ATTACHMENT 1

(GPU Letter to NRC dated November 26, 1990)

Nuclear

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201-316-7000
TELEX 136-482
Writer's Direct Dial Number:

November 26, 1990
5000-90-1993
C320-90-264

U. S. Nuclear Regulatory Commission
Attention: Document Control Desk
Washington, DC 20555

Gentlemen:

Subject: Oyster Creek Nuclear Generating Station (OCNGS)
Docket No. 50-219
License No. DPR-16
Oyster Creek Drywell Containment

References: (1) NRC letter dated October 3, 1990 - Summary of September 19, 1990 meeting

(2) NRC letter dated October 16, 1990 - Requested Clarifications

On Wednesday, September 19, 1990, a meeting was held with the NRC at the NRC offices, One White Flint North, Rockville, Maryland. The purpose of this meeting was to discuss GPUN's overall plan to address the drywell corrosion issue at the Oyster Creek Nuclear Generating Station. The Reference (1) letter documents the participants, morning and afternoon presentations and summarizes the significant items discussed.

The NRC requested detailed supplemental information supporting GPUN's assessment be submitted no later than December 31, 1990.

The requested information specified by Reference (2) consists of the following four (4) items:

(1) Drywell Inspection Plan Details (original and augmented) which includes justification of Sampling Techniques and Statistical Methodology.

(2) Point-By-Point Code Comparison justifying ASME Section III, NE Methodology for the ASME Section VIII Drywell/Containment Vessel.

(3) Structural Design Report justifying operation to 14R refueling outage based on ASME Section III, NE Methodology using 62 psig as drywell design pressure.

(4) GPUN Actions to prevent leakage into the drywell gap and the effects of leakage on other structures or equipment.

In order to expedite NRC review of the requested information, individual submittals will be provided as the documentation of each item is finalized.

Attachment I to this letter provides the information requested by the NRC for Item (1) and includes a brief summary of the overall drywell inspection plan and the following technical documentation.

- GPUN TDR 948, Rev. 1, "Statistical Analysis of Drywell Thickness Data."
- GPUN Specification IS-328227-004, Rev. 8, "Functional Requirements for Drywell Containment Vessel Thickness Examination."
- GPUN Calculation C-1302-187-5300-011, Rev. 0, "Statistical Analysis of Drywell Thickness Data from 4/24/90" (Appendices 6.1 to 6.3 not attached).
- GPUN TDR 1027, Rev. 1, "Design of a UT Inspection Plan for the Drywell Containment Using Statistical Inference Methods."
- GPUN Specification IS-402950-001, Rev. 0, "Functional Requirement for Augmented Drywell Inspection."

It is GPUN's goal to provide submittal items (2) through (4) as they become available but no later than December 31, 1990. GPUN will, of course, inform the NRC of any changes to the corrosion assessment which would compromise our technical justification for continued operation of the OCNGS.

If you have any questions on this submittal or the overall drywell corrosion program, please contact Mr. Michael Laggart, Manager, Corporate Nuclear Licensing at (201) 316-7968.

Sincerely,

J. C. DeVine, Jr.
Vice President, Technical Functions

JCD/RZ/plp
Attachment
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ATTACHMENT I

SUMMARY OF GPUN OVERALL DRYWELL INSPECTION PLAN

The GPUN drywell inspection plan is separated in two portions. The first portion is an inspection program intended to determine corrosion rates which are utilized to develop conservative projections.

In this portion of the program, UT inspections are performed over time at the same specific locations. The inspections are performed during outages of opportunity when a drywell entry is made for reasons other than program inspections. 20 priority #1 locations are inspected not more frequently than 3 months, and 7 priority #2 locations are inspected not more frequently than 18 months. These inspection locations were identified during detailed inspection of elevations 11'-3", 50'-2", 51'-10" and 87-5" conducted in 1986, 1987 and 1990. During the 13R outage, GPUN will perform inspection of all priority #1 locations, once at the beginning of the outage and once at the end of the outage. Included in this attachment are copies of the GPUN internal reports which provide details of data collection and data reduction, as well as the most recent results for inspection up to April 1990. Also provided is Specification IS-328227-004, Rev. 8 which presents functional requirements for inspection implementation.

The second portion of the program will be implemented for the first time during the 13R outage and is intended to statistically confirm required drywell thicknesses. This portion of the program relies on UT inspection of 57, 6 x 6 inch randomly chosen locations. The resulting inspection data will characterize the condition of the upper elevations of the drywell.

As part of this Attachment are copies of a GPUN Report which provides details of how the amount and the location of the 57 inspection locations were determined and Specification IS-402950-001 which presents functional requirements for this augmented inspection implementation in 13R.

ATTACHMENT I (CONTINUED)
TECHNICAL DOCUMENTATION

- GPUN TDR 948, Rev. 1, "Statistical Analysis of Drywell Thickness Data."
- GPUN Specification IS-328227-004, Rev. 8, "Functional Requirements for Drywell Containment Vessel Thickness Examination."
- GPUN Calculation C-1302-187-5300-011, Rev. 0, "Statistical Analysis of Drywell Thickness Data from 4/24/90" (Appendices 6.1 to 6.3 not attached).
- GPUN TDR 1027, Rev. 1, "Design of a UT Inspection Plan for the Drywell Containment Using Statistical Inference Methods."
- GPUN Specification IS-402950-001, Rev. 0, "Functional Requirement for Augmented Drywell Inspection."

GPU Nuclear Technical Data Report	TDR No. 948	Revision No. ~~0~~ 1
	Budget Activity No. 315302	Page 1 of 26
Project: OYSTER CREEK	Department/Section 5300	
	Revision Date 2-1-89	

Document Title: STATISTICAL ANALYSIS OF DRYWELL THICKNESS DATA

Originator Signature	Date	Approval(s) Signature	Date
J. P. Moore Jr.	1-23-89	G. Capodanno	1/26/89
Mark A. Brake	1-24-89		
		Approval for External Distribution	Date

Does this TDR include recommendation(s)? ___Yes X No If yes, TFWR/TR# ____

*	Distribution	Abstract:
	J. D. Abramovici F. P. Barbieri G. R. Capodanno D. W. Covill D. G. Jerko M. W. Laggart L. C. Lanese S. D. Leshnoff J. A. Martin J. P. Moore M. A. Orski S. C. Tumminelli M. O. Sanford D. G. Slear R. W. Keaten	<u>Statement of Problem</u> The design of the carbon steel drywell includes a sand bed which is located around the outside circumference between elevations 8'-11- 1/4" and 12'-3". Leakage was observed from the sand bed drains during the 1980, 1983 and 1986 refueling outages indicating that water had intruded into the annular region between the drywell shell and the concrete shield wall. A long term monitoring program was established in 1986 to take Ultrasonic Thickness (UT) measurements at representative locations on the drywell shell to determine the corrosion rate and monitor it over time. The initial program included six locations in the sand bed region. The program was expanded in 1987 to include measurements at higher elevations. (For Additional Space Use Side 2)

* Abstract Only

A cathodic protection system is being installed in selected regions of the sand bed to minimize corrosion of the drywell. The long term monitoring program was further expanded in 1988 to monitor the effectiveness of the cathodic protection system and to monitor additional sand bed regions not covered by cathodic protection.

A critical part of the long term program is the statistical analysis of the UT measurements to determine the corrosion rate at each location. This report documents the assumptions, methods, and results of the statistical analyses of UT measurements taken through December 31, 1988.

Summary of Key Results

Bay Area	Location	Corrosion Rate**	Mean Thickness***
11A	Sand Bed	Not significant	908.6 ±5.0 mils
11C	Sand Bed	Indeterminable	916.6 ±10.4 mils
17D	Sand Bed	-27.6 ±6.1 mpy	864.8 ±6.8 mils
19A	Sand Bed	-23.7 ±4.3 mpy	837.9 ±4.8 mils
19B	Sand Bed	-29.2 ±0.5 mpy	856.5 ±0.5 mils
19C	Sand Bed	-25.9 ±4.1 mpy	860.9 ±4.0 mils
9D	Sand Bed	Indeterminable*	1021.4 ±9.7 mils
13A	Sand Bed	Not significant*	905.3 ±10.1 mils
15D	Sand Bed	Possible*	1056.0 ±9.1 mils
17A	Sand Bed	Indeterminable*	957.4 ±9.2 mils
5	51' Elev.	-4.3 ±0.03 mpy	750.0 ±0.02 mils
9	87' Elev.	Not significant	620.3 ±1.0 mils
13	87' Elev.	Not significant	635.6 ±0.7 mils
15	87' Elev.	Not significant	634.8 ±0.7 mils
17D	Trench	Not significant*	981.2 ±6.7 mils
17/19	Frame Cutout	Indeterminable*	981.7 ±4.4 mils
1D	Sand Bed	Indeterminable*	1114.7 ±30.6 mils
3D	Sand Bed	Not significant*	1177.7 ±5.6 mils
5D	Sand Bed	Not significant*	1174.0 ±2.2 mils
7D	Sand Bed	Possible*	1135.1 ±4.9 mils
9A	Sand Bed	Indeterminable*	1154.6 ±4.8 mils
13C	Sand Bed	Not significant*	1147.4 ±3.7 mils
13D	Sand Bed	Not significant*	962.1 ±22.3 mils
15A	Sand Bed	Not significant*	1120.0 ±12.6 mils

One data point in Bay 19A and one data point in Bay 5 Elev. 51' fell outside the 99% confidence interval and thus are statistically different from the mean thickness.

*Based on limited data. See text for interpretation.
**Mean corrosion rate in mils per year ± standard error of the mean
***Current mean thickness in mils ± standard error of the mean

GPU Nuclear	DOCUMENT NO. TDR 948

TITLE

STATISTICAL ANALYSIS OF DRYWELL THICKNESS DATA

REV	SUMMARY OF CHANGE	APPROVAL	DATE
1	Corrected outage numbers on pages 3 and 5 (two places). Deleted redundant discussion of Bay 15D on pages 12, 19, 25 and 26.	S. Moore G. Capodanno	1-30-89 1/31/89

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Background

The design of the carbon steel drywell includes a sand bed which is located around the outside circumference between elevations 8'-11-1/4" and 12'-3". Leakage was observed from the sand bed drains during the 1980, 1983 and 1986 refueling outages indicating that water had intruded into the annular region between the drywell shell and the concrete shield wall.

The drywell shell was inspected in 1986 during the 11R outage to determine if corrosion was occurring. The inspection methods, results and conclusions are documented in Ref. 3.1, 3.2, and 3.3. As a result of these inspections it was concluded that a long term monitoring program would be established. This program includes repetitive Ultrasonic Thickness (UT) measurements in the sand bed region at a nominal elevation of 11'-3" in bays 11A, 11C, 17D, 19A, 19B, and 19C.

The continued presence of water in the sand bed raised concerns of potential corrosion at higher elevations. Therefore, UT measurements were taken at the 51' and 87' elevations in November 1987 during the 11M outage. As a result of these inspections, repetitive measurements in Bay 5 at elevation 51' and in Bays 9, 13 and 15 at the 87' elevation were added to the long term monitoring program to confirm that corrosion is not occurring at these higher elevations.

A cathodic protection system is being installed in selected regions of the sand bed during the 12R outage to minimize corrosion of the drywell. The long term monitoring program was also expanded during the 12R outage to include measurements in the sand bed region of Bays 1D, 3D, 5D, 7D, 9A, 13A, 13C, 13D, 15A, 15D and 17A which are not covered by the cathodic protection system. It also includes measurements in the sand bed region between Bays 17 and 19 which is covered by the cathodic protection system, but does not have a reference electrode to monitor its effectiveness in this region.

Some measurements in the long term monitoring program are to be taken at each outage of opportunity, while others are taken during each refueling outage. The functional requirements for these inspections are documented in Ref. 3.4. The primary purpose of the UT measurements in the sand bed region is to determine the corrosion rate and monitor it over time. When the cathodic protection system is installed and operating, these data will be used to monitor its effectiveness. The purpose of the measurements at other locations is to confirm that corrosion is not occurring in those regions.

This report documents the assumptions, methods, and results of the statistical analyses used to evaluate the corrosion rate in each of these regions. The complete analyses are documented in Ref. 3.7.

1.2 Statistical Inferences

1.2.1 Statistical Hypotheses

The objective of these statistical analyses is to make statistical decisions or inferences about populations on the basis of sample information. In attempting to reach these decisions, it is useful to make assumptions or guesses about the populations involved. Such assumptions, which may or may not be true, are called statistical hypotheses and in general are statements about the probability distributions of the populations.

In many instances we formulate a statistical hypothesis for the sole purpose of rejecting or nullifying it. For example, in performing a t-test to test the difference between the means of two samples we first hypothesize that there is no difference between the two means. This is referred to as a null hypothesis. Any hypothesis which differs from the null hypothesis is referred to as an alternative hypothesis, eg., the means are not equal, one mean is greater than the other, etc.

1.2.2 Tests of Hypotheses and Significance

If on the supposition that a particular null hypothesis is true we find that results observed in a random sample differ markedly from those expected under the hypothesis on the basis of pure chance, we would say that the observed differences are significant and we would be inclined to reject the hypothesis (or at least not accept it on the basis of the evidence obtained). Procedures which enable us to decide whether to reject or not reject hypotheses are called tests of hypotheses.

1.2.3 Type I and Type II Errors

If we reject a hypothesis when it should not have been rejected, we say that a Type I error has been made. If, on the other hand, we fail to reject a hypothesis when it should have been rejected, we say a Type II error has been made. In either case a wrong decision or error in judgement has occurred.

1.2.4 Level of Significance

In testing a given hypothesis, the maximum probability with which we would be willing to risk a Type I error is called the level of significance of the test. This probability is usually denoted by the Greek letter alpha. In practice a level of significance of 0.05 (5%) or 0.01 (1%) is customary. If 0.05 has been selected, we say that the hypothesis is rejected (or not rejected) at a level of significance of 0.05.

2.0 METHODS

2.1 Selection of Areas to be Monitored

A program was initiated during the 11R outage to characterize the corrosion and to determine its extent. The details of this inspection program are documented in Ref. 3.3. The greatest corrosion was found via UT measurements in the sand bed region at the lowest accessible locations. Where thinning was detected, additional measurements were made in a cross pattern at the thinnest section to determine the extent in the vertical and horizontal directions. Having found the thinnest locations, measurements were made over a 6"-6" grid.

To determine the vertical profile of the thinning, a trench was excavated into the floor in Bay 17 and Bay 5. Bay 17 was selected since the extent of thinning at the floor level was greatest in that area. It was determined that the thinning below the top of the curb was no more severe than above the curb, and became less severe at the lower portions of the sand cushion. Bay 5 was excavated to determine if the thinning line was lower than the floor level in areas where no thinning was detected above the floor. There were no significant indications of thinning in Bay 5.

It was on the basis of these findings that the 6"x6" grids in Bays 11A, 11C, 17D, 19A, 19B and 19C were selected as representative locations for longer term monitoring. The initial measurements at these locations were taken in December 1986 without a template or markings to identify the location of each measurement. Subsequently, the location of the 6"x6" grids were permanently marked on the drywell shell and a template is used in conjunction with these markings to locate the UT probe for successive measurements. Analyses have shown that including the non-template data in the data base creates a significant variability in the thickness data. Therefore, to minimize the effects of probe location, only those data sets taken with the template are included in the analyses.

The presence of water in the sand bed also raised concern of potential corrosion at higher elevations. Therefore, UT measurements were taken at the 51' and 87' elevations in 1987 during the 11M outage. The measurements were taken in a band on 6-inch centers at all accessible regions at these elevations. Where these measurements indicated potential corrosion, the measurements spacing was reduced to 1-inch on centers. If these additional readings indicated potential corrosion, measurements were taken on a 6"x6" grid using the template. It was on the basis of these inspections that the 6"x6" grids in Bay 5 at elevation 51' and in bays 9, 13 and 15 at the 87' elevation were selected as representative locations for long term monitoring.

The long term monitoring program was expanded as follows during the 12R outage:

(1) Measurements on 6"x6" grids in the sand bed region of Bays 9D, 13A, 15D and 17A. The basis for selecting these locations is that they were originally considered for cathodic protection but are not included in the system being installed.

(2) Measurements on 1-inch centers along a 6-inch horizontal strip in the sand bed region of Bays 1D, 3D, 5D, 7D, 9A, 13C, and 15A. These locations were selected on the basis that they are representative of regions which have experienced nominal corrosion and are not within the scope of the cathodic protection system.

(3) A 6"x6" grid in the curb cutout between Bays 17 and 19. The purpose of these measurements is to monitor corrosion in this region which is covered by the cathodic protection system but does not have a reference electrode to monitor its performance.

2.2 UT Measurements

The UT measurements within the scope of the long term monitoring program are performed in accordance with Ref. 3.4. This involves taking UT measurements using a template with 49 holes laid out on a 6"x6" grid with 1" between centers on both axes. The center row is used in those bays where only 7 measurements are made along a 6-inch horizontal strip.

The first set of measurements were made in December 1986 without the use of a template. Ref. 3.4 specifies that for all subsequent readings, QA shall verify that locations of UT measurements performed are within ±1/4" of the location of the 1986 UT measurements. It also specifies that all subsequent measurements are to be within ±1/8" of the designated locations.

2.3 Data at Plug Locations

Seven core samples, each approximately two inches in diameter were removed from the drywell vessel shell. These samples were evaluated in Ref. 3.2. Five of these samples were removed within the 6"x6" grids for Bays 11A, 17D, 19A, 19C and Bay 5 at elevation 51'. These locations were repaired by welding a plug in each hole. Since these plugs are not representative of the drywell shell, UT measurements at these locations on the 6"x6" grid must be dropped from each data set.

The following specific grid points have been deleted:

Bay Area	Points
11A	23, 24, 30, 31
17D	15, 16, 22, 23
19A	24, 25, 31, 32
19C	20, 26, 27, 33,
5	20, 26, 27, 28, 33, 34, 35

2.4 Bases for Statistical Analysis of 6"x6" Grid Data

2.4.1 Assumptions

The statistical evaluation of the UT measurement data to determine the corrosion rate at each location is based on the following assumptions:

(1) Characterization of the scattering of data over each 6"x6" grid is such that the thickness measurements are normally distributed.

(2) Once the distribution of data for each 6"x6" grid is found to be normal, then the mean value of the thickness is the appropriate representation of the average condition.

(3) A decrease in the mean value of the thickness with time is representative of the corrosion occurring within the 6"x6" grid.

(4) If corrosion has ceased, the mean value of the thickness will not vary with time except for random errors in the UT measurements.

(5) If corrosion is continuing at a constant rate, the mean thickness will decrease linearly with time. In this case, linear regression analysis can be used to fit the mean thickness values for a given zone to a straight line as a function of time. The corrosion rate is equal to the slope of the line.

The validity of these assumptions is assured by:

(a) Using more than 30 data points per 6"x6" grid

(b) Testing the data for normality at each 6"x6" grid location.

(c) Testing the regression equation as an appropriate model to describe the corrosion rate.

These tests are discussed in the following section. In cases where one or more of these assumptions proves to be invalid, non-parametric analytical techniques can be used to evaluate the data.

2.4.2 Statistical Approach

The following steps are performed to test and evaluate the UT measurement data for those locations where 6"x6" grid data has been taken at least three times:

(1) Edit each 49 point data set by setting all invalid points to zero. Invalid points are those which are declared invalid by the UT operator or are at a plug location. (The computer programs used in the following steps ignore all zero thickness data points.)

(2) Perform a chi-squared goodness of fit test of each 49 point data set to ensure that the assumption of normality is valid at the 95% and 99% confidence levels.

(3) Calculate the mean thickness of each 49 point data set.

(4) Using the mean thickness values for each 6"x6" grid, perform linear regression analysis over time at each location.

(a) Perform F-test for significance of regression at the 95% confidence level. The result of this test indicates whether or not the regression model is more appropriate than the mean model. In other words, it tests to see if the variation of the regression model is statistically significant over that of a mean model.

(b) Calculate the co-efficient of determination (R^2) to assess how well the regression model explains the percentage of total error and thus how useful the regression line will be as a predictor.

(c) Determine if the residual values for the regression equations are normally distributed.

(d) If the regression model is found to be appropriate, calculate the y-intercept, the slope and their respective standard errors. The y-intercept represents the fitted mean thickness at time zero, the slope represents the corrosion rate, and the standard errors represent the uncertainty or random error of these two parameters.

(5) Use a z score of 2.58 and the standard deviation to establish a 99% confidence interval about the mean thickness values for each 6"x6" grid location to determine whether low thickness measurements or "outliers" are statistically significant. If the data points are greater than the 99% lower confidence limit, then the difference between the value and the mean is deemed to be due to expected random error. However, if the data point is less than the lower 99% confidence limit, this implies that the difference is statistically significant and is probably not due to chance.

2.5 Analysis of Two 6"x6" Grid Data Sets

Regression analysis is inappropriate when data is available at only two points in time. However, the t-Test can be used to determine if the means of the two data sets are statistically different.

2.5.1 Assumptions

This analysis is based upon the following assumptions:

(1) The data in each data set is normally distributed.

(2) The variances of the two data sets are equal.

2.5.2 Statistical Approach

The evaluation takes place in three steps:

(1) Perform a chi-squared test of each data set to ensure that the assumption of normality is valid at the 95% and 99% confidence levels.

(2) Perform an F-test of the two data sets being compared to ensure that the assumption of equal variances is valid at the 95% and 99% confidence levels.

(3) Perform a two-tailed t-Test for two independent samples to determine if the means of the two data sets are statistically different at the 0.05 and 0.01 levels of significance.

A conclusion that the means are not statistically different is interpreted to mean that significant corrosion did not occur over the time period represented by the data. However, if equality of the means is rejected, this implies that the difference is statistically significant and could be due to corrosion.

2.6 Analysis of Single 6"x6" Grid Data Set

In those cases where a 6"x6" data set is taken at a given location for the first time during the current outage, the only other data to which they can be compared are the UT survey measurements taken in 1986 to identify the thinnest regions of the drywell shell in the sand bed region. For the most part, these are single point measurements which were taken in the vicinity of the 49-point data set, but not at the exact location. Therefore, rigorous statistical analysis of these single data sets is impossible. However, by making certain assumptions, they can be compared with the previous data points. If more extensive data is available at the location of the 49-point data set, the t-test can be used to compare the means of the two data sets as described in paragraph 2.5.

When additional measurements are made at these exact locations during future outages, more rigorous statistical analyses can be employed.

2.6.1 Assumptions

The comparison of a single 49-point data sets with previous data from the same vicinity is based on the following assumptions:

(1) Characterization of the scattering of data over the 6"x6" grid is such that the thickness measurements are normally distributed.

(2) Once the distribution of data for the 6"x6" grid is found to be normal, then the mean value of the thickness is the appropriate representation of the average condition.

(3) The prior data is representative of the condition at this location in 1986.

2.6.2 Statistical Approach

The evaluation takes place in four steps:

(1) Perform a chi-squared test of each data set to ensure that the assumption of normality is valid at the 95% and 99% confidence levels.

(2) Calculate the mean and the standard error of the mean of the 49-point data set.

(3) Determine the two-tailed t value from a t distribution table at levels of significance of 0.05 and 0.01 for n-1 degrees of freedom.

(4) Use the t value and the standard error of the mean to calculate the 95% and 99% confidence intervals about the mean of the 49-point data set.

(5) Compare the prior data point(s) with these confidence intervals about the mean of the 49-point data sets.

If the prior data falls within the 95% confidence intervals, it provides some assurance that significant corrosion has not occurred in this region in the period of time covered by the data. If it falls within the 99% confidence limits but not within the 95% confidence limits, this implication is not as strong. In either case, the corrosion rate will be interpreted to be "Not Significant".

If the prior data falls above the upper 99% confidence limit, it could mean either of two things: (1) significant corrosion has occurred over the time period covered by the data, or (2) the prior data point was not representative of the condition of the location of the 49-point data set in 1986. There is no way to differentiate between the two. In this case, the corrosion rate will be interpreted to be "Possible".

If the prior data falls below the lower 99% confidence limit, it means that it is not representative of the condition at this location in 1986. In this case, the corrosion rate will be interpreted to be "Indeterminable".

2.7 Analysis of Single 7-Point Data Set

In those cases where a 7-point data set is taken at a given location for the first time during the current outage, the only other data to which they can be compared are the UT survey measurements taken in 1986 to identify the thinnest regions of the drywell shell in the sand bed region. For the most part, these are single point measurements which were taken in the vicinity of the 7-point data sets, but not at the exact locations. However, by making certain assumptions, they can be compared with the previous data points. If more extensive data is available at the location of the 7-point data set, the t-test can be used to compare the means of the two data sets as described in paragraph 2.5.

When additional measurements are made at these exact locations during future outages, more rigorous statistical analyses can be employed.

2.7.1 Assumptions

The comparison of a single 7-point data sets with previous data from the same vicinity is based on the following assumptions:

(1) The corrosion in the region of each 7-point data set is normally distributed.

(2) The prior data is representative of the condition at this location in 1986.

The validity of these assumptions cannot be verified.

2.7.2. Statistical Approach

The evaluation takes place in four steps:

(1) Calculate the mean and the standard error of the mean of the 7-point data set.

(2) Determine the two-tailed t value using the t distribution tables at levels of significance of 0.05 and 0.01 for n-1 degrees of freedom.

(3) Use the t value and the standard error of the mean to calculate the 95% and 99% confidence intervals about the mean of the 7-point data set.

(4) Compare the prior data point(s) with these confidence intervals about the mean of the 7-point data sets.

If the prior data falls within the 95% confidence intervals, it provides some assurance that significant corrosion has not occurred in this region in the period of time covered by the data. If it falls within the 99% confidence limits but not within the 95% confidence limits, this implication is not as strong. In either case, the corrosion rate will be interpreted to be "Not Significant".

If the prior data falls above the upper 99% confidence interval, it could mean either of two things: (1) significant corrosion has occurred over the time period covered by the data, or (2) the prior data point was not representative of the condition of the location of the 7-point data set in 1986. There is no way to differentiate between the two. In this case, the corrosion rate will be interpreted to be "Possible".

If the prior data falls below the lower 99% confidence limit, it means that it is not representative of the condition at this location in 1986. In this case, the corrosion rate will be interpreted to be "Indeterminable".

2.8 Evaluation of Drywell Mean Thickness

This section defines the methods used to evaluate the drywell thickness at each location within the scope of the long term monitoring program.

2.8.1 Evaluation of Mean Thickness Using Regression Analysis

The following procedure is used to evaluate the drywell mean thickness at those locations where regression analysis has been deemed to be more appropriate than the mean model.

(1) The best estimate of the mean thickness at these locations is the point on the regression line corresponding to the time when the most recent set of measurements was taken. In the SAS Regression Analysis output (Ref. 3.7), this is the last value in the column labeled "PREDICT VALUE".

(2) The best estimate of the standard error of the mean thickness is the standard error of the predicted value used above. In the SAS Regression Analysis output, this is the last value in the column labeled "STD ERR PREDICT".

(3) The two-sided 95% confidence interval about the mean thickness is equal to the mean thickness plus or minus t times the estimated standard error of the mean. This is the interval for which we have 95% confidence that the true mean thickness will fall within. The value of t is obtained from a t distribution table for <u>equal tails</u> at n-2 degrees of freedom and 0.05 level of significance, where n is the number of sets of measurements used in the regression analysis. The degrees of freedom is equal to n-2 because two parameters (the y-intercept and the slope) are calculated in the regression analysis with n mean thicknesses as input.

(4) The one-sided 95% lower limit of the mean thickness is equal to the estimated mean thickness minus t times the estimated standard error of the mean. This is the mean thickness for which we have 95% confidence that the true mean thickness does not fall below. In this case, the value of t is obtained from a t distribution table for <u>one tail</u> at n-2 degrees of freedom and 0.05 level of significance.

2.8.2 <u>Evaluation of Mean Thickness Using Mean Model</u>

The following procedure is used to evaluate the drywell mean thickness at those locations where the mean model is deemed to be more appropriate than the linear regression model. This method is consistent with that used to evaluate the mean thickness using the regression model.

(1) Calculate the mean of each set of UT thickness measurements.

(2) Sum the means of the sets and divide by the number of sets to calculate the grand mean. This is the best estimate of the mean thickness. In the SAS Regression Analysis output (Ref. 3.7), this is the value labelled "DEP MEAN".

(3) Using the means of the sets from (1) as input, calculate the standard error. This is the best estimate of the standard error of the mean thickness.

(4) The two-sided 95% confidence interval about the mean thickness is equal to the mean thickness plus or minus t times the estimated standard error of the mean. This is the interval for which we have 95% confidence that the true mean thickness will fall within. The value of t is obtained from a t distribution table for equal tails at n-1 degrees of freedom and 0.05 level of significance.

(5) The one-sided 95% lower limit of the mean thickness is equal to the estimated mean thickness minus t times the estimated standard error of the mean. This is the mean thickness for which we have 95% confidence that the true mean thickness does not fall below. In this case, the value of t is obtained from a t distribution table for one tail at n-1 degrees of freedom and 0.05 level of significance.

2.8.3 Evaluation of Mean Thickness Using Single Data Set

The following procedure is used to evaluate the drywell thickness at those locations where only one set of measurements is available.

(1) Calculate the mean of the set of UT thickness measurements. This is the best estimate of the mean thickness.

(2) Calculate the standard error of the mean for the set of UT measurements. This is the best estimate of the standard error of the mean thickness.

Confidence intervals about the mean thickness cannot be calculated with only one data set available.

3.0 REFERENCES

3.1 GPUN Safety Evaluation SE-000243-002, Rev. 0, "Drywell Steel Shell Plate Thickness Reduction at the Base Sand Cushion Entrenchment Region"

3.2 GPUN TDR 854, Rev. 0, "Drywell Corrosion Assessment"

3.3 GPUN TDR 851, Rev. 0, "Assessment of Oyster Creek Drywell Shell"

3.4 GPUN Installation Specification IS-328227-004, Rev. 3, "Functional Requirements for Drywell Containment Vessel Thickness Examination"

3.5 Applied Regression Analysis, 2nd Edition, N.R. Draper & H. Smith, John Wiley & Sons, 1981

3.6 Statistical Concepts and Methods G.K. Bhattacharyya & R.A. Johnson, John Wiley & sons, 1977

3.7 GPUN Calculation C-1302-187-5300-005, Statistical Analysis of Drywell Thickness Data Thru 12/31/88.

4.0 EVALUATION OF DATA THROUGH 12/31/88

4.1 Results for 6"x6" Grids in Sand Bed Region at Original Locations

4.1.1 Bay 11A: 5/1/87 to 10/8/88

Six 49-point data sets were available for this bay covering the time period from May 1, 1987 to October 8, 1988. Since a plug lies within this region, four of the points were voided in each data set. The data were analyzed as described in paragraphs 2.4 and 2.8.2.

(1) The data are normally distributed.

(2) The mean model is more appropriate than the regression model.

(3) The current mean thickness ± standard error is 908.6 ±5.0 mils.

(4) There was no significant corrosion from May 1, 1987 to October 8, 1988.

4.1.2 Bay 11C: 5/1/87 to 10/8/88

Five 49-point data sets were available for this bay covering the time period from May 1, 1987 to October 8, 1988. These data were analyzed as described in paragraphs 2.4 and 2.8.2. The initial analysis of this data indicated that the data are not normally distributed. The lack of normality was tentatively attributed to minimal corrosion in the upper half of the 6"x6" grid with more extensive corrosion in the lower half of the grid. To test this hypothesis, each data set was divided into two subsets, with one containing the top three rows and the other containing the bottom four rows.

The top subset was normally distributed but the bottom subset was not. For both subsets, the mean model is more appropriate than the regression model.

Since there is an observable decrease in the mean thickness with time, there appears to be some on-going corrosion at this location. Further analysis is required.

The current mean thickness ± standard error is 916.6 ±10.4 mils for the lower subset and 1057.6 ±16.9 mils for the upper subset.

4.1.3 Bay 17D: 2/17/87 to 10/8/88

Six 49-point data sets were available for this bay covering the time period from February 17, 1987 to October 8, 1988. Since a plug lies within this region, four of the points were voided in each data set. The data were analyzed as described in paragraphs 2.4 and 2.8.1.

(1) The data are normally distributed.

(2) The regression model is appropriate.

(3) The regression model explains 84% of the total variation about the mean.

(4) The residuals are normally distributed.

(5) The current mean thickness ± standard error is 864.8 ±6.8 mils.

(6) The corrosion rate ± standard error is -27.6 ±6.1 mils per year.

(7) The measurements below 800 mils were tested and determined not to be statistically different from the mean thickness.

4.1.4 Bay 19A: 2/17/87 to 10/8/88

Six 49-point data sets were available for this bay covering the time period from February 17, 1987 to October 8, 1988. Since a plug lies within this region, four of the points were voided in each data set. The data were analyzed as described in paragraphs 2.4 and 2.8.1.

(1) The data are nearly normally distributed.

(2) The regression model is appropriate

(3) The regression model explains 88% of the total variation about the mean.

(4) The residuals are normally distributed.

(5) The current mean thickness ± standard error is 837.9 ±4.8 mils.

(6) The corrosion rate ± standard error is -23.7 ±4.3 mpy.

(7) One data point that was below 800 mils at two different times was tested and determined to be statistically different from the mean thickness. The probability of this occurring is less than 1% at each specific time.

4.1.5 Bay 19B: 5/1/87 to 10/8/88

Five 49-point data sets were available for this bay covering the time period from May 1, 1987 to October 8, 1988. The data were analyzed as described in paragraphs 2.4 and 2.8.1.

(1) The data are normally distributed.

(2) The regression model is appropriate.

(3) The regression model explains 99% of the total variation about the mean.

(4) The residuals are normally distributed.

(5) The current mean thickness ± standard error is 856.5 ±0.5 mils.

(6) The corrosion rate ± standard error is -29.2 ±0.5 mpy.

(7) The measurements below 800 mils were tested and determined not to be statistically different from the mean thickness.

4.1.6 Bay 19C: 5/1/87 to 10/8/88

Five 49-point data sets were available for this bay covering the time period from May 1, 1987 to October 8, 1988. Since a plug lies within this region, four of the points were voided in each data set. The data were analyzed as described in paragraphs 2.4 and 2.8.1.

(1) The data are normally distributed.

(2) The regression model is appropriate.

(3) The regression model explains 91% of the total variation about the mean.

(4) The residuals are normally distributed.

(5) The current mean thickness ± standard error is 860.9 ±4.0 mils.

(6) The corrosion rate ± standard error is -25.9 ±4.1 mpy.

(7) The measurements below 800 mils were tested and determined not to be statistically different from the mean thickness.

4.2 Results for 6"x6" Grids in Sand Bed Region at New Locations

4.2.1 Bay 9D: 11/25/86 to 12/19/88

The 6"x6" grid data was taken in December 1988 during the 12R outage. This bay was considered for cathodic protection, but is not within the scope of the cathodic protection system being installed. The primary purpose of this data is to establish a base line to monitor corrosion in the future. However, previous measurements were taken in November 1986 in a 10-point 6"x6" cruciform pattern. Measurements were also taken in a 6"x6" grid in December 1986. The new data were compared with both of the previous data sets. These comparisons were made using the chi-squared test, F-test and two-tailed t-test as described in paragraph 2.5. The mean thickness was determined as described in paragraph 2.8.3.

(1) The data are normally distributed.

(2) The variances are equal in both comparisons.

(3) It is appropriate to use the two-tailed t-test in both comparisons.

(4) The difference between the means of the 1988 49-point data set and the 1986 10-point data set is not significant. However, there is a significant difference between the means of the 1988 49-point data set and the 1986 49-point data set. Therefore, significance of the corrosion rate is classified as "Indeterminable".

(5) The current mean thickness $\pm$ standard error is 1021.4 $\pm$9.7 mils.

4.2.2 Bay 13A: 11/25/86 to 12/17/88

The 6"x6" grid data was taken for the first time in December 1988 during the 12R outage. This bay was considered for cathodic protection, but is not within the scope of the cathodic protection being installed. The primary purpose of this data is to establish a base line to monitor corrosion in the future. However, previous measurements were taken in November 1986 in abutting 6"x6" cruciform patterns across the entire bay. As a best approximation, 13 of these data points are at the same location as the new 6"x6" grid data set. Therefore, the new data were first compared with these 13 data points, and then with 21 data points which include the 13 plus 8 additional points within one inch on either side. These comparisons were made using the chi-squared test, F-test and two-tailed t-test as described in paragraph 2.5. The mean thickness was determined as described in paragraph 2.8.3.

(1) The data are normally distributed.

(2) The variances are equal in both comparisons.

(3) It is appropriate to use the two-tailed t-test in both comparisons.

(4) The difference between the means of the data sets is not signficant. Therefore, the corrosion is classified as "Not Significant".

(5) The current mean thickness ± standard error is 905.3 ±10.1 mils.

4.2.3 Bay 15D: 11/25/86 to 12/17/88

The 6"x6" grid data was taken for the first time in December 1988 during the 12R outage. This bay was considered for cathodic protection, but is not within the scope of the cathodic protection being installed. The primary purpose of this data is to establish a base line to monitor corrosion in the future. However, a previous 1-point measurement was taken in November 1986. The location of this point may have been somewhat removed from the location of the new 6"x6" grid data set. The previous measurement was compared with the new data set using the methods described in paragraph 2.6. The mean thickness was determined as described in paragraph 2.8.3.

(1) The new data are normally distributed.

(2) The previous measurement falls above the 99% upper bound of the new data.

(3) This implies that the corrosion may have occurred in the time period covered by this data. Therefore, the corrosion is classified as "Possible".

(4) The current mean thickness ± standard error is 1056.0 ±9.1 mils.

4.2.4 Bay 17A: 11/25/86 to 12/17/88

The 6"x6" grid data was taken for the first time in December 1988 during the 12R outage. This bay was considered for cathodic protection, but is not within the scope of the cathodic protection being installed. The primary purpose of this data is to establish a base line to monitor corrosion in the future. However, a previous

1-point measurement was taken in November 1986. The location of this point may have been somewhat removed from the location of the new 6"x6" grid data set. The previous measurement was compared with the new data set using the methods described in paragraph 2.6. The mean thickness was determined as described in paragraph 2.8.3.

(1) The new data are not normally distributed. However, the top three rows and the bottom four rows are each normally distributed.

(2) The previous measurement falls below the 99% confidence interval for the top three rows, and above the 99% confidence interval for the bottom four rows.

(3) The corrosion is classified as "Indeterminable".

(4) The current mean thickness ± standard error is 1133.1 ±6.9 milsfor the top three rows and 957.4 ±9.2 mils for the bottom four rows.

4.3 Results for 6"x6" Grids at Upper Elevations

4.3.1 Bay 5 51' Elevation: 11/01/87 to 10/8/88

Three 49-point data sets were available for this bay covering the time period from November 1, 1987 to October 8, 1988. The data were analyzed as described in paragraphs 2.4 and 2.8.1.

(1) Except for the first data set, the data are normally distributed.

(2) The regression model is appropriate.

(3) The regression model explains 99% of the total variation about the mean.

(4) The residuals are normally distributed.

(5) The current mean thickness ± standard error is 750.0 ±0.02 mils.

(6) The corrosion rate ± standard error is -4.3 ±0.03 mpy.

(7) One data point was determined to be statistically different from the mean thickness. The probability of this occurring due to expected random error is less than 1% at each specific time.

4.3.2 Bay 9 87' Elevation: 11/6/87 to 10/8/88

Three 49-point data sets were available for this bay covering the time period from November 6, 1987 to October 8, 1988. The data were analyzed as described in paragraphs 2.4 and 2.8.2.

(1) The data are normally distributed.

(2) The mean model is appropriate than the regression model.

(3) There was no significant corrosion from November 6, 1987 to October 8, 1988.

(4) The current mean thickness ± standard error is 620.3 ±1.0 mils.

4.3.3 Bay 13 87' Elevation: 11/10/87 to 10/8/88

Three 49-point data sets were available for this bay covering the time period from November 10, 1987 to October 8, 1988. The data were analyzed as described in paragraphs 2.4 and 2.8.2.

(1) The data are normally distributed.

(2) The mean model is more appropriate than the regression model.

(3) There was no significant corrosion from November 10, 1987 to October 8, 1988.

(4) The current mean thickness ± standard error is 635.6 ±0.7 mils.

4.3.4 Bay 15 87' Elevation: 11/10/87 to 10/8/88

Three 49-point data sets were available for this bay covering the time period from November 10, 1987 to October 8, 1988. The data were analyzed as described in paragraphs 2.4 and 2.8.2.

(1) The data are normally distributed.

(2) The mean model is more appropriate than the regression model.

(3) There was no significant corrosion from November 10, 1987 to October 8, 1988.

(4) The current mean thickness ± standard error is 634.8 ±0.7 mils.

4.4 Results for Multiple 6"x6" Grids in Trench

4.4.1 Bay 17D Trench: 12/9/86 to 12/23/88

The two sets of measurements in the Bay 17D Trench were taken on December 9, 1986 and December 23, 1988. The 1986 data is a 7 column by 36 row array. The 1988 data is a 7 column by 42 row array. The 1986 data is at the same elevation as the lower 36 rows of the 1988 data, but is centered about 3-/12 inches to the left of the 1988 data. To compare these two data sets, the 1986 data set and the lower 36 rows of the 1988 data set were each subdivided into six 7 column by 6 row subsets. Each pair of subsets was compared as described in paragraphs 2.5 and 2.8.3.

Fourth Subset From The Top:

The chi-squared statistic for the fourth subset from the top from the 1986 data set slightly exceeded the critical value for level of significance of 0.05, but was within the critical value for level of significance of 0.01. Also, the F statistic exceeded the critical value for levels of significance of 0.05 and 0.01. Therefore, it is inappropriate to apply the two-tailed t-test based on equal variances. However, the approximate t-test based on unequal variances can be applied. From the results of this test, it is concluded that the difference between the mean thicknesses is not significant. This implies that corrosion at this location was not significant.

All Other Subsets:

(1) The data are normally distributed.

(2) The variances are equal.

(3) Comparison of the means using the two-tailed t-test is appropriate.

(4) The difference between the means of the subsets was not significant. This implies that there was no significant corrosion in the period from December 9, 1986 to December 23, 1988.

(5) The current mean thickness ± standard error of the top subset is 981.2 ±6.7 mils. This is the thinnest area in the trench.

4.4.2 Bays 17/19 Frame Cutout: December 1988

Two sets of 6"x6" grid measurements were taken in December 1988. The upper one is located 25" below the top of the high curb and the other below the floor. There is no previous data. The upper location has been added to the long term monitoring program. With no prior data, the only possible analysis was to check the data sets for normality using the chi-squared test.

The data at the upper location are not normally distributed. The lack of normality was tentatively attributed to minimal corrosion in the lower half of the 6"x6" grid with more extensive corrosion in the upper half of the grid. To test this hypothesis, each data set was divided into two subsets, with one containing the top three rows and the other containing the bottom four rows. These subsets proved to be normally distributed, thus confirming the hypothesis. The current mean thickness ± standard error is 981.7 ±4.4 mils for the top three rows and 1003.8 ±6.6 mils for the bottom four rows.

The data at the location below the floor is normally distributed. Also, the mean thickness is higher than at the upper location. The mean thickness ± standard error is 1034.1 ±6.8 mils.

4.5 Results for 6" Strips in Sand Bed Region

4.5.1 Bay 1D: 11/25/86 to 12/17/88

The 7-point data set was taken in December 1988 and a single point measurement was taken in November 1986. The data were compared as described in paragraph 2.7. The previous measurement falls below the 99% lower bound of the new 7-point data set. Thus, the corrosion rate is classified as indeterminable. The current mean thickness ± standard error is 1114.7 ±30.6 mils.

4.5.2 Bay 3D: 11/25/86 to 12/17/88

The 7-point data set was taken in December 1988 and a single point measurement was taken in November 1986. The data were compared as described in paragraph 2.7. The previous measurement falls within the 99% upper and lower bounds of the new 7-point data set. This implies that significant corrosion has not occurred at this location in the time period covered by the data. The current mean thickness ± standard error is 1177.7 ±5.6 mils.

4.5.3 Bay 5D: 11/25/86 to 12/17/88

The 7-point data set was taken in December 1988 and a single point measurement was taken in November 1986. The data were compared as described in paragraph 2.7. The previous measurement falls within the 95% upper and lower bounds of the new 7-point data set. This implies that significant corrosion has not occurred at this location in the time period covered by the data. The current mean thickness rate ± standard error is 1174.0 ±2.2 mils.

4.5.4 Bay 7D: 11/25/86 to 12/17/88

The 7-point data set was taken in December 1988 and a single point measurement was taken in November 1986. The data was compared as described in paragraph 2.7. The previous measurement falls just above the 99% upper bound of the new 7-point data set. This implies that corrosion has possibly occurred at this location in the time period covered by the data. The current mean thickness ± standard error is 1135.1 ±4.9 mils.

4.5.5 Bay 9A: 11/25/86 to 12/17/88

The 7-point data set was taken in December 1988 and a single point measurement was taken in November 1986. The data were compared as described in paragraph 2.7. The previous measurement falls below the 99% lower bound of the new 7-point data set. Thus, the corrosion rate is classified as indeterminable. The current mean thickness ± standard error is 1154.6 ±4.8 mils.

4.5.6 Bay 13C: 11/25/86 to 12/17/88

The 7-point data set was taken in December 1988 and a single point measurement was taken in November 1986. The data were compared as described in paragraph 2.7. The previous measurement falls within the 95% upper and lower bounds of the new 7-point data set. This implies that significant corrosion has not occurred at this location in the time period covered by the data. The current mean thickness ± standard error is 1147.4 ±3.7 mils.

4.5.7 Bay 13D: 11/25/86 to 12/17/88

The 7-point data set was taken in December 1988 and a single point measurement was taken in November 1986. The data were compared as described in paragraph 2.7. The previous measurement falls within the 95% upper and lower bounds of the new 7-point data set. This implies that significant corrosion has not occurred at this location in the time period covered by the data. The current mean thickness ± standard error is 962.1 ±22.3 mils.

4.5.8 Bay 15A: 11/25/86 to 12/19/88

The 7-point data set was taken in December 1988 and a single point measurement was taken in November 1986. Also, a 6"x6" grid data set was taken on December 2, 1986 at this location. As a best approximation, the first 5 points in the 7-point data set are at the same location as points 38 to 42 of the 6"x6" grid. These five points all fall within the 99% confidence interval of the new 7-point data set. The single measurement falls below the 99% lower bound. This implies that significant corrosion has not occurred at this location in the time period covered by the data. The current mean thickness ± standard error is 1120.0 ±12.6 mils.

4.6 Summary of Conclusions

Bay & Area	Location	Corrosion Rate**	Mean Thickness***
4.6.1 6"x6" Grids in Sand Bed Region at Original Locations			
11A	Sand Bed	Not significant	908.6 ±5.0 mils
11C	Sand Bed	Indeterminable	916.6 ±10.4 mils
17D	Sand Bed	-27.6 ±6.1 mpy	864.8 ±6.8 mils
19A	Sand Bed	-23.7 ±4.3 mpy	837.9 ±4.8 mils
19B	Sand Bed	-29.2 ±0.5 mpy	856.5 ±0.5 mils
19C	Sand Bed	-25.9 ±4.1 mpy	860.9 ±4.0 mils
4.6.2 6"x6" Grids in Sand Bed Region at New Locations			
9D	Sand Bed	Indeterminable*	1021.4 ±9.7 mils
13A	Sand Bed	Not significant*	905.3 ±10.1 mils
15D	Sand Bed	Possible*	1056.0 ±9.1 mils
17A	Sand Bed	Indeterminable*	957.4 ±9.2 mils
4.6.3 6"x6" Grids at Upper Elevations			
5	51' Elev.	-4.3 ±0.03 mpy	750.0 ±0.02 mils
9	87' Elev.	Not significant	620.3 ±1.0 mils
13	87' Elev.	Not significant	635.6 ±0.7 mils
15	87' Elev.	Not significant	634.8 ±0.7 mils
4.6.4 Multiple 6"x6" Grids in Trench			
17D	Trench	Not significant*	981.2 ±6.7 mils
17/19	Frame Cutout	Indeterminable*	981.7 ±4.4 mils

4.6.5 6" Strips in Sand Bed Region

1D	Sand Bed	Indeterminable*	1114.7 ±30.6 mils
3D	Sand Bed	Not significant*	1177.7 ±5.6 mils
5D	Sand Bed	Not significant*	1174.0 ±2.2 mils
7D	Sand Bed	Possible*	1135.1 ±4.9 mils
9A	Sand Bed	Indeterminable*	1154.6 ±4.8 mils
13C	Sand Bed	Not significant*	1147.4 ±3.7 mils
13D	Sand Bed	Not significant*	962.1 ±22.3 mils
15A	Sand Bed	Not significant*	1120.0 ±12.6 mils

4.6.6 Evaluation of Individual Measurements Below 800 Mils

One data point in Bay 19A and one data point in Bay 5 Elev. 51' fell outside the 99% confidence interval and thus are statistically different from the mean thickness.

*Based on limited data. See text for interpretation.
**Mean corrosion rate in mils per year ± standard error of the mean
***Current mean thickness in mils ± standard error of the mean

DRF 82745 R-6
DRF 82948 R-7

GPU Nuclear

SPECIFICATION
IS-328227-004

INSTALLATION SPECIFICATION FOR

OYSTER CREEK

FUNCTIONAL REQUIREMENTS FOR DRYWELL CONTAINMENT VESSEL
THICKNESS EXAMINATION

PREPARATION John A. Martin DATE 2/19/87

ENGINEERING APPROVAL DATE 2/19/87

QA CONCURRENCE MWQ 2-20-87 for B. Slataney DATE 2/20/87

DRF 62981 R3
DRF 52142 R0
DRF 53067 R-1
DRF 062876 Rev 4

REV. 8

A000 0023 10-82

GPU Nuclear

DOCUMENT NO. IS-328227-004

FUNCTIONAL REQUIREMENTS FOR DRYWELL SHELL THICKNESS INSPECTION

REV	SUMMARY OF CHANGE	APPROVAL	DATE
1	1.0 Added instructions on data submittal and that evaluation is not needed for restart. 3.1.3.1 Revised areas to be inspected. 5.0 Added statement on analysis of data.	JPR [illegible]	3/2/87 3/2/87
2	4.2 Incorporate FCN C039843.	JPR [illegible] [illegible]	4/30/87 4/30/87 4/30/87
3	Added Elevations 23'-6" and 46'-2", 82'-2" requirements throughout.	[illegible] [illegible] [illegible]	8/21/87 [illegible] 9/17/87
4	o Incorporated FCN C052217. o Made the following changes to reflect new inspection program: Amended 1.1 and deleted 1.2 and 1.3. - Replaced Reference 2.6, and added 2.8 thru 2.12. - Modified 3.1.3.1 to add new grid locations. - Deleted 3.1.3.3, 3.1.4.3, 3.2.1.3, renumbered remaining paragraphs. - Modified 3.1.4.2 to define new grid inspection program. - Modified References in 3.2.1.2. - Modified 3.2.1.3 to require repainting of all areas. - Modified 4.2 to reflect new inspection program of baseline areas. - Deleted 4.2.3, 4.3 and 4.4. - Modified 3.2.2.1 to reflect and direct interface between QA and Technical Functions.	[illegible] F.P. Barbieri [illegible]	2/10/88 2/19/88 [illegible]
5	- Incorporated FCR C057638 to Section 3.2.1.3. - Added new UT areas to Section 3.1.3. - Prioritized areas in Section 3.1.3. - Revised scope to reflect changes to Section 3.1.3. - Revised 3.1.4.1 for clarification of intent. - Defined minimum intervals between inspections.	[illegible] Fred P. Barbieri	9/1/89 9/12/89

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GPU Nuclear

DOCUMENT NO
[illegible]

TITLE FUNCTIONAL REQUIREMENTS FOR DRYWELL CONTAINMENT VESSEL THICKNESS EXAMINATION

REV	SUMMARY OF CHANGE	APPROVAL	DAT
6	Due to unexpected results from February 9, 1990 Revision 6 provides an expanded inspection scope and frequency for the time period from March 21, 1990 to January 1991. - Added Section [illegible]. - Revised section 1.1 [illegible], 3.1.4.1, 3.2.1.2 and 4.2.1.	Peter Tamburro Fred P. Barbieri Bob [illegible] Conn QA	[illegible] 3/24/[illegible] 3/24/[illegible]
7	Revision 7 provides for an expanded inspection scope at elevation 51'-10" which previously has not been inspected. This inspection is required to demonstrate that the drywell plate between elevation 51' and 65' have adequate margin. Revision 7 also adds several new priority #1 inspection locations based on previous inspections at elevation 50' 2". In addition, several priority #2 locations have been changed to priority #1.	Peter Tamburro Fred P. Barbieri Bob [illegible]	4/23/[illegible] 4/23/[illegible] 4/23/[illegible]

GPU Nuclear		DOCUMENT NO. IS-328227-004	
TITLE	FUNCTIONAL REQUIREMENTS FOR DRYWELL CONTAINMENT VESSEL THICKNESS EXAMINATION		
REV	**SUMMARY OF CHANGE**	**APPROVAL**	**DATE**
8	Revision 8 adds a new priority #1 inspection location based on previous inspections at elevation 51' 10". Also, the requirement for an expanded scope inspection of this elevation (performed in April per revision 7) was deleted. QA Review of this revision is not required. FPB.	Peter Tate Fred P. Barbieri	5/2/90 5/2/90

N0036 (03-90)

TABLE OF CONTENTS

1.0 SCOPE

This specification establishes the minimum requirements for ultrasonic testing (examination) of the Oyster Creek drywell containment vessel for wall thickness measurements.

1.1 Revision 8 of this specification provides an inspection scope and frequency up to the 13R outage. Ultrasonic testing (UT) is to be performed during forced outages whenever a drywell entry is otherwise planned or required (referred to as "Outage of Opportunity") as well as refueling outages. Data shall be taken as a minimum at the time indicated in Section 3.1.3 herein.

1.2 All data shall be forwarded to Technical Functions for evaluation. Evaluation of data is not required for plant restart.

2.0 REFERENCES

2.1 ASME B&PV Code Section V, 1977 Edition through Addenda Summer, 1978.

2.2 ASME B&PV Code Section XI, 1977 Edition through Addenda Summer, 1978.

2.3 NRC letter dated January 14, 1987, titled "December 19, 1986, Third Meeting with GPU Nuclear (GPUN) to Discuss Corrosion of the Outer Surface of the Drywell Shell."

2.4 GPUN 6100-STD-7230.01, "NDE Personnel Qualification and Certification."

2.5 GPUN 6130-QAP-7209.24, Rev. 0, "Ultrasonic Thickness Measurement."

2.6 GPUN Sketch, Dwg. No. SK-S-89.

2.7 GPU Sketch, Dwg. No. SK-2B3.

2.8 QC Thickness Data Sheet as listed herein.

3.0 REQUIREMENTS

3.1 Non-destructive Examinations

3.1.1 Personnel Qualification

3.1.1.1 Ultrasonic personnel shall be qualified and certified in accordance with Reference 2.4 or a GPUN approved vendor SNT-TC-1A program.

3.1.2 Examination Methods/Equipment

3.1.2.1 Ultrasonic examination pulse-echo equipment capable of thickness measurement by the digital and A-scan on a CRT screen shall be utilized. One instrument capable of both presentations or two separate instruments are acceptable.

Digital readout equipment shall have printout capabilities and memory storage traceable to sequential readings.

The digital readout equipment shall be the primary technique employed to measure wall thinning. A-scan on a CRT screen shall be utilized to confirm in wall reflectors. The UT method shall be performed in accordance with Reference 2.5.

3.1.3 Data Acquisition Priorities Locations

3.1.3.1 Each area indicated in Section 3.1.3.2 shall be inspected, at the time interval required, on the basis of its assigned priority.

Inspection requirements for each priority are as follows:

Priority 1 areas are to be inspected in each outage of opportunity but not more frequently than approximately once every three months.

Priority 2 areas are to be inspected in an outage of opportunity if the previous set of data was taken 18 months or more before the outage.

3.1.3.2 Revision 8 of this specification adds several priority #1 locations at elevation 51' 10". These locations were initially inspected in April 1990.

The drywell vessel wall at the following locations shall be investigated:

a. Grids at floor elevation 11'3"

Area	6"x6" Grid (See Exhibits 1 & 2	Original QC Thickness Data Sheet Number	Priority
9	D	87-026-59	1
11	A	86-049-24	1
11	C	86-049-37	1
13	A	87-026-58	1
13	D	87-026-67	1
15	D	87-026-58	1
17	A	87-026-58	1
17	D	86-049-26	1
17/19	Frame	87-026-66	1
19	A	86-049-27	1
19	B	86-049-28	1
19	C	86-049-29	1

b.

Grids At	Original QC Thickness Data Sheet	Priority
Floor Elevation 51-D1	87-026-26	1
Elevation 51', Bay 13	87-026-122	1
Elevation 51', Bay 5	87-026-124	1
Elevation 51', Bay 15	87-026-123	1
Elevation 52', Bay 13 (area 32)	87-026-144	1
Top of Biological Shield 86-20	87-026-30	1

b. (Cont.)

Grids At	Original QC Thickness Data Sheet	Priority
Top of Biological Shield 86-28	87-026-37	1
Top of Biological Shield 86-31	87-026-38	1

c.

Strips at Floor Elevation 11'3"	Original QC Thickness Data Sheet	Priority
1D	87-026-54	2
3D	87-026-55	2
5D	87-026-56	2
7D	87-026-57	2
9A	87-026-60	2
13C	87-026-61	2
15A	87-026-62	2

3.1.4 Records

3.1.4.1 All grid UT data in Section 3.1.3.2 shall be taken at the same locations as those taken previously and using the 6"x6" grid (7x7 array) as defined in QC data sheet 86-049-13. The readings shall be taken within the tolerance specified in 4.2.1.

3.1.4.2 All UT data in Section 3.1.3.2 shall be taken at the same locations as those indicated on the original thickness data sheets.

3.2 Organizational and Functional Requirements

3.2.1 Work to be performed by Maintenance, Construction and Facilities (MCF)

3.2.1.1 Supply tools and materials required for surface preparation of the coated steel (coating removal) as required.

3.2.1.2 Prepare the 6"x6" grid identified in 3.1.3.1 and 3.1.3.2, and 3.1.3.3 as directed by Quality Control (QC). Preparation technique shall be such that no base material is removed.

3.2.1.3 After UT inspection of grids, the area shall be coated with Syncogel White E.P. grease stock #412-120-66-00-0.

3.2.1.4 Temporary planking shall be provided as necessary at the top of the biological shield extending to the drywell wall. It is not intended that the planking be continuous for the entire circumference. The planking shall be such that it can be moved along as work continues.

3.2.2 Duties to be performed by Quality Assurance Department

3.2.2.1 The NDE/ISI Group shall perform the thickness examinations required by this specification and interface with Technical Functions as required.

3.2.2.2 The NDE/ISI Group shall be responsible for the conduct and implementation of the requirements of this specification and the interface requirements of 3.2.2.

4.0 <u>QUALITY ASSURANCE</u>

4.1 All work shall be performed in accordance with GPUN Operational QA Program. This work is classified Important to Safety/Nuclear Safety Related.

4.2 Locations of Inspection Points

4.2.1 NDE/ISI shall verify that locations (specified in Section 3.1.3.2) of UT measurements performed are within ±1/8" of the designated locations. This shall be accomplished by use of a template (see Exhibit 2). The drywell wall was previously stamped at the notches provided in the template with low stress die stamps. The locations of investigation shall be repeated by use of these stamps for relocating the template.

4.2.2 This template shall be made of 304 or 316 SS sheet metal of approximately .030 inch thickness. The template shall be six inches square with circular holes cut out on one inch centers. The diameter of the holes shall be sufficient to allow 1/2 inch diameter UT transducers to fit through the template. Typical grid pattern shall be as shown in Exhibit 2.

5.0 INFORMATION TO BE SUBMITTED

5.1 UT data sheets and calibration sheets in accordance with Reference 2.5. Analysis of data is not required prior to restart.

6.0 ATTACHMENTS

6.1 Exhibit 1 - Typical Area of Exams at Elevation 11'3".

6.2 Exhibit 2 - Typical Grid Pattern (6"x6").

6.3 Exhibit 3 - UT Layout Number System.

EXHIBIT 1

Typical Area of Exams at Elevation 11'3"

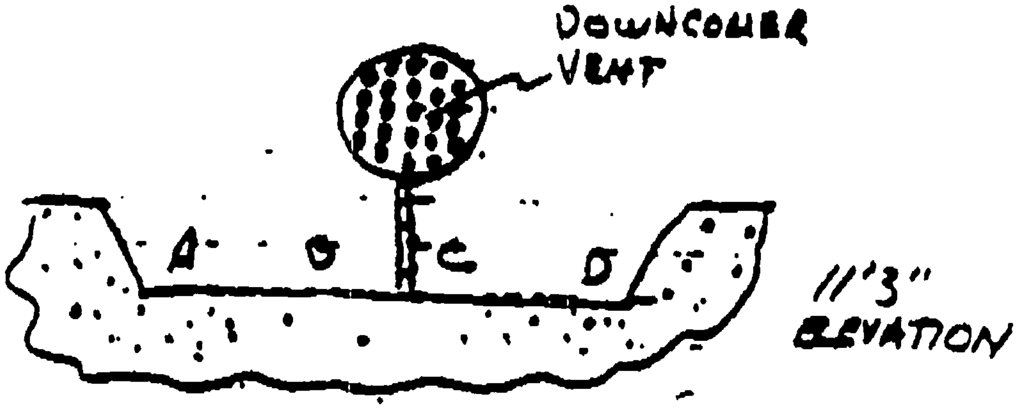

EXHIBIT 2

Typical Grid Pattern (6" x 6")

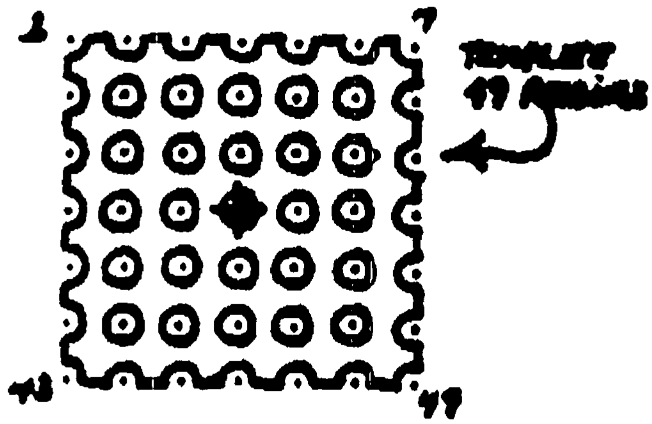

EXHIBIT 3

UT Layout Numbering System

	A	B	C	D
Bay 1	1	2	3	4
3	5	6	7	8
5	9	10	11	12
7	13	14	15	16
9	17	18	19	20
11	21	22	23	24
13	25	26	27	28
15	29	30	31	32
17	33	34	35	36
19	37	38	39	40

GPU Nuclear **Calculation Sheet**

DRF 92863 R.0

Subject	Calc No.	Rev. No.	Sheet No.
STATISTICAL ANALYSIS OF DRYWELL THICKNESS DATA THRU 4-24-90	C-1302-187-5300-011	0	1 of 454

Originator	Date	Reviewed by	Date
[signature] Moore	6-13-90	[signature]	6/13/90

[signature] 6/13/90

Verification V-1302-187-005 R2

1.0 PROBLEM STATEMENT

The basic purpose of this calculation is to update the thickness measurement analyses documented in References 3.7, 3.8, and 3.11 by incorporating the measurements taken in March and April 1990.

Specific objectives of this calculation are:

(1) Statistically analyze the thickness measurements in the sand bed region to determine the mean thickness and corrosion rate.

(2) Analyze the data taken since the 12R outage for Bays 11A, 11C, 17D, 19A, 19B, 19C, and the Frame Cutout between Bays 17 and 19 to determine if cathodic protection has reduced the corrosion rate.

(3) Statistically analyze the thickness measurements for Bay 5 at elevation 51' and Bays 9, 13 and 15 at elevation 87' to determine the mean thickness and corrosion rate.

(4) To the extent possible, analyze the data for the new locations at elevation 51' and elevation 52'.

2.0 SUMMARY OF RESULTS

Bay & Area	Corrosion Rate **	Mean Thickness ***	F-Ratio
2.1 Sand Bed Region With Cathodic Protection - All Data			
11A	-15.6 ±2.9 mpy	870.4 ± 5.7 mils	5.4
11C Top	-35.2 ±6.8 mpy	977.0 ±12.5 mils	4.6
11C Bottom	-22.4 ±4.3 mpy	865.0 ± 7.8 mils	4.9
17D	-25.0 ±2.0 mpy	829.5 ± 4.0 mils	29.4
19A	-21.4 ±1.5 mpy	807.6 ± 3.0 mils	39.5
19B	-19.0 ±1.7 mpy	836.9 ± 3.2 mils	21.3
19C	-24.3 ±1.3 mpy	825.1 ± 2.3 mils	66.2
2.2 Sand Bed Region With Cathodic Protection - Since October 1988			
11A	Not Significant*	878.0 ± 5.9 mils	
11C Top	Not Significant*	996.6 ± 8.3 mils	
11C Bottom	Not Significant*	878.1 ± 5.6 mils	
17D	-23.7 ±4.6 mpy	830.1 ± 3.8 mils	2.7
19A	-20.6 ±3.9 mpy	808.2 ± 3.2 mils	2.8
19B	-11.8 ±3.9 mpy	841.2 ± 3.3 mils	0.9
19C	-21.5 ±3.5 mpy	826.3 ± 2.9 mils	3.7
2.3 Sand Bed Region Frame Cutout			
17/19 Top	Not Significant*	986.0 ± 4.7 mils	
17/19 Bottom	Not Significant*	1008.4 ± 3.9 mils	
2.4 Sand Bed Region Without Cathodic Protection			
9D	Not Significant*	1021.7 ± 8.9 mils	
13A	-39.1 ± 3.4 mpy	853.1 ± 2.4 mils	16.9
13D	Indeterminate	931.9 ±22.6 mils	
15D	Not Significant*	1056.5 ± 2.3 mils	
17A Top	Not Significant*	1128.3 ± 2.2 mils	
17A Bottom	Not Significant*	745.2 ± 2.1 mils	1.3

* Not statistically significant compared to random variations in measurements
** Mean corrosion rate in mils per year ± standard error of estimate
***Best estimate of current mean thickness in mils ± standard error of the mean

Bay & Area	Corrosion Rate **	Mean Thickness ***	F-Ratio
2.5 Elevation 51'			
5/D-12	- 4.6 ± 1.6	745.2 ± 2.1 mils	1.3
5/5	Indeterminate	745.1 ± 3.2 mils	
13/31	Indeterminate	750.8 ±11.5 mils	
15/23	Indeterminate	751.2 ± 3.8 mils	
2.6 Elevation 52'			
7/25	Indeterminate	715.5 ± 2.9	
13/6	Indeterminate	724.9 ± 2.9	
13/32	Indeterminate	698.3 ± 5.0	
19/13	Indeterminate	712.5 ± 3.1	
2.7 Elevation 87'			
9	Not Significant*	619.9 ± 0.6	
13	Not Significant*	636.5 ± 0.8	
15	Not Significant*	636.2 ± 1.1	

2.5 Apparent Corrosion Rates

These estimates of the corrosion rate are based on a least squares fit of the data. In those cases where the F-Ratio is less than 1.0 they should not be used to make future projections. For bays with cathodic protection, these apparent rates are for the period from October 1988 to April 1990. For the other bays, it is for all data.

Bay	Apparent Corrosion Rate (mpy)	F-Ratio	Bay	Apparent Corrosion Rate (mpy)	F-Ratio
11A	-16.2 ± 8.6	0.2	9D	-21.0 ±18.1	0.1
11C Top	-25.0 ±10.6	0.6	13A	-39.1 ± 3.4	16.9
11C Bottom	-16.7 ± 7.1	0.6	15D	- 4.6 ± 4.8	0.1
17D	-23.7 ± 4.6	2.7	17A Top	- 6.8 ± 3.7	0.3
19A	-20.6 ± 3.9	2.8	17A Bottom	-17.7 ± 7.6	0.01
19B	-11.8 ± 3.9	0.9	5 EL 51'	- 4.6 ± 1.6	1.3
19C	-21.5 ± 3.5	3.7	9 EL 87'	- 0.2 ± 0.9	zero
17/19 Top	- 8.2 ±10.7	0.1	13 EL 87'	zero	
17/19 Bottom	-13.1 ±11.6	0.1	15 EL 87'	zero	

2.6 Evaluation of Individual Measurements Exceeding 99%/99% Tolerance Interval

One data point in Bay 5 Elev. 51' fell outside the 99%/99% tolerance interval and thus is statistically different from the mean thickness.

Based on a linear regression analysis for this point, it is concluded that the corrosion rate in this pit is essentially the same as the overall grid.

3.0 REFERENCES

3.1 GPUN Safety Evaluation SE-000243-002, Rev. 0, "Drywell Steel Shell Plate Thickness Reduction at the Base Sand Cushion Entrenchment Region"

3.2 GPUN TDR 854, Rev. 0, "Drywell Corrosion Assessment"

3.3 GPUN TDR 851, Rev. 0, "Assessment of Oyster Creek Drywell Shell"

3.4 GPUN Installation Specification IS-328227-004, Rev. 3, "Functional Requirements for Drywell Containment Vessel Thickness Examination"

3.5 Applied Regression Analysis, 2nd Edition, N.R. Draper & H. Smith, John Wiley & Sons, 1981

3.6 Statistical Concepts and Methods, G.K. Bhattacharyya & R.A. Johnson, John Wiley & sons, 1977

3.7 GPUN Calculation C-1302-187-5300-005, Rev. 0, "Statistical Analysis of Drywell Thickness Data Thru 12-31-88"

3.8 GPUN TDR 948, Rev. 1, "Statistical Analysis of Drywell Thickness Data"

3.9 Experimental Statistics, Mary Gibbons Natrella, John Wiley & Sons, 1966 Reprint. (National Bureau of Standards Handbook 91)

3.10 Fundamental Concepts in the Design of Experiments, Charles C. Hicks, Saunders College Publishing, Fort Worth, 1982

3.11 GPUN Calculation C-1302-187-5300-008, Rev. 0, "Statistical Analysis of Drywell Thickness Data thru 2-8-90"

4.0 ASSUMPTIONS & BASIC DATA

4.1 Background

The design of the carbon steel drywell includes a sand bed which is located around the outside circumference between elevations 8'-11-1/4" and 12'-3". Leakage was observed from the sand bed drains during the 1980, 1983 and 1986 refueling outages indicating that water had intruded into the annular region between the drywell shell and the concrete shield wall.

The drywell shell was inspected in 1986 during the 10R outage to determine if corrosion was occurring. The inspection methods, results and conclusions are documented in Ref. 3.1, 3.2, and 3.3. As a result of these inspections it was concluded that a long term monitoring program would be established. This program includes repetitive Ultrasonic Thickness (UT) measurements in the sand bed region at a nominal elevation of 11'-3" in bays 11A, 11C, 17D, 19A, 19B, and 19C.

The continued presence of water in the sand bed raised concerns of potential corrosion at higher elevations. Therefore, UT measurements were taken at the 51' and 87' elevations in November 1987 during the 11R outage. As a result of these inspections, repetitive measurements in Bay 5 at elevation 51' and in Bays 9, 13 and 15 at the 87' elevation were added to the long term monitoring program to confirm that corrosion is not occurring at these higher elevations.

A cathodic protection system was installed in selected regions of the sand bed during the 12R outage to minimize corrosion of the drywell. The cathodic protection system was placed in service on January 31, 1989. The long term monitoring program was also expanded during the 12R outage to include measurements in the sand bed region of Bays 1D, 3D, 5D, 7D, 9A, 13A, 13C, 13D, 15A, 15D and 17A which are not covered by the cathodic protection system. It also includes measurements in the sand bed region between Bays 17 and 19 which is covered by the cathodic protection system, but does not have a reference electrode to monitor its effectiveness in this region.

The high corrosion rate computed for Bay 13A in the sand bed region through February 1990 (Ref. 3.11) raised concerns about the corrosion rate in the sand bed region of Bay 13D. Therefore, the monitoring of this location using a 6"x6" grid was added to the long term monitoring program. In addition, a 2-inch core sample was removed in March 1990 from a location adjacent to the 6"x6" monitored grid in Bay 13A.

Measurements taken in Bay 5 Area D-12 at elevation 51' through March 1990 indicated that corrosion is occurring at his location. Therefore, survey measurements were taken to determine the thinnest locations at elevation 51'. As a result, three new locations were added to the long term monitoring program (Bay 5 Area 5, Bay 13 Area 31, and Bay 15 Area 2/3).

The indication of ongoing corrosion at elevation 51' raised concerns about potential corrosion of the plates immediately above which have a smaller nominal thickness. Therefore, survey measurements were taken in April 1990 at the 52' elevation in all bays to determine the thinnest locations. As a result of this survey, four new locations were added to the long term monitoring plan at elevation 52' (Bay 7 area 25, Bay 13 Area 6, Bay 13 Area 32, and Bay 19 Area 13).

Some measurements in the long term monitoring program are to be taken at each outage of opportunity, while others are taken during each refueling outage. The functional requirements for these inspections are documented in Ref. 3.4. The purpose of the UT measurements is to determine the corrosion rate and monitor it over time, and to monitor the effectiveness of the cathodic protection system.

4.2 Selection of Areas to be Monitored

A program was initiated during the 11R outage to characterize the corrosion and to determine its extent. The details of this inspection program are documented in Ref. 3.3. The greatest corrosion was found via UT measurements in the sand bed region at the lowest accessible locations. Where thinning was detected, additional measurements were made in a cross pattern at the thinnest section to determine the extent in the vertical and horizontal directions. Having found the thinnest locations, measurements were made over a 6"x6" grid.

To determine the vertical profile of the thinning, a trench was excavated into the floor in Bay 17 and Bay 5. Bay 17 was selected since the extent of thinning at the floor level was greatest in that area. It was determined that the thinning below the top of the curb was no more severe than above the curb, and became less severe at the lower portions of the sand cushion. Bay 5 was excavated to determine if the thinning line was lower than the floor level in areas where no thinning was detected above the floor. There were no significant indications of thinning in Bay 5.

It was on the basis of these findings that the 6"x6" grids in Bays 11A, 11C, 17D, 19A, 19B and 19C were selected as representative locations for longer term monitoring. The initial measurements at these locations were taken in December 1986 without a template or markings to identify the location of each measurement. Subsequently, the location of the 6"x6" grids were permanently marked on the drywell shell and a template is used in conjunction with these markings to locate the UT probe for successive measurements. Analyses have shown that including the non-template data in the data base creates a significant variability in the thickness data. Therefore, to minimize the effects of probe location, only those data sets taken with the template are included in the analyses.

The presence of water in the sand bed also raised concern of potential corrosion at higher elevations. Therefore, UT measurements were taken at the 51' and 87' elevations in 1987 during the 11M outage. The measurements were taken in a band on 6-inch centers at all accessible regions at these elevations. Where these measurements indicated potential corrosion, the measurements spacing was reduced to 1-inch on centers. If these additional readings indicated potential corrosion, measurements were taken on a 6"x6" grid using the template. It was on the basis of these inspections that the 6"x6" grids in Bay 5 at elevation 51' and in bays 9, 13 and 15 at the 87' elevation were selected as representative locations for long term monitoring.

A cathodic protection system was installed in the sand bed region of Bays 11A, 11C, 17D, 19A, 19B, 19C, and at the frame between Bays 17 and 19 during the 12R outage. The system was placed in service on January 31, 1989.

The long term monitoring program was expanded as follows during the 12R outage:

(1) Measurements on 6"x6" grids in the sand bed region of Bays 9D, 13A, 15D and 17A. The basis for selecting these locations is that they were originally considered for cathodic protection but are not included in the system being installed.

(2) Measurements on 1-inch centers along a 6-inch horizontal strip in the sand bed region of Bays 1D, 3D, 5D, 7D, 9A, 13C, and 15A. These locations were selected on the basis that they are representative of regions which have experienced nominal corrosion and are not within the scope of the cathodic protection system.

(3) A 6"x6" grid in the curb cutout between Bays 17 and 19. The purpose of these measurements is to monitor corrosion in this region which is covered by the cathodic protection system but does not have a reference electrode to monitor its performance.

The long term monitoring program was expanded in March 1990 as follows:

(1) Measurements in the sand bed region of Bay 13D: This location was added due to the high indicated corrosion rate in the sand bed region of Bay 13A. The measurements taken in March 1990 were taken on a 1"x6" grid. All subsequent measurements are to be taken on a 6"x6" grid.

(2) Measurements on 6"x6" grids at the following locations at elevation 51': Bay 5 Area 5, Bay 13 Area 31, and Bay 15 Area 2/3. These locations were added due to the indication of ongoing corrosion at elevation 51', Bay 5 Area D-1.

The long term monitoring program was expanded in April 1990 by adding the following locations at elevation 52': Bay 7 Area 25, Bay 13 Area 6, Bay 13 Area 32, and Bay 19 Area 13. All measurements are taken on 6"x6" grids. These locations were added due to the indication of ongoing corrosion at elevation 51' and the fact that the nominal plate thickness at elevation 52' is less than at elevation 51'.

4.3 UT Measurements

The UT measurements within the scope of the long term monitoring program are performed in accordance with Ref. 3.4. This involves taking UT measurements using a template with 49 holes laid out on a 6"x6" grid with 1" between centers on both axes. The center row is used in those bays where only 7 measurements are made along a 6-inch horizontal strip.

The first set of measurements were made in December 1986 without the use of a template. Ref. 3.4 specifies that for all subsequent readings, QA shall verify that locations of UT measurements performed are within ± 1/4" of the location of the 1986 UT measurements. It also specifies that all subsequent measurements are to be within ± 1/8" of the designated locations.

4.4 Data at Plug Locations

Seven core samples, each approximately two inches in diameter were removed from the drywell vessel shell. These samples were evaluated in Ref. 3.2. Five of these samples were removed within the 6"x6" grids for Bays 11A, 17D, 19A, 19C and Bay 5 at elevation 51'. These locations were repaired by welding a plug in each hole. Since these plugs are not representative of the drywell shell, UT measurements at these locations on the 6"x6" grid must be dropped from each data set.

The following specific grid points have been deleted:

Bay Area	Points
11A	23, 24, 30, 31
17D	15, 16, 22, 23
19A	24, 25, 31, 32
19C	20, 26, 27, 33,
5 EL 51'	13, 20, 25, 26, 27, 28, 33, 34, 35

The core sample removed in the sand bed region of Bay 13A was not within the monitored 6"x6" grid.

4.5 Bases for Statistical Analysis of 6"x6" Grid Data

4.5.1 Assumptions

The statistical evaluation of the UT measurement data to determine the corrosion rate at each location is based on the following assumptions:

(1) Characterization of the scattering of data over each 6"x6" grid is such that the thickness measurements are normally distributed.

(2) Once the distribution of data for each 6"x6" grid is found to be normal, then the mean value of the thickness is the appropriate representation of the average condition.

(3) A decrease in the mean value of the thickness with time is representative of the corrosion occurring within the 6"x6" grid.

(4) If corrosion has ceased, the mean value of the thickness will not vary with time except for random errors in the UT measurements.

(5) If corrosion is continuing at a constant rate, the mean thickness will decrease linearly with time. In this case, linear regression analysis can be used to fit the mean thickness values for a given zone to a straight line as a function of time. The corrosion rate is equal to the slope of the line.

The validity of these assumptions is assured by:

(a) Using more than 30 data points per 6"x6" grid

(b) Testing the data for normality at each 6"x6" grid location.

(c) Testing the regression equation as an appropriate model to describe the corrosion rate.

These tests are discussed in the following section. In cases where one or more of these assumptions proves to be invalid, non-parametric analytical techniques can be used to evaluate the data.

4.5.2 Statistical Approach

The following steps are performed to test and evaluate the UT measurement data for those locations where 6"x6" grid data has been taken at least three times:

(1) Edit each 49-point data set by setting all invalid points to zero. Invalid points are those which are declared invalid by the UT operator or are at a plug location. (The computer programs used in the following steps ignore all zero thickness data points.)

(2) Perform a Chi-squared goodness of fit test of each 49 point data set to ensure that the assumption of normality is valid at the 5% and 1% level of significance.

(3) Calculate the mean thickness and variance of each 49 point data set.

(4) Perform an Analysis of Variance (ANOVA) F-test to determine if there is a significant difference between the means of the data sets.

(5) Using the mean thickness values for each 6"x6" grid, perform linear regression analysis over time at each location.

(a) Perform F-test for significance of regression at the 5% level of significance. The result of this test indicates whether or not the regression model is more appropriate than the mean model. In other words, it tests to see if the variation of the regression model is statistically significant over that of a mean model.

(b) Calculate the ratio of the observed F value to the critical F value at 5% level of significance. For data sets where the Residual Degress of Freedom in ANOVA is 4 to 9, this F-Ratio should be at least 8 for the regression to be considered "useful" as opposed to simply "significant." (Ref. 3.5 pp. 92-93, 129-133)

(c) Calculate the coefficient of determination (R^2) to assess how well the regression model explains the percentage of total error and thus how useful the regression line will be as a predictor.

(d) Determine if the residual values for the regression equations are normally distributed.

(e) If the regression model is found to be appropriate, calculate the y-intercept, the slope and their respective standard errors. The y-intercept represents the fitted mean thickness at time zero, the slope represents the corrosion rate, and the standard errors represent the uncertainty or random error of these two parameters.

(6) Use a K factor from Table A-7 of Reference 3.9 and the standard deviation to establish a one-sided 99%/99% tolerance limit about the mean thickness values for each 6"x6" grid location to determine whether low thickness measurements or "outliers" are statistically significant. If the data points are greater than the 99%/99% lower tolerance limit, then the difference between the value and the mean is deemed to be due to expected random error. However, if the data point is less than the lower 99%/99% tolerance limit, this implies that the difference is statistically significant and is probably not due to chance.

4.6 Analysis of Two 6"x6" Grid Data Sets

Regression analysis is inappropriate when data is available at only two points in time. However, the t-test can be used to determine if the means of the two data sets are statistically different.

4.6.1 Assumptions

This analysis is based upon the following assumptions:

(1) The data in each data set is normally distributed.

(2) The variances of the two data sets are equal.

4.6.2 Statistical Approach

The evaluation takes place in three steps:

(1) Perform a chi-squared test of each data set at 5% and 1% levels of significance to ensure that the assumption of normality is valid.

(2) Perform an F-test at 5% and 1% level of significance of the two data sets being compared to ensure that the assumption of equal variances is valid.

(3) Perform a two-tailed t-test for two independent samples at the 5% and 1% levels of significance to determine if the means of the two data sets are statistically different.

A conclusion that the means are not statistically different is interpreted to mean that significant corrosion did not occur over the time period represented by the data. However, if equality of the means is rejected, this implies that the difference is statistically significant and could be due to corrosion.

4.7 Analysis of Single 6"x6" Grid Data Set

In those cases where a 6"x6" data set is taken at a given location for the first time during the current outage, the only other data to which they can be compared are the UT survey measurements taken at an earlier time. For the most part, these are single point measurements which were taken in the vicinity of the 49-point data set, but not at the exact location. Therefore, rigorous statistical analysis of these single data sets is impossible. However, by making certain assumptions, they can be compared with the previous data points. If more extensive data is available at the location of the 49-point data set, the t-test can be used to compare the means of the two data sets as described in paragraph 4.5.

When additional measurements are made at these exact locations during future outages, more rigorous statistical analyses can be employed.

4.7.1 Assumptions

The comparison of a single 49-point data sets with previous data from the same vicinity is based on the following assumptions:

(1) Characterization of the scattering of data over the 6"x6" grid is such that the thickness measurements are normally distributed.

(2) Once the distribution of data for the 6"x6" grid is found to be normal, then the mean value of the thickness is the appropriate representation of the average condition.

(3) The prior data is representative of the condition at this location at the earlier date.

4.7.2 Statistical Approach

The evaluation takes place in four steps:

(1) Perform a chi-squared test of each data set to ensure that the assumption of normality is valid at the 95% and 99% confidence levels.

(2) Calculate the mean and the standard error of the mean of the 49-point data set.

(3) Determine the two-tailed t value from a t distribution table at levels of significance of 0.05 and 0.01 for n-1 degrees of freedom.

(4) Use the t value and the standard error of the mean to calculate the 95% and 99% confidence intervals about the mean of the 49-point data set.

(5) Compare the prior data point(s) with these confidence intervals about the mean of the 49-point data sets.

If the prior data falls within the 95% confidence intervals, it provides some assurance that significant corrosion has not occurred in this region in the period of time covered by the data. If it falls within the 99% confidence limits but not within the 95% confidence limits, this implication is not as strong. In either case, the corrosion rate will be interpreted to be "Not Significant".

If the prior data falls above the upper 99% confidence limit, it could mean either of two things: (1) significant corrosion has occurred over the time period covered by the data, or (2) the prior data point was not representative of the condition of the location of the 49-point data set in 1986. There is no way to differentiate between the two. In this case, the corrosion rate will be interpreted to be "Possible".

If the prior data falls below the lower 99% confidence limit, it means that it is not representative of the condition at this location at the earlier date. In this case, the corrosion rate will be interpreted to be "Indeterminable".

4.8 Analysis of Single 7-Point Data Set

In those cases where a 7-point data set is taken at a given location for the first time during the current outage, the only other data to which they can be compared are the UT survey measurements taken at an earlier time to identify the thinnest regions of the drywell shell in the sand bed region. For the most part, these are single point measurements which were taken in the vicinity of the 7-point data sets, but not at the exact locations. However, by making certain assumptions, they can be compared with the previous data points. If more extensive data is available at the location of the 7-point data set, the t-test can be used to compare the means of the two data sets as described in paragraph 4.5.

When additional measurements are made at these exact locations during future outages, more rigorous statistical analyses can be employed.

4.8.1 Assumptions

The comparison of a single 7-point data sets with previous data from the same vicinity is based on the following assumptions:

(1) The corrosion in the region of each 7-point data set is normally distributed.

(2) The prior data is representative of the condition at this location at the earlier date.

The validity of these assumptions cannot be verified.

4.8.2. Statistical Approach

The evaluation takes place in four steps:

(1) Calculate the mean and the standard error of the mean of the 7-point data set.

(2) Determine the two-tailed t value using the t distribution tables at levels of significance of 0.05 and 0.01 for n-1 degrees of freedom.

(3) Use the t value and the standard error of the mean to calculate the 95% and 99% confidence intervals about the mean of the 7-point data set.

(4) Compare the prior data point(s) with these confidence intervals about the mean of the 7-point data sets.

If the prior data falls within the 95% confidence intervals, it provides some assurance that significant corrosion has not occurred in this region in the period of time covered by the data. If it falls within the 99% confidence limits but not within the 95% confidence limits, this implication is not as strong. In either case, the corrosion rate will be interpreted to be "Not Significant".

If the prior data falls above the upper 99% confidence interval, it could mean either of two things: (1) significant corrosion has occurred over the time period covered by the data, or (2) the prior data point was not representative of the condition of the location of the 7-point data set in 1986. There is no way to differentiate between the two. In this case, the corrosion rate will be interpreted to be "Possible".

If the prior data falls below the lower 99% confidence limit, it means that it is not representative of the condition at this location at the earlier date. In this case, the corrosion rate will be interpreted to be "Indeterminable".

4.9 Evaluation of Drywell Mean Thickness

This section defines the methods used to evaluate the drywell thickness at each location within the scope of the long term monitoring program.

4.9.1 Evaluation of Mean Thickness Using Regression Analysis

The following procedure is used to evaluate the drywell mean thickness at those locations where regression analysis has been deemed to be more appropriate than the mean model.

(1) The best estimate of the mean thickness at these locations is the point on the regression line corresponding to the time when the most recent set of measurements was taken. In the SAS Regression Analysis output (App. 6.2), this is the last value in the column labeled "PREDICT VALUE".

(2) The best estimate of the standard error of the mean thickness is the standard error of the predicted value used above. In the SAS Regression Analysis output, this is the last value in the column labeled "STD ERR PREDICT".

(3) The two-sided 95% confidence interval about the mean thickness is equal to the mean thickness plus or minus t times the estimated standard error of the mean. This is the interval for which we have 95% confidence that the true mean thickness will fall within. The value of t is obtained from a t distribution table for equal tails at n-2 degrees of freedom and 0.05 level of significance, where n is the number of sets of measurements used in the regression analysis. The degrees of freedom is equal to n-2 because two parameters (the y-intercept and the slope) are calculated in the regression analysis with n mean thicknesses as input.

(4) The one-sided 95% lower limit of the mean thickness is equal to the estimated mean thickness minus t times the estimated standard error of the mean. This is the mean thickness for which we have 95% confidence that the true mean thickness does not fall below. In this case, the value of t is obtained from a t distribution table for one tail at n-2 degrees of freedom and 0.05 level of significance.

4.9.2 Evaluation of Mean Thickness Using Mean Model

The following procedure is used to evaluate the drywell mean thickness at those locations where the mean model is deemed to be more appropriate than the linear regression model. This method is consistent with that used to evaluate the mean thickness using the regression model.

(1) Calculate the mean of each set of UT thickness measurements.

(2) Sum the means of the sets and divide by the number of sets to calculate the grand mean. This is the best estimate of the mean thickness. In the SAS Regression Analysis output, this is the value labelled "DEP MEAN".

(3) Using the means of the sets from (1) as input, calculate the standard error about the mean. This is the best estimate of the standard error of the mean thickness.

(4) The two-sided 95% confidence interval about the mean thickness is equal to the mean thickness plus or minus t times the estimated standard error of the mean. This is the interval for which we have 95% confidence that the true mean thickness will fall within. The value of t is obtained from a t distribution table for equal tails at n-1 degrees of freedom and 0.05 level of significance.

(5) The one-sided 95% lower limit of the mean thickness is equal to the estimated mean thickness minus t times the estimated standard error of the mean. This is the mean thickness for which we have 95% confidence that the true mean thickness does not fall below. In this case, the value of t is obtained from a t distribution table for one tail at n-1 degrees of freedom and 0.05 level of significance.

4.9.3 Evaluation of Mean Thickness Using Single Data Set

The following procedure is used to evaluate the drywell thickness at those locations where only one set of measurements is available.

(1) Calculate the mean of the set of UT thickness measurements. This is the best estimate of the mean thickness.

(2) Calculate the standard error of the mean for the set of UT measurements. This is the best estimate of the standard error of the mean thickness.

Confidence intervals about the mean thickness cannot be calculated with only one data set available.

4.10 Evaluation of Drywell Corrosion Rate

4.10.1 Mean Model

If the ratio of the observed F value to the critical F value is less than 1 for the F-test for the significance of regression, it indicates that the mean model is more appropriate than the regression model at the 5% level of significance. In other words, the variation in mean thickness with time can be explained solely by the random variations in the measurements. This means that the corrosion rate is not significant compared to the random variations.

In this case, an F-test is performed to compare the variability of the data set means between data sets with the variability of individual measurements within the data sets. If the observed F value is less than the critical F value, it confirms that the mean model is appropriate.

If the F-test indicates that the variability of the means is significant, the Least Significant Difference (LSD) is computed. This is the maximum difference between data set mean thicknesses that can be attributed to random variation in the measurements. If the difference between the means of data sets exceeds LSD, it indicates that difference is significant. The difference between means is subtracted from LSD and the result is divided by the time between measurements to estimate the "Significant Corrosion Rate" in mils per year (mpy). If the difference between the means does not exceed LSD, then it is concluded that no significant corrosion occurred during that period of time.

4.10.2 Regression Model

If the ratio of the observed F value to the critical F value is 1 or greater, it indicates that the regression model is more appropriate than the mean model at the 5% level of significance. In other words, the variation in mean thickness with time cannot be explained solely by the random variations in the measurements. This means that the corrosion rate is significant compared to the random variations.

Although a ratio of 1 or greater indicates that regression is significant, it does not mean that the slope of the regression line is an accurate prediction of the corrosion rate. The ratio should be at least 4 or 5 to consider the slope to be a useful predictor of the corrosion rate (Ref.

3.5, pp. 93, 129-133). A ratio of 4 or 5 means that the variation from the mean due to regression is approximately twice the standard deviation of the residuals of the regression.

To have a high degree of confidence in the predicted corrosion rate, the ratio should be at least 8 or 9 (Ref. 3.5, pp. 129-133).

4.10.3 Best Estimate of Recent Corrosion Rate

In most instances, four sets of measurements over a period of about one year do not provide a significant regression model which can be used to predict future thicknesses. However, a least squares fit of the four data points does provide a reasonable estimate of the recent corrosion rate. This information is particularly valuable for assessing the effectiveness of cathodic protection and the draining of the sand bed region. Since a linear regression analysis performs a linear least squares fit of the data, the best estimate of the recent corrosion rate is the slope from the regression analysis for the period of interest.

These values are tabulated as the "Apparent Corrosion Rate" in paragraph 2.5.

5.0 CALCULATIONS

5.1 6"x6" Grids in Sand Bed Region With Cathodic Protection

5.1.1 Bay 11A

5.1.1.1 Bay 11A: 5/1/87 to 2/8/90

Nine 49-point data sets were available for this bay covering 4/24/90 period. Since a plug lies within this region, four of the points were voided in each data set. The data were analyzed as described in paragraphs 4.4, 4.5.1 and 4.6.1.

(1) The data are normally distributed.

(2) The regression model is appropriate.

(3) The regression model explains 78.3% of the variation about the mean.

(4) The residuals are normally distributed.

(5) The current mean thickness ± standard error is 870.4 ± 5.7 mils.

(6) The corrosion rate ± standard error is -15.6 ± 2.9 mils per year.

(7) F/F critical = 5.4.

(8) The measurement below 800 mils was tested and determined not to be statistically different from the mean thickness.

5.1.1.2 Bay 11A: 10/8/88 to 4/24/90

Five 49-point data sets were available for this bay covering this period.

(1) The data are normally distributed.

(2) The mean model is more appropriate than the regression model.

(3) The F-test for the significant of the difference between the means shows that the difference between the mean thickness are not significant.

(4) The t-test of the last two data sets shows that the difference between the mean thickness is not significant.

(5) The current thickness based on the mean model is 878.9 ± 5.9 mils.

(6) These analyses indicate that the corrosion rate with cathodic protection is not significant compared to random variations in the measurements.

(7) The best estimate of the corrosion rate during the period based on a least squares fit is -16.2 ± 8.6 mils per year.

5.1.2 Bay 11C

5.1.2.1 Bay 11C: 5/1/87 to 4/24/90

Nine 49-point data sets were available for this bay covering this period. The initial analysis of this data indicated that the data are not normally distributed. The lack of normality was tentatively attributed to minimal corrosion in the upper half of the 6"x6" grid with more extensive corrosion in the lower half of the grid. To test this hypothesis, each data set was divided into two subsets, with one containing the top three rows and the other containing the bottom four rows.

Top 3 Rows

(1) The data are normally distributed.

(2) The regression model is appropriate.

(3) The regression model explains 79% of the total variation about the mean.

(4) The residuals are normally distributed.

(5) The current mean thickness ± standard error is 977.0 ± 12.5 mils.

(6) The corrosion rate is -35.2 ± 6.8 mils per year.

(7) F/F critical = 4.6.

Bottom 4 Rows

(1) Seven of the nine data sets are normally distributed. The other two are skewed toward the thinner side of the mean. The Chi-square test shows that they are close to being normally distributed at the 1% level of significance.

(2) The regression model is appropriate.

(3) The regression model explains 80% of the total variation about the mean.

(4) The residuals are normally distributed.

(5) The current mean thickness ± standard error is 865.0 ± 7.8 mils.

(6) The corrosion rate ± standard error is -22.4 ± 4.3 mils per year.

(7) F/F critical = 4.9

5.1.2.2 Bay 11C: 10/8/88 to 4/24/90

Five 49-point data sets were available for this period. These data were divided into two subsets as described above.

Top 3 Rows

(1) The data are normally distributed.

(2) The mean model is more appropriate than the regression model.

(3) The F-test for the significance of the difference between the means shows that the differences between the mean thicknesses are not significant.

(4) The t-test of the last two data sets shows that there is no statistical difference between their means.

(5) These analyses indicate that the current corrosion rate with cathodic protection is not significant compared to random variations in the measurements.

(6) Based on the mean model, the current thickness ± standard error is 996.6 ± 8.3 mils.

(7) The best estimate of corrosion rate during this period based on a least squares fit is -25.0 ± 10.6 mils per year.

Bottom 4 Rows

(1) Four of the five data sets are normally distributed. (See 5.1.2.1 above).

(2) The mean model is more appropriate than the regression model.

(3) The F-test for the significance of the difference between the means shows that the differences between the mean thicknesses are significant.

(4) The t-test of the last two data sets shows that there is no significant statistical difference between their means.

(5) Based on the mean model, the current thickness ± standard error is 878.1 ± 5.6 mils.

(6) Based upon examination of the distribution of the five data set mean values, it is concluded that the current corrosion rate is not significant compared to random variations in the measurements. The measurements alternated as follows: 897, 877, 891, 869, 863. Therefore the difference must be due to variations other than corrosion.

(7) The best estimate of the corrosion rate during this period based on a least squares fit is -16.7 ± 7.1 mils per year.

5.1.3 Bay 17D

5.1.3.1 Bay 17D: 2/17/87 to 4/24/90

Ten 49-point data sets were available for this period. Since a plug lies within this region, four of the points were voided in each data set. Point 24 in the 2/8/90 data was voided since it is characteristic of the plug thickness.

(1) The data are normally distributed.

(2) The regression model is appropriate.

(3) The regression model explains 95% of the total variation about the mean.

(4) The residuals are normally distributed.

(5) The current mean thickness ± standard error is 829.5 ± 4.0 mils.

(6) The corrosion rate ± standard error is -25.0 ± 2.0 mils per year.

(7) F/F critical = 29.4

(8) The measurements below 800 mils were tested and determined not to be statistically different from the mean thickness.

5.1.3.2 Bay 17D: 10/8/88 to 4/24/90

Five 49-point data sets were available for this period.

(1) The data are normally distributed.

(2) The regression model is more appropriate than the mean model.

(3) The regression model explains 90% of the variation about the mean.

(4) The residuals are normally distributed.

(5) The current mean thickness ± standard error is 830.1 ± 3.8 mils.

(6) The corrosion rate ± standard error is -23.7 ± 4.6 mpy.

(7) F/F critical = 2.7

5.1.4 Bay 19A

5.1.4.1 Bay 19A: 2/17/87 to 4/24/90

Ten 49-point data sets were available for this period. Since a plug lies within this region, four of the points were voided in each data set.

(1) The data are normally distributed at the 1% level of significance.

(2) The regression model is appropriate

(3) The regression model explains 96% of the total variation about the mean.

(4) The residuals are normally distributed.

(5) The current mean thickness ± standard error is 807.6 ± 3.0 mils.

(6) The corrosion rate ± standard error is -21.4 ± 1.5 mpy.

(7) F/F critical = 39.5

(8) The data points that were below 800 mils were tested and determined not to be statistically different from the mean thickness.

5.1.4.2 Bay 19A: 10/8/88 to 4/24/90

Five 49-point data sets were available for this period.

(1) The data are normally distributed.

(2) The regression model is more appropriate than the mean model.

(3) The regression model explains 90% of the variation about the mean.

(4) The residuals are normally distributed.

(5) The current mean thickness ± standard error is 808.2 ± 3.2 mils.

(6) The corrosion rate ± standard error is -20.6 ± 3.9 mpy.

(7) F/F critical = 2.8

5.1.5 Bay 19B

5.1.5.1 Bay 19B: 5/1/87 to 4/24/90

Nine 49-point data sets were available for this period.

(1) The data are normally distributed.

(2) The regression model is appropriate.

(3) The regression model explains 94% of the total variation about the mean.

(4) The residuals are normally distributed.

(5) The current mean thickness ± standard error is 836.9 ± 3.2 mils.

(6) The corrosion rate ± standard error is -19.0 ± 1.7 mpy.

(7) F/F critical = 21.3

(8) The measurements below 800 mils were tested and determined not to be statistically different from the mean thickness.

5.1.5.2 Bay 19B: 10/8/88 to 4/24/90

Five 49-point data sets were available for this period.

(1) The data are normally distributed.

(2) The regression model is more appropriate than the mean model.

(3) The regression model explains 75% of the variation about the mean.

(4) The residuals are normally distributed.

(5) The current mean thickness ± standard error is 841.2 ± 3.3 mils.

(6) The corrosion rate ± standard error is -11.8 ± 3.9 mpy.

(7) F/F critical = 0.9

5.1.6 Bay 19C

5.1.6.1 Bay 19C: 5/1/87 to 4/24/90

Nine 49-point data sets were available for this period. Since a plug lies within this region, four of the points were voided in each data set.

(1) The data are normally distributed at the 1% level of significance, but appears to be developing two peaks.

(2) The regression model is appropriate.

(3) The regression model explains 98% of the total variation about the mean.

(4) The residuals are normally distributed.

(5) The current mean thickness ± standard error is 825.1 ± 2.3 mils.

(6) The corrosion rate ± standard error is -24.3 ± 1.3 mpy.

(7) F/F critical = 66.2

(8) The measurements below 800 mils were tested and determined not to be statistically different from the mean thickness.

5.1.6.2 <u>Bay 19C: 10/8/88 to 4/24/90</u>

Five 49-point data sets were available for this period.

(1) The data are normally distributed at the 1% level of significance.

(2) The F-test for significance of regression indicates that the regression model is appropriate.

(3) The regression model explains 93% of the total variation about the mean.

(4) The residuals are normally distributed.

(5) The current mean thickness ± standard error is 826.3 ± 2.9 mils.

(6) The corrosion rate ± standard error is -21.5 ± 3.5 mpy.

(6) F/F critical = 3.7.

5.1.7 <u>Bays 17/19 Frame Cutout: 12/30/88 to 4/24/90</u>

Two sets of 6"x6" grid measurements were taken in December 1988. The upper one is located 25" below the top of the high curb and the other below the floor. There is no previous data. The upper location was added to the long term monitoring program.

Five 49-point data sets were available for this period. These data were analyzed as described in 4.4, 4.5.2 and 4.6.1. The initial analysis of this data indicated that the first and last data sets are not normally distributed. The lack of normality was tentatively attributed to more extensive corrosion in the upper half of the grid than the bottom half. To test this hypothesis, each data set was divided into two subsets, with one containing the top three rows and the other containing the bottom four rows.

Top 3 Rows

(1) Four of the five subsets are normally distributed at the 1% level of significance but one is not.

(2) The mean model is appropriate.

(3) The F-test for the significance of the difference between the means shows that the differences between the mean thicknesses are not significant at 1% level of significance.

(4) These analyses indicate that the corrosion rate is not significant compared to the random variations in the measurements.

(5) Based on the mean model, the current thickness ± standard error is 986.0 ± 4.7 mils.

(6) The best estimate of the corrosion rate during this period based on a least squares fit is -8.2 ± 10.7 mils per year.

Bottom 4 Rows

(1) Four of the five subsets are normally distributed at the 5% level of significance, and one at the 1% level of significance.

(2) The mean model is appropriate.

(3) The F-test for the significance of the difference between the means shows that the differences between the mean thicknesses are not significant at 1% level of significance.

(4) These analyses indicate that the corrosion rate is not significant compared to the random variations i the measurements.

(5) Based on the mean model, the current thickness ± standard error is 1005.7 ± 5.6 mils.

(6) The best estimate of the corrosion rate during this period based on a least squares fit is -13.1 ± 11.6 mils per year.

5.2 6"x6" Grids in Sand Bed Region Without Cathodic Protection

5.2.1 Bay 9D: 12/19/88 to 4/24/90

Five 49-point data sets were available for this period.

(1) The data are normally distributed.

(2) The mean model is more appropriate than the regression model.

(3) The current mean thickness is 1021.7 ± 8.9 mils.

(4) The F-test for the significance of the difference between the mean thicknesses indicates that the differences between the means are significant. The LSD analysis shows that this is due to the second measurement on 6/26/89 which is 33 to 52.3 mils higher than the other four.

(5) The t-test of the last two data sets shows that the difference between the mean thicknesses is not significant.

(6) The overall analysis indicates that there was no significant corrosion from December 19, 1988 to April 24, 1990.

(7) The best estimate of the corrosion rate during this period based on a least squares fit is -21.0 ± 18.1 mils per year.

5.2.2 Bay 13A: 12/17/88 to 4/24/90

Seven 49-point data sets were available for this period.

(1) The data are normally distributed.

(2) The regression model is appropriate.

(3) The regression model explains 97% of the total variation about the mean.

(4) The residuals are normally distributed.

(5) The current mean thickness ± standard error is 853.1 ± 2.4 mils.

(6) The indicated corrosion rate ± standard error is -39.1 ± 3.4 mils per year.

(7) F/F critical = 16.9

(8) The measurements below 800 mils were tested and determined not to be statistically different from the mean thickness.

5.2.3 <u>Bay 13D: 3/28/90 to 4/25/90</u>

One 7-point data set and one 49-point data set are available for this bay covering this period.

(1) The 7-point data set is normally distributed at 5% level of significance. The 49-point data set is normally distributed at 1% level of significance. However, there is a diagonal line of demarcation separating a zone of minimal corrosion at the top from a corroded zone at the bottom. Thus, corrosion has occurred at this location.

(2) The mean of the 7-point data set is not significantly different from the mean of the corresponding 7 points in the 49-point data set.

(3) The current means thickness is 931.9 ± 22.6 mils.

It is concluded that corrosion has occurred at this location. However, with minimal data over a one-month period, it is impossible to determine the current corrosion rate.

5.2.4 <u>Bay 15D: 12/17/88 to 4/24/90</u>

Five 49-point data sets were available for this period.

(1) The data are normally distributed.

(2) The mean model is more appropriate than the regression model.

(3) The current mean thickness ± standard error is 1056.5 ± 2.3 mils.

(4) The F-test for the significance of the difference between the mean thicknesses indicates that the differences between the means are not significant.

(5) The t-test of the last two data sets shows that the difference between the mean thicknesses is not significant.

(6) There was no significant corrosion from December 17, 1988 to April 24, 1990.

(7) The best estimate of the corrosion rate during this period based on a least squares fit is -4.6 mils per year.

5.2.5 Bay 17A: 12/17/88 to 4/24/90

Five 49-point data sets were available for this period.

The initial analysis of this data indicated that the data are not normally distributed. The lack of normality was tentatively attributed to minimal corrosion in the upper half of the 6"x6" grid with more extensive corrosion in the lower half of the grid. To test this hypothesis, each data set was divided into two subsets, with one containing the top three rows and the other containing the bottom four rows.

Top 3 Rows

(1) The data are normally distributed.

(2) The mean model is more appropriate than the regression model.

(3) The current mean thickness ± standard error is 1128.3 ± 2.2 mils.

(4) The F-test for the significance of the difference between the mean thicknesses indicates the differences between the means are not significant.

(5) The t-test of the last two data sets indicates that the difference between the mean thicknesses is not significant.

(6) There was no significant corrosion during this period.

(7) The best estimate of the corrosion rate during this period based on a least squares fit is -6.8 ± 3.7 mils per year.

Bottom 4 Rows

(1) The data are normally distributed.

(2) The mean model is more appropriate than the regression model.

(3) The current mean thickness ± standard error 950.83 ± 5.3 mils.

(4) The F-test for the significance of the difference between the mean thicknesses indicates that the differences between the means are not significant.

(5) The t-test of the last two data sets indicates that the difference between the mean thicknesses is not significant.

(6) There was no significant corrosion during this period.

(7) The best estimate of the corrosion rate during this period based on a least squares fit is -17.7 ± 7.6 mils per year.

5.3 6"x6" Grids at 51' Elevation

5.3.1 Bay 5 Area D-1 2 51' Elevation: 11/1/87 to 4/24/90

Eight 49-point data sets were available for this period.

The initial analysis of this data indicated that the data are not normally distributed. These data sets names start with E. The following adjustments were made to the data:

(1) Point 29 in the 9/13/89 data is much greater than the preceding or succeeding measurements. Therefore, this reading was dropped from the analysis.

(2) Point 9 is a significant pit. Therefore, it was dropped from the overall analysis and is evaluated separately.

(3) Points 13 and 25 are extremely variable and are located adjacent to the plug which was removed from this grid. They were also dropped from the analysis.

(4) Point 43 in the 11/01/87 data is much less than any succeeding measurement. Therefore, this reading was dropped from the analysis.

With these adjustments, the first and last data sets are normally distributed at the 1% level of significance and the other five at 5%. These data set names start with F.

It was noted that the D-Meter calibration at 0.750" yielded readings which ranged from -1 mil for one set of measurements to + 4 mils for another. The data was adjusted to eliminate these biases. These data set names start with G. The final analyses are based on these adjusted data sets.

(1) The data are normally distributed.

(2) The regression model is appropriate.

(3) The regression model explains 57% of the total variation about the mean.

(4) The residuals are normally distributed.

(5) The current mean thickness ± standard error is 745.2 ± 2.1 mils.

(6) The indicated corrosion rate ± standard error is -4.6 ± 1.6 mils per year.

(7) F/F critical = 1.3. Thus, the regression is just barely significant.

(8) The F-test for significance of the difference between the mean thickness indicates that the differences are significant.

(9) The t-test of the last two data sets shows that the difference between the mean thickness is not significant.

(10) The measurements of the pit at point 9 were 706, 746, 696, 694, 700, 688, 699 and 689 mils. The mean value of these measurements is 702.3 ± 6.5 mils. A least squares fit shows that the best estimate of the corrosion rate during this period is -11.5 mils per year with R^2=31%. The second measurement is much higher than the others. Dropping this point, the mean of the remaining measurements is 696.0 ± 2.4 mils, and the best estimate of the corrosion rate is -4.9 mils per year with R^2 = 49%. Recognizing that the variability of single measurements will be about 6 times the variability of the mean of 40 measurements, it is concluded that the corrosion rate in the pit is essentially the same as the overall grid.

5.3.2 Bay 5 Area 51-5 at 51' Elevation: 3/31/90 to 4/25/90

Two 49-point data sets are available for this time period.

(1) The data are not normally distributed. This is due to a large corroded patch near the center of the grid, and several small patches on the periphery.

When the data less than the grand mean were segregated, it was found that these subsets are normally distributed.

(2) The t-tests of the two complete data sets and the two subsets indicate that the difference between the mean thicknesses are not significant.

(3) The current mean thickness ± standard error is 745.1 ± 3.2 mils.

It is concluded that corrosion has occurred at this location. However, with minimal data over such a brief period, it is impossible to determine the current corrosion rate.

5.3.3 Bay 13 Area 31 Elevation 51': 3/31/90 to 4/25/90

Two 49-point data sets are available for this time period.

(1) The data are to normally distributed. This is due to a large corroded patch at the left edge of the grid.

When the data less than the grand mean were segregated, it was found that these subsets are normally distributed.

(2) The t-test of the two complete data sets indicate that the difference between the means is statistically significant. However, the difference between the means of the two subsets is not statistically significant.

(3) The current mean thickness is ± standard error is 750.8 ± 11.5 mils.

It is concluded that corrosion has occurred at this location. However, with minimal data over such a brief period, it is impossible to determine the current corrosion rate.

5.3.4 Bay 15 Area 23 Elevation 51': 3/31/90 to 4/25/90

Two 49-point data sets are available for this time period.

(1) The data are not normally distributed. This is due to a large corroded patch.

When the data less than the grand mean were segregated, it was found that these two subsets are normally distributed.

(2) The t-tests of the two complete data sets and the two subsets indicate that the differences between the mean thicknesses are not significant.

(3) The current mean thickness ± standard error is 751.2 ± 3.8 mils.

It is concluded that corrosion has occurred at this location. However, with minimal data over such a brief period, it is impossible to determine the current corrosion rate.

5.4 6" x 6" Grids at 52' Elevation

5.4.1 Bay 7 Area 25 Elevation 52': 4/26/90

One 49-point data set is available.

(1) The data are not normally distributed.

The subset of the data less than the mean thickness is not normally distributed.

When four points below 700 mils were dropped from the data set, the remaining data was found to be normally distributed. Therefore, the lack of normality of the complete data set is attributed to these thinner points. Three of these could be considered to be pits (626, 657 and 676 mils) since they deviate from the mean by more than 3 sigma.

(2) The current mean thickness ± standard is 715.5 ± 2.9 mils.

It is concluded that corrosion has occurred at this location.

5.4.2 Bay 13 Area 6 Elevation 52': 4/26/90

One 49-point data set is available.

(1) The data are not normally distributed.

The subset of the data less than the mean thickness is normally distributed. Thus, the lack of normality of the complete data set is attributed to a large corroded patch at the left side of the grid.

(2) The current mean thickness ± standard error is 724.9 ± 2.9 mils.

(3) It is concluded that corrosion has occurred at this location.

5.4.3 Bay 13 Area 32 Elevation 52': 4/26/90

One 49-point data set is available.

(1) The data are not normally distributed.

The subset of the data less than the mean thickness is normally distributed. Thus, the lack of normality of the complete data set is attributed to these corrosion patches.

(2) The current mean thickness ± standard error is 698.3 ± 5.0 mils.

It is concluded that corrosion has occurred at this location.

5.4.4 Bay 19 Area 13 Elevation 52': 4/26/90

One 49-point data set is available.

(1) The data are normally distributed. However, two adjacent points differ from the mean by 3 sigma and 5 sigma. Thus, there is a pit.

(2) The current means thickness ± standard error is 712.5 ± 3.1 mils.

It is concluded that some corrosion has occurred at this location.

5.5 6" x 6" Grids at 87' Elevation

5.5.1 Bay 9 87' Elevation: 11/6/87 to 3/28/90

Five 49-point data sets were available for this period.

(1) The data are normally distributed.

(2) The mean model is more appropriate than the regression model.

(3) There was no significant corrosion during this period.

(4) The current mean thickness ± standard error is 619.9 ± 0.6 mils.

(5) The best estimate of the corrosion rate during this period based on a least squares fit is -0.2 ± 0.9 mils per year.

5.5.2 Bay 13 87' Elevation: 11/10/87 to 3/28/90

Five 49-point data sets were available for this period.

(1) The data are normally distributed.

(2) The mean model is more appropriate than the regression model.

(3) There was no significant corrosion during this period.

(4) The current mean thickness ± standard error is 636.5 ± 0.8 mils.

(5) The best estimate of the corrosion rate during this period based on a least squares fit is zero mils per year.

5.5.3 Bay 15 87' Elevation: 11/10/87 to 3/28/90

Five 49-point data sets were available for this period.

(1) The data are normally distributed.

(2) The mean model is more appropriate than the regression model.

(3) There was no significant corrosion during this period.

(4) The current mean thickness ± standard error is 636.2 ± 1.1 mils.

(5) The best estimate of the corrosion rate during this period based on a least squares fit is zero mils per year.

6.0 APPENDICES

6.1 SPEAKEZ Programs

6.2 SAS Program

6.3 Computer Calculations

GPU Nuclear

TDR No. 1027 Revision No. 1

Technical Data Report

	Budget Activity No. 402950	Page 1 of 38
Project: OYSTER CREEK DRYWELL CORROSION	Department/Section ENGINEERING & DESIGN	
	Release Date ______	Revision Date ______

Document Title: DESIGN OF A UT INSPECTION PLAN FOR THE DRYWELL CONTAINMENT USING STATISTICAL INFERENCE METHODS

Originator Signature	Date	Approval(s) Signature	Date
S. D. LESHNOFF		B. Elam	11/1/90
S. D. Leshnoff	10/31/90		
		Approval for External Distribution	Date

Does this TDR include recommendation(s)? ___Yes _X_No If yes, TFWR/TR# ___

*	Distribution	Abstract:
	A. R. Baig F. P. Barbieri B. D. Elam, Jr. J. C. Flynn J. P. Moore, Jr. M. A. Orski D. G. Slear P. Tamburro	BACKGROUND: As a result of drywell corrosion at Oyster Creek, Ultrasonic Test (Ut) thickness measurements are periodically being taken. In the past these measurements have been utilized to identify locations whose thickness is reduced. By repeated measurements in these areas at the same location, statistically derived corrosion rates have been determined. A new UT inspection plan whose purpose was to provide a basis for statistical inference that the drywell thickness satisfies minimum required was developed. The drywell is statistically characterized using a limited number of plate thickness measurements. The purpose of this TDR is to document the basis for this inspection plan. (For Additional Space Use Side 2)

* Abstract Only

SOLUTION:

Using 6" x 6" grids for UT measurements, randomly choose 60 loctaions but do not include sand bed grids. Finding no unsatisfactory areas in remaining observations is the basis to conclude, with a 5% risk of error, that 95% of the drywell is free of such areas. A different sample is used each time that the assessment is made. Finding no repairable areas within grids provides a level of assurance of better than 99% that the drywell is free of such areas. Apply statistical inference methods as far as possible and where there are limitations use a judgement approach in order to determine whether corrosion is or is not occurring.

GPU Nuclear	DOCUMENT NO. TDR 1027		
TITLE	DESIGN OF A UT INSPECTION PLAN FOR THE DRYWELL CONTAINMENT USING STATISTICAL INFERENCE METHODS		
REV	SUMMARY OF CHANGE	APPROVAL	DATE
1	1. Add to both Background and Solution sections that there are limits to statistical inference which are overcome by judgement methods. 2. Change derived to estimated. 3. Change reference in text. 4. Add section for References. 5. Clarify Table 1. 6. Explain simulation notation and practice and number of units sampled. 7. Use Figure 1b for section distribution equal to 0.05. 8. Define stratification. 9. Use sand bed plates instead of sand bed when describing stratification. 10. Use estimate instead of failure and clarify multiple trials. 11. Add a statement showing that simulations demonstrate both accuracy and sensitivity of inspection plan. 12. Introduce insignificant change when using acutal number of plates per strata. 13. Add section addressing finding one or more unacceptable observations, including Figure 3. 14. Add statements to clarify approach to local low areas. 15. Correct equations for variance. 16. Add section on disposition of results.		

N0036 (03-90)

TABLE OF CONTENTS

BACKGROUND:

As a result of drywell corrosion at Oyster Creek, Ultrasonic Test (UT) thickness measurements are periodically being taken. In the past these measurements have been utilized to identify locations whose thickness is reduced. By repeated measurements in these areas at the same location, statistically estimabed corrosion rates have been determined. A new UT inspection plan whose purpose was to provide a basis for statistical inference that the drywell thickness satisfies minimum required was developed. The drywell is statistically characterized using a limited number of plate thickness measurements. The purpose of this TDR is to document the basis for this inspection plan.

②

①

SOLUTION:

Using 6" X 6" grids for UT measurements, randomly choose 60 locations of a possible 60,000 but do not include sand bed grids. Finding no unsatisfactory areas in remaining observations is the basis to conclude, with a 5% risk of error, that 95% of the drywell is free of such areas. Therefore, this sampling plan will develop 95% confidence that 95% of the drywell is free of such areas. A different sample is used each time that the assessment is made. Finding no repairable areas within grids provides a level of assurance of better than 99% that the drywell is free of such areas. Apply statistical inference methods as far as possible and where there are limitations use a judgement approach in order to determine whether corrosion is or is not occurring.

①

TECHNICAL APPROACH:

A non-parametric statistical approach using attribute sampling that assumes no prior knowledge of the distribution of corrosion above the sand bed region is the basis for the augmented inspection plan. The acceptance criteria is that the mean and local thicknesses of the shell equals or exceeds a required minimum thickness plus a corrosion allowance necessary in order to reach the next inspection.

Statistically, a predicted value, A_u, of the maximum number of defects in the population, N, reflecting a selected level of risk can be used so that for this value "a" defects in sample "n" are expected at a low probability, α_u. The lower the probability, the larger the sample size. If "a" or less are found, then the selected risk is not exceeded. If ">a" are found, the selected risk is exceeded. Sample size "n" can be computed given A_u and α_u. For 5% of the surface as unacceptably degraded for A_u, then "n" is found to be 59 at $\alpha_u = 0.05$ and a = 0. That is, no observations which do not satisfy the acceptance criteria (i.e., grids) can be found in a sample of 59 with a 5% risk that the actual number of grids which would not satisfy the acceptance criteria exceeds A_u without rejecting the hypothesis. Using 60 grids, there is only a 5% chance of finding no grids whose thickness is below the acceptance criteria given 5% of the population below this thickness. Finding none in a sample of 60 is remote so that if none are found below this thickness, then the assumption about the defective proportion below the acceptance criteria thickness is probably an overestimate. Sixty observations is a good basis for a sampling plan. There is also the possibility that the actual number of defective grids is less than A_u and the hypothesis is rejected due to chance alone. This is evaluated in the discussion of finding one or more unacceptable observations (see below). The determination of the appropriate sample size is expressed formally by: (3)

$$\sum_{i=0}^{a} Pr\ (i,\ n-i)\ |(A_u,\ N-A_u) =$$

$$({}_{A_u}C_a) \times ({}_{(N-A_u)}C_{(n-a)}) \ /\ {}_{N}C_n \ < \alpha_u \quad \text{(Ref. 1)}$$ (4)

Where ${}_N C_n$ is the number of combinations of n units chosen from N,

$${}_N C_n = \frac{N!}{n!\ (N-n)!}$$

Results as shown in Table 1

For a sample size n = 59 observations, it is evident from Table 1, that the probability for finding zero unsatisfactory observations is 0.0482, which is less than the assumed value of 0.05. Therefore, finding no occurrences in 59 observations satisfies the selected level of risk with only a .05 probability of error.

It is also evident from Table 1 that for a sample size n = 124 that the cumulative probability of finding up to two occurrences of failures, which is the sum of all three row entries, also satisfies .05. If, for this larger sample only one occurrence is observed, then this is the basis to conclude that the actual number of occurrences in the population is less than the assumed value. Furthermore, finding no occurrences is even more evidence of this. (5)

TABLE 1

PROBABILITY OF OCCURRENCES

N = 60,000

	NUMBER OF OCCURRENCES		
SAMPLE SIZE	0	1	2
2	---	---	---
-	---	---	---
58	0.0508	0.156	.234
59	0.0482	0.15	.230
-	---	---	---
123	0	0.0116	0.0374
124	0	0.0111	0.0361

Using this same method, it can be shown that for 10% of the total surface area as the selected risk, the sample size is reduced to 29 at a 5% risk. At n = 60, the risk is only 2%.

The results in Table 1, the work of Mr. J. P. Moore of GPUN, have been independently verified by Dr. D. G. Harlow, Associate Professor of Mechanics, Department of Mechanical Engineering and Mechanics, Lehigh University.

Simulation of Stratified Sampling:

The most severe corrosion has occurred in the sand bed region. This region may not always contain the most service limiting location, however, because of as-supplied local thickness. The previous measurement locations in this region will not be abandoned as part of this program since these are necessary in order to determine corrosion rate. It is appropriate to deliberately proportion the new observation locations in order to limit the total number of random grids that can fall in any one region. For purposes of assessing the performance of a random sampling, simulations will be performed.

Accuracy of Random Sampling Evaluated by Simulations:

A stratified sampling plan has been simulated by Professor Harlow. In Figure 1a, a total of 100 panels is used to represent the total number of plates used to fabricate the drywell. Consider the drywell divided into two strata without bias as to proportion of occurrences when the acceptance criteria is not met, the sand bed region and everywhere else. Ten plates, which are not necessarily contiguous, represent the lower strata, including portions of those plates which may be under the drywell floor and 90 comprise the upper strata. It is assumed that as much as five percent of the entire population does not meet the acceptance criteria. Assuming an equal probability of these observations in each strata (0.05), the actual proportion, P1, arrived at by simply counting the randomly simulated defective units in both strata is, P1 = 0.04833. The sample of the simulation is accomplished by randomly observing 15 units in the first stratum and 45 from the second stratum of a total of 60 observations, representing a one percent sample of available units. The measured characteristics are recorded as 1 if the unit does not meet the thickness criterion and as 0 otherwise. The estimated proportion p1, for sampling without replacement, is 0.047, a slight underestimate.

The simulation shows that the sampling plan is very promising. Figure 1b uses the same assumptions and proportion as for the first section distribution (0.05). The only difference is that a different random selection of 60 observations was made. The bottom line, however, changed. The overall estimated strata proportion, p1, has declined to 0.02. The simulation of the sampling plan no longer accurately reflects the reference proportions. A sampling plan is judged on satisfying this criteria. Repeated sampling using different grids each time will resolve this problem. The simulation studies show that the estimated proportions are more or less accurate depending on random selection of observations only. Based on the simulations it would be incorrect to conclude, using a single sample, that the overall risk assumption is not violated or that it is violated because of random selection. A number of selections of different samples will consistently provide a good estimate of the actual number of defects in the population on average. A good, experimental design uses a different sample each time an estimate is made. It is proposed for this program that a different sample, each of the same size, be used each time an estimate of the defective proportion needs to be made so that the conclusion is not based on chance alone.

Finding no unacceptable occurrences after a number of repetitions of the sampling plan, using different samples, is evidence that the assumed risk is not exceeded. A single finding of no unacceptable occurrences is consistent with the assumed risk.

Simulations of larger populations with the sample assumed risk at the same probability for error show the same good overall performance, but with like sensitivity to random variation.

MORE COMPLICATED SIMULATIONS AND RECOMMENDED SAMPLING PLAN:

A five part stratified random sampling plan is proposed in order to make the most of 60 grids. The five strata represent five zones of the drywell (Figure 2). Stratification divides a heterogeneous population into subpopulation, each of which is internally homogeneous. Each strata is sampled at the same portion, considering plates, as for the total population of plates. Better precision should be obtained than by ignoring the differences in the population. Plates in each zone will be randomly selected with one grid selected randomly per plate. The simulation of this scheme is (8) included in Attachment 1, Part A. The stratification is based on relative proportions using existing qualitative knowledge of both material lost due to corrosion and rate of material lost. The sampling plan is summarized as follows:

ZONE	DESCRIPTION	NUMBER OF PLATES SAMPLED @ 1 GRID PER PLATE FROM TOTAL NUMBER OF PLATES PER STRATA (ESTIMATED)
I	Intersection of sand bed plates and drip zones	3
II	Drip zone	12
III	Sand bed plates	9
IV	All else	32
V	Cylinder	4

The sampling plan simulation shows satisfactory accuracy over 25 trials. No single estimate exceeding 5% is reason to reject the assumed level of risk. A single sample may be unrepresented due to chance alone. A different random sample is used each time this assessment is made.

Attachment 1, Part B, is an additional simulation of the same five part stratified sampling plan where 100 repeated random samplings of size 60 are considered. In this simulation the performance of sampling process is characterized by forming a distribution of the estimation results. At the 90% confidence limit, the estimate of defect proportion falls between 0.096 and 0.0037. This shows the risk, due to chance, that the structure is concluded to be unsatisfactory where, in fact, it is.

Using a one-sided t-score, an appropriate measure of the distribution of the estimates about the true mean, at = 0.05, the performance of the sampling process does not exceed 0.05, 95% of the time. This verifies the utility of the stratified sampling plan.

The confidence interval can be narrowed by increasing the proportion of the surface area that is scanned by UT. Using the grid location as a center, use of the A-scan on a best effort basis, will provide this process improvement. The A-scan device need only be set to the local minimum thickness as a threshold.

The sand bed condition with respect to material lost due to corrosion has already been characterized. About 67% of the sand bed zone perimeter has been surveyed by UT. By this means, the most severely corroded zones have been identified throughout the sand bed, including that portion below the drywell floor.

Attachment 2 is an additional simulation of the same five part stratified sampling plan, except that sand bed zone grids are excluded, if they are randomly selected. The saving of inspection time and exposure, the amount depending on chance for each sample, is justified by comparing mean estimates and standard deviations for 100 trials. Assuming 5% defective, the simulation including the sand bed zone grids as they are selected, shows a mean estimate of 0.046 with a standard deviation of 0.024 while the simulation excluding the sand bed zone grids as they are selected shows a mean estimate of 0.044 and standard deviation equal to 0.026 (using proportion P1 for comparison).

Also, using the t-score, as described above, this sampling process does not exceed 0.048, 95% of the time. By comparison, this is slightly less accurate.

Simulation of non-stratified sampling is shown in Attachment 3. This sampling plan does not use the accumulated corrosion information. This simulation shows that by ignoring what is already known about the degree of corrosion, the sampling process accuracy is reduced because of the increased standard deviation. The mean estimate is 0.047, but the standard deviation has increased to 0.030.

Also, using the t-score as above, the upper 95% confidence limit, U_{95}, is 0.052. This is slightly inaccurate, but in a nonconservative direction.

Table 2 summarizes the results of the simulations.

Simulation also shows that the random sampling plans are not only acceptably accurate but acceptably sensitive, as well. Simulation shows that finding no unacceptable observations occurs less than 5% of the time, as intended. (11)

Changing the simulation in Attachment 1b to reflect the actual number of plates per strata results in U_{95} = 0.055. The change is insignificant so that the estimates used in the above simulations are representative of the performance of the random sampling process. (12)

Finding One or More Unacceptable Observations:

In the simulations, finding one or more of the 60 observations to be less than the minimum thickness predominated. Finding one or more using this sample doesn't prove anything unique and conclusive about the level of structural assurance. For example, one or more unacceptable observations can occur at a 5% probability with 99.9% of the drywell free of unacceptable observations. A conclusion about drywell, structural adequacy with one such observation is not appropriate because a better condition can result in an unacceptable observation. Finding none does confirm the original hypothesis. 12

The probabilities of finding none (α) or finding one or more unacceptable observations using a sample of 60 observations for a number of populations containing different portions of unacceptable observations are shown in Figure 3. The probability of finding one or more, β, is $\beta = (1 - \alpha)$.

Use of Cells Within Grids:

Minimum required mean plate thickness and minimum required local plate thickness each must satisfy design basis stress criteria. In addition, minimum required mean plate thickness must satisfy ASME design basis stability criteria to prevent buckling. Minimum required mean plate thickness pertains to a shell course and minimum required local plate thickness pertains to a single local area or the sum of local areas within reference distances, if there are more than one local area.

TABLE 2

RESULTS OF SIMULATIONS

	5% DEFECTIVE				
	P1			P2	
	MEAN ESTIMATE	STANDARD DEVIATION	U_{95}	MEAN ESTIMATE	STANDARD DEVIATION
Five part stratification including sand bed	0.046	0.024	0.050	0.052	0.022
Five part stratification not including sand bed	0.044	0.026	0.048	0.043	0.026
No stratification, not including sand bed	0.047	0.030	0.052	---	---

NOTE: By simulation it can be shown that the mean estimate is less accurate for an assured 10% defective population using a sample size of = 30.

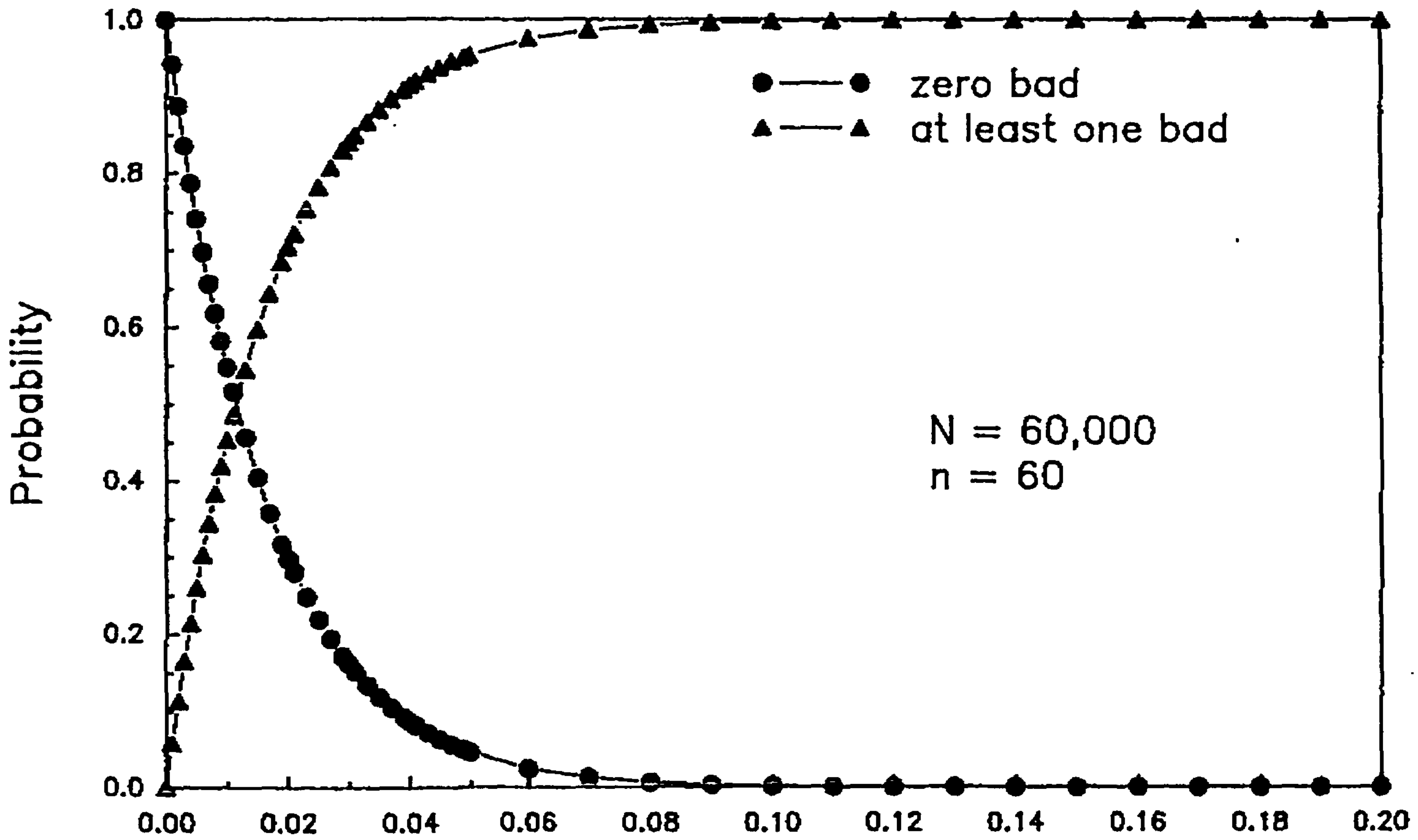

FIG. 3 Fraction of BAD Grids

A grid of individual measurements will be the basis for estimating the mean plate thickness. There is no code requirement for either the minimum or maximum grid size necessary to determine mean plate thickness. However, the grid size should be large enough to capture the local, minimum thickness in a 2.5" diameter or smaller circle and no larger than 2.5√Rt, which is the distance that uniform shell thickness must extend around an unreinforced opening. Local minimum thickness must satisfy both local membrane stress criteria and code rules for unreinforced openings.

The grid size should be large enough to contain enough single observations to minimize the impact of a pit on the mean thickness while minimizing radiation exposure of personnel taking the measurements. A 6" X 6" grid of 49 data points on two inch centers fulfills these criteria. It conservatively captures a 2" diameter circle and is more conservative than a 2.5√Rt radius circle since there is less benefit from averaging. The 6" X 6" grids will also be used to establish that not more than 0.1% of the surface area satisfying the required mean thickness criteria contains locally low areas. That is, no more than one locally low area per reference circle. Therefore, equate the requirement that 99% of the area is free of holes to a 99% probability of finding no locally low area. (14)

Analysis of variance of 2" X 2" cells contained within a single 6" X 6" grid will show whether the difference between the required mean and local thickness is significantly more than the lower 99.9% tolerance limit one-sided, times the standard deviation for the 2" X 2" cells. The one percent probability is consistent with the one percent local reduction permitted by the code.

Statistical inference regarding the variance of the observed grid means about the true grid mean of the population is not important. The concern here is variance of reference 2" X 2" cell measurements about an assumed mean equal to the acceptance thickness for a particular plate.

As developed by Messrs. J. P. Moore and M. A. Orski of GPUN, with review and concurrence by Dr. J. Orsini, Professor of Management and System Design, Fordham University, the pooled variance of 49 cell measurements per grid, the average of four points per 2" X 2" cell, taken over 60 grids, totalling 540 observations, is the basis to establish the lower, single-sided tolerance limit for a single cell thickness.

The definition of X^2, the parameter characterizing a normal distribution, relates sample variance, s^2, and population variance, σ^2:

$$X^2 = \frac{s^2 (n-1)}{\sigma^2} \qquad \text{EQUATION 1}$$

Where n = sample size = 540 and

$$s^2 = \frac{\sum_{i=1}^{j} (n_i - 1) s_i^2}{\sum_{i=1}^{j} (n_i - 1)}, \qquad \text{for } j = 540 \text{ and } n_i = 4 \text{ for all } i$$

Where

$$s^2_i = \frac{\sum_{i=1}^{j} (x_i - \bar{x})^2}{(j - 1)}, \qquad \text{where } j = 4$$

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Since n is large, σ^2 can be computed accurately using X^2 at a significance equal to 0.1.

Here the mean plate thickness is assumed and a tolerance limit is necessary to predict an individual observation. For a normal distribution of a large number of individual observations, the difference between the population mean, μ , and an individual observation, x, is given by the Z parameter,

$$Z = \frac{|x - \mu|}{\sigma} \qquad \text{EQUATION 2}$$

σ is obtained from Equation 1, above. The difference $|x - \mu|$ is the difference, $\underline{\Delta}$, between the assumed population mean and a local thickness of

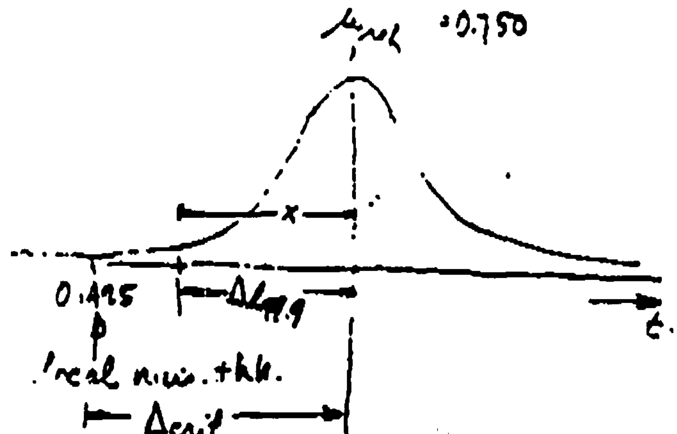

FIG. 2 DIFFERENCE OF MEAN AND LOCAL THICKNESSES DOES NOT EXCEED CRITICAL VALUE

an individual cell. It is highly unlikely for a local cell thickness to be less than:

$$|x - \mu| = Z_{99.9} \cdot \sigma \qquad \text{EQUATION 3}$$

The distribution of results should show that the probability of an unacceptable local low area is very small. (14)

Using pooled variance, an individual cell thickness is estimated at the lower 99.9% confidence limit. Based on the distribution of local thicknesses, there is a high confidence that no repairable local areas will be found, i.e., that the critical differences are more than that shown by the measurements, ($\underline{\Delta}$ crit. < $\underline{\Delta}_{99.9}$) as shown in Figure 4.

SCOPE OF APPLICATION:

Since no portion of the drywell is purposely excluded on theoretical grounds, the inspection plan applies to the entire structure except welds, those areas over which a 6" X 6" simply won't fit, and penetrations.

Grids drawn at random falling in the sand bed region of the sphere will be disregarded because this zone is characterized in an ongoing manner by numerous grids and strip measurements. Previous measurements below the drywell floor in excavated trenches, showed that material loss due to corrosion was no worse than above the floor. This results in ALARA savings without sacrifice in sampling accuracy.

ACCEPTANCE CRITERIA:

A repairable grid is one that does not satisfy the local low spot minimum thickness. The 6" X 6" grid is a conservative gauge that could have been larger. Its utility is for corrosion rate assessment. Larger grids tend to drive the mean thickness upward. The use of pooled variance of grids with the reference mean thickness ensures that the local minimum thickness is obtained conservatively. Finding no repairable areas within grids provides a level of assurance of better than 99% that the drywell is free of such areas.

The corrosion allowance can be based on the estimated corrosion rate because nothing can be inferred about rate by this assessment. It is not appropriate to use a 95% confidence interval rate estimate based on other, routinely revisited grids.

Sampling Scheme Contingency Plan:

Should a randomly selected grid turn out to be inaccessible, consistent rules will be provided, in the inspection specification, to locate an alternate without introducing any biases.

Disposition of Results:

Finding an unacceptable mean thickness is reason to better characterize the area in order to show that the region is, in general, in much better condition. If a mean thickness, established using a 6" x 6" grid, does not meet minimum requirements, enlarge the inspection grid to an area one and a half feet on a side and obtain additional readings. Use the enlarged grid to compute a new mean thickness. This will improve accuracy, as well.

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REFERENCES:

1. Personal, communication entitled "Sampling Plans for the Oyster Creek Drywell," D. G. Harlow to S. D. Leshnoff, 5/22/90. (4)

```
      STRAT2SIM
THE number ns OF SECTIONS. i.e. strata, IS 2.
ENTER THE number OF PANELS IN stratum 1
□:
      10
ENTER THE number OF PANELS IN stratum 2
□:
      90
THE total number OF PANELS = 100
ASSUME: TOTAL NUMBER OF UNITS IS identical FOR EACH PANEL.
ENTER THE number nu OF UNITS PER PANEL.
□:
      60
THE total number OF UNITS = 6000
THE number OF UNITS IN SECTIONS 1 TO 2 IS 600 5400
ENTER x = P(bad unit) WHICH DESCRIBES THE ENTIRE POPULATION.
□:
     .05

SECTION DISTRIBUTION no. 1: 0.05 0.05
SECTION DISTRIBUTION no. 2: 0.1538461538 0.03846153846
SECTION DISTRIBUTION no. 3: 0.25 0.02777777778

PROPORTION P1 = 0.04833333333
PROPORTION P2 = 0.049
PROPORTION P3 = 0.05133333333

 ENTER THE NUMBER n1 OF SAMPLES DESIRED FOR stratum 1
 □:
       15
 ENTER THE NUMBER n2 OF SAMPLES DESIRED FOR stratum 2
 □:
       45

 ENTER THE total number OF UNITS TO BE SAMPLED.
 □:
       60

 sampling without replacement

 ESTIMATED STRATA PROPORTIONS p1 = 0.06666666667 0.04444444444
 ESTIMATED STRATA PROPORTIONS p2 = 0.06666666667 0.04444444444
 ESTIMATED STRATA PROPORTIONS p3 = 0.1333333333 0.02222222222

 ESTIMATED PROPORTION p1 = 0.04666666667
 ESTIMATED PROPORTION p2 = 0.04666666667
 ESTIMATED PROPORTION p3 = 0.03333333333

 ESTIMATED VARIANCE OF p1 = 7.987264485E¯4
 ESTIMATED VARIANCE OF p2 = 7.987264485E¯4
 ESTIMATED VARIANCE OF p3 = 4.631601949E¯4
```

FIG. 1a SIMULATION OF RANDOM SAMPLING USING TWO STRATA

```
      STRAT2SIM
THE number ns OF SECTIONS, i.e. strata, IS 2.
ENTER THE number OF PANELS IN stratum 1
⎕:
      10
ENTER THE number OF PANELS IN stratum 2
⎕:
      90
THE total number OF PANELS = 100
ASSUME: TOTAL NUMBER OF UNITS IS identical FOR EACH PANEL.
ENTER THE number nu OF UNITS PER PANEL.
⎕:
      60
THE total number OF UNITS = 6000
THE number OF UNITS IN SECTIONS 1 TO 2 IS 600 5400
ENTER q = Prob(bad unit) WHICH DESCRIBES THE ENTIRE POPULATION.
⎕:
      .05

SECTION DISTRIBUTION no. 1: 0.15 0.05
SECTION DISTRIBUTION no. 2: 0.4567307692 4.807692308E¯3
SECTION DISTRIBUTION no. 3: 0.4583333333 4.629629631E¯3

PROPORTION P1 = 0.05033333333
PROPORTION P2 = 0.04816666667
PROPORTION P3 = 0.04833333333

ENTER THE NUMBER n1 OF SAMPLES DESIRED FOR stratum 1
⎕:
      15
ENTER THE NUMBER n2 OF SAMPLES DESIRED FOR stratum 2
⎕:
      45

ENTER THE total number OF UNITS TO BE SAMPLED.
⎕:
      60

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0 0.02222222222
ESTIMATED STRATA PROPORTIONS p2 = 0.4666666667 0
ESTIMATED STRATA PROPORTIONS p3 = 0.4666666667 0

ESTIMATED PROPORTION p1 = 0.02
ESTIMATED PROPORTION p2 = 0.04666666667
ESTIMATED PROPORTION p3 = 0.04666666667

ESTIMATED VARIANCE OF p1 = 3.879236896E¯4
ESTIMATED VARIANCE OF p2 = 1.620478575E¯4
ESTIMATED VARIANCE OF p3 = 1.620478575E¯4
```

FIG. 1b SIMULATION OF RANDOM SAMPLING USING TWO STRATA.

DRYWELL

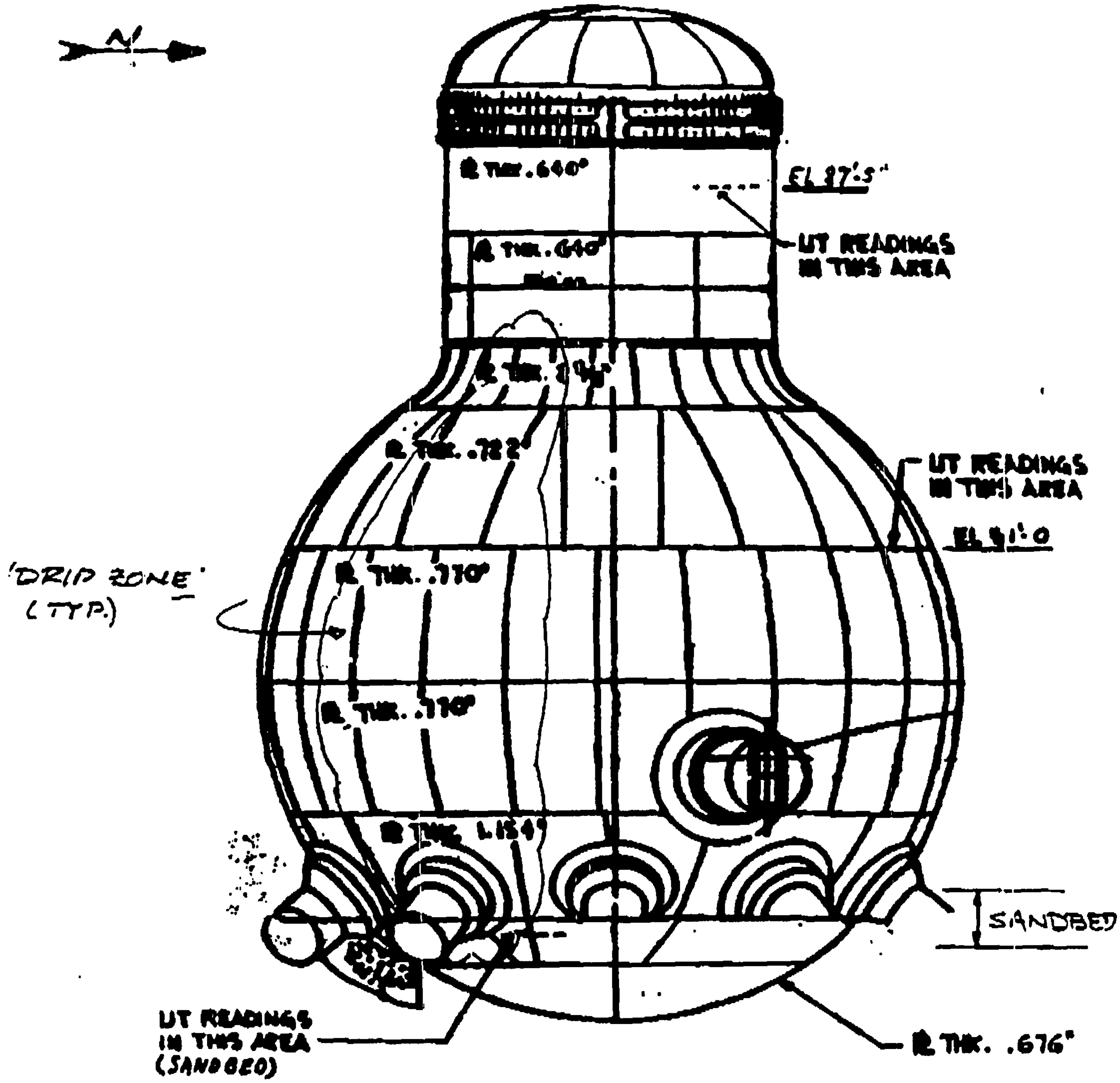


FIG. 2

ILLUSTRATION OF DRYWELL STRATA

ATTACHMENT 1a
SIMULATION OF 5 PART
STRATIFIED SAMPLING PLAN.

```
THE NUMBER OF SUBSETS ns = 5.
SUBSET 1 = drip zone and sandbed:  WORST
SUBSET 2 = drip zone only:  VERY BAD
SUBSET 3 = sand bed:  BAD
SUBSET 4 = rest of the sphere:  GOOD
SUBSET 5 = cylinder:  BEST
THE number OF PANELS IN SUBSETS 1.2.3.4.5 IS 5 20 15 52 8
THE total number OF PANELS = 100
ASSUME: TOTAL NUMBER OF 6x6 SAMPLE UNITS IS identical FOR EACH PANEL.
THE NUMBER OF UNITS PER PANEL nu = 600.
THE total number OF UNITS = 60.000.
THE number OF UNITS IN SUBSETS 1.2.3.4.5 IS 3000 12000 9000 31200 4800
ENTER q = Pr(bad unit):  A CHARACTERIZATION OF THE ENTIRE POPULATION.
□:
      0.05
SUBSET DISTRIBUTION no. 1: 0.2524487529 0.1262243765 0.06311218823
      5.048975059E¯3 5.048975058E¯4
SUBSET DISTRIBUTION no. 2: 0.3924646782 0.07849293564 0.03924646782
      0.01569858713 7.849293564E¯3

PROPORTION P1 = 0.05125
PROPORTION P2 = 0.0501

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0 0.1666666667 0.1111111111 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0 0 0.1111111111 0 0

ESTIMATED PROPORTION p1 = 0.05
ESTIMATED PROPORTION p2 = 0.01666666667

ESTIMATED VARIANCE OF p1 = 7.092326223E¯4
ESTIMATED VARIANCE OF p2 = 2.466940771E¯4

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0 0.08333333333 0 0.03125 0
ESTIMATED STRATA PROPORTIONS p2 = 0 0.08333333333 0 0 0

ESTIMATED PROPORTION p1 = 0.03291666667
ESTIMATED PROPORTION p2 = 0.01666666667

ESTIMATED VARIANCE OF p1 = 5.099525677E¯4
ESTIMATED VARIANCE OF p2 = 2.543961997E¯4

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0.3333333333 0.08333333333 0.1111111111 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0.6666666667 0 0.1111111111 0.03125 0

ESTIMATED PROPORTION p1 = 0.05
ESTIMATED PROPORTION p2 = 0.06625
```

ESTIMATED VARIANCE OF p2 = 6.0731213238E¯4

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0.3333333333 0.1666666667 0 0.03125 0
ESTIMATED STRATA PROPORTIONS p2 = 0 0 0 0 0

ESTIMATED PROPORTION p1 = 0.06625
ESTIMATED PROPORTION p2 = 0

ESTIMATED VARIANCE OF p1 = 9.0315660012E¯4
ESTIMATED VARIANCE OF p2 = 0

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0 0.25 0.1111111111 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0.3333333333 0 0 0.03125 0

ESTIMATED PROPORTION p1 = 0.06666666667
ESTIMATED PROPORTION p2 = 0.03291666667

ESTIMATED VARIANCE OF p1 = 8.7112111127E¯4
ESTIMATED VARIANCE OF p2 = 4.4061805528E¯4

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0.3333333333 0.1666666667 0.3333333333 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0.3333333333 0 0 0.03125 0

ESTIMATED PROPORTION p1 = 0.1
ESTIMATED PROPORTION p2 = 0.03291666667

ESTIMATED VARIANCE OF p1 = 1.2026619068E¯3
ESTIMATED VARIANCE OF p2 = 4.4061805528E¯4

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0 0.1666666667 0 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0.6666666667 0.08333333333 0.1111111111
0.03125 0

ESTIMATED PROPORTION p1 = 0.03333333333
ESTIMATED PROPORTION p2 = 0.08291666667

ESTIMATED VARIANCE OF p1 = 4.6253854498E¯4
ESTIMATED VARIANCE OF p2 = 9.417083328E¯4

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

ATT 1a

0.03125 0

ESTIMATED PROPORTION p1 = 0.03333333333
ESTIMATED PROPORTION p2 = 0.03291666667

ESTIMATED VARIANCE OF p1 = 4.394579865E¯4
ESTIMATED VARIANCE OF p2 = 1.12672889E¯3

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0 0.1666666667 0.2222222222 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0.6666666667 0.1666666667 0 0 0.25

ESTIMATED PROPORTION p1 = 0.06666666667
ESTIMATED PROPORTION p2 = 0.08666666667

ESTIMATED VARIANCE OF p1 = 8.942531798E¯4
ESTIMATED VARIANCE OF p2 = 9.474126931E¯4

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0 0.1666666667 0 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0.3333333333 0 0 0 0

ESTIMATED PROPORTION p1 = 0.03333333333
ESTIMATED PROPORTION p2 = 0.01666666667

ESTIMATED VARIANCE OF p1 = 4.625385449E¯4
ESTIMATED VARIANCE OF p2 = 1.850616872E¯4

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0 0.08333333333 0 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0.6666666667 0.1666666667 0 0 0

ESTIMATED PROPORTION p1 = 0.01666666667
ESTIMATED PROPORTION p2 = 0.06666666667

ESTIMATED VARIANCE OF p1 = 2.543961997E¯4
ESTIMATED VARIANCE OF p2 = 6.476002321E¯4

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0.3333333333 0.1666666667 0.2222222222 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0.6666666667 0.08333333333 0 0.03125 0

ESTIMATED PROPORTION p1 = 0.08333333333
ESTIMATED PROPORTION p2 = 0.06625

ESTIMATED VARIANCE OF p1 = 1.079314867E¯3

ATT. 1A

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0 0 0.1111111111 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0.6666666667 0 0 0.03125 0

ESTIMATED PROPORTION p1 = 0.01666666667
ESTIMATED PROPORTION p2 = 0.04958333333

ESTIMATED VARIANCE OF p1 = 2.466940771E¯4
ESTIMATED VARIANCE OF p2 = 4.406180552E¯4

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0.6666666667 0.1666666667 0 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0.6666666667 0.08333333333 0.1111111111 0.09375 0

ESTIMATED PROPORTION p1 = 0.06666666667
ESTIMATED PROPORTION p2 = 0.1154166667

ESTIMATED VARIANCE OF p1 = 6.476002321E¯4
ESTIMATED VARIANCE OF p2 = 1.403358545E¯3

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0.3333333333 0.08333333333 0.2222222222 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0 0.08333333333 0.1111111111 0.03125 0

ESTIMATED PROPORTION p1 = 0.06666666667
ESTIMATED PROPORTION p2 = 0.04958333333

ESTIMATED VARIANCE OF p1 = 8.711725219E¯4
ESTIMATED VARIANCE OF p2 = 7.566466448E¯4

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0.3333333333 0.08333333333 0 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0 0.1666666667 0.1111111111 0 0

ESTIMATED PROPORTION p1 = 0.03333333333
ESTIMATED PROPORTION p2 = 0.05

ESTIMATED VARIANCE OF p1 = 4.394578869E¯4
ESTIMATED VARIANCE OF p2 = 7.09232622E¯4

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0.3333333333 0.1666666667 0.1111111111 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0.3333333333 0.1666666667 0 0 0

ESTIMATED PROPORTION p1 = 0.0[illegible]

ATT. 1a

ESTIMATED VARIANCE OF p2 = 6.476002321E¯4

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0 0.1666666667 0.3333333333 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0 0.08333333333 0 0.03125 0

ESTIMATED PROPORTION p1 = 0.08333333333
ESTIMATED PROPORTION p2 = 0.03281666667

ESTIMATED VARIANCE OF p1 = 1.017500216E¯3
ESTIMATED VARIANCE OF p2 = 5.095525677E¯4

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0 0.08333333333 0 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0 0.25 0 0 0

ESTIMATED PROPORTION p1 = 0.01666666667
ESTIMATED PROPORTION p2 = 0.05

ESTIMATED VARIANCE OF p1 = 2.543961997E¯4
ESTIMATED VARIANCE OF p2 = 6.244270356E¯4

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0 0.08333333333 0 0 0
ESTIMATED STRATA PROPORTIONS p2 = 1 0 0 0 0

ESTIMATED PROPORTION p1 = 0.01666666667
ESTIMATED PROPORTION p2 = 0.05

ESTIMATED VARIANCE OF p1 = 2.543961997E¯4
ESTIMATED VARIANCE OF p2 = 0

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0 0.08333333333 0 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0 0.25 0 0.03125 0

ESTIMATED PROPORTION p1 = 0.01666666667
ESTIMATED PROPORTION p2 = 0.06625

ESTIMATED VARIANCE OF p1 = 2.543961997E¯4
ESTIMATED VARIANCE OF p2 = 8.799834036E¯4

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ATT. 1a.

ESTIMATED PROPORTION p1 = 0.01666666667
ESTIMATED PROPORTION p2 = 0.06666666667

ESTIMATED VARIANCE OF p1 = 2.466940771E¯4
ESTIMATED VARIANCE OF p2 = 2.543961997E¯4

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0 0.25 0.2222222222 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0.6666666667 0.08333333333 0 0.0625 0

ESTIMATED PROPORTION p1 = 0.08333333333
ESTIMATED PROPORTION p2 = 0.0825

ESTIMATED VARIANCE OF p1 = 1.056141671E¯3
ESTIMATED VARIANCE OF p2 = 9.340831153E¯4

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0.6666666667 0.25 0 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0.6666666667 0 0.1111111111 0 0

ESTIMATED PROPORTION p1 = 0.08333333333
ESTIMATED PROPORTION p2 = 0.05

ESTIMATED VARIANCE OF p1 = 8.094887228E¯4
ESTIMATED VARIANCE OF p2 = 4.317557643E¯4

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.

sampling without replacement

ESTIMATED STRATA PROPORTIONS p1 = 0.3333333333 0.08333333333 0.1111111111 0 0
ESTIMATED STRATA PROPORTIONS p2 = 0.3333333333 0.1666666667 0 0 0

ESTIMATED PROPORTION p1 = 0.05
ESTIMATED PROPORTION p2 = 0.05

ESTIMATED VARIANCE OF p1 = 6.861519641E¯4
ESTIMATED VARIANCE OF p2 = 6.476002321E¯4

ATTACHMENT 1b
SIMULATION OF 5 PART
STRATIFIED SAMPLING PLAN.

```
SUBSET25:M
THE NUMBER OF SUBSETS ns = 5.
SUBSET 1 = drip zone and sandbed:  WORST
SUBSET 2 = drip zone only:  VERY BAD
SUBSET 3 = sand bed:  BAD
SUBSET 4 = rest of the sphere:  GOOD
SUBSET 5 = cylinder:  BEST
THE number OF PANELS IN SUBSETS 1,2,3,4,5 IS 5 20 15 52 8
THE total number OF PANELS = 100
ASSUME: TOTAL NUMBER OF 6X6 SAMPLE UNITS IS identical FOR EACH PANEL.
THE NUMBER OF UNITS PER PANEL nu = 600.
THE total number OF UNITS = 60,000.
THE number OF UNITS IN SUBSETS 1,2,3,4,5 IS 3000 12000 9000 31200 4800
ENTER q = Pr(bad unit): A CHARACTERIZATION OF THE ENTIRE POPULATION.
0:
      0.05

SUBSET DISTRIBUTION no. 1:
        0.2524487529
        0.1262243765
        0.0631121882
        0.0050489751
        0.0005048975
SUBSET DISTRIBUTION no. 2:
        0.3924646782
        0.0784929356
        0.0392464678
        0.0156985871
        0.0078492936

PROPORTION P1 = 0.04735
PROPORTION P2 = 0.0515

sampling without replacement

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.


MAXIMUM OF THE ESTIMATES:  0.1166666667 0.03726821082 1 1 0.1325 0.03469665474
      1 1
MINIMUM OF THE ESTIMATES:  0 0 0 0 0 0 0 0
AVERAGE OF THE ESTIMATES:  0.045925 0.02282403069 0.91 0.99 0.05165
      0.02247775817 0.88 0.98
STD DEV OF THE ESTIMATES:  0.02409039543 7.305016591E¯3 0.2876234913 0.1
      0.02850819482 8.331828116E¯3 0.3265986324 0.1407052941

UPPER TWO-SIDED NORMAL 0.90 AND 0.95 CONFIDENCE LIMIT = 0.09628466044
      0.1051476805
LOWER TWO-SIDED NORMAL 0.90 AND 0.95 CONFIDENCE LIMIT = 3.715339564E¯3
      ¯5.147680519E¯3
```

p1(hat)	s1(hat)	TEST90	TEST95	p2(hat)	s2(hat)	TEST90	TEST95
0.0333333	0.0209633	1	1	0.0829167	0.0300526	1	1
0.0500000	0.0261937	1	1	0.0162500	0.0159861	1	1
0.0658333	0.0305628	1	1	0.0333333	0.0209633	1	1
0.0333333	0.0215067	1	1	0.0333333	0.0209633	1	1
0.0500000	0.0261945	1	1	0.0829167	0.0306873	1	1
0.0000000	0.0000000	0	1	0.0662500	0.0300526	1	1
0.0333333	0.0209633	1	1	0.0500000	0.0207787	1	1
0.0829167	0.0339088	1	1	0.1162500	0.0296645	0	0
0.0495833	0.0263631	1	1	0.0829167	0.0306873	1	1
0.1000000	0.0324990	0	1	0.0333333	0.0209633	1	1
0.0666667	0.0284515	1	1	0.1000000	0.0266314	0	1
0.0333333	0.0223650	1	1	0.0662500	0.0300526	1	1
0.0166667	0.0159498	1	1	0.0333333	0.0207787	1	1
0.0000000	0.0000000	0	1	0.0500000	0.0261937	1	1
0.0166667	0.0126037	1	1	0.0662500	0.0263631	1	1

ATT. 1b.

[illegible]	[illegible]	1	1	[illegible]	[illegible]	1	[illegible]
[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	1	1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	1
[illegible]	[illegible]	1	1	0.0491667	0.0272272	1	1
0.0500000	0.0254480	1	1	0.0166667	0.0136037	1	1
0.0166667	0.0159498	1	1	0.0829167	0.0225821	1	1
0.0495833	0.0263631	1	1	0.0833333	0.0294515	1	1
0.0166667	0.0159499	1	1	0.0500000	0.0209633	1	1
0.0500000	0.0261945	1	1	0.0495833	0.0209909	1	1
0.0500000	0.0254480	1	1	0.0829167	0.0225821	1	1
0.0333333	0.0207787	1	1	0.0333333	0.0136037	1	1
0.0829167	0.0215534	1	1	0.0000000	0.0000000	0	1
0.0500000	0.0266314	1	1	0.1000000	0.0324990	0	1
0.0333333	0.0223850	1	1	0.0662500	0.0306873	1	1
0.0333333	0.0215067	1	1	0.0666667	0.0254480	1	1
0.0333333	0.0207787	1	1	0.0829167	0.0300526	1	1
0.0166667	0.0136037	1	1	0.0495833	0.0263631	1	1
0.0333333	0.0215067	1	1	0.0662500	0.0300526	1	1
0.0333333	0.0223850	1	1	0.0662500	0.0306873	1	1
0.0666667	0.0254480	1	1	0.0162500	0.0159861	1	1
0.0662500	0.0263631	1	1	0.0662500	0.0310611	1	1
0.0829167	0.0300526	1	1	0.0666667	0.0159498	1	1
0.0495833	0.0209909	1	1	0.0162500	0.0159861	1	1
0.0991667	0.0372682	0	1	0.0491667	0.0273683	1	1
0.0166667	0.0159498	1	1	0.0495833	0.0263631	1	1
0.0500000	0.0249885	1	1	0.0333333	0.0223850	1	1
0.1000000	0.0261937	0	1	0.0495833	0.0263631	1	1
0.0666667	0.0157065	1	1	0.0833333	0.0324990	1	1.
0.0333333	0.0207787	1	1	0.0000000	0.0000000	0	1
0.0500000	0.0254480	1	1	0.0491667	0.0272272	1	1
0.0500000	0.0207787	1	1	0.0162500	0.0159861	1	1
0.0500000	0.0249885	1	1	0.0700000	0.0271895	1	1
0.0500000	0.0254480	1	1	0.0825000	0.0337968	1	1
0.0000000	0.0000000	0	1	0.0162500	0.0159861	1	1
0.1166667	0.0342318	0	0	0.0833333	0.0207777	1	1
0.0500000	0.0254480	1	1	0.0500000	0.0207787	1	1
0.0666667	0.0299041	1	1	0.0329167	0.0224109	1	1
0.0166667	0.0159498	1	1	0.0000000	0.0000000	0	1
0.0166667	0.0136037	1	1	0.0162500	0.0159861	1	1
0.0333333	0.0209633	1	1	0.0333333	0.0223850	1	1
0.0333333	0.0207787	1	1	0.0333333	0.0207787	1	1
0.0500000	0.0254480	1	1	0.0495833	0.0263631	1	1
0.0666667	0.0295156	1	1	0.0500000	0.0261945	1	1
0.0333333	0.0209633	1	1	0.0833333	0.0299048	1	1
0.0333333	0.0209633	1	1	0.0500000	0.0209633	1	1
0.0500000	0.0254480	1	1	0.0000000	0.0000000	0	1
0.0500000	0.0254480	1	1	0.1325000	0.0346967	0	0
0.0333333	0.0215067	1	1	0.0166667	0.0159498	1	1
0.0333333	0.0136037	1	1	0.0333333	0.0136037	1	1
0.0166667	0.0136037	1	1	0.0333333	0.0209633	1	1
0.0166667	0.0136037	1	1	0.0829167	0.0306873	1	1
0.0666667	0.0295148	1	1	0.0500000	0.0254480	1	1
0.0166667	0.0157065	1	1	0.0825000	0.0304365	1	1
0.0333333	0.0215067	1	1	0.0825000	0.0222402	1	1
0.0333333	0.0207777	1	1	0.0491667	0.0272272	1	1
0.0833333	0.0295156	1	1	0.0500000	0.0254480	1	1
0.0000000	0.0000000	0	1	0.0666667	0.0159498	1	1
0.0166667	0.0157065	1	1	0.0166667	0.0159498	1	1
0.0833333	0.0324990	1	1	0.0333333	0.0209633	1	1
0.0500000	0.0261945	1	1	0.0833333	0.0299048	1	1
0.0500000	0.0261945	1	1	0.0495833	0.0275072	1	1
0.0662500	0.0295353	1	1	0.0000000	0.0000000	0	1
0.0166667	0.0157065	1	1	0.0833333	0.0215067	1	1
0.0500000	0.0254480	1	1	0.0829167	0.0335668	1	1
0.0333333	0.0136037	1	1	0.0166667	0.0157065	1	1
0.0333333	0.0215067	1	1	0.0666667	0.0222775	1	1

ATT. 15

0.0333333	0.0215067	1	1	0.0333333	0.0209633	1	1
0.0666667	0.0299048	1	1	0.0495833	0.0262166	1	1
0.0662500	0.0300526	1	1	0.0000000	0.0000000	0	1
0.0333333	0.0209633	1	1	0.0991667	0.0323377	0	1
0.0666667	0.0299156	1	1	0.0166667	0.0136037	1	1
0.0166667	0.0159498	1	1	0.0500000	0.0207787	1	1
0.0500000	0.0266314	1	1	0.0829167	0.0335668	1	1
0.0500000	0.0209633	1	1	0.0658333	0.0260708	1	1
0.0495833	0.0262166	1	1	0.0495833	0.0209909	1	1
0.0995833	0.0362179	0	1	0.0662500	0.0300526	1	1
0.0666667	0.0284515	1	1	0.0666667	0.0159498	1	1
0.0333333	0.0223850	1	1	0.0658333	0.0260708	1	1
0.0500000	0.0266314	1	1	0.0325000	0.0222402	1	1
0.0500000	0.0207787	1	1	0.0495833	0.0267973	1	1
0.0333333	0.0207787	1	1	0.0333333	0.0207787	1	1
0.0662500	0.0306873	1	1	0.0829167	0.0300526	1	1
0.0500000	0.0254480	1	1	0.0166667	0.0159498	1	1
0.0829167	0.0339660	1	1	0.0166667	0.0136037	1	1
0.0500000	0.0266314	1	1	0.0000000	0.0000000	0	1

ATT. 2

SAND BED EXCLUDED

```
SUBSIT4SIM
THE NUMBER OF SUBSETS ns = 5.
SUBSET 1 = drip zone and sandbed: WORST
SUBSET 2 = drip zone only: VERY BAD
SUBSET 3 = sand bed: BAD
SUBSET 4 = rest of the sphere: GOOD
SUBSET 5 = cylinder: BEST
THE number OF PANELS IN SUBSETS 1,2,3,4,5 IS 5 20 15 52 8
THE total number OF PANELS = 100
ASSUME: TOTAL NUMBER OF 6x6 SAMPLE UNITS IS identical FOR EACH PANEL.
THE NUMBER OF UNITS PER PANEL nu = 600.
THE total number OF UNITS = 60,000.
THE number OF UNITS IN SUBSETS 1,2,3,4,5 IS 3000 12000 9000 31200 4800
ENTER q = Pr(bad unit): A CHARACTERIZATION OF THE ENTIRE POPULATION.
Q:
      0.05

SUBSET DISTRIBUTION no. 1:
        0.2524487529
        0.1262243765
        0.0531121882
        0.0050489751
        0.0005048975
SUBSET DISTRIBUTION no. 2:
        0.3924646782
        0.0784929356
        0.0392464678
        0.0156985871
        0.0078492936

PROPORTION P1 = 0.05015
PROPORTION P2 = 0.05103333333

sampling without replacement

THE NUMBER OF PANELS TO BE SAMPLED FOR subsets 1 - 5 = 3,12,9,32,4.
THE BOTTOM HALF OF THE PANELS IN subsets 1 AND 5 ARE EXCLUDED,
   IF AND ONLY IF THEY ARE RANDOMLY SELECTED.

CONDITIONAL PROPORTION P1 = 0.04312962963
CONDITIONAL PROPORTION P2 = 0.04181481481

MAXIMUM OF THE ESTIMATES:  0.1203703704 1 1 58 0.1226851852 1 1
MINIMUM OF THE ESTIMATES:  0 0 0 49 0 0 0
AVERAGE OF THE ESTIMATES:  0.04425562169 0.94 0.97 53.9 0.04344973545 0.94
     0.95
STD DEV OF THE ESTIMATES:  0.02582932443 0.2386832566 0.171446608 1.702642035
     0.02656310082 0.2386832566 0.2190429136

UPPER TWO-SIDED NORMAL 0.90 AND 0.95 CONFIDENCE LIMIT FOR CASE 1 =
     0.08617206874 0.09453338687
LOWER TWO-SIDED NORMAL 0.90 AND 0.95 CONFIDENCE LIMIT FOR CASE 1 =
     ¯1.280948283E¯5 ¯8.274127611E¯3
UPPER TWO-SIDED NORMAL 0.90 AND 0.95 CONFIDENCE LIMIT FOR CASE 2 =
     0.08432373684 0.09246374318
LOWER TWO-SIDED NORMAL 0.90 AND 0.95 CONFIDENCE LIMIT FOR CASE 2 =
     ¯6.941072062E¯4 ¯8.834113353E¯3
p1(hat)  TEST90  TEST95  no. sampled  p2(hat)  TEST90  TEST95
  0.0689815  1  1   54  0.0685185  1  1
  0.0365741  1  1   54  0.0185185  1  1
  0.0365741  1  1   55  0.0370370  1  1
  0.0000000  1  1   51  0.0180556  1  1
  0.0643519  1  1   53  0.1226852  0  0
  0.0759259  1  1   53  0.0185185  1  1
```

ATT. 2

0.0351852	1	1	55	0.0685185	1	1
0.0555556	1	1	51	0.0277778	1	1
0.0995370	0	0	53	0.0462963	1	1
0.0629630	1	1	54	0.0921296	0	1
0.0638889	1	1	51	0.0828704	1	1
0.0370370	1	1	56	0.0277778	1	1
0.0629630	1	1	53	0.0277778	1	1
0.0856481	1	1	52	0.0277778	1	1
0.0000000	1	1	52	0.0736111	1	1
0.0736111	1	1	50	0.0643519	1	1
0.0185185	1	1	54	0.0370370	1	1
0.0324074	1	1	55	0.0490741	1	1
0.0509259	1	1	55	0.0458333	1	1
0.0462963	1	1	54	0.0185185	1	1
0.0324074	1	1	55	0.0361111	1	1
0.0393519	1	1	53	0.0361111	1	1
0.0555556	1	1	55	0.0550926	1	1
0.0185185	1	1	54	0.0555556	1	1
0.0370370	1	1	53	0.0643519	1	1
0.0370370	1	1	55	0.0462963	1	1
0.0138889	1	1	56	0.0365741	1	1
0.0550926	1	1	54	0.0365741	1	1
0.0277778	1	1	49	0.1009259	0	0
0.0648148	1	1	54	0.0277778	1	1
0.0416667	1	1	52	0.0462963	1	1
0.0393519	1	1	53	0.0638889	1	1
0.0000000	1	1	54	0.0689815	1	1
0.0319444	1	1	55	0.0555556	1	1
0.0319444	1	1	56	0.0324074	1	1
0.0925926	0	1	52	0.0370370	1	1
0.0462963	1	1	54	0.1189815	0	0
0.0462963	1	1	53	0.0648148	1	1
0.0185185	1	1	53	0.0324074	1	1
0.0324074	1	1	55	0.0185185	1	1
0.0370370	1	1	57	0.0689815	1	1
0.0578704	1	1	54	0.0324074	1	1
0.0643519	1	1	54	0.0462963	1	1
0.0925926	0	1	54	0.0458333	1	1
0.0717593	1	1	54	0.0504630	1	1
0.0740741	1	1	54	0.0277778	1	1
0.0370370	1	1	53	0.0731481	1	1
0.0555556	1	1	57	0.0185185	1	1
0.0648148	1	1	57	0.0601852	1	1
0.0092593	1	1	54	0.0277778	1	1
0.0185185	1	1	53	0.0370370	1	1
0.0324074	1	1	[illegible]	[illegible]	1	1
0.0648148	1	1	56	0.0319444	1	1
0.0532407	1	1	[illegible]	[illegible]	1	1
0.0092593	1	1	[illegible]	0.0185185	1	1
0.0000000	1	1	[illegible]	0.0138889	1	1
0.0671296	1	1	53	0.0185185	1	1
0.0370370	1	1	53	0.0138889	1	1
0.0555556	1	1	54	0.0277778	1	1
0.0277778	1	1	55	0.0000000	1	1
0.0370370	1	1	56	0.0599206	1	1
0.0740741	1	1	56	0.0277778	1	1
0.0185185	1	1	55	0.0138889	1	1
0.0277778	1	1	52	0.0833333	1	1
0.0555556	1	1	54	0.0185185	1	1
0.0185185	1	1	54	0.0555556	1	1
0.0185185	1	1	54	0.0833333	1	1
0.0767196	1	1	55	0.0458333	1	1
0.0347222	1	1	54	0.0319444	1	1
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

ATT. 2

0.0347222	1	1	54	0.0319444	1	1
0.0185185	1	1	53	0.0000000	1	1
0.0787037	1	1	55	0.1046296	0	0
0.0578704	1	1	54	0.0319444	1	1
0.0370370	1	1	55	0.0092593	1	1
0.0324074	1	1	57	0.0416667	1	1
0.0504630	1	1	56	0.0685185	1	1
0.0166667	1	1	54	0.0000000	1	1
0.0185185	1	1	53	0.0185185	1	1
0.0740741	1	1	51	0.0458333	1	1
0.0185185	1	1	54	0.0000000	1	1
0.0462963	1	1	49	0.0277778	1	1
0.0537037	1	1	55	0.0370370	1	1
0.0509259	1	1	55	0.0402778	1	1
0.0370370	1	1	52	0.0185185	1	1
0.0000000	1	1	55	0.0828704	1	1
0.0324074	1	1	54	0.0324074	1	1
0.0000000	1	1	55	0.0000000	1	1
0.0555556	1	1	53	0.0615741	1	1
0.0370370	1	1	54	0.0833333	1	1
0.0925926	0	1	52	0.0689815	1	1
0.0289352	1	1	58	0.0319444	1	1
0.0388889	1	1	55	0.0185185	1	1
0.0458333	1	1	54	0.0462963	1	1
0.1203704	0	0	51	0.0185185	1	1
0.0722222	1	1	54	0.0458333	1	1
0.0000000	1	1	53	0.0939815	0	0
0.0324074	1	1	54	0.0324074	1	1
0.0000000	1	1	51	0.0462963	1	1
0.0555556	1	1	53	0.0185185	1	1
0.0509259	1	1	52	0.0000000	1	1

ATT. 3

NON-STRATIFIED

```
SIMPSIM
ASSUME: TOTAL NUMBER OF 6x6 SAMPLE UNITS IS identical FOR EACH PANEL.
THE NUMBER OF UNITS PER PANEL nu = 600.
THE total number OF UNITS = 60,000.
ENTER q = Pr(bad unit): A CHARACTERIZATION OF THE ENTIRE POPULATION.
Q:
      0.05

PROPORTION P1 = 0.05061666667

sampling without replacement

THE NUMBER OF PANELS TO BE SAMPLED IS 60.
THE BOTTOM HALF OF THE PANELS IN THE SAND BED (20 PANELS) ARE
EXCLUDED, IF AND ONLY IF THEY ARE RANDOMLY SELECTED.

CONDITIONAL PROPORTION P1 = 0.05096296296

MAXIMUM OF THE ESTIMATES:  0.1346153846 1 1 55
MINIMUM OF THE ESTIMATES:  0 0 0 44
AVERAGE OF THE ESTIMATES:  0.0470419326 0.83 0.95 49.77
STD DEV OF THE ESTIMATES:  0.03059222548 0.3775251681 0.2190429136 2.407291113

UPPER TWO-SIDED NORMAL 0.90 AND 0.95 CONFIDENCE LIMIT FOR CASE 1 =
      0.09766751304 0.1066109375
LOWER TWO-SIDED NORMAL 0.90 AND 0.95 CONFIDENCE LIMIT FOR CASE 1 =
      4.258412886E¯3 ¯4.685011597E¯3
p1(hat)  TEST90  TEST95  no. sampled
  0.0000000  0  1   51
  0.0196078  1  1   51
  0.0576923  1  1   52
  0.0212766  1  1   47
  0.0000000  0  1   49
  0.0196078  1  1   51
  0.0392157  1  1   51
  0.0188679  1  1   53
  0.0377358  1  1   53
  0.0000000  0  1   48
  0.0196078  1  1   51
  0.0200000  1  1   50
  0.0612245  1  1   49
  0.0566038  1  1   53
  0.0408163  1  1   49
  0.0980392  0  1   51
  0.0600000  1  1   50
  0.0833333  1  1   48
  0.1346154  0  0   52
  0.0408163  1  1   49
  0.0000000  0  1   52
  0.0425532  1  1   47
  0.0600000  1  1   50
  0.0425532  1  1   47
  0.0384615  1  1   52
  0.0208333  1  1   48
  0.0588235  1  1   51
  0.0784314  1  1   51
  0.0566039  1  1   53
  0.1086957  0  0   46
  0.0384615  1  1   52
  0.0392157  1  1   51
  0.0576923  1  1   52
```

ATT. 2

[illegible]	[illegible]	1	[illegible]
0.0377358	1	1	53
0.0576923	1	1	52
0.0833333	1	1	48
0.0800000	1	1	50
0.0400000	1	1	50
0.0416667	1	1	48
0.0638298	1	1	47
0.0200000	1	1	50
0.0384615	1	1	52
0.0612245	1	1	49
0.1041667	[illegible]	1	48
0.0576923	1	1	52
0.0196078	1	1	51
0.0566038	1	1	53
0.0370370	1	1	54
0.0217391	1	1	46
0.0000000	0	1	50
0.0188679	1	1	53
0.0384615	1	1	52
0.0612245	1	1	49
0.0400000	1	1	50
0.0851064	1	1	47
0.1200000	0	0	50
0.0588235	1	1	51
0.0638298	1	1	47
0.0000000	0	1	49
0.0612245	1	1	49
0.0384615	1	1	52
0.0833333	1	1	48
0.0196078	1	1	51
0.0566038	1	1	53
0.0555556	1	1	54
0.0204082	1	1	49
0.0425532	1	1	47
0.0000000	0	1	54
0.0444444	1	1	45
0.0833333	1	1	48
0.0888889	1	1	45
0.0192308	1	1	52
0.0212766	1	1	47
0.0638298	1	1	47
0.0625000	1	1	48
0.0566038	1	1	53
0.0784314	1	1	51
0.0816327	1	1	49
0.1224490	0	0	49
0.0227273	1	1	44
0.0000000	0	1	49
0.0600000	1	[illegible]	[illegible]
0.0833333	1	[illegible]	[illegible]
0.0000000	0	[illegible]	[illegible]
0.0196078	1	[illegible]	51
0.0000000	0	1	47
0.0769231	1	1	52
0.0196078	1	1	51
0.0222222	1	1	45
0.0434783	1	1	46
0.0208333	1	1	48
0.0400000	1	1	50
0.0181818	1	1	55
0.0212766	1	1	47
0.0384615	1	1	52
0.1111111	0	0	45
0.0816327	1	1	49
0.0638298	1	1	47

GPU Nuclear

SPECIFICATION

IS-402950-001

"NUCLEAR SAFETY RELATED"

INSTALLATION SPECIFICATION FOR

OYSTER CREEK

FUNCTIONAL REQUIREMENTS FOR

AUGMENTED DRYWELL INSPECTION

PREPARATION Peter Tamburro *Pete Tambu* **DATE** 9/30/90

ENGINEERING APPROVAL F.P.BARBIERI *Fred P. Barbieri* **DATE** 10/2/90

QA CONCURRENCE *Bob [signature]* **DATE** 10/4/90

REV. 0

FORM 5000-ADM-7350.02-1

A0000023 7-84

TABLE OF CONTENTS

1.0 **SCOPE**

This specification establishes the minimum requirements for the augmented ultrasonic testing (examination) program of the Oyster Creek drywell containment vessel.

This specification requires UT examination of 57, 6" by 6" areas (grids) randomly chosen from all drywell plates above the sandbed elevation. Each 6" by 6" grid will be segmented into 9, 2" by 2" areas (cells). Acceptance criteria for each grid will be dependent upon the average thickness of each 2" by 2" cell and the average of the 9 cell thicknesses.

It may be necessary to expand an inspection location to an 18" by 18" area which will be segmented into 81, 2" by 2" cells. Figure #1 presents a schematic of the inspection logic for each of the 57 inspections locations.

1.1 Ultrasonic testing (UT) required by this specification is to be performed during refueling outage only.

1.2 All data shall be forwarded to Technical Functions for evaluation.

1.3 The inspections required by this specification are in addition to the inspections required by Reference 2.6. ROC shall coordinate all activities in the drywell associated with this specification and reference 2.6.

2.0 **REFERENCES**

2.1 ASME B&PV Code Section V, 1977 Edition through Addenda Summer, 1978.

2.2 ASME Section V, 1986 Edition.

2.3 ASME B&PV Code Section XI, 1977 Edition through Addenda Summer, 1978.

2.4 SNT-TC-1A, 1980 Edition, "American Society of Non-destructive Testing, Recommended Practice."

2.5 TDR 1027, "Design of a UT Inspection Plan for the Drywell Containment Using Statistical Inference Methods."

2.6 GPUN Specification IS-328227-004 "Functional Drywell Requirements for Drywell Containment Vessel Thickness Examination" (most recent revision).

SPEC 402950-001 INSPECTION LOGIC

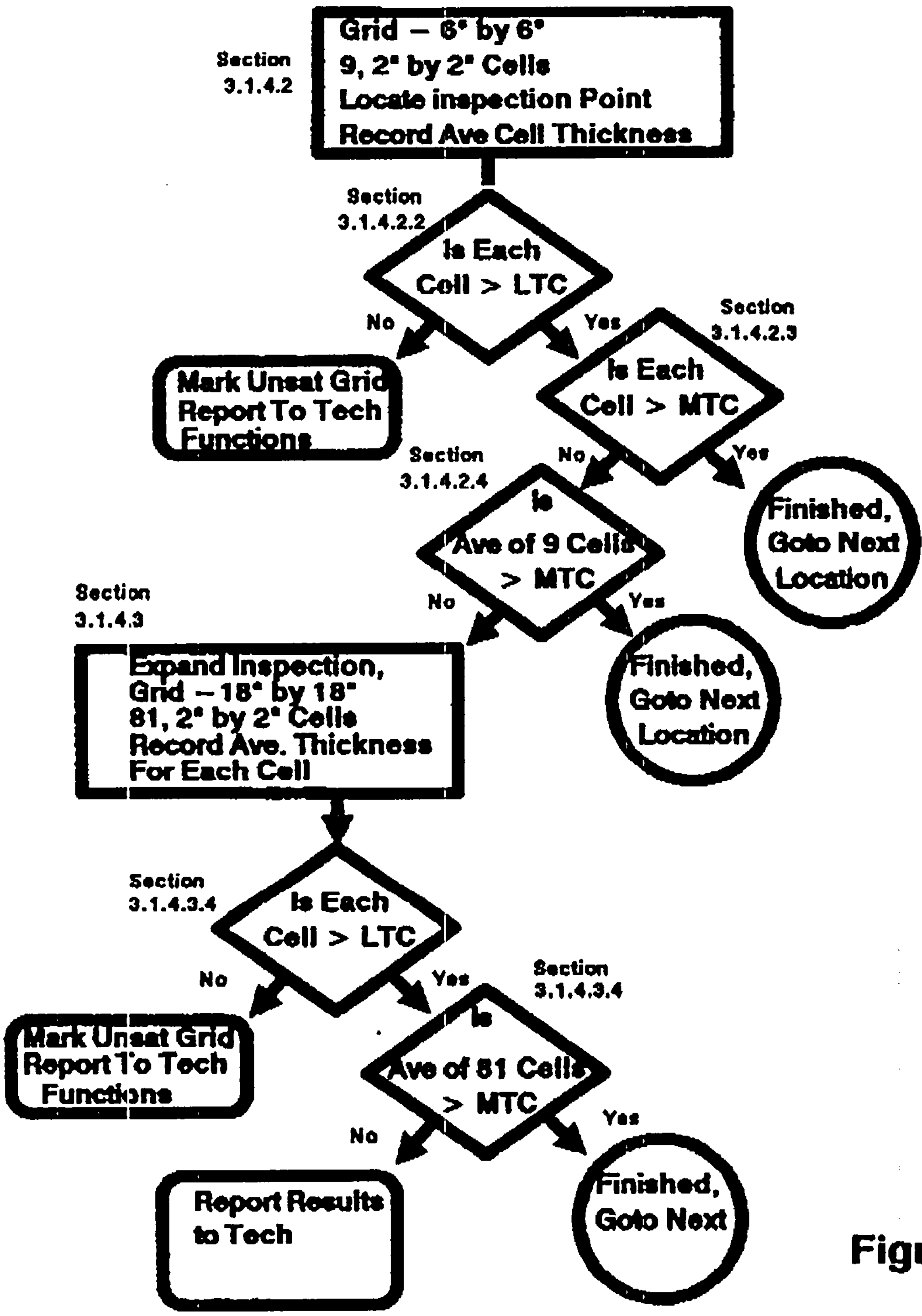


Figure 1

2.7 CBI Company Drawings 9-0971, Sheets 1 through 92.

2.8 GPUN Sketches 3E-SKM-339, Sheets 1 through 20.

2.9 GPUN Memo 5360-90-396, P. Tamburro to A. Baig

3.0 REQUIREMENTS

3.1 Non-Destructive Examinations

3.1.1 Personnel Qualification

3.1.1.1 Ultrasonic personnel shall be qualified and certified as a level 2 NDE Inspector in accordance with Reference 2.4.

3.1.2 Examination Equipment

3.1.2.1 Ultrasonic examination pulse-echo equipment capable of thickness measurement by the digital and/or A-scan on a CRT screen shall be utilized.

Digital readout equipment shall have printout capabilities and memory storage traceable to sequential readings.

3.1.2.2 Ultrasonic examination by use of robotic equipment may be performed; however, the performance of ultrasonic examination devices shall be in accordance with Sections 3.1.1.1 and 3.1.2.1. UT thickness examination through paint shall be performed per qualified techniques and procedures.

Qualification shall be performed to the satisfaction of the GPUN Manager of NDE/ISI. This qualification shall be documented.

3.1.3 Plate Number Scheme and Inspection Designation

3.1.3.1 To locate each inspection location, a series of drywell plate drawings have been developed (Reference 2.8).

Each inspection location will be numbered in the following format:

E - PN - GN

where:

E - Plate Elevation (6, 23, 50, and 71)

PN - Plate Number (per Exhibit #1)

GN - Grid Number

3.1.3.2 Inspection locations have been randomly chosen and are listed in Section 3.1.5 and are shown in Reference 2.8.

3.1.4 Inspections shall consist of the following for each inspection point.

3.1.4.1 The random locations have been chosen based on Reference 2.5. The inspection point shall be located by measuring first from the horizontal weld and then from the vertical welds as shown on the sketches in Reference 2.8.

Due to ALARA considerations and the random nature of these inspections it is not necessary to precisely verify the location of each inspection point. However, the robotic equipment operator or NDE Inspector shall ensure (the to best of their abilities) that each inspection point is properly located per Section 3.1.5 and Reference 2.8.

It is recognized that not all the randomly chosen locations may be accessible for inspection, or surface conditions may not allow for proper UT scan. In these instances, an alternate inspection location shall be chosen (as shown in Exhibit #2) with concurrence of Technical Functions.

3.1.4.2 <u>6" by 6" Inspection</u>

3.1.4.2.1

The UT Inspection shall be performed over a 6" by 6" area centered on each inspection point. Each 6" by 6" area (referred to as a "grid") shall be divided into 9, 2" by 2" areas (referred to as "cells"). As shown in Figure 2A.

UT examination shall be performed in a manner which will result in a nominal thickness value for each 2" by 2" cell (for a total of 9 values).

3.1.4.2.2

If one or more cell thickness values are less than LTC (Section 3.1.4.4), then this grid shall be marked and results reported to Technical Functions as soon as reasonable (approximately 12 hours). Additional inspections shall be determined following data evaluation.

If all 9 cell thickness values are greater than or equal to LTC then evaluate the data per Section 3.1.4.2.3.

Figure 2A

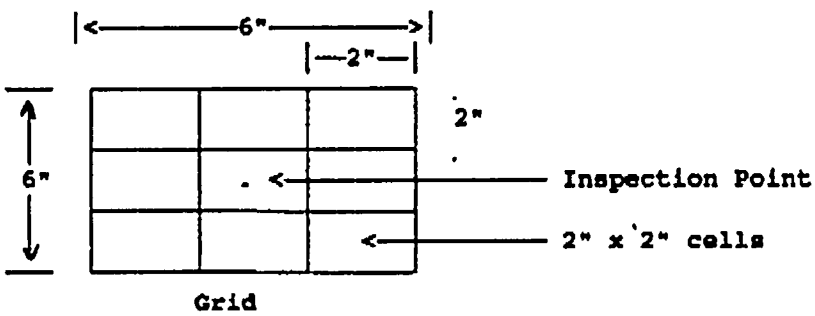
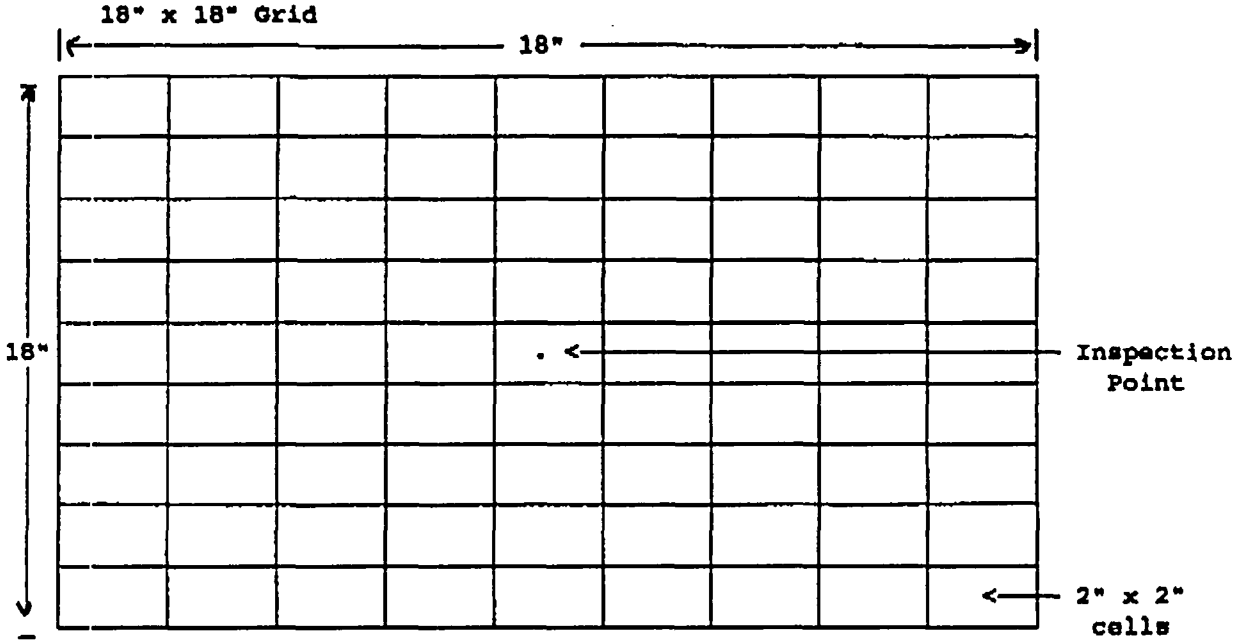


Figure 2B



3.1.4.2.3

If all 9 cell thickness values are greater than or equal to the MTC (Section 3.1.4.4), then no further inspections are required for this inspection point. Thickness values for all 9 cells shall be transmitted to Technical Functions (per Section 3.1.6.1).

If one or more of the 9 cell thickness values are less than the MTC, then data evaluation per Section 3.1.4.2.4 shall be performed.

3.1.4.2.4

The average of all 9 cell thickness values shall be calculated. If the average is greater than or equal to the MTC and the thickness value of all 9 cells is greater than or equal to the LTC, then no further inspections are required for this inspection point. Thickness data for the 9 cells shall be transmitted to Technical Functions (per Section 3.1.6.1).

If the average is less than MTC then an expanded inspection shall be performed per Section 3.1.4.3.

3.1.4.3 <u>18" by 18" Expanded Inspection</u>

3.1.4.3.1

An 18" by 18" expanded inspection shall be performed on all inspection points which do not meet the criteria in Section 3.1.4.2. Technical Functions shall be notified (as soon as reasonable) of all inspection points which require an 18" by 18" expanded inspection.

3.1.4.3.2

The 18" by 18" area shall be centered about the original inspection point and the 6" by 6" grid (Section 3.1.4.2). If the 18" by 18" area cannot be properly centered due to penetrations, welds, or surface conditions, the 18" by 18" area shall be placed and oriented in a manner in which the entire 18" by 18" area is located on the original vessel plate and overlaps the original 6" by 6" grid.

3.1.4.3.3

The 18" by 18" area shall be divided into 81, 2" by 2" cells, as shown in Figure 2B.

UT examination shall be performed in a manner which will result in a nominal thickness value for each 2" by 2" cell (total of 81 values).

3.1.4.3.4

If all 81 cell thickness values are greater than or equal to LTC <u>and</u> the average of the 81 cell thickness values is greater than or equal to MTC then no further inspections are required for this inspection point. Thickness data for all 81 cells shall be transmitted to Tech Functions.

If one or more cell thickness value(s) are less than LTC, then this expanded inspection area shall be marked, and results reported to Tech Functions as soon as reasonable (approximately 12 hours).

If the average of all 81 cell thickness values is less than MTC then results shall be reported to Technical Functions as soon as reasonable (approximately 12 hours).

Thickness data for all 81 cells shall be transmitted to Technical Functions (per section 3.1.6.1).

3.1.4.4 Thickness Criteria

3.1.4.4.1 (Reference 2.9)

The following Mean Thickness Criteria (MTC) shall be applied in Section 3.1.4.2 and 3.1.4.3:

Plate Evaluation	Nominal Delivered Thickness	MTC
11'-3" to 23'-6"	1.154"	.780"
23'-6" to 51'	.77"	.735"
51' to 65'	.722"	.695"
65' to 71'-6"	2.625"	TBD
71'-6" to 95'	0.64"	0.605"

3.1.4.4.2 (Reference 2.9)

The following Local Thickness Criteria (LTC) shall be applied in Sections 3.1.4.2 and 3.1.4.3.

Plate Evaluation	Nominal Delivered Thickness	LTC
11'-3" to 23'-6"	1.154"	.5"
23'-6" to 51'	.77"	.5"
51' to 65'	.722"	.470"
65' to 71'-6"	2.625"	TBD
71'-6" to 95'	0.64"	.435"

3.1.4.5 UT thickness examinations through paint shall be performed per qualified techniques and procedures. Qualification shall be performed to the satisfaction of the GPUN Manager of NDE/ISI.

3.1.5 13R Inspections Locations

For the 13R Outage, 57 inspection locations shall be examined (per Section 3.1.4). These locations shall be examined as follows:

Plate Elevation	Plate Number	Grid Number	Distance From Center Line of Vertical Weld (Right/Left)	Distance From Center Line of Horizontal Weld (Top/Bottom)
6'-10" to 23'-6"	6-7	99	Left 4'- 4"	Top 2'- 10"
6'-10" to 23'-6"	6-10	42	Left 1'- 0"	Top 1'- 5"
6'-10" to 23'-6"	6-12	149	Right 1'- 7"	Top 5'- 5"
6'-10" to 23'-6'	6-13	185	Left 0'- 5"	Top 6'- 10"
6'-10" to 23'-6"	6-14	31	Right 5'- 2"	Top 0'- 11"
6'-10" to 23'-6"	6-16	64	Left 2'- 5"	Top 1'- 11"
6'-10" to 23'-6"	6-18	155	Left 0'- 5"	Top 5'- 11"
6'-10" to 23'-6"	6-19	88	Right 1'- 4"	Top 2'- 2"
6'-10" to 23'-6"	6-20	196	Left 0'- 10"	Top 8'- 11"
23'-6" to 50'-11"	23-8	118	Left 3'- 1"	Top 4'- 0"
23'-6" to 50'-11"	23-11	629	Left 6'- 8"	Bottom 7'- 0"
23'-6" to 50'-11"	23-15	726	Right 0'- 6"	Bottom 1'- 6"
23'-6" to 50'-11"	23-17	368	Left 0'- 9"	Top 12'- 0"
23'-6" to 50'-11"	23-19	494	Right 0'- 8"	Bottom 12'- 0"
23'-6" to 50'-11"	23-20	190	Right 2'- 2"	Top 11'- 6"
23'-6" to 50'-11"	23-21	256	Left 4'- 3"	Top 11'- 6"
23'-6" to 50'-11"	23-22	311	Right 4'- 3"	Top 12'- 6"
23'-6" to 50'-11"	23-23	22	Left 2'-11"	Top 1'- 0"
23'-6" to 50'-11"	23-24	216	Right 3'- 1"	Top 6'- 6"

Plate Elevation	Plate Number	Grid Number	Distance From Center Line of Vertical Weld (Right/Left)	Distance From Center Line of Horizontal Weld (Top/Bottom)
50'-11" to 65'-2"	50-1	116	Left 1'- 3"	Bottom 8' - 11"
50'-11" to 65'-2"	50-3	277	Left 3'- 7"	Bottom 1' - 11
50'-11" to 65'-2"	50-4	2	Left 1'- 11"	Top 7' - 11"
50'-11" to 65'-2"	50-5	277	Right 2'- 3"	Bottom - 11"
50'-11" to 65'-2"	50-7	292	Left 3'- 8"	Bottom 1' - 5"
50'-11" to 65'-2"	50-8	597	Left 3'-11"	Bottom 2' - 5"
50'-11" to 65'-2"	50-10	442	Left 2'- 5"	Bottom 6' - 5"
50'-11" to 65'-2"	50-11	235	Left 3'- 3"	Bottom 3' - 5"
50'-11" to 65'-2"	50-12	114	Right 0'- 5"	Top 2' - 11"
50'-11" to 65'-2"	50-13	85	Left 0'- 6"	Top 7' - 11"
50'-11" to 65'-2"	50-14	492	Left 1'- 5"	Bottom 3' - 5"
50'-11" to 65'-2"	50-17	219	Left 1'- 8"	Bottom 3' - 11"
50'-11" to 65'-2"	50-18	359	Left 1'- 5"	Bottom 7' - 5"
50'-11" to 65'-2"	50-19	147	Right 1'- 0"	Bottom 7' - 5"
50'-11" to 65'-2"	50-21	190	Right 1'- 1"	Bottom 4' - 5"
50'-11" to 65'-2"	50-22	236	Left 3'- 11"	Top 6' - 5"

Plate Elevation	Plate Number	Grid Number	Distance From Center Line of Vertical Weld (Left/Right)	Distance From Center Line of Horizontal Weld (Top/Bottom)
65'- 2" to 71'-6'	65-2	35	Right 0'- 6"	Top 2' - 5"
65'- 2" to 71'-6"	65-5	49	Right 0'- 7"	Top 3' - 5"
65'- 2" to 71'-6"	65-6	22	Left 0'- 6"	Top 1' -11"
65'- 2" to 71'-6"	65-8	124	Right 0'- 6"	Bottom 0" - 5"
65'- 2" to 71'-6"	65-10	124	Right 0'- 6"	Bottom 0' - 5"
65'- 2" to 71'-6"	65-11	18	Right 2'- 0"	Top 1' - 5"
65'- 2" to 71'-6"	65-13	95	Right 1'- 4"	Bottom 1' -11"
65'- 2" to 71'-6'	65-14	112	Right 1'-11"	Bottom 0" -11"
65'- 2" to 71'-6"	65-16	85	Right 1'- 9"	Bottom 2' - 5"
65'- 2" to 71'-6"	65-17	113	Right 1'- 5"	Bottom 0" -11"
65'- 2" to 71'-6"	65-18	122	Right 1'- 5"	Bottom 0" - 5"
65'- 2" to 71'-6"	65-20	99	Left 0"- 10"	Bottom 1' - 5"
65'- 2" to 71'-6"	65-21	122	Right 1'- 5"	Bottom 0" - 5"
65'- 2" to 71'-6'	65-22	27	Left 1'- 0"	Top 1' -11"
65'- 2"	65-23	45	Right 2'- 1"	Top 3' - 5"
65'- 2"	65-24	82	Left 1'- 3"	Top 1' - 3"
65'- 2"	65-25	119	Left 1'- 11"	Bottom 2' - 11"
65'- 2"	65-26	32	Right 2'- 0"	Top 2' - 5"
71'- 6" to 83'	71-1	461	Left 4'- 6"	Bottom 5' - 1"
71' -6" to 83'	71-4	920	Right 3'- 0"	Bottom 0' - 7"
83' to 94'	83-1	482	Left 11'- 5"	Bottom 4' - 0"
83' to 94'	83-4	401	Left 1'- 11"	Top 4' - 0"

All Specific locations are shown on Reference 2.8.

3.1.6 Records

3.1.6.1 All data shall be recorded on data sheets which identify the inspection location number (per Section 3.1.5.1) as shown in Reference 2.8. Data sheet format shall be consistent with Figures 2A & 2B. Copies shall be transmitted to Technical Functions as soon as practical. Also, data shall be sent to Technical Functions on a floppy disk in an ASCII format.

3.2 Support Work

3.2.1 Work to be performed by the Refueling Outage Contractor (referred to as the ROC).

3.2.1.1 The ROC shall schedule and coordinate all activities necessary to perform the inspections.

3.2.1.2 When required, the ROC shall erect scaffolding.

4.0 QUALITY ASSURANCE

4.1 All work shall be performed in accordance with GPUN Operational QA Program. This work is classified Important to Safety/Nuclear Safety Related.

5.0 INFORMATION TO BE SUBMITTED

5.1 UT data sheets and calibration sheets in accordance with Reference 2.4.

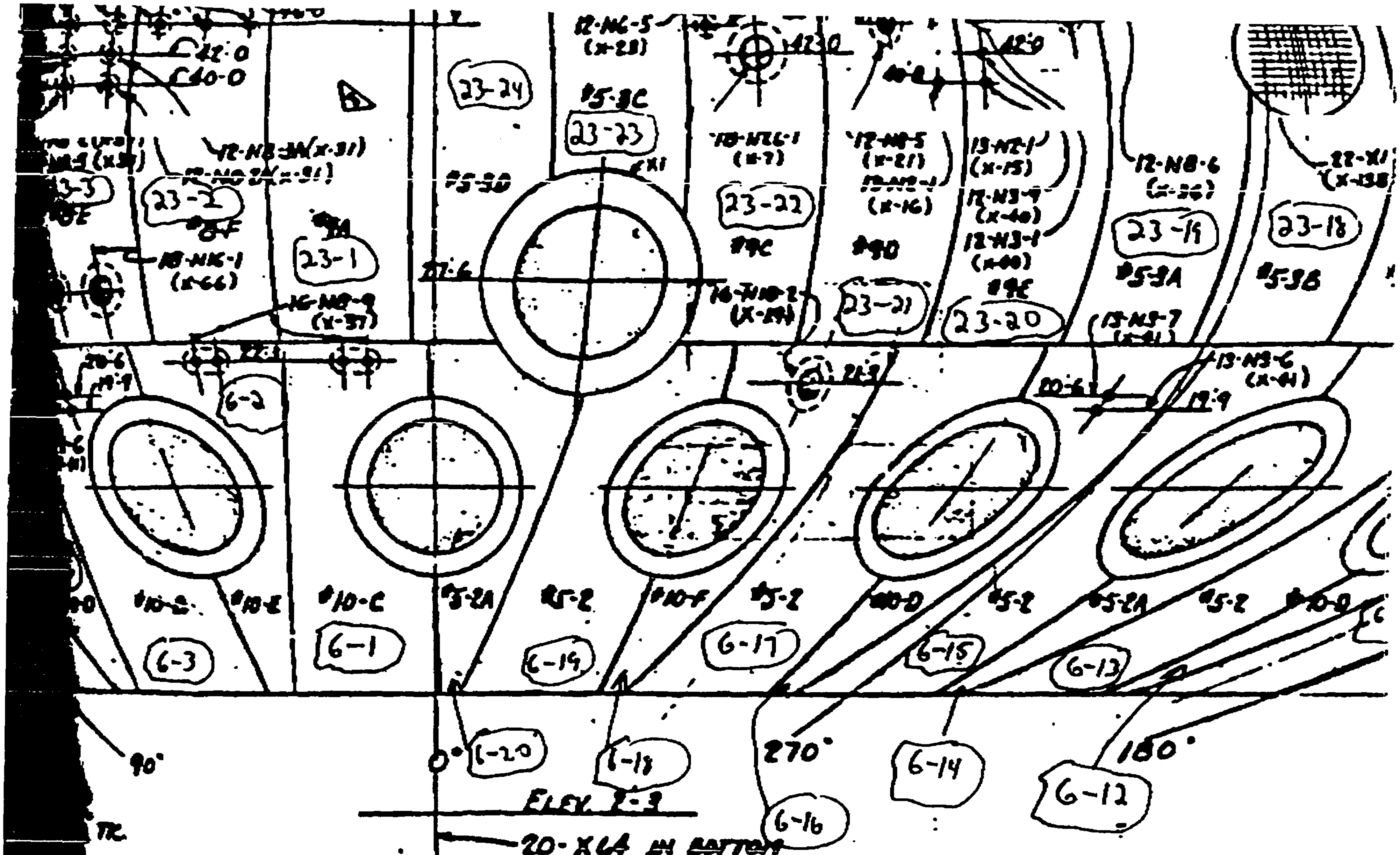
6.0 ATTACHMENTS

6.1 Exhibit 1 - Plate Numbering scheme shown on CBI drawing 9-0971, Sheet 2.

6.2 Exhibit 2 - Alternate Inspection Location Selection Scheme.

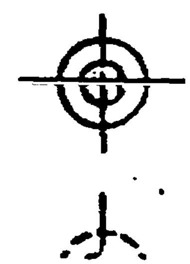
EXHIBIT #1

**Plate Numbering Scheme Shown on
CBI Drawing 9-0971 Sheet #2**

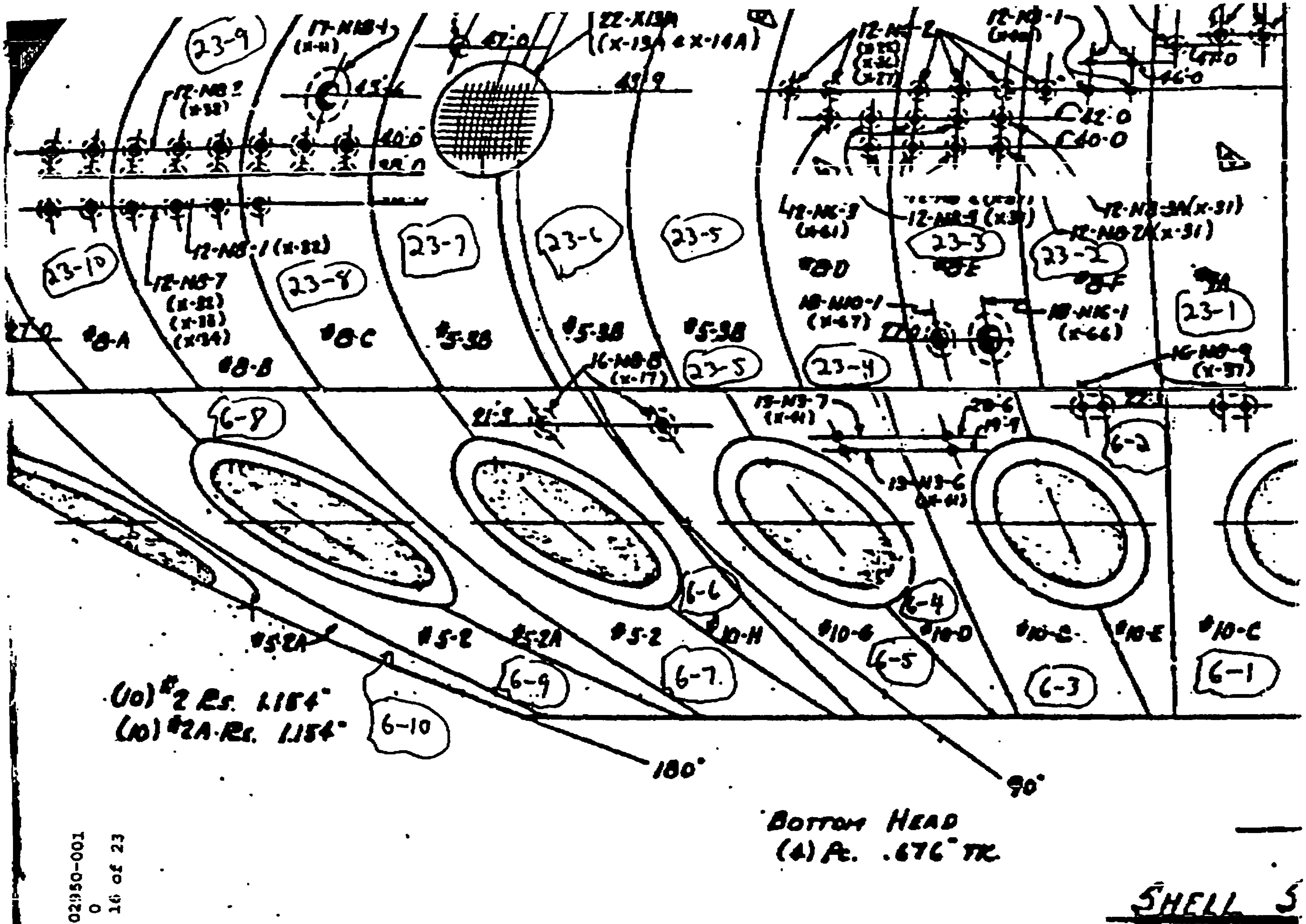


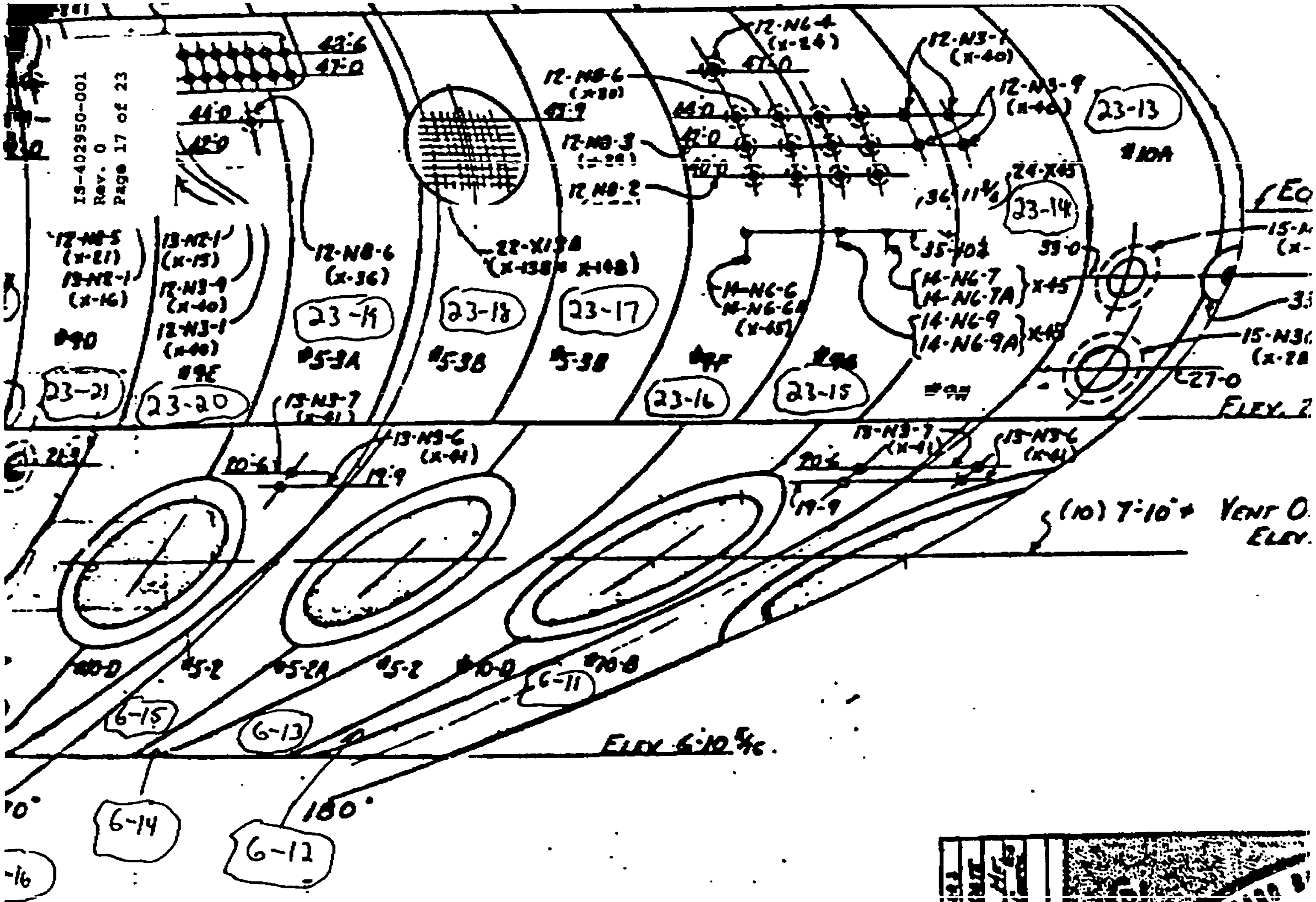
SHELL STRETCHOUT

SYMBOL



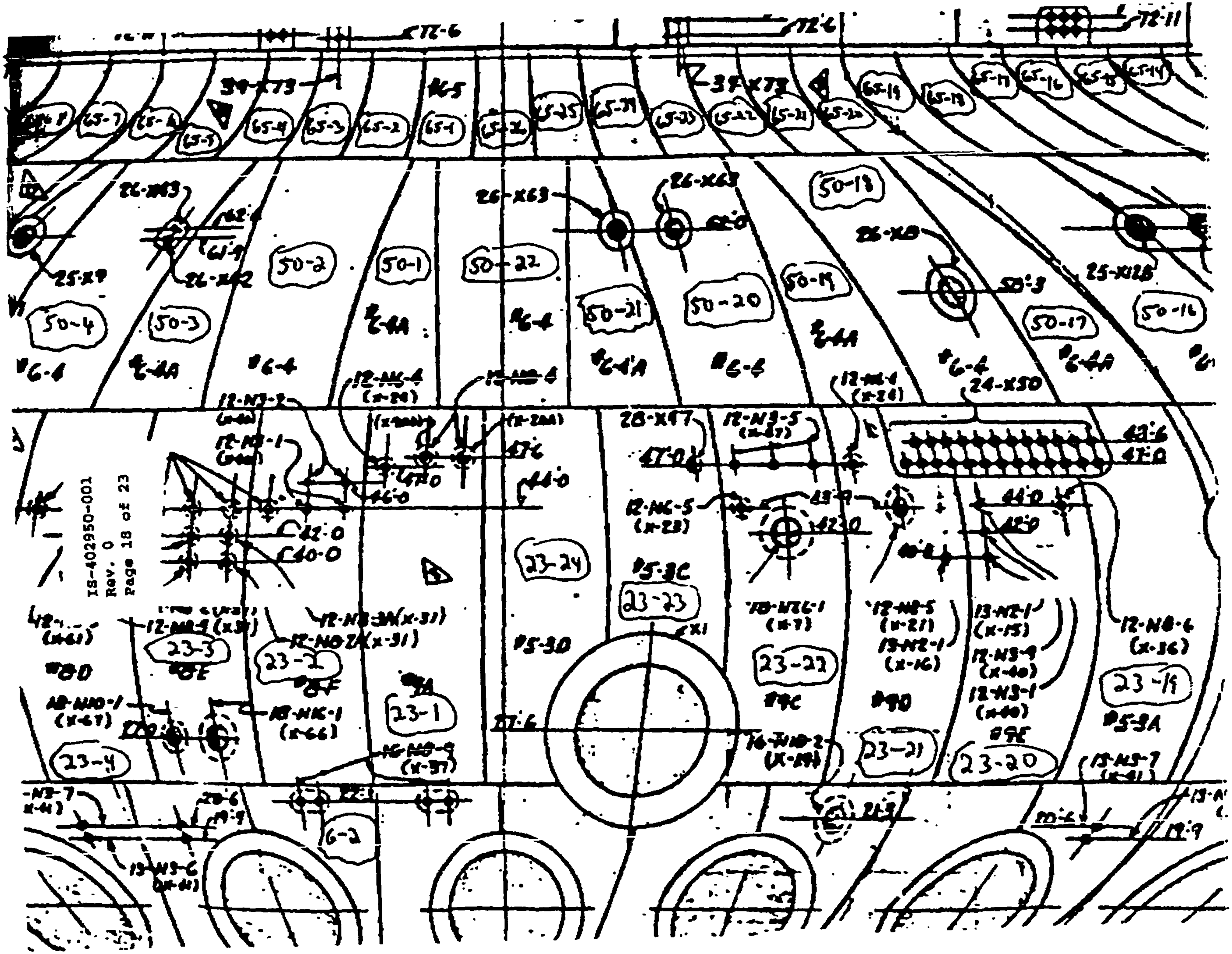
• PENETRATION USING
FIELD INST


23-9
23-10
23-8
23-7
23-6
23-5
23-3
23-2
23-1
23-5
23-4
6-8
6-9
6-10
6-7
6-6
6-5
6-4
6-3
6-2
6-1
22-X13A
(X-13A & X-14A)
12-N5-1 (X-32)
16-N5-9
(X-37)
(10) #2 Rs. 1.154"
(10) #2A Rs. 1.154"
180°
90°
Bottom Head
(4) Pc. .676" TK.
SHELL 5

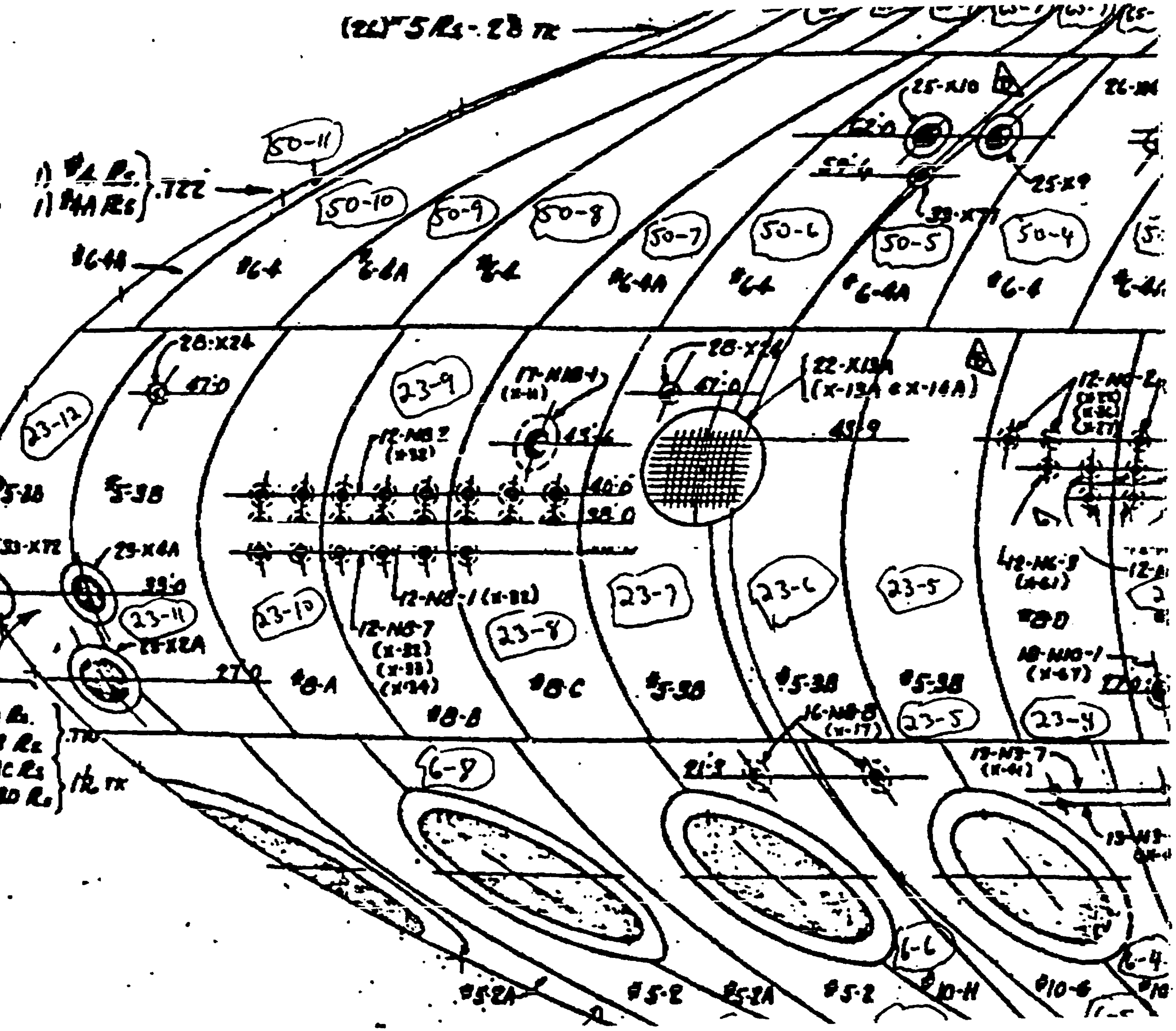


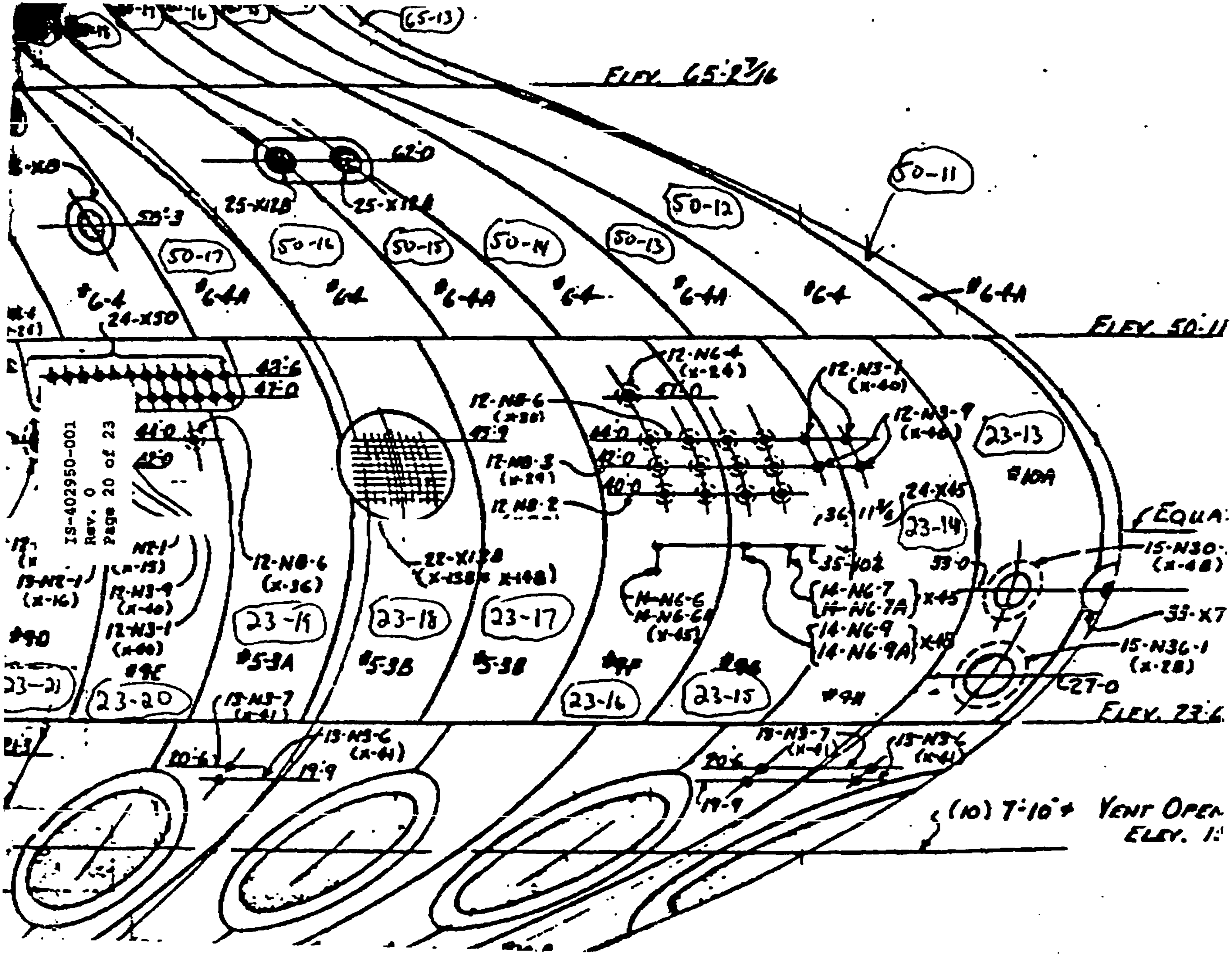
SYMBOLS

• FENESTRATION USING INSERT PLATE

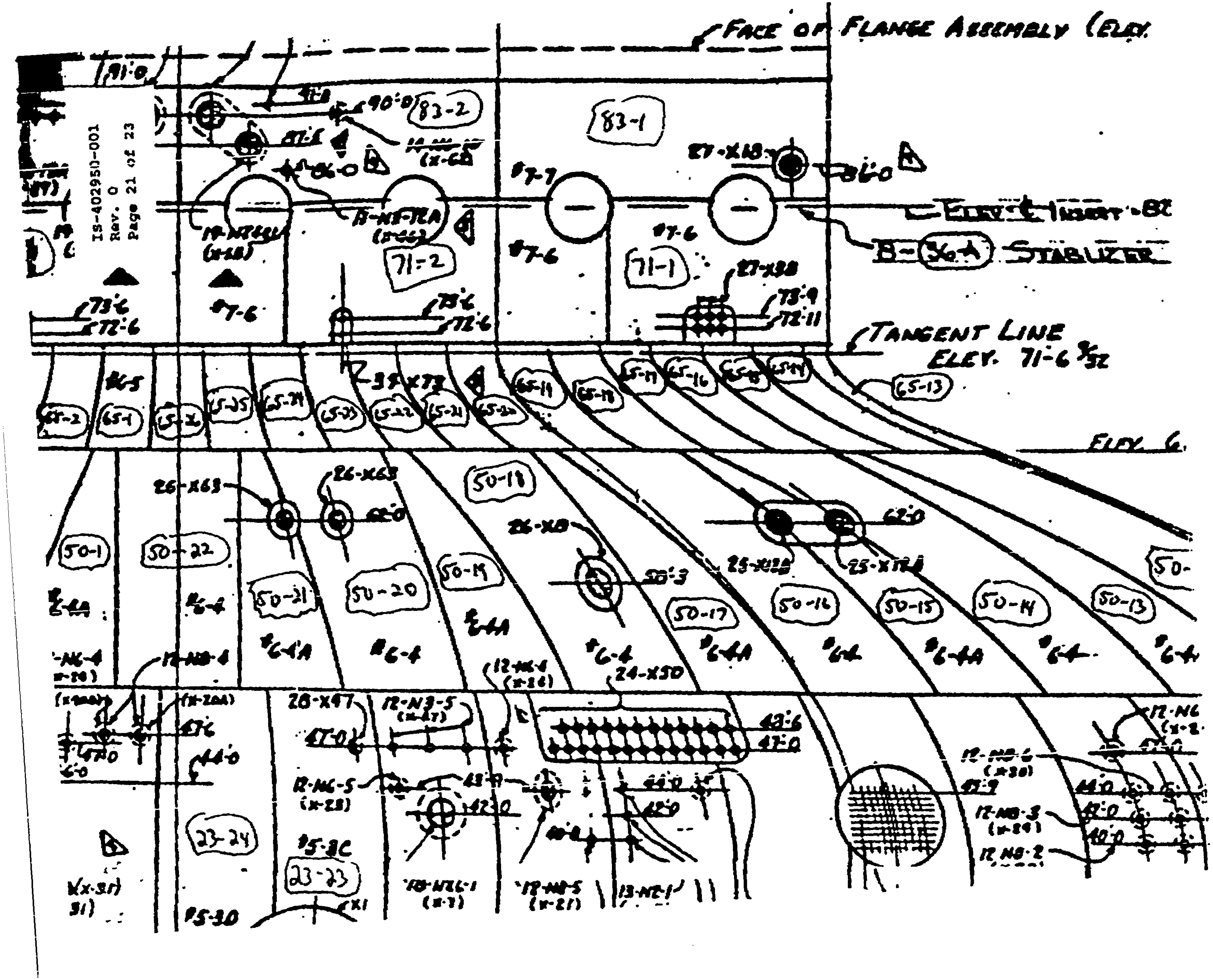

65-7
65-4
65-3
65-2
65-1
50-4
50-3
50-2
50-1
50-22
50-21
50-20
50-19
50-18
50-17
50-16
26-X63
24-X50
23-24
23-23
23-22
23-21
23-20
23-19
23-4
23-3
23-2
23-1
6-2

SHEET NO. B-80 8-80 9/19/80





ELEV. 65'-2 7/16
ELEV. 50'-11
ELEV. 23'-6
EQUA
50-11
50-12
50-13
50-14
50-15
50-16
50-17
65-13
#6-4
#6-4A
24-X50
25-X12B
25-X12A
62'-0
53'-3
12-N6-4
(x-24)
12-N3-1
(x-40)
12-N3-9
(x-40)
12-N8-6
(x-38)
12-N8-3
(x-29)
12-N8-2
12-N8-6
(x-36)
22-X138
(x-138 & x-148)
23-13
23-14
23-15
23-16
23-17
23-18
23-19
23-20
#10A
24-X45
35-X02
33'-0
15-N30
(x-48)
33-X7
15-N36-1
(x-28)
27'-0
14-N6-6
14-N6-6A
(x-45)
14-N6-7
14-N6-7A
14-N6-9
14-N6-9A
x-45
#5-3A
#5-3B
#9E
13-N3-7
(x-41)
13-N3-6
(x-41)
19'-9
20'-6
(10) 7'-10" Ø VENT OPEN


FACE OF FLANGE ASSEMBLY (ELEV.
91'-0
90'-0
83-2
83-1
71-2
71-1
ELEV ℄ INSERT
B-36-A STABILIZER
73'-6
72'-6
TANGENT LINE
ELEV. 71-6 9/32
65-13
ELEV. 6
50-18
50-1
50-22
50-21
50-20
50-19
50-17
50-16
50-15
50-14
50-13
26-X63
26-X60
62'-0
24-X50
28-X47
23-24
23-23
47'-0
44'-0

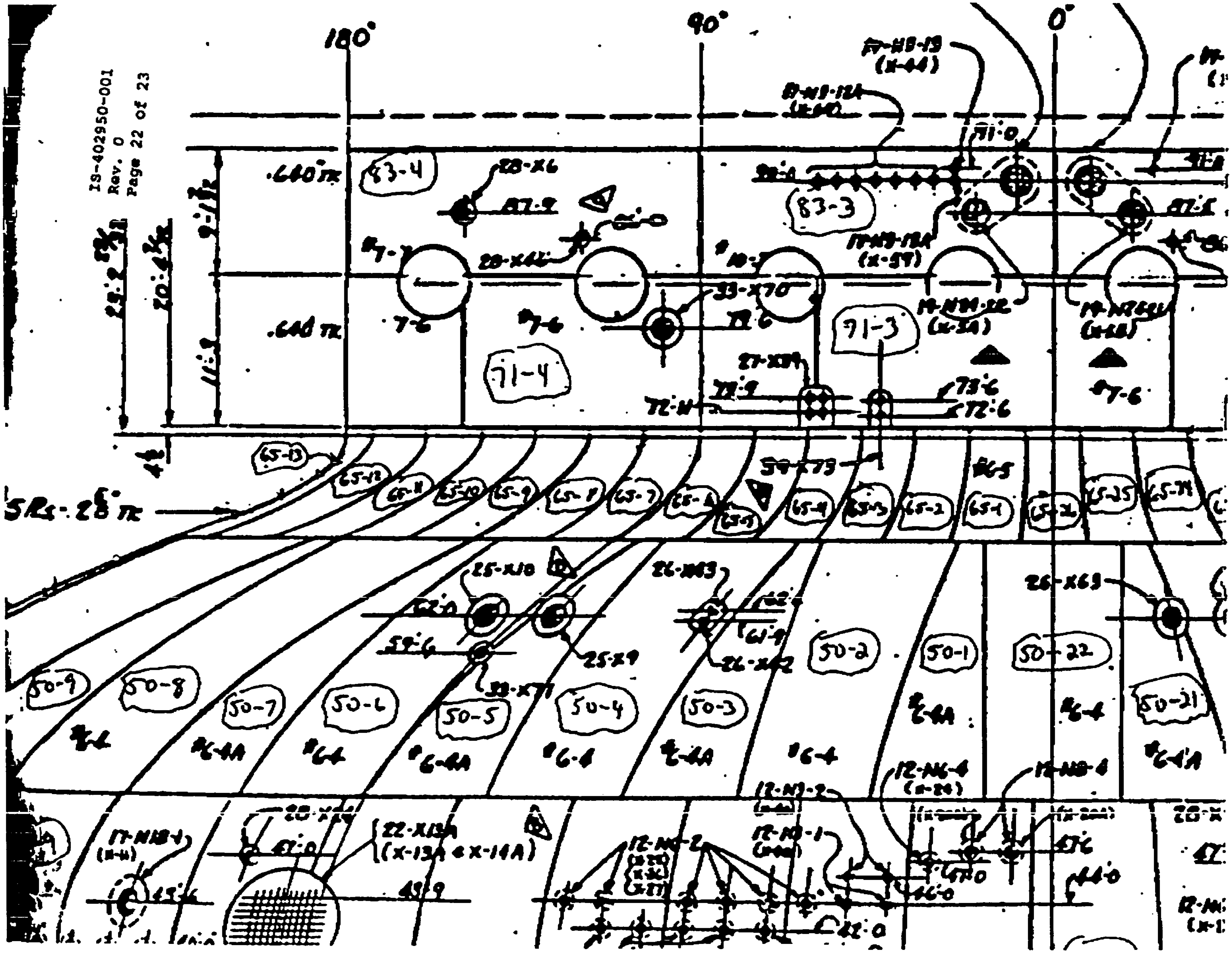

180°
90°
0°
83-4
83-3
71-4
71-3
50-9
50-8
50-7
50-6
50-5
50-4
50-3
50-2
50-1
50-22
50-21
25-X10
25-X9
26-X63
22-X13A
(X-13A & X-14A)

EXHIBIT #2

Alternate Inspection Location Selection Scheme

				9
	7	8	1	10
	6	original	2	11
	5	4	3	12
				13

Figure #3

Figure #3 illustrates the selection scheme in which an alternate inspection point shall be determined. The original inspection point, which is unaccessible, or cannot be scanned due to surface conditions, shall be located on the applicable sketch (Reference 2.8). If the original randomly chosen point is unaccessible, or cannot be scanned due to surface conditions, then per Figure #2 Grid #1 shall be the alternate location.

If Grid #1 is also unaccessible, or cannot be scanned due to surface conditions, then Grid 2, 3, 4, etc. shall be selected until a location is accessible.

If the original randomly chosen location borders a weld or penetration, and is unaccessible,then the grid which is accessible in the clockwise direction per Figure #3 shall be selected as the alternate inspection location. In all cases, the alternate inspection location shall be located on the original vessel plate.