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Superseded by Rev 1

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OFFICE OF SECRETARY
RULEMAKINGS AND
ADJUDICATIONS STAFF

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

U.S. NUCLEAR REGULATORY COMMISSION
In the Matter of AMERGEN ENERGY CO., LLC
Docket No. 50-0219-LR Official Exhibit No. 23
OFFERED by Applicant/Licensee Intervenor ______
NRC Staff Other ______
IDENTIFIED on 9/24/07 Witness/Panel N/A
Action Taken: ADMITTED REJECTED WITHDRAWN
Reporter/Clerk ______

001/0004.2

OCLR00020057

Template = SECY-028

SECY-02

2.0 SUMMARY OF RESULTS

Bay & Area	Corrosion Rate (mpy) Best Estimate*	95% Conf.**	Mean Thickness ***	F-Ratio	N	Yrs	
2.1 Sand Bed Region With Cathodic Protection - All Data							
11A	-15.6 ±2.9 mpy	-21.0	870.4 ± 5.7 mils	5.4	9	3.0	
11C Top	-35.2 ±6.8 mpy	-48.2	977.0 ±12.5 mils	4.6	9	3.0	
11C Bottom	-22.4 ±4.3 mpy	-30.5	865.0 ± 7.8 mils	4.9	9	3.0	
17D	-25.0 ±2.0 mpy	-28.7	829.5 ± 4.0 mils	29.4	10	3.2	
19A	-21.4 ±1.5 mpy	-24.1	807.6 ± 3.0 mils	39.5	10	3.2	
19B	-19.0 ±1.7 mpy	-22.3	836.9 ± 3.2 mils	21.3	9	3.0	
19C	-24.3 ±1.3 mpy	-26.7	825.1 ± 2.3 mils	66.2	9	3.0	
2.2 Sand Bed Region With Cathodic Protection - Since October 1988							
11A	Not Significant****		878.0 ± 5.9 mils		5	1.5	
11C Top	Not Significant****		996.6 ± 8.3 mils		5	1.5	
11C Bottom	Not Significant****		878.1 ± 5.6 mils		5	1.5	
17D	-23.7 ±4.6 mpy	-34.2	830.1 ± 3.8 mils	2.7	5	1.5	
19A	-20.6 ±3.9 mpy	-29.7	808.2 ± 3.2 mils	2.8	5	1.5	
19B	-11.8 ±3.9 mpy	-21.1	841.2 ± 3.3 mils	0.9	5	1.5	
19C	-21.5 ±3.5 mpy	-29.5	826.3 ± 2.9 mils	3.7	5	1.5	
2.3 Sand Bed Region Frame Cutout							
17/19 Top	Not Significant****		986.0 ± 4.7 mils		5	1.3	
17/19 Bottom	Not Significant****		1005.7 ± 5.6 mils		5	1.3	| 1
2.4 Sand Bed Region Without Cathodic Protection							
9D	Not Significant****		1021.7 ± 8.9 mils		5	1.3	
13A	-39.1 ± 3.4 mpy	-46.4	853.1 ± 2.4 mils	16.9	6	1.4	
13D	Indeterminate		931.9 ±22.6 mils		1	0	
15D	Not Significant****		1056.5 ± 2.3 mils		5	1.5	
17A Top	Not Significant****		1128.3 ± 2.2 mils		5	1.4	
17A Bottom	Not Significant****		950.8 ± 5.3 mils		5	1.4	| 1

* Mean corrosion rate in mils per year ± standard error of estimate
** Upper bound of the one-sided 95% confidence interval
*** Best estimate of current mean thickness in mils ± standard error of the mean
****Not statistically significant compared to random variations in measurements

N = Number of data sets
Yrs = Years from first to last data set

GPU Nuclear	DOCUMENT NO. C-1302-187-5300-011	

TITLE STATISTICAL ANALYSIS OF DRYWELL THICKNESS THRU 4-24-90

REV	SUMMARY OF CHANGE	APPROVAL	DATE
1	Computed 95% upper bound of the corrosion rate in each bay where regression model is appropriate. Computed maximum potential corrosion rate at 95% confidence for each bay where mean model is appropriate. Deleted Summary of Apparent Corrosion Rates and added Summary of Maximum Potential Corrosion Rates at 95% Confidence. Revised paragraphs 2.0, 4.5.2, and 4.10 to reflect these changes. Corrected typos on Summary Sheets (pg. 2 & 3) & Pgs 4, 21	J. Moore Verification V-1302-187-005 Rev. 4 [signature] Fred P Barbieri	1-22-91 1/22/91 4/12/91

N0036 (03-90)

OCLR00020059

Superseded Original

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	

Bay & Area	Corrosion Rate (mpy) Best Estimate*	95% Conf.**	Mean Thickness ***		F-Ratio	N	Yrs
2.5 Elevation 51'							
5/D-12	- 4.6 ± 1.6 mpy	-2.2	745.2	± 2.1 mils	1.3	8	2.5
5/5	Indeterminate		745.1	± 3.2 mils		2	1.1
13/31	Indeterminate		750.8	±11.5 mils		2	1.1
15/23	Indeterminate		751.2	± 3.8 mils		2	1.1
2.6 Elevation 52'							
7/25	Indeterminate		715.5	± 2.9 mils		1	0
13/6	Indeterminate		724.9	± 2.9 mils		1	0
13/32	Indeterminate		698.3	± 5.0 mils		1	0
19/13	Indeterminate		712.5	± 3.1 mils		1	0
2.7 Elevation 87'							
9	Not Significant****		619.9	± 0.6 mils		5	2.4
13	Not Significant****		636.5	± 0.8 mils		5	2.4
15	Not Significant****		636.2	± 1.1 mils		5	2.4

2.8 Potential Corrosion Rates at 95% Confidence

For those locations where the corrosion rate is not statistically significant, the possibility does exist that the variability in the data may be masking an actual corrosion rate. The potentially masked corrosion rate at 95% confidence is bounded by the upper bound of the 95% one-sided confidence interval about the slope computed in the regression analysis (see Paragraph 4.10.1).

Bay	Elevation	95% Upper Bound Corrosion Rate (mpy)	N	Yrs
11A (Since 10/88)	Sand Bed	-36.4	5	1.5
11C Top (Since 10/88)	Sand Bed	-49.9	5	1.5
11C Bottom (Since 10/88)	Sand Bed	-33.3	5	1.5
17/19 Top	Frame Cutout	-33.4	5	1.3
17/19 Bottom	Frame Cutout	-40.5	5	1.3
9D	Sand Bed	-63.4	5	1.3
15D	Sand Bed	-16.0	5	1.4
17A Top	Sand Bed	-15.5	5	1.4
17A Bottom	Sand Bed	-35.6	5	1.4
9	87'	-2.2	5	2.4
13	87'	-2.1	5	2.4
15	87'	-0.6	5	2.4

NOTE: The high value for Bay 9D results from one extremely high mean value on 6/26/89. Without this data point, the 95% upper bound is -29.2 mpy.

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2.9 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 <u>Selection of Areas to be Monitored</u>

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 <u>UT Measurements</u>

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 <u>Statistical Approach</u>

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 "reliable" as opposed to simply "significant." (See Paragraph 10.2)

(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. Calculate the upper bound of the 95% one-sided confidence interval about the computed slope to provide an estimate of the maximum probable corrosion rate at 95% confidence. This is explained in greater detail in paragraph 4.10.2.

(f) If the mean model is found to be more appropriate than the regression model, the corrosion rate is not statistically significant compared to random variations in the mean thickness. Although the mean model is deemed more appropriate than the regression model, the upper bound of the 95% one-sided confidence interval about the slope computed in the regression analysis provides an estimate at 95% confidence of the maximum corrosion rate which could be masked by the random variations. This is explained in greater detail in paragraph 4.10.1.

(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.

4.19 The possibility does exist that the variability in the data may be masking an actual corrosion rate. Although the mean model is deemed more appropriate than the regression model, the results of the regression analysis can be used to estimate the potentially masked corrosion rate. We can state with 95% confidence that the potential corrosion rate cannot exceed the upper bound of the 95% one-sided confidence interval of the slope computed in the regression analysis. The 95% upper bound is equal to the computed slope plus the one-sided t-table value times the standard error of the slope. The value of t is determined for n-2 degrees of freedom.

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.

Superseded

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. 1

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

Superseded

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. 1

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

The upper bound of the 95% one-sided confidence interval about the computed slope is an estimate of the maximum probable corrosion rate at 95% confidence. The 95% upper bound is equal to the computed slope plus the one-sided t-table value times the standard error of the slope. The value of t is determined for n-2 degrees of freedom. 1

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~~ 4/24/90

1

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 Bay 19C: 10/8/88 to 4/24/90

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 Bays 17/19 Frame Cutout: 12/30/88 to 4/24/90

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 Bay 13D: 3/28/90 to 4/25/90

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 Bay 15D: 12/17/88 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 ± 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 $\pm$ standard error is 751.2 $\pm$ 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 $\pm$ standard is 715.5 $\pm$ 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.