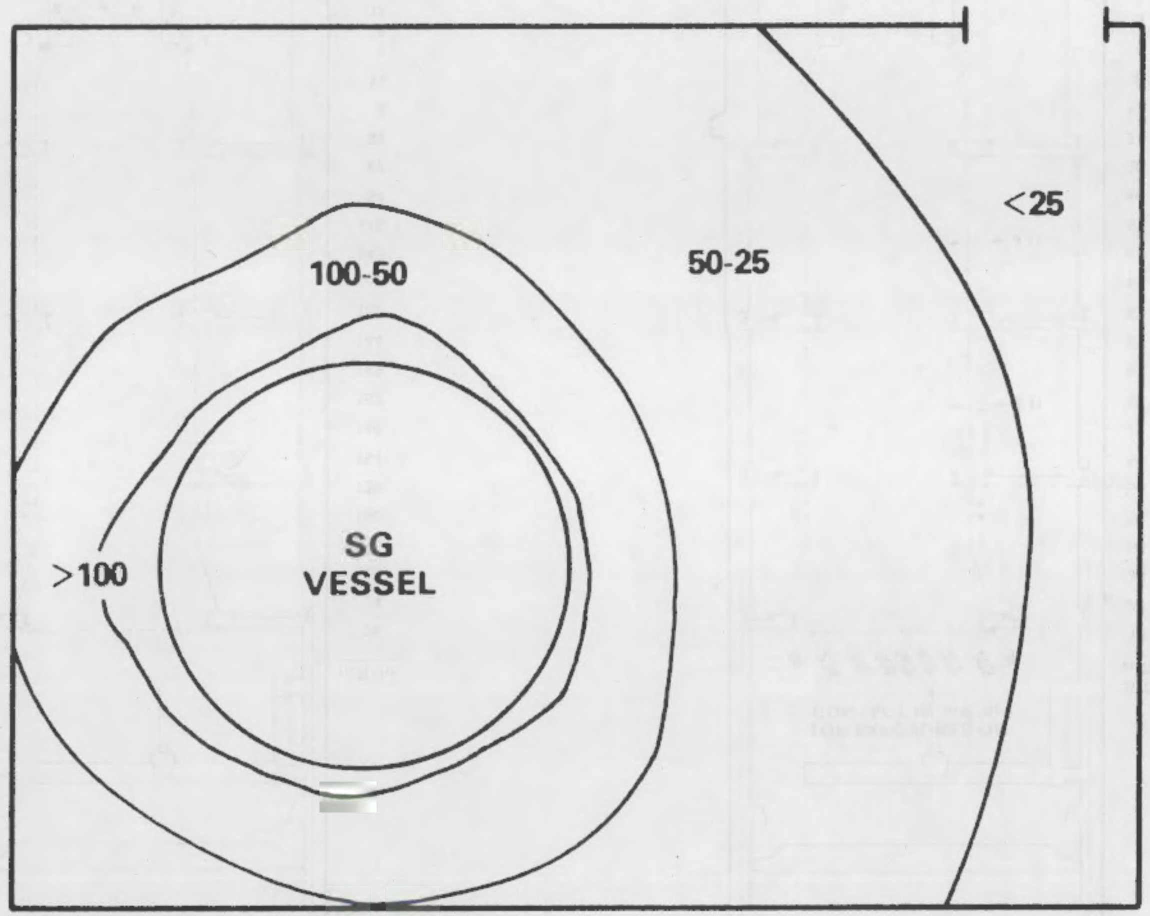


Figure 6. Radiation Levels at 3-ft Distance from the Sides of the Generator

RADIOLOGICAL SURVEY DOSE PROFILE OF SURRY STEAM GENERATOR

LEVEL - 1st FLOOR



*DOSE RATES ARE IN mR/hr

FIGURE 7.

TABLE 1. Radiation Levels, in R/hr, at Designated Points Through the Tube Bundle. (Note: Measurements made on 2/8/82 at the elevation of the first support plate, four feet above the tube sheet in the tube lane.)

Outside Surface of Steam Generator (between 72 and 66 inches) — P-1 Opening

Towards Manways ← | Centerline of Steam Generator (0) | → Towards Nozzles

Radiation Level, R/hr	0.39	0.69	1.7	3.7	6.0	8.2	10.1	11.0	10.9	10.4	11.0	11.1	10.1	9.6	9.0	9.5	9.2	9.8	9.2	9.7	10.2
Distance from Centerline, inches	84	78	72	66	60	54	48	42	36	30	24	18	12	6	0	6	12	18	24	30	36

A topical report will be issued in early 1983 describing the method and results of the radiation mapping program on and in the steam generator and in the SGEF.

Personnel radiation exposures are tabulated in Table 2 for the groups of people who have been working on the project. The major activities at the SGEF during each quarter are shown in the footnotes to the table. A correlation may be made of experiment activities with the exposures shown. Exposure rates are also measured in the environs around the SGEF. At the nearest fence accessible to the public a field of 0.6 mR/hr exists.

TABLE 2. 1982 Personnel Radiation Exposures of Groups Working on the Steam Generator

	Total Exposure, mRem				
	Jan-Mar	Apr-Jun	July-Sept	Oct-Dec	Totals
Battelle Engineers & Technicians	2,472	831	4,351	4,151	11,805
Battelle Crafts Personnel	4,125	975	2,933	629	8,662
Visitors	5	79	93	0	177
Subcontractor Personnel	0	0	1,620	634	2,254
Totals	6,602	1,885	8,997	5,414	22,898

Notes: The following are the major tasks taking place in each of the above quarters.

- Jan-Mar: Move steam generator into SGEF; Reopen and inspect preshipment openings
- Apr-Jun: Inspect secondary side of steam generator
- July-Sept: Decontaminate channel head cold leg
- Oct-Dec: Decontaminate channel head hot leg; Profilometer 96 tubes.

INITIAL RADIATION READINGS (COLD LEG - R/h)

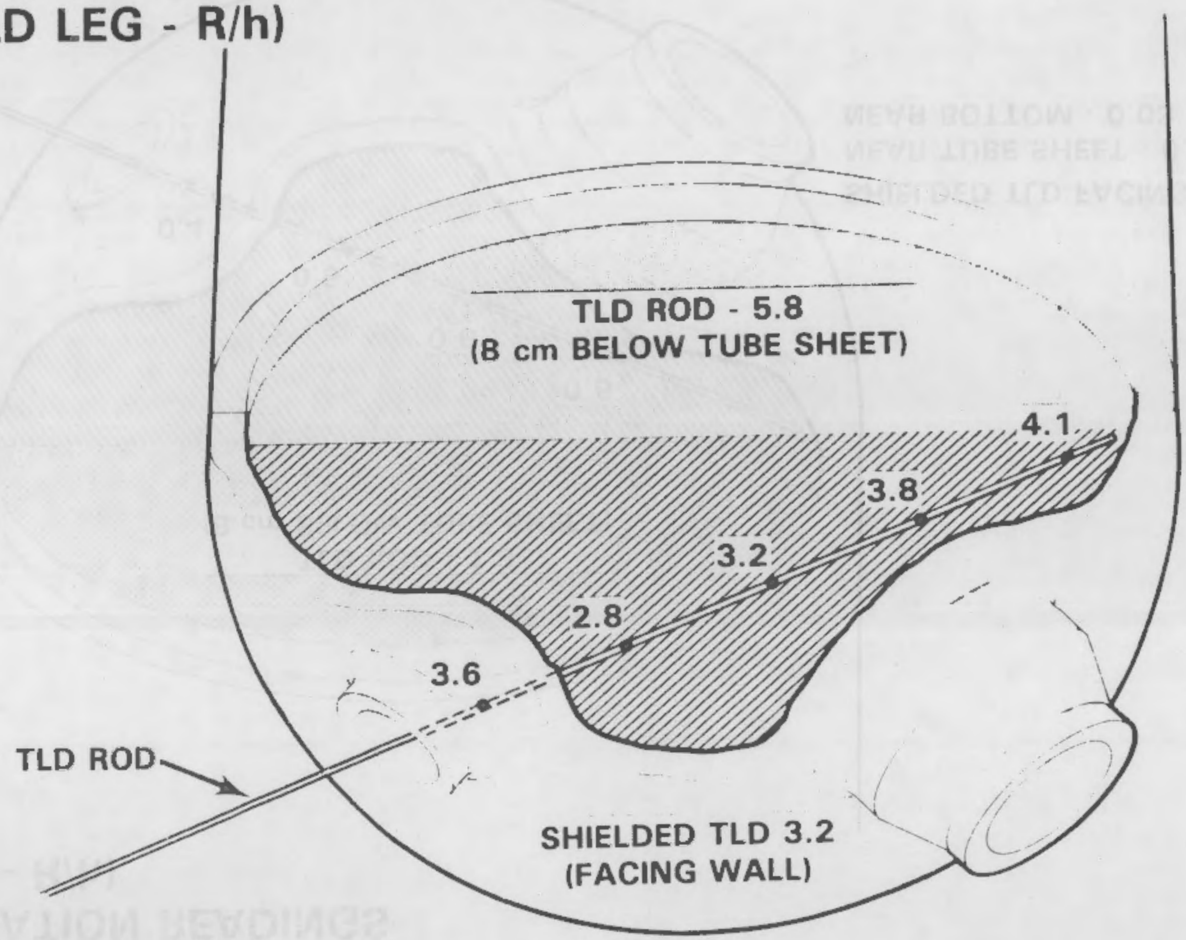


FIGURE 8.

FINAL RADIATION READINGS
(COLD LEG - R/h)

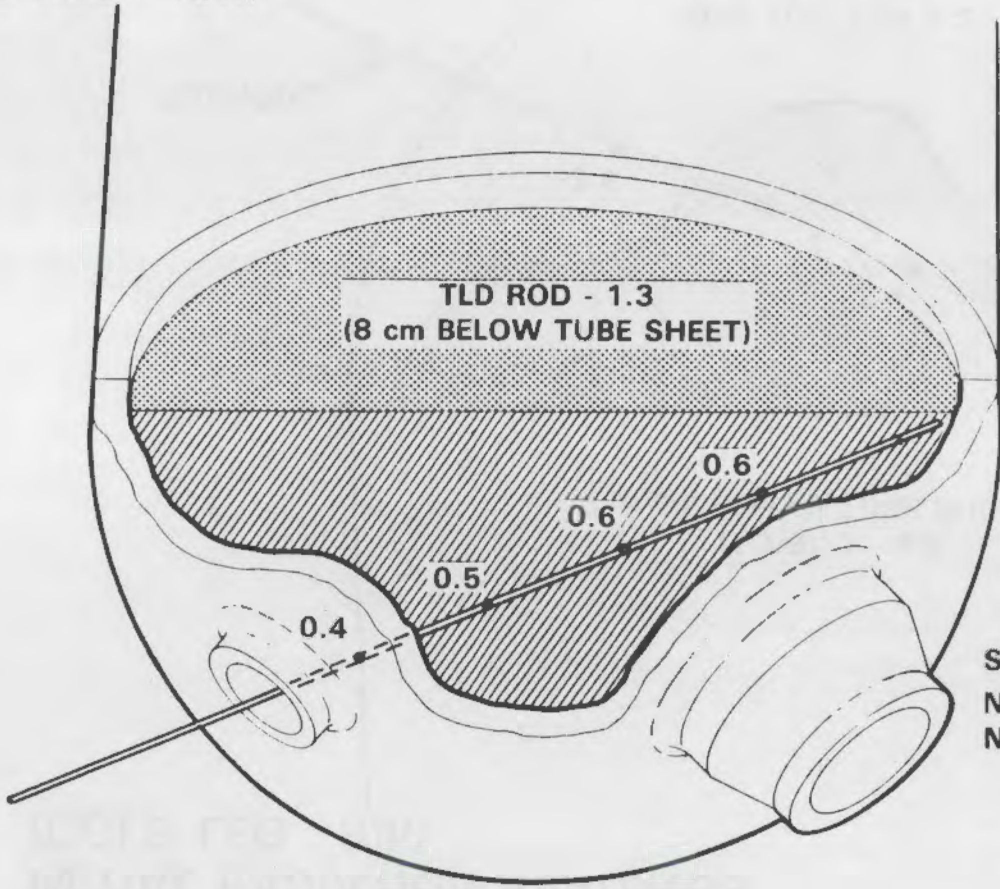


FIGURE 9.

RADIATION READING CHANGE (COLD LEG - R/h)

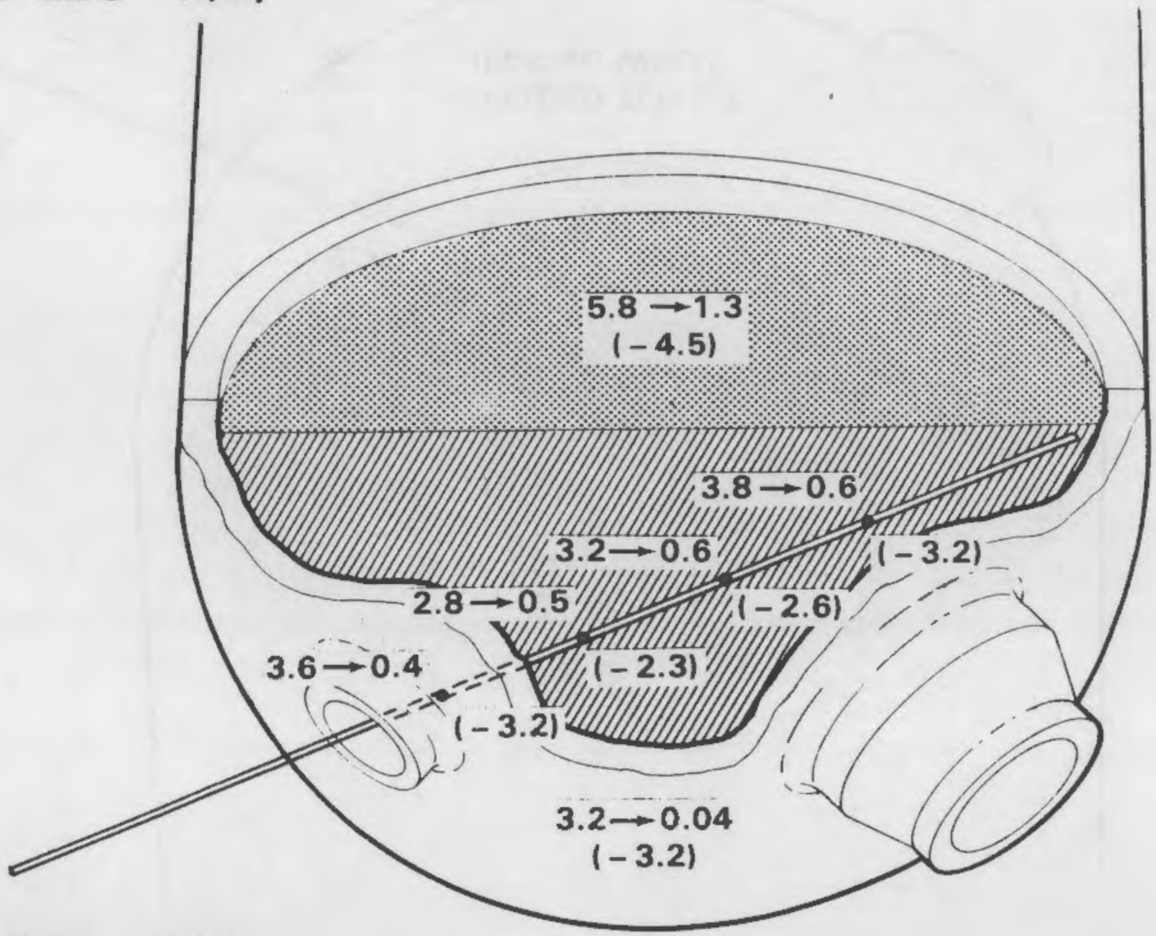


FIGURE 10.

INITIAL RADIATION READINGS
(HOT LEG - R/h)

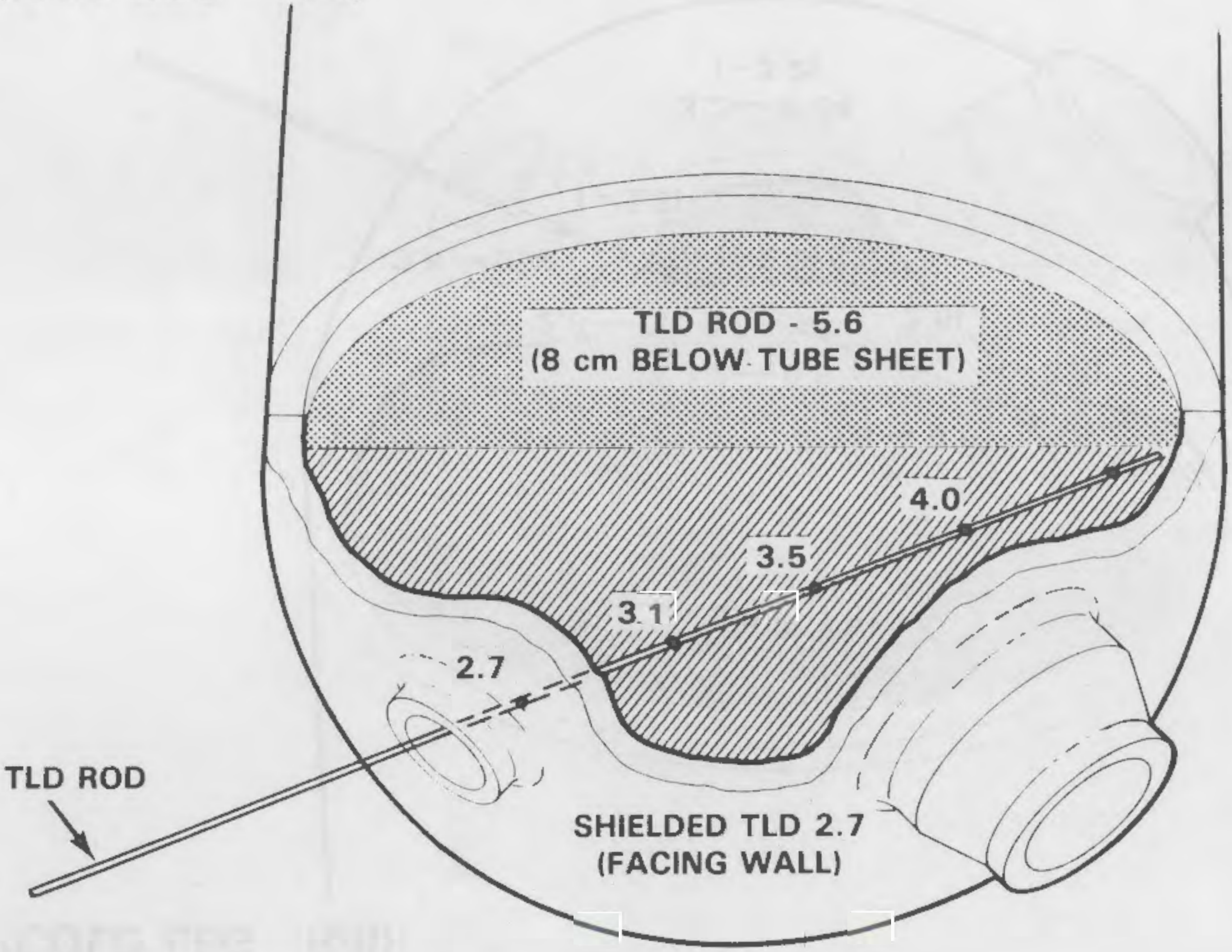


FIGURE 11.

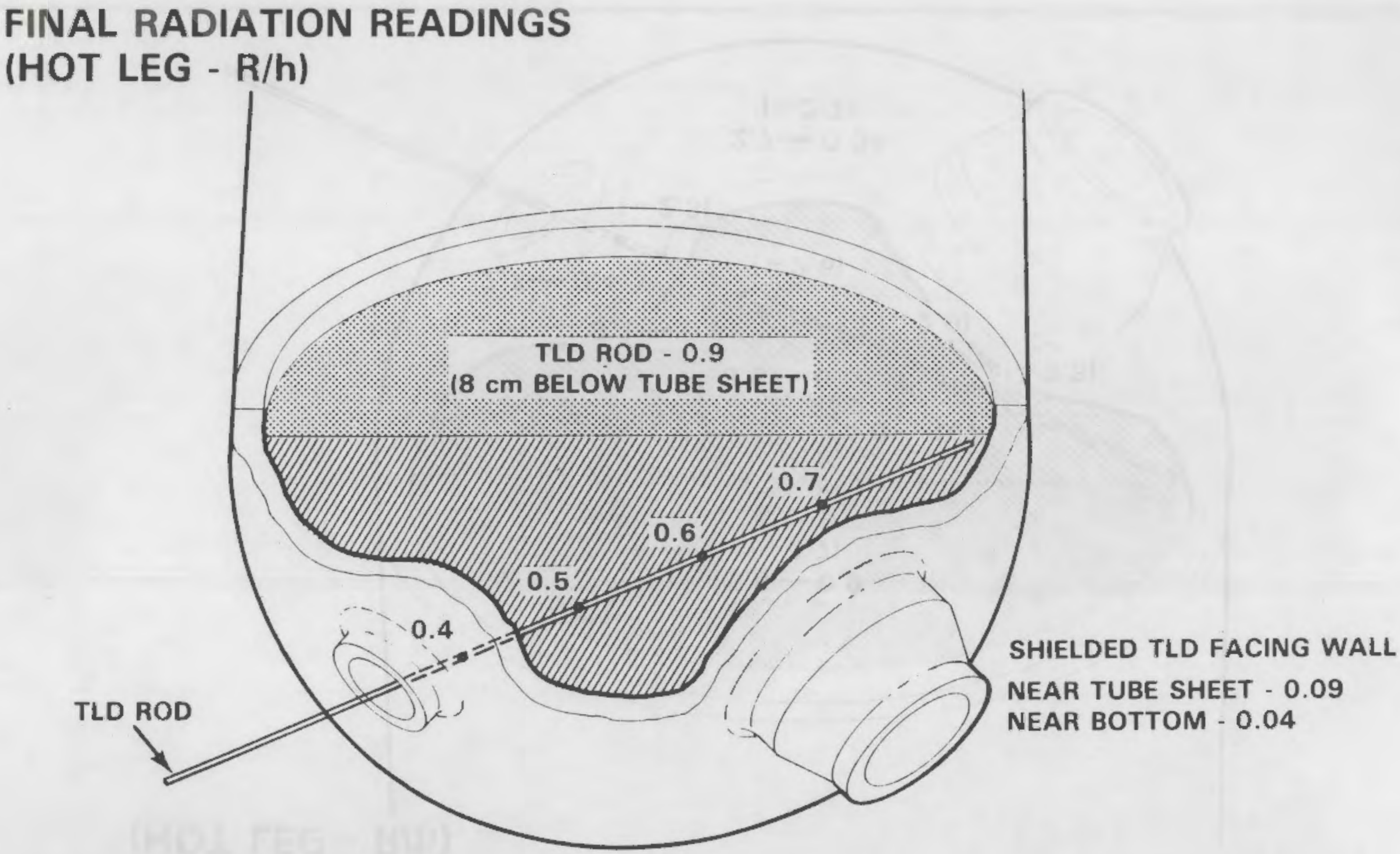
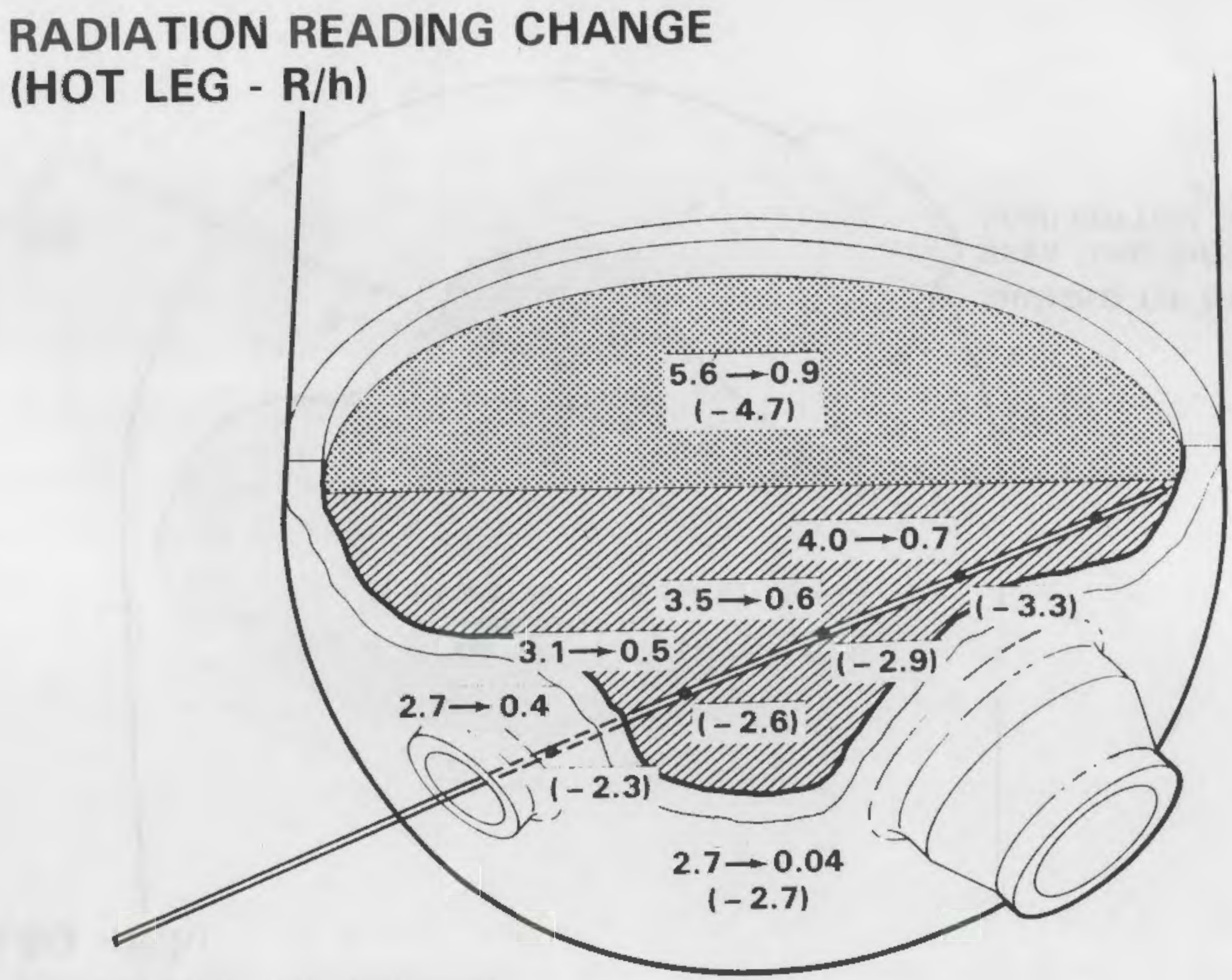

FINAL RADIATION READINGS
(HOT LEG - R/h)
TLD ROD - 0.9
(8 cm BELOW TUBE SHEET)
0.7
0.6
0.5
0.4
TLD ROD
SHIELDED TLD FACING WALL
NEAR TUBE SHEET - 0.09
NEAR BOTTOM - 0.04

FIGURE 12.



RADIATION READING CHANGE
(HOT LEG - R/h)
5.6 → 0.9
(-4.7)
4.0 → 0.7
(-3.3)
3.5 → 0.6
(-2.9)
3.1 → 0.5
(-2.6)
2.7 → 0.4
(-2.3)
2.7 → 0.04
(-2.7)

FIGURE 13.

During the decontamination of both sides of the channel head, detailed measurements were made of radiation levels before, during and after each operation. Several measurement methods were utilized. These included (a) external monitoring of the channel head with shielded NaI and hand-held Ge detectors, (b) gamma spectroscopy of contaminated corrosion specimens with a GeLi detector, and (c) exposure rate measurements on the inside of the channel head with both shielded and unshielded thermoluminescent detectors (TLD's). Numerical results using method (c) are shown in Figures 8 through 13. The plastic rods (actually tubes) containing the unshielded TLD's were placed in two positions, as indicated: (1) hanging 8 cm below the tube sheet and parallel to it, and (2) extending through the manways to the far corners of the channel head. These latter TLD's were at differing elevations. These measurements were the primary basis for evaluating the effectiveness of the two decontamination operations. The post-decontamination (final) readings were all taken after both sides of the channel head had been decontaminated. Before the hot leg side was decontaminated, the readings on the cold leg side were double those shown in Figure 9. This illustrates that there is significant "shine" from one side to the other. Examination of the data shows that volumetric decontamination factors (DF's) of 6 to 7 were achieved by both processes, except close to the tube sheet where they are only about 4. Since the tubes were intentionally not decontaminated, there is still significant "shine" from the tubes, which strongly influences the volumetric radiation levels in the channel head. On the other hand, the dosimeters that were placed against the channel head inner surfaces and shielded by four inches of lead, showed very low radiation levels after decontamination, corresponding to DF's greater than 30.

The radiation levels shown in Figures 9 and 12 were confirmed by TLD's attached to a worker who later entered the channel head to place equipment for a profilometry experiment. TLD's attached to his head and wrists showed exposure rates of 615 to 681 mRem/hr. Much of the time he was working to place templates on the tube sheet above his head. On the other hand, TLD's attached to his torso and ankles showed rates at those points of 394 to 418 mR/hr.

Task 4 - Statistics-Data Acquisition, Management and Analysis

The data acquisition computer system was completed, and is being fully tested before relocation in the computer facility, located in the administrative trailer in the SGEF compound. Required atmosphere controls and fire protection equipment were installed and tested. Realtime software was developed that will be used during the baseline eddy current inspection. An intelligent controller was designed and built to enable computer control of probe motion. This was successfully demonstrated in November. The entire system, including an active probe and a pusher-puller controlled by the intelligent controller, is in the final stages of testing and demonstration at the end of this reporting period. It will be relocated and operational in January.

A massive amount of data has been provided to the project by Virginia Electric Power Company (VEPCO), operators of the Surry Plant. These included a complete set of inspection reports, which supplement the Westinghouse database obtained earlier. Together they provide a complete record of inspection data for the 2A steam generator. Mr. Tom Brombach, formerly of VEPCO, and serving as a consultant to the project, reviewed the reports with the project staff. He provided valuable insight and interpretation of data and identified additional chemistry data for the project records. These later were provided by VEPCO's Mr. William Thornton, along with secondary side water chemistry specifications. Almost all of this information has been entered into the database. One of the first uses was to compare gauging data with new measurements made in a 96-tube profilometry experiment. The profilometry confirmed the rather minimal denting recorded in the database on these non-plugged tubes. This suggests that the generator has not changed much in this respect since 1977.

Dr. R.L. Dillon, chemistry and corrosion consultant to the project, evaluated the blowdown chemistry data from the database, originally obtained from Westinghouse. His evaluation suggests some relationships between several water chemistry parameters to be investigated. Analytical plots are being prepared of these parameters to assess functional relationships between them. A similar service is being performed to analyze the chemistry data from the channel head decontaminations which were recently entered into the data system.

Task 6 - Channel Head Decontamination

During the period of this report, both sides of the channel head were decontaminated. London Nuclear Services, Inc. applied the Canadian-developed CANDECON process to the cold leg side. Following that, Quadrex Corporation applied a British-developed process, LOMI (for Low Oxidation state Metal Ion), to the hot leg side. Quadrex also demonstrated electropolishing as a final step to produce a shiny, smear-free surface in local areas. This was useful in the manway areas where frequent entries are made by personnel performing project tasks.

Both subcontractors performed well. The results of their operations are considered to be satisfactory as shown by the measurements recorded in Figures 8 through 13, earlier in this report. From analysis of the wastes, it is estimated that 2.1 curies of Co-60 were removed from the cold leg side, and 1.3 curies from the hot leg side. At least a part of the difference may be attributed to radioactive material being loosened and flushed from the tubes overhead by an excursion of decontaminating solution into the tube sheet portion of the tubes during the cold leg channel head decontamination. On both sides, water evaporated from the process solutions up into the tubes where it was condensed, often carrying over to the opposite side.

Both operations left their respective treated surfaces with a smearable tan film that could be easily wiped off. Cloths smeared on the surface were contaminated with several thousand counts per minute. Therefore, after each operation, Battelle technical staff performed a flushing of this film with a pressurized jet of water. This was very effective in removing the film, although no significant radiation level change was observed on either side as a result of this water-lancing operation. Radiation levels on the cold leg side were observed to drop by a factor of two as a result of the decontamination of the hot leg side. Radiation "shine" from the overhead tubes still contributes a large amount of radiation to the channel head volume. Whereas surface decontamination factors (DF's) of greater than 30 were measured, volumetric DF's were only 6 to 7. Nevertheless, this reduction, along with removal of the smearable film, makes future tasks much easier to perform. Longer safe working times are permissible, and contamination control will be superior.

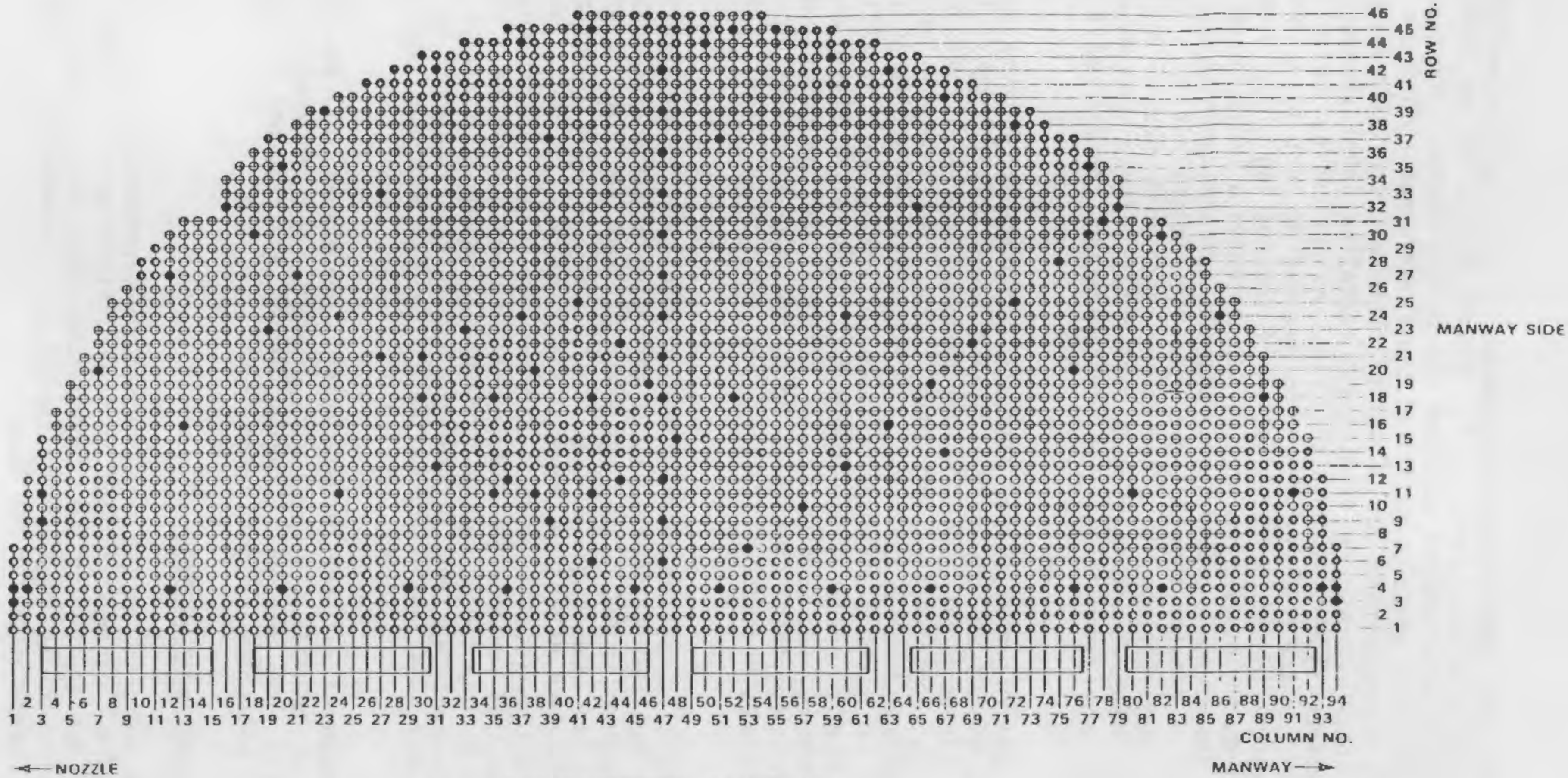
A number of lessons were learned from the decontamination operations. The capability of the SGEF to house large scale, wet chemical operations was tested. Although not ideal for the purpose, the facility served well with minor modifications and adaptations. For example, interconnecting openings between the tower, the laboratory and the truck lock were required for passage of hoses and people. These were installed, and are now available for future operations. A detailed liquid waste transfer procedure and equipment to perform the operation were developed. The importance of back-up units for major pieces of process equipment was brought home forcefully, by one subcontractor's pump problems.

It appears that flow of the decontamination solutions had an important effect on the quality of the result. A through-flow pattern produced a more uniform-appearing result than one which allowed the fluid to enter and leave from the same area. Results of this task will aid in improved systems engineering for future process applications. It also appears that it is worthwhile, at least in the SGEF as it is constructed, to include a step that concentrates the radioactive waste. Either process could operate with a concentrating ion exchange column to minimize the volume of liquid waste. This arrangement was actually integral to the CANDECON process, and was demonstrated to be feasible for the LOMI process.

After completion of all the decontamination operations, all equipment was cleaned to required standards for shipment, and returned to the subcontractors. The SGEF was likewise cleaned and returned to normal condition for additional program tasks.

<u>Task 7 - Baseline Eddy Current ISI</u>

A request for proposal for the baseline study was prepared for distribution to potential bidders. Owing to the difficulties in selecting a subcontractor for unplugging the plugged tubes (see Task 8), there may be a significant delay in starting the study. Nevertheless, work is proceeding in preparation for the task.



PROFILOMETRY PLAN MAP

2A STEAM GENERATOR

(TUBE SHEET VIEWED FROM INSIDE PRIMARY PLENUM WITH OBSERVERS BACK TO DIVIDER PLATE)

NOTES

1. TOTAL NUMBER OF TUBES - 3,388
2. "x" COORDINATE - 1.281"
3. "y" COORDINATE - 1.281"
4. TUBE O.D. - 7/8"
5. TUBE WALL - 0.050"

10/11/82

FIGURE 14. PROFILOMETRY PLAN MAP.

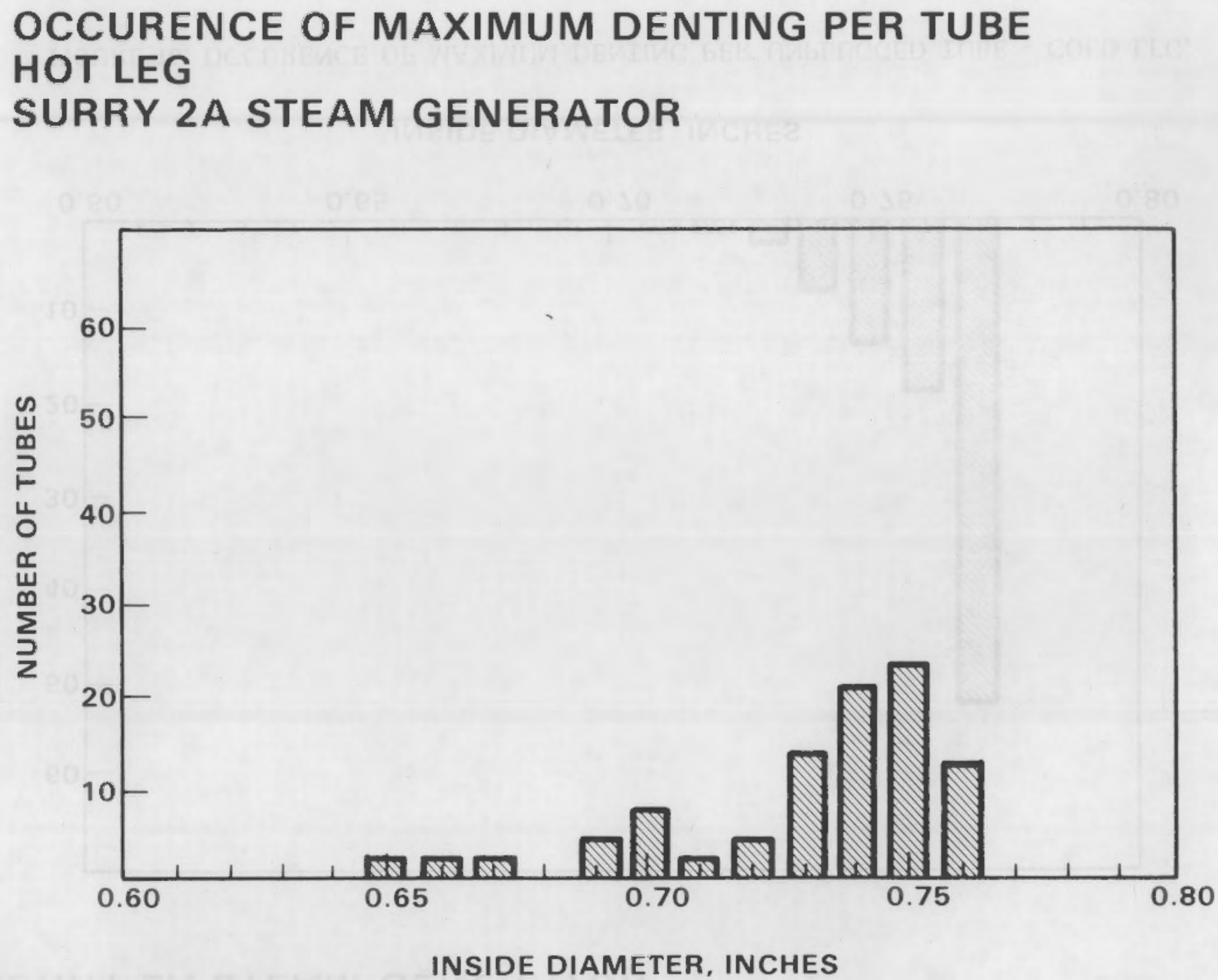


FIGURE 15. OCCURENCE OF MAXIMUM DENTING PER UNPLUGGED TUBE - HOT LEG.

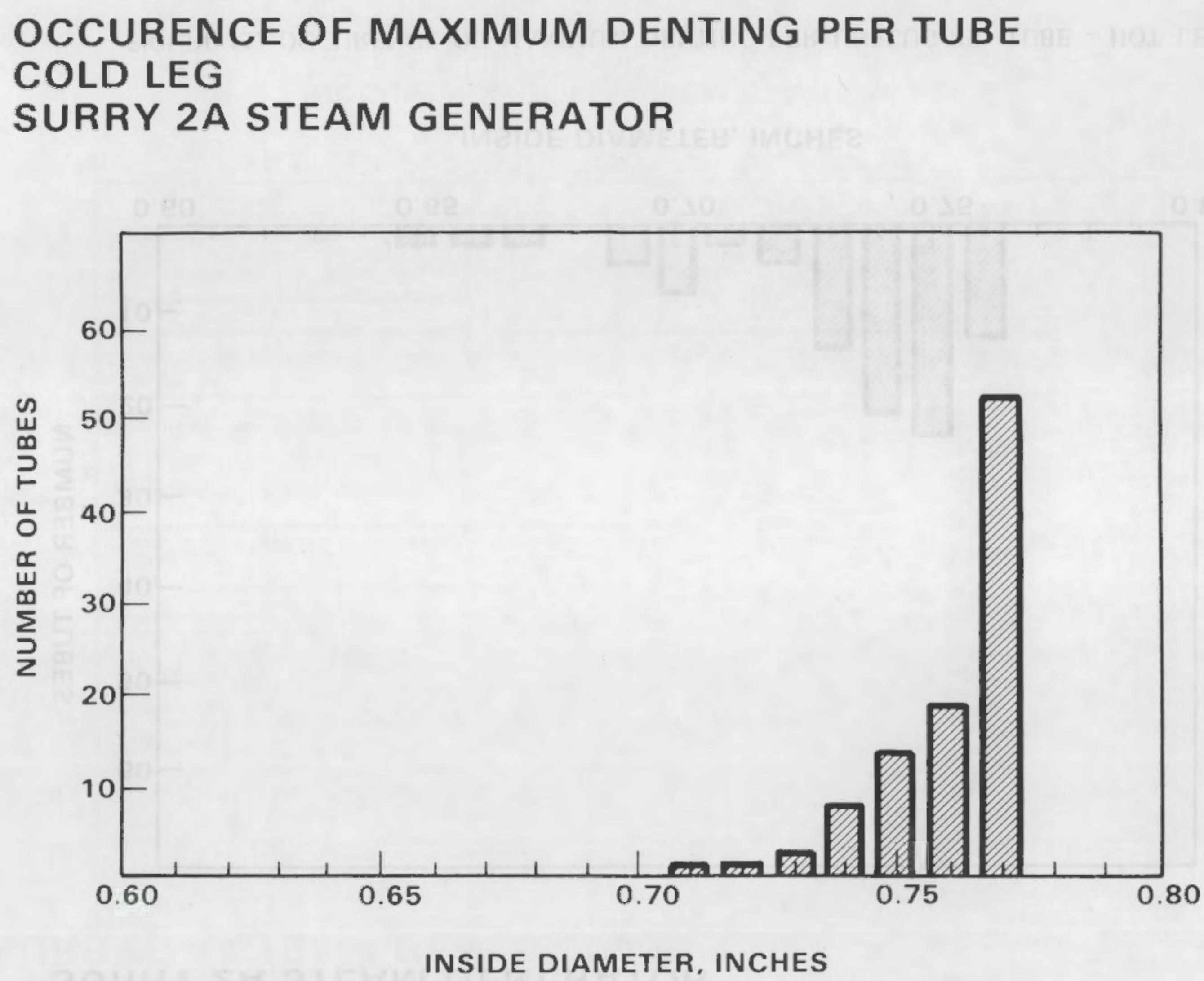


FIGURE 16. OCCURENCE OF MAXIMUM DENTING PER UNPLUGGED TUBE - COLD LEG.

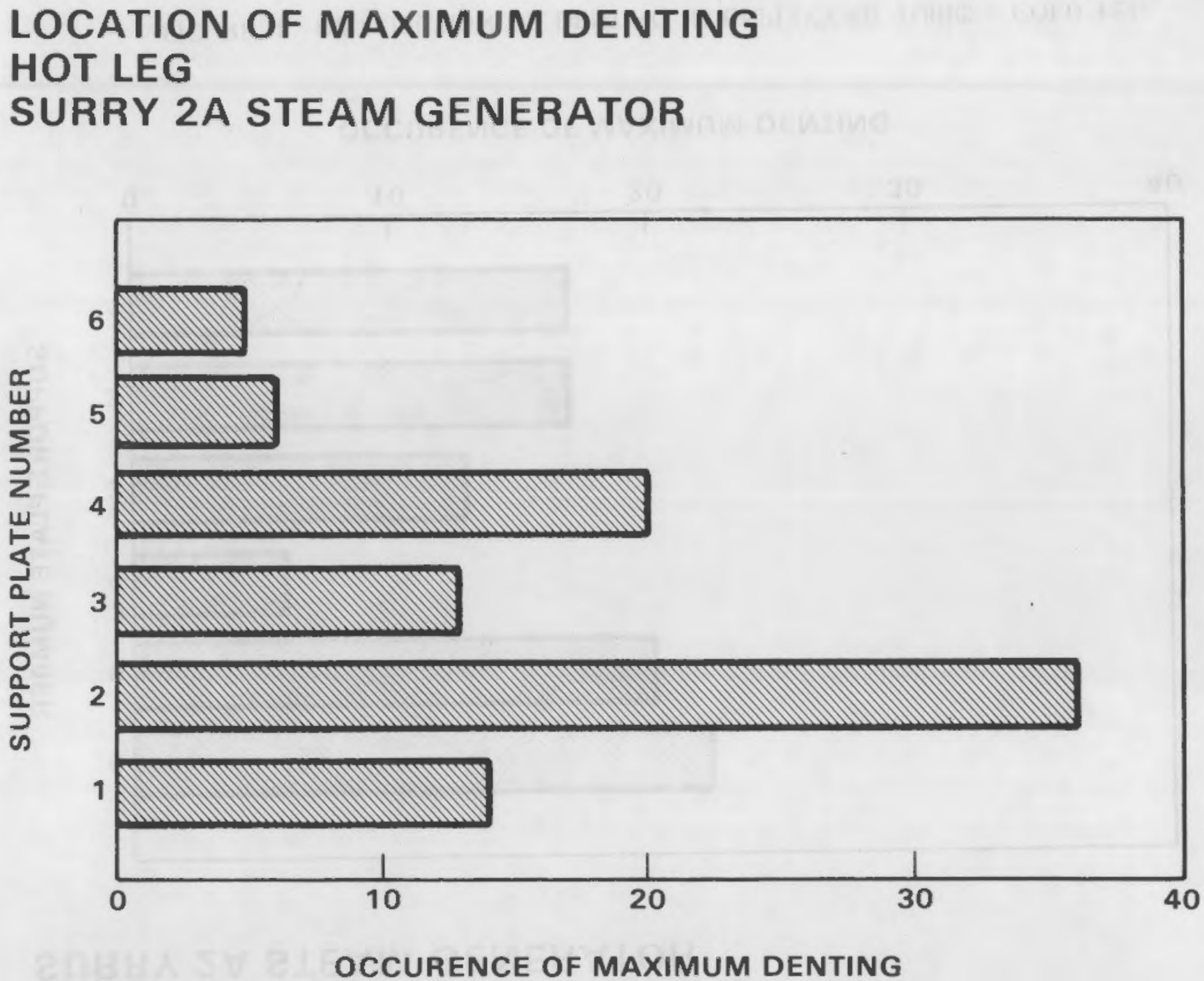


FIGURE 17. DISTRIBUTION OF DENTING IN UNPLUGGED TUBES - HOT LEG.

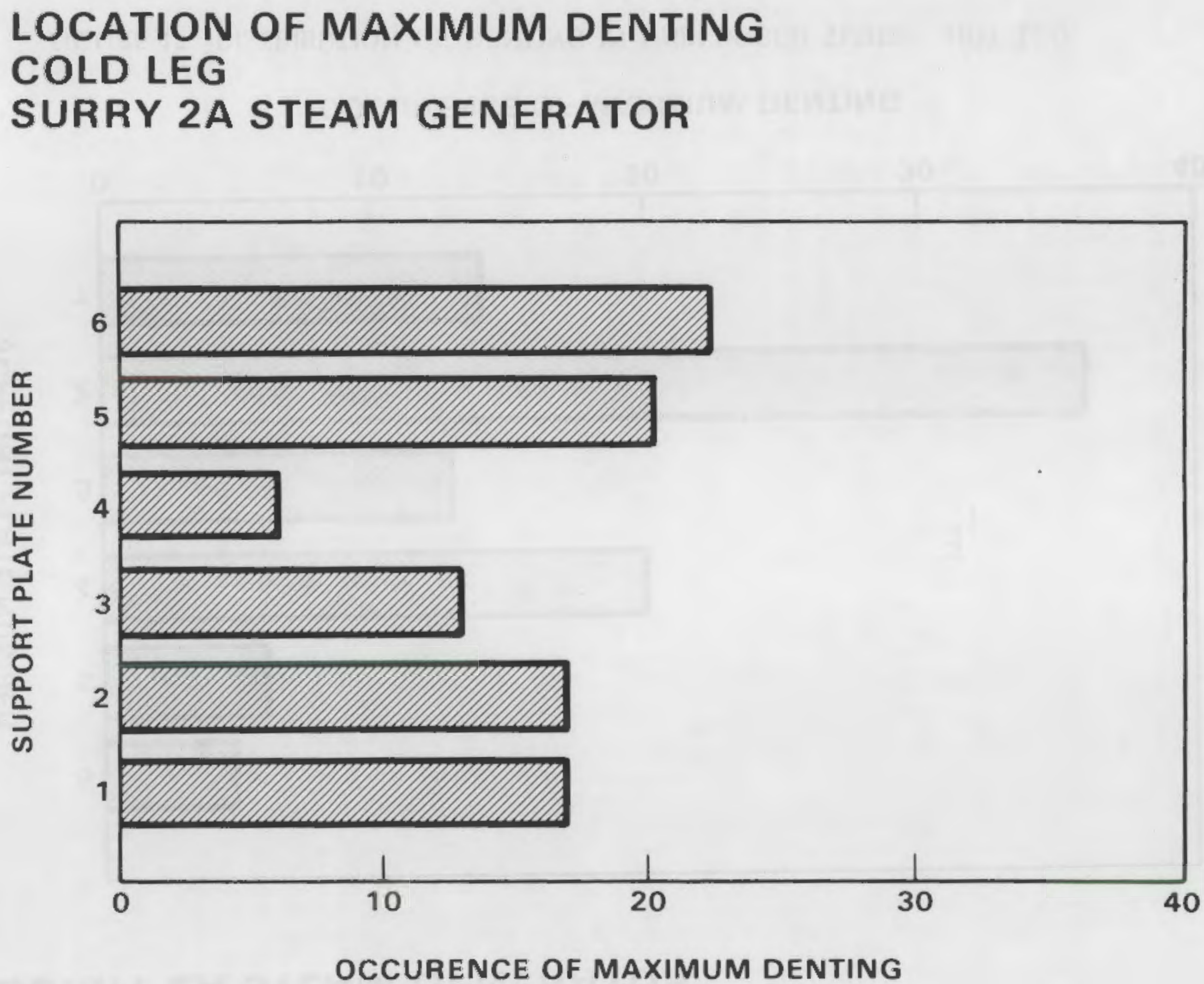


FIGURE 18. DISTRIBUTION OF DENTING IN UNPLUGGED TUBES - COLD LEG.

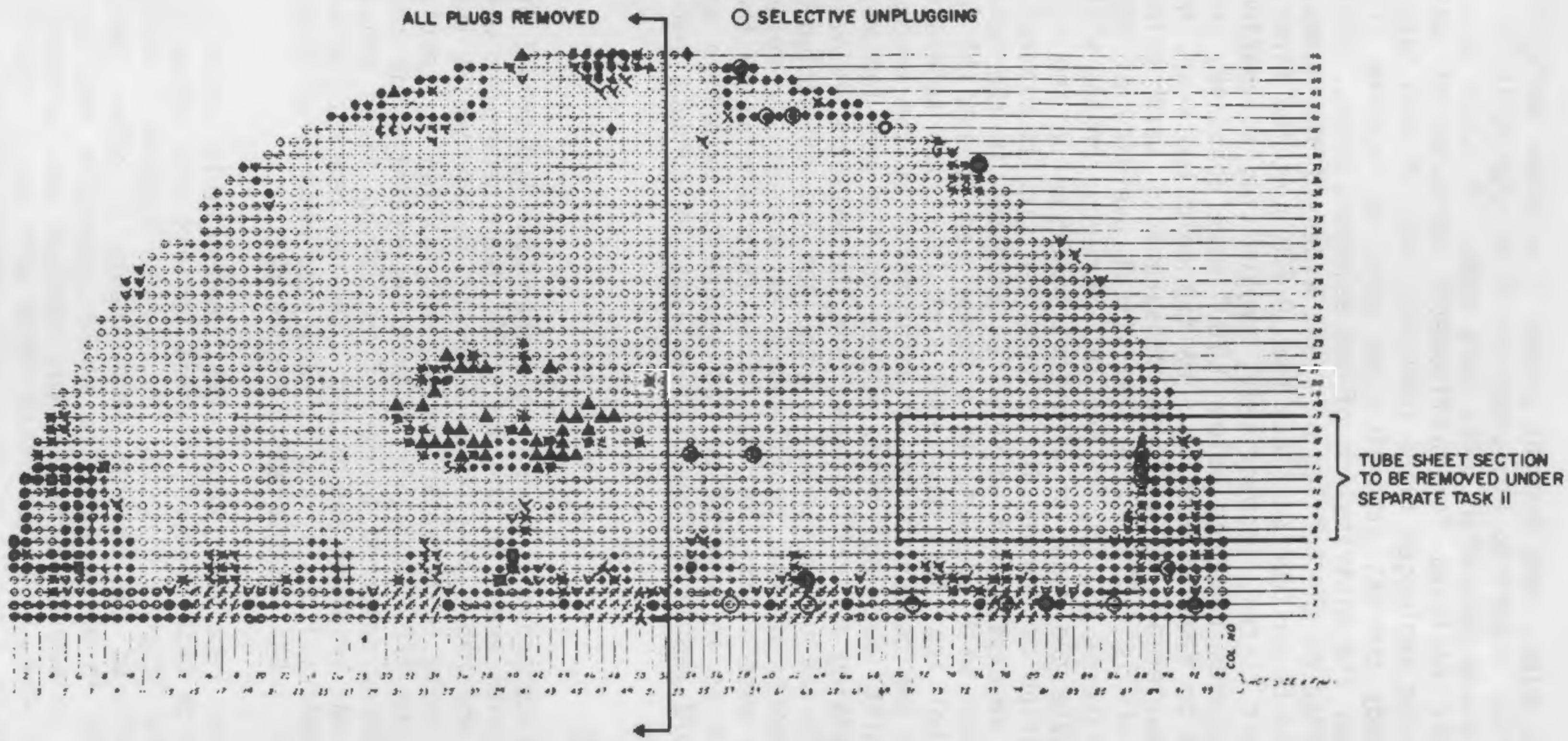
Recognizing the need to select eddy current probes in a proper array of sizes to perform the ISI, diametric measurements of a statistically-selected sample of 96 steam generator tubes were made. A 0.600" diameter eddy current probe designed for profilometry measurements was passed through the selected unplugged tubes from both ends of each tube. A Zetec Model MIZ-15 eddy current apparatus was used to measure the signals. Figure 14 shows the distribution of the selected tubes. Most of the denting was detected on the hot leg or inlet sides of the tubes. Three tubes were found to be obstructed (less than 0.600") at the first, third, and fourth support plates, respectively, prohibiting evaluation beyond those points. Eleven readings below 0.700" were obtained, and two tubes were found to be free of denting. On the cold leg side, no obstructions were encountered. Only three measurements were below 0.740" (nominal tube i.d. is 0.775"). A statistical overview of the test data is shown in Figures 15, 16, 17 and 18. Numerous probes will be required to accommodate the range of diameters observed on the hot leg side. The distribution of denting in the cold leg side is minimal. Based on these results, we expect to find very few problems in the cold leg, and full size probes with adequate fill factor can be applied in almost all cases. The hot leg tubes may require at least two separate examinations. Based on the concentration of deformation at the second support plate of the inlet (hot leg) side, access to the hot leg may have to be gained by passing a flexible probe from the outlet side over the U-bend and down into the upper reaches of the hot leg on occluded tubes. A detailed report of the profilometry experiment is being cleared for issue. The most significant result is that denting in the hot leg unplugged tubes is in general not as severe or extensive as anticipated. This should result in improved ability to conduct non-destructive examinations.

Task 8 - Tube Unplugging

A request for a fixed price proposal to unplug either 250, 500 or all of the 748 plugged tubes (both ends) in the Surry 2A steam generator was sent to eleven bidders who had expressed an interest in performing the task. No bid response could be accepted because of failing to comply with certain terms in the RFP. Recognizing that uncertainties in the required operation probably deterred bidders from making fixed price bids, a new bid package was prepared and issued. The new request called for bids on a time and material basis, and it requested removal of plugs from both ends of the 461 tubes designated in Figure 19.

Only two responses were received, both with unacceptable aspects. Following discussions with both bidders, several options were drawn up for consideration by the Program Director, Dr. Joseph Muscara. Among the options are requests to the program participants to offer their services, and one option in which Battelle would undertake the task directly with its own personnel. The various options are currently under consideration. At best, it appears that there will be a significant delay in the program as a result of these procurement problems.

SURRY 2A STEAM GENERATOR
TUBE PLUGGING MAP AS OF 8/8/78



- ● DEFECTS - 2/24/77
- ● SOFT SPOTS 10-20-76 W RECOM (UBEND ROW1-COL1-9 REMOVED)
- / W REC (HARD SPOTS) (2-48 AND 3-63 LEAKERS)
- ● W RECOMMENDED PATTERN 3/18/77
- □ LEAKERS - 11/2/76
- × MISTAKES - 2/24/77
- ■ LEAKER - 2/24/77
- ● MISTAKE - 3/18/77
- ✱ LEAKERS - 3/18/77
- ◇ W REC. - 3/29/77
- △ LEAKER - 3/29/77
- × DENTING - 9/77
- # DEFECTS - 9/77
- S MISTAKES - 9/77
- + GAGING (DENTING) - 11/77
- ✦ LEAKER - 11/77 R5C26
- V DENTING - 4/78 (PREVENTATIVE AND ENG. JUDGEMENT)
- O PLUGGED DURING MFG
- ⊄ MISTAKE - 4/78
- ≺ DENTING - 7/78 (PREVENTATIVE AND ENG. JUDGEMENT)
- ✱ MISTAKE - 7/78
- ≺ MISTAKE - 5/19/76
- ✱ DEFECTS - 5/19/76
- △ PLUGGED - 5/75 FOR DEFECTS
- O PLUGGED PRIOR TO - 5/75 FOR DEFECTS (10/74 AND BEFORE)
- ● SUPPORT PLATE REMOVAL

FIGURE 19.

Task 10 - Secondary Side Access

Locations were selected for a set of 14 six-inch-minimum diameter holes to be cut into the steam generator shell. These new openings, along with the existing preshipment openings and the handholes, would provide access for a characterization study of the secondary side. A fiberscope and video equipment plus sampling tools have been acquired for the purpose. A high quality periscope was obtained at no cost to the program from the Battelle loan pool. Much practice and experimentation in a mock-up of the tube bundle has been done to familiarize the experimentors with the equipment.

An RFP has been prepared to seek a subcontractor to cut the 14 new openings in the shell. Great care is required of the subcontractor to avoid metal spatter and debris in the tube bundle from the cutting operations. Concern has been expressed about the effects of debris on the quality of the nondestructive measurements in the baseline study. No pre-decision has been made on the type of cutting device to be used in hopes that bidders will propose methods that can meet the stringent requirements.

Task 11 - Tube Sheet Section Removal

This task faces scheduling delays until completion of Tasks 8 and 7. Planning continues with exploration of various methods of obtaining useful and representative section(s). One alternative to removing a large contiguous section would involve a series of core drilled sections to remove tube and surrounding tube sheet material. This would allow samples from widespread regions, and access to the sludge pile in several locations. Detailed NDE would assess interesting areas for removal. The intent of the task remains unchanged, to nondestructively and destructively characterize the tube and tube sheet condition. This task will require inputs from the various project participants to aid in determination of location, type and number of specimens that are desirable.

Figures

References

1. K. R. Wheeler and R. A. Clark, "Initial Inspection of a Service-Degraded Steam Generator Removed from Service," PNL-SA-10501, June 1982.

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