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Steam Generator Group Project

Task 7 Final Report: Post-Service Baseline Eddy Current Examination

Prepared by P.G. Doctor, A.S. Birks, R.H. Ferris, H. Harty, G.E. Spanner

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ABSTRACT

The Steam Generator Group Project (SGGP) is using a retired-from-service pressurized water reactor steam generator as a test bed to investigate the reliability of in-service nondestructive (NDE) eddy current inspections. This information will provide the technical basis for recommended changes to the regulations concerning in-service inspections of steam generator tubes and tube plugging criteria.

The estimates of inspection reliability are being made from NDE data collected during a series of round robin inspections of a subset of tubes from the generator. Segments of these tubes have been removed from the generator and are being destructively analyzed to determine the actual state of tube degradation. To determine NDE reliability, a large number of service-induced defects were needed in the set of tubes selected for the round robin inspections. Thus two complete baseline eddy current inspections were performed to identify those tubes with a high probability of containing defects. The results of the baseline inspections are described in this report.

The baseline inspections were performed by field-experienced personnel using two different commercially-available multifrequency eddy current systems. The analysis of the results showed larger than expected differences in the detection of suspected wall-loss defects (indications) and the subsequent estimates of the depth of the defects. One inspection reported 773 outer-diameter (OD) indications and the other 1041. The detection agreement between teams, based on the reporting of the same indication, was 84% and 61% for the inspections with the fewer and larger numbers of indications, respectively. The sizes of the same indications reported by different teams were observed to be significantly different.

EXECUTIVE SUMMARY

This report is the summary of results from Task 7 Post-Service Baseline Eddy Current Inspection, of the SGGP. The SGGP is an NRC project with group participation from the Electric Power Research Institute and consortia from France, Italy and Japan.

The generator used for this study is a Model 51, Westinghouse generator which was retired and removed from the Virginia Electric and Power Company's Surry 2 Nuclear Power Station. Two post-service baseline inspections of the Surry 2A steam generator, using commercially-available multifrequency eddy current (EC) systems, were performed in accordance with the ASME Boiler and Pressure Vessel Code and U.S. Nuclear Regulatory Requirements. The purpose of the baseline examination was to provide an assessment of the current condition of the generator's Inconel 600 tubing. This assessment served as the basis for selecting a subset of tubes for round robin EC examinations. This report provides a detailed description of the post-service inspection procedures and results.

The post-service baseline examinations, using both Zetec and Intercontrole inspection systems, provided information on the condition of approximately 3000 of the 3388 tubes in the generator. The majority of reported wall-loss indications were located underneath the sludge pile at the top of the tube sheet on the inlet (hot leg) side of the generator. Very few wall-loss indications were reported at the tube-to-tube support plate intersections. Tube denting at these intersections reduced the effectiveness of the eddy current inspection techniques used in the baseline examination.

The results of the two inspections showed substantial disagreement in the detection and sizing of EC indications. Other than at the top of the tube sheet on the hot leg side of the generator, there were very few common defect detections reported by the two baseline examinations. The number of OD wall-loss indications reported by the two inspections were 773 and 1041, respectively. A direct comparison of the individual defect indications between the two inspections found that the detection agreement was 84% for the inspection with the fewer numbers of indications and 61% for the inspection with the larger number of indications. A comparison of the reported sizes of the common indications showed that one team sized an indication significantly larger than the other. The size differences ranged over ±60% of wall thickness, with the average size difference over 5%.

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1.0 INTRODUCTION

1.1 BACKGROUND AND PURPOSE OF THE STEAM GENERATOR GROUP PROJECT

U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.83 requires the periodic in-service nondestructive evaluation (NDE) of nuclear steam generators. The Regulatory Guide refers to the ASME Boiler and Pressure Vessel Code, Section XI, for specific procedures for conducting the inspection. The ASME Code specifies single frequency eddy current (EC) testing as an acceptable technique for meeting the inspection requirements. Current nuclear industry inspection practice uses multifrequency eddy current inspections. Typically, the required inspection is only a small percentage of the steam generator tubes. However, if defect indications are found, depending on the number and size, additional tube inspections are required. The use of a small subset of tubes for the initial inspection is based on the assumption that existing defect conditions are widespread, randomly distributed, and can be readily detected.

A major goal of the Steam Generator Group Project (SGGP) is to establish the reliability of eddy current defect detection and sizing in service-degraded steam generator tubing. This information, combined with burst test results of service-degraded tubing will be used to revise the current tube inspection and plugging criteria.

Figure 1 is a schematic of recirculating-type steam generators showing the known damage forms and their locations. The generator providing the service-degraded tubing for the project was removed from service from the Virginia Electric and Power Company's Surry #2 Nuclear Plant due to severe degradation after approximately six years of operation. The generator is a Westinghouse Series 51 Steam Generator containing 3388 U-bend tubes. The tubes used in this generator were fabricated from drawn Inconel 600, having design dimensions of outside diameter of 0.875", inside diameter of 0.775", and wall thickness of 0.050". The Surry unit was known, at the time of removal, to have severe denting and support plate degradation. There was also wastage reported at the top of the tube sheet due to the phosphate water chemistry used during initial service. In addition, the generator experienced an inner row U-bend failure, associated with denting-induced stresses. Approximately 22% of the tubes were plugged during the service life of the generator.

The 220-ton generator was barged from Virginia to the Hanford Site near Richland, Washington and installed in a specially designed and constructed Steam Generator Examination Facility (SGEF). It was positioned in its normal vertical operating position (Figure 2).

A subset of the plugged tubes was unplugged to provide access to tubes with suspended defects. The post-service eddy current baseline examination was conducted to determine the condition of the tubes. Two independent multifrequency eddy current examinations were performed on all accessible tubes. One inspection used equipment designed and manufactured by Zetec, Incorporated, of Issaquah, Washington (U.S.A.),

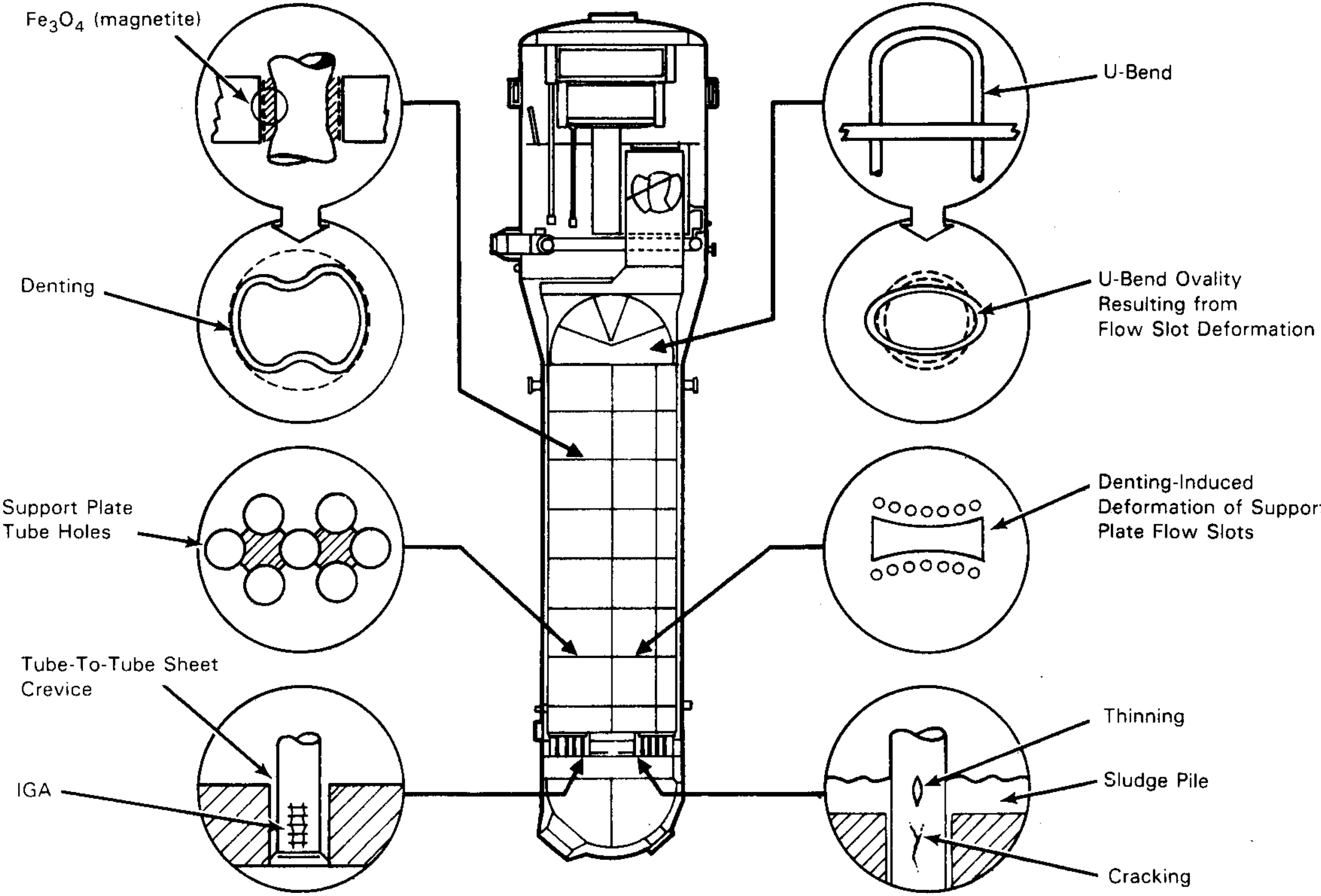

FIGURE 1. Typical Defect Types and Locations Identified for Recirculating-Type Steam Generators

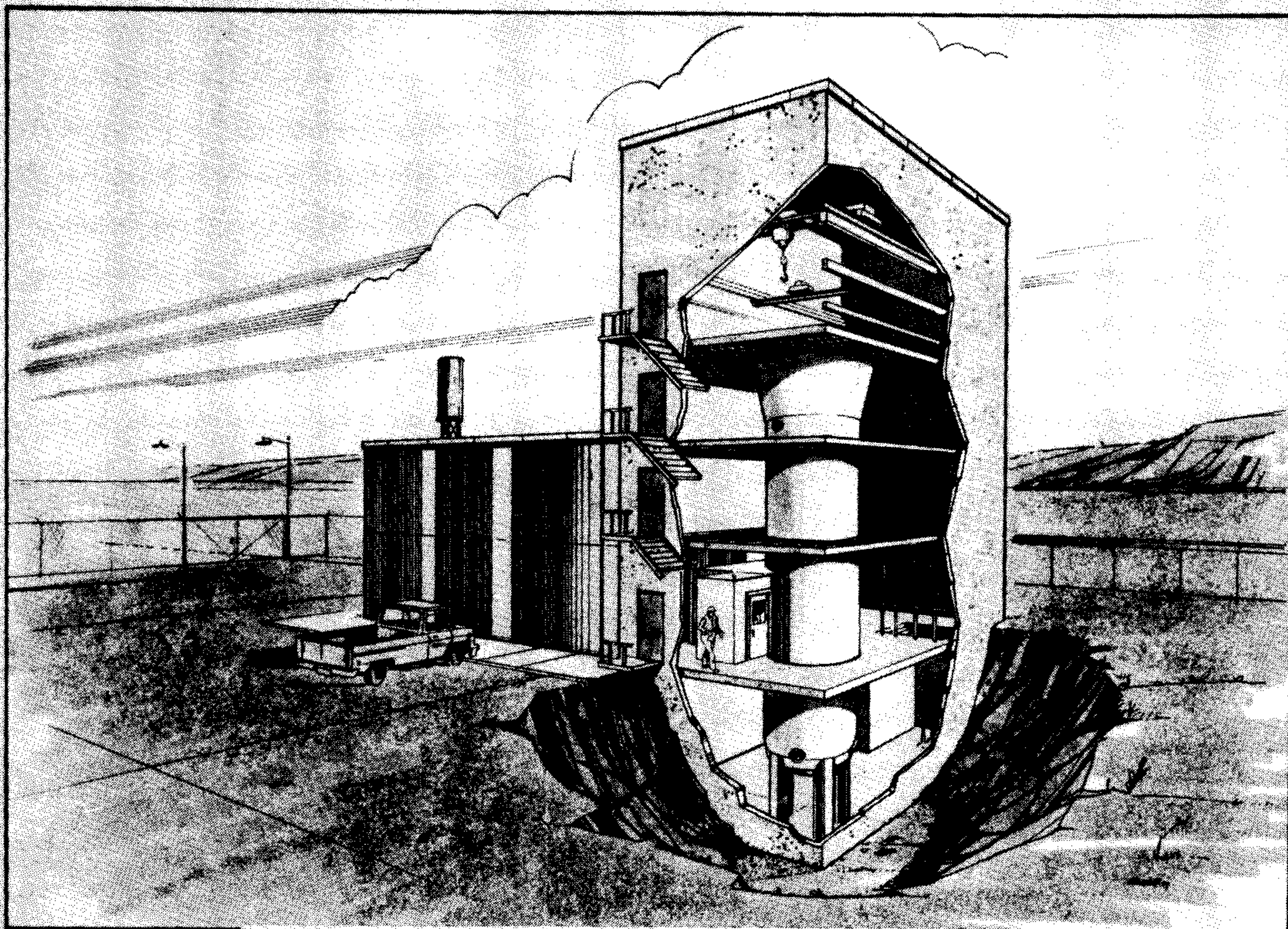

FIGURE 2. Picture of Steam Generator in Research Facility

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while the other equipment used was designed by the Commissariat a L'Energie Atomique (CEA - France) and manufactured by Intercontrole, Rungis, France. Both manufacturers' equipment are extensively used worldwide.

1.2 IN-SERVICE INSPECTION HISTORY OF SURRY 2A GENERATOR

Current in-service inspection requirements are based on Regulatory Guide 1.83, which describes the examination method, sampling plan, inspection intervals, supplementary sampling requirements and acceptance limits. Regulatory Guide 1.83, Rev. 1, dated July 1975, requires a baseline examination of all tubes in the steam generator by eddy current or equivalent techniques. The baseline examination is to be conducted prior to operation or upon a major change of secondary water chemistry. For operating plants without an initial baseline inspection, the first in-service inspection performed according to the Regulatory Guide defines the baseline condition for subsequent inspections. The ASME Boiler and Pressure Vessel Code, Sections XI and V, describes the inspection methodology and provides additional guidelines for equipment calibration, personnel qualification and certification, and reporting requirements for in-service inspections.

The Surry 2 Nuclear Power Plant licensing in 1973 preceded the requirements for a pre-service baseline examination. In-service inspections were performed on a subset of tubes using single frequency eddy current equipment according to historical data. There was no complete inspection of tubes when the secondary water chemistry was changed from phosphate to all volatile treatment in late 1974. In the later part of this steam generator's operating life, eddy current inspection consisted mainly of gauging the tubes to determine if denting at the support plates prevented the passage of a 0.610"-diameter EC probe. When this condition was detected, the tube, and those adjacent to it, were plugged as a preventive measure. Although single frequency eddy current data were collected during the last three years of service, no formal analysis was performed.

During the service life of the Surry 2A generator, tubes were plugged as a result of leaks, eddy current indications and gauging, or engineering judgment to prevent future failures. A map of the Surry generator tube sheet face (Figure 3), shows the extent and reasons for plugging of individual tubes.

1.3 PREPARATIONS OF THE GENERATOR FOR THE BASELINE EXAMINATION

Preparation of the generator for conducting a comprehensive post-service baseline eddy current examination included channel head decontamination and removal of most of the tube plugs placed during service.

Channel head decontamination was needed to reduce personnel exposure during the tube plug removal effort and the numerous NDE inspections planned during the course of the SGGP. The decontamination, which reduced fields to <1 R/h, used dilute chemical reagent techniques. Care was taken during decontamination to avoid chemical intrusions into the tube sheet region to ensure that the condition of the tubes would not be

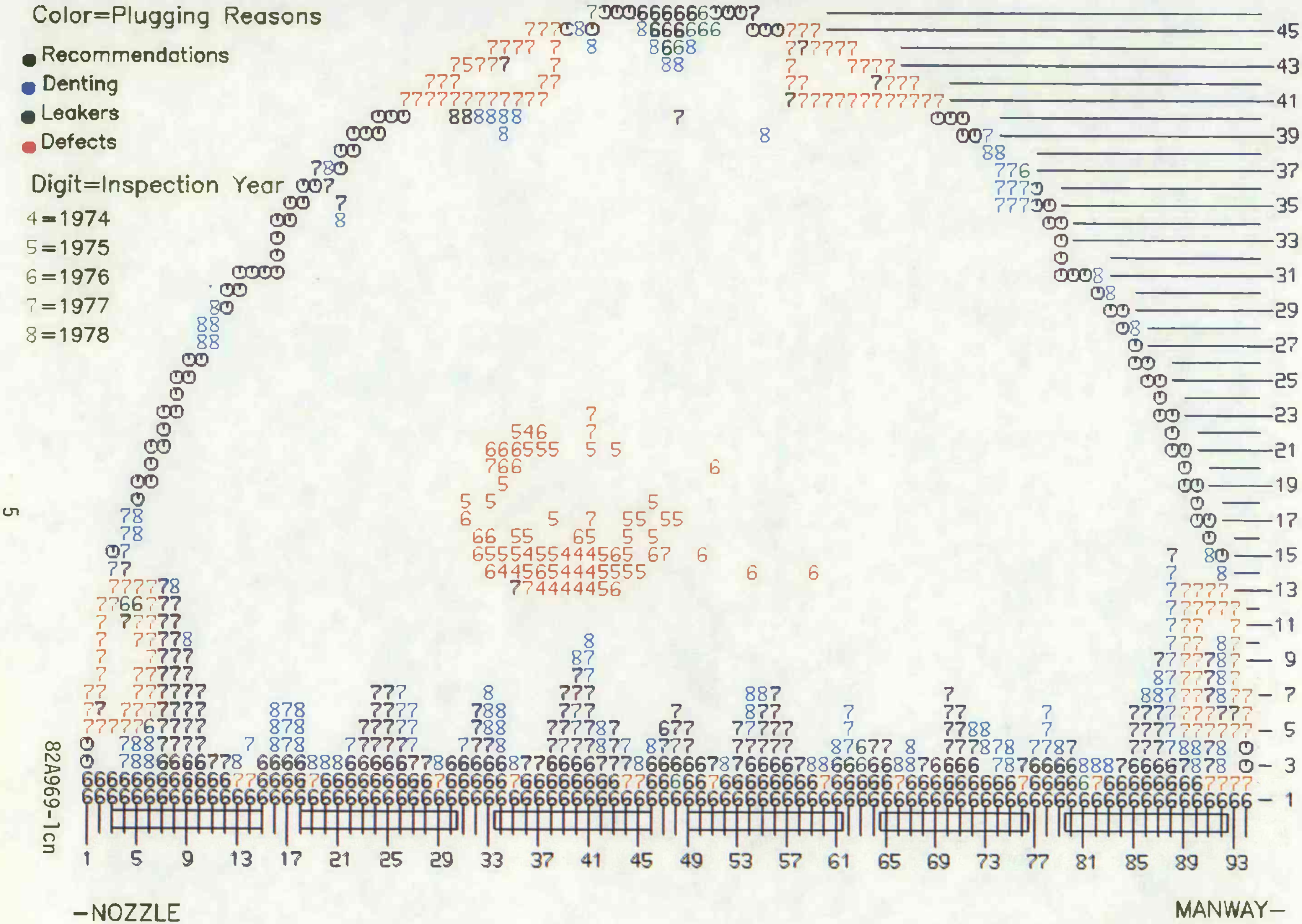

FIGURE 3. Tube Plugging Map of Surry 2A Steam Generator, Detailing Reasons for Plugging

modified by the process. A detailed description of the decontamination work is presented in PNL-4712, "Steam Generator Group Project Task 6 - Channel Head Decontamination."

To allow access to the primary side of the tube bundle for eddy current testing of tubes plugged in service, 470 of the 748 plugged tubes were unplugged on both the inlet and outlet side of the tube. All tubes that had defect indications reported during in-service NDE inspections were unplugged. The removal process involved drilling out the explosively-bonded plugs. The unplugging procedure removed the roll expanded area of the tube, which is located about 2.5" above the primary side of the tube sheet and which prevented the examination of this area on these tubes. In a few cases, the drilling was not concentric with the plug/tube centerline, leaving a machined ridge in a few tubes. This ridge interfered with the insertion of eddy current probes, which prevented effective inspection of some of the unplugged tubes. Details of the tube unplugging are described in PNL-4876, "Steam Generator Group Project Task 8 - Selective Tube Unplugging."

To better determine the degree and extent of denting at the support plates and its effect on the baseline inspections, eddy current profilometry, using the Zetec MIZ-15 EC tester and an 8x1 pancake coil array probe, was performed on 100 tubes distributed over the entire generator, as shown in Figure 4. A histogram of the minimum tube diameter at the hot leg support plates is shown in Figure 5. The corresponding histogram for the cold leg (outlet side) support plates are shown in Figure 6. The minimum reported diameter is 0.650" on the hot leg and 0.710" on the cold leg. Maximum denting was observed at the second support plate on the inlet side. The results of the profilometry indicated that denting would not prevent eddy current examinations in most tubes.

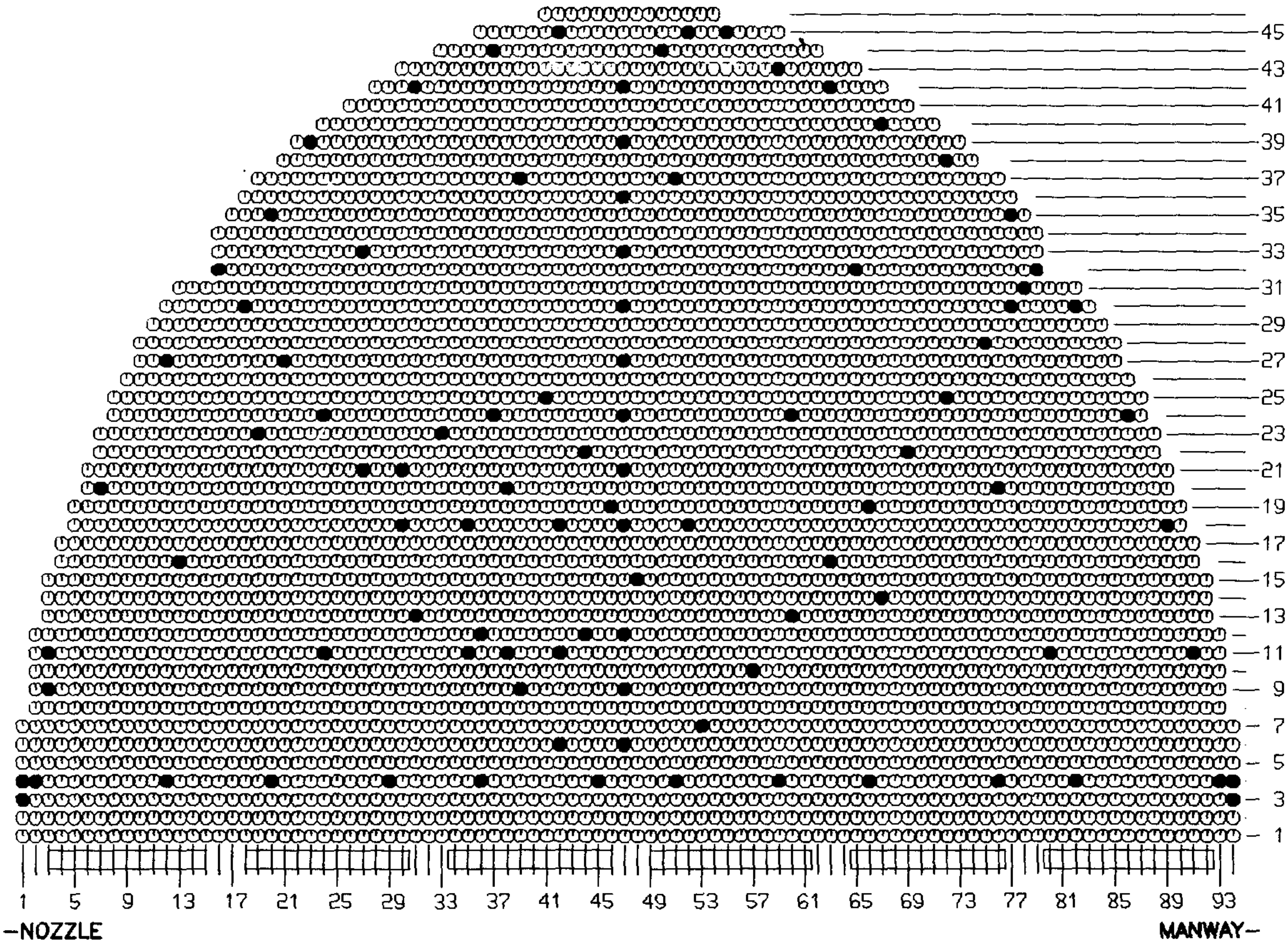

FIGURE 4. Tubes Inspected by Profilometry using the Zetec MIZ-15

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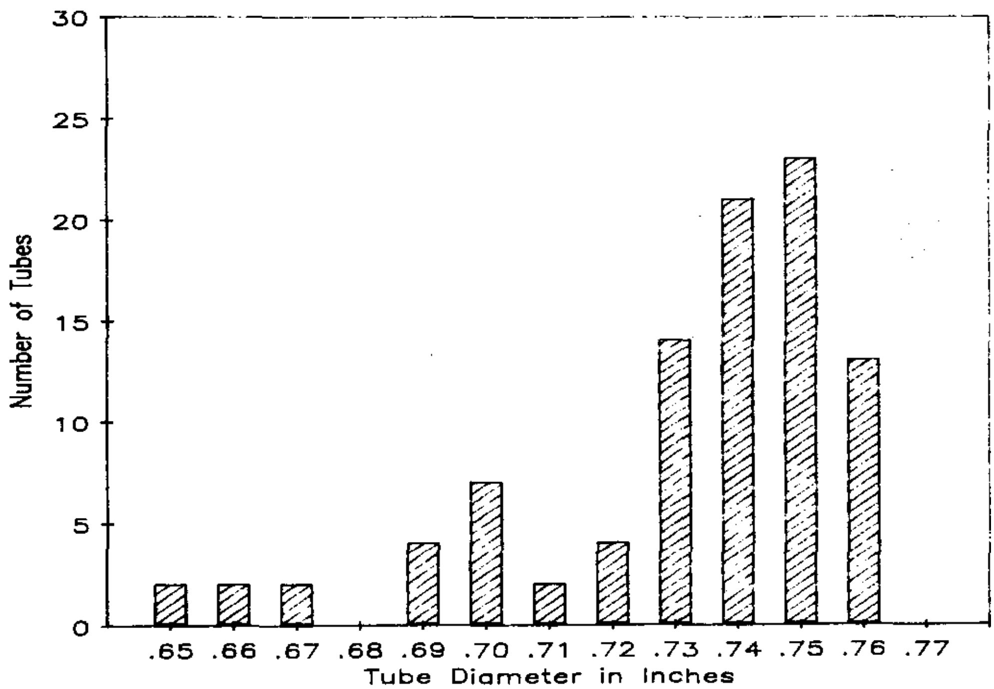

FIGURE 5. Histogram of Minimum Tube Diameter - Hot Leg

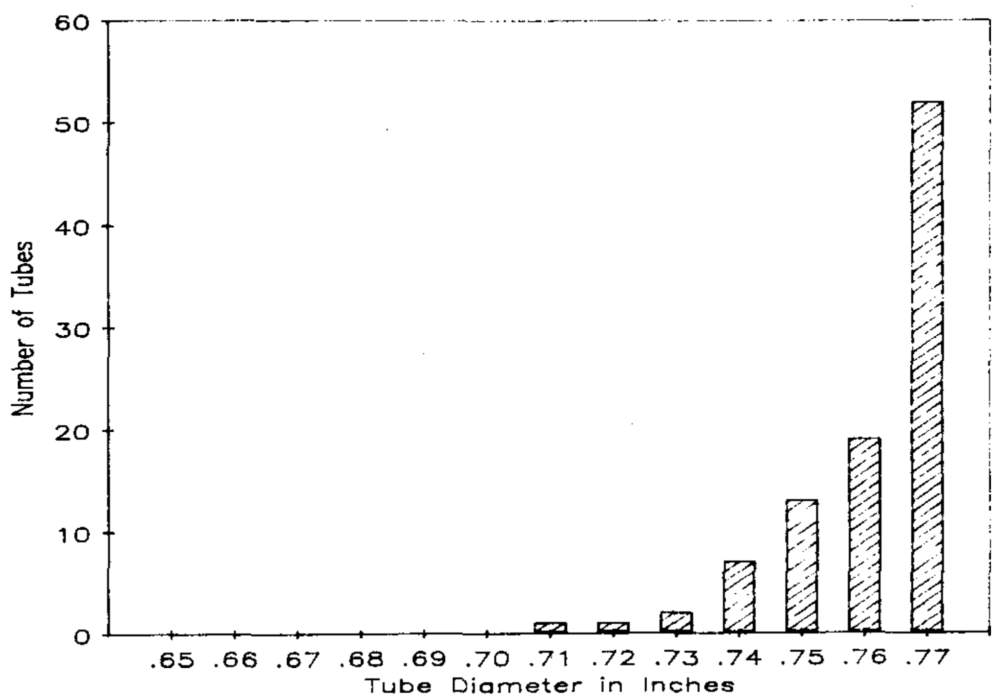

FIGURE 6. Histogram of Minimum Tube Diameter - Cold Leg

2.0 INSPECTION PROCEDURES AND EQUIPMENT

The majority of steam generator in-service inspections performed worldwide are conducted with Zetec or Intercontrole multifrequency EC equipment. Therefore, it was decided that the baseline examination should include inspections with both inspection systems to provide the most comprehensive characterization of the condition of the generator.

Specifications were established for the solicitation of bids from commercial in-service inspection companies to obtain qualified teams to conduct the baseline EC inspections. The statement of work for conducting a post-service baseline EC inspection of the Surry steam generator using a Zetec eddy current inspection system was issued in March 1983, to several potential sources, requesting technical and cost proposals to perform the examination. Revision 4 of this specification is given in Appendix A.

The technical specification for the Zetec inspection required that the tubes be tested with both single-frequency equipment, Model EM-3300 (which was used in-service), and multifrequency equipment, Model MIZ-12. The objective of using both Zetec instruments was to demonstrate the equivalence of the older single-frequency equipment with the corresponding frequency from the newer multifrequency equipment, thus permitting the comparison of the post-service eddy current signals from the tubes with data obtained during the in-service inspections.

A work statement similar to the one for the Zetec baseline inspection was prepared for the Intercontrole baseline inspection. This statement of work is given in Appendix B. The teams selected to perform the two baseline inspections were from Zetec, Incorporated, and Intercontrole, Incorporated.

The specifications required that the two inspections be conducted in accordance with the ASME, Section XI, "Rules for Inservice Inspection of Nuclear Power Plant Components," Appendix IV and IWA 2240 (1980 Edition); USNRC Regulatory Guide 1.83, "Inservice Inspection of Pressurized Water Reactor Steam Generator Tubes," Rev. 1, July 1975; and ASME, Section V, "Nondestructive Examination," Article 8, Appendix I (1980 Edition).

The inspection procedures used by both teams employed test frequencies and differential bobbin coil probes that met the requirements of the ASME Code. Specific test frequencies, probe designs, and modes of operation are separately described for each team in Section 2.1 and Section 2.2. The code-required calibration standard was used by both teams. Specifications for the calibration standard are described in Appendix C. The calibration standard was positioned in the probe guide just below the tube sheet, providing a scan of the standard along with the scan of each tube being examined. This assured that the system was always in calibration and free from drift or other influences that would have affected the validity of the data.

Prior to starting the baseline examination activity, Radiation Work Procedure 377-2 (Appendix D) was established to control the activities of NDE and support staff operating within the SGEF during NDE equipment installation, adjustment, maintenance and removal. All activities with respect to procedures were reviewed by the PNL Safety Committee prior to their approval and implementation. These procedures were very effective in controlling radiation exposure; for example, the Intercontrole team acquired a total exposure of 910 mR during their entire baseline inspection activities.

2.1 ZETEC INSPECTION

2.1.1 Zetec Equipment Setup

A remote trailer building was selected as the site for locating the eddy current remote controls and instrumentation. This building afforded adequate room for the equipment and operator, and the PNL staff that monitored the entire data acquisition and analysis procedures. This building was located approximately 200 feet from the facility (SGEF) containing the generator. This distance plus the length of cable within the SGEF required the addition of preamplifiers to compensate for signal loss and distortion. The amplifiers for the eddy current signals and the controls for the pusher-puller servo-drive motor were housed in a temperature controlled box fastened to the outside of the SGEF. This arrangement essentially duplicates the arrangement used to conduct examinations at nuclear power stations. The externally-mounted control box also contained connections that would allow future round robin in-service inspection (ISI) teams to test from a trailer or van parked outside the SGEF.

A Zetec remote probe positioning system (tube sheet templates, probe positioner with video camera and pusher-puller) was purchased to minimize personnel radiation exposure for both the baseline and future round robin examination activities.

The Zetec baseline inspection was designated the archival inspection for the project. In addition to the code requirement of recording eddy current signals on magnetic tape and strip charts, a PNL-designed computer data acquisition system, shown in Figure 7, digitized and recorded the signals real-time on disk for subsequent signal processing and analysis. This system consisted of a PDP 11/44 computer, a NEFF A/D converter, and a high-speed digital tape and hard disk drives.

The standard Zetec pusher-puller equipment has no encoder to identify the exact location of the eddy current probe in the tube, which is needed to locate potential defects for validation. A digital controller was designed and fabricated to allow computer control of the pusher-puller for probe insertion and removal, and to provide probe position information along with eddy current signals. The pusher-puller was modified to incorporate a direct current servo-motor drive to permit computer control. Figure 8 is a functional diagram of the system, and Figure 9 shows the encoder attached to the pusher-puller. A description

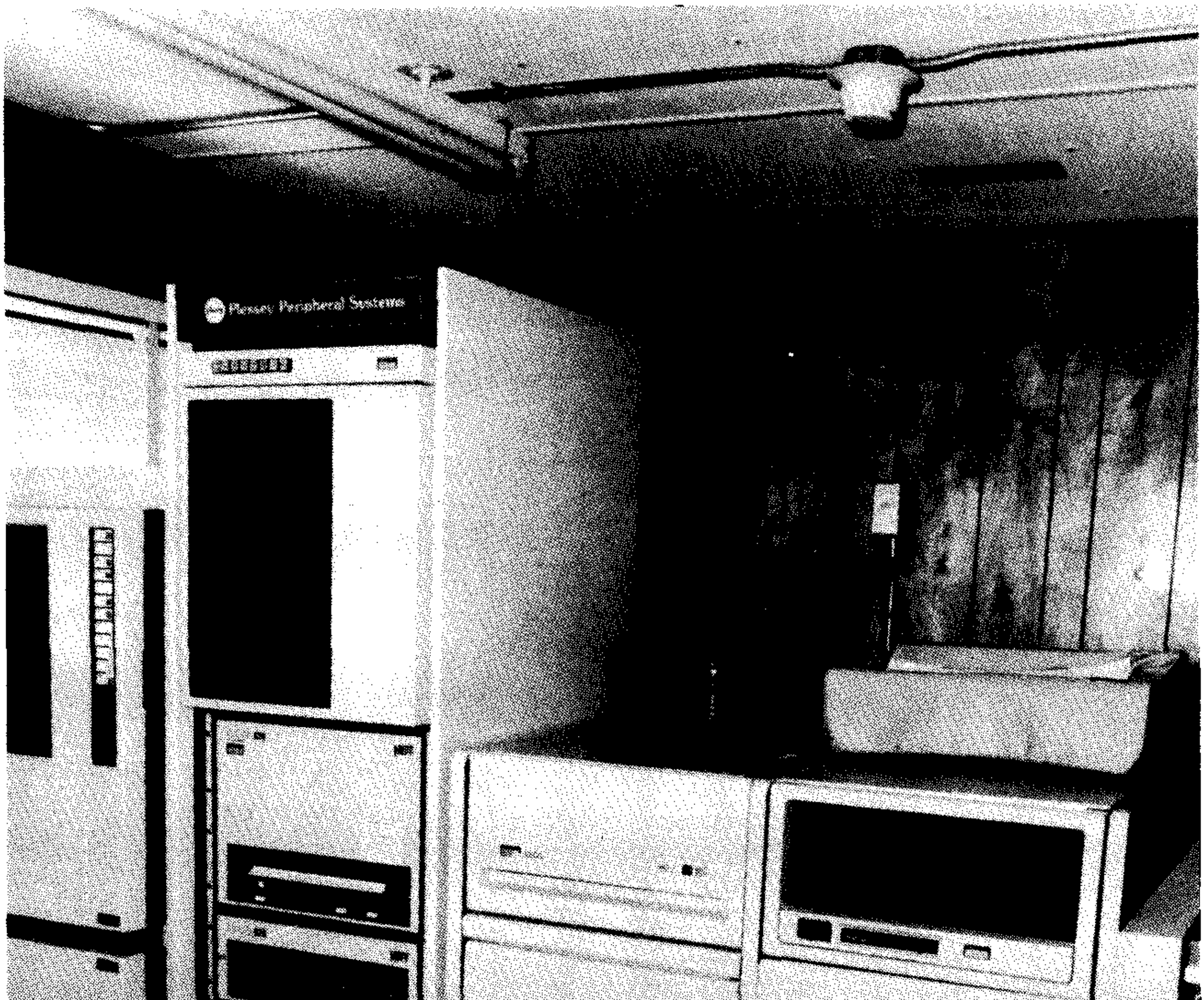

FIGURE 7. Data Acquisition Computer System

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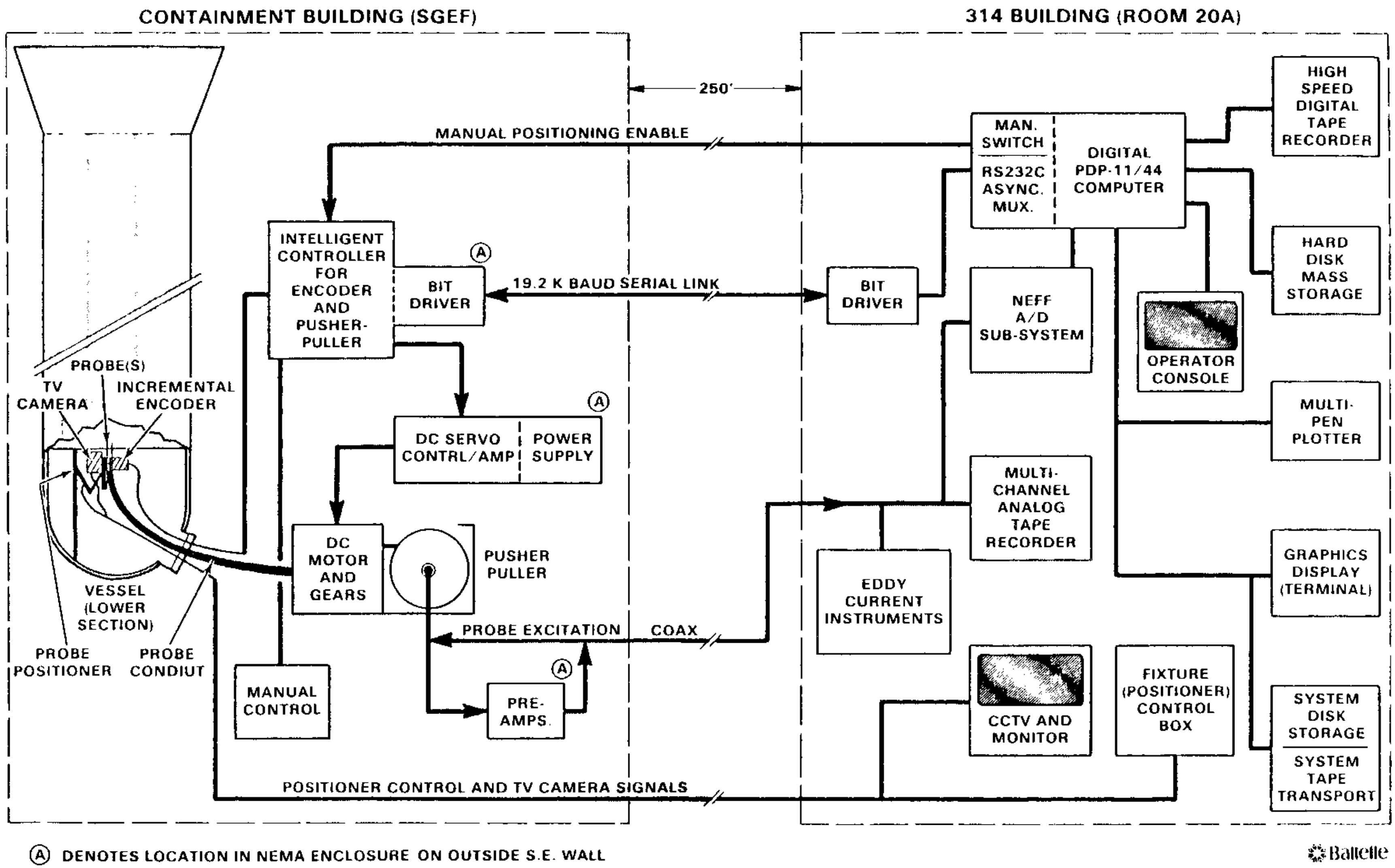

FIGURE 8. Conceptual Diagram of Steam Generator Inspection System

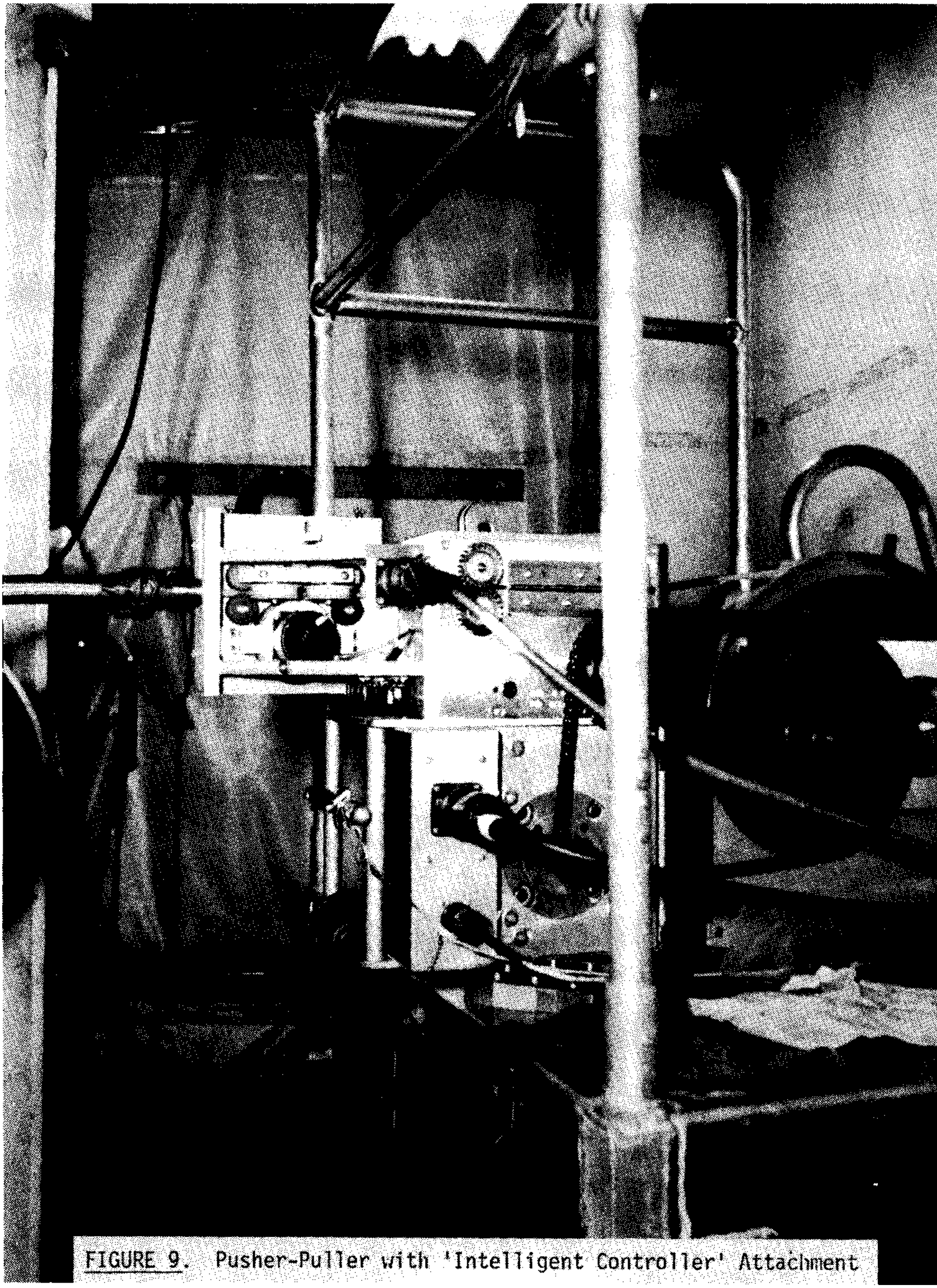

FIGURE 9. Pusher-Puller with 'Intelligent Controller' Attachment

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of the controller and the data acquisition computer equipment is presented in PNL-3955, "Steam Generator Group Project Progress Report on *Data Acquisition/Statistical Analysis.*"

The Zetec team submitted their procedures to the PNL nondestructive testing task manager for review and acceptance. In addition to the procedures, the personnel qualification certificates for all members of the inspection team and certificates documenting the calibration of eddy current instrumentation, were submitted to the SGGP NDE staff.

2.1.2 Operation of the Data Acquisition Computer System and Quality Assurance of the Archival Eddy Current Data Base

The data acquisition computer system was designed to collect the archival eddy current baseline data in real-time during the Zetec inspection. Two operators (a Zetec and a PNL staff member) were required to acquire the data, as opposed to one operator normally used during field examinations. The technician selected the tube to be examined and positioned the probe over the correct row and column. The technician also recalibrated the eddy current instrument periodically in accordance with the procedure for calibration. A PNL staff member was responsible for initiating the scan by controlling the pusher-puller. The data acquisition software was designed to make the data collection as automated as possible to minimize errors.

Procedures for operating the PNL computerized data acquisition system are given in Appendix E. An example of how these procedures helped to ensure both adequacy and accuracy of data is typified by the tube identity verification. Prior to scanning each tube, the operator was queried by the computer for information needed to provide a positive and unique identification of the tube. The operator was also asked to describe the pertinent parameters of that inspection. The information (Table 1), once provided, was then recorded with the eddy current data for each scan.

TABLE 1. Information Recorded with Each Inspection in the Zetec Baseline Archival Data Base

Data and Time
Eddy Current Operator's Name
Eddy Current Instrument Model
Probe Type
Eddy Current Instrument Channel Assignments; Frequency, Phase, Gain
Tube Row Number
Tube Column Number
Origin of Inspection (Inlet or Outlet Side)
Zetec Magnetic Tape Reel Number
Data Set Name
Type of Sampling (Time or Distance)
Sample Interval
Probe Start Position
Probe Stop Position
Probe Speeds During Inspection and Scanning

The header information contained information such as eddy current instrument model, origin of inspection, and sample interval. The operator was required to make written entries into a logbook regarding changes in instrument, probe type, origin leg of the inspection, date, and to note errors in entering tube identification parameters. As a further aid in documenting parameter information, the operator was required to generate a hard copy of the terminal screen parameter status display. Row and column numbers changed for each scan, affording the greatest opportunity for operator error.

As an added precaution, a video recorder was automatically switched on at the beginning of each inspection to record the tube row and column number from the tube sheet template as viewed by a TV monitor positioned on the manipulator arm. The voice channel was also recorded by the video recorder. The objective of the video recording was to provide a quality assurance (QA) measure that would allow a review of the actual tubes examined, as assurance that the eddy current technician did not inadvertently announce the wrong tube row and column number. Figure 10 shows the Zetec equipment operator and supporting equipment in the remote control room.

During real-time data acquisition, the data from each inspection was written to a hard disk rather than magnetic tape to avoid the possibility of electromagnetic interference between the high-speed tape drive and the eddy current instrumentation located in the same room. The data was then transferred to digital tape at the end of each shift by the computer operator. As part of the documentation of this process, the operator generated a directory listing of all files to be archived, then examined the logbook to determine what data files were retests, needed to be deleted, or had been assigned an incorrect file name. If a file name was incorrect, the operator renamed the file before transferring it to tape. Each change was noted on the directory listing. In addition, the operator noted on the directory listing the digital tape number used to store the data collected during the shift, so that an individual inspection could be readily located.

The Zetec baseline resulted in the generation of over 70 high-density digital tapes containing over 9000 data files. Despite the automated acquisition system and the fixed procedure for the computer operator to follow, some errors in specifying the inspection parameters did occur. Examples of the most frequent errors are a failure to change the instrument channel assignments, such as the phase and gain after instrument calibration, the assignment of the wrong row and/or column numbers, and the failure to change the instrument type or analog tape number at the appropriate time. In addition, if the computer operator renamed a file before it was transferred to tape at the end of a shift, then that file's data set name within the file itself had to be changed.

There was not time at the end of each shift to check and correct the inspection parameters before storing the data on tape, so the file correction had to be done after the baseline inspection was completed. Some of the errors were caught by the operators and noted in the log, but some were not; therefore, corrections had to be made for inconsistencies even when none were reported. The file corrections first

FIGURE 10. Control Station for Zetec Operations

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involved copying the files from tape to disk. Then each file was examined and checked against the logbook, the terminal screen copies of the parameter status displays, and the tape file directory listings. The corrected files were archived back to the digital tape and a master tape directory was prepared, which lists not only the file names and tape number, but the parameters associated with each inspection. This master directory is maintained in the data base management system on the computer, so the data from any inspection or tube can be easily located. The entire quality assurance process required several months to complete since each file had to be individually inspected. Approximately 500 of the 9000 inspections required some form of correction.

2.1.3 Zetec Inspection and Signal Analysis Procedures

The Zetec team provided two eddy current examination procedures to PNL for the baseline inspection. They were ZQA-301, Rev. 3, March 1981, "Eddy Current Inspection of Non-Ferrous Tubing by Single Frequency Techniques," and ZQA-301MF, Rev. 3, March 1981, "Eddy Current Inspection of Non-Ferrous Tubing by Multifrequency Techniques." The Quality Assurance practices for the Zetec examination equipment and personnel were described in Zetec QA documents, QAP MD-2 and QAP MD-2A.

The MIZ-12 multifrequency eddy current equipment allows the examination of tubing by as many as four separate frequencies simultaneously, using multiplexing techniques. The equipment provides quadrature output for each frequency, which permits dynamic mixing to remove unwanted signals caused by support plate denting and deposits. The quadrature outputs of the MIZ-12, for both mixed and unmixed channels, are recorded on frequency-modulated magnetic tape. In parallel with the recording of eddy current signals on magnetic tape, two channels of the eddy current output are recorded on a strip chart.

A selection of Ultraflex™ and Superultraflex™ probes was used to perform the examination. The probes and the eddy current instrumentation were supplied by the Zetec team for the examination. Although Zetec manufactures a probe containing a magnet to provide a saturation field for tubes exhibiting permeability variations, the probe was not used for this examination. Probes with diameters of 0.720", 0.700", 0.650", and 0.610" were used to perform this examination. Initial tube scanning was performed with the two largest diameter probes. The smaller diameter probes were used to allow access to tubes too badly dented to permit the passage of the larger diameter probes. Scanning speeds used by the Zetec team averaged 36" per second for insertion and 12" per second for withdrawal. Data were acquired only on withdrawal (pulling).

The test frequencies selected by the Zetec operator for the multifrequency baseline examination data acquisition are given in Table 2.

TABLE 2. Frequencies Used for Zetec Baseline Inspection

400 kHz operated at normal gain - differential mode
400 kHz operated at reduced gain - differential mode
100 kHz - differential mode
100 kHz - absolute mode

The 400 kHz frequency reduced gain was used to allow analysis of a significant number of wastage signals; these signals would saturate the instrument using the normal gain setting. It was anticipated that the reduced gain 400 kHz signal could be mixed with the 100 kHz signal to filter out the effects of denting and conductive deposits. This latter effort did not prove effective. The effects of the conditions could not be eliminated using conventional frequency-mixing procedures.

The single frequency inspection was conducted using a 400 kHz differential mode. One of the objectives of the inspections was to demonstrate the equivalence of the response of the single-frequency equipment and the multifrequency equipment at 400 kHz. Historically, 400 kHz single frequency was used to examine the Surry generator while it was in service. Therefore, the reinspection of tubes with the same frequency was thought to be desirable for comparisons between inservice data and the current generator condition. Two-hundred-eighteen tubes were scanned with the EM-3300 single-frequency instrument.

Analysis of recorded inspection data was performed by a Level II Analyst using a Zetec DDA-4 eddy current analyzer. This analysis system, illustrated in Figure 11, converts the analog signals recorded on magnetic tape to digital signals which are then displayed in a format that allows the analyst to review the data from one or two channels at a time. Any two of the eight recorded channels can be viewed and analyzed on this equipment simultaneously. Once an indication is observed by the operator, the phase angle of the Lissajous pattern formed by the quadrature output of the eddy current system is measured automatically by the analyzer software and the depth of the indication is determined. A hard copy printout of the DDA-4 analyzer display is illustrated in Figure 12. While the DDA-4 software automatically measures the phase angle based on peak-to-peak reference points, the analyst can place the cursors defining the angle at his discretion to correct for possible signal distortion. The location of the reference points where the cursors have been set are shown as hollow dots in Figure 12.

The data format used to report the findings of the analysis of eddy current signals is illustrated in Figure 13. The information for each inspected tube is given in Table 3.

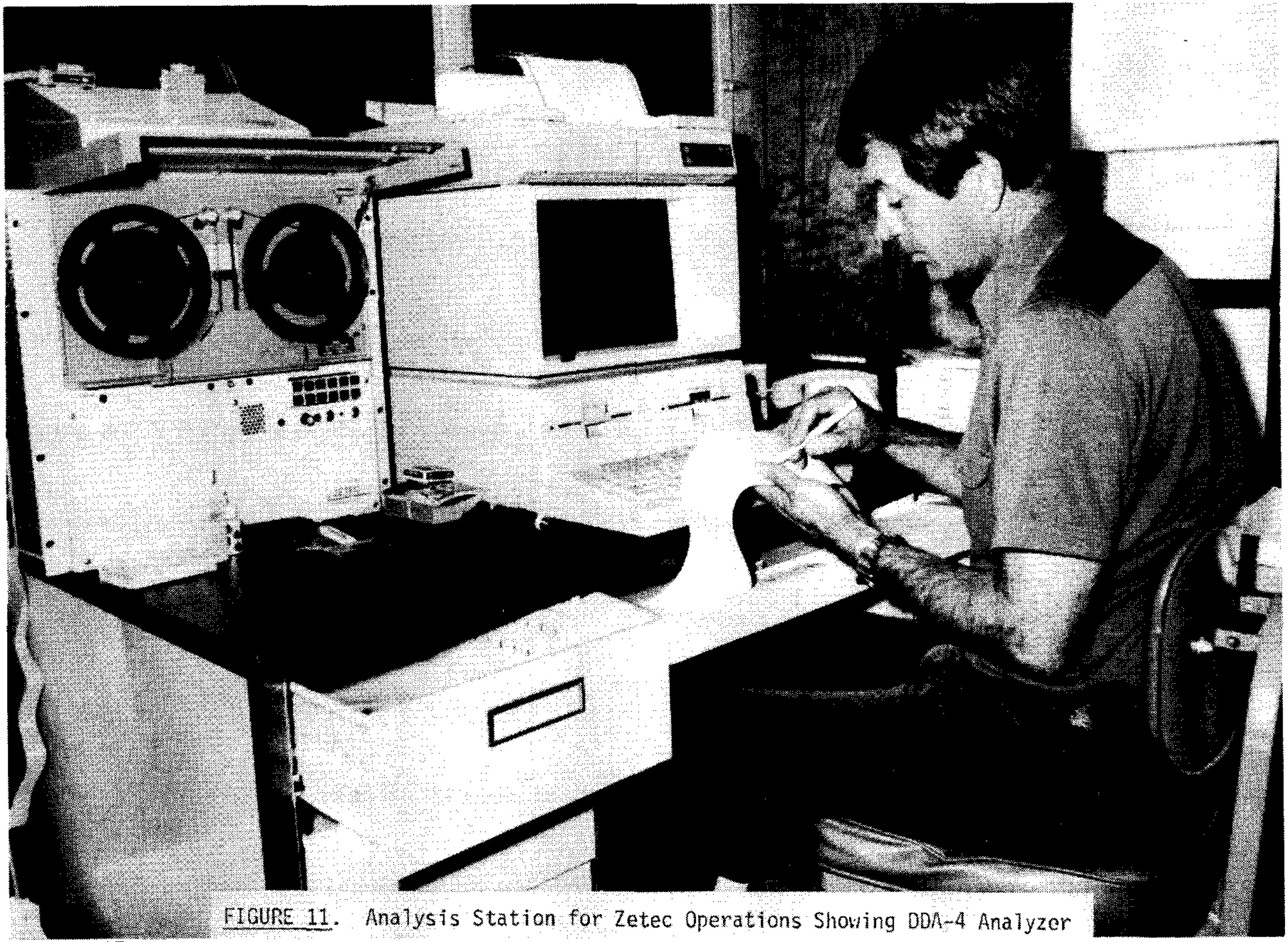

FIGURE 11. Analysis Station for Zetec Operations Showing DDA-4 Analyzer

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MULTIFREQUENCY TEST R46C45; 63% INDICATION FROM COLD LEG

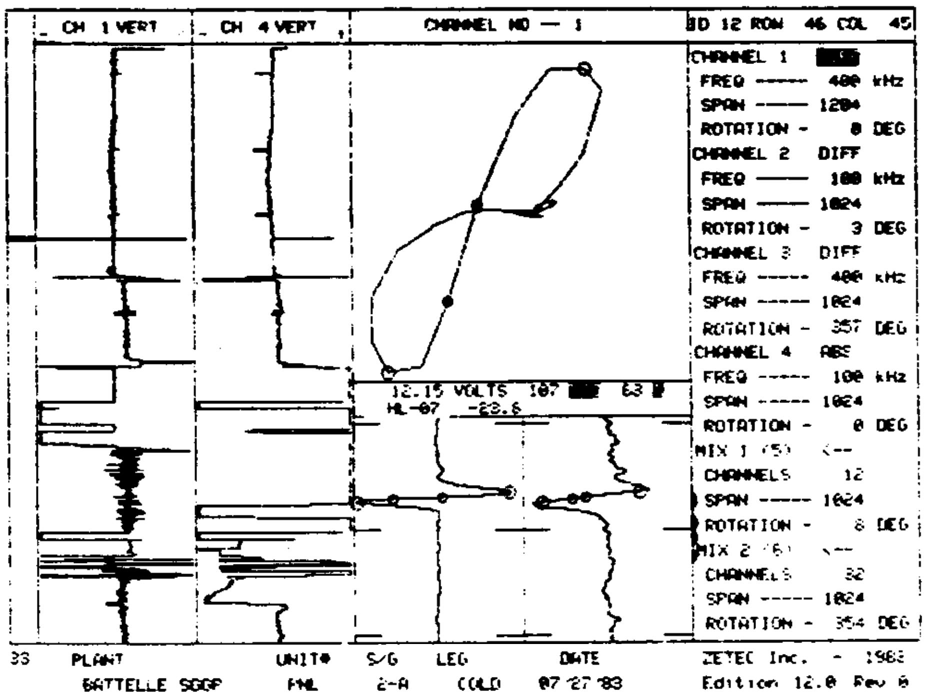

FIGURE 12. Zetec DDA-4 Analyzer Display

PLANT				UNIT#	S/G	LEG	REEL	TO	REEL	DATE
BATTELLE SGGP*				PNL	2-A	COLD	26		32	08/03/83

SG	ROW	COL	VOLTS	DEG	%	CH#	LOCATION	EXTENT
12	006	076	15.63	066	054	2	HL TTS	F/L
			04.08	108	062	3	HL TTS	F/L
			13.47	109	060	5	HL TTS	F/L
			04.31	104	060	6	HL TTS	F/L
12	005	076	08.46	016	040	1	CL-07 +3.1 I.D. CRACK	CL-07
			03.15	024	057	2	CL-07 +3.1 I.D. CRACK	CL-07
			09.12	014	035	5	CL-07 +3.1 I.D. CRACK	CL-07
12	004	076						CL-07
12	003	076	00.04	000	000	1	PLUGGED +0000.0	NO TEST
12	002	076	00.04	000	000	1	PLUGGED	NO TEST
12	001	076	00.05	000	000	1	PLUGGED	NO TEST
12	001	077	01.13	000	000	1	PLUGGED +0000.0	NO TEST
12	002	077	00.02	000	000	1	PLUGGED +0000.0	NO TEST
12	003	077	00.02	000	000	1	PLUGGED	NO TEST
12	004	077	00.03	000	000	1	PLUGGED	NO TEST
12	005	077	10.55	016	040	1	CL-07 +3.1 I.D. CRACK	CL-07
			03.50	019	045	2	CL-07 +0003.1	CL-07
			03.21	012	030	3	CL-07 +0003.1	CL-07
12	006	077	02.53	151	024	1	HL TTS +0000.0	F/L
			03.00	080	026	2	HL TTS +0000.0	F/L
			02.38	146	025	5	HL TTS +0000.0	F/L
12	007	077	03.93	127	048	1	HL TTS +0000.0	F/L
			04.95	077	032	2	HL TTS +0000.0	F/L
12	008	077						F/L
12	009	077						CL-07
12	010	077	01.10	142	034	1	HL TTS +0000.0	F/L
12	011	077	01.41	145	031	1	HL TTS +0000.0	F/L
12	012	077						F/L
12	013	077						F/L
12	014	077						F/L
12	015	077						F/L
12	016	077						F/L
12	017	077						F/L
12	018	077						F/L
12	019	077						F/L
12	020	077						F/L
12	021	077						F/L
12	022	077						F/L
12	023	077						F/L
12	024	077						U-BEND
12	025	077						U-BEND
12	026	077						F/L
12	027	077						U-BEND
12	028	077						U-BEND
12	029	077						U-BEND
12	030	077						HL-07
12	031	077						U-BEND
12	032	077						CL-TTS

PAGE 11 OF 20	EVALUATOR	LEVEL

FIGURE 13. Zetec Baseline Final Report Data Format (Typical)

TABLE 3. Inspection Information Produced by Zetec DDA-4 Eddy Current Analyzer

Date of analysis
The side of the generator (hot or cold leg) from which the tube was inspected
The magnetic tape reel number
The probe type and size
The tube row number
The tube column number
Phase angle of indication
Voltage level of signal
Origin OD or ID and location of the indication
Depth of the indication in terms of percent of wall thickness
Channel number from which determination was made
Miscellaneous findings; such as notations, loose parts, sludge height, permeability and denting.
The extent of inspection [full-length (F/L)]

2.2 INTERCONTROLE INSPECTION

2.2.1 Intercontrole Equipment Setup

The Intercontrole equipment is designed to operate using dedicated software and specially developed controllers, so the equipment procured for the Zetec inspection was not directly adaptable for real-time acquisition of the Intercontrole inspection data. All of the equipment used for the Intercontrole inspection was supplied by Intercontrole. The major components of the Intercontrole equipment: pusher-puller, finger-walker probe positioner, and data acquisition system, are shown in Figures 14-16, respectively. Instead of a manually-controlled probe positioner, the Intercontrole system uses a microprocessor-based controller which directs the pneumatically-powered finger-walker (Figure 15) to the appropriate tube row and column, potentially avoiding a mistake or omission.

It was determined at the time of the Intercontrole inspection that there was sufficient room in the SGEF truck unloading area to allow NDE teams to operate from within the SGEF. The Intercontrole examination was not interfaced with the PNL data acquisition computer, so there was no need to be located in the remote trailer. This change in operating location reduced the distance between the eddy current signal-conditioning equipment and the probe from approximately 200 ft. to about 30 ft., affording an improvement in signal-to-noise ratio.

2.2.2 Intercontrole Inspection and Signal Analysis Procedures

Intercontrole prepared and submitted a project plan to PNL describing the eddy current procedures, field modification records, personnel qualification and certification procedures, equipment calibration certificates, and calibration standard certificate. Quality Assurance

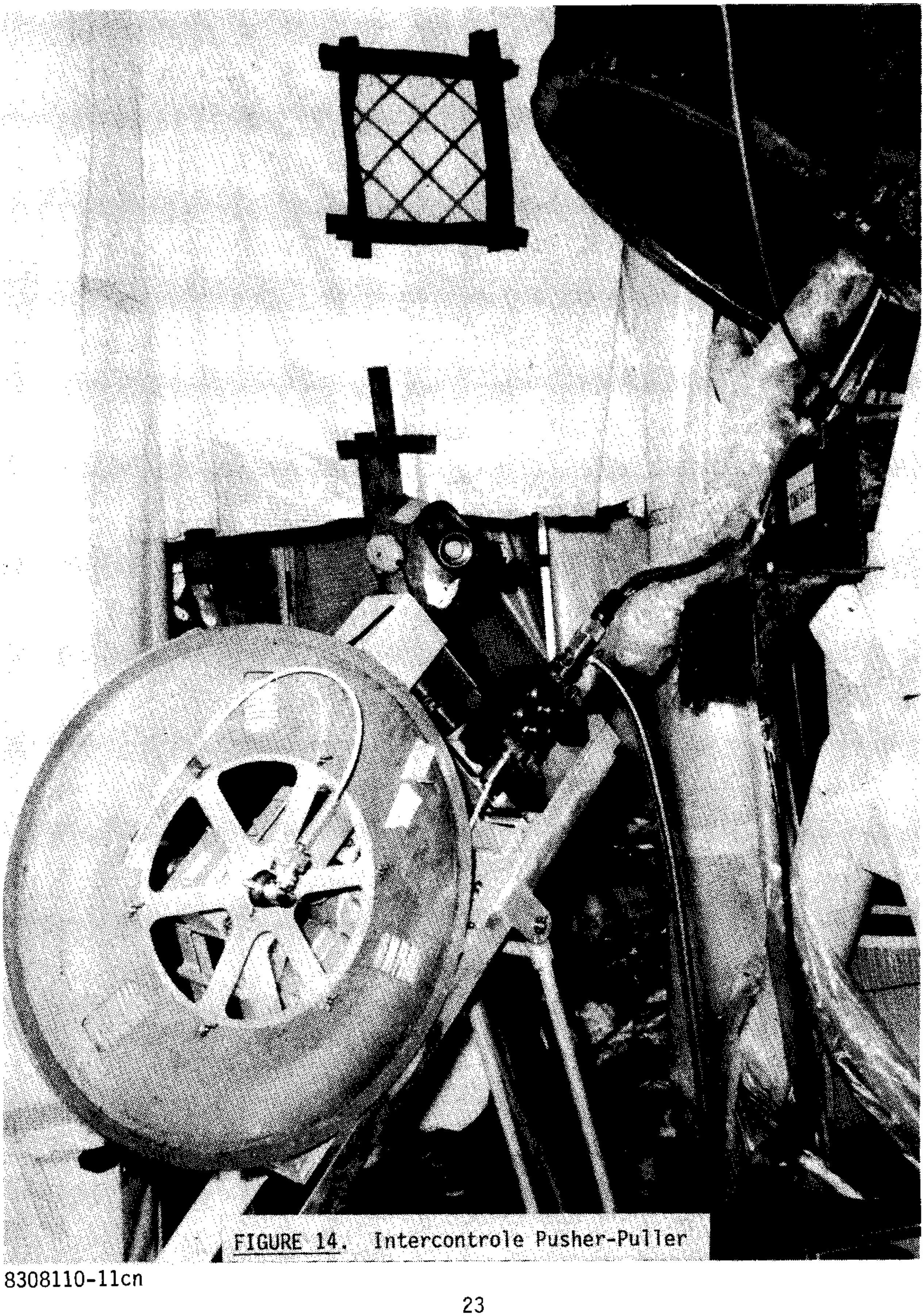

FIGURE 14. Intercontrole Pusher-Puller

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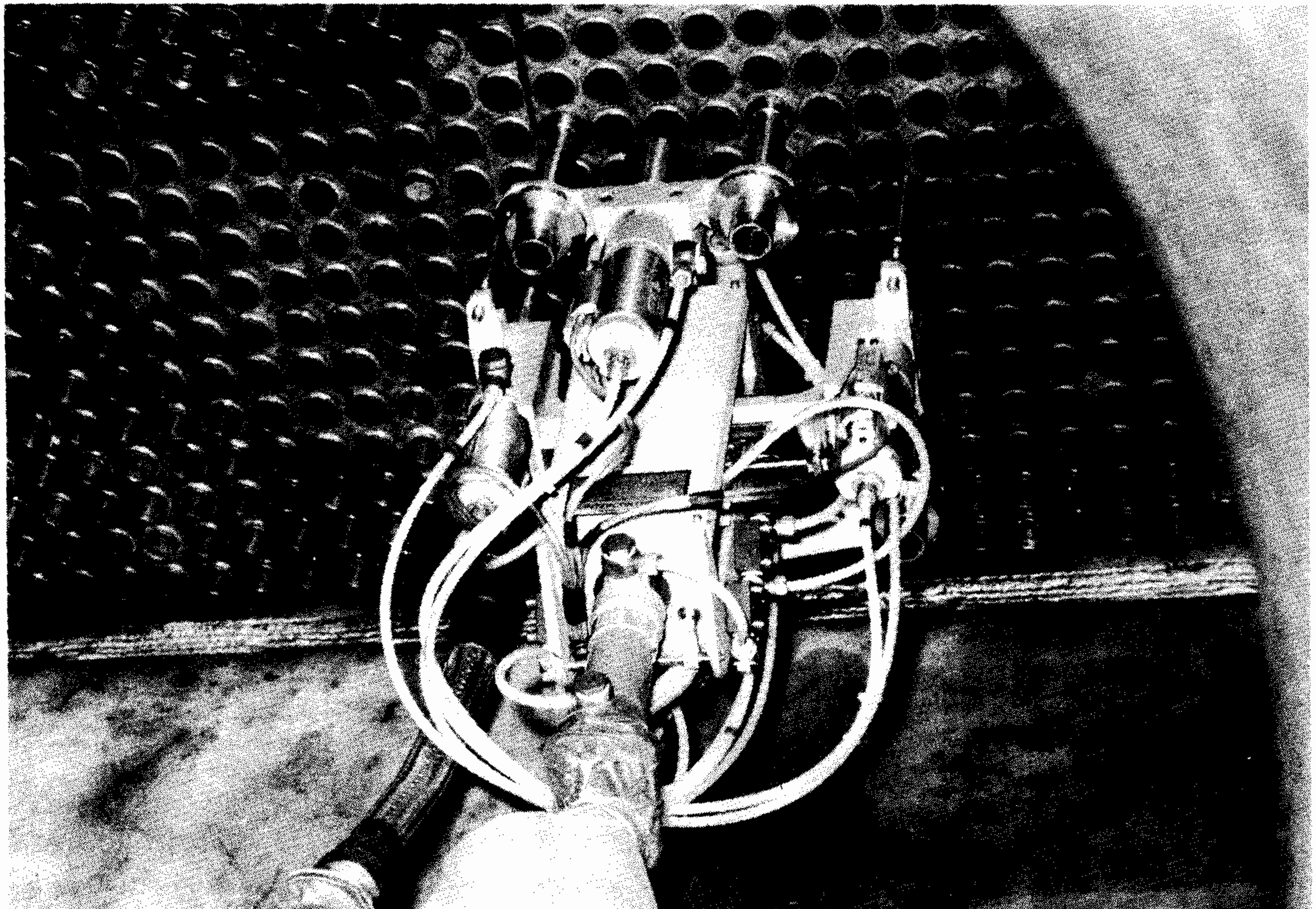

FIGURE 15. Intercontrole Finger-Walker Probe Positioner on the Tube Sheet

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FIGURE 16. Control Station for Intercontrole Operations

8308110-8cn

Manual, Rev. B, October 17, 1983, was also submitted to PNL for review and acceptance. The specific eddy current procedure used by Intercontrole for the baseline examination is QA-PCER-040, Rev. A, November 4, 1983, "Multifrequency Eddy Current Procedure for Surry Steam Generator (2A)."

Bobbin coil probes used by the Intercontrole team were 0.708", 0.688", 0.669", 0.650", 0.629", 0.610", and 0.590" in diameter. All Intercontrole probe designs incorporated a magnetic saturation coil. The saturation field can be activated at any time during scanning to eliminate the effects of permeability variations which might be present in the tube base material. Intercontrole eddy current data was collected by both during insertion and withdrawal of the probe. During withdrawal (pull) of the probe, the saturation field was automatically applied to the coil. This provided serial acquisition of data both with and without magnetic saturation, which allowed permeability conditions to be identified.

Test frequencies used by the Intercontrole team for the baseline examination data acquisition are given in Table 4.

TABLE 4. Frequencies Used by Intercontrole Baseline Inspection

500 kHz - Differential Mode
240 kHz - Differential Mode
100 kHz - Differential Mode
100 kHz - Absolute Mode

The inspection procedures used by the Intercontrole team were similar to those used by the Zetec team. Scanning speeds used by the Intercontrole team were 20" per second for both insertion and withdrawal.

As a quality control function during the examination, PNL staff monitored the entire Intercontrole data acquisition operation, checking the location of the finger-walker on a television camera against the intended locations selected by the Intercontrole operator. Prior to the installation of equipment into the channel head, specific tube rows and columns were painted red allowing the finger-walker locations to be confirmed. No errors were observed in the operation of this device, but no permanent record was kept for later verification.

The Intercontrole inspection system uses a four-channel digital tape recorder which allows up to eight channels of information to be recorded using serial multiplexing. Tube identification was automatically recorded by the microprocessor controller during scanning. PNL simultaneously recorded the Intercontrole eddy current signals real-time during data acquisition using the Zetec four-channel FM tape recorder (see Figure 16). This allowed data acquired by the Intercontrole IC3FA multifrequency equipment to be recorded on a media that could be subsequently processed and analyzed on the Zetec DDA-4 analyzer.

The signal analysis equipment used by Intercontrole differed significantly from that used by the Zetec team. The Intercontrole data analysis equipment is shown in Figure 17. The digitally-recorded data was converted to analog by an IC4ID data interface, for analysis using the IC4AN signal processor and analyzer. The IC4AN processor includes differentiation and low-pass filtering to enhance signal presentation and analysis. Following the signal processing, eddy current signals are recorded off-line using an eight-channel strip chart recorder at 40" per second. The channels recorded on the strip chart recorder are given in Table 5.

TABLE 5. Frequencies Recorded on Strip Chart During Intercontrole Data Analysis

240 kHz - Horizontal and Vertical
100 kHz - Absolute Horizontal and Vertical
240 and 100 kHz Mix for Support Plates - Horizontal and Vertical
500, 240 and 100 kHz Mix for Support Plates and Dents - Horizontal and Vertical

The concurrent display of the responses of all acquisition frequencies and test modes on this strip chart record afforded the opportunity to characterize indications as well as to detect them. The appearance of a signal at different frequencies, mixes, and saturation conditions aided the characterization of indications. The phase angle of indications identified by this procedure were subsequently measured and the depth determined.

The results of the Intercontrole baseline examination were submitted to PNL in a typed report. A copy of a typical page from the report is shown in Figure 18. The interpretation of the eddy current signal data for each tube inspected is given in Table 6.

TABLE 6. Inspection Information Produced by Intercontrole Baseline Data Analysis

Row (line)
Column number of the tube
Origin of the indication (ID or OD)
Depth of the indication in percent of tube wall
Location of the indication(s) along the length of the tube
Sludge height above the tube sheet on both the hot leg (HL) and cold leg (CL) sides of the generator
Location of obstructions encountered which prevented the passage of the eddy current probe (block)
Notes describing other observations, such as CD (conductive deposit), M (magnetic indications), and denting

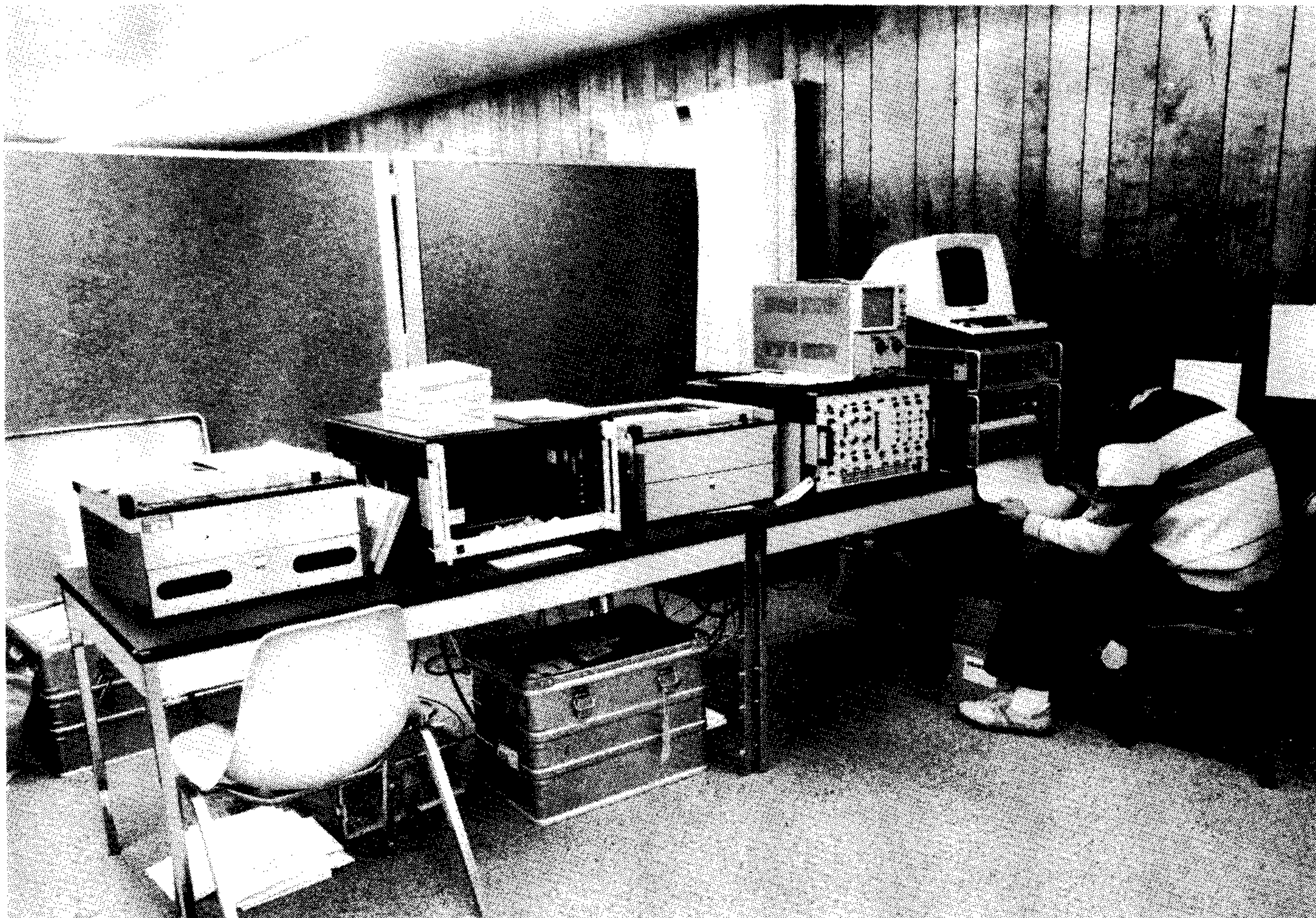


FIGURE 17. Analysis Station for Intercontrole Operations

8304563-1cn

EDDY CURRENT FINAL REPORT

PLANT: Battelle UNIT #: 2A COMP.: S/G PROCEDURE: QA-PCER-040

SIDE: CL CALIBRATION SHEET #: 5 PEEL #: 3

TUBE# L	TUBE# C	WALL LOSS Origin	WALL LOSS %	WALL LOSS Location	WALL LOSS Origin	WALL LOSS %	WALL LOSS Location	SLUDGE (CM) HL	SLUDGE (CM) CL	BLOCK	NOTES
18	67							10	12		CD
17	67	OD	27	HTSE				8*	12		CD
16	67	CD	42	HTSE				8*	10		CD DCP67
15	67	CD	50	HTSE				8*	12		CD
14	67							8*	12		M CD
13	67	OD	52	HTSE				10*	16		CD
12	67	OD	47	HTSE				10*	18		CD
11	67	OD	75	HTSE				10	18*		CD
10	67	OD	40	HTSE				10*	16*		CD
9	67	CD	42	HTSE				8*	16		CD
8	67	CD	40	HTSE				10*	14*		M CD
7	66	OD	42	HTSE				10*	16		CD
8	66	OD	45	HTSE				10*	16		CD
9	66	OD	50	HTSE				8*	16*		CD
10	66	OD	40	HTSE				8*	18*		M CD
11	66	OD	41	HTSE				10*	18		CD
12	66	CD	70	HTSE				8*	18*		CD
13	66	OD	40	HTSE				10	18*		CD
14	66	OD	37	HTSE				8*	18		CD
15	66	OD	42	HTSE				12*	18		CD
16	66	OD	44	HTSE				8*	16		CD
17	66	OD	37	HTSE				8*	16		CD
19	66							10*	14		CD
20	66	OD	44	HTSE				8*	12		CD
21	66							8*	12		CD
22	66	OD	57	HTSE				10*	10		CD
22	65							10	10		CD
20	65							10*	12		CD
19	65	OD	60	HTSE				10*	14		CD

FIGURE 18. Intercontrole Baseline Final Report Data Format (Typical)

The Intercontrole analysis team also provided maps showing the location of reported indications and other conditions to provide a summary of the examination results.

3.0 CONSTRUCTION OF THE INSPECTION RESULTS DATA BASE

A computerized data base was established by PNL for the maintenance and analysis of the eddy current baseline inspection results. In addition to the summary reports of the inspection results, both teams provided strip charts and magnetic tape recordings of raw data collected during the data acquisition portions of the examination. This was needed for subsequent re-analysis and validation of reported defects by PNL analysts. Calibration data verifying that equipment was set up in accordance with ASME Code requirements was also supplied.

The Zetec team initiated their inspection in July 1983, and completed the data analysis and reporting of the data in September. The Intercontrole team initiated their inspection in November 1983, and submitted their report in February 1984. The Zetec team examined 3125 tubes using the multifrequency technique. Figure 19 shows the tubes inspected by Zetec. A full length inspection means that all sections of the tube were inspected. The single-frequency equipment was used to evaluate 218 of the tubes examined by the multifrequency technique. The Intercontrole team examined 2783 tubes with the multifrequency technique; the inspected tubes are shown in Figure 20.

The Zetec team performed over 9000 separate inspections. Some were repeat scans of dented tubes with progressively smaller diameter probes in an attempt to inspect the full length of a tube. However, in many cases little improvement in penetration beyond the first obstruction encountered was obtained with the smaller probe. The Intercontrole team reported approximately 4000 separate data entries. The use of their conventional pusher-puller coupled with pressurized air helped to a small degree to force the probe through tube obstructions, but the major reason for the smaller number of inspections was that there was little emphasis on using smaller probes because of Zetec's experience.

The reports provided by the two teams on their interpretation of the inspection data were organized differently (see Figures 13 and 18) and were presented to PNL on different types of digital computer media, which meant that different processing steps were needed to convert each team's data into a form suitable for computer analysis by the SGGP. This section describes how the interpretation data was obtained from the two inspection teams and input into the SGGP data base. Time was saved by obtaining the interpretation data from both teams directly from their computerized report files.

3.1 PROCESSING OF ZETEC DATA

Zetec performed the analysis and interpretation of the eddy current signals on a Hewlett-Packard (HP) 9836 desk-top computer (Zetec DDA-4), which allowed for the storage of certain pieces of information for each inspection and/or indication on floppy disks; these data records constituted the bulk of the technical report from Zetec. The transfered records required some formatting changes on the HP so that they would be compatible with the file structure of the SGGP data analysis computer (a Digital Equipment Corporation VAX 11/780).

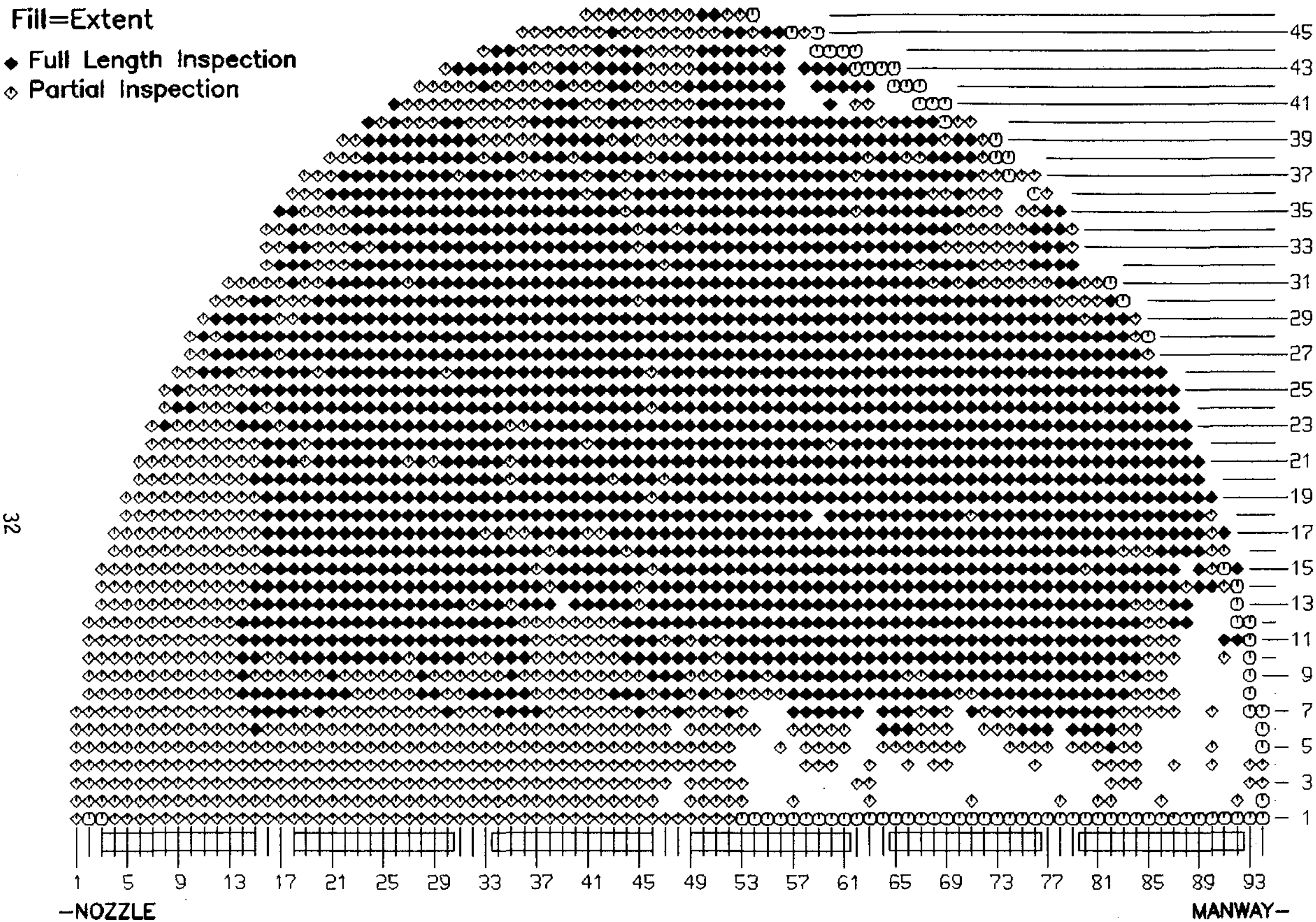


FIGURE 19. Extent of Inspection by Xetec

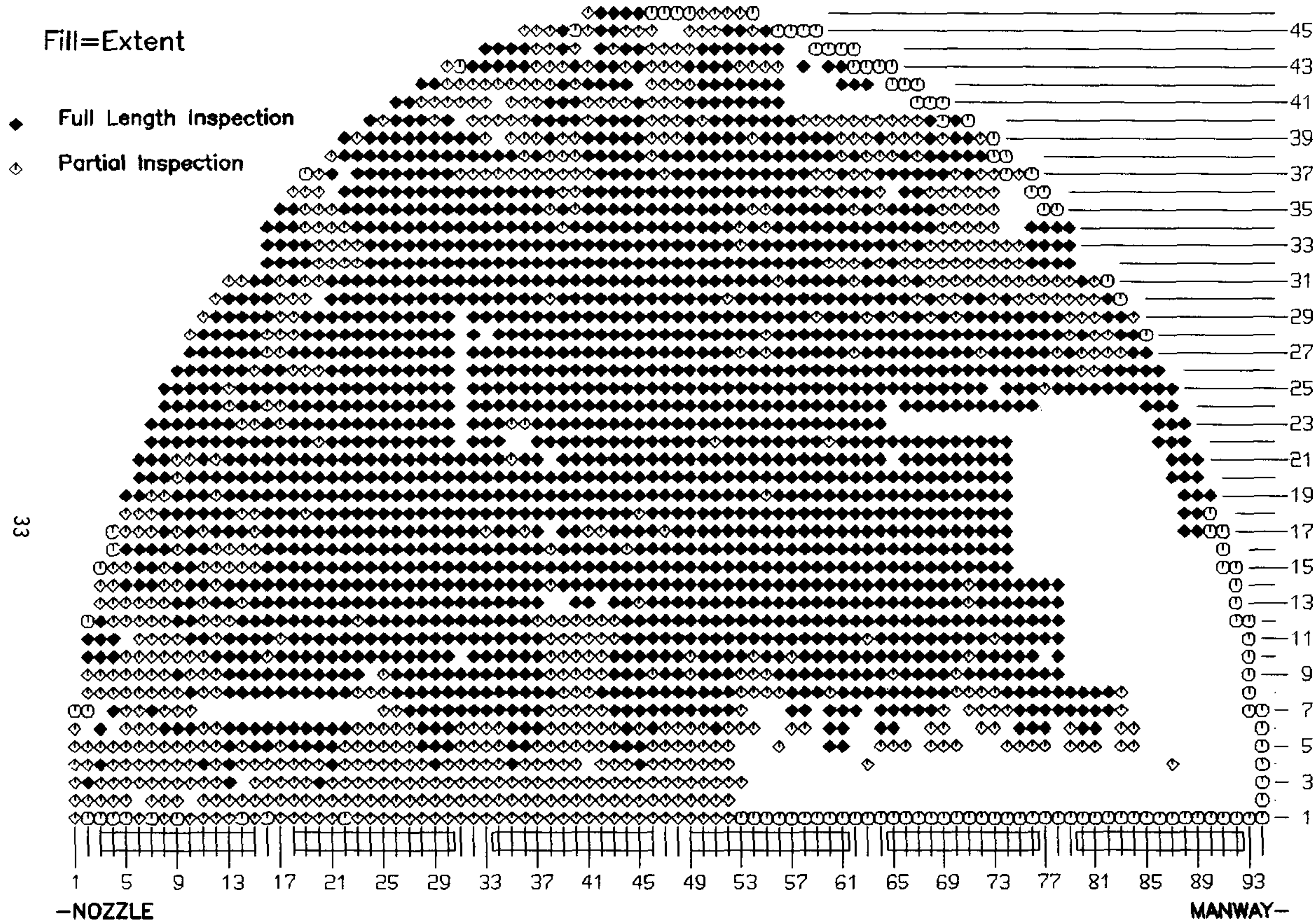


FIGURE 20. Extent of Inspection by Intercontrole

Intercontrole did not record their interpretation data on a computer as part of the analysis process but typed the final report, including data sheets, on an IBM Displaywriter word processor. The file, although not as large as that produced by Zetec, still consisted of 3392 separate data records. Since the Displaywriter is a computer, PNL's computer specialist was able to transfer the inspection interpretation results from the Displaywriter storage medium directly to the analysis computer, thereby saving time and avoiding transcription errors.

The form of the Zetec eddy current interpretation data on the HP floppy disks (see Figure 13) is given in Table 3.

In addition to the quantitative information on indication size and location, qualitative information (permeability variation, restriction of tube and other reasons why a tube was not inspected, loose parts, dent, copper deposit, support plate removal or damage) was listed in a comments section. The interpretation results for the in-line standard were listed where they occurred in the inspection sequence, and were appropriately labeled. The date of the inspection and information on the instrument used (single or multifrequency) and the probe type and size were given when the standard was run.

As was mentioned earlier, the Zetec baseline inspection consisted of multiple inspections per tube using different diameter probes, even in some cases where the inspections were full length. The arrangement of the data on the data sheet made it difficult for computer processing. For example, comments were included in the defect location and extent-of-inspection columns in the data records. A fairly extensive re-arranging and editing of the data file was needed in order to get the data in the appropriate form for the computer analysis. This editing consisted of adding the type and diameter of probe to each inspection record and coding the qualitative information, such as the reason why an inspection was considered a 'no test', into separate data fields. Twenty-eight separate data fields were produced from the 12 data fields on the original DDA-4 data records. They are given in Table 7.

Ten result categories captured the qualitative information in the defect location, extent of inspection, and the comment fields of the original inspection records. They are given in Table 8.

All categories except for dent are self explanatory. A dent refers to a dent-like signal that occurs between support plates. Dents at support plates were not specifically called out. For the result code of 'no test', there is a further explanation of the cause. They are coded into the categories given in Table 9.

Consistency checks were performed as part of the analysis process. Examples of inconsistencies are a measured defect without a location or an extent of inspection, and records for which the extent of inspection did not agree with the location of indications. Also there were occurrences of duplicate entries of indications, making it appear that more than one indication existed at a given location. Findings of this nature were easily resolved by discussions with the Zetec analyst. Some

TABLE 7. Organization of Zetec Inspection Information in PNL Data Base

Master sequence number - a unique identifier for each inspection needed for internal quality assurance purposes
Instrument - single or multifrequency
Origin (leg) of the inspection
Probe type and diameter
Row
Column
Retest flag - activated if inspection is labeled a retest of an earlier inspection
Analog reel number - actual reel the analog record of the inspection is on, as opposed to the range of reels given in the HP data sheets
Inspection date
Report date - date the analog tape was analyzed
Voltage
Phase angle
Flag - for 'less than' size measurements, such as <20%
Percent of wall thickness
Channel
Phase flag - used if phase was altered from original by analyst
Result code - this will be described below
Reason code - also explained below
Location-leg of indication
Location reference point of indication - tube sheet, support plate number, or U-bend
Location of indication from reference point in inches
Inclusive leg - used to locate anomalies, such as permeability variation, over an interval of tubing and pertains to the next two items
Inclusive reference
Inclusive distance
Extent of inspection - leg
Extent of inspection - reference
Extent of inspection - distance from reference point
Location and extent columns information from the HP data sheets were preserved for rechecking and correction of the above coding if needed

TABLE 8. Categories of Inspection Results for Zetec Baseline Inspection

Standard
No defect detected
Permeability variation
Dents
ID crack
OD defect
Copper
Loose part
Tube support plate removal/damage
No test

TABLE 9. Categories of Reasons for No Inspection of a Tube for Zetec Baseline

Template plug
Tube plugged
Tube restricted
Tube blocked by fixture
Tube missed
Saturated signal
Bad data

inconsistencies were not so easily resolved and still remain in question. There was evidence of instances when the tube reported as being inspected was not the tube that was actually inspected. There were three cases of transcription error where the tube reported as inspected does not exist, and six cases where plugged tubes were reportedly inspected.

Because the inspections were done sequentially up and down the columns, all inspections following a misidentified inspection are questionable (that is, until a change in the sequence of tube numbers because of changing columns or moving to a tube farther down the column). However, only one, a 21% OD indication was detected in a potentially misidentified tube.

For some inspections, the information from the different frequencies appeared to present conflicting information to the analyst, so that wall-loss measurements were reported for more than one frequency for the same indication. At the advice of the Zetec analyst, the wall loss reported by the 400 kHz differential channel was used for purposes of these analyses as the estimate of the size of the indication. However, 49 of the indications reported by Zetec were not sized using the 400 kHz differential channel. In those cases, the indication size obtained by the reported frequency was used. In two cases the same indication was reported on more than one non-400 kHz differential channel; the median of the reported sizes was used to estimate the size of the indication for that inspection.

In analyzing the separate inspections of the same tube, some issues had to be addressed that normally do not arise during in-service inspections (ISIs). Knowledge of the exact location of an indication in the tube is not crucial in ISIs because the important factor is whether the indication size exceeds the plugging limit. However, in comparing separate inspections using the computer analyses, the exact location of an indication is important as a measure of whether the same physical event is being observed. The manner in which Zetec reported their distances from the reference points posed a slight problem. The distance away from the reference point was assigned a positive or negative value depending on the pull direction of the probe. For example, an inspection from the hot leg would locate an indication three inches above hot leg support plate 1 as plus three, while an inspection from the cold leg would locate the same indication minus three inches from support plate 1. This situation had to be corrected to avoid indications created by improper reference. For consistency, the location of an indication above the reference point, with respect to the normal vertical operating position of the generator, was defined to be positive.

Reported indications were located to the nearest tenth of an inch. Repeat inspections of the same indication often showed slightly different locations. Figure 21 shows a histogram of the differences in distance from the reference point between the same reported indications for different inspections. The variable plotted on the vertical axis is the difference in location (in inches) between the reported indications from two inspections; the horizontal axis gives the counts of the number of inspection pairs that fall into the category. The distribution was quite skewed, with nearly 80% of the indications from separate inspections located within 0.25" of each other. The largest distance difference was 1.5", so it is apparent that the reported locations of the same indication from different inspections was quite consistent. There were 125 indications for which the location from different inspections was within 0.2". From other inspections, separate indications within 0.2" of each other were apparently capable of being resolved, so a criterion was established that separate inspections reporting the same indication must locate it within 0.2". Reported indications over 0.2" apart were considered separate indications for this analysis.

Because of the larger probe fill factor, one would expect to detect indications with a larger probe that are not consistently detectable with a smaller probe (due to probe wobble), and the depth of the reported indication should be more accurate with the larger probe. Therefore, for inspections using different size probes, the results from the larger probe should be the most accurate estimate of the presence, and depth of an indication. Multiple inspections of the same tube did not always produce the expected results. Inspections with different size probes were evaluated to see whether they produced results consistent with the theory that larger probes should detect indications missed

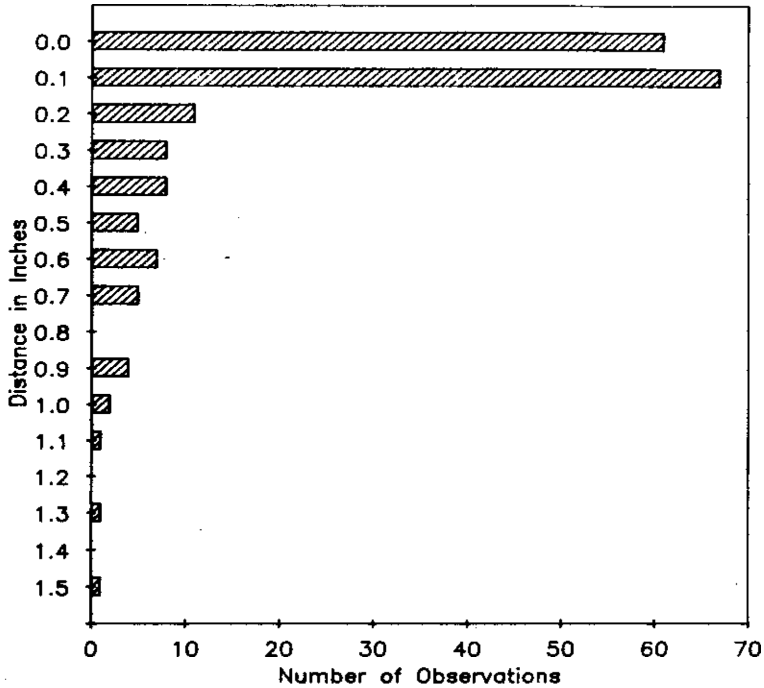


FIGURE 21. Histogram Showing Distance Between Reported Indications from the Same Tube for the Same Reference from Different Inspections by Zetec

by smaller probes. There were 23 indications found with a larger probe that were missed by smaller probes, but there were 41 indications for which a smaller probe detected an indication that was missed by an equal or larger size probe.

As part of the data processing consistency checks, the reported depths of indications from different inspections located within 0.2" were compared. Out of 125 such indications, the larger probe detected a deeper indication 47 times. A histogram of the difference in reported size between two inspections of the same indication is given in Figure 22. The vertical axis is the difference in reported depth in percent of wall thickness, and the horizontal axis represents the number of cases in that class. The distribution is skewed, but it is much more spread out than the histogram of the reported distances between the same indications from different inspections (Figure 21). A cutoff value of a 14% difference was used for purposes of determining the depth of indications reported by more than one inspection for comparison to the Intercontrole interpretation results, because it appears that the main body of the data is located below this value, and the indications with a larger difference in depth may, for example, be caused by errors in tube number. The median of the reported depth indications that were within 0.2" of each other and whose depth was within 14% was used as the estimate of depth for comparison to the Intercontrole inspection results. Indications which had reported depths differing by more than 14% of wall thickness were labeled as being of indeterminate depth for the purpose of the comparison.

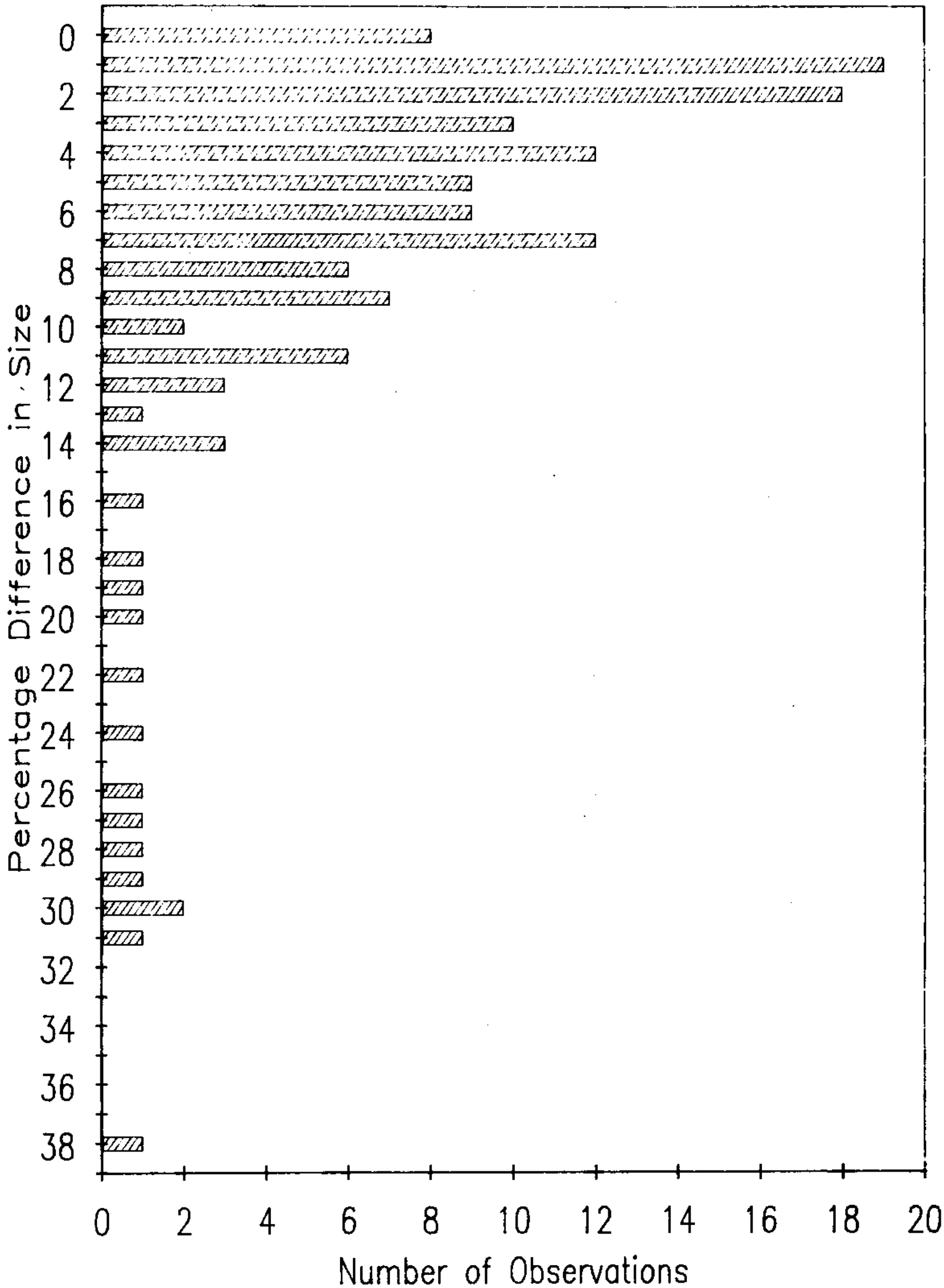


FIGURE 22. Histogram Showing Percentage Difference in Depth Between Different Inspections of the Same Indication by Zetec

3.2 PROCESSING OF INTERCONTROLE DATA

The inspection interpretation data from the Intercontrole data sheets did not contain as much detail as the Zetec data. However, it arrived in a form that was more readily accessible for computer processing. The items on the data sheets (see Figure 18) are listed in Table 10.

TABLE 10. Inspection Information from Intercontrole Baseline Data Sheets

- Origin (leg) of the inspection
- Calibration sheet number
- Data reel number
- Row number
- Column number
- Wall loss origin (ID or OD)
- Wall loss as % throughwall
- Wall loss location (reference ± distance in cm)
- Sludge height
- Extent of inspection
- Qualitative findings (conductive deposit, permeability indication, dent, bulge)

Intercontrole reported dents and bulges in some tubes outside the region of the support plates. The data sheets did not provide information on the size of probe used for each inspection nor the calibration; however, copies of the separate calibration sheets from which this information could be obtained were provided. The Intercontrole data preprocessing included separate coding of the qualitative comments. The same type of data checking that was done for the Zetec inspection results, such as making sure that the location of an indication was consistent with the extent of inspection, was done for the Intercontrole inspection results. However, since there were very few multiple inspections per tube section, the extensive processing needed to obtain a single depth estimate for an indication that was done for the Zetec data base was not required for the Intercontrole data base.

4.0 STATISTICAL COMPARISON OF THE INSPECTION RESULTS

The statement of work required the teams to report all indications of degradation, regardless of size. Therefore, wall-loss indications less than 20% were reported although the current U.S. regulations do not require it. Other items reported included the height of sludge on the tube sheet, the presence of permeability variations, conductive deposits, denting, loose parts and bulges. Denting is present at nearly all of the support plate intersections of the Surry generator. Therefore, it was decided after several tube inspections that the reporting of denting would be omitted. Permeability variations were also found to be present in a majority of tubes, so it was decided that the permeability variations would not have to be reported either due to the excessive time required to identify and report several thousand such indications.

Results of the baseline eddy current examinations yielded a large number of indications. In order to maintain each team's anonymity, the two baseline examination teams will be referred to as Team 'X' and Team 'Y' in subsequent comparisons of the inspection results.

A preliminary comparison analysis of the two teams' inspection results revealed that there were unexpected disagreements between the teams in defect detection which amounted to about 35% of the indications reported by Team X and 25% of the indications reported by Team Y. Each team was asked to re-examine its results in light of the other team's findings to resolve some of the disagreement.

Information on the unmatched indications (that is, those reported by only one team) were furnished to each team: Zetec's unmatched to Intercontrole and vice versa. Because of time constraints, the teams were asked to review only the tubes where there was a difference in detection of indications reported as $\geq$20%. This produced a total of 160 inspections to be reanalyzed.

The process used to resolve these differences required that analysts review magnetic tapes, strip charts and other data collected during their examinations. No reinspections of tubes (scanning) were performed.

Thirty-seven of the inspections did represent agreements in detection between the two teams that had been missed because of differences in the teams' reporting practices or the project's data analysis procedures. In only nine of the inspections did the teams revise the original baseline results; these changes consisted of indications that had been previously missed by the analyst or the relocation or resizing of previously reported indications.

Although the re-analysis of the data resulted in no more than a 25% decrease in the number of discrepancies in detection, the reasons for the difference between the teams became evident. In all but 18 of the 160 inspections, both teams saw a signal in their data, but differed as to its cause. For example, one team called a 45% wall-loss indication, but the other team thought the signal was due to a copper deposit so it was not reported as wall loss.

As part of their re-analysis, Intercontrole described the confidence of their findings using one of four levels:

1) CL1 - Good confidence in both the presence of wall loss and the reported depth.
2) CL2 - There appears to be wall loss, but the reported depth is debatable. The analyst uses discretion in whether or not to report an indication at this level depending on the depth.
3) CL3 - The presence and depth of wall loss is debatable. Eddy current analyst uses discretion in whether or not to report an indication.
4) CL4 - The signal is not the result of wall loss.

The following ratings were assigned by Intercontrole to their >40% unmatched indications - one CL1, seven CL2, and three CL3 confidence levels out of the 20 signals analyzed. The rest were labeled CL4. For the 20 to 40% unmatched indications, there were two CL1, three CL2, and eleven CL3 confidence level ratings out of the 66 signals reanalyzed. The number of CL1 confidence levels assigned to the reviewed signals indicates that the signals were actually missed on the initial analysis and should have been identified as an indication by the data analyst. The large number of lower confidence ratings given to the reanalyzed indications is indicative of the difficulty experienced by the analysts in determining the presence of wall loss in the distorted eddy current signal data from this service-degraded generator.

Both teams reported that the effects of denting and conductive deposits on eddy current signals could not be eliminated by mixing the responses of various test frequencies. The differences in the inspection results between the teams appear to be due more to a function of the analysts' interpretations of complex eddy current signals than to any other cause, and the teams' analysts have basically agreed to disagree in their interpretations of the signals. Both teams agreed that better flaw characterization was not possible due to the nature of the eddy current response. Additional scanning by specialized probes, such as a rotating pancake coil probe, or increased saturation field strength, would be needed to provide an improved characterization by eddy current examination.

In addition to the data obtained as a result of the multifrequency examinations, the Zetec team conducted an examination of 218 tubes in the generator to determine the equivalency of single frequency tests conducted during the service life of the generator with results from multifrequency equipment operated in single frequency mode. The single frequency data was collected using the Zetec EM-3300, and the multifrequency data was collected using the MIZ-12. Both sets of data were analyzed using the Zetec DDA-4 analyzer. The comparison of the analysis results of the eddy current signals from six randomly selected tubes are shown in Table 11. The differences are small. The single frequency and multifrequency signal response resulting from the examination of two of the tubes listed in Table 11 are illustrated in Figures 23 and 24. Note that the difference in response for R22C36 is related to signal gain, the single frequency test being conducted at the normal code-required gain setting, while for R22C61 the difference in the indications is that one appears to be inverted as a result of being scanned by the probe in different directions during data acquisition. The signals and depth of defect called are similar for single frequency 400 kHz and the comparable channel of the multifrequency examination.

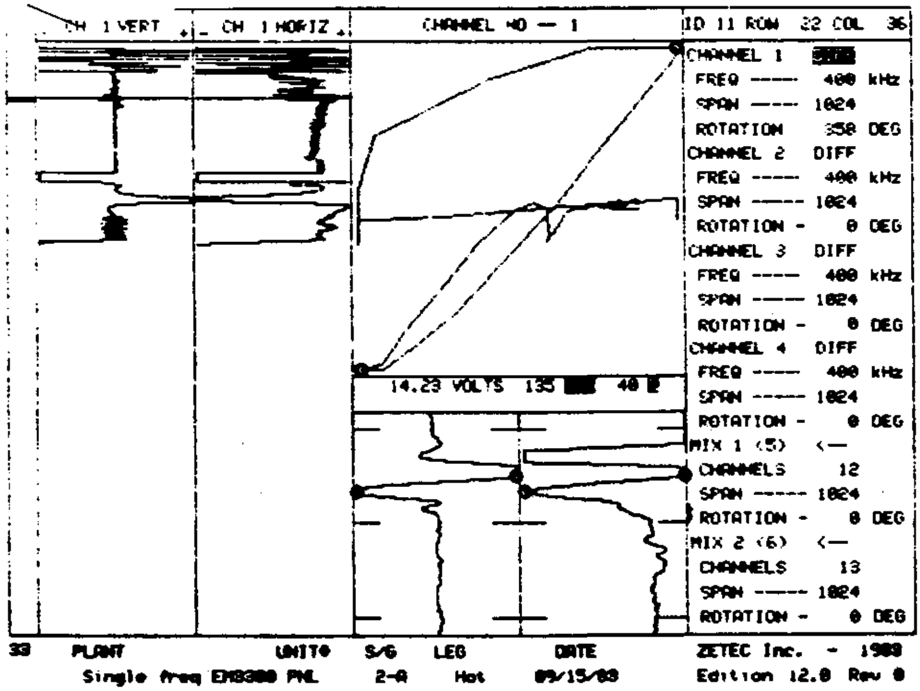
TABLE 11. Comparison of Typical Multifrequency/ Single Frequency Eddy Current Results - Zetec Baseline Examination

Tube			Single
Row	Col	Multifrequency	Frequency
46	45	63%	65%
22	36	43%	40%
21	43	78%	78%
16	46	72%	76%
22	61	56%	54%
15	69	42%	49%

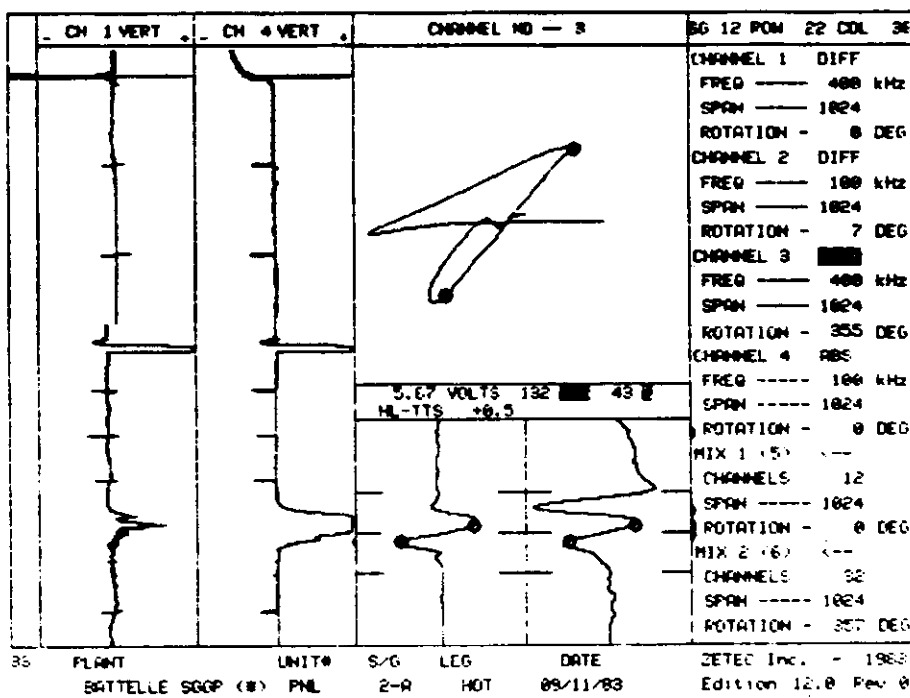
A review was conducted of data collected during the in-service inspections of the Surry generator during the 1977-78 period. The objective of this comparison was to determine if the depth of indications had changed during the period following plugging. Of 110 tubes randomly selected, half of the in-service inspection results were labeled as 'dent'. Of the tubes where there was agreement on the presence of wall loss, the reported size from the post-service baseline inspection was often smaller than the size reported during the in-service inspection. A possible explanation for the differences was operator interpretation of complex signals and a desire to be conservative to avoid leaking tubes during the generator service life.

4.1 TABULATION OF INSPECTION INTERPRETATION RESULTS

Table 12 lists the number of reported occurrences of the different types of conditions reported by Teams X and Y. Part of the difference in the types of conditions reported is due to inconsistency in terminology between the teams. The copper deposits reported by Team X refer to the same condition as the conductive deposits reported by Team Y. The Team Y analyst, however, differentiated between generalized conductive deposits that covered a large section of tube and localized conductive deposits that were confined to several inches of tube between the tube sheet and 1st support plate. The reporting of nonwall-loss conditions was not required in the statement of work. The differences between the teams in number of conditions reported does not imply that one team is more observant or skilled than the other. Also, the prevalence in the generator of the various nonwall-loss conditions cannot be inferred from

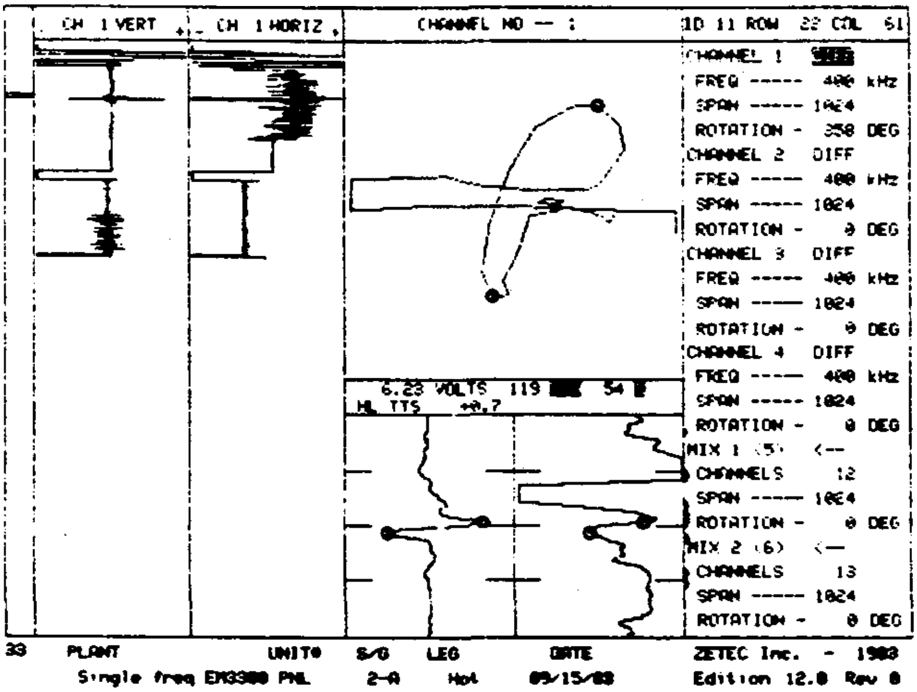


a) EM-3300, 40% Indication

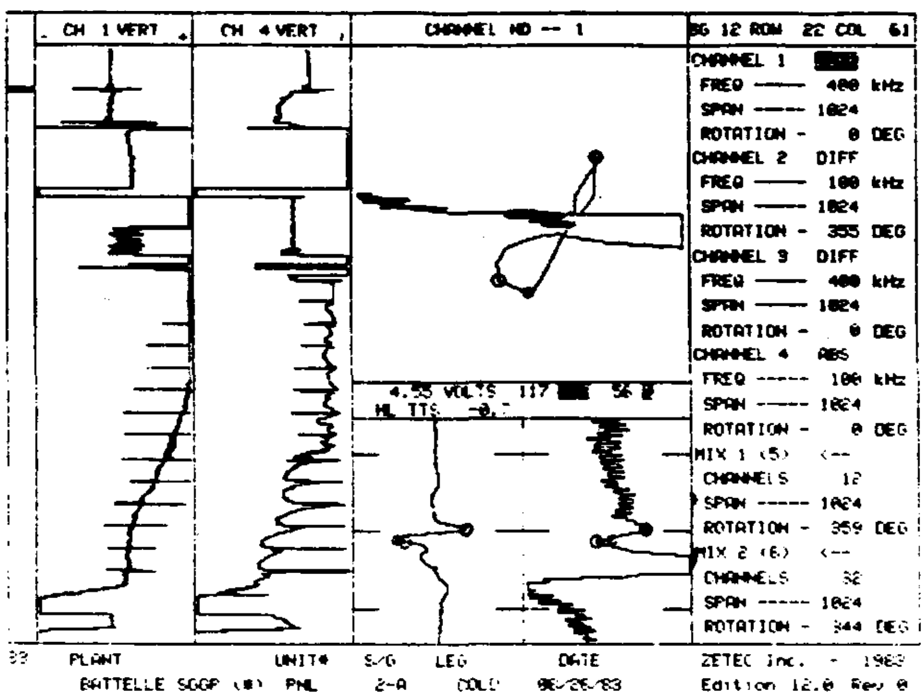


b) MIZ-12, 43% Indication

FIGURE 23. Comparison of EM-3300 and MIZ-12 Test Results at 400 kHz for Tube R22C36 HL



a) EM-3300, 54% Indication



b) MIZ-12, 56% Indication

FIGURE 24. Comparison of EM-3300 and MIZ-12 Test Results at 400 kHz for Tube R22C61 HL

the reported number of occurrences because they were not required to be reported. Teams X and Y differed in the number of wall-loss indications (both ID and OD) - 779 for Team X and 1061 for Team Y.

TABLE 12. Number of Occurrences of Each Type of Condition Reported by Team X and Y

Type of Condition	Number of Observations Team X	Number of Observations Team Y
Permeability Variations	71	495
Generalized Conductive Deposits		2,413
ID Indications	6	20
OD Indications	773	1,041
Localized Conductive Deposits		209
Bulges		29
Dings (between supports)	5	14
Denting		46
U-bend Transitions		4
Magnetite		6
Copper Deposits	35	
Loose Parts	9	
Support Plate Removal/Damage	1	

Note: Reporting of nonwall-loss conditions was not required.

Table 13 shows the number of wall-loss indications referenced to each of the support plates and the tube sheet for the hot and cold legs and the U-bend by the two teams. Team Y referenced locations in the tube sheet region somewhat differently than Team X. Reference points used within the tube sheet include the tube end, tube sheet gap or crevice, top of tube sheet and unspecified tube sheet location. Most of the reported indications for both teams were referenced to the hot leg top of the tube sheet where tube wastage in the sludge pile was expected. Team Y tended to call more indications at all locations in the generator than did Team X. As will be discussed later, this was due to the tendency of Team Y to call many small (<10%) indications. There were a few exceptions however. For example, Team X called 20 indications at the cold leg support plate 7, to 10 for Team Y. But this may have been due to the difference between the teams in the reference point used for U-bend indications; Team Y reported 22 indications located in the U-bend region and Team X reported none.

TABLE 13. Locations of Wall-Loss Indications from the Baseline Inspections

Reference Location	Number of Indications			
	Hot Leg		Cold Leg	
	Team X	Team Y	Team X	Team Y
Tube End	1			
Tube Sheet Gap		1		
Unspecified Tube Sheet		2		4
Top of Tube Sheet	713	731	22	113
Support Plate 1	3	5	1	6
Support Plate 2		3		2
Support Plate 3	2	3	2	1
Support Plate 4		1	2	3
Support Plate 5	1	9		1
Support Plate 6		20	1	9
Support Plate 7	11	115	20	10
U-bend		22		

Histograms of the depths (in percent of wall thickness) of the indications reported by Teams X and Y are given in Figures 25 and 26, respectively. The six 100% throughwall indications reported by Team X were found to have been caused by drill marks made during tube unplugging and were intentionally not reported by Team Y. The largest number of indications reported by Team Y are less than 10% of wall thickness. When these indications are not considered, the number of indications that Team Y reported (608) is less than the number found by Team X (713). The largest number of indications called by Team Y (excluding those <10%) were in the 40-45% range as compared to the 20-30% range for Team X. In the ranges from 10-40% and 90%-and-larger, Team X called more indications, but the number found by Team Y in the range from 40-80% is larger.

The comparison of the locations of the reported indications (Table 13) or the histograms of the depths of those indications (Figures 25 and 26) is not sufficient to evaluate how well the two baseline inspections agree. The reported indications should occur in the same location in the tube with respect to the reference point, such as a support plate or top of the tube sheet, for the inspections to agree (a common detection). In addition, the depths of these common indications must be close.

Maps of the locations of indications referenced to each support plate and the tube sheet corresponding to the information in Table 13 are given in Appendices F and G for Team X and Y, respectively. Maps are given only for reference locations with at least one indication; for example, there is no map for the hot leg 2nd support plate. The plotted symbols represent the size of the indications based on three categories, ≥40%, 20-40%, <20%. If there is more than one indication at the same reference location, then the number of indications, rather than the depth, is plotted.

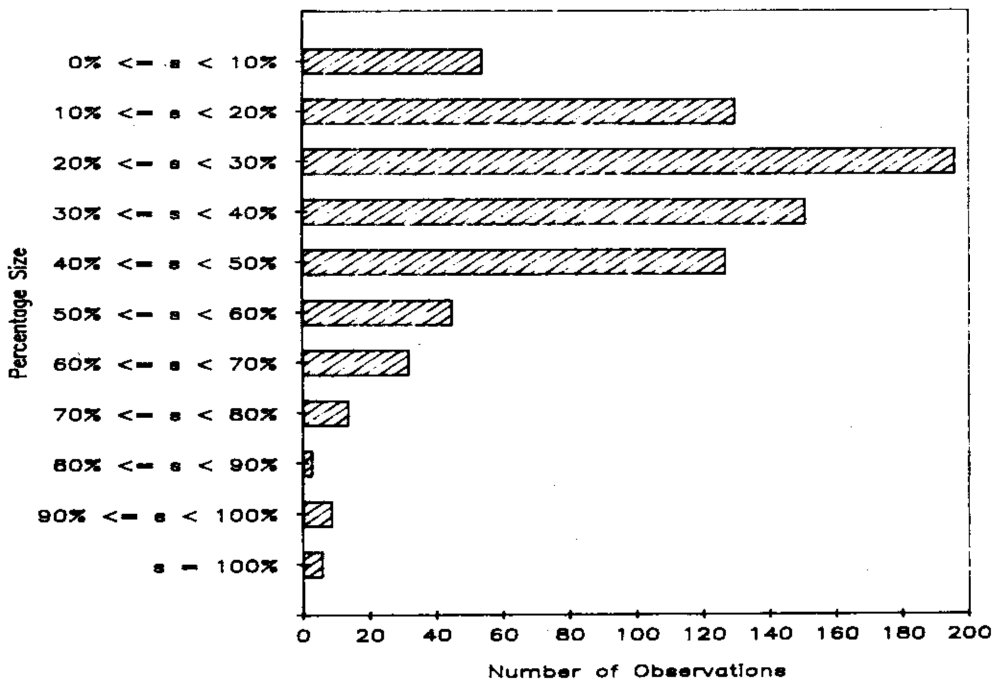


FIGURE 25. Histogram Showing Sizes of Defects Reported by Team X

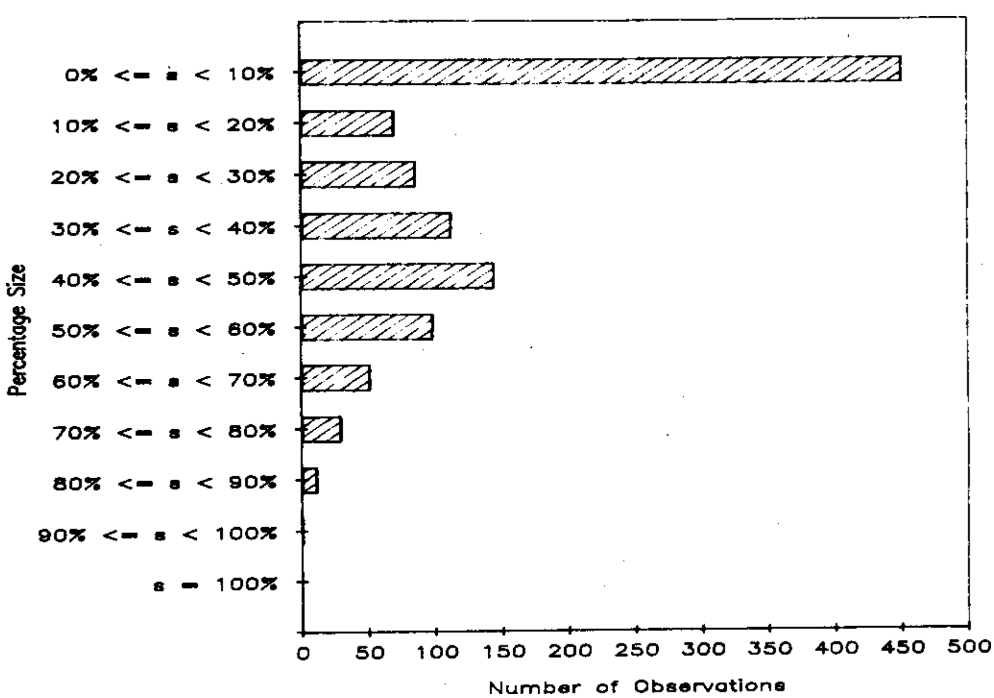


FIGURE 26. Histogram Showing Sizes of Defects Reported by Team Y

4.2 DETECTION AGREEMENT

The criteria for determining a common detection was defined as follows: Both teams had to report an indication in the same tube, reference it to the same support plate or other reference point, and the specific locations of the indication reported by the two teams had to be within 5" of each other. The reported depth of the indication was not considered as part of the agreement criteria at this stage of the analysis. A 1" limit had initially been chosen for the specific location requirement by considering the thickness of the support plates and the degree of uncertainty in the distance measurements of repeat inspections. Upon consulting both teams' analysts, the 1" limit was expanded to 5" because the method of analysis by one team did not locate indications as precisely as the other.

The 5" range was not adequate to match indications at the top of the tube sheet. The reason was due, in part, to the large number of indications not given specific locations by Team Y. The Team Y analyst chose not to report an exact location for many of the indications at the top of the tube sheet because the wall loss extended over a long vertical distance (several inches) in most cases; this made the selection of a point location for the indication difficult. Team X, on the other hand, reported the location of the maximum wall-loss signal regardless of the length of the indication. The Team Y analyst stated that all indications reported at the top of the tube sheet occurred within the sludge. The maximum sludge height called by Team Y was 8.7". The Team X analyst had also called a smaller, though significant, number of indications without specific locations at the top of the tube sheet. Thus it was necessary to disregard the 5" range within which indications had to be located to be considered in agreement at the top of the tube sheet.

The lack of a specific location for indications referenced at the top of the tube sheet had other significant implications. There were 87 tubes where one or both teams called more than one indication at the top of the tube sheet. Without specific locations, it was impossible to create a one-to-one matching among these indications. The number of agreements for multiple indications was based on all possible combinations of these indications and, therefore, are probably somewhat inflated.

There are only four reference locations in the generator where both teams agreed on a reported indication. They are the top of tube sheet on the hot and cold legs, the hot leg 7th support plate and the cold leg 1st support plate. Tables 14 through 17 are the detection/no detection tables of Team X and Team Y indications for the four reference locations, respectively. Both teams had to have inspected the same section of tube for an indication to be included in the tabulation. The upper left-hand cell contains the number of indications reported by both Team X and Team Y (detection agreement). The upper right-hand cell shows the number of indications that Team X reported that Team Y did not. The lower left-hand cell contains the number of indications that Team X did not report that Team Y reported. The lower right-hand cell is empty. It should contain the number of indications that neither Team X nor Team Y reported and that could be estimated by dividing each

TABLE 14. Comparison of Detections for Team X and Team Y at Hot Leg Top of Tube Sheet/Tube Sheet Edge

		Team Y D	Team Y ND
Team X	D	655	125
	ND	92	

Number of Team Y detections without specific locations: 0

Number of Team X detections without specific locations: 0

TABLE 15. Comparison of Detections for Team X and Team Y at Cold Leg Top of Tube Sheet/Tube Sheet Edge

		Team Y D	Team Y ND
Team X	D	11	11
Team X	ND	102	

Number of Team Y detections without specific locations: 0

Number of Team X detections without specific locations: 0

TABLE 16. Comparison of Detections for Team X and Team Y at Hot Leg Support Plate 7

		Team Y: D	Team Y: ND
Team X	D	3	8
	ND	110	

Number of Team Y detections without specific locations: 0

Number of Team X detections without specific locations: 0

TABLE 17. Comparison of Detections for Team X and Team Y at Cold Leg Support Plate 1

	Team Y: D	Team Y: ND
Team X: D	1	0
Team X: ND	4	

Number of Team Y detections without specific locations: 1

Number of Team X detections without specific locations: 0

tube into 2" (or other size) segments and counting the number of segments that have no detections, but the count would be very large and would focus attention away from the reported detections which are of primary concern for safe and reliable steam generator operation. At the bottom of the table is a count of the number of indications that each team did not give a specific location. Any indications that fell into this category were not included in the cells.

Tables 14-17 show that there is not much agreement between the teams on indications except at the hot leg top of tube sheet (Table 14). Table 14 shows that 655, 75% of the total number, of 872 indications reported by the two teams at the hot leg top of tube sheet in commonly inspected tube sections are common indications. The percentage of each team's indications that are common indications are similar - 84% for Team X and 87% for Team Y. The pattern is different for the cold leg top of tube sheet data (Table 15). Only 9% of the total of 124 reported indications were common detections. Because Team Y reported over five times as many indications, the percentage of each team's indications that were common indications differed: 50% of Team X's indications compared to 10% for Team Y. The detection agreement at the hot leg 7th support plate is similar to that at the cold leg top of the tube sheet, although the agreement percentages are somewhat smaller. There were only five indications reported by either team at the cold leg 1st support plate (Table 17) and there was agreement on one.

Although the non-tube sheet indications are referenced to a support plate, they are not located at the support plate, but may be 2 or 3' from it.

The summary of agreements in detection between Teams X and Y for the entire generator are given in Table 18. Considering only the indications in tubes that both teams inspected, 55% of the total number of 1219 indications are agreements in detection. Looking at each team's indications separately, the rate of common detections is 84% for Team X and 61% for Team Y.

4.3 COMPARISON OF REPORTED DEPTHS FOR COMMON DETECTIONS

Figure 27 shows a histogram of the difference (in percent of wall loss) in the reported depth between indications reported by both Team X and Team Y (matched indications) anywhere in the generator. In cases where a team sized an indication as <10%, the size of the indication was assumed to be 10%. The vertical axis of the histogram is the difference in depth, with the number representing the middle of the interval rather than an endpoint. The top of the y-axis represents indications that Team X sized deeper than Team Y. The bottom of the y-axis is the reverse. In preparing the data for this histogram, all possible avenues were taken to minimize the difference in depths between matching indications. In cases where one team called more than one indication and the other team called only one indication, a depth was calculated for each possible pair of indications. However, when both teams called more than one indication at the same location, the depths were matched by hand to

TABLE 18. Summary of Comparison of Detections for Team X and Team Y for All Locations

		Team Y: D	Team Y: ND
Team X	D	670	179(129)
	ND	424(420)	

Number of Team Y detections without specific locations: 0

Number of Team X detections without specific locations: 0

( ) Indications in sections of tube inspected by both teams.

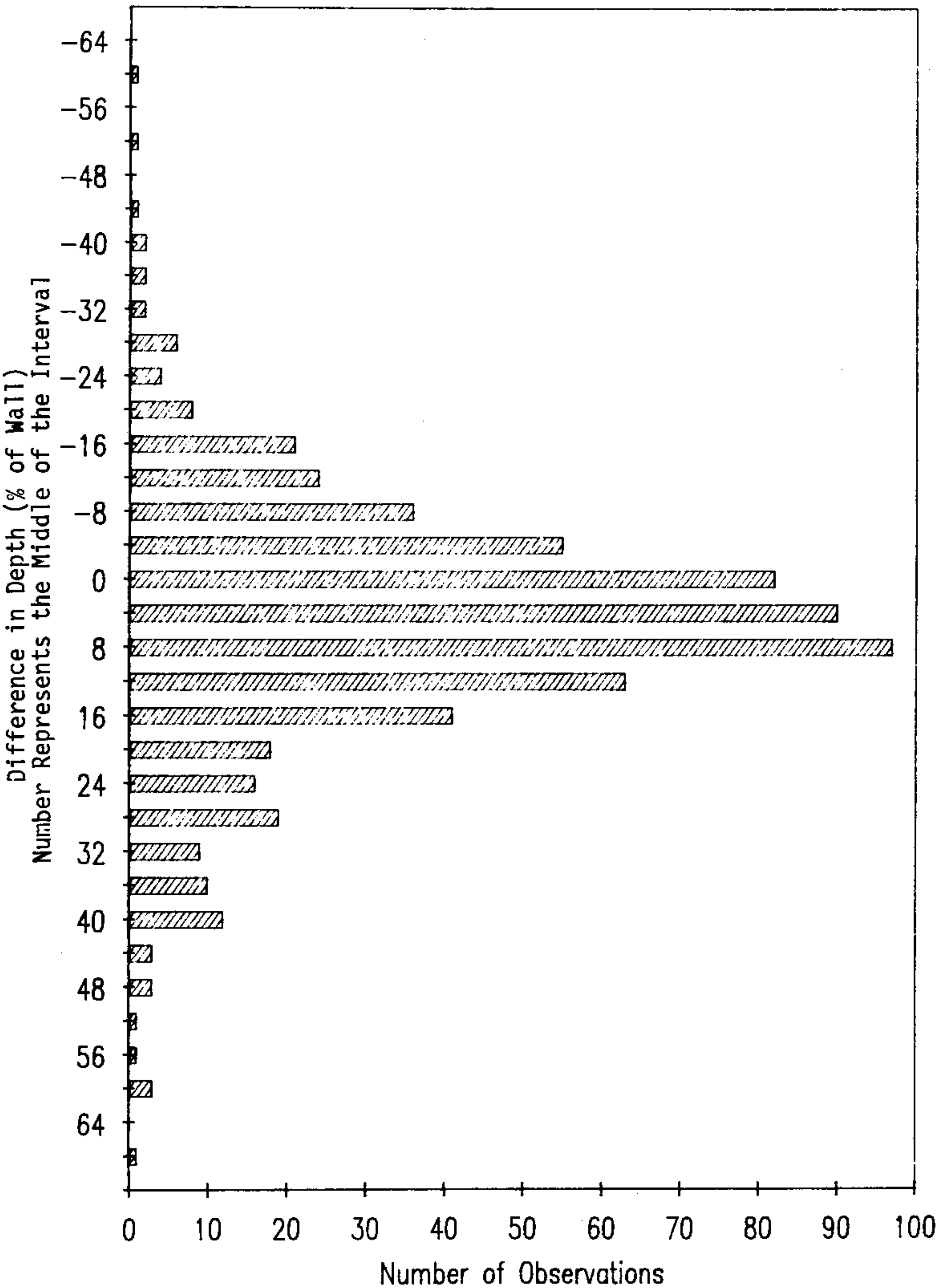


FIGURE 27. Histogram Showing the Difference in Reported Depth of Indications Called by Both Team X and Team Y

minimize the size difference. Because this was done, the number of points on the histogram will not match the sum of the elements in the cells of the Detection Agreement Tables (Tables 14-18). The mean of the differences is 5.3 and the standard deviation is 15.5. A mean of 5% is statistically significantly different from 0 (by the single sample t-test, Snedecor and Cochran, p.70) which shows that Team Y consistently sized the same indications deeper than Team X.

A summary of the level of agreement between the two baseline examinations by depth is given in Table 19. The wall-loss indications for each team are divided into three depth classes: ≥40%, 20-40%, and <20%, corresponding to current U.S. plugging and reporting requirements. Within each size class, the indications were further classified according to the level of agreement between the two teams. The class that represents the best agreement between the teams is a matched (common) detection with the size difference ≤10%. The next level of agreement is a matched detection with the size difference >10%. The third class is the one in which the teams disagreed on a detection--whether it was due to absence of a signal or disagreement on the interpretation of the signal. Next to the number of indications in a class is a percent of the total number of indications in that class.

TABLE 19. Summary of Wall-Loss Indications Reported by Teams X and Y by Depth and Agreement Categories

Depth		Matched Detection Size Diff <10%		Matched Detection Size Diff >10%		Unmatched Detection	
≥40%	Team X	132	60%	73	33%	15	7%
	Team Y	160	45%	174	48%	25	7%
20-40%	Team X	158	46%	131	38%	55	16%
	Team Y	125	60%	49	24%	33	16%
<20%	Team X	88	48%	41	23%	53*	29%
	Team Y	89	17%	44	8%	390*	75%

* <20% indications not reviewed.

Sixty percent of Team X's and 45% of Team Y's indications that are ≥40% are included in the best agreement category (two detections and size difference <10%). For the 20-40% size range, the situation is reversed: 46% of Team X's and 60% of Team Y's indications are in this category. This is consistent with the histograms of the sizes of indications called by the two teams (Figures 25 and 26). If the two agreement on detection categories (i.e., size difference <10% or >10%) are combined, their proportion of agreements is much larger than if size of the difference is also considered. The percent of matched detections for the >40% size class is 93% for both Teams X and Y. The percent of matched detections for both teams is 84% for the 20-40% size category.

The mismatched indications <20% were not reviewed by the two teams, so the agreement categories are not as accurate as those for the other depth categories. However, there appears to be less agreement in detection for the smaller defects because of the larger number of small indications reported by Team Y.

4.4 COMPARISON OF >10% and >20% INDICATIONS ONLY

During the analysis of the baseline data, a question was raised whether both teams placed the same emphasis on the reporting of <20% indications. The teams were asked to report all indications, but the reporting of <20% indications is not required under ASME guidelines. Therefore, the agreement analyses (Section 4.1) were repeated to compare >20% indications only, where there is no question about the need for reporting under ASME guidelines.

Since Team Y reported many very small (<10%) indications, two separate analyses were performed for completeness: <10% indications omitted and <20% indications omitted.

Tables 20 and 21 are the Detection Agreement Tables for the >10% and ≥20% indications, respectively, regardless of location. They should be compared to Table 18. The percent of common detections of the total number of indications is 64% and 67% for the ≥10% and ≥20% indications, respectively. For the Team X indications, the percents of common detections are 75% and 80%, respectively. The corresponding results for the Team Y indications are 81% and 80%, respectively. Because the removal of the small indications preferentially reduced the number of Team Y's indications, the overall common detection rates (64% and 67%) improved from the 55% agreement for indications regardless of size, shown in Table 18. For the same reason, the common detection rates for Team Y's indications improved from 61% to 81% and 80%, respectively. Interestingly, the agreement percentages for Team X's indications decreased somewhat, from 84% to 75% and 80% for the ≥10% and ≥20% indications, respectively.

Figures 28 and 29 show histograms of the sizing difference for matched indications for the ≥10% and ≥20 indications, respectively. The shapes of the distributions are the same as that of Figure 28. The mean and standard deviations of the two distributions are 7.1% and 14.2%, respectively, for the >10% indications, and 6.8% and 13.0%, respectively, for the >20% indications. Although the standard deviations are smaller in these data than for all indications, removing the small indications has made the difference in depth between matched indications larger than if all the data were used.

The summary of the two baseline inspection results for the >10% and >20% indications are shown in Tables 22 and 23, respectively. These tables should be compared with Table 18. For the >40% depth category, the numbers of indications did not change for the best agreement category. However, the numbers of indications in the size difference ≥10% agreement category decreased with a corresponding increase in the unmatched detection category.

TABLE 20. Comparison of Detection for Team X and Team Y, <10% Indications Removed

Team X \ Team Y	D	ND
D	539	183
ND	126(123)	

Number of Team X detections without specific locations: 0

Number of Team Y detections without specific locations: 0

( ) Indications in sections of tube inspected by both teams.

TABLE 21. Comparison of Detections for Team X and Team Y, <20% Indications Removed

		Team Y D	Team Y ND
Team X	D	470	162(121)
Team X	ND	117(114)	

Number of Team X detections without specific locations: 0

Number of Team Y detections without specific locations: 0

( ) Indications in sections of tube inspected by both teams.

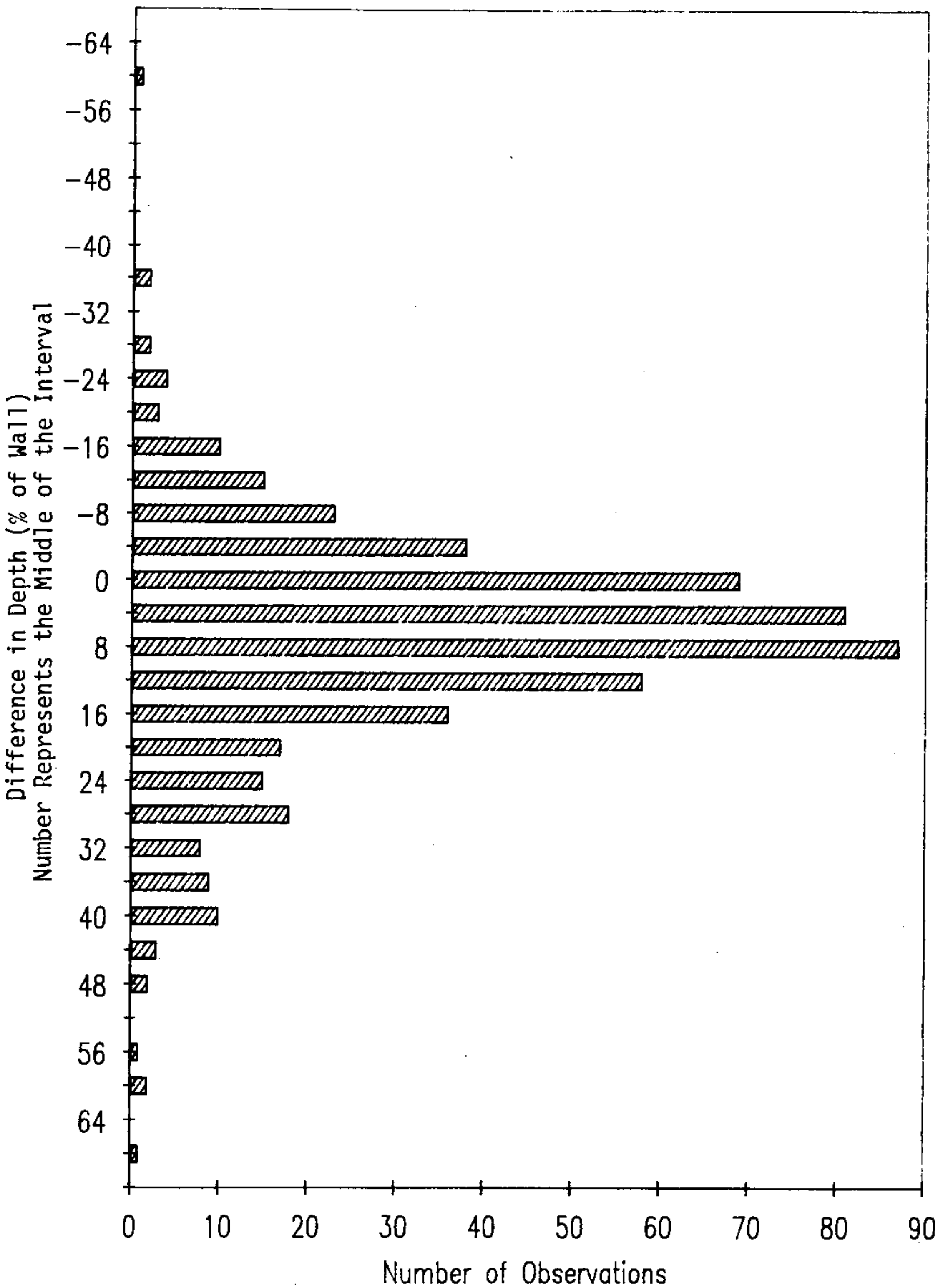


FIGURE 28. Histogram of Difference in Depth of Reported Indications Called by Both Teams X and Y, <10% Indications Deleted

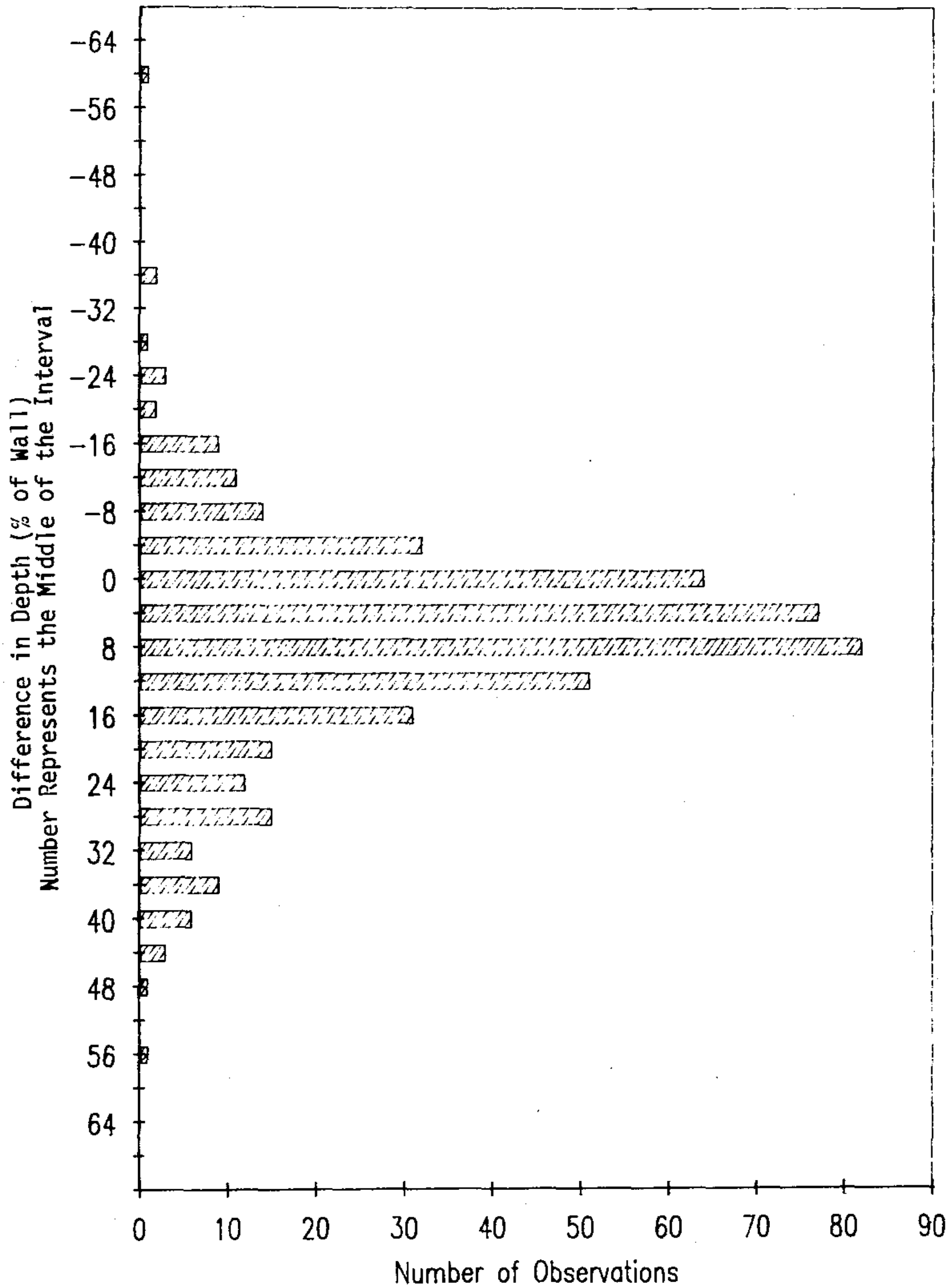


FIGURE 29. Histogram of Difference in Reported Depth of Indications Called by Both Team X and Y, <20% Indications Deleted

TABLE 22. Summary of Wall-Loss Indications Reported by Teams X and Y by Depth and Agreement Category, <10% Indications Deleted

Depth		Two Detections Size Difference <10%		Two Detections Size Difference >10%		Unmatched Detection	
≥40%	Team X	132	60%	67	30%	21	10%
	Team Y	160	45%	169	47%	30	8%
20-40%	Team X	148	45%	106	32%	78	23%
	Team Y	117	58%	42	21%	40	20%
<20%	Team X	21	17%	28	22%	77	61%
	Team Y	21	29%	9	13%	42	58%

TABLE 23. Summary of the Wall-Loss Indications Reported by Teams X and Y by Depth and Agreement Category, <20% Indications Deleted

Depth		Two Detections Size Difference <10%		Two Detections Size Difference >10%		Unmatched Detection	
≥40%	Team X	132	60%	66	30%	22	10%
	Team Y	160	45%	157	44%	41	11%
20%-40%	Team X	158	43%	102	30%	92	27%
	Team Y	125	57%	26	13%	63	31%

The results for the 20-40% depth category showed a decrease in the number of common detections in the best agreement category, with the largest decrease for the set of ≥20% indications. The percent of unmatched detections for this depth category increased from 16% for the entire data set to 27-31% for the ≥20% only indications.

The <20% size category for the set of ≥10% indications (Table 22) is interesting compared to the same category in Table 19. The size of the best agreement category for Team X decreased, while the size of the same category for Team Y increased. The opposite behavior occurred for the unmatched detection category. These reversals were due to the fact that Team Y called many more <10% indications, but fewer indications in the range 10-20%, than did Team X.

In summary, the omission of the small indications (either <10% or <20%) has not improved the agreement, either in detection or sizing of common indications.

4.5 HEIGHT OF THE SLUDGE ON THE TUBE SHEET

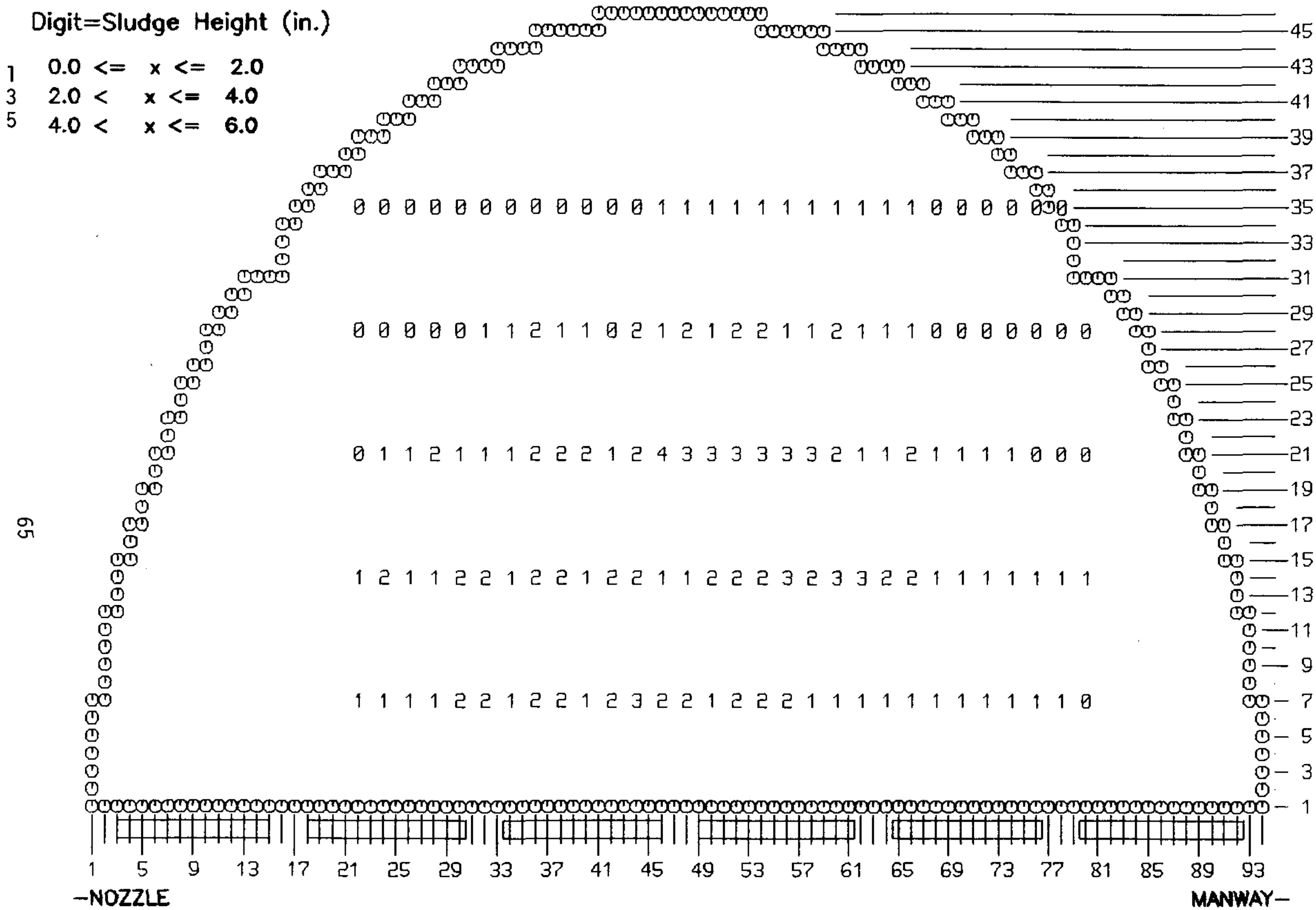
During the service life of the generator, a sludge pile formed in the center of the tube sheet on both the hot and cold legs. Several attempts were made to dislodge the sludge pile, but without success. The height of the sludge pile was measured using a 25 kHz eddy current inspection before and after the sludge-lancing procedures. The sludge was reported to be deepest on the cold leg. The sludge height data measured during the service life of the generator is presented in Doctor et al., PNL-3955, "A Description of the Data Acquisition and Statistical Analysis Computer Systems for the Steam Generator Group Project," October 1983.

During the post-service baseline inspections, both teams also produced sludge height measurements. Figures 30-33 show maps of the sludge height for the hot and cold leg side of the generator for Teams X and Y, respectively. A comparison of Figures 30 and 32, and 31 and 33 suggests that Team Y reported deeper sludge heights than Team X. The observation was submitted to a formal statistical test by comparison of the sludge height data for tubes in which both teams had measurements. The differences between the two teams' reported sludge height measurements in the same tubes are shown in Figures 34 and 35. The result of the test for the difference of means (Snedecor and Cochran, 1980, p. 85) for both legs of the generator is that Team Y reported sludge heights significantly deeper than Team X.

4.6 USES OF THE BASELINE INSPECTION DATA

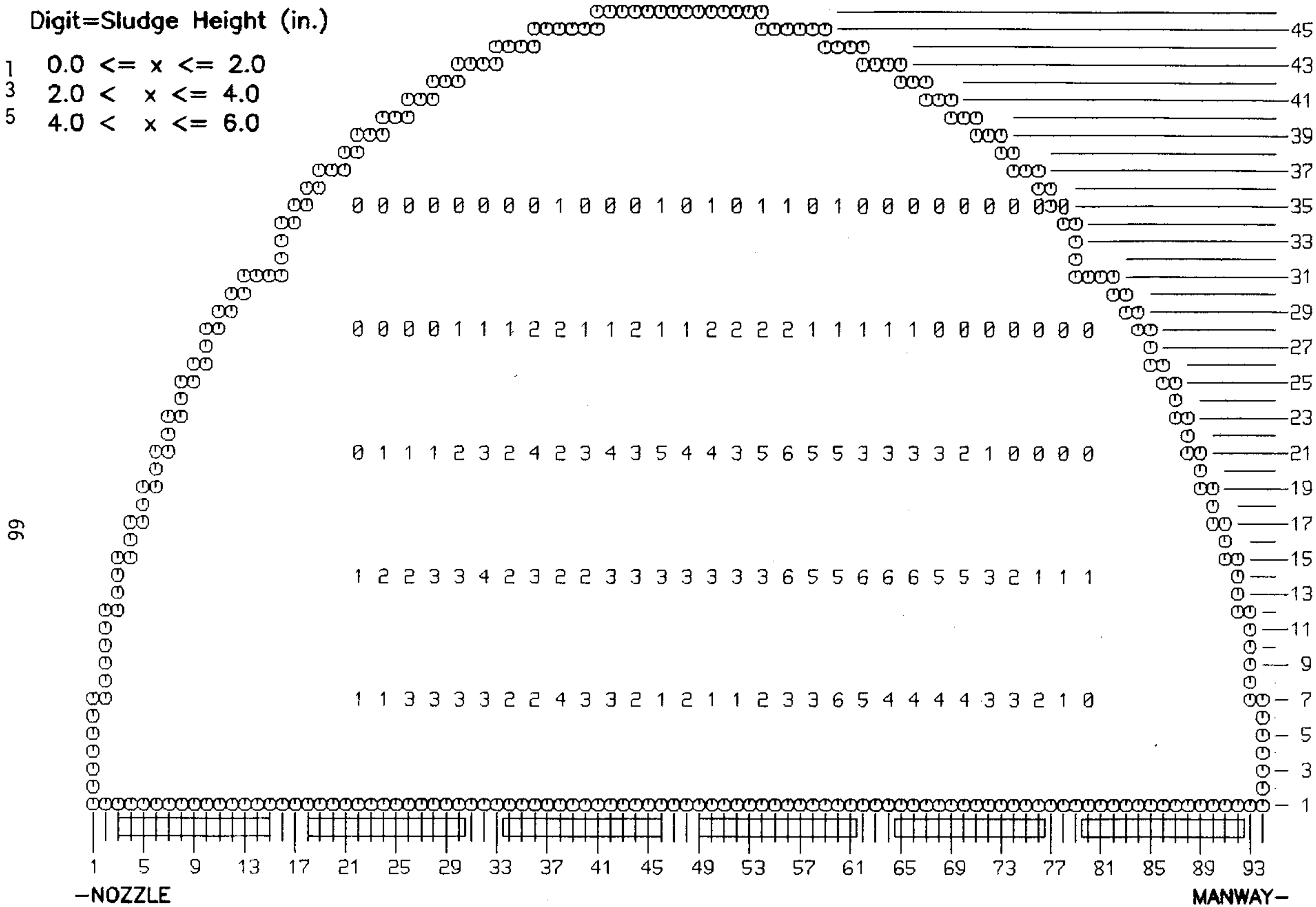
As mentioned in Section 1.0, the purpose of the baseline inspections was to determine the location of defects within the generator to ensure selection of tubes with an adequate number of defects for NDE inspection during the round robin activities and subsequent destructive analysis. The round robin inspections provide the data to evaluate differences between teams for statistical analyses of inspection reliability. The validated round robin data will provide an estimate of the accuracy and precision of defect detection and sizing of reported wall-loss indications. The baseline inspections also provided a measure of the number and distribution of defects in the generator.

The process for selecting the tubes for the NDE round robins was based on statistical stratified sampling. A detailed description of how the baseline inspection results were used in the stratified sampling process is given in Doctor et al., PNL-5868, "Task 9 Final Report - Nondestructive Evaluation Round Robin".



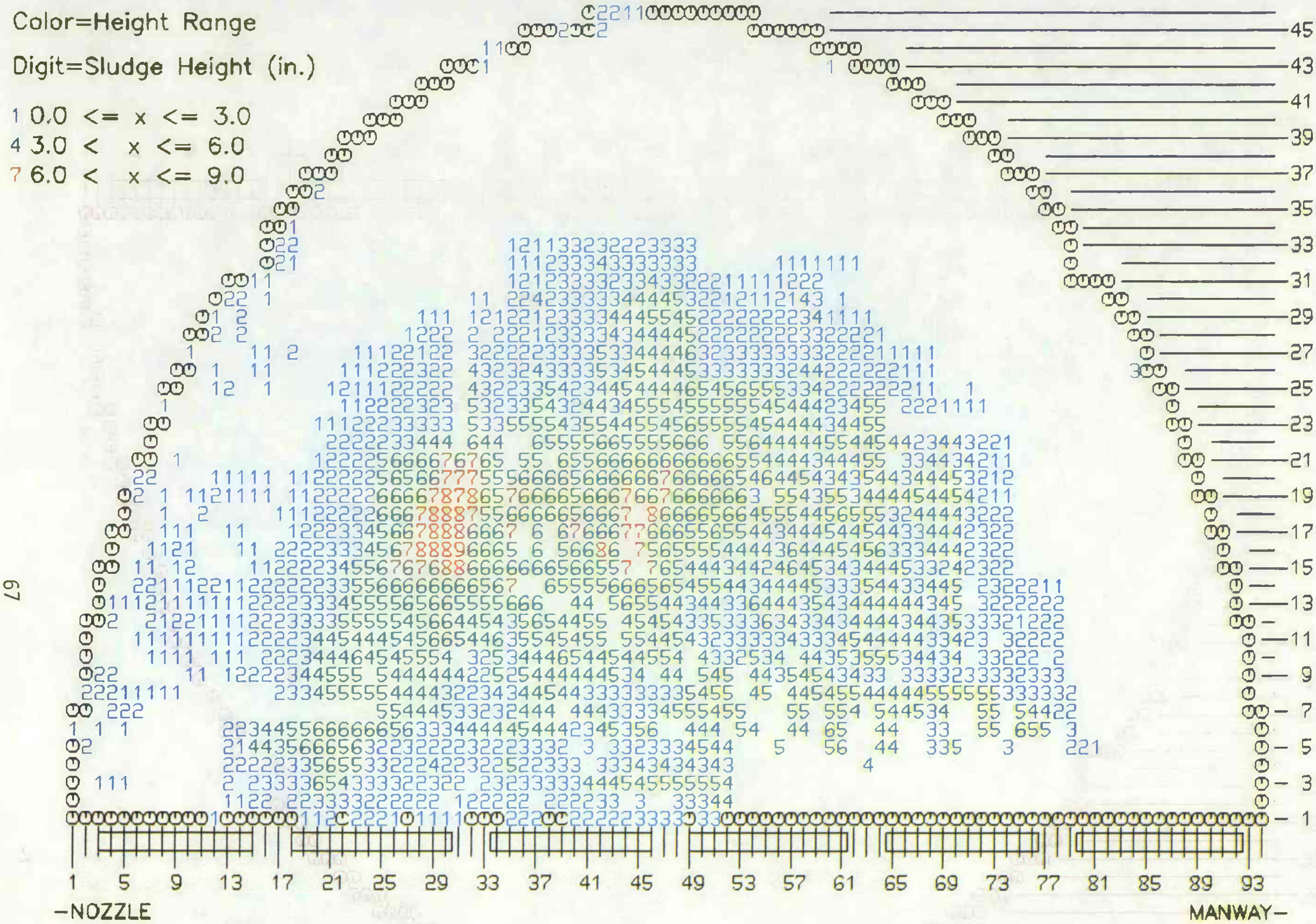
Height of Sludge on Hot Leg Measured by Team X

FIGURE 30.



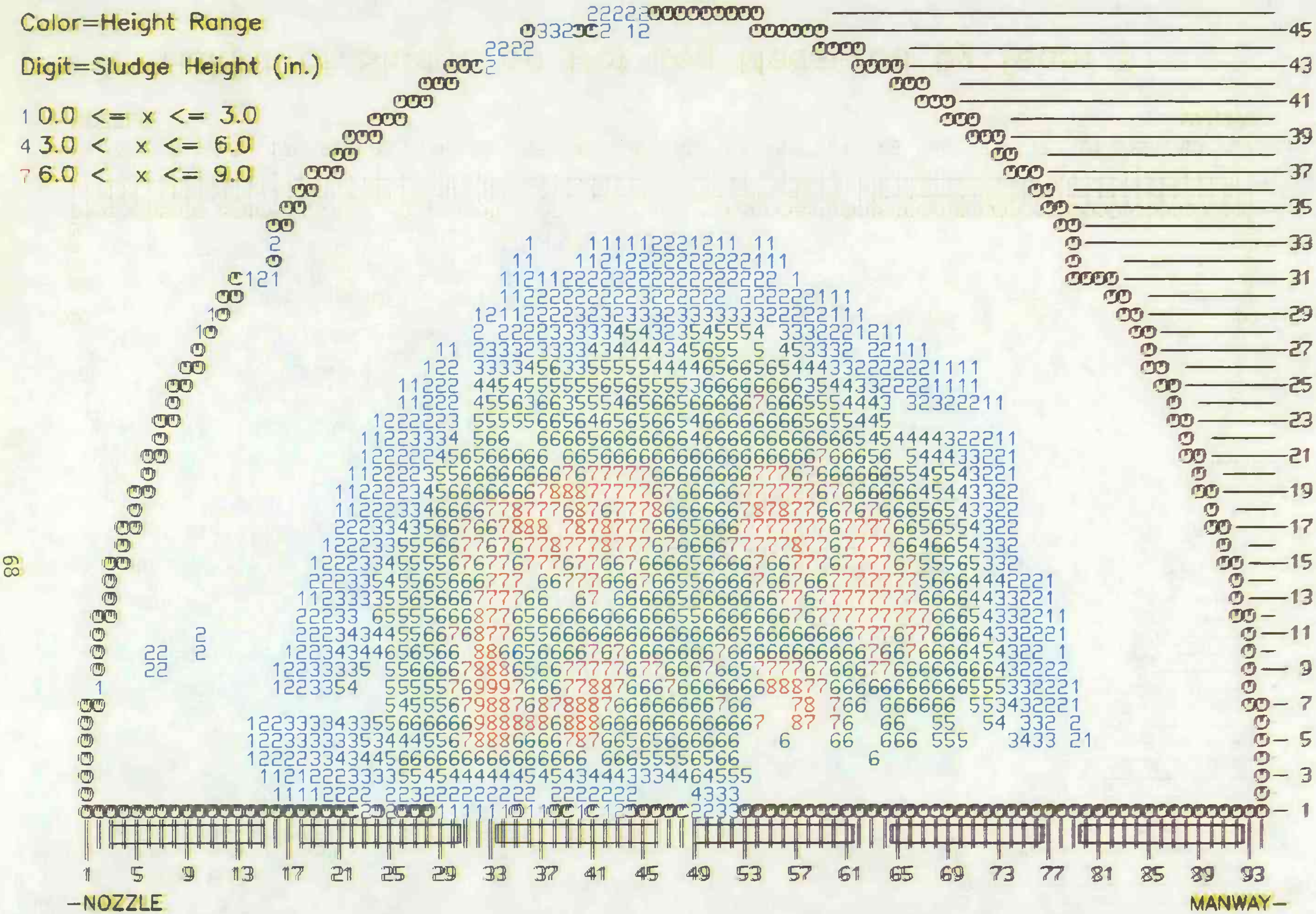
Height of Sludge on Cold Leg Measured by Team B

FIGURE 31.



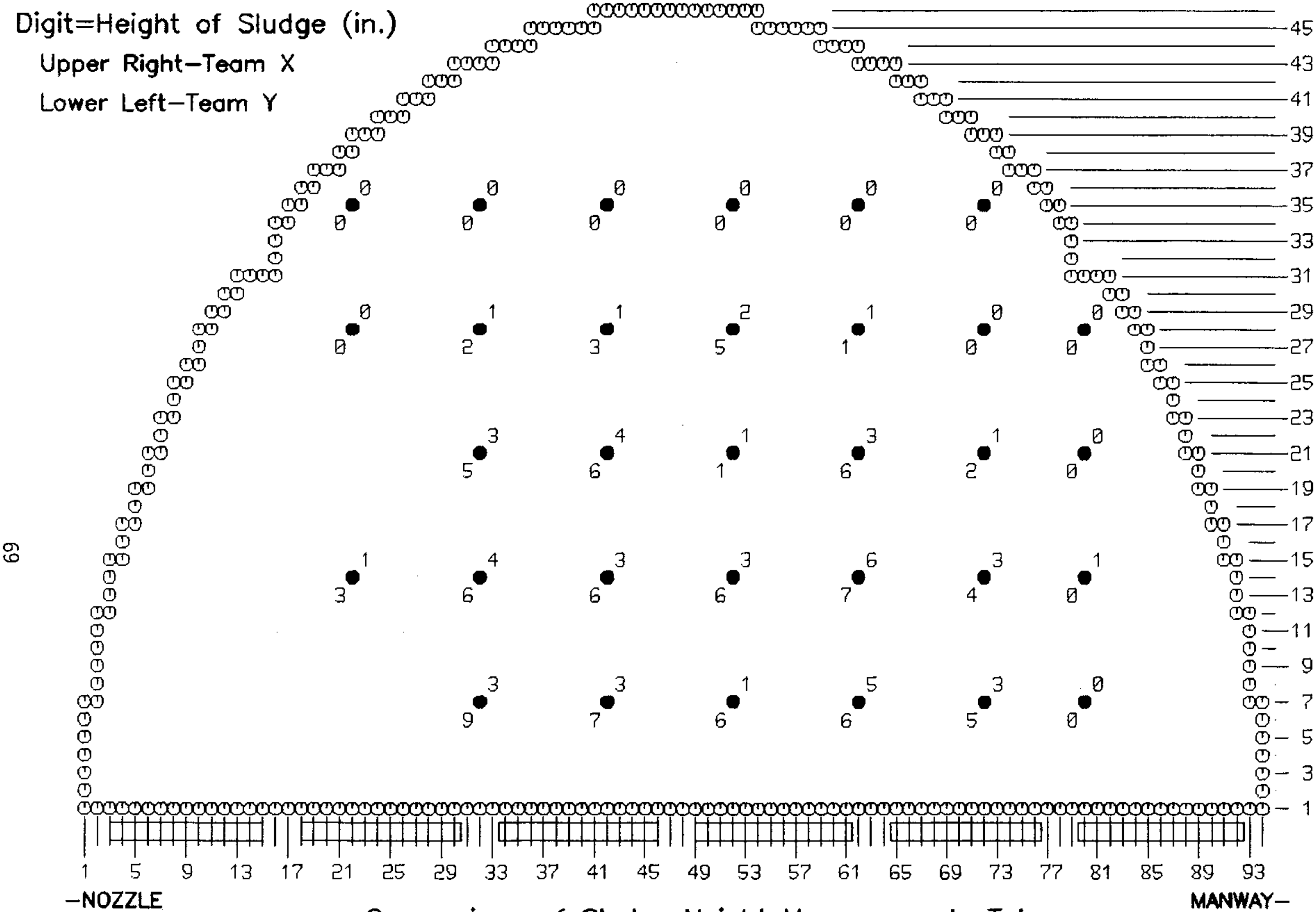
Height of Sludge on Hot Leg Measured by Team Y

FIGURE 32.



Height of Sludge on Cold Leg Measured by Team Y

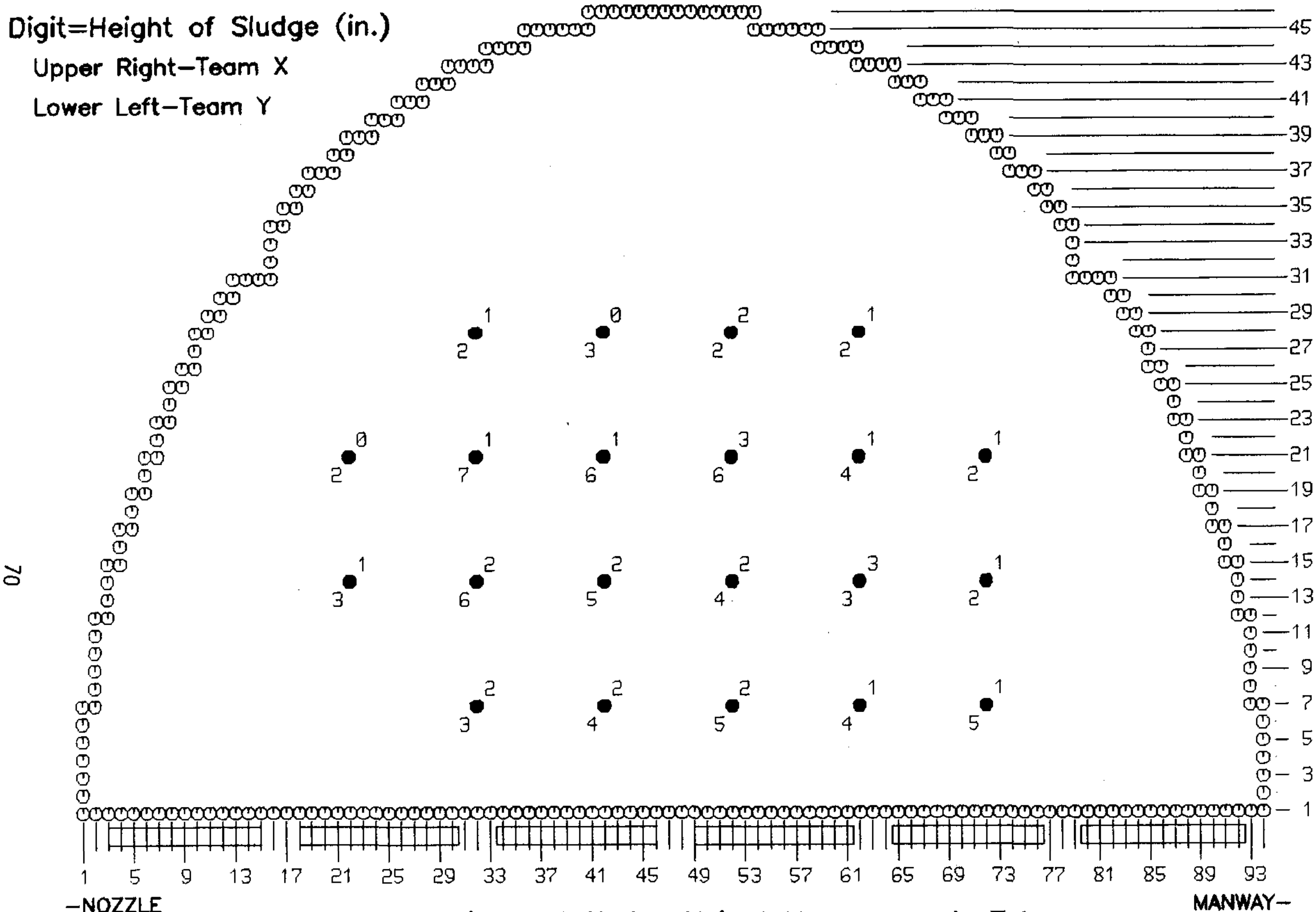
FIGURE 33.



Comparison of Sludge Height Measurements Taken
by Team X and Team Y on the Cold Leg

01/07/86

FIGURE 34.



Comparison of Sludge Height Measurements Taken

by Team X and Team Y on the Hot Leg

01/07/86

<u>FIGURE 35.</u>

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6.0 ACKNOWLEDGMENTS

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APPENDIX A

ZETEC BASELINE INSPECTION
STATEMENT OF WORK
(REVISION 4)

APPENDIX A

STATEMENT OF WORK FOR CONDUCTING POST-SERVICE BASELINE EDDY CURRENT EXAMINATION OF SURRY 2A STEAM GENERATOR TUBES USING ZETEC EDDY CURRENT TECHNOLOGY

by

Battelle, Pacific Northwest Laboratory
Nondestructive Testing Section
Richland, Washington

STEAM GENERATOR PROGRAM

March 11, 1983
Revision: 4

Table of Contents

TECHNICAL SPECIFICATION
FOR THE BASELINE EDDY CURRENT INSPECTION OF
TUBING FROM A RETIRED SURRY STEAM GENERATOR

1.0 SCOPE

This document defines the technical specifications and requirements governing the conduct of the baseline post-service eddy current inspection of thin-wall tubing in the Surry 2A steam generator. The steam generator is a Westinghouse Series 51 which was removed from service in 1979 and transported from Gravel Neck, Virginia to the U.S. Department of Energy Hanford Reservation in Richland, Washington. Battelle Pacific Northwest Laboratory is under contract with the U.S. Nuclear Regulatory Commission and other project sponsors to conduct the Surry Steam Generator Group Project. One of the tasks of the program is to perform a complete eddy current inspection of the steam generator tubing. At Hanford, the steam generator is housed and positioned vertically in the Steam Generator Examination Facility (SGEF). The SGEF was constructed specifically for nondestructive and destructive examinations of the Surry steam generator. The eddy current inspection of the Surry 2A steam generator will be performed at the SGEF. It is intended that this post-service inspection will simulate an inspection at an actual nuclear plant. However, due to the non-service nature of the unit, ample time will be available for additional tests that would serve to maximize information from the examination.

2.0 GENERAL

2.1 STEAM GENERATOR BACKGROUND

The unit to be extensively examined and serve as a test bed in this research program is the 'A' steam generator removed from service at the Surry 2 pressurized water reactor operated by

Virginia Electric and Power Company. The Surry 2A generator is a U-tube design Westinghouse Series 51 with 3,388 tubes. Tube material is Inconel-600 alloy with a nominal outside diameter of 0.875 inch (± .003) and a wall thickness of 0.050 inch (± .002). Design features of the Surry 2A generator include seven drilled hole carbon steel support plates of the type with an annulus about each tube with flow holes. A portion of the tube length extending through the tube sheet has been roll-expanded to provide a tight fit. The tube ends have been seal-welded to the tube sheet cladding. The tube ends extend approximately 1/4" beyond the tube sheet face into the water box. The Surry 2 nuclear plant initiated operation in early 1973. Secondary side water conditioning was initially by sodium phosphate additions. In September 1974 the unit was converted to the all volatile treatment (AVT) chemistry. The Surry reactors are sited adjacent to the James River. Cooling water condensors were tubed with 90:10 Cu:Ni alloy and have a history of leakage. A significant number of tubes on the hot leg side have been compressed where they intersect tube support plates by corrosion products. This phenomenon is known as "denting."

Approximately 500 plugs installed in flawed tubes during operation will be removed to allow access for re-examination. Approximately 250 tubes will remain plugged and will not be subject to evaluation in this test. The water box interior surfaces will also be de-contaminated so that the background radiation level is not greater than approximately 1 R/hour, exclusive of shine from the tubes.

2.2 WORK TO BE PROVIDED - CONTRACTOR

The Contractor shall provide services which shall include, but not be limited to, the following:

2.2.1 The preparation of a baseline post-service eddy current inspection plan which describes the Contractor's policies, practices, and inspection procedures. The plan shall include as a minimum: the eddy current inspection procedures, document control procedure, personnel qualification procedure, administration procedures for approval of reports, equipment calibration procedures, data analysis procedure, procedure for control and maintenance of equipment, etc., necessary to fulfill the requirements of the contract specification. The major participating organizations and their designated responsibilities and authorities shall be defined with respect to their function in the overall program activities. The plan shall be submitted to Battelle for approval prior to commencement of work on the plant site.

2.2.2 Performance of field post-service eddy current inspection of approximately 3,138 tubes over their entire length. Battelle reserves the right to reduce the number of tubes to be inspected. Each tube will be examined twice; once using the single frequency technique, and once using the multifrequency technique (see 3.3.1).

2.2.3 Testing, calibration, and qualification of examination equipment and procedures prior to commencing the inspection program.

2.2.4 Data acquisition, reduction and transcription where necessary.

2.2.5 Evaluation and interpretation of inspection results.

2.2.6 Providing qualified supervisory and inspection personnel.

2.2.7 Upon completion of the inspection, advise Battelle during a scheduled interview of the overall status and results of the inspection, including the findings and method of analysis.

2.2.8 Providing conclusive evidence verifying the identification and location of all tubes inspected (see 3.8.4).

2.2.9 Providing the total manpower and equipment necessary to perform and evaluate all the inspection and evaluations required by this document in accordance with the schedules defined in Paragraph 6.1.

2.2.10 Compliance with cleanliness and health physics requirements established by Battelle.

2.2.11 Providing preliminary and final reports.

2.3 WORK BY OTHERS

Battelle shall provide the following services to the successful bidder in support of the inspection activities:

2.3.1 Health physics personnel throughout the inspection activity.

2.3.2 Casual labor, scaffolding, clean facilities, change room, electrical power, office/storage space, and telephone.

2.3.3 Equipment and personnel to record all inspection data in a computerized data acquisition system, in addition to the data recorded by the Contractor as part of a normal steam generator inservice inspection (see 4.0).

2.3.4 All required safety clothing, respirators, etc.

2.4 DEFINITIONS OF TERMS AND ABBREVIATIONS

2.4.1 Battelle - Denotes the organization responsible for the Surry Steam Generator Research Program; specifically, Battelle Pacific Northwest Laboratory.

2.4.2 Contractor - The inspecting Agent responsible for meeting the requirements of the Technical Specification and other terms and conditions of the contract.

2.4.3 Inspection (or Examination) - Denotes the performance of an eddy current examination of Inconel-600 tubing and shall be in compliance with the Codes, Standards, and requirements dictated in Section 2.5 of this work statement, as applicable.

2.4.4 Post-Service Inspection - The eddy current examination performed by the Contractor on the retired-from-service radioactive Surry 2A steam generator.

2.4.5 Designated Representative - The primary technical contact within Battelle and the Contractor's organization.

2.4.6 Examiner - Denotes the person performing any nondestructive examination.

2.4.7 Calibration Standard - A calibration device with real or simulated defects in material, the purpose of which is to calibrate examination equipment.

2.5 CODES, STANDARDS AND REGULATIONS

The below listed Codes, Standards and Regulations are part of this Technical Specification. Specific Code Editions and Addenda, Standards and Regulatory requirements are specified where appropriate. The services rendered by the Contractor shall be in compliance with the requirements of the following Codes, Standards, and Regulations. If any conflicts of requirements are noted by the Contractor, each conflict shall be brought to the attention of Battelle for resolution.

2.5.1 American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, Appendix IV, and IWA-2240, 1980 Edition with Addenda through Winter 1980.

2.5.2 American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section V, Article 8, Appendix I, Nondestructive Examination.

2.5.3 United States Nuclear Regulatory Commission Regulatory Guide 1.83, Inservice Inspection of Pressurized Water Reactor Steam Generator Tubes, Revision 1, July 1975.*

2.5.4 American Society of Nondestructive Testing (ASNT), Recommended Practice No. SNT-TC-1A, 1980 Edition, Personnel Qualification and Certification in Nondestructive Testing.

*EXCEPTIONS: (1) Section C.2.f, note 3 - the entire U-bend and cold leg portions of the tube length shall be examined; and (2) Section C.2.6 - equipment required will consist of both Zetec EM-3300 and MIZ-12 testers.

2.6 DRAWINGS

The sketches included are furnished to prospective contractors for general reference information only. The sketches do not necessarily reflect the current or future configurations in every detail.

3.0 DETAILED REQUIREMENTS

The Contractor shall be responsible for performance of the post-service inspection described herein.

3.1 EXCEPTIONS

Exceptions to this Technical Specification taken by a prospective contractor shall be clearly identified in his proposal, along with justification for the exceptions and proposed alternatives for achieving the objective of the requirement. Each exception shall be referenced to the corresponding section(s) in this Technical Specification. Unless specific exceptions are identified in this manner and reflected in any resulting contract, the Contractor's full compliance with the Technical Specification will be mandatory.

3.2 INSPECTION

The inspection of the steam generator tubing shall be in compliance with U.S. Nuclear Regulatory Commission Regulatory Guide 1.83. Guidance for the performance of the eddy current inspections may be taken from ASME Section XI, 1980 Edition through 1980 Winter Addenda.

3.2.1 Extent of Inspection

Each of the 3,138 tubes in the steam generator will be inspected for defects and imperfections over the entire length of the tube. The inspection will be carried out primarily from the cold leg side due to severe denting at the lowest support plate on the hot leg side. The hot leg tubes will also be inspected from the hot leg side as far as possible using the largest probe that will fit, with 0.610" Ø the smallest probe used. It is understood that some of the tubes will be physically impossible to examine over their entire length due to denting, small bend radii, etc.

3.3 INSPECTION SYSTEM

The inspection equipment shall be in compliance with Regulatory Guide 1.83.

3.3.1 Eddy Current Instruments

The Automation Industries/Zetec EM-3300 single frequency and Zetec MIZ-12 multi-frequency inspection systems provided by the Contractor will be used for tubing inspection.

3.3.2 Inspection Frequencies

Single frequency and multi-frequency techniques are required for this examination. The inspection equipment shall be capable of being calibrated and operated using a single test frequency and a differential coil probe in accordance with ASME Section V, Article 8, Appendix I, Section I-30, "Calibration." Multi-frequency inspection equipment shall be capable of being operated utilizing the basic frequency selected for the single frequency examination. Other frequencies selected to minimize the effects of parameters such as tube supports, copper deposits, tube sheets, etc., using a differential coil probe shall also be utilized. Equipment for performing an absolute coil technique shall be performed utilizing a frequency of 100 kHz.

3.3.3 Probe Pusher/Puller

Battelle will provide a modified Zetec Model 2-D pusher/puller including a variable speed D.C. motor and a digital display of the probe position, which must be used under computer control for this examination (see 4.0). The Contractor will maintain and repair the pusher/puller during the course of the examination.

3.3.4 Probes

Battelle will provide all eddy current probes, cable, and probe shafts required for the examination. The Contractor may supply and use, with Battelle's specific approval, any nonstandard or special probe. The Contractor will be responsible for changing probes as required to complete the examination.

3.3.5 Remote Operations

The inspection is to be performed from outside the steam generator containment area, from a remote lab. Battelle will provide all electrical connection points and also a four-channel communications system including headsets and cables. See Figures 1, 2 and 3 for sketches of the equipment layout.

3.3.6 Probe Positioning Fixture

Battelle will provide a Zetec SM-4 pole fixture and controls to position the probe at the tubes. Zetec tube sheet templates will also be provided and installed by Battelle prior to the examination for tube identification. TV cameras for monitoring operation of the probe positioner (SM-4) will also be furnished by Battelle (see Figure 1). Any required maintenance or repairs on this equipment will be performed by Battelle.

3.3.7 Recording Equipment

The Contractor will provide the reel-to-reel tape recorders and strip chart recorders required for this examination. Battelle will provide a Zetec O.M.B.-1 and cables to interconnect the recording devices.

3.4 INSTRUMENT CERTIFICATION

All examination instruments which are used for eddy current examination shall be certified in accordance with the requirements of ANSI N45.2 Item 13, and as follows:

3.4.1 The oscillator output frequency(s) to the drive coil shall be certified* as of the specified test frequency ±5%.

3.4.2 The vertical and horizontal linearity of the Cathode Ray Tube (CRT) display shall be certified* as being ±10% of deflection input voltage.

3.4.3 The CRT vertical and horizontal trace alignment shall be certified* as being parallel to graticule lines ±2 degrees.

3.4.4 The output voltage from the tape recorder shall be certified* as being ±5% of the input voltage for each channel of the tape recorder.

3.4.5 The chart speed from the strip chart recorder shall be certified* as being the indicated value ±5%.

3.4.6 The amplification in all channels of the eddy current instrument shall be certified* as being equal to all sensitivity settings ±5%.

3.4.7 The two output channels of the eddy current instrument shall be certified* as being orthogonal ±3 degrees at the test frequency.

3.4.8 Certified test reports shall be provided to Battelle for each piece of test equipment utilized.

*The performance capability shall meet the minimum requirement of 10 CFR 50, Appendix B.

3.5 INSPECTION PROCEDURE REQUIREMENTS

All eddy current inspections shall be conducted in accordance with written procedures. All procedures shall be approved by Battelle prior to the commencement of work. It is the responsibility of the Contractor to comply with all of Battelle's comments in a satisfactory manner. Each inspection procedure shall be approved and signed by the Contractor's SNT-TC-1A Level III examiner, and shall contain, as a minimum, the items of information listed below:

3.5.1 Tube material, diameter, and wall thickness.

3.5.2 Size and type of test probe including manufacturer's name, part number, and length of probe cable.

3.5.3 Test frequency or frequencies.

3.5.4 Manufacturer, type, and model of eddy current equipment.

3.5.5 Scanning direction and speed during examination (insertion, retraction, or both--from hot leg or cold leg).

3.5.6 Description of inspection technique, i.e., mechanized probe drive, remote control fixture, etc.

3.5.7 Description of calibration procedure and calibration standards, including multiparameter optimization techniques.

3.5.8 Description of data recording equipment and procedures.

3.5.9 Procedure for interpretation of test results, and the applicable criteria for reportable indications.

3.5.10 Additional information as necessary to describe the examination.

3.6 INSPECTION PERSONNEL QUALIFICATIONS

3.6.1 The Contractor shall furnish necessary inspection and supervisory personnel qualified, as a minimum, to the requirements and recommendations of the applicable Codes, Standards, and Regulations described in Paragraph 2.5. Individual certifications, including eye test results, shall be submitted to Battelle for review and approval after the award of the contract and prior to start of work. Past experience in eddy current examination of steam generators shall be submitted for supervisory personnel (Levels II and III).

3.6.2 The examiner performing the eddy current inspection shall be qualified to at least Level II in accordance with SNT-TC-1A. The assistant to the examiner (if required) shall be qualified to at least Level I in accordance with SNT-TC-1A.

3.6.3 The supervisory personnel shall be qualified to Level II or III in accordance with SNT-TC-1A.

3.6.4 Evaluation personnel shall be qualified to Level II or III in accordance with SNT-TC-1A. The evaluation personnel shall have had additional training specifically in data evalution and this must be supported by documentation submitted with the certifications for approval by Battelle.

3.6.5 All examination personnel are subject to approval by Battelle.

3.7 CALIBRATION STANDARDS

Battelle will provide the calibration standards required. The calibration standards shall be manufactured from tube material Inconel Alloy 600. The tube outside diameter is 0.875 inch nominal, and wall thickness is 0.050 inch nominal. The defect standards shall contain defect areas as follows:

3.7.1 100% through wall hole 0.067 inch diameter.

3.7.2 Flat-bottomed hole 5/64 inch diameter x 80% through from the outer wall surface.

3.7.3 Flat-bottomed hole 7/64 inch diameter x 60% through wall from the outer tube wall surface.

3.7.4 Flat-bottomed hole 3/16 inch diameter x 40% through wall from the outer tube wall surface.

3.7.5 Four flat-bottomed holes, 3/16 inch diameter, 20% through the tube wall from the outer tube wall surface spaced 90 degrees apart around the tube circumference.

3.7.6 A 360 degree circumferential groove 1/16 inch wide and 20% through from the inner tube wall surface.

3.7.7 Battelle may provide a dent standard, or other supporting standards, based on current industry practices and experience.

3.7.8 Each standard shall be identified by a serial number. Artificial flaw dimensions shall be measured to the nearest 0.003 inch. Flaw dimensions and systems response to the flaw shall be part of permanent record of the standard.

3.8 RECORDS, EVALUATIONS, ACCEPTANCE CRITERIA AND REPORTS

3.8.1 Records

All test results from this baseline examination are proprietary to the U.S. Government. Due to the nature of future work on this program, dissemination of the test results to any outside parties is expressly forbidden.

3.8.1.1 The eddy current data from all tube inspections shall be recorded on both magnetic tape and strip chart as the probe traverses the tubes. The magnetic tapes provided shall be good quality polyester based, such as AUDUA, L-1800, manufactured by TDK Electronic Company, Ltd., Japan, or equal.

3.8.1.2 The Contractor may make duplicate copies of the magnetic tapes for his own use.

3.8.1.3 The Contractor shall have equipment available to photograph the memory oscilloscope CRT display of any indications selected by Battelle.

3.8.1.4 The inspection data will be concurrently digitized and recorded with position information by Battelle during the inspection to the maximum extent possible. Battelle will provide all equipment and personnel to perform this task (see 4.0).

3.8.2 Record Identification

The start of each reel of magnetic tape and its companion roll of chart paper shall, as a minimum, contain the following information:

3.8.2.1 The identity of "Battelle" (the steam generator owner).

3.8.2.2 The steam generator identity.

3.8.2.3 The date of inspection.

3.8.2.4 The test frequencies (Hz).

3.8.2.5 Pertinent probe data (manufacturer, model, type, etc.)

3.8.2.6 Reel number and side.

3.8.2.7 Calibration standard reference number.

3.8.2.8 Operator's name, certification level, and affiliation.

3.8.3 <u>Tube Numbering System</u>

Each tube examined shall be identified on the magnetic tape and strip chart in accordance with the tube numbering system provided by Battelle.

3.8.4 <u>Tube Identity Verification</u>

At periodic intervals (approximately every tenth tube), the tube identity will be verified by a member of Battelle's staff. Verification of the positive identification of tube location shall be recorded on both the magnetic tape and strip charts. In the event an error is discovered, all data generated since the previous verification of location shall be voided in an appropriate manner, and any tubes examined since the previous verification will be re-examined.

3.8.5 <u>Evaluation</u>

All recorded indications shall be evaluated to determine the location, type of defect or imperfection, and size. All indications resulting from the presence of dings, excessive tube chatter, permeability changes, and other significant indications shall be recorded and evaluated. Indications of tube wall penetration shall be evaluated and the depth of penetration and axial location along the length of the tube be determined. All suspect indications equal to or greater than 20% through the tube wall shall be recorded, evaluated, and reported to Battelle. Any indications less than 20% that have a high probability of being defects shall also be recorded, evaluated and reported to Battelle.

3.8.6 Report

The Contractor shall prepare a report documenting the results of the eddy current inspection. Procedures, equipment and other pertinent information shall be described in sufficient detail to permit comparison (duplication) of the inspection(s) for future examinations. The report shall include a record indicating the tube(s) examined, the extent to which each tube was examined, the axial location and depth of each reported indication, characterization of the flaw, and the identification of the operator(s) and data evaluator(s) who conducted each examintion or part thereof.

All records, including magnetic tapes and strip charts, shall become the property of the Government. The final report shall be reviewed, approved and signed by the cognizant SNT-TC-1A Level III personnel.

4.0 COMPUTER DATA ACQUISITION AND CONTROL

Battelle will concurrently record real-time eddy current inspection data and probe position in digital form while the examination is in progress. This operation is intended to not impede the Contractor's progress in any way. Battelle will control the pusher/puller using a computer terminal. The Contractor will be responsible for selecting the tube for inspection and recording the analog data. In the event of Battelle's computer system failing, a conventional Zetec pusher/puller remote controller is provided so that the Contractor may continue the examination as scheduled.

The real-time X-Y analog signal outputs from the eddy current instrument that are normally recorded on analog tape will also be routed to a NEFF A/D subsystem where they will be digitized and stored on 6250 bpi tape along with the probe position information. This will require tapping into the eddy current instrument signal outputs between the EC instrument and the analog tape recorder (see Figure 3). When using the MIZ-12, there will be eight analog outputs. These are the X and Y components for each of the four frequencies. When using the EM-3300, there will be only two analog outputs. These are the X and Y components for one frequency.

5.0 SURVEILLANCE

Battelle reserves the right to perform the following type of surveillance of the Contractor's programs and activities as they relate to the scope of work of this Technical Specification.

5.1 TECHNICAL SURVEILLANCE

Technical surveillance of the Contractor's activities at the SGEF site will be maintained to monitor compliance with this Technical Specification and the Contractor's ability to support the inspection schedule.

6.0 SCHEDULES AND INFORMATION TO BE SUBMITTED

6.1 SCHEDULES

The following schedule defines the desired milestones for the conduct of field post-service eddy current inspection of the Surry 2A steam generator tubing.

6.1.1 Familiarize Battelle personnel with inspection procedures -- within 15 DAC.

6.1.2 Start inspection -- between May 15, 1983 and June 30, 1983. (Exact date is subject to other program constraints.)

6.1.3 Complete inspection -- no later than 30 days after starting.

6.1.4 Complete data evaluation and exit interview -- 20 days after inspections are completed.

6.1.5 Submittal of "Preliminary Report" to Battelle -- September 1, 1983.

6.1.6 Submittal of "Final Report" to Battelle -- November 1, 1983.

6.2 INFORMATION TO BE SUBMITTED WITH PROPOSAL

The Contractor shall submit the information specified in the following paragraphs. Failure to submit this information may be cause for rejection of the proposal.

6.2.1 Exceptions

The Contractor shall provide a description of any qualifications, restrictions or exceptions to the content of this Technical Specification. For each exception, alternative compliance with the objective of the requirement being excepted, or justification for deletion of the requirements, shall be included.

Tacit compliance shall be assumed for all requirements for which no exceptions are listed. If no exceptions are taken, the Contractor shall so state.

6.2.2 Contractor's Qualifications

The Contractor shall furnish information concerning his previous work experience, capabilities and personnel who will be performing the work.

6.2.2.1 Contractor's Experience

Describe experience with single frequency and multi-frequency-multiparameter techniques using differential and absolute coil probes, and list of Westinghouse Steam Generators on which the Contractor has performed an eddy current tube inspection. List the percentage (%) of the total number of tubes inspected for each steam generator.

6.2.2.2 List any experience in inspecting other steam generator tubing which may be applicable to the work defined herein (particularly supervisory personnel to be assigned to this job).

6.2.2.3 Describe the method used to analyze and interpret the eddy current examination data.

6.2.2.4 Describe any unique methods the Contractor employs to differentiate between signals from tube sheets and support plates from tube indications in these areas. Discuss how the effect of I.D. roughness, wobble, copper deposit, and dents are minimized to enhance flaw signals.

6.2.2.5 Describe any additional inspection techniques that the Contractor would perform to aid in the analysis of indications or to verify a completed analysis.

6.2.2.6 Capability to meet the schedules as defined in paragraph 6.1 of this Technical Specification.

6.2.3 Information about Contractor's Proposed Organization

6.2.3.1 The Contractor shall provide the following information for key personnel in the organization who will be performing the work. This shall include the supervisory personnel and those interpreting the data:

Name:
Title:
Position Description:
Education and Training:
Level of Certification:
Other Qualifications:
Total Years Experience:
Summary of Experience (for past 5 years):

6.2.3.2 List the number of personnel and positions that would be used to perform this work.

6.2.4 Contractor's Management Plan

The Contractor shall include in his proposal a draft Management Plan. That Plan shall describe the personnel who will be involved in the inspection, their responsibilities and level of authority. The Plan should list the designated representative who will interface with Battelle's project manager. The Plan should include the method for scheduling inspections and monitoring progress. The Plan shall include provisions for reporting to Battelle on a daily basis the progress of inspection.

6.2.5 Additional Support Requirements

The Contractor should submit a list of site requirements over and above those listed in paragraph 2.3.2 for performing the inspection. Provision of these requirements is subject to approval by Battelle.

6.2.6 Comments and Other Information

Provide comments on the scope of work as outlined in this Technical Specification and any other additional information which the Contractor believes may be pertinent to Battelle's evaluation of his proposal.

6.3 INFORMATION TO BE SUBMITTED AFTER AWARD OF CONTRACT

The following information shall be submitted no later than twenty-one (21) days after award of contract for Battelle's review and approval.

6.3.1 Controlled copy(s) of the detailed inspection plan for eddy current inspection as defined in paragraph 2.2.1 of this Technical Specification.

6.3.2 Personnel certifications including eye test results and resumes.

6.3.3 Schedule and Management Plan including number of personnel required, shifts/day and hours per shift, quantities and type of equipment to be used, etc.

7.0 DOCUMENTATION

The Contractor shall be responsible for documenting the results of all eddy current inspections, including the evaluation of indications found during the conduct of the examination, in a final report. The final report shall be prepared by the Contractor as defined in paragraph 3.8.6 of this Technical Specification. The Contractor shall also be responsible for control and storage of all the data obtained during the inspection. The original magnetic tapes and strip chart recordings shall be turned over to Battelle upon completion of the inspection.

7.1 DATA CONTROL SYSTEM

All data shall be acquired, recorded, handled, and stored according to an approved procedure as described in the Contractor's program.

7.1.1 Data Sheets

The data sheet forms to be used for recording inspection data shall be included with the procedures.

STEAM GENERATOR EVALUATION FACILITY
EQUIPMENT DIAGRAM

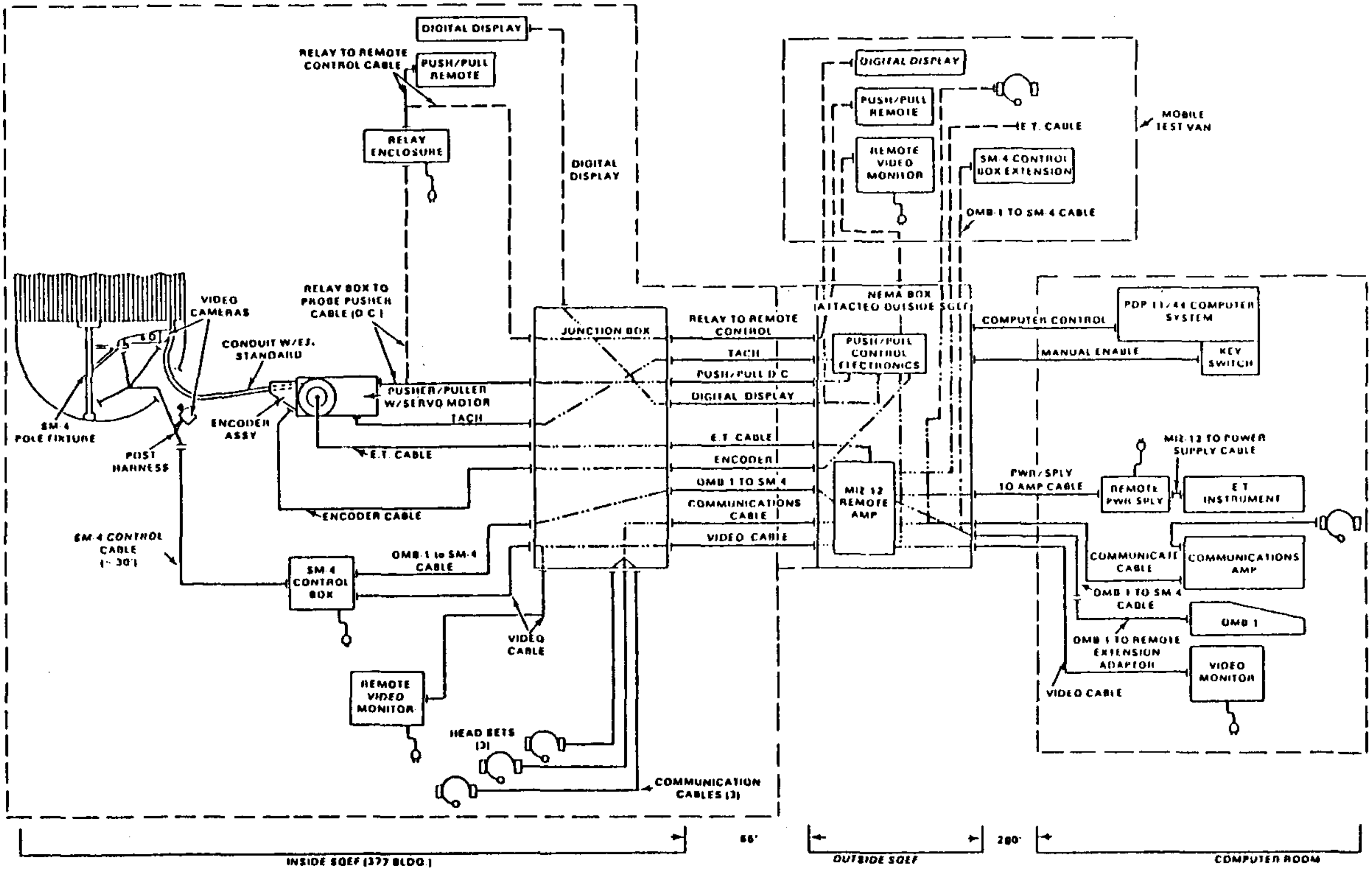
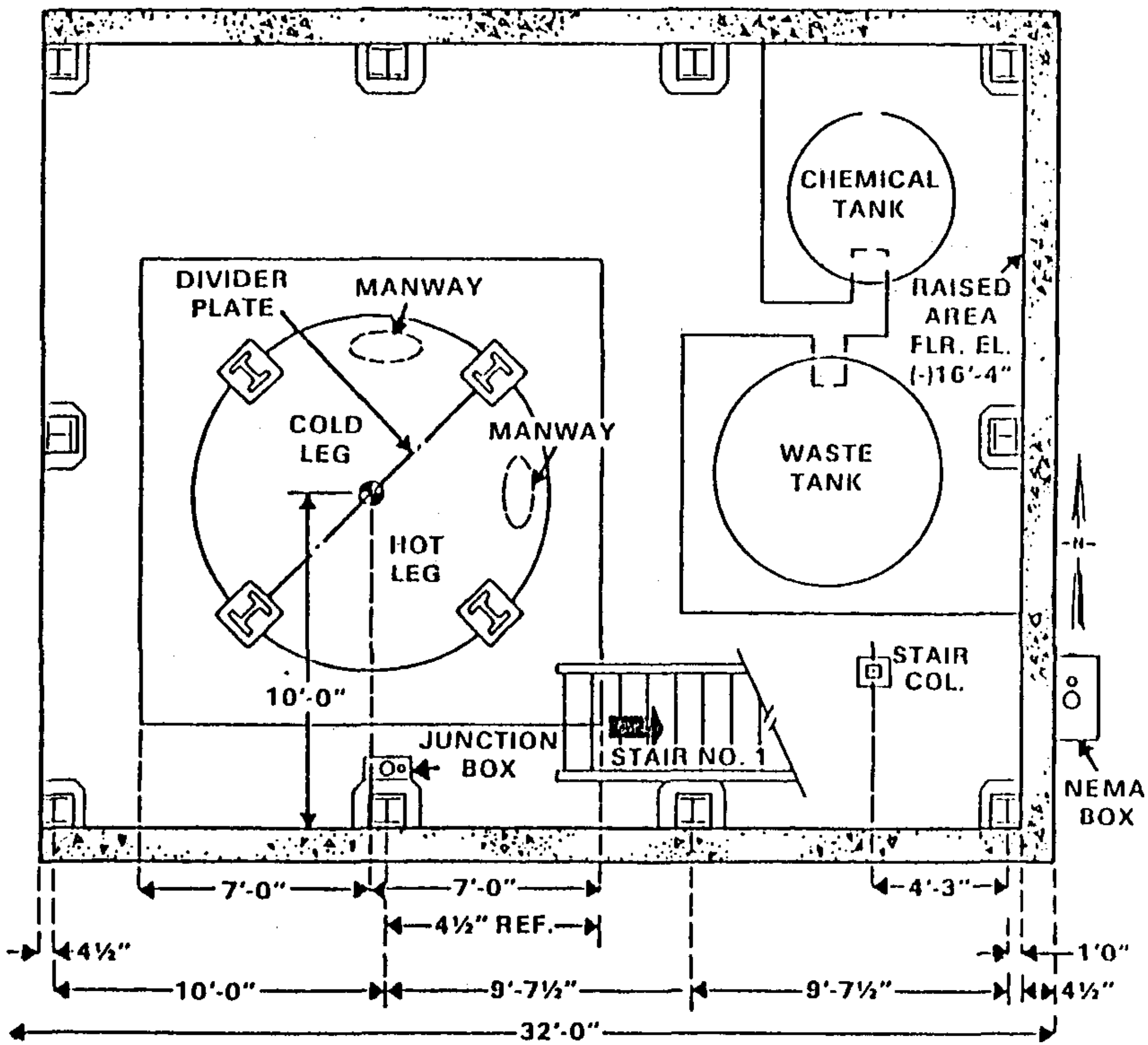
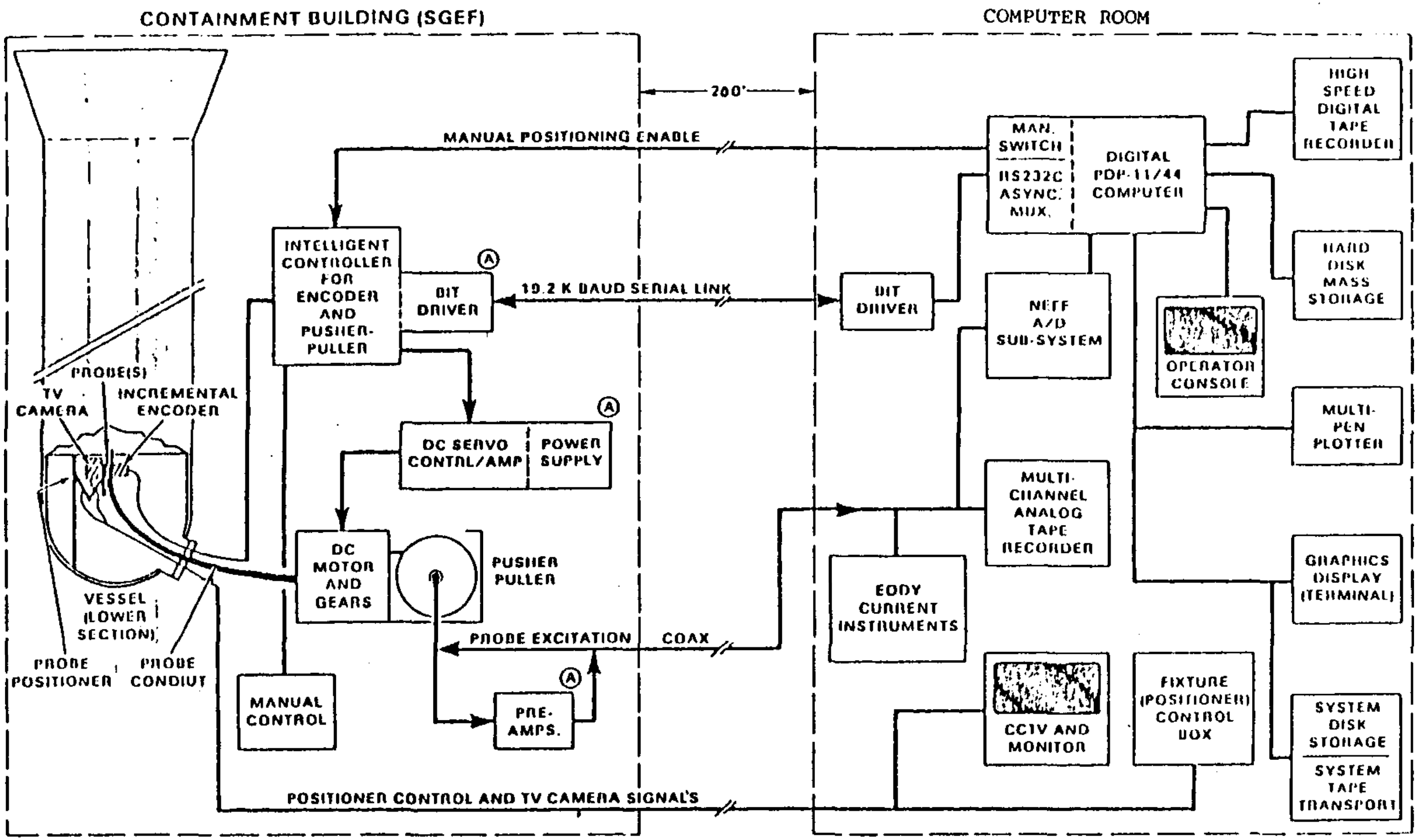


Figure 1.

STEAM GENERATOR TEST FACILITY BASEMENT PLAN



CONCEPTUAL STEAM GENERATOR INSPECTION SYSTEM



Ⓐ DENOTES LOCATION IN NEMA ENCLOSURE ON OUTSIDE S.E. WALL

Battelle

Figure 3.

APPENDIX B

INTERCONTROLE BASELINE INSPECTION
STATEMENT OF WORK

APPENDIX B

STATEMENT OF WORK FOR CONDUCTING POST-SERVICE BASELINE EDDY CURRENT EXAMINATION OF SURRY 2A STEAM GENERATOR TUBES USING INTERCONTROLE MULTIFREQUENCY EDDY CURRENT TECHNOLOGY

by

Battelle, Pacific Northwest Laboratory
Nondestructive Testing Section
Richland, Washington

STEAM GENERATOR GROUP PROGRAM

October 18, 1983

TABLE OF CONTENTS

TECHNICAL SPECIFICATION
FOR THE BASELINE EDDY CURRENT INSPECTION OF
TUBING FROM A RETIRED SURRY STEAM GENERATOR

1.0 SCOPE

This document defines the technical specifications and requirements governing the conduct of the baseline post-service eddy current inspection of thin wall tubing in the Surry 2A steam generator. The steam generator is a Westinghouse Series 51 which was removed from service in 1979 and transported from Gravel Neck, Virginia to the U.S. Department of Energy Hanford Reservation in Richland, Washington. Battelle, Pacific Northwest Laboratory is under contract with the U.S. Nuclear Regulatory Commission to conduct the Surry Steam Generator Group Project. One of the tasks of the program is to perform a complete eddy current inspection of the steam generator tubing. At Hanford, the steam generator is housed and positioned vertically in the Steam Generator Examination Facility (SGEF). The SGEF was constructed specifically for nondestructive and destructive examinations of the Surry steam generator. The eddy current inspection of the Surry 2A steam generator will be performed at the SGEF. It is intended that this post-service inspection will simulate an inspection at an actual nuclear plant. However, due to the non-service nature of the unit, ample time will be available for additional tests that would serve to maximize information from the examination.

2.0 GENERAL

2.1 STEAM GENERATOR BACKGROUND

The unit to be extensively examined and serve as a test bed in this research program is the "A" steam generator removed from service at the Surry 2 pressurized water reactor operated by the Virginia Electric and Power Company. The Surry 2A generator is a U-tube design, Westinghouse Series 51, with 3,388 tubes. Tube material is Inconel 600 alloy with a nominal outside diameter of 0.875 inch (± .003) and a wall thickness of 0.050 inch ±.002). Design features of the Surry 2A generator include seven drilled hole carbon steel support plates of the type with an annulus about each tube with flow holes. A portion of the tube length extending through the tube sheet has been roll-expanded to provide a tight fit. The tube ends have been seal-welded to the tube sheet cladding. The tube ends extend approximately 1/4" beyond the tube sheet face into the water box. The Surry 2 nuclear plant initiated operation in early 1973. Secondary side water conditioning was initially by sodium phosphate additions. In September 1974, the unit was converted to the all volatile treatment (AVT) chemistry. The Surry reactors are sited adjacent to the James River. Cooling water condensors were tubed with 90:10 Cu:Ni alloy and have a history of leakage. A significant number of tubes on the hot leg side have been compressed where they intersect tube support plates by corrosion products. This phenomenon is known as "denting."

Approximately 500 plugs installed in flawed tubes during operation will be removed to allow access for re-examination. Approximately 273 tubes will remain plugged and will not be subject to evaluation in this test. Cavities resulting from the plug removal have been gaged: 0.795" (20.19 mm) go/0.816" (20.73 mm) no-go. Tubes in Row 1, Columns 1-9 have had sections removed and cannot be examined full length. Several other tubes have had sections of support plate removed. The channel head interior surfaces are decontaminated so that the background radiation level is not greater than approximately 1 R/hour, including shine from the tubes.

2.2 WORK TO BE PROVIDED - CONTRACTOR

The Contractor shall provide services which shall include, but not be limited to, the following:

2.2.1 The preparation of a baseline post-service eddy current inspection plan which describes the Contractor's policies, practices, and inspection procedures. The plan shall include as a minimum: the eddy current inspection procedures, document control procedure, personnel qualification procedure, administration procedures for approval of reports, equipment calibration procedures, data analysis procedure, procedure for control and maintenance of equipment, etc., necessary to fulfill the requirements of the contract specification. The major participating organizations and their designated responsibilities and authorities shall be defined with respect to their function in the overall program activities. The plan shall be submitted to Battelle for review and comment prior to commencement of work on the plant site.

2.2.2 Performance of field post-service eddy current inspection of approximately 3,000 tubes over their entire length. Each tube will be examined using the multifrequency technique (see 3.2.2).

2.2.3 Testing, calibration, and qualifications of examination equipment and procedures prior to commencing the inspection program.

2.2.4 Data acquisition, reduction and transcription where necessary.

2.2.5 Evaluation and interpretation of inspection results.

2.2.6 Providing qualified supervisory and inspection personnel.

2.2.7 Upon completion of the inspection, advise Battelle during a scheduled interview of the overall status and results of the inspection, including the findings and methods of analysis.

2.2.8 Providing conclusive evidence verifying the identification and location of all tubes inspected (see 3.7.4).

2.2.9 Providing the total manpower and equipment necessary to perform and evaluate all the inspection and evaluations required by this document in accordance with the schedules defined in Paragraph 6.1.

2.2.10 Compliance with cleanliness and health physics requirements established by Battelle.

2.2.11 Providing preliminary and final reports.

2.3 WORK BY OTHERS

Battelle shall provide the following services in support of the inspection activities:

2.3.1 Health physics personnel throughout the inspection activity.

2.3.2 Casual labor, scaffolding, clean facilities, change room, electrical power, office/storage space, and telephone.

2.3.3 Equipment and personnel to independently record inspection data during scanning from a limited number of tubes directly from the IC3FA on eight channel analog magnetic tape.

2.3.4 All required safety clothing, respirators, etc.

2.3.5 Areas for conducting examinations at the SGEF site and for analysis of collected data adjacent to the test site.

2.4 DEFINITIONS OF TERMS AND ABBREVIATIONS

2.4.1 Battelle - Denotes the organization responsible for the (Surry) Steam Generator Group Project; specifically, Battelle, Pacific Northwest Laboratory.

2.4.2 Contractor - The inspecting agent (Intercontrole), who is responsible for meeting the requirements of the technical specification and other terms and conditions of the contract.

2.4.3 Inspection for Examination - Denotes the performance of an eddy current examination of Inconel 600 tubing and shall be in compliance with the codes, standards, and requirements dictated in Section 2.5 of this work statement, as applicable.

2.4.4 Post-Service Inspection - The eddy current examination performed by the Contractor on the retired-from-service radioactive Surry 2A steam generator.

2.4.5 Designated Representative - The primary technical contact within Battelle and the Contractor's organization.

2.4.6 Examiner - Denotes the person performing any nondestructive examination.

2.4.7 Calibration Standard - A calibration device with real or simulated defects in material, the purpose of which is to calibrate examination equipment.

2.5 CODES, STANDARDS AND REGULATIONS

The below listed codes, standards and regulations are part of this technical specification. Specific code editions and addenda, standards and regulatory requirements are specified where appropriate. The services rendered by the Contractor shall be in compliance with the requirements of the following codes, standards, and regulations. If any conflicts of requirements are noted by the Contractor, each conflict shall be brought to the attention of Battelle for resolution.

2.5.1 American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section XI, Rules for Inservice Inspection of Nuclear Power Plant Components, Appendix IV, and IWA-2240, 1980 Edition with Addenda through Winter 1980.

2.5.2 American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, Section V, Article 8, Appendix I, Nondestructive Examination.

2.5.3 United States Nuclear Regulatory Commission Regulatory Guide 1.83, Inservice Inspection of Pressurized Water Reactor Steam Generator Tubes, Revision 1, July 1975.

2.5.4 American Society of Nondestructive Testing (ASNT), Recommended Practice No. SNT-TC-1A, 1980 Edition, Personnel Qualification and Certification in Nondestructive Testing.

2.6 DRAWINGS

The sketches and data to be furnished to prospective contractors are general reference information only. The sketches may not necessarily reflect the current or future configurations in every detail.

3.0 DETAILED REQUIREMENTS

The Contractor shall be responsible for performance of the post-service inspection described herein.

3.1 INSPECTION

The inspection of the steam generator tubing shall be in compliance with U.S. Nuclear Regulatory Commission Regulatory Guide 1.83. Guidance for the performance of the eddy current inspections may be taken from ASME Section XI, 1980 Edition through 1980 Winter Addenda.

3.1.1 Extent of Inspection. Each of the 3,070 tubes in the steam generator shall be inspected for defects and imperfections over the entire length of the tube. The inspection will be carried out primarily from the outlet side due to severe denting on the inlet side. The inlet side tubes not examined from the outlet side will be examined from the inlet side to the maximum extent possible, using the largest diameter probe that will pass through obstructed tubes. The smallest probe diameter to be used is 0.610 inch. It is understood that some of the tubes will be physically impossible to examine over their entire length due to denting, small bend radii, etc.

3.2 INSPECTION SYSTEM

The inspection equipment shall be in compliance with Regulatory Guide 1.83.

3.2.1 Eddy Current Instruments. The Intercontrole IC3FA multifrequency digital system will be used for the examination. The Intercontrole IC4AN analyzer will be used in the analysis of collected eddy current signals.

3.2.2 Inspection Frequencies. Multifrequency techniques are required for this examination. The inspection equipment shall be capable of being calibrated and operated using a differential coil probe in accordance with ASME Section V, Article 8, Appendix I, Section I-30, "Calibration." Multifrequency inspection equipment shall be capable of being operated utilizing the basis frequency selected for a single frequency examination. Other frequencies selected to minimize the effects of parameters such as tube supports, copper deposits, tube sheets, etc., using a differential coil probe shall also be utilized.

3.2.3 Probe Pusher-Puller and Positioning Fixtures. Intercontrole will provide finger walker and pusher-puller equipment and controls for remote selection and scanning of tubes. A readout of the selected position shall be indicated. The contractor will maintain and repair the equipment, as required, during the course of the examination.

3.2.4 Probes. The Contractor will provide all eddy current probes, cable, and probe shafts required for the examination. The Contractor may supply and use any nonstandard or special probe as required to complete the examination. Battelle shall be advised of all special probes used.

3.2.5 Remote Operations. The inspection is to be performed from outside the steam generator containment area in the truck lock area. The communication system will be provided by the Contractor. Battelle will provide all electrical connections as required.

3.2.6 Recording Equipment. The Contractor will provide the digital tape recorders and strip chart recorders required for this examination.

3.3 INSTRUMENT CERTIFICATION*

All examination instruments which are used for eddy current examination shall be certified in accordance with the requirements of ANSI N45.2 Item 13, and as follows:

3.3.1 The oscillator output frequency(s) to the drive coil shall be certified as of the specified test frequency ±5%.

3.3.2 The vertical and horizontal linearity of the Cathode Ray Tube (CRT) display shall be certified as being ±10% of deflection input voltage.

3.3.3 The CRT vertical and horizontal trace alignment shall be certified as being parallel to graticule lines ±2 degrees.

3.3.4 The output voltage from the tape recorder shall be certified as being ±5% of the input voltage for each channel of the tape recorder.

3.3.5 The chart speed from the strip chart recorder shall be certified as being the indicated value ±5%.

3.3.6 The amplification in all channels of the eddy current instrument shall be certified as being equal to all sensitivity settings ±5%.

3.3.7 The output channels of the eddy current instrument shall be certified as being orthogonal ±3 degrees at the test frequency.

3.3.8 Certified test reports shall be provided to Battelle for each piece of test equipment utilized.

*Note: Performance capability of items listed under 3.3 shall meet the minimum requirement of 10 CFR 50, Appendix B.

3.4 INSPECTION PROCEDURE REQUIREMENTS

All eddy current inspections shall be conducted in accordance with written procedures. All procedures shall be approved by Battelle prior to the commencement of work. It is the responsibility of the Contractor to comply with all of Battelle's comments in a satisfactory manner. Each inspection procedure shall be approved and signed by the Contractor's SNT-TC-1A Level III examiner, and shall contain as a minimum, the items of information listed below:

3.4.1 Tube material, diameter, and wall thickness.

3.4.2 Size and type of test probe including manufacturer's name, part number, and length of probe cable.

3.4.3 Test frequency or frequencies.

3.4.4 Manufacturer, type, and model of eddy current equipment.

3.4.5 Scanning direction and speed during examination (insertion, retraction, or both, from hot and cold leg).

3.4.6 Description of inspection technique, (i.e., mechanized probe drive, remote control fixture, etc.)

3.4.7 Description of calibration procedure and calibration standards, including multiparameter optimization techniques.

3.4.8 Description of data recording equipment and procedures.

3.4.9 Procedure for interpretation of test results and the applicable criteria for reportable indications.

3.4.10 Additional information as necessary to describe the examination.

3.5 INSPECTION PERSONNEL QUALIFICATIONS

3.5.1 The Contractor shall furnish necessary inspection and supervisory personnel qualified, as a minimum, to the requirements and recommendations of the applicable codes, standards, and regulations described in Paragraph 2.5. Individual certifications, including eye test results, shall be submitted to Battelle for review and approval after the award of the contract and prior to start of work. Past experience in eddy current examination of steam generators shall be submitted for supervisory personnel (Levels II and III).

3.5.2 The examiner performing the eddy current inspection shall be qualified to at least Level II in accordance with SNT-TC-1A. The assistant to the examiner (if required) shall be qualified to at least Level I in accordance with SNT-TC-1A.

3.5.3 The supervisory personnel shall be qualified to Level II or III in accordance with SNT-TC-1A.

3.5.4 Evaluation personnel shall be qualified to Level II or III in accordance with SNT-TC-1A. The evaluation personnel shall have had additional training specifically in data evaluation and this must be supported by documentation submitted with the certifications for approval by Battelle.

3.5.6 All examination personnel are subject to approval by Battelle.

3.6 CALIBRATION STANDARDS

Battelle will provide the calibration standards required. The càlibration standards shall be manufactured from tube material Inconel Alloy 600. The tube outside diameter is 0.875 inch nominal, and wall thickness is 0.050 inch nominal. The defect standards

Shall contain defect areas as follows:

3.6.1 100% through wall hole 0.067 inch diameter.

3.6.2 Flat bottomed hole 5/64 inch diameter by 80% through from the outer wall surface.

3.6.3 Flat bottomed hole 7/64 inch diameter by 60% through wall from the outer tube wall surface.

3.6.4 Flat bottom hole 3/16 inch diameter by 40% through wall from the outer tube wall surface.

3.6.5 Four flat bottomed holes, 3/16 inch diameter, 20% through the tube wall from the outer tube wall surface spaced 90 degrees apart around the tube circumference.

3.6.6 A 360 degree circumferential groove 1/16 inch wide and 20% through from the inner tube wall surface.

3.6.7 The Contractor may provide a dent standard, or other supporting standards, based on current industry practices and experience. The Battelle supplied standard must be used to establish and verify calibration.

3.6.8 Each standard shall be identified by a serial number. Artificial flaw dimensions shall be measured to the nearest 0.003 inch. Flaw dimensions and systems response to the flaw shall be part of permanent record of the standard.

3.7 <u>RECORDS, EVALUATIONS, ACCEPTANCE CRITERIA AND REPORTS</u>

3.7.1 <u>Records</u>. All test results from this baseline examination are proprietary to the U.S. Government.

3.7.1.1 The eddy current data from all tube inspections shall be recorded on magnetic tape as the probe traverses the tubes. The magnetic tapes provided shall be good quality polyester-based, such as AUDUA, L-1800, manufactured by TDK Electronic Company, Ltd., Japan or equal.

3.7.1.2 The Contractor shall have equipment available to photograph the memory oscilloscope CRT display of any indications selected by Battelle.

3.7.2 Record Identification. The start of each reel of magnetic tape shall, as a minimum, contain the following information:

3.7.2.1 The identity of "Battelle" (the steam generator owner).

3.7.2.2 The steam generator identity.

3.7.2.3 The date of inspection

3.7.2.4 Reel number and side.

3.7.2.5 Operator's name

3.7.3 Tube Numbering System. Each tube examined shall be identified on the magnetic tape in accordance with the tube sheet map provided by Battelle.

3.7.4 Tube Identity Verification. At periodic intervals (approximately each tenth tube), the tube identity will be verified by the contractor. Verification of the positive identification of tube location shall be recorded on a control sheet. In the event an error is discovered, all data generated since the previous verification of location shall be voided in an appropriate manner, and any tubes examined since the previous verification will be re-examined.

3.7.5 Evaluation. All recorded indications shall be evaluated to determine the location, type of defect or imperfection, and size. All indications resulting from the presence of dings, excessive tube chatter, permeability changes, and other significant indications shall be recorded and evaluated. Indications of tube wall penetration shall be evaluated and the depth of penetration and axial location along the length of the tube be determined. All suspect indications equal to or greater than 20% through the tube wall shall be reported. Any indications less than 20% that have a high probability of being defects shall also be reported.

3.7.6 Report. The Contractor shall prepare a report documenting the results of the eddy current inspection. Procedures, equipment and other pertinent information shall be described in sufficient detail to permit comparison (duplication) of the inspection(s) for future examinations. The report shall include a record indicating the tube(s) examined, the extent to which each tube was examined, the axial location and depth of each reported indication, characterization of the flaw, and the indentification of the operator(s) and data evaluator(s) who conducted each examination or part thereof. Probe size and type used shall also be identified.

The final report shall be reviewed, approved and signed by the cognizant SNT-TC-IA Level III personnel.

4.0 EXAMINATION DATA ACQUISITION BY BATTELLE

Battelle will concurrently record real-time eddy current inspection data and tube identification on analog magnetic tape while the examination is in progress. This operation is intended not to impede the Contractor's progress in any way. Battelle will obtain eight channels of information directly from the IC3FA eddy current instrument. Control and operation of this equipment will be the responsibility of Battelle.

5.0 SURVEILLANCE

Battelle reserves the right to perform the following type of surveillance of the Contractor's programs and activities as they relate to the scope of work of this technical specification.

5.1 TECHNICAL SURVEILLANCE

Technical surveillance of the Contractor's activities at the SGEF site and data analysis area will be maintained to monitor compliance with this technical specification and the Contractor's ability to support the inspection schedule.

6.0 SCHEDULES AND INFORMATION TO BE SUBMITTED

6.1 SCHEDULES

The following schedule defines the desired milestones for the conduct of field post-service eddy current inspection of the Surry 2A steam generator tubing.

6.1.1 Submit quality program description and familiarize Battelle personnel with inspection procedures within 15 days prior to the start of the examination.

6.1.2 Start inspection between October 15, and November 15, 1983. (exact date is subject to other prgram constraints)

6.1.3 Complete inspection no later than 60 days after starting.

6.1.4 Complete data evaluation and exit interview 20 days after inspections are completed.

6.1.5 Submittal of "Preliminary Report" to Battelle by December 15, 1983.

6.1.6 Submittal of "Final Report" to Battelle by January 30, 1984.

6.2 INFORMATION TO BE SUBMITTED AFTER AWARD OF CONTRACT

The following information shall be submitted no later than twenty-one (21) days after award of contract.

6.2.1 Controlled copy(s) of the detailed inspection plan for eddy current inspection as defined in paragraph 2.2.1 of this technical specification.

6.2.2 Personnel certifications including eye test results and resumes.

6.2.3 Schedule and Management Plan including number of personnel required, shifts per day and hours per shift, quantities and type of equipment to be used, etc.

7.0 DOCUMENTATION

The Contractor shall be responsible for documenting the results of all eddy curent inspections, including the evaluation of indications found during the conduct of the examination, in a final report. The final report shall be prepared by the Contractor as defined in paragraph 3.7.6 of this technical specification. The Contractor shall also be responsible for control and storage of all the data during the inspection. The original magnetic tapes and strip chart recordings shall be turned over to Battelle upon completion of the inspection.

8.0 DECONTAMINATION OF EQUIPMENT

Reusable equipment such as the pusher-puller, remote amplifiers and cables will be examined by Battelle radiation monitors and decontaminated, if possible, to allow normal handling and shipping. Those components that cannot be decontaminated will be temporarily stored or shipped in suitable containers to a site designated by Intercontrole. The SGGP will accept storage responsibility only at our designated site (i.e., 305B specimen storage facility) at no program cost. The cost of monitoring and decontamination will also be borne by the Steam Generator Program. Special shipping casks, if required, will be supplied by Intercontrole.

APPENDIX C

EDDY-CURRENT
CALIBRATION STANDARD SPECIFICATIONS

Westinghouse Electric Corporation

Water Reactor Divisions

Specialty Metals Division

RD #4 Box 333
Blairsville Pennsylvania 15717
(412) 459 9400

CUSTOMER Zetec Inc. CUSTOMER ORDER NO. 0607 MT It. Nos.1,2

(W) ORDER NUMBER T10-00731 DRAWING NUMBER

TYPE OF MATERIAL WESTRO 600T Seamless Tube Non-Thermally Treated

MATERIAL SPECIFICATION

BOX IDENTITY Item 1 - 0.875" OD x .050" Avg. Wall x 10 ft. L -20pcs.-NX-1019
Item 2 - 0.750" OD x .043" Avg. Wall x 10 ft. L -20 pcs-NX-1748

MECHANICAL PROPERTIES

FLARE TEST - On each end of each tube - Satisfactory.

NON-DESTRUCTIVE TESTS:

ULTRASONIC - Tested to a .500" long axial notch x .040" wide .004" deep OD and ID using a bidirectional test for axial flaws.

EDDY CURRENT - Tested to an EDM OD hole .03" diameter x .03" deep and a .500" long transverse notch x .040" wide x .004" deep OD and ID.

HYDROSTATIC - Tubes have been hydrostatically tested to 3106 psig minimum.

TENSILE & HARDNESS - Shown at least once by heat and item on attached sheet.

CHEMISTRY - Copy of vendor report of chemistry attached.

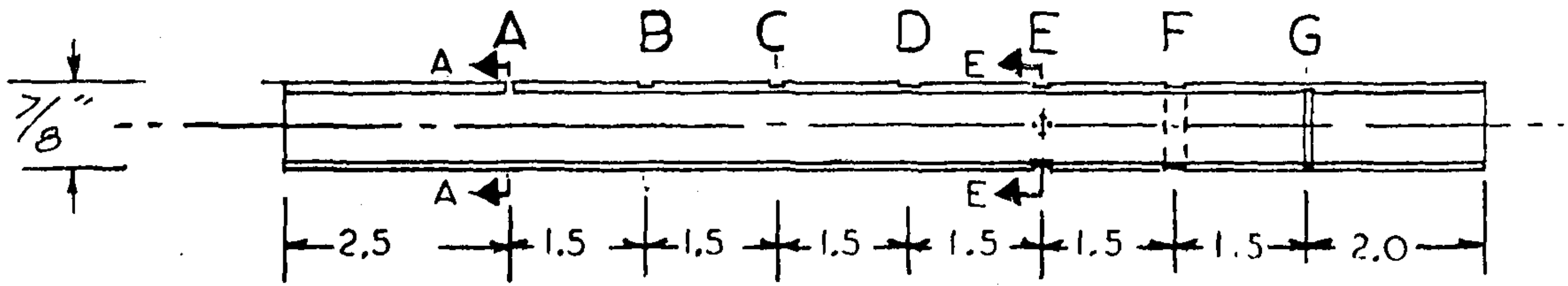
This is to certify that to the best of our knowledge and belief, and based on actual inspection and/or tests, the above described parts are in accordance with drawing and/or specifications.

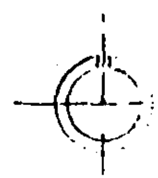
R. D. Petrosky 3/12/80
R. D. Petrosky Date
Manager of Inspection

R. J. Moran 3/12/80
R. J. Moran Date
Manager Quality Services

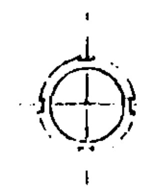
cas

LOCATION	A	B	C	D	E	F	G
PHYSICAL MEASURED DEPTH IN %	100%	82%	61%	37%	19%	10%	20%
E T PHASE ANGLE MEASUREMENT	39°	73°	99°	130°	151°	153°	7°
DIA. OF DEFECT	.067	5/64	7/64	3/16	3/16	OD GROOVE 1/8 WIDE	I.D. GROOVE 1/16 WIDE





SECTION AT AA SHOWS 100% DEFECT



SECTION AT EE SHOWS FOUR 20% DEFECTS 90° APART

MATERIAL INCONEL 600
NOMINAL WALL THICKNESS .050
HEAT TREAT # 1019
TEST FREQ. USED 400 KHZ
SERIAL # Z-1103

NOTE: ALL OD DEFECTS ARE FLAT BOTTOM HOLES

ZETEC INC. ISSAQUAH, WA.

SCALE: 1/2	APPROVED BY: 7-23-80	DRAWN BY
DATE: 7-22-80		REVISED
TOLERANCES		
DECIMAL		

WESTINGHOUSE SPECIALTY METALS DIVISION
WESTRO ALLOY 600T MATERIAL CERTIFICATION

(W) Order Number T10-00731 Customer Order No. 0607 MT It. Nos. 1,2

ieat mber	C	Mn	Fe	S	Si	Cu	Ni	Cr	Al	Ti	Co	P	B	Ultimate Strength PSI	Yield Strength PSI	% Elong.	Rb Har ne
VX-1019	.047	.26	9.00	.001	.18	.28	74.49	15.74	.24	.23	.04	.008	.005	96,000 (Item 1	.875" O.D.)	34.0	88
VX-1748	.032	.25	8.75	.001	.19	.27	75.36	15.15	.21	.16	.03	.008	.004	109,000 (Item 2	.750" O.D.)	37.0	87

APPENDIX D

RADIATION WORK PROCEDURE

CONTRACTOR

BATTELLE-PACIFIC NORTHWEST LABORATORIES

RADIATION PROTECTION RECORDS

RADIATION WORK PROCEDURE

NUMBER	SUPERSEDES NO.	VALID	REQUESTED BY
377-2	New	FROM 11-15-82 TO 11-15-83	Corrosion Research and Engineering 7H56

LOCATION

Steam Generator, 377 Building Tower, 300 Area

DESCRIPTION OF JOB

Eddy current examination of all unplugged tubes which provide a complete NDT baseline of the generators condition as specified in Task #7 of Surry Generator Research Program Plan.

RADIATION CONDITIONS

SURFACE CONTAMINATION	AIRBORNE CONTAMINATION	PERSONNEL DOSE RATES
TYPE: Beta-Gamma	TYPE: Beta-Gamma	TYPE: [X] γ [X] β [ ] η
POTENTIAL: [ ] LOW [X] MEDIUM [ ] HIGH	POTENTIAL: [ ] LOW [X] MEDIUM [ ] HIGH	ESTIMATED MAX.: 100 mrem/hr to
OTHER:		1 rem/hr to extremities (when cover plates removed)

PROTECTIVE EQUIPMENT REQUIREMENTS

PERSONNEL DOSIMETERS	BODY	FEET	HANDS	HEAD	RESPIRATORY
[X] MP	[X] NO PERSONAL OUTER CLOTHING	[ ] SHOE COVERS	[X] CANVAS GLOVES (1)	[ ] CAP	[ ] HALF MASK
[ ] NEUTRON BADGE	[X] ONE PAIR COVERALLS or	[X] CANVAS BOOTS	[X] SURGEONS GLOVES	[X] HOOD (1)	[X] FILTER MASK
[ ] GAMMA PENCILS	[X] TWO PAIR COVERALLS	[X] RUBBERS (1)	[ ] WATERPROOF GLOVES	[ ] WATERPROOF HOOD	[ ] CHEMCX
[X] SELF READING PENCILS	[ ] WATERPROOF OUTER LAYER	[ ] BRITISH LEGGINGS	[ ] WATERPROOF GAUNTLET	[ ]	[X] FRESH AIR
[X] FINGER RINGS	[X] LAB COAT (1)	[ ] HIP BOOTS	[X] LEATHER GLOVES	[ ]	[ ] RESPIRATOR

RADIATION MONITORING REQUIREMENTS

[X] INTERMITTENT BY RM — CONTACT RM FOR MONITORING: prior to performing any work under this RWP.

[X] CONTINUOUS MONITORING BY RM — CONTINUOUS MONITORING REQUIRED UNTIL: dose rates to personnel have been established.

[X] RELEASE SURVEY ON AREA OR EQUIPMENT REQUIRED

[X] OTHER: RM telephone: 376-4391, 376-3155, 376-5470

SPECIAL INSTRUCTIONS

[X] HAND COUNT WHEN LEAVING ZONE

[X] PERSONAL SURVEY WHEN LEAVING ZONE

[X] OBSERVE DUAL STEPOFF PAD PROCEDURE

[ ] OBSERVE GENERAL FACILITY RADIATION WORK PROCEDURE

[ ] PROTECTIVE CLOTHING TO BE SURVEYED PERIODICALLY

[X] SPECIAL PROTECTION FOR CUTS, ABRASIONS, IRRITATIONS OR INFECTIONS

[X] MASKS TO BE WORN AS REQUIRED BY RM

[X] IN CASE OF INJURY, FLUSH WOUND WITH CLEAN RUNNING WATER, NOTIFY RM IMMEDIATELY

1. Protective equipment requirements may be increased or reduced by Radiation Monitoring if radiological conditions change or job conditions warrant. Laboratory coat, rubbers and cotton gloves shall be the minimum clothing requirements.
2. Only the personnel involved in the job shall be permitted in the work area. Other personnel shall remain outside the tower area unless approved by RM
3. Personnal shall work as expeditiously as possible when in the work area to help conserve their exposure.
4. RM shall be given sufficient prior notice before personnel enters tower area to perform any work. The researcher responsible for the effort shall keep operations and RM informed of the progress being made and prior to making any changes that might create a radiological and/or radiation problem.
5. RM may request the use of sheet plastic and/or other types of material to help prevent the spread of contamination.

APPROVALS

OPERATIONS: Robert A. Clark 11/12/82

RADIATION MONITORING: Ed McFall

[signature]

SPECIAL INSTRUCTIONS (cont)

6. All radioactive waste shall be handled and disposed of in accordance with PNL-MA-8.

7. Welding, burning, grinding or decontaminating contaminated material shall require wearing respiratory equipment as specified by the Radiation Monitor. Any deviation from this instruction shall require RM Management approval.

8. Respiratory equipment shall be worn only by those persons who have been satisfactorily mask fitted and have not grown additional facial hair since last satisfactory fit. All other personnel shall be restricted from the work area during operations requiring respiratory protection.

9. Personnel dosimeter shall be worn on that portion of the body which is likely to receive the highest radiation dose. Radiation Monitoring may request additional dosimetry for personnel to wear when performing certain work to assist in evaluating radiation doses being received by personnel.

10. SPECIAL ALARA CONSIDERATIONS: RM may recommend additional requirements if deemed necessary to help conserve personnel exposure and/or spread of contamination.

11. Any change (e.g. - procedure, scope of research, equipment, etc.) which may increase the radiological hazards shall be reviewed with the RM Supervisor prior to implementation. A new or modified RWP shall be issued if considered necessary because of the change.

12. Radioactive water containers and/or laundry bags 6 mrem/hr or greater may be stored in the tower area. Not more than 6 containers of radioactive waste and 6 bags of laundry can be stored in the tower area at one time.

13. Radioactive waste containers and/or laundry bags <6 mrem/hr may be stored inside a metal shed located outside the 377 Building.

14. Personnel are not authorized to work in areas of 5 rem/hr or greater to the whole body.

15. A job may be suspended in the event of a contamination spread or if recommended by RM.

APPENDIX E

COMPUTER DATA ACQUISITION SYSTEM PROCEDURES

SURRY DATA RECOVERY COMPUTER SYSTEM OPERATORS GUIDE FOR
THE EDDY CURRENT BASELINE EXAMINATION OF THE SURRY 2A GENERATOR

James M. McIntyre

Battelle Memorial Institute
Pacific Northwest Laboratories

June 21, 1983

INTRODUCTION

This document recommends the procedures that the operators of the Surry Data Recovery (SDR) computer system should follow during the eddy current (EC) baseline examination of the Surry 2A Steam Generator. Zetec, a subcontractor, has been awarded the contract to conduct the EC examination of all tubes within the generator. They will be responsible for conducting two complete examinations of the generator, once using the EM3300 single frequency instrument, and once using the MIZ-12 multi-frequency instrument. Both of these instruments output analog data that they will analyze and, based on their interpretations, report all defects found within each tube.

The SDR computer system was developed to digitize and archive the EC signals for later digital processing. Since probe position information is also being acquired, the probe motion control must be managed with the SDR system. Battelle staff will be responsible for the operation of this system. The use of the SDR commands is documented in the SURRY DATA RECOVERY OPERATIONS MANUAL. New commands for controlling the probe will be documented here. It is assumed that the operator is familiar with the use of utilities and hardware devices associated with the SDR system (PDP 11/44 computer operating under RSX-11M).

This document will cover the following topics:

1) "Booting" the computer system
2) Initializing the SDR system
3) Positioning the probe
4) Collecting the data
5) Maintaining the operator's log book
6) Handling system hardware problems.

REBOOTING THE COMPUTER

Normally the computer is operating from the RL02 disk drive (DL0). If for some reason the computer "locks up" and needs to be re-booted then there are two methods for doing so. Both methods require using the system console (DECWRITER III terminal).

METHOD 1 (most prefered)

1) Login to the console as follows:
   HELLO SYSTEM
   Password> EDDY

2) RUN $SHUTUP
   Respond "0" to the "minutes to wait before shutdown" prompt.
   Respond "Y" to the "proceed to shutdown" prompt.

3) When the console prints ">>>" type "B DL".

4) After a few seconds the terminal will start printing out the commands it is executing from the startup command file.

5) Enter date and time when prompted.

6) The startup procedure will continue for a few more seconds.

7) Login again (follow step 1).

8) Type "INS [1,4]RESET".

9) Type "RSET ALL".

10) Type "BYE".

11) The system is now ready.

METHOD 2 (least prefered)

1) Type "CONTROL-P" then "H".

2) Perform steps 3-11 for Method 1.

NOTE: Anytime the system is re-booted, the SDR system needs to be re-initalized.

INITIALIZING THE SDR SYSTEM

1) Login to the VT100 terminal as follows:
HELLO REALTIME
Password> EDDY

2) Type "@START".

3) Respond "Y" to the "use magtape for data collection" prompt.
Make sure that the tape is mounted on the SI tri-density tape drive with the density set at 6250 BPI.

4) Respond "Y" the the "tape initialization" prompt if the tape needs initializing.
NOTE: All tapes are to be labeled with the pre-printed labels containing the following information:

STEAM GENERATOR GROUP PROJECT
TAPE NO DATE:
VOLUME LABEL: ZETEC
DENSITY: 6250 BPI (9-TRACK)
FORMAT: BUFFIO

The operator must fill out the date field. The tape numbers will be pre-printed on the labels.

4) Upon completion of the startup procedure type "SDR".

5) You are now in the SDR mode. You must now initilize some variables within SDR.

6) From SDR type the following:

```
LOGIN NAME=ZETEC
SELECT SCB=INIT
```

The SCB file contains the following parameters:

```
LEG=H
INDEX=.02
MODE=D
ICB=INIT
ROW=0
COL=0
TRAVEL=0
CABLE=426
SPEED=12:36
DEV=TAPE
CALIB=PX0583
```

Note: the SCB file will load in the ICB file. The ICB file should contain the following for the MIZ-12:

```
ZETEC MIZ-12
.610 INCHES
T T T T T T T T
X-100K
Y-100K
X-150K
Y-150K
X-200K
Y-200K
X-400K
Y-400K
```

The ICB file should contain the following for the EM3300:

```
ZETEC EM3300
.610 INCHES
T T F F F F F F
X-400K
Y-400K
NOT USED
NOT USED
NOT USED
NOT USED
NOT USED
NOT USED
```

Once these parameters are specified, the operator may issue a select command to change or add a new parameter. If the changes are major, it is suggested that the operator exit SDR by typing CONTROL-Z and then use an editor to edit the appropriate ICB or SCB file. Major modifications will normally involve the ICB file when the EC instrument type, probe type, and/or frequency assignments change. NOTE: Eight channels of data will normally be used from the MIZ-12 instrument. These channels (1-8) will always be in X-Y pairs, one pair per frequency. For the EM3300, only channels 1 and 2 will be used as a X-Y pair since this is a single frequency instrument.

POSITIONING THE PROBE

A new function mode has been implemented to make probe positioning easier within a tube. This mode, called FUN, is easier and better to use than the MPC mode. So what follows is a description of the FUN mode commands and how to use them. To enter the FUN mode, type FUN at an SDR prompt. The following commands are now available:

"I" move probe in (forward).
"O" move probe out (reverse).
"0" assign 0 location.
"S" stop probe motion.
"1" set probe speed to 1 inch/second.
"2" set probe speed to 12 inches/second.
"3" set probe speed to 36 inches/second.
"Space" display current probe position.

To position the probe within the tube opening, do the following:

1) Type 1 to set probe rate to 1 in/sec.

2) Move probe in (I) or out (O).

3) Stop the probe (S).

4) Assign 0 location (0).

Note: the probe motion must be stopped before the probe direction can change. Once the 0 location is specified, then move the probe to the data collection start position by issuing the following commands:

1) Type 3 to set probe rate to 36 in/sec.

2) Move probe in (I) or out (O).

3) Stop the probe (S).

Note: the probe will automatically stop when a dent is hit or when the probe has reached the end of its probe cable.

COLLECTING THE DATA

Now it is time to take the data. Type CONTROL-Z to exit FUN. Upon exiting FUN there will be a prompt asking if the final probe position is to be used as the data collection start position. Normally the response will be "Y". When the response is "Y" then FUN will update the SDR SELECT POSITION parameters. Note: Within the FUN mode there is a display of probe position. This display will be continuously updated during probe motion. Upon exiting FUN you should have a SDR prompt. Now enter the following to start the actual data collection process:

1) Type "SELECT DATA=filename"
   Note: there will be a unique data filename for each tube inspection. The filename shall consist of R++C++* where ++ are the tube row/column numbers and * is a letter (A-Z) to represent a repeat inspection.

2) Type "SELECT ROW=++".

3) Type "SELECT COLUMN=++".

4) Type "C /INIT".

5) Type "C /START".
   Note: the probe should now move and the digitized data written to magtape.

6) Type "MON" to monitor the data collection process.

7) When finished hit the "RETURN" key to exit the monitor mode then type C /STOP

8) You are now ready to invoke FUN to reposition the probe.

During data collection the probe will automatically move out from the start position, through the tubesheet (0), through the calibration standard, stop, reverse direction and then move in towards the tubesheet but stop at the tip of the probe positioner nozzle. Digitized data will only by generated on the outward movement of the probe.

During calibration (every 4 hours?) the FUN commands can be used to move the probe in-out of the calibration standard. When calibration is complete then the operator will digitize the calibration standard as if the standard were an actual tube. The operator will use the data file naming convention "C******+" as follows:

C stands for calibration,
****** stands for date (062383) and
+ is a letter (A-Z) to represent a repeat calibration for that date.

Once the calibration standard is digitized then the operator will exit SDR by typing "CONTROL-Z". Then the operator will run a program call SDRPLOT to plot the digitized calibration data and compare the results with the analog strip chart recorder output.

When a mag tape is full, the operator must exit SDR by typing "CONTROL-Z" and dismount the tape by issuing a "DMO MM0:" command. After another tape has been installed on the tape drive the operator types "@TAPE". This command file will initialize the tape and issue a "MOU MM0:" command.

NOTE: when the SDR mode is exited the probe 0 location must be redefined upon re-entry into SDR.

OPERATORS LOG BOOK

For each tube inspection the operator is required to record the time, data filename, probe height and comments pertaining to the success/failure to examine the tube. In addition, the operator needs to record his/her initials, date, tape number, instrument type, probe size and inspection leg at the top of each page of the operators log. When one or more of these general items change, then a new form will be used. Comments should include any operator/system errors that were generated.

SYSTEM HARDWARE ERRORS

In the event the system "hangs up", it could be that there is a memory contention problem do to the way the programs are occupying memory. One thing to try before re-booting the computer is to exit SDR and then type "@STOP". The stop command file will remove all inactive SDR tasks from memory. However, active tasks must be aborted and removed by typing "ABO task" and "REM task". To display active tasks, type "ACT". Abort all active tasks except "MCR..." and "...MCR". Now type "@START" to re-initialize the SDR system.

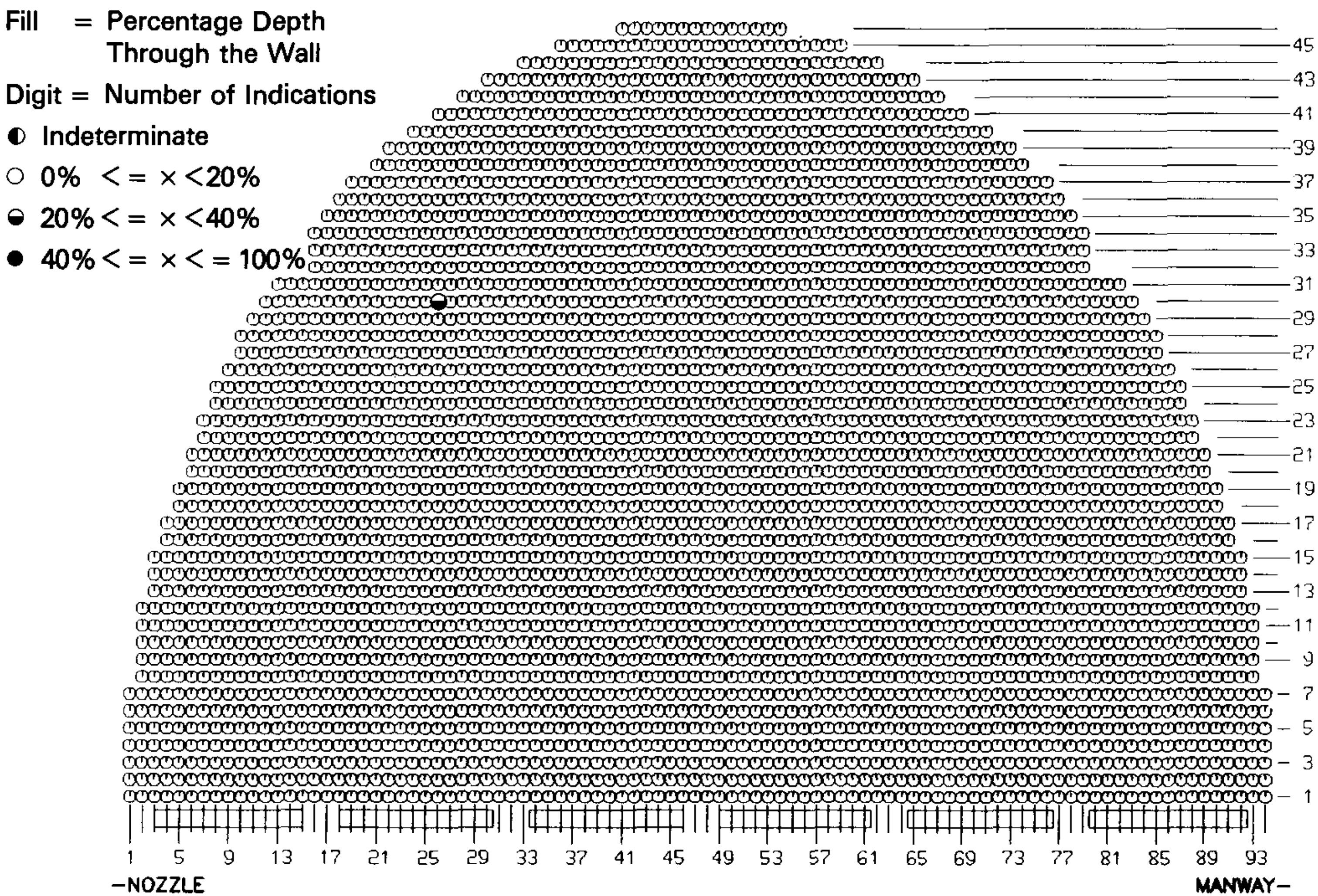
In the event of a hardware problem with either the SI tri-density tape drive (MM0:) or the RL02 disk drive (DL0:), provisions have been made to continue system operation and/or data collection using the RM05 disk drive (DR0:). There will be two RM05 disk packs available, each with a bootable operating system. If MM0: is down but DL0: is operating then mount one of the RM05 packs into DR0:. Then issue a "MOU DR0:/OVR" command. From SDR issue a "SELECT DEV=DISK" command. Now DR0: is ready for use. When this disk pack becomes full with data, issue a "DMO DR0:" command, remove the pack and mount the other disk pack. The full disk pack must be taken to the AVAX computer for dumping the data to tape using the SDRCOPY program under the account called SURRY (Password EDDY). When the data has been copied, all *.DAT files under [300,302] must be deleted. Do not re-initialize the RM05 disk packs.

If DL0: is down and MM0: is still operating, mount one of the RM05 disk packs in the DR0: disk drive and reboot the computer and initialize SDR as you would with the DL0: disk drive. You must use "B DB" instead of "B BL" to boot the computer. If the tape drive is also down then issue the SDR command "SELECT DEV=DISK". Now when the RM05 disk packs become full you must halt the computer (RUN $SHUTUP), swap packs and then reboot the computer. Again the full packs must be taken to the AVAX computer in order to dump the files to magtape.

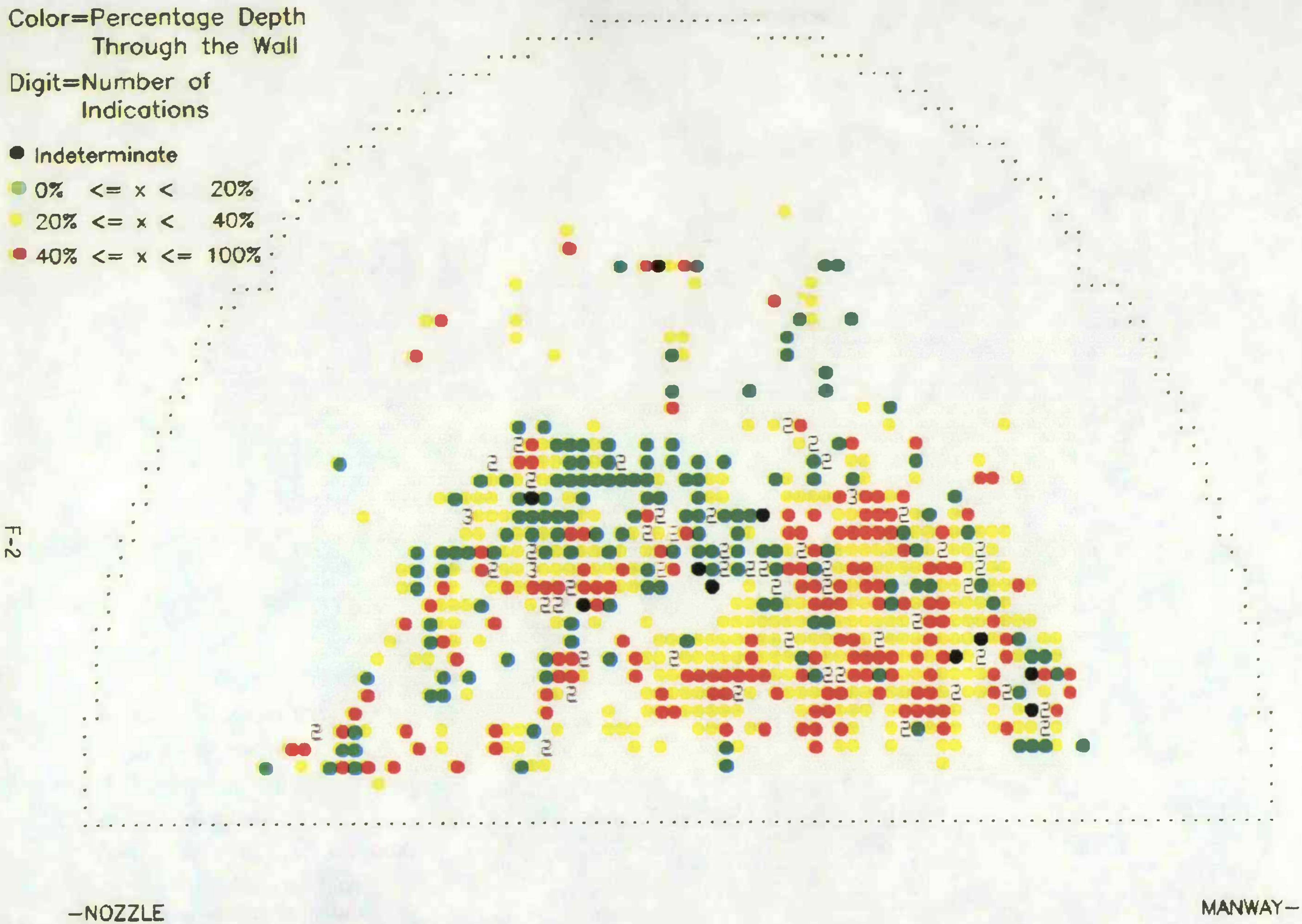
If the computer or the intelligent controller is completely inoperable then the inspection must continue by using the manual probe control box. This box will have to be wired in by the NDT staff. The key switch below the NEFF A/D subsystem will have to be in the "manual" position. The data on ZETEC's analog tape will have to be digitized in the SDR off-line mode when the computer or intelligent controller becomes operable.

<u>APPENDIX F</u>

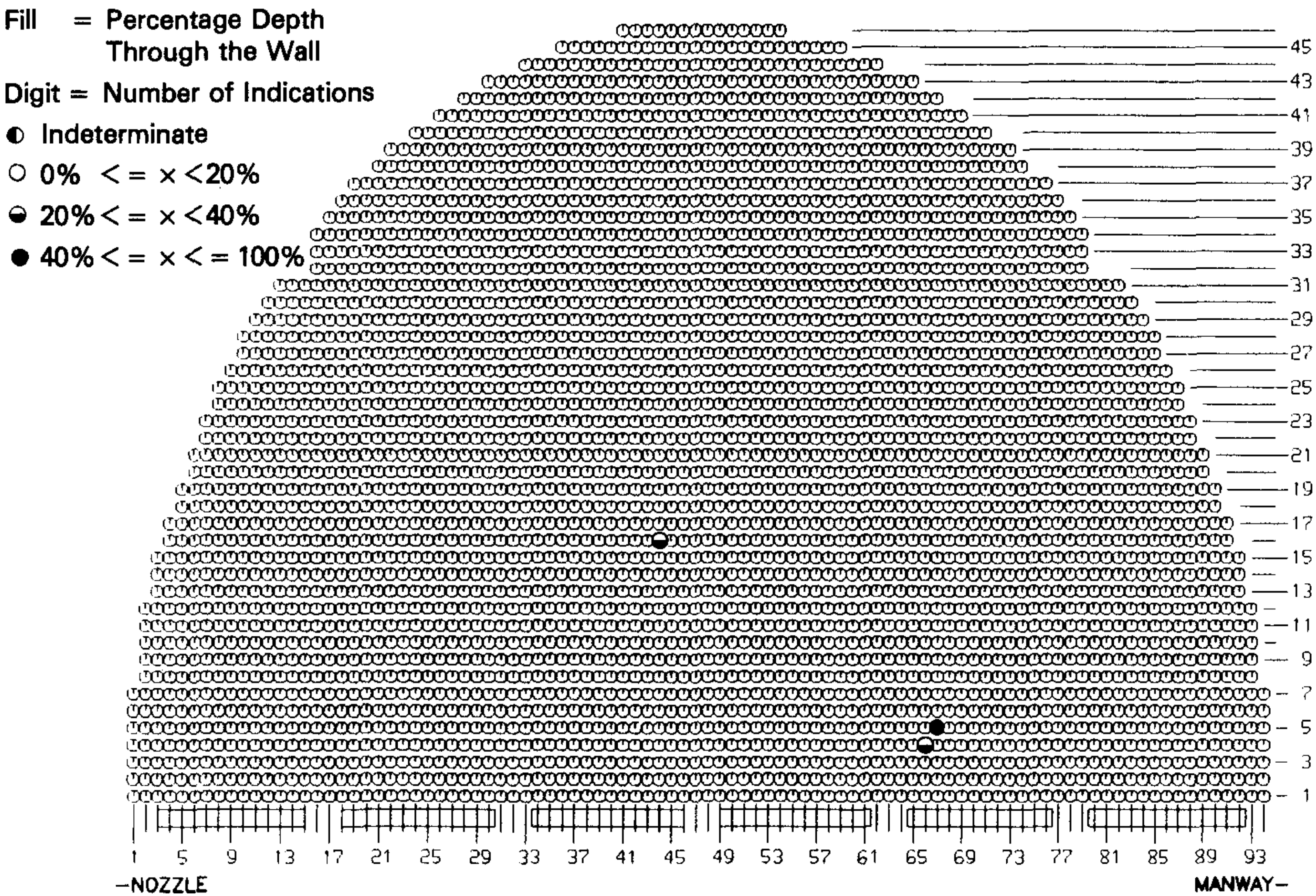
DEFECT INDICATIONS REFERENCED TO STEAM GENERATOR LOCATIONS FOR TEAM X



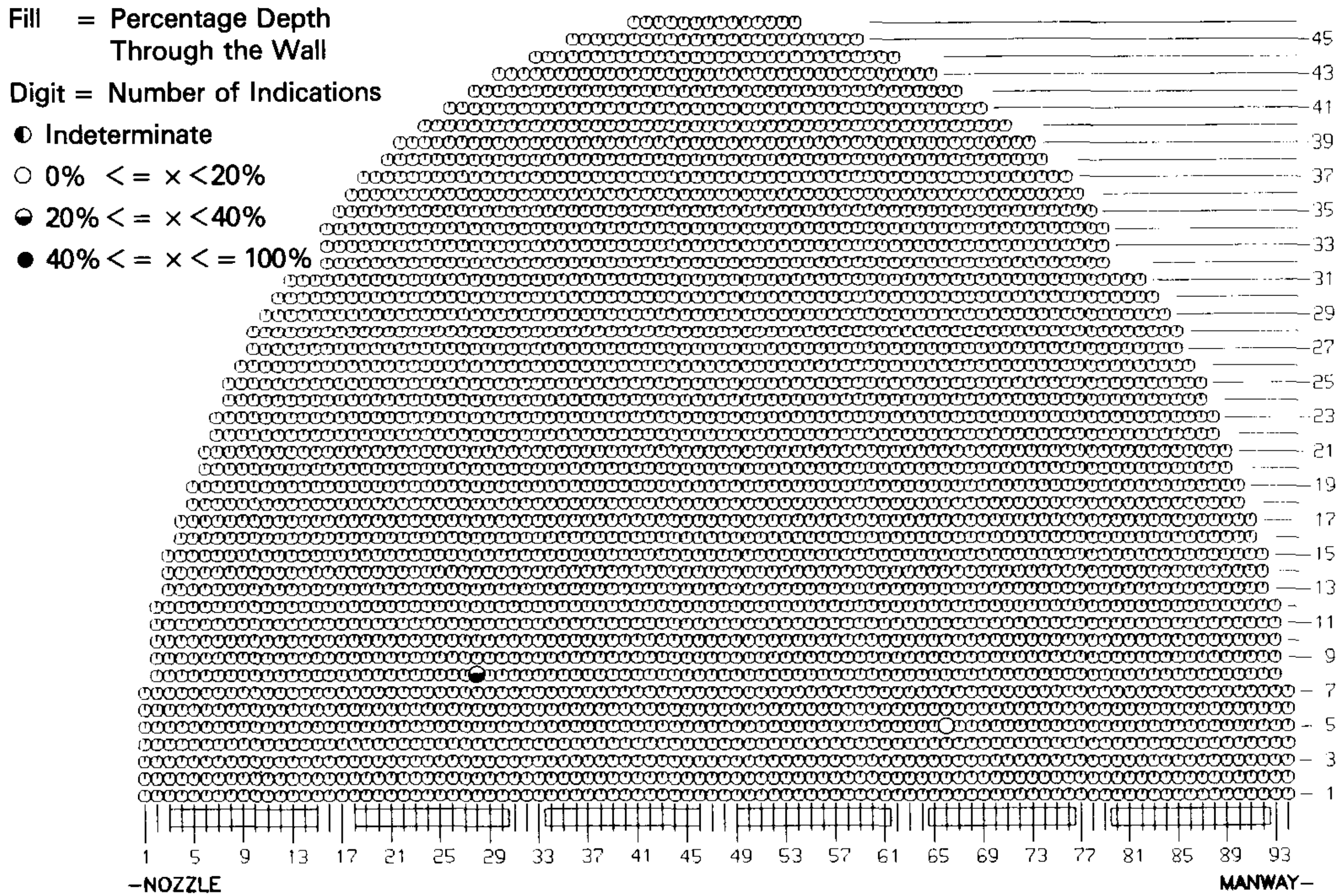
Tubes With O.D. Indications Occurring at the
Tube End on the Hot Leg Found by Team X



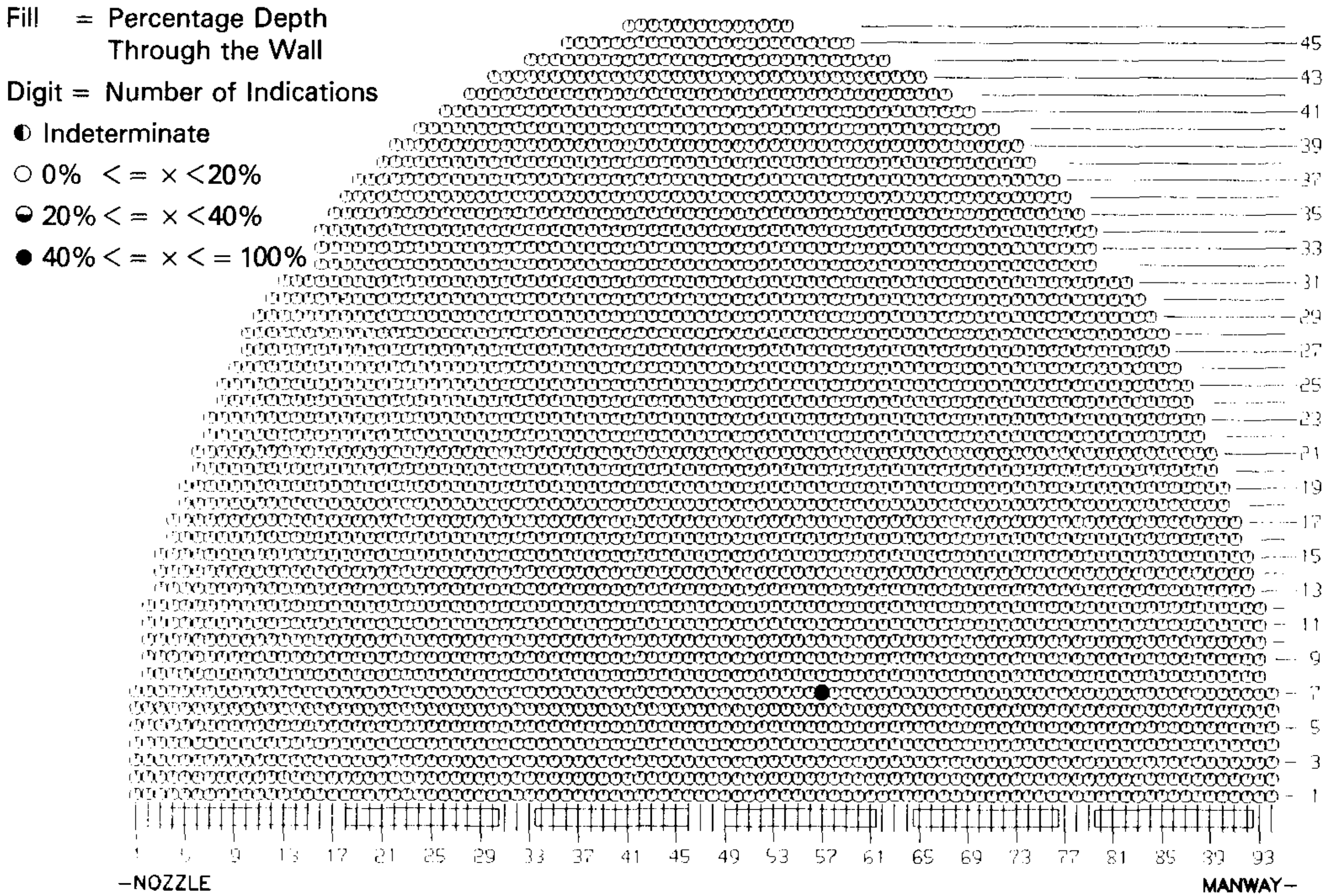
Tubes with O.D. Indications Occurring at the Top of the Tube Sheet on the Hot Leg Found by Team X



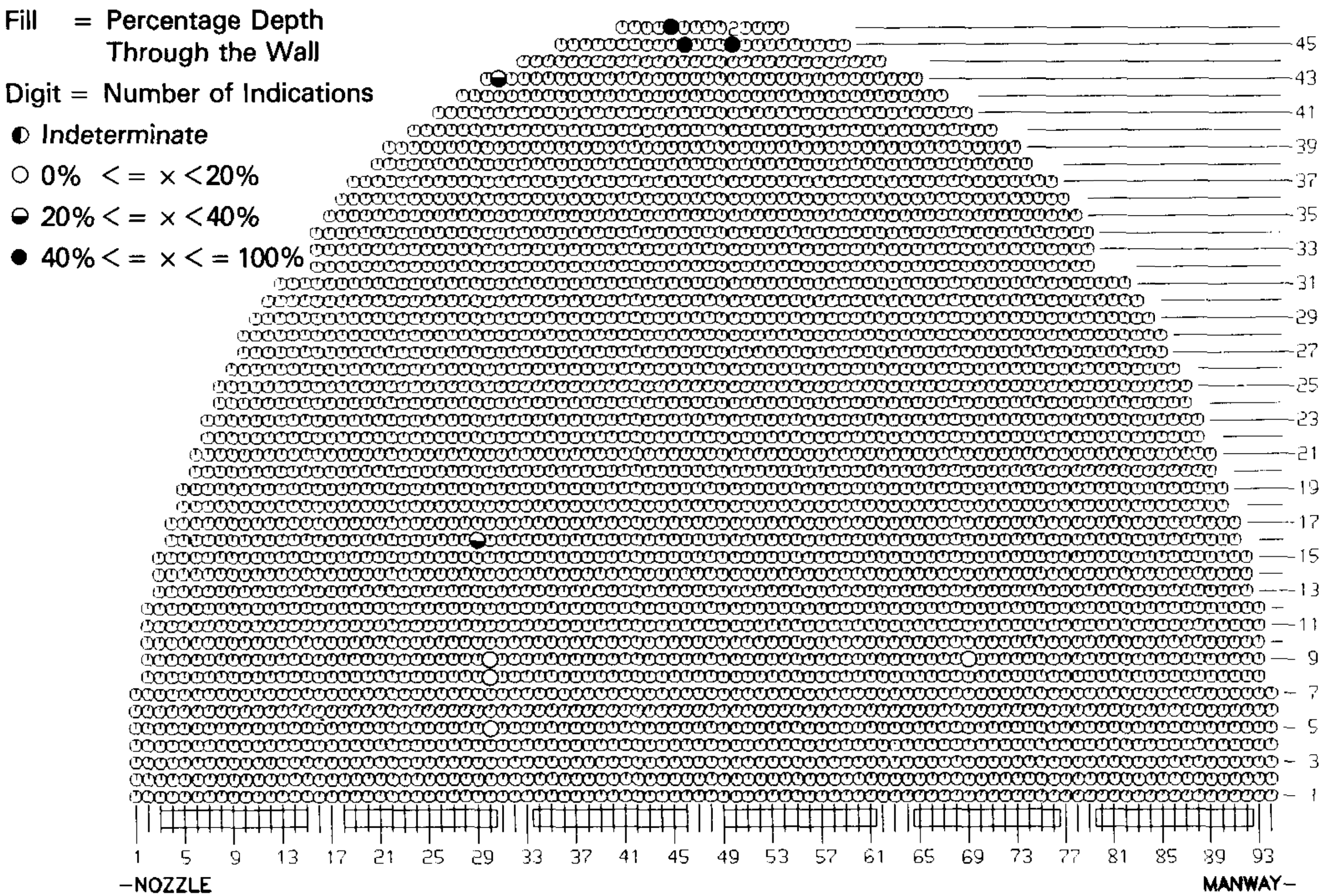
Tubes with O.D. Indications Occurring at the First Support Plate on the Hot Leg Found by Team X



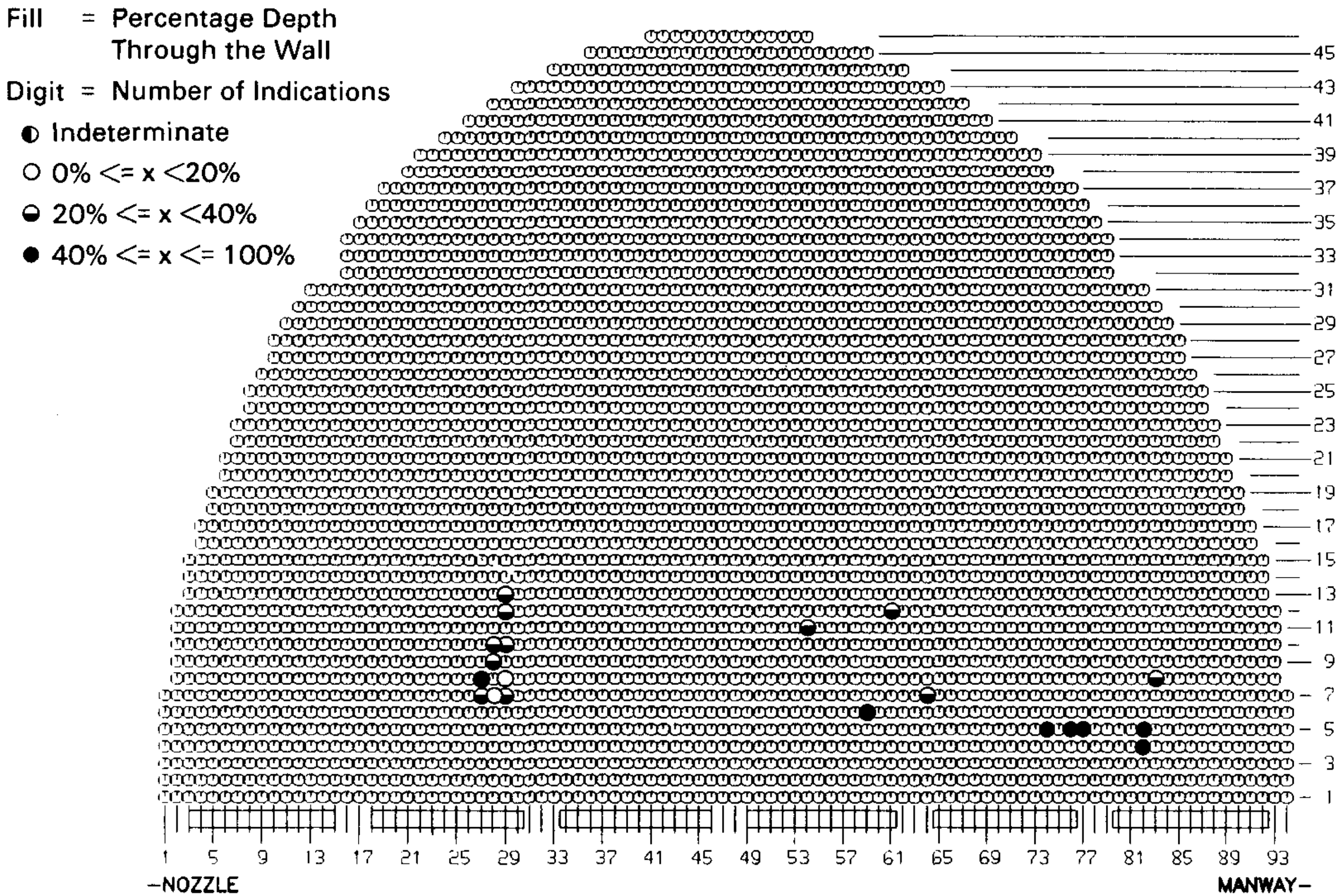
Tubes with O.D. Indications Occurring at the Third Support Plate on the Hot Leg Found by Team X



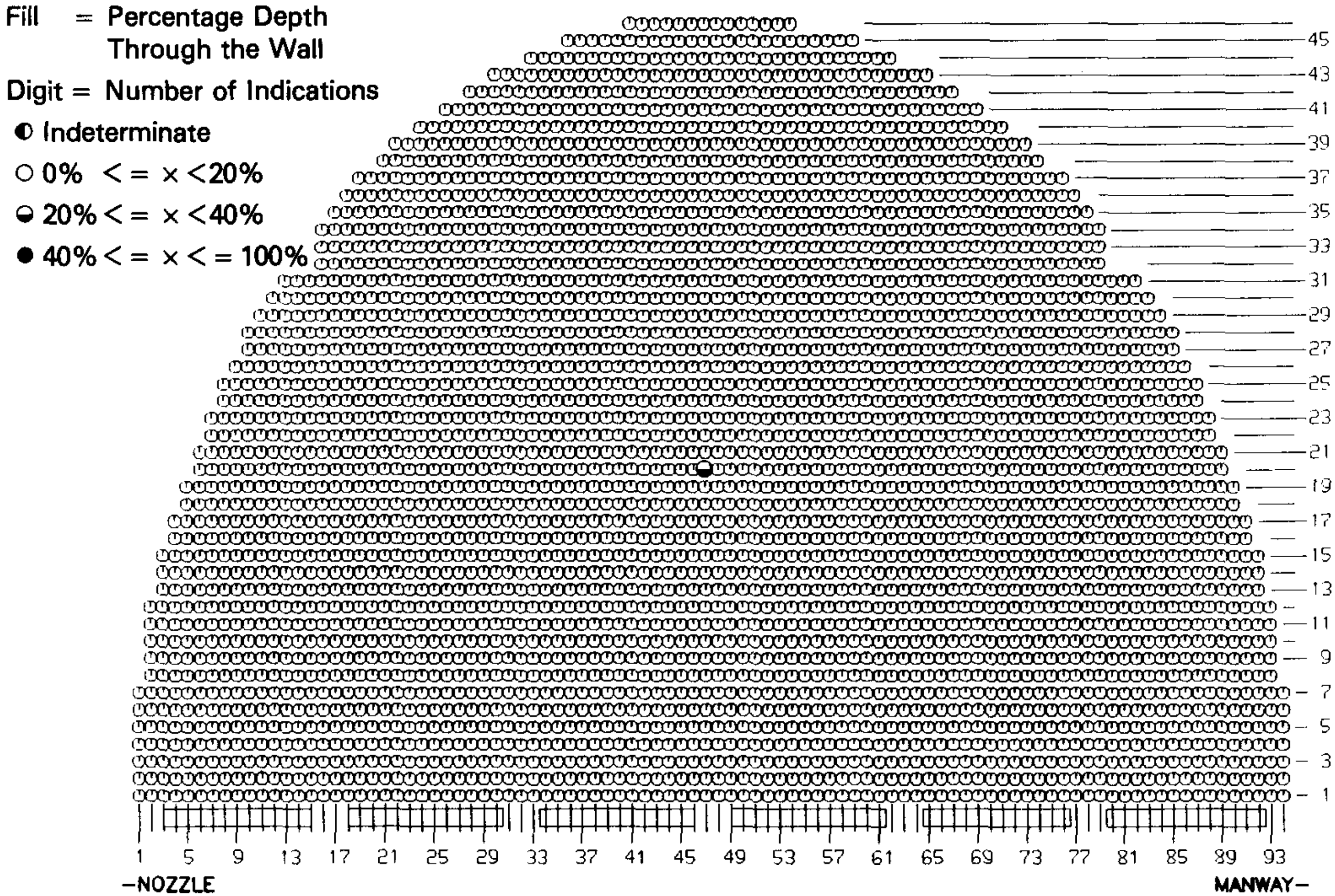
Tubes with O.D. Indications Occurring at the Fifth Support Plate on the Hot Leg Found by Team X



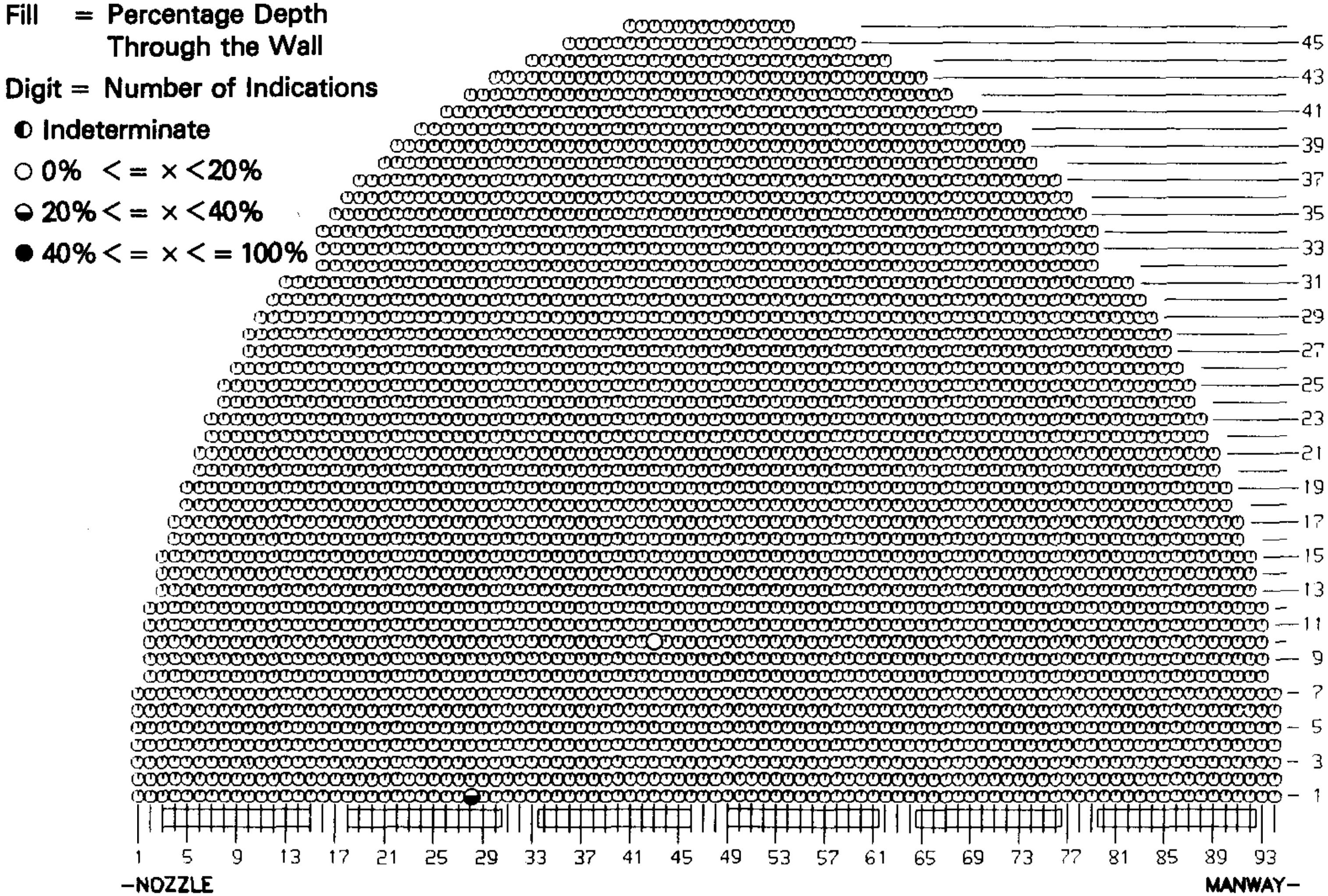
Tubes with O.D. Indications Occurring at the Seventh Support Plate on the Hot Leg Found by Team X



Tubes with I.D. or O.D. Indications Occurring at the Seventh Support Plate on the Cold Leg Found by Team X



Tubes with O.D. Indications Occurring at the Sixth Support Plate on the Cold Leg Found by Team X



Tubes with O.D. Indications Occurring at the Fourth Support Plate on the Cold Leg Found by Team X

Fill = Percentage Depth Through the Wall

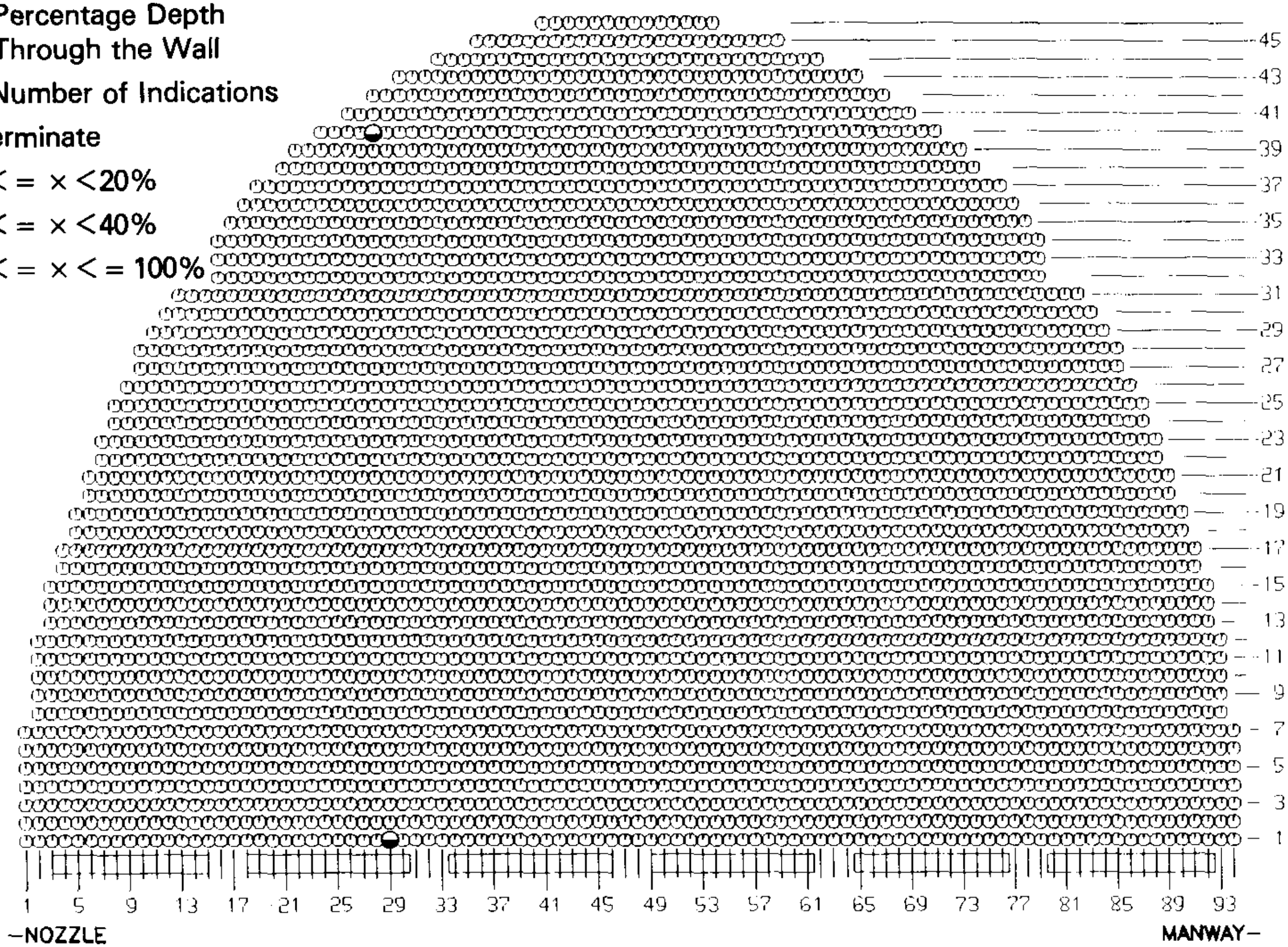
Digit = Number of Indications

◐ Indeterminate

○ 0% <= x <20%

◒ 20% <= x <40%

● 40% <= x <= 100%



Tubes with O.D. Indications Occurring at the Third Support Plate on the Cold Leg Found by Team X

Fill = Percentage Depth Through the Wall

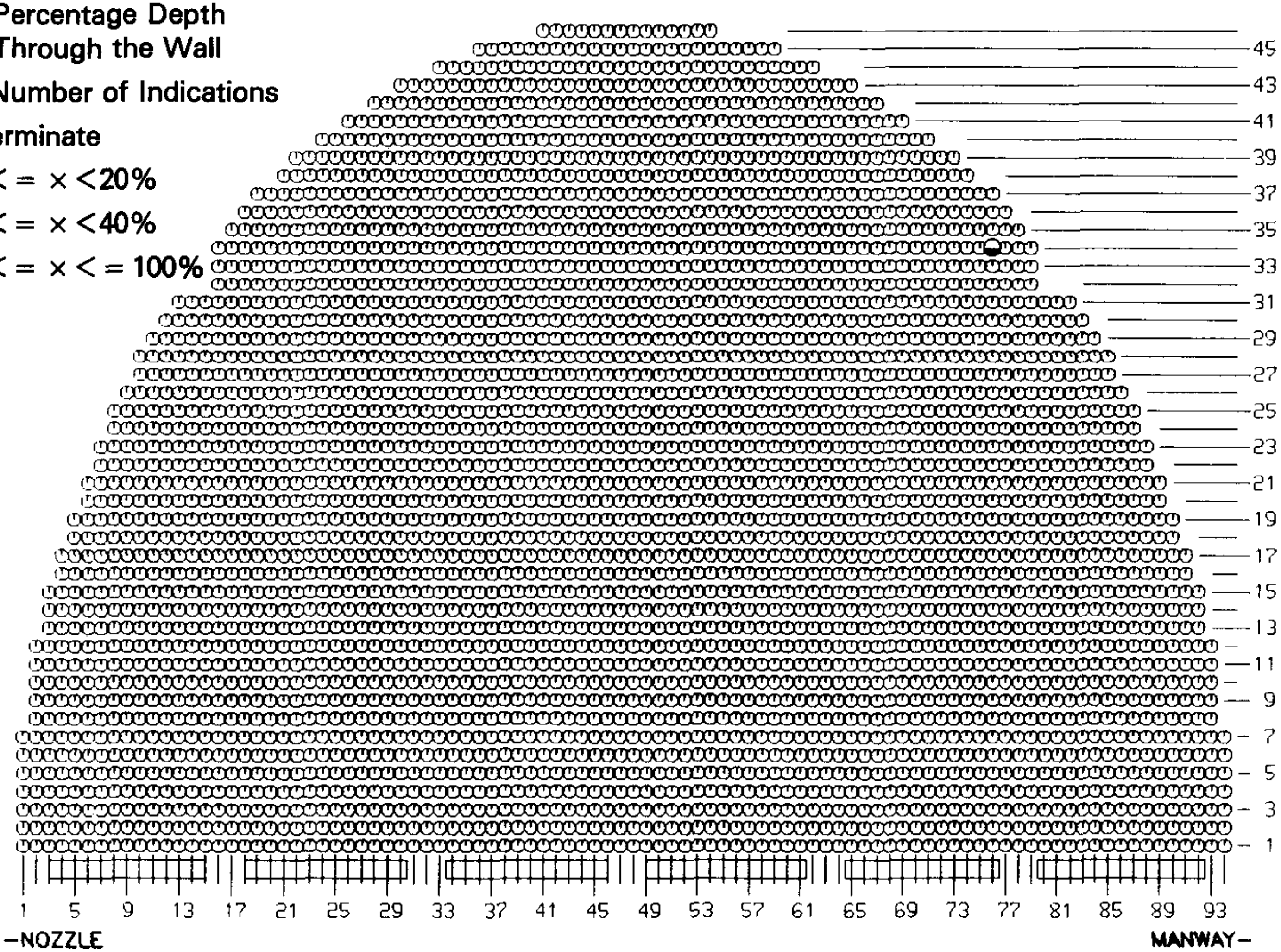
Digit = Number of Indications

◐ Indeterminate

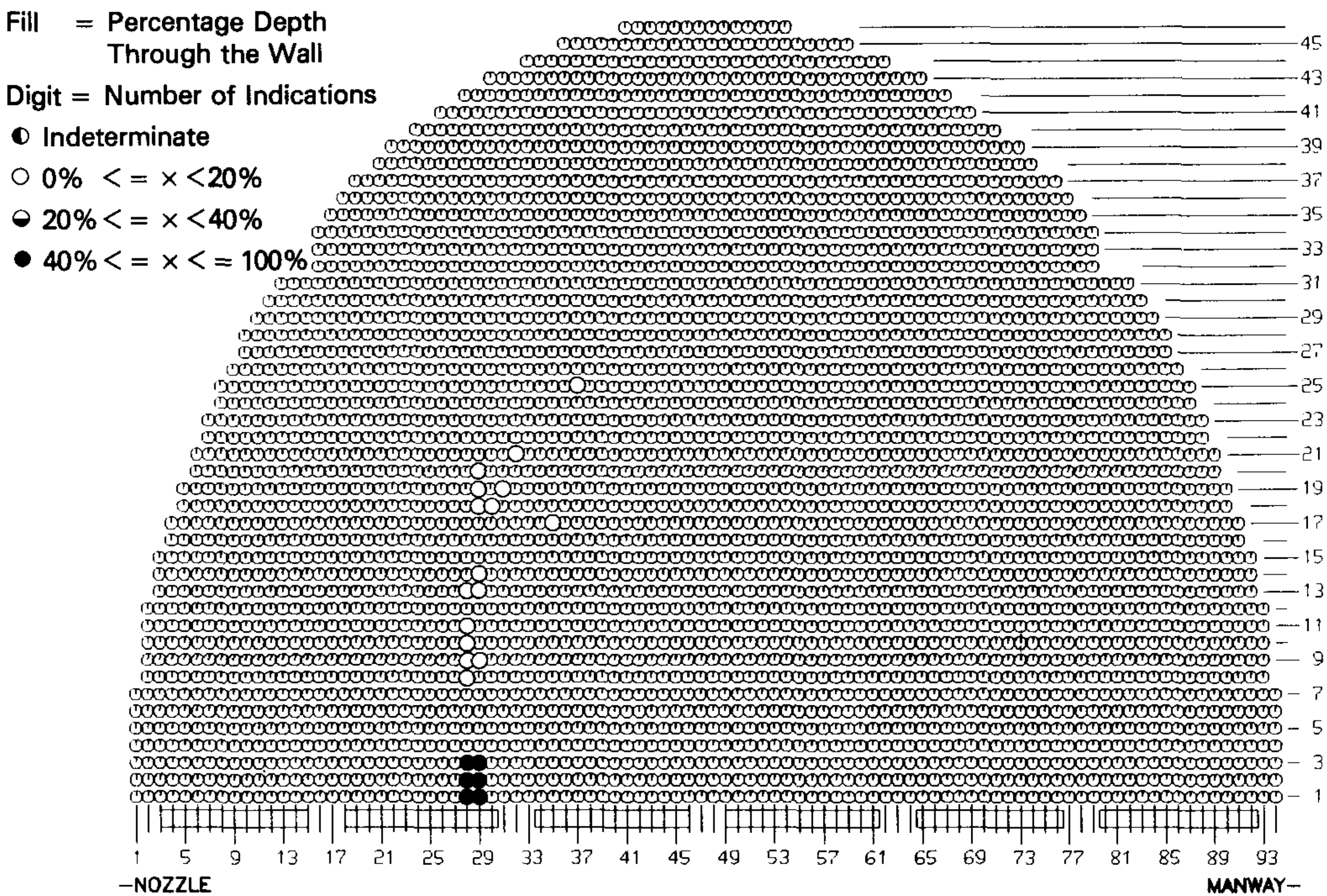
○ 0% <= x <20%

◒ 20% <= x <40%

● 40% <= x <= 100%



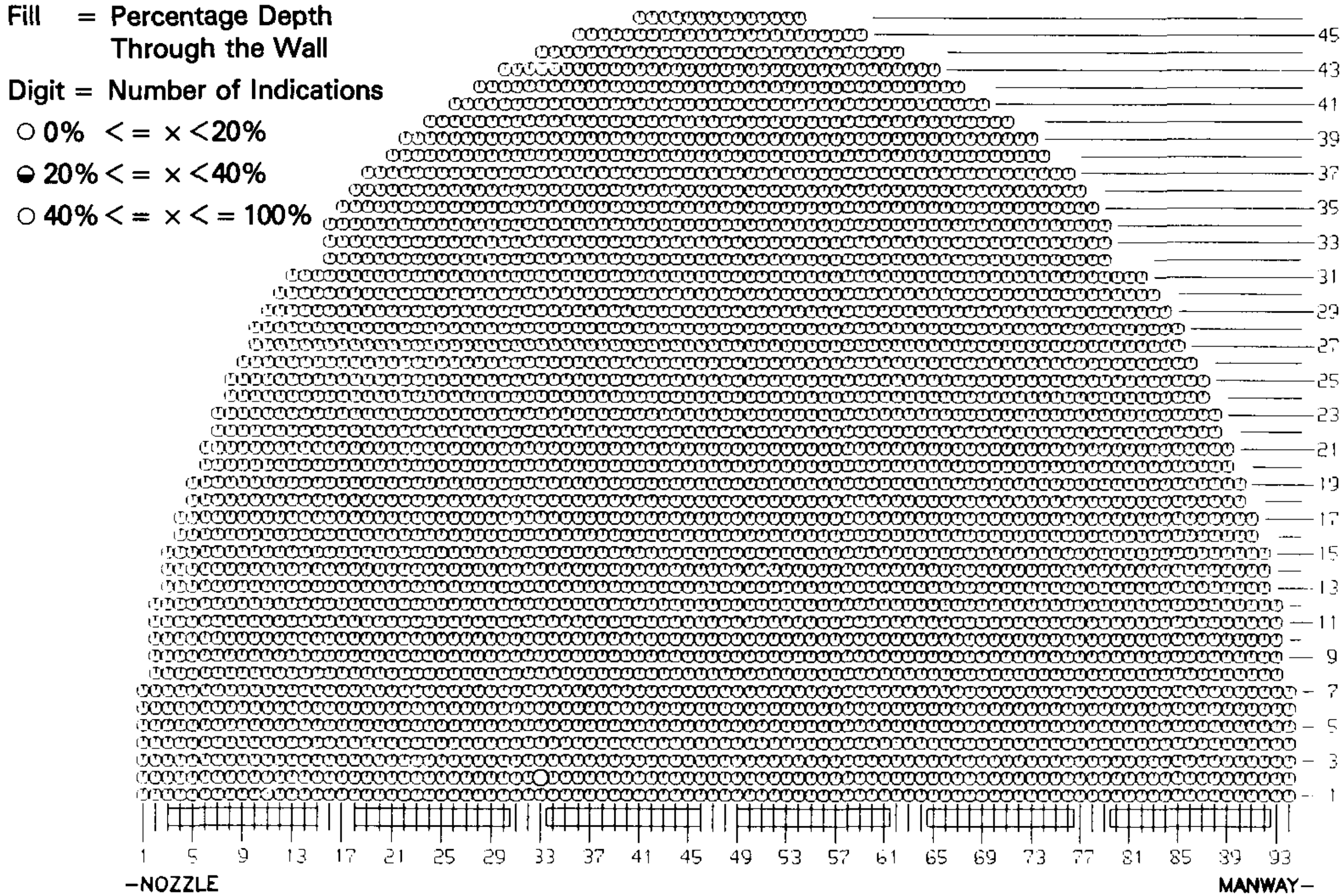
Tubes with O.D. Indications Occurring at the First Support Plate on the Cold Leg Found by Team X



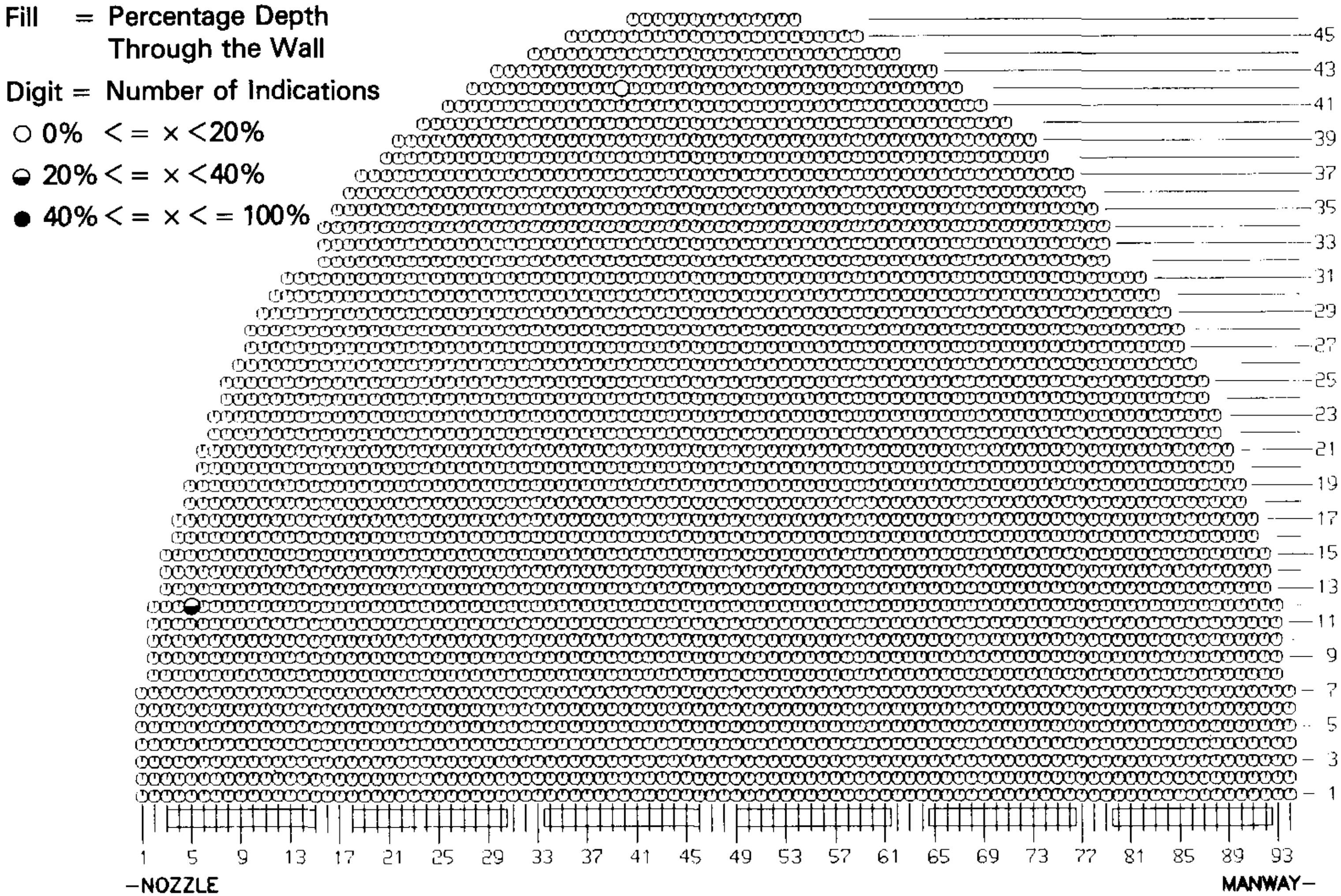
Tubes with O.D. Indications Occurring at the Top of the Tube Sheet on the Cold Leg Found by Team X

APPENDIX G

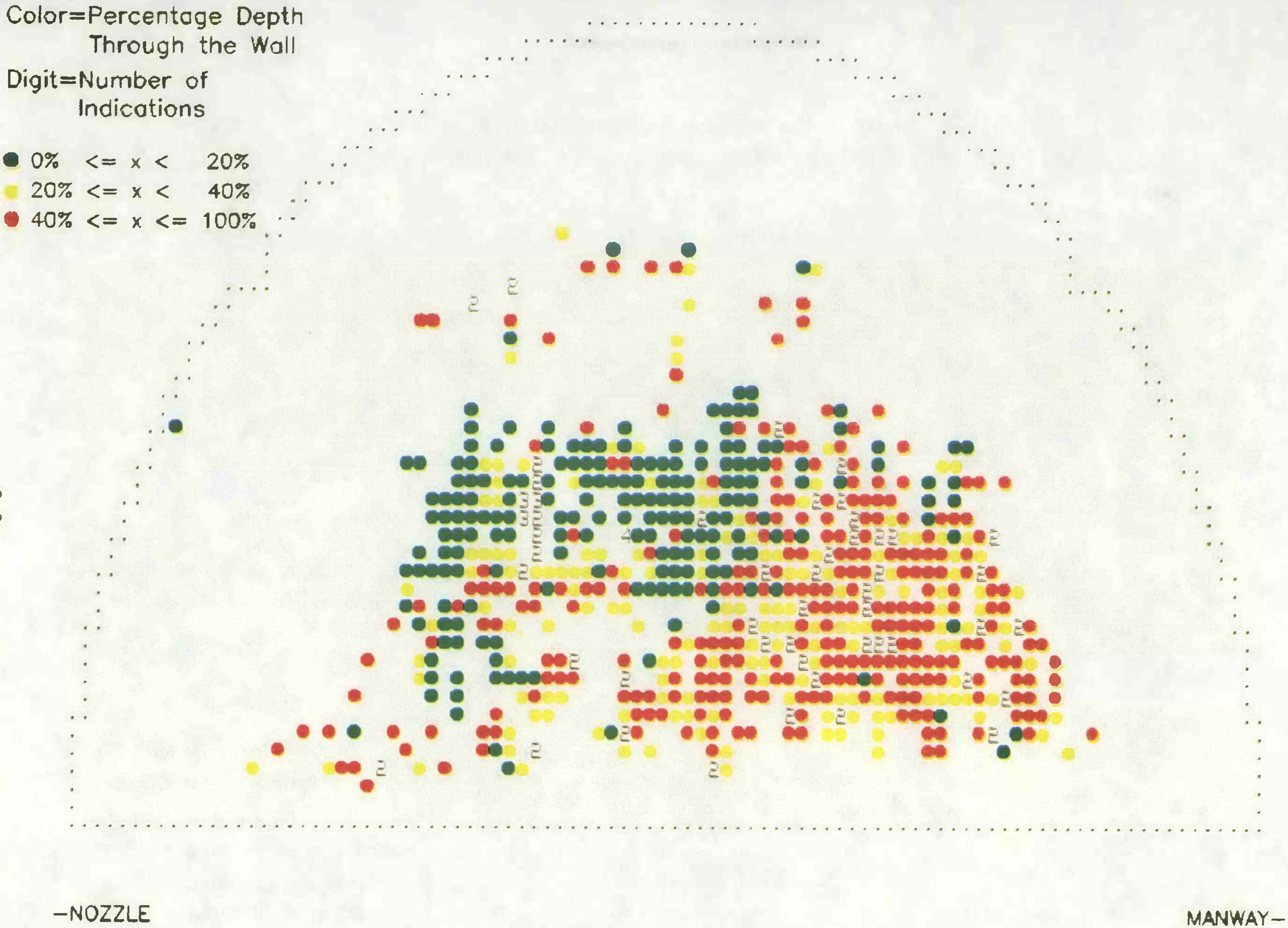
DEFECT INDICATIONS REFERENCED TO STEAM GENERATOR LOCATIONS FOR TEAM Y



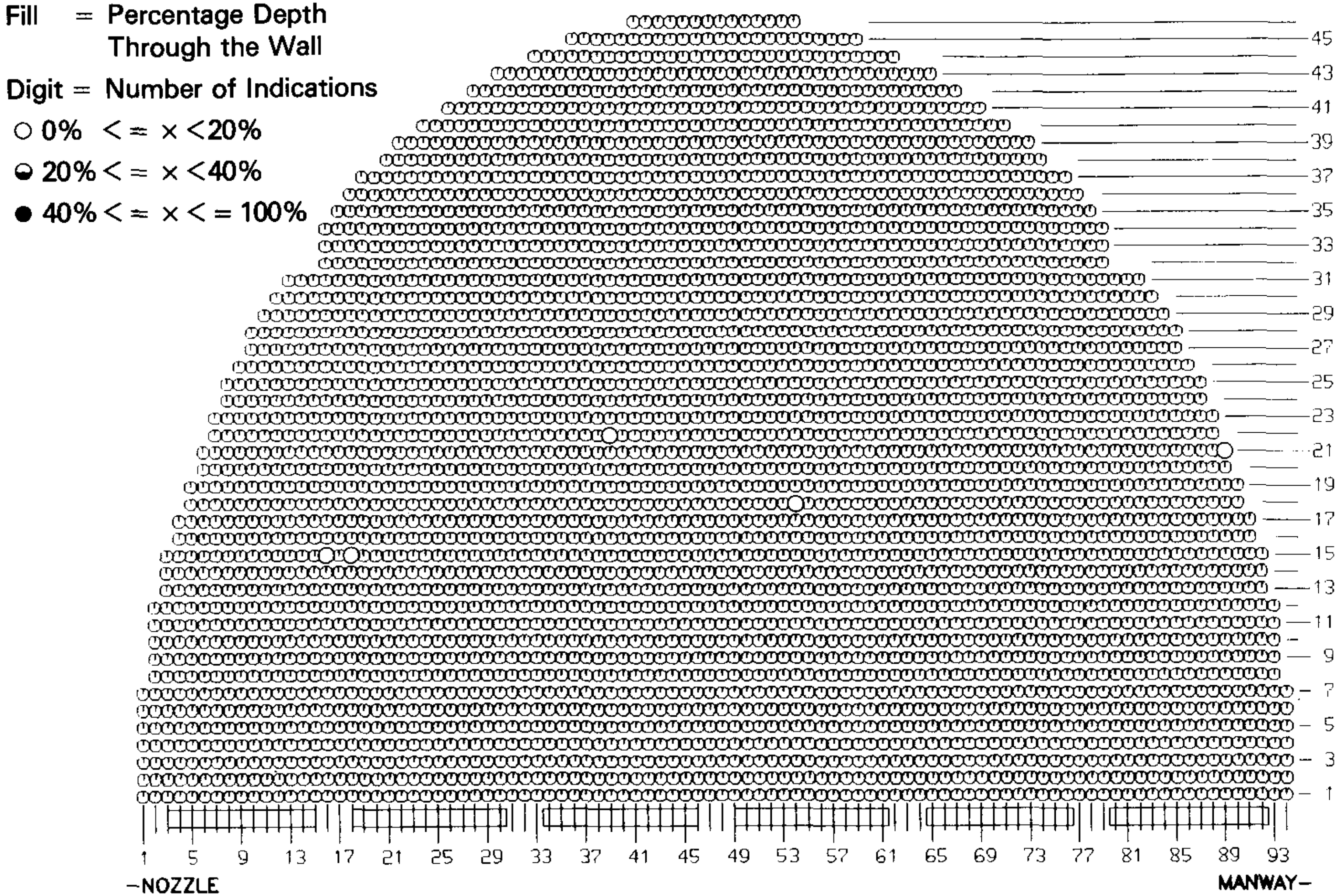
Tubes With I.D. Indications Occurring at the Tube Sheet Crevice on the Hot Leg Found by Team Y



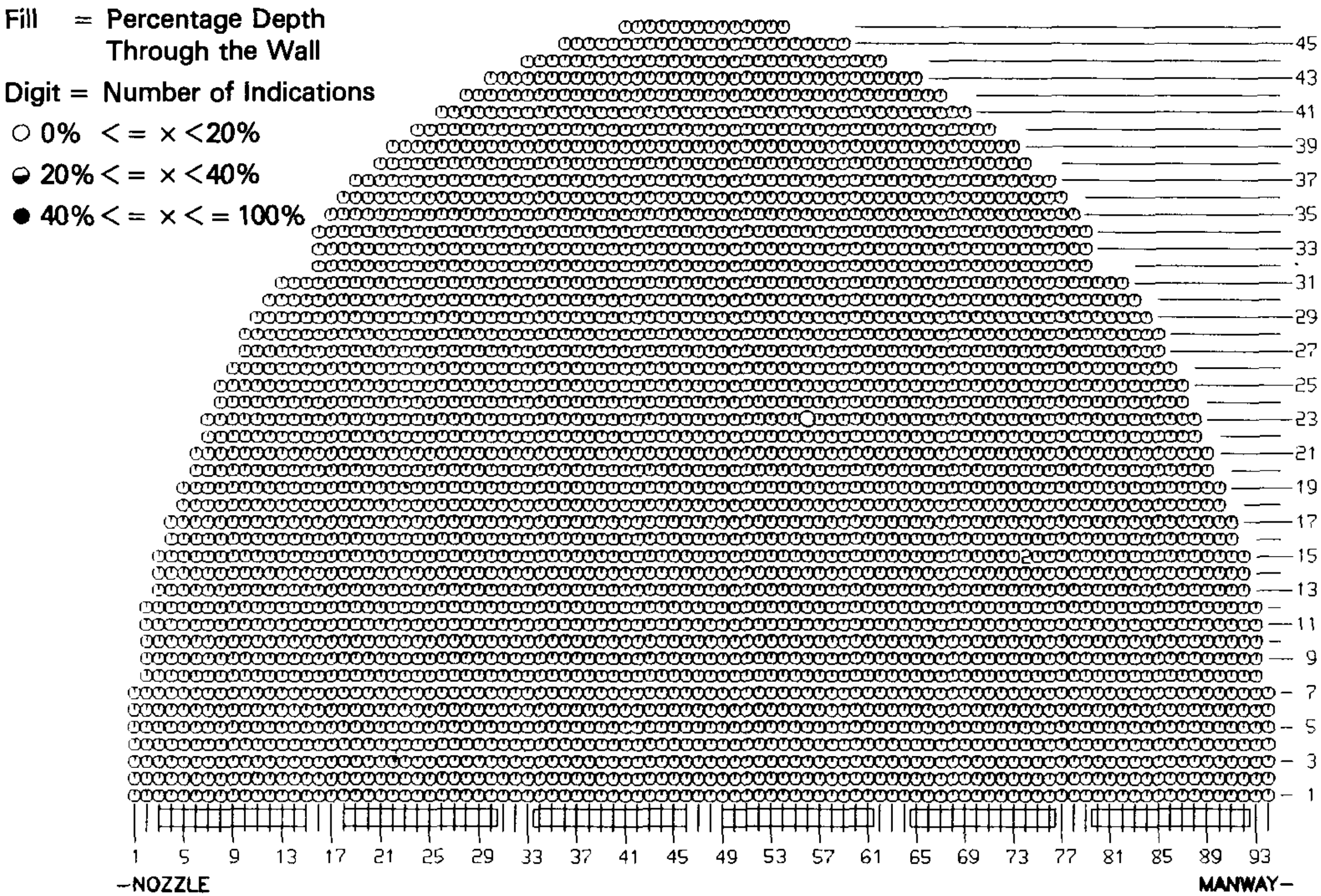
Tubes With O.D. or I.D. Indications Occurring Within the Tube Sheet on the Hot Leg Found by Team Y



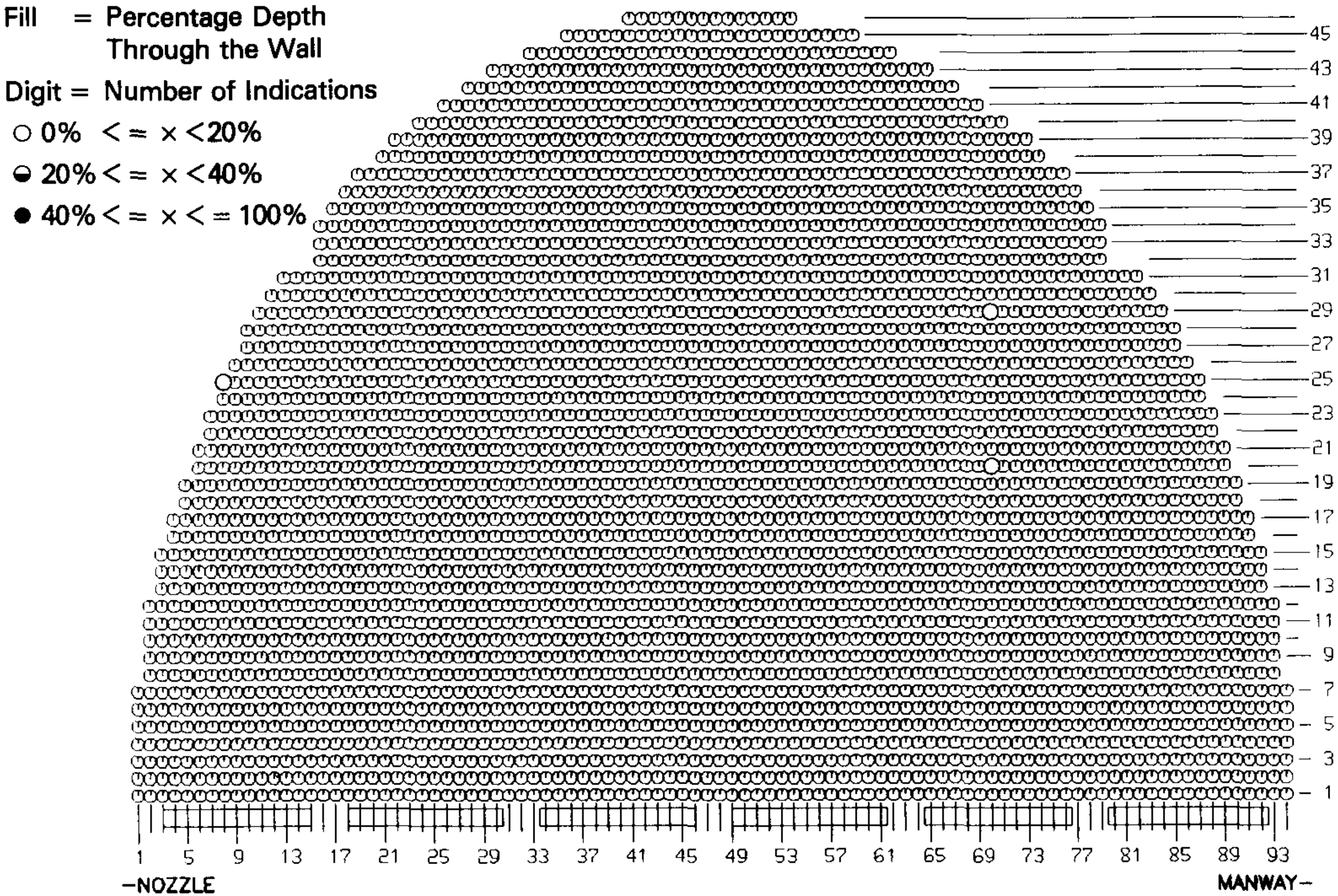
Tube With O.D. Indications Occurring at the Top
of Tube Sheet on the Hot Leg Found by Team Y



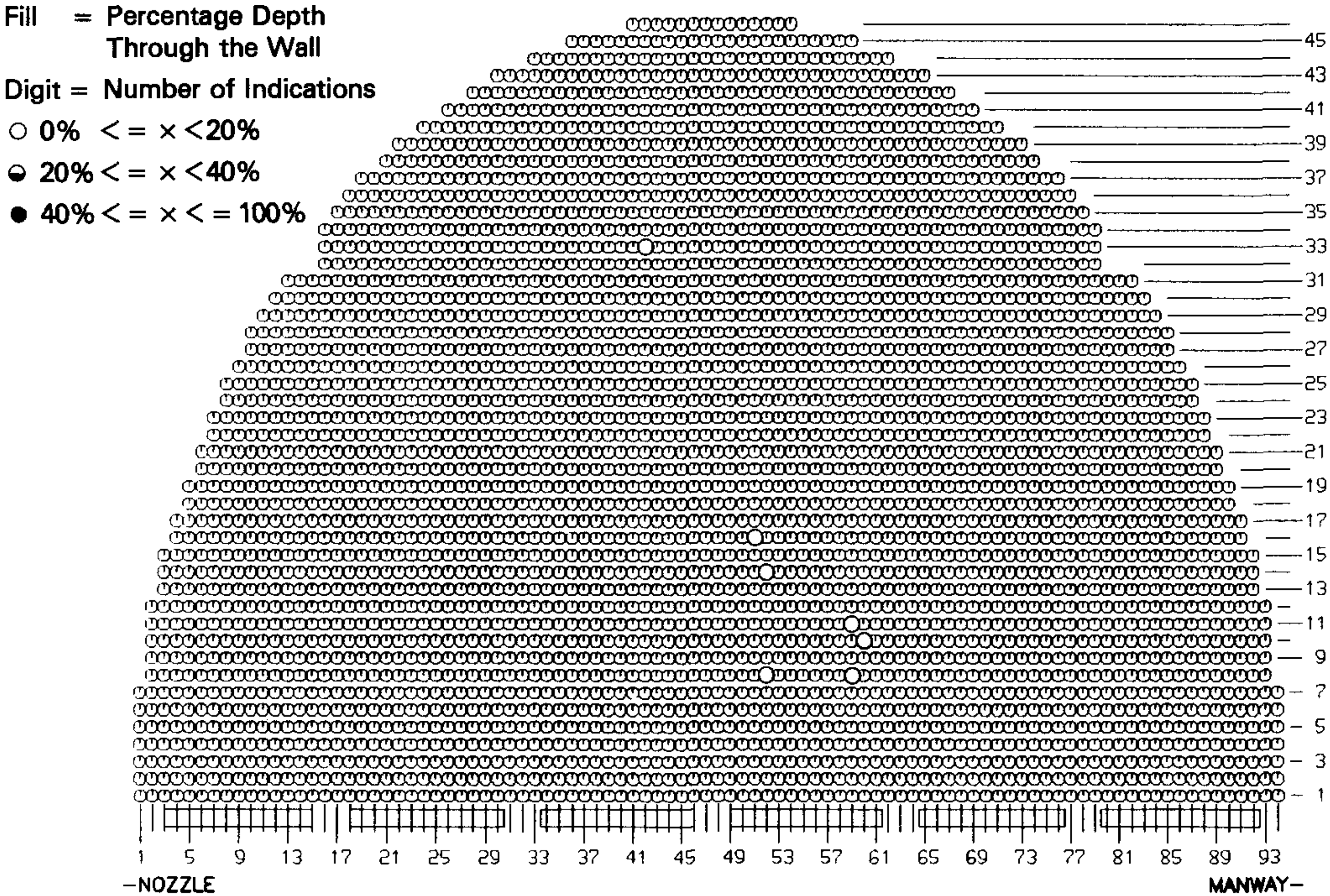
Tubes with O.D. Indications Occurring at the First Support Plate on the Hot Leg Found by Team Y



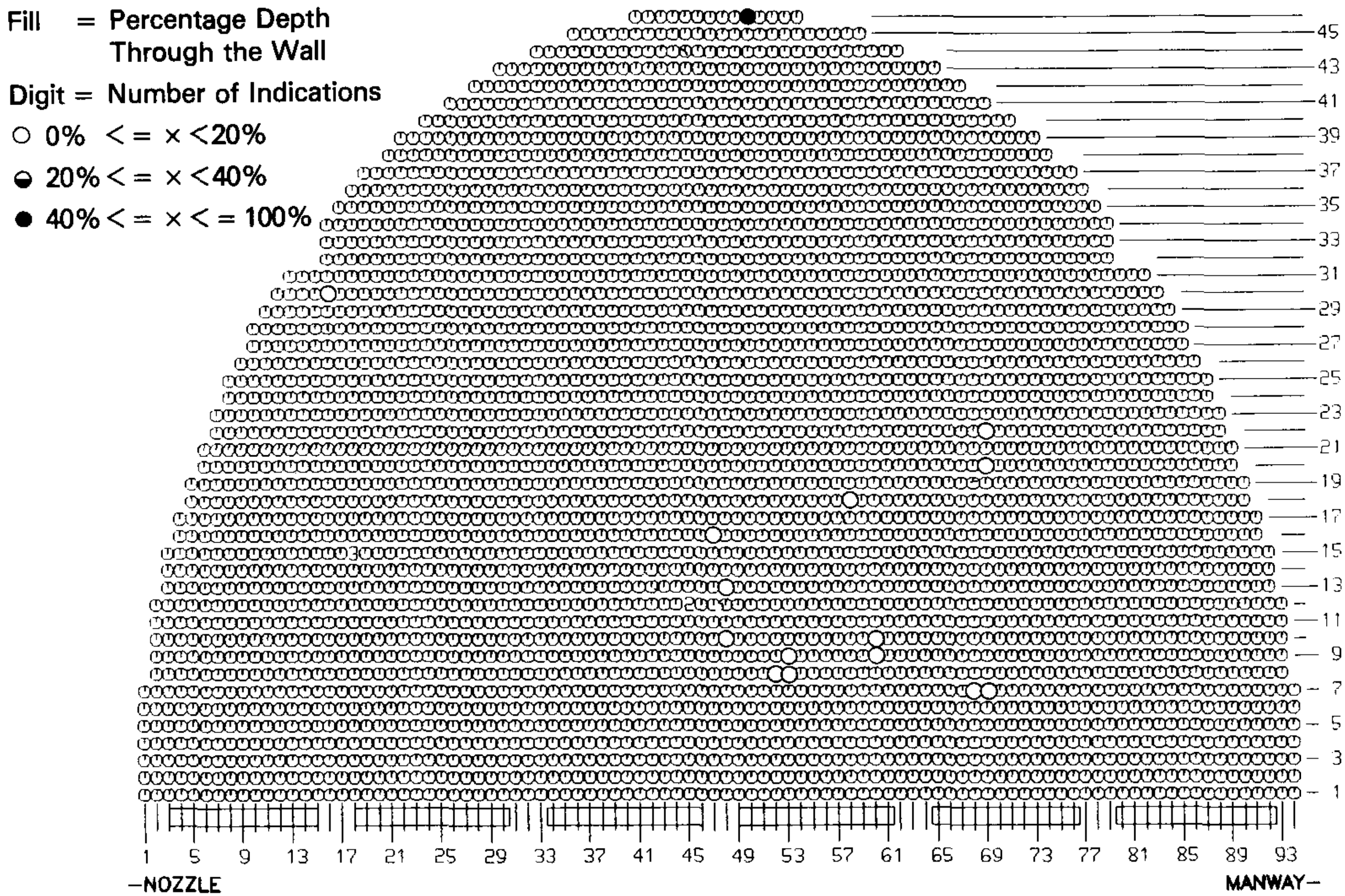
Tubes with O.D. Indications Occurring at the Second Support Plate on the Hot Leg Found by Team Y



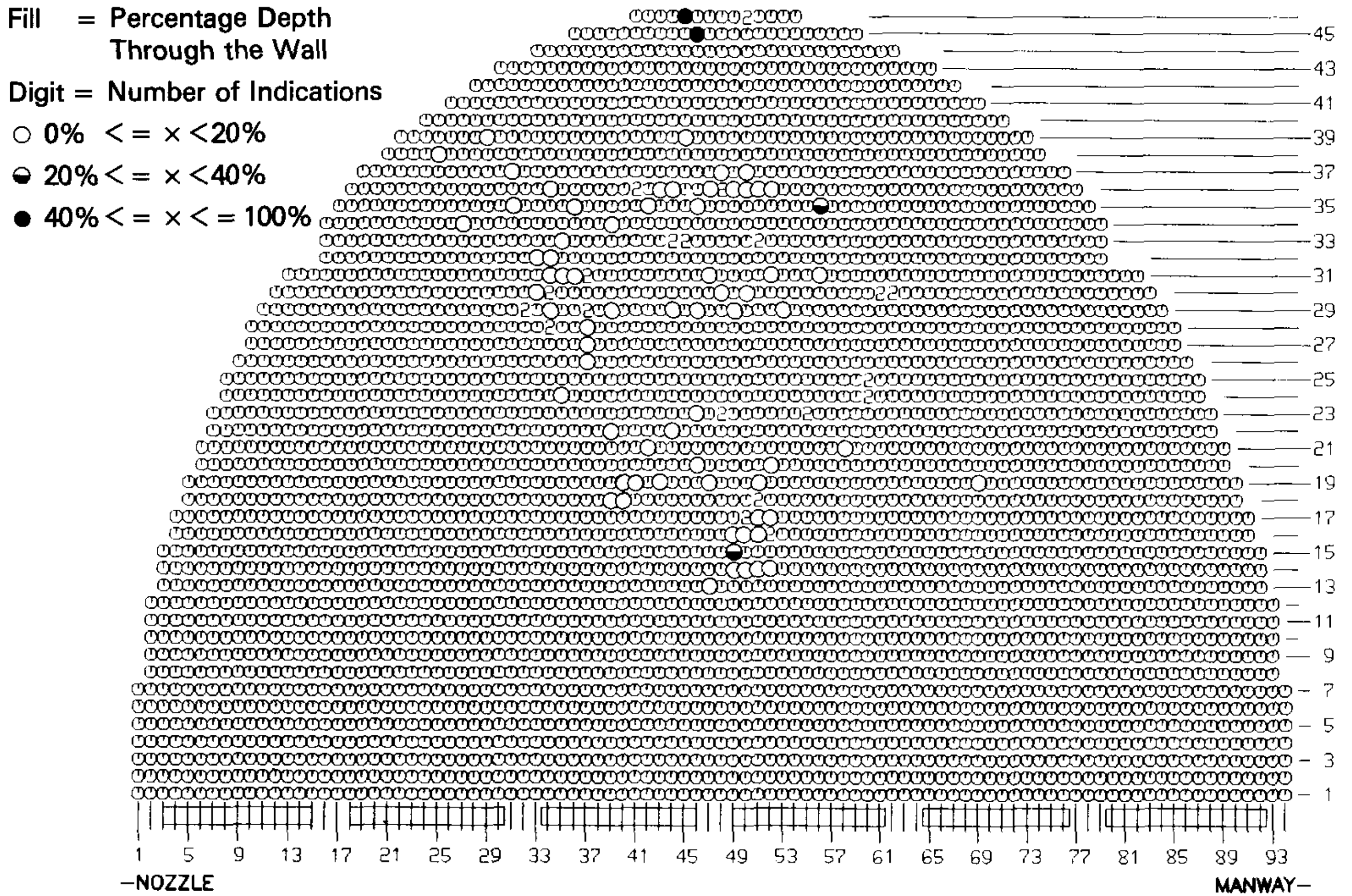
Tubes with O.D. Indications Occurring at the Third Support Plate on the Hot Leg Found by Team Y



Tubes with O.D. or I.D. Indications Occurring at the Fifth Support Plate on the Hot Leg Found by Team Y



Tubes with O.D. Indications Occurring at the Sixth Support Plate on the Hot Leg Found by Team Y



Tubes with O.D. or I.D. Indications Occurring at the Seventh Support Plate on the Hot Leg Found by Team Y

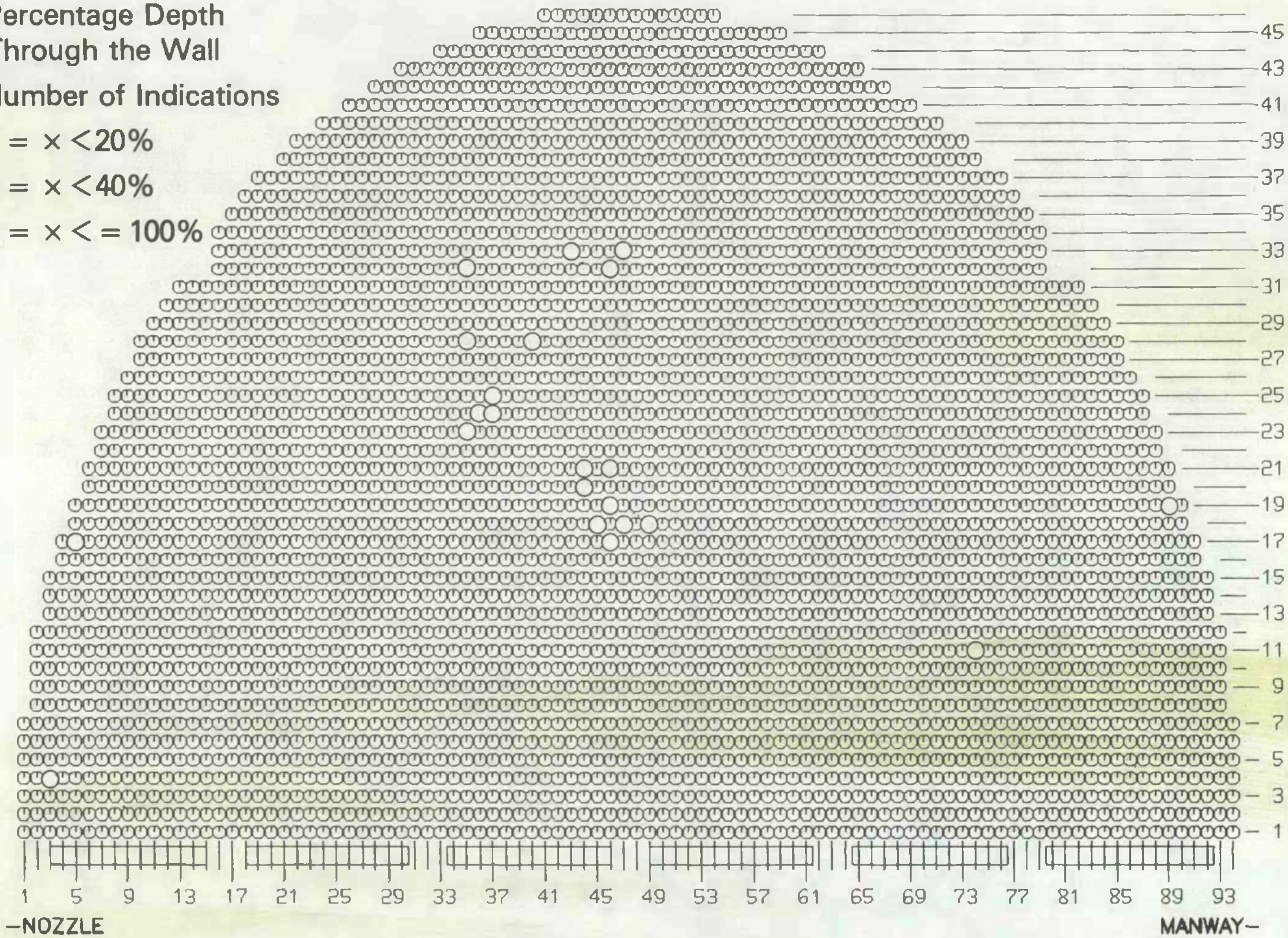
Fill = Percentage Depth Through the Wall

Digit = Number of Indications

○ 0% <= x <20%

◒ 20% <= x <40%

● 40% <= x <= 100%



Tubes with O.D. Indications Occurring in the U-Bend Found by Team Y

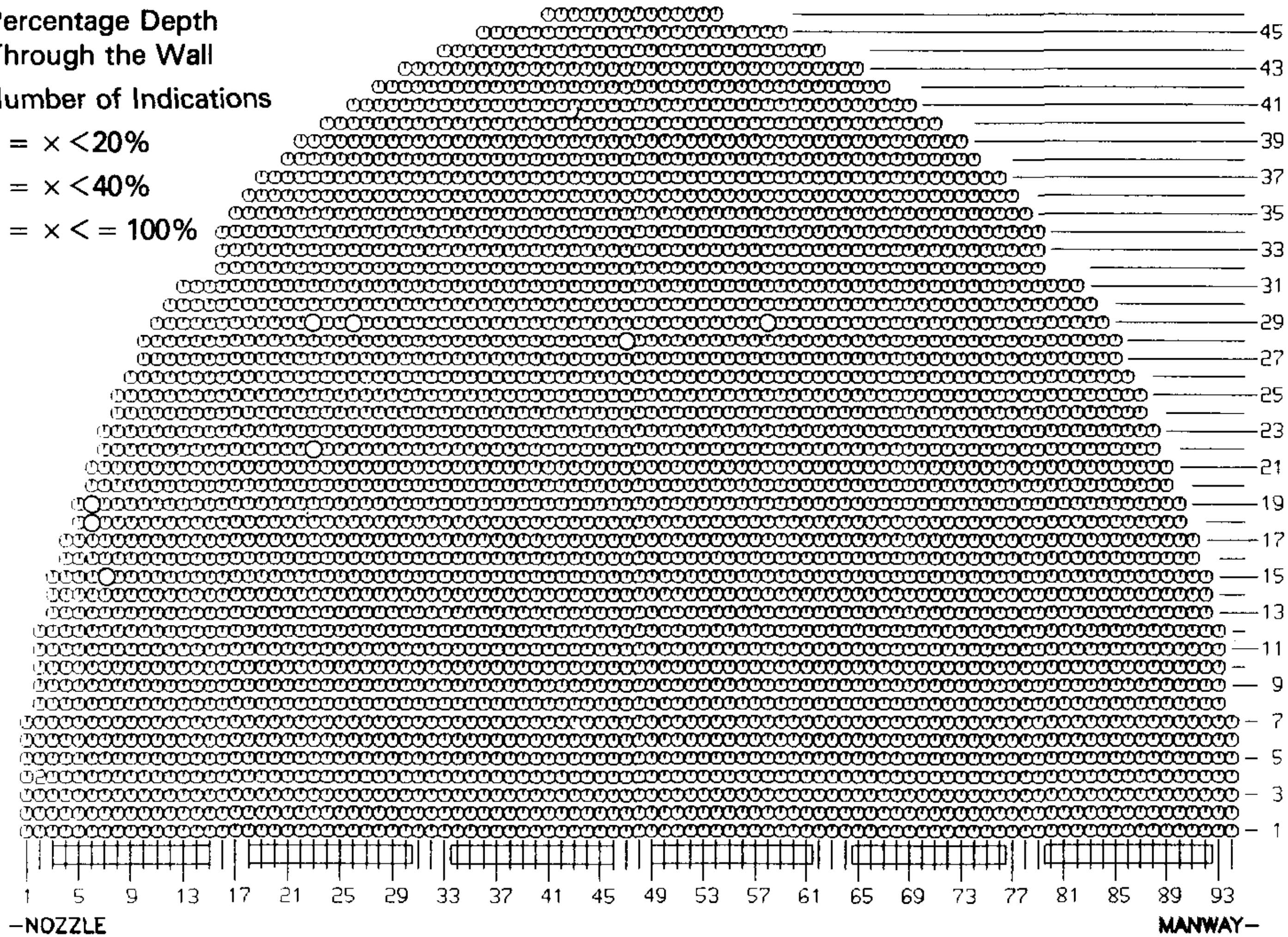
Fill = Percentage Depth Through the Wall

Digit = Number of Indications

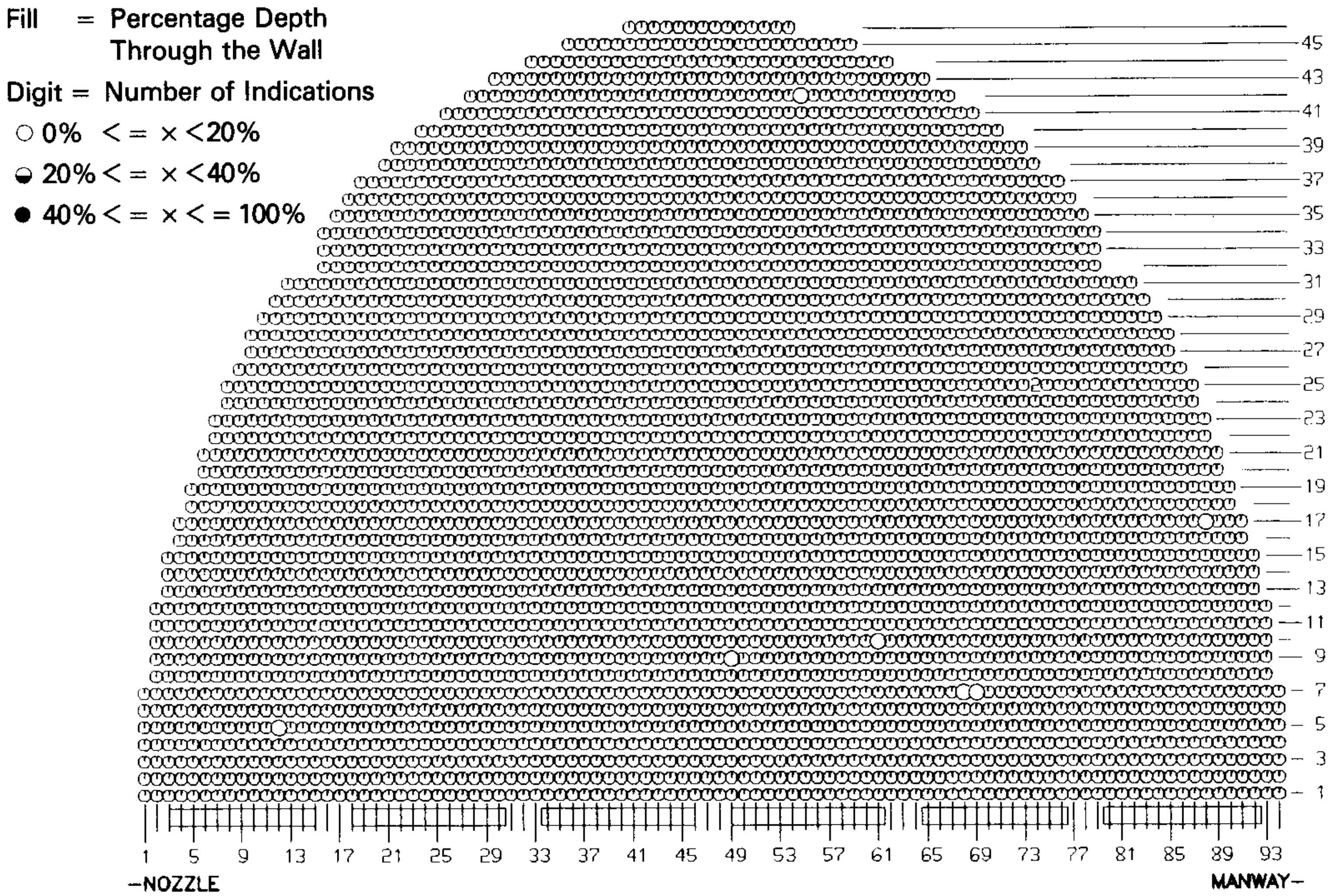
○ 0% <= x <20%

◒ 20% <= x <40%

● 40% <= x <= 100%



Tubes with I.D. or O.D. Indications Occurring at the Seventh Support Plate on the Cold Leg Found by Team Y



Tubes with O.D. or I.D. Indications Occurring at the Sixth Support Plate on the Cold Leg Found by Team Y

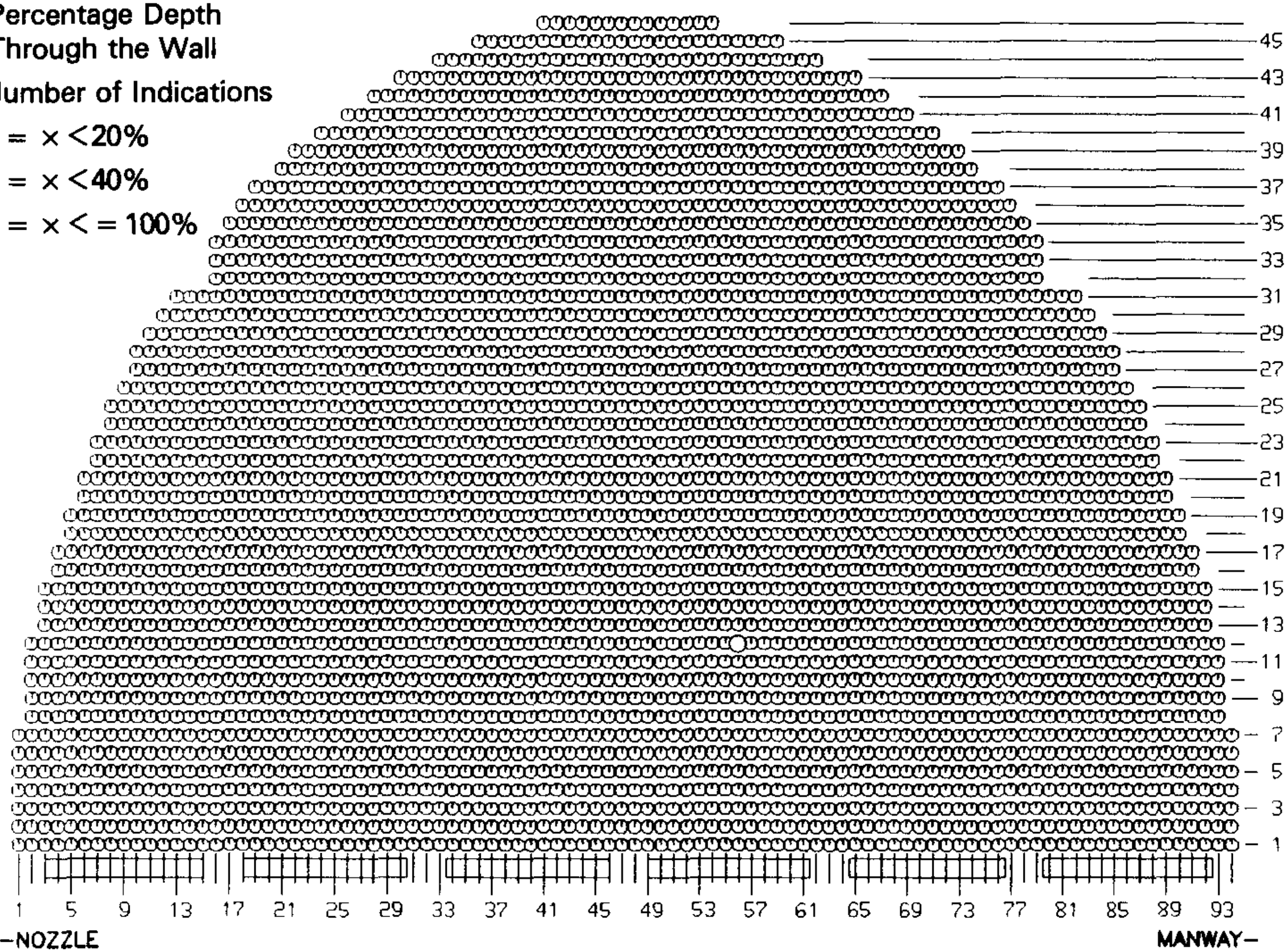
Fill = Percentage Depth Through the Wall

Digit = Number of Indications

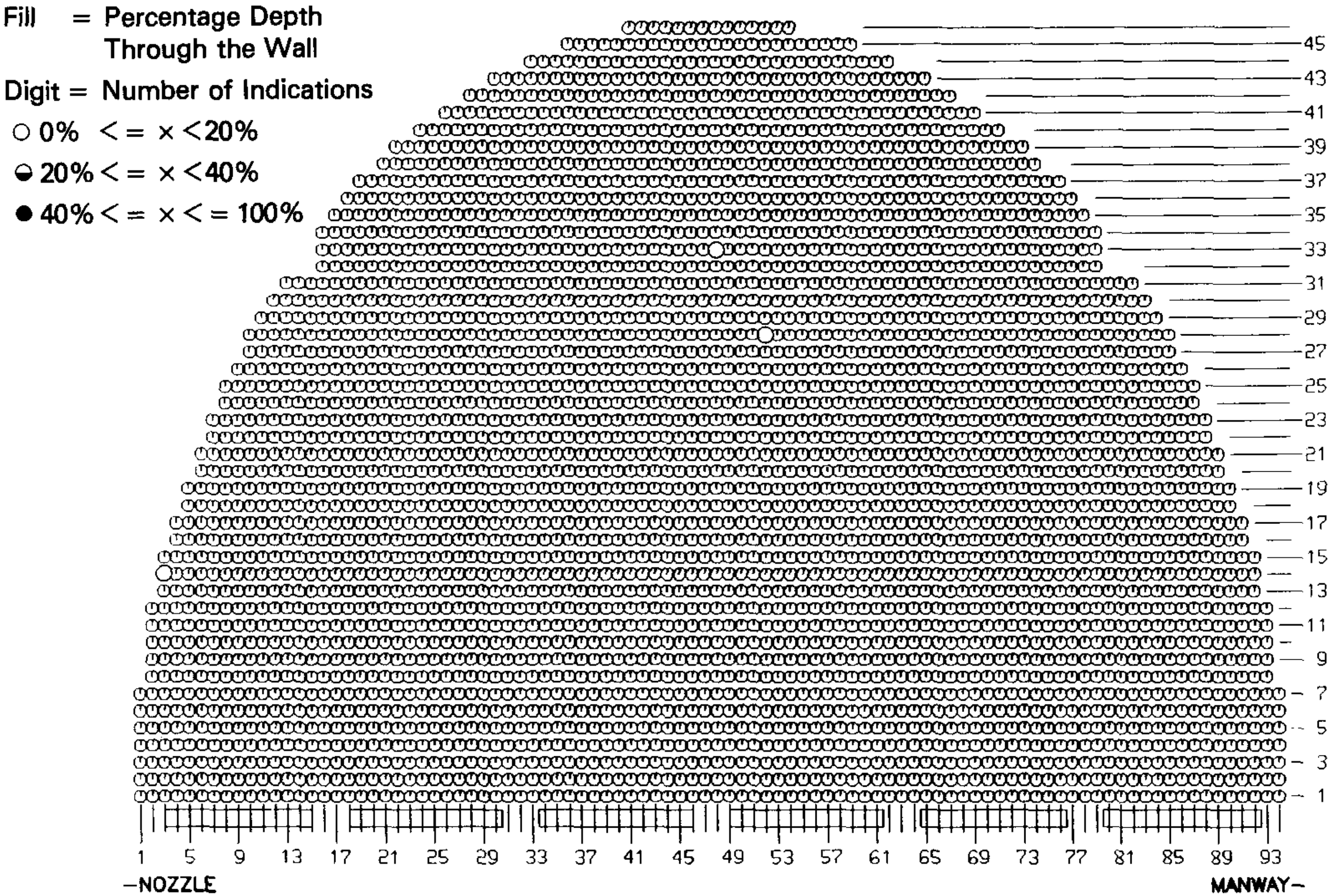
○ 0% <= x <20%

◒ 20% <= x <40%

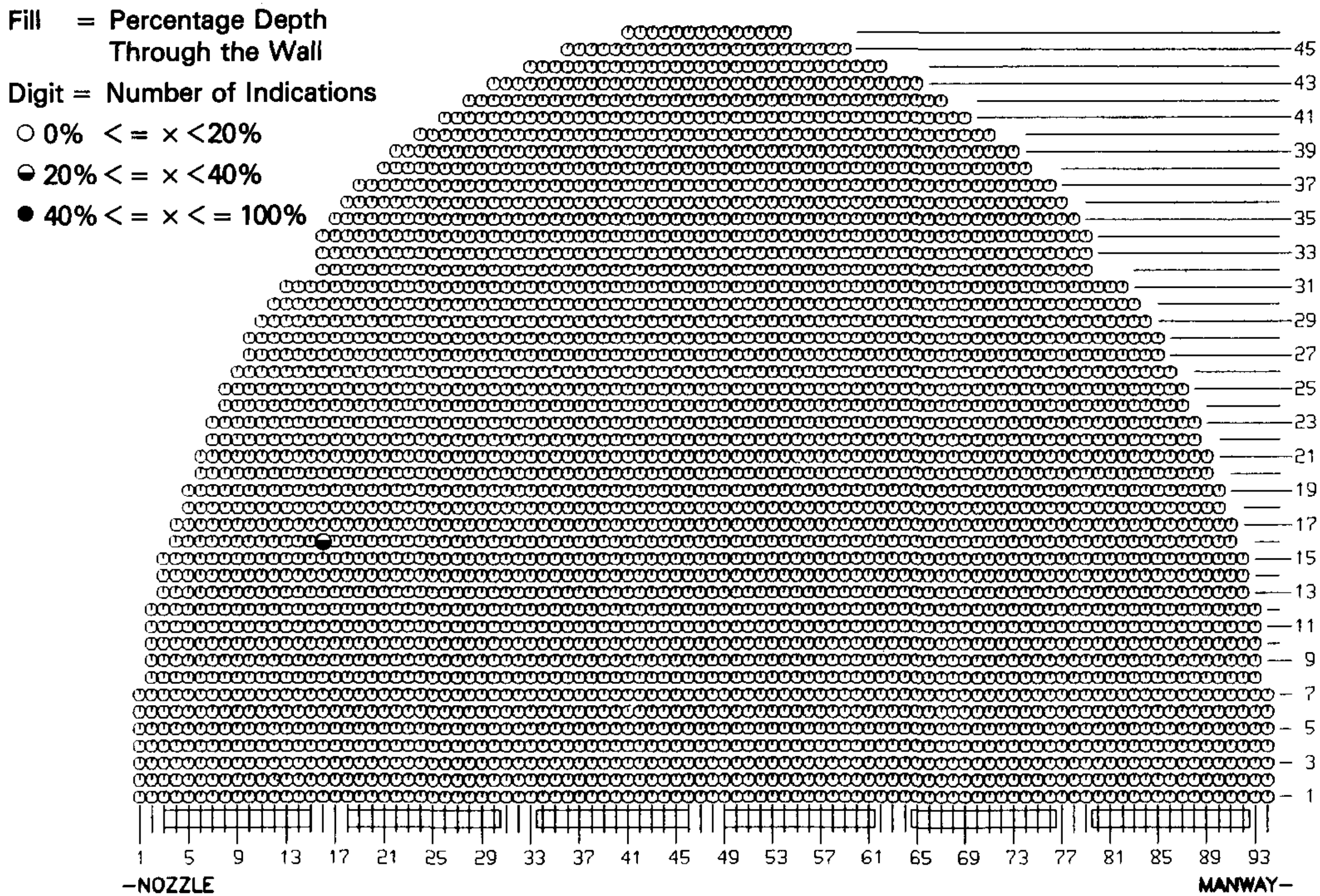
● 40% <= x <= 100%



Tubes with O.D. Indications Occurring at the Fifth Support Plate on the Cold Leg Found by Team Y



Tubes with O.D. or I.D. Indications Occurring at the Fourth Support Plate on the Cold Leg Found by Team Y



Tubes with I.D. Indications Occurring at the Third Support Plate on the Cold Leg Found by Team Y

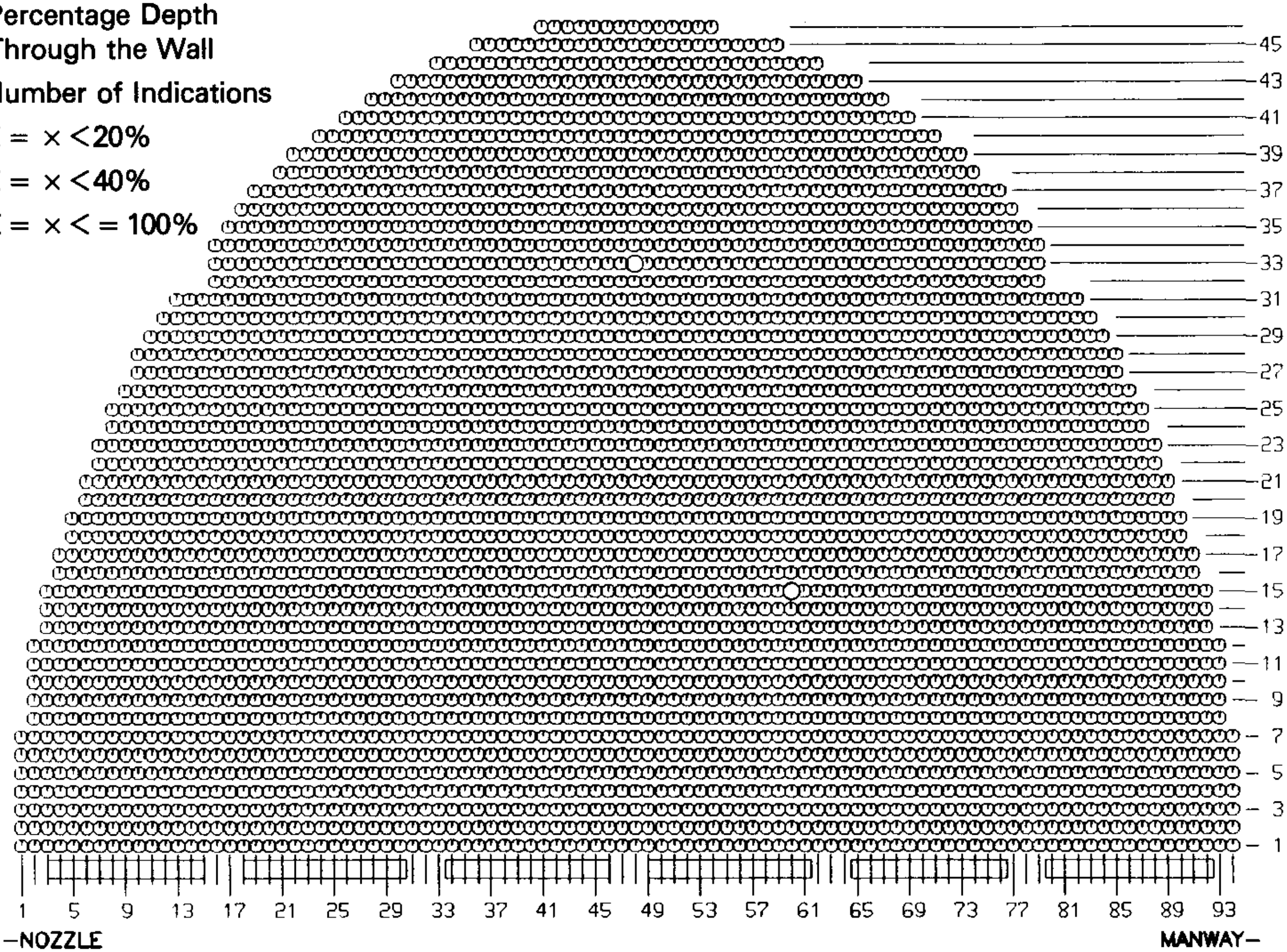
Fill = Percentage Depth Through the Wall

Digit = Number of Indications

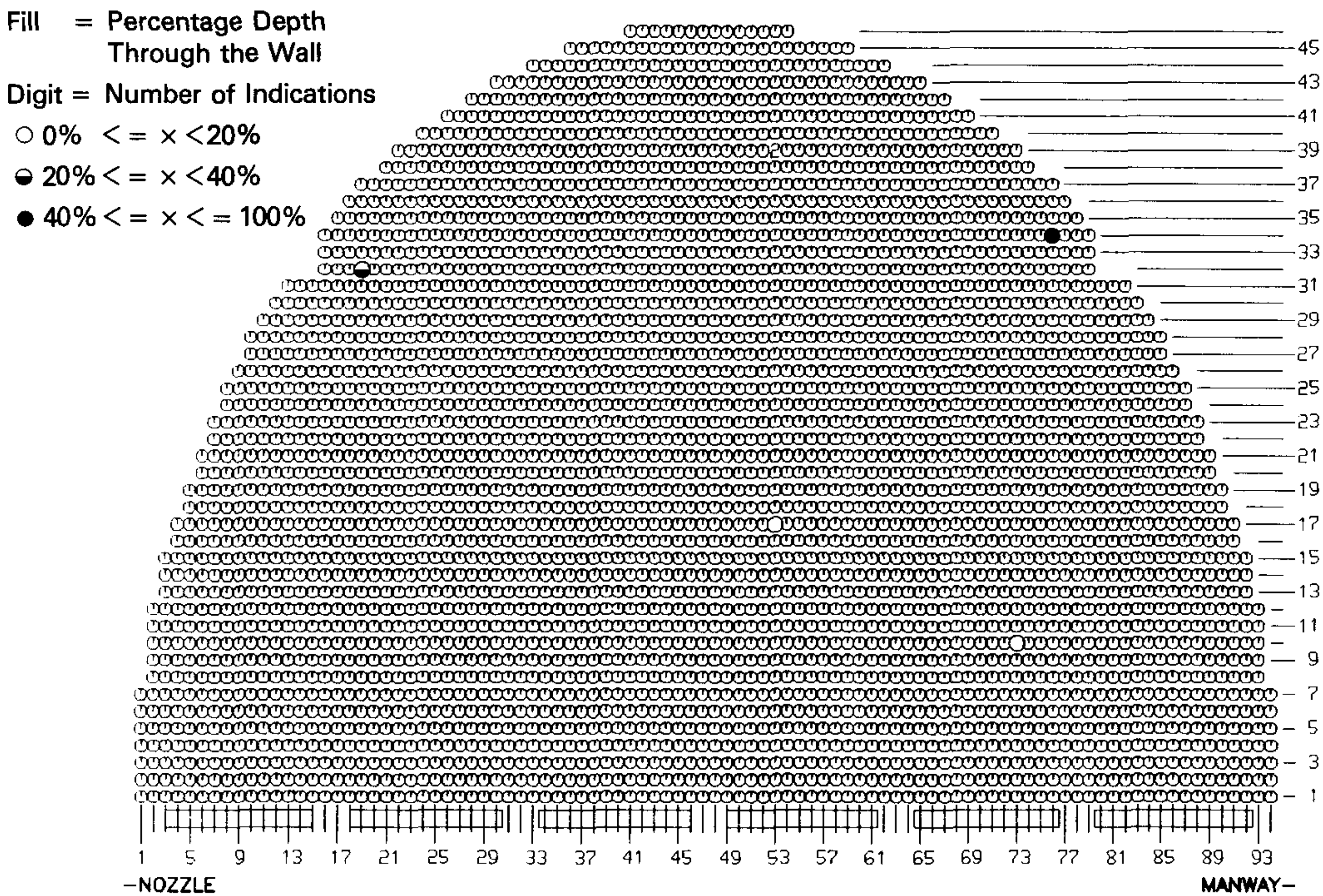
○ 0% <= x <20%

◒ 20% <= x <40%

● 40% <= x <= 100%



Tubes with O.D. or I.D. Indications Occurring at the Second Support Plate on the Cold Leg Found by Team Y



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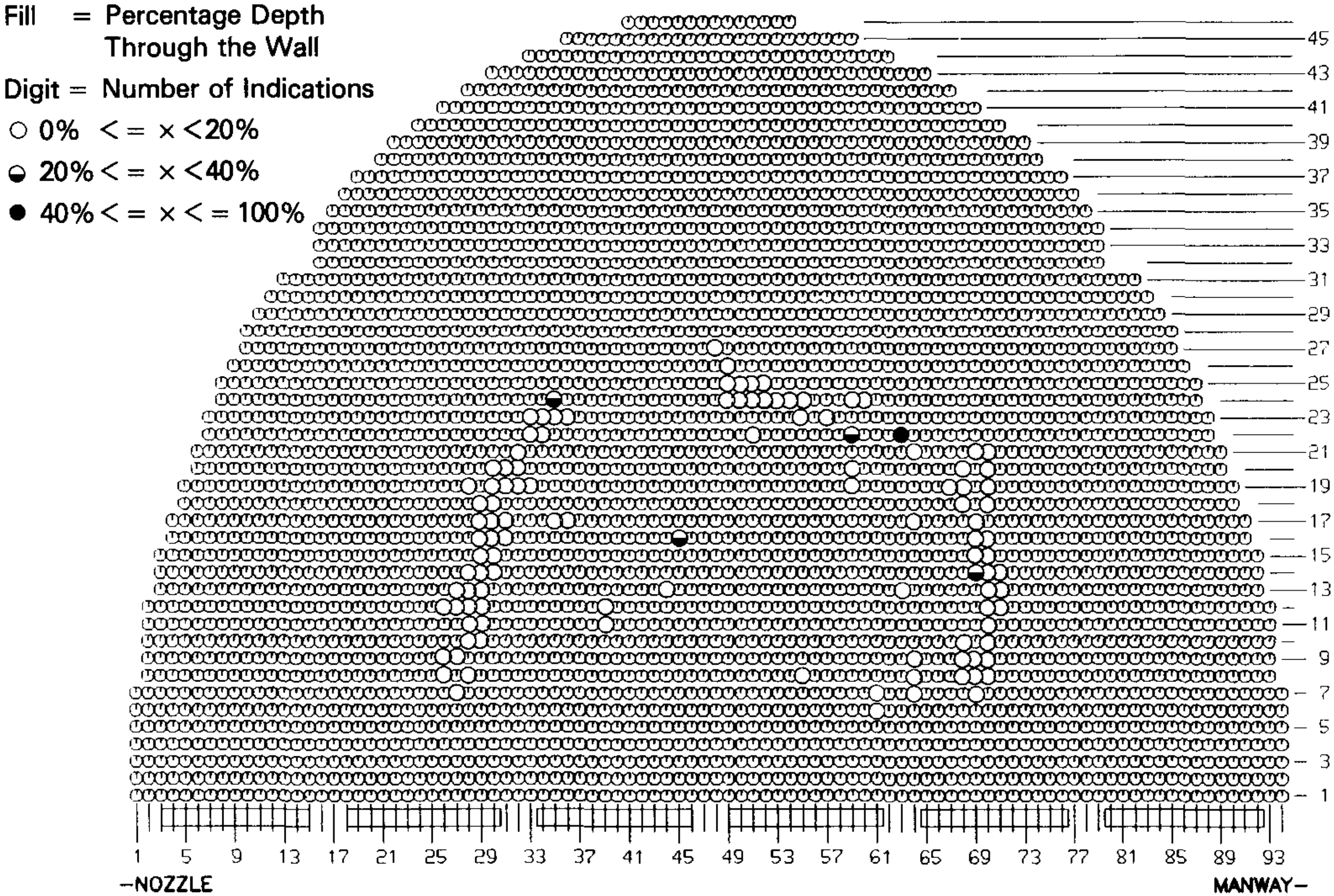
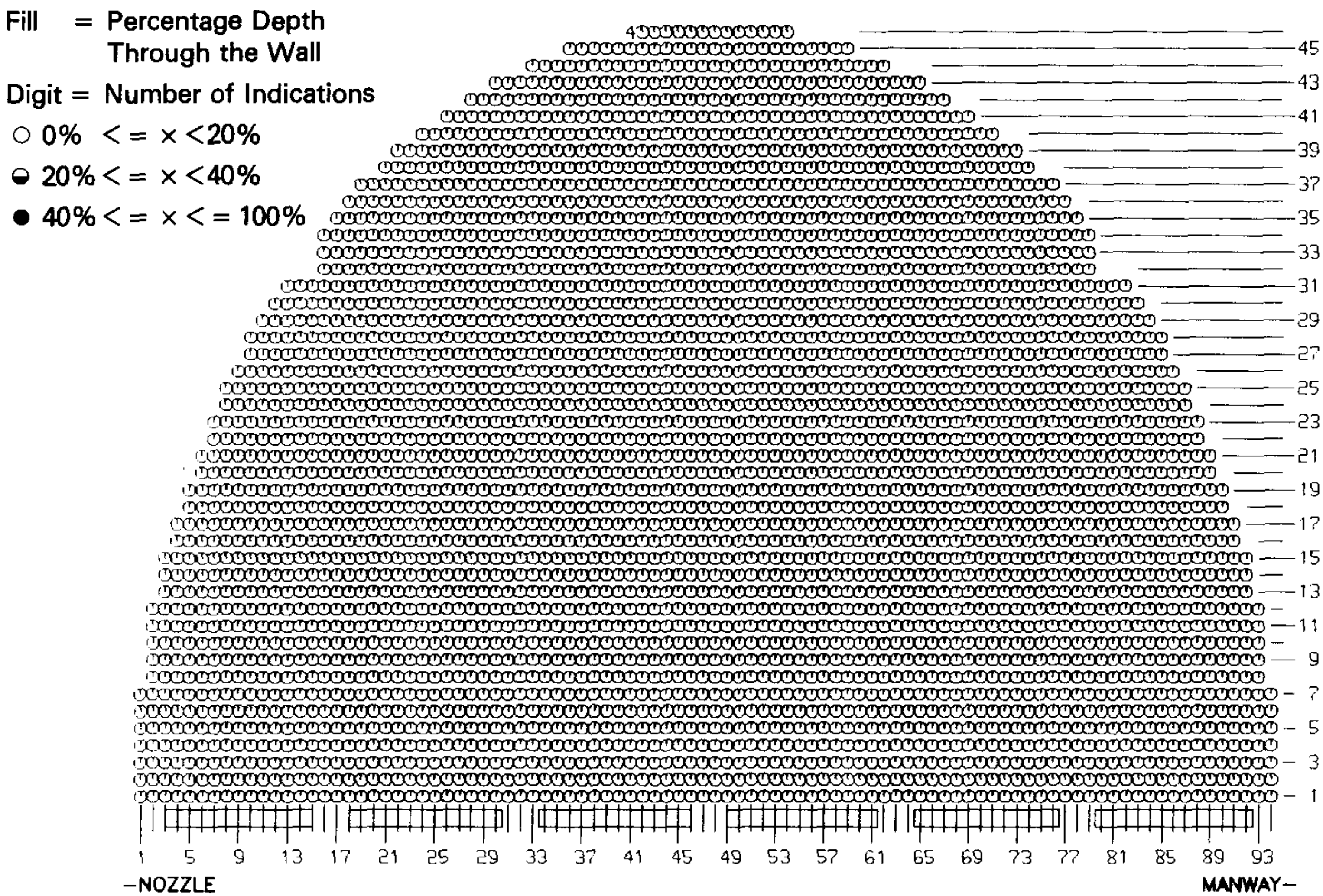


Tubes With O.D. Indications Occurring at the Top of Tube Sheet on the Cold Leg Found by Team Y



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13. ABSTRACT (200 words or less)

The Steam Generator Group Project (SGGP) is using a retired-from-service pressurized water reactor steam generator as a test bed to investigate the reliability of in-service nondestructive (NDE) eddy current inspections. This information will provide the technical basis for recommended changes to the regulations concerning in-service inspections of steam generator tubes and tube plugging criteria.

The estimates of inspection reliability are being made from NDE data collected during a series of round robin inspections of a subset of tubes from the generator. Segments of these tubes have been removed from the generator and are being destructively analyzed to determine the actual state of tube degradation. To determine NDE reliability, a large number of service-induced defects were needed in the set of tubes selected for the round robin inspections. Thus, two complete baseline eddy current inspections were performed to identify those tubes with a high probability of containing defects. The results of the baseline inspections are described in this report.

The baseline inspections were performed by field-experienced personnel using two different commercially-available multifrequency eddy current systems. The analysis of the results showed larger than expected differences in the detection of suspected wall-loss defects (indications) and the subsequent estimates of the depth of the defects One inspection reported 773 outer-diameter (OD) indications and the other 1041. The detection agreement between teams, based on the reporting of the same indication, was 84% and 61% for the inspections with the fewer and larger numbers of indications, respectively. The sizes of the same indications reported by different teams were observed to be significantly different.

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