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Memorandum

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13-Sept.-2007

Subject: **Further Discussion of the External Corrosion on the Drywell Shell in the Sandbed Region.**

I. Introduction

The objective of this discussion is to put a few misconceptions, erroneous statements and poor judgment in perspective. We never used the "wrong data the wrong way". We used AmerGen's data a different way, which we think, and will show below, leads to more concise conclusions. In the forefront of this discussion are the contours, or response surfaces, which we generated on the basis of the most accurate external (and in one case internal) UT measurements reported by AmerGen. It turns out, and is discussed below in meticulous detail, that the differences between Tamburro's methodology and that of the response surface methodology, is simply one of greater consistency and reduced arbitrariness.

I would like to highlight a statement which, to some extent, exemplifies the errant logic involved in much of AmerGen's testimony (Ref. 9, A7).

> *The contour plots presented by Dr. Hausler are not accurate [1]. The contours generated by Dr. Hausler show drywell thinning that has not been observed or measured by AmerGen.* [This testimony is ascribed to all members of this particular rebuttal group; see Ref. 9, at A7].

The above quote is a recurring theme in AmerGen's rebuttal testimony and therefore needs to be put in perspective.

At no point in time have we attempted to make the corrosion of the drywell shell to look more severe or extensive. While we have in the past deplored the fact that the external UT measurements had not been extended to a larger area, we have evaluated

[1]) Messrs Gallagher, Ouaou, and Dr. Metha, have not shown in their testimony how our contours are not accurate. It is an incredible disservice to the professionalism of these proceedings to promulgate such unsubstantiated accusations.

the data generated by AmerGen (and earlier by GPUN) by means of a standard well known method which, as it turns out, bears some similarities to Tamburro's procedures, but are far more systematic and much less prone to observer bias. The fact that averaging (which is also Tamburro's methodology) results in numbers, which have not been measured is inherent in the process of averaging. In fact, the entire approach of AmerGen is based on averages. AmerGen can hardly claim that Tamburro's averages are valid, while mine are not.

> Mr. Polaski, Dr. Harlow, Mr. Abramovici, Mr. Tamburro, and Mr. McAllister completely misunderstand (or are not familiar with) the process of generating iso-response line in a two-parameter field when they assert that *we have inappropriately statistically treated the external UT data (Ref. 10, at A 2).*

Let's be very clear about this, establishing the contour plots is only a statistical process to the extent taking averages is a statistical process. Both Tamburro and I use averaging to represent the surface, because there is no reasonable alternative approach. In this case I used the mathematical routine developed by the SAS Institute, Inc, (formerly known as Statistical Analysis Software, Inc.) in the Statistical Discovery Software, Ver. 3.1, Chapter 3, page 23, pg 443 of the User's guide. The process it uses was described in detail in previous submissions [2).]

> The gentlemen listed above assure us that *these data cannot represent the thickness of the drywell shell. First, there are two few of them for the points to be statistically representative of the shell as a whole. Second they are biased toward the thin side.* And finally, we understand that we have *ignored the limited number of data points,* and that we *have performed our calculations and computer contouring assuming that these external locations were selected at random and, thus, could be representative of the condition of the drywell shell in the sandbed region.* AmerGen Rebuttal Test. Part 3 A38-41.

However, AmerGen is once again being entirely inconsistent. It is precisely the external data, which have been used for the last 15 years to convince the NRC that the shell is still in serviceable condition. Although it was assumed that the most severe corrosion had been identified and that the rest of the sandbed area was less corroded, that assumption has never been verified [3)], and was designed solely to satisfy the NRC.

All parties to the proceeding are by now well aware of the paucity of data available, but we have to work with what we have. It is AmerGen that has to show that it can use the available data for the purpose of providing reasonable assurance that the drywell shell meets the CLB. It is therefore rather ironic that AmerGen has now decided that there are too few external measurements to be statistically representative

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[2)] R. H. Hausler Memorandum to Richard Webster, Esq., July 18, 2007 page 5 par. Chapter VI, The development of Contour Plots.

[3)] Indeed the task would be difficult. One must visualize an access hole (or canal) of 2 feet in diameter of the shell as a whole. I have attempted to provide the best analysis possible given the limitations of the data. The ideal would probably be to combine all the data on a contour plot. Unfortunately, because the plot provided of all the data is at such a small scale and does not give exact locations, I have been unable to combine the locations of the internal data with those of the external data. The other alternative is to conclude that because neither the external measurements nor the internal measurements are representative of the drywell shell thickness, there is no reasonable assurance of compliance with the acceptance criteria or the ASME code. Unfortunately, instead of combining all the data, AmerGen has chosen to try to ignore the external data. This makes no sense, because when data is sparse, one should try to extract as much information as possible from what is available. And if there are apparent contradictions within the data it should be taken as and opportunity to learn more rather than a reason to discard one or the other of the data sets non representative.. Furthermore, AmerGen has ignored the trench data, which also contains valuable information.

AmerGen has stated in the past that the internal grids are not representative of the shell as a whole. I agree with this because the 600 odd internal UT grid measurements are not evenly (or randomly) spread over the area of the sandbed, but are in each bay centered on small 6" by 6" areas at height 11'3". These grids cannot capture the severity of corrosion in the bathtub ring in some of the most corroded Bays because they are located too high. They therefore systematically over-represent the average thickness in some of the most critical Bays. This is one of the reasons that the external UT measurements were required by NRC in the first place. The internal data also cannot be used to evaluate whether the drywell meets the local area acceptance criterion. (4)

It has been asserted by AmerGen time and time again that the locations for the external UT measurements were made visually and by micrometer measurements for the purpose of selecting the "thinnest" wall locations. The examples for Bays 1 and 13 to be discussed below clearly show that this assertion does not hold across the board.

And finally, we learn from AmerGen that in order to establish meaningful contour plots, the points of measurement would have to be selected randomly in order to represent the drywell shell in its entirety. AmerGen Rebuttal Test. Part 3 at A40. There is absolutely no such a priori requirement in the use of contour plots. As we have pointed out earlier, the only assumption that is being made in the interpretation of the contour plots (also sometimes called the response surface) is that the remaining wall thickness between two measured points can be represented by the average of the two points, or more accurately, by the slope of the line between the two points. That is exactly the same approach taken by Tamburro, as is explained below.

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4) The fact that there are 49 data points in the internal grids versus at best 20 in the external data sets does not make the internal measurements any more representative of the rest of the bay than the external measurements, as AmerGen and the NRC might want to have it. More points on a smaller area simply do not increase the confidence for the state of the whole.

We have not assumed anything, other than that the points measured by UT and presented by AmerGen were reliable data. The contour plotting routine is an averaging routine and there is no up-front requirement for the data to have been gathered randomly. We have in fact questioned whether the available data would be representative of the drywell shell, which AmerGen has assured us they were, because there was apparently no need for additional measurements in areas where there might be any doubts.

To be absolutely clear about the intentions of this discussion: Our only intention is to try and answer the question as to how much confidence one can have in the integrity of the drywell shell. For that purpose we have among other things resorted to contour plots solely for the purpose of visualizing what one actually knows. In doing that we have done the same thing Mr. Tamburro has done, only using computers to the maximum extent possible rather than using largely manual methods, and have come to quite similar conclusions. Once the obvious errors in Mr. Tamburro's calculations are corrected, they broadly agree with mine within the range of the large uncertainties that remain.

To extrapolate beyond the area that was measured, one can use the response surface routine in the JMP module to extrapolate and predict the remaining wall thickness in the remaining areas of the sandbed region. I have now done this to show just how simplistic AmerGen's approach to this issue is. Although the results outside the measured area are spatial extrapolations from the data, and are therefore less certain than the contours within the measured area, they are better estimates than assuming no degradation in these areas.

II. Discussion of Bay 1

The attached Table 1 shows the external UT data for Bay 1 with the coordinates associated with each point. There were several sources for these data, which were reconciled. However, it turned out that point 6 had the same coordinates as point 17 (-48 vertical and 16 horizontal) but the reported measurements differed by 115 mils. We thought at first that point 6 should perhaps be at –16 horizontal, i.e. on the other side of the centerline. But then we found a graph where the positions of 6 and 7 were reversed to the right of the center line (positive coordinates) and finally there were representations were point 6 was indeed slightly higher and to the left of point 17. We therefore felt justified to change the coordinates from –48 and 16 to –44 and 14 as suggested by most of the graphical presentations.

The resulting contour plot is shown in Figure 1. We have inserted the measurement ID's for each point as well as the respective remaining wall thicknesses. Additionally, we have superimposed Mr. Tamburro's evaluation, which is merely a coarse manual version of the contour plot.

Tamburro in Fig. 1-2 (Ref. 4) defines three areas as shown in Fig.1 below for individual evaluation. Thus Area I contains points 5, 9 and 13 for an "average thickness of 718 mils in an area of 22 inch by approx. 30 inch, or 4.6 sq. feet. Strangely, in Fig 1-6 of Tamburro's work, the same area (referenced in Fig. 1-2) was narrowed and elongated to also contain points 4 and 19. The average residual thickness now was increased to 751 mils, while the estimated area was reduced to 23" by 16" or 2.6 square feet. Fig. 1 below, illustrates that the crude manual estimation by Tamburro is a coarse approximation to the surfaces generated by contouring. The advantage of using the computer is that the manual method is vulnerable to observer bias and does not provide an objective test of whether the results meet the local area acceptance criterion.

The important feature to recognize in all this is that both the contouring process and that used by Tamburro use averaging. However, the contouring is the preferred approach because Tamburro manually defines areas and then calculates average residual wall thickness from the measurements contained in this area, whereas the contours do not select specific areas, but use the measured point as a totality to calculate most likely average wall thicknesses between measured points.

Next, Tamburro defines in Fig. 1-2 an area, which he dubs the "Bathtub Ring". Curiously, he does not include points 11, 2, and 21 in this area even though they are clearly part of the bathtub ring (see Fig. 1 below), but includes these points in another area, which we identified as area III in Fig. 1 below. But when this area (Area III in our Fig. 1) is discussed by Tamburro in his Fig 3-1 (page 30 Ref. 4) he is not consistent in the dimensions. Nevertheless, he identifies this area as the 736 mil boundary and inserts in the same graph a 636 mil boundary somewhat arbitrarily in the middle. Now, Tamburro has identified an area of 14 x 18 inches in his Fig 1-3 as having an average wall thickness of 696 mils (points 7, 11 and 21) and being 1.75 sqft in area. But curiously, point 6 (clearly a companion point to 7 and certainly part of a corroded area) is left out of this exercise.

The peculiar thing about this is that we have been accused of *using the wrong data the wrong way*. The contours are calculated by triangulating between all the points. Tamburro averages (a primitive form of triangulating) across a few points. Please note that point 7 is a good 16 inches removed from points 21, 11 and 2, with other measurements (point 22) in between. The contours indicate that there is not a straight-line slope between point 7 and the others as Tamburro assumes, but that there is in fact a "hump" over point 22. Consequently, the interpretation of the external UT measurements by means of the response surface methodology results in a less severe picture than the one Tamburro arrives at.

There are, however, other, more serious slights of hand in the Tamburro evaluation. In Fig 1-4 (Ref. 4 pg 31) he compares the area covered by points 2, 7, 11 and 21 to the local buckling criterion. He tells us that the area covered by these points is 7 inch by 4 inch or only 0.2 sq feet, when it can easily be seen from our Fig 1 below that the area attributed to these points would be of the order of 18 by 14 inches or nearly 2 sq feet. Figure 1-4 is therefore incorrect. The same error is repeated in Tamburro's Fig 1-5.

And when it comes to the bathtub ring (Fig. 1-6) and an assessment of points 5, 13, and 4 he conveniently adds points 9 and 19 (see Fig. 1 below) to arrive at an average wall thickness of 751 mils. There is no obvious justification for including point 19 in the bathtub ring. Without it the average would have been 722 mils over an area of about 14 by 14 inches or 1.4 sq ft.

When all is said and done, Tamburro rearranges the data again in Fig. 1-7 and finds an area of 9 sq feet that has a residual wall thickness of 696. However, as clearly shown on Figure 1 this Fig. 1-7 is again incorrect because the area selected must actually be at least 42 inches by 36 inches to capture all the points show on Fig. 1-7, which is considerably larger than 9 square feet.

The question now is how one can reconcile these results with the local buckling criteria. This was, and still is the objective of the external UT measurements (see Tamburro's Figs. 1-4 and 1-5).

1. Originally the local wall thickness criteria derived from the GE sensitivity study (AmerGen Ex. 39) which found that if a local area of 0.5 sq. ft. in two adjacent Bays has a residual wall thickness of 536 mils and then tapers back to a uniform 0.736 inches, the load factor is reduced by 9.5% compared with the load factor found for a uniform wall thickness of 736 mils over the sandbed area (which gave an EFS of 2.0 for the refueling case). Similarly if the 0.5 sq. ft. central area in each Bay has a residual wall thickness of 636 mils, the load factor is reduced by 3.9%. These reduced load factors correspond to EFS's of 1.81 and 1.92. It was stressed that this sensitivity study assumed that the local thinning would gradually over a distance of a foot taper up to the 736 mils specified for the general limiting buckling wall thickness. From these general local buckling wall thickness criteria resulting from the sensitivity analysis it was left to the individual engineer to decide whether a particular corroded area would violate the one or the other of these two cases. The problem is this, the area of reduced wall thickness below 736 mils was never conveniently in the shape of the modeled cut-outs. Therefore, it is unclear what is to be done with an area that measures say 6.9 sq feet with an average wall thickness of 704 mils (total bathtub ring area in Fig. 1 below) and which tapers asymmetrically on one side toward 800 mils and on the other side toward 1150 mils. If the intention was that the cut-outs would bound the corroded areas, the dimensions of the bath tub ring, which is 10 inches wide by 66 inches long exceed the boundaries of the cut-outs and therefore presumably must violate the acceptance criterion for local areas.

2. While the definition for the local buckling criterion used in the various revisions of Calc 24 has varied, in Rev. 2 a more restrictive definition was promulgated in: *If an area is less than 0.736 inches then that area shall be greater than 693 mil*

thick and shall be no larger than 6 inch by 6 inch. (It was admitted that Calc. 024 had previously positioned an area of this magnitude in Bay 13 [5]). It is clear, however, that areas of this magnitude exist with wall thicknesses less than 693 mils all through the sandbed area (see above discussion). Consequently, Mr. Tamburro devised a way whereby the measured corroded areas were broken up into separate "mini areas" of which it could be shown that, even though severe corrosion in excess of 736 mil residual wall thickness had been observed, these areas were small enough such that they would satisfy the local buckling criteria. The advantage, of course, of this formulation of the criteria was that one could choose the areas for analysis almost arbitrarily. The disadvantage is that the decisions are left to the judgment of the engineer, which may be biased or influenced by considerations other than the need for an objective assessment of the data. In the end, comparing the Tamburro assessment with Figure 2, we see that Tamburro's assessment is a crude version of the assessment produced by the more sophisticated analysis.

3. Figure 1-7, perhaps inadvertently, illustrates that, according to Tamburro, an area of average thickness 0.696 inches extends over an area that is larger than 9 square feet. Based on this assessment, Tamburro should have concluded that the drywell failed the local area acceptance criterion he was using, which required contiguous areas that are thinner than 0.736 inches on average to be less than 9 square feet in extent. It is unclear why he arbitrarily labeled the area as 36 inches by 36 inches.

The triangulation, on the basis of which the response surfaces are generated, first generates the equations (correlation functions) used to draw the contours. These same equations can then also be used to define a grid larger than the area that had actually been covered by measurements, and to extend the contours for the purpose of predicting, in this case, the extent of corrosion one might expect outside the measured areas. This was done in Figure 2 below for Bay 1. The reason why this was done was because it was suspected that the bathtub ring might extend away from the vent line into the center of the bay. Indeed, as can be seen from Figure 2, a large area of about 15 by 20 inches might exist with a residual wall thickness of less than 750 mils and might actually extend into Bay 19. This is a prediction based on the existing data, and if verification of this prediction is outside the scope of the present intervention, it is certainly a better prediction than the assumption that corrosion stopped with the evaluation of points 5 (680 mils), and 9 (745 mils) 30 to 35 inches below the top of the sandbed.

We also see from Figures 1 and 2 that at the top of the sandbed essentially no corrosion occurred. This is in agreement with the internal grid measurements which essentially showed the same thing, **and which is in part the reason why we have concluded earlier that the internal grid measurements do not reflect the corrosion in the sand bed area and are not in anyway representative of the corrosion of the drywell liner.**

[5] This criterion is also repeated in Calc. C-1302-187-E310-041, pg. 11, 12/15/06.

III. Discussion of Bay 13

Table 2 below lists all the data for Bay 13 external UT residual wall thickness measurements. The original data were somewhat confusing. On 1/8/93 an initial set of 8 readings were obtained and listed from 1 through 8 with the associated coordinates. Then on 1/11/93 an additional set of 19 readings were obtained and again listed from 1 through 19 with the associated coordinates. Some of these readings from the second set were new, others were at or near the old coordinates. For this reason all the readings from 1/11/93 were given the suffix a. It appears that additional measurements were made at or near some of these older ones with only minimal grind of the surface (to better place the UT probe). However, these repeat or confirmatory measurements, which differed from the previous ones considerably, did not have the coordinates associated with them and could therefore not be officially included in the data set. (Nevertheless, attempts to insert these measurements at reasonable shifts of the coordinates might have better revealed the "pimpled nature of the surface.")

In 2006 it was reported that a number of the location identified in 1992 could not be "found" and therefore no 2006 data were reported for these locations. This was most unfortunate, because it appeared that one could not now deal with the spots of severe corrosion in the upper right hand corner of Figure 3. However, since it had been observed that on average all 2006 data were 20 mils lower than the 1992 results, the missing 2006 data were filled in with the corresponding 1992 data reduced by 20 mils. These "calculated" measurements are shown in the last column in Table 2 below in italics. Since there were duplicate measurements at the same coordinates, in some cases the coordinates of the second set of data were slightly shifted in order to include all data in the contours [6)]

Figure 3 below thus shows the response surface for the 2006 external UT measurements in the sandbed region. Superimposed are the three areas, I, II, and III,which Tamburro proposed in order to analyze Bay 13 corrosion in greater detail. Tamburro locates all measured points in an approximate graph of Figure 13-1 on page 63 of Ref. 4. It is noted first of all that the relative position of the individual points is distorted when compared to Fig. 3 below which is drawn with the accurate coordinates. Second, as one looks at the numbering of the points it is hard to believe that an argument could be made that the points to be measured **had not been selected at random**. Finally, we also notice that all measuring locations are indicated in Fig. 13-1, however, as we proceed to examine Tamburro's individual areas we find that for some unexplained reasons some of the most corroded points are left out. Thus within the three areas Tamburro proposes to discuss in Fig. 13-2 we find that points 1 and 2 and 1a and 2a are missing. Clearly, the absence of these heavily corroded areas from Tamburro's analysis grossly distort his conclusions.

[6)] When two points have the same coordinates, one set will be dropped from the triangulation even though the values may be different. By shifting the coordinates ever so slightly the particular location in question will be given more weight as it should be because of the additional data.

Tamburro and AmerGen have insisted all through these discussions that the most heavily corroded areas had been selected for UT measurements, and that their evaluation were conservative. However, in the final analysis the most heavily corroded areas are simply overlooked. It turns out that the bathtub ring in Bay 13 is not horizontal, but tilted toward the center of the bay.

Figure 4 shows the predictive contours derived from the triangulation correlations. Note, that the areas predicted to have less the a residual wall thickness of 750 mils (dark green shading) extend all the way up to 0 on the scale of vertical coordinates, a few inches below the "internal grid measurements." Three internal grids had been measured in this Bay (Ref. 11, Section 6, Table 6) with average residual wall thicknesses of 846 (13A). 904 (13D bottom), 1047 (13 B top) and 1142 (13 C). Thus, it is likely that the internal measurements are mostly above the angled bathtub ring, which is tapering out at 11'3" or thereabouts. **Clearly, however, none of the Internal Grid UT measurements reflects the severity of the actual corrosion in the sandbed area below 11'3" in Bay 13.**

IV. The Relationship between the Internal and External UT Measurements

Finally we find the need to comment on the comparison between the internal UT measurements in Bay 17 and their relationship to the external and trench UT measurements. It has been said that if we had chosen the internal grid measurements 17 D instead of 17 A the comparison between the external and trench measurements would have turned out different, and we might have concluded that the internal grid measurements actually did represent the overall corrosion damage of Bay 17 or in fact of all Bays (AmerGen Rebuttal testimony, part 3, pg 3.). As a consequence we have augmented Figure 4 from our Memo of April 25, 2007 to include both sets of internal grid measurements. The results are shown in Figure 5 below. Indeed the horizontal averages plotted as function of the elevation for the data 17 D show considerably more reduced wall thickness than those for 17 A. Now, one needs to remember that the lateral position in the Bay of these data is not represented in the Figure 5, in fact we don't know what the lateral position is because it has not been reported with any precision. Nevertheless, Fig. 5 clearly demonstrates the uncertainty of the assessment of the corrosion damage in the sandbed area if one were to rely on only one set of data, namely the internal grid data. This has earlier also been demonstrated by means of an analysis of the results for Bays 1 and 13.

V. Conclusions

The above discussion has shown that:

- Developing contours is not using "the Wrong Data the Wrong Way", but is in fact the most rational approach to visualizing the external UT measurements in the sandbed area.

- The response surfaces showing the correlations as well as the raw data present a more comprehensive way towards deciding whether certain corroded areas are within the acceptance criteria.
- The approach Tamburro took of dissecting the totality of the measurements for each Bay into mini areas, for the purpose of demonstrating agreement with the acceptance criteria, appears to be rather arbitrary and self-serving. At best, it is a crude approximation of the contouring which is carried out in an objective manner by a computer.
- The correlation equations on the basis of which the response surfaces are calculated allow extrapolation into areas of no measurements. **For certain, prediction on the basis of these equations as shown in Figures 2 and 4 carries more weight than the blanket assertion that there is no severe corrosion outside the areas examined. These predictions show that areas of severe corrosion are probably present at precisely the locations that AmerGen has admitted are most vulnerable to buckling.**
- Finally, reexamination of the data for Bay 17 show just how questionable the assertion is that the internal grid measurements are representative of the entire corrosion damage which may have occurred in the sandbed area.

References

A. Data Sources

1. GPU Nuclear; Calculation C-1302-187-5320-024 Rev. 1, 1/12/93, this revision contained the original raw data on pages 67 to 117,
2. GPU Nuclear, Calculation C-1302-187-5320-024, Rev. 0, 1/12/93, this document explains in detail the rational for the "Evaluation Thickness".
3. Passport 0054604907 (AR A2152754 E09), 11/2/06; this document contains the results of the 2006 external UT measurements.
4. Exelon Nuclear; Calculation C-1302-187-5320-024 Rev. 2, 3/28/07; this document also contains the rational for acceptance within the "acceptance criteria" of the areas which were most corroded.
5. IR 0553792-02 Drywell Structural Integrity Basis IR21 Inspection, 11/06/06, Document contains all 2006 internal Grid data

B. Rebuttal References

6. NRC Staff Rebuttal Testimony of H. G. Ashar, Dr. J. A. Davis, Dr, Mark Hartzman, T. L. O'Hara, A. D. Salomon.
7. NRC Staff Response to Initial Presentations and Response to Board questions.
8. Affidavit of Mark Hartzman, PhD, Aug. 23,2007, par. 2
9. AmerGen's Pre-filed Rebuttal Testimony, Part 2, Acceptance Criteria, by M.P. Gallagher, A. Ouaou, H. S. Metha, PhD,

AmerGen's Pre-Filed Rebuttal Testimony, Part 3, Available Margin: by F. W. Polaski, D. G. Harlow, PhD, Julien Abramovici, Peter Tamburro, and M. E. McAllister.

11. 2006 Inspection Report for ACRS

Bay 1 UT Measurements for External Corrosion.

Measurement ID	Vertical Position inches	Horizontal Position inches	Remaining Wall Thickness 1992 inches	Remaining Wall Thickness 2006 inches	Comments
1	-16	30	720	710	
2	-22	17	716	690	
3	-23	-3	705	665	
4	-24	-33	760	738	
5	-24	-45	710	680	
6	44	14	760	731	location given as -48/16 - duplicate of 17 not likely, therefore moved closer to point 7
7	-39	5	700	669	
8	-48	0	805	783	
9	-36	-38	805	754	
10	-16	23	839	824	
11	-23	12	714	711	
12	-24	-5	724	722	
13	-24	-40	792	719	
14	-2	35	1147	1151	
15	-8	-51	1156	1160	
16	-50	40	796	795	
17	-48	16	860	846	
18	-38	-2	917	899	
19	-38	-24	890	856	
20	-18	13	965	912	
21	-24	15	726	712	
22	-32	13	852	854	
23	-48	15	850	828	

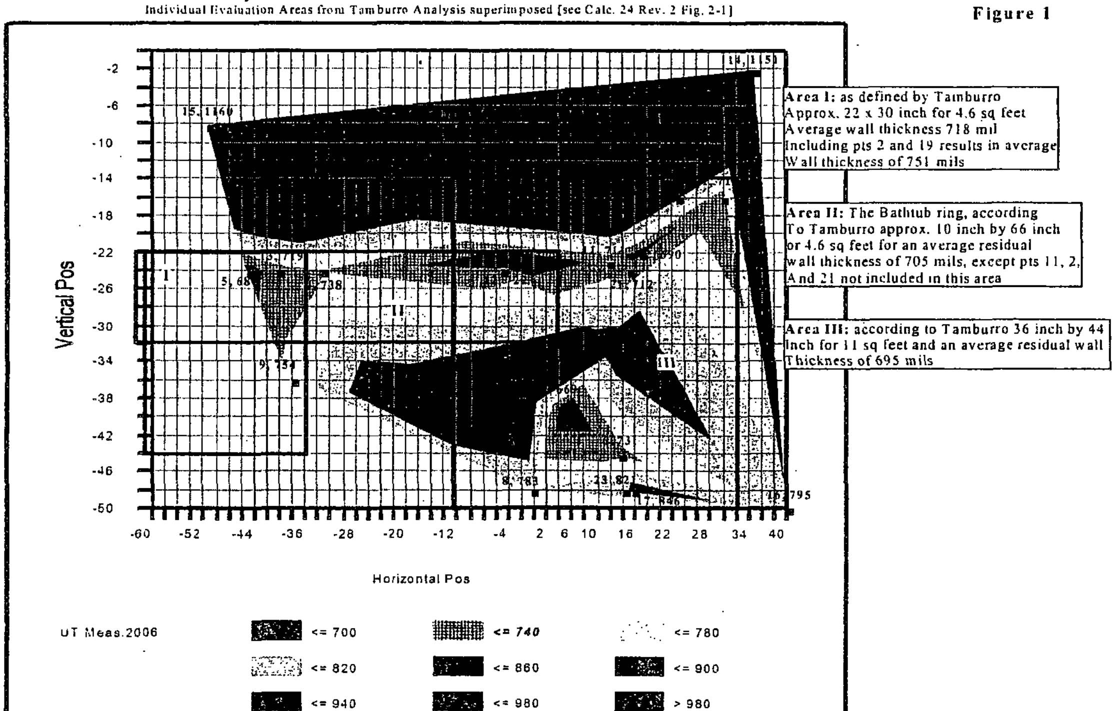
Bay 13 UT Measurements for External Corrosion.

Measurement ID	Vertical Position inches	Horizontal Position inches	Remaining Wall Thickness 1992 inches (1)	Vertical Position inches	Horizontal Position inches	Remaining Wall Thickness 2006 inches (1)	Comments
1a	1	45	672	1	45	***652***	
2a	1	38	727	1	38	***705***	
3a	-21	48	941	-21	48	923	
1	-6	46	814	-6	46	***873***	
2	-6	38	615	-6	38	***595***	
3	-26	42	934	-26	-42	***914***	
4	-12	35	914	-12	-35	***894***	
4a	-12	36	915	-12	36	873	
5	-26	6	735	-26	6	***715***	
5a	-21	6	713	-21	6	708	
6	-24	-8	683	-24	-8	***663***	
6a	-24	-8.5	655	-24	-8	658	
7	-17	-23	632	-17	-23	***612***	
7a	-17	-23	616	-17	-23	602	
8	-22	-20	744	-22	-20	***724***	
8a	-24	-20	718	-24	-20	704	
9a	-28	41	924	-28	41	915	
10a	-28	12	728	-28	12	741	
11a	-28	-15	685	-28	-15	669	
12a	-28	-23	885	-28	-23	886	
13a	-18	40	923	-18	40	814	
14a	-18	8	868	-18	8	870	
15a	-20	-9	683	-20	-9	666	
16a	-20	-29	829	-20	-29	814	
17a	-9	28	807	-9	28	***787***	
18a	-22	38	825	-22	38	***805***	
19a	-37	38	912	-37	38	916	

Calc. 24, Rev. 1 measurements 1/8/93
The numbers with postsript (a) are dated 1/11/93 and are in part duplicate measusrements from the previous entry and in part new measurements
bold numbers in italics are numbers missing in the 2006 survey. They have therefore been calculated by subtracting 20 mils from the 1992 measurements.
This was necessary because otherwise the upper right hand corner of the plot would have been grossly and erroneously distorted.

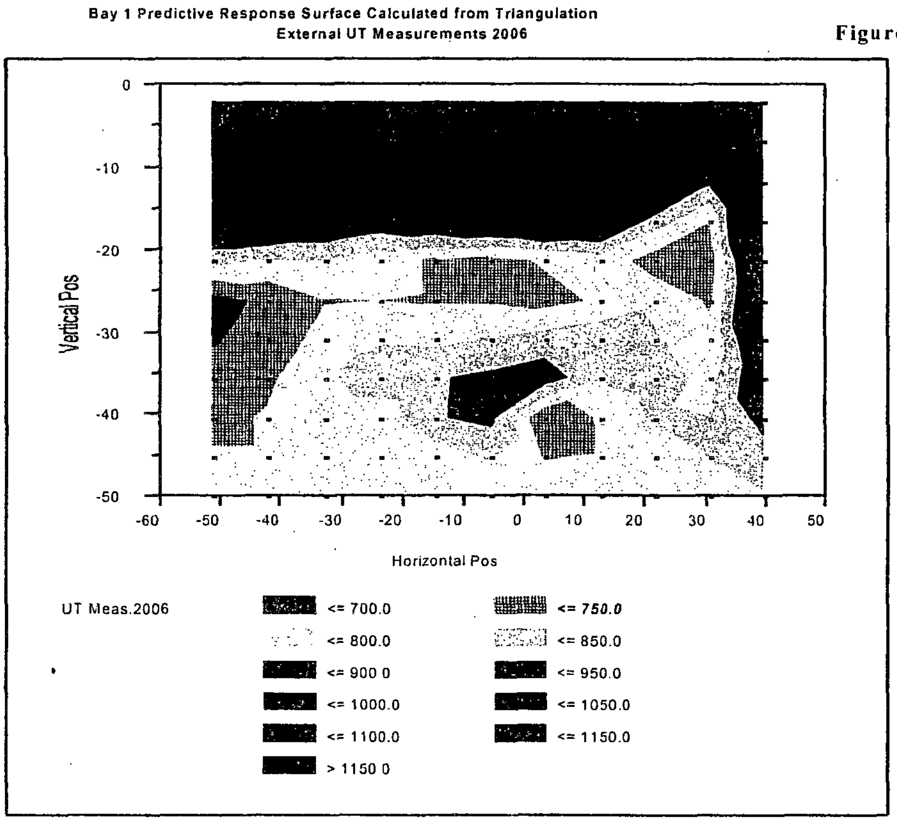
Bay 1 Contour Plot for 2006 External Measurement Data
Individual Evaluation Areas from Tamburro Analysis superimposed [see Calc. 24 Rev. 2 Fig. 2-1]

Figure 1



Note: Numbers associated with the measured points: first number is measurement ID, second number is remaining Wall Thickness

Figure 2


Bay 1 Predictive Response Surface Calculated from Triangulation
External UT Measurements 2006
Vertical Pos
Horizontal Pos
UT Meas.2006
<= 700.0
<= 750.0
<= 800.0
<= 850.0
<= 900 0
<= 950.0
<= 1000.0
<= 1050.0
<= 1100.0
<= 1150.0
> 1150 0

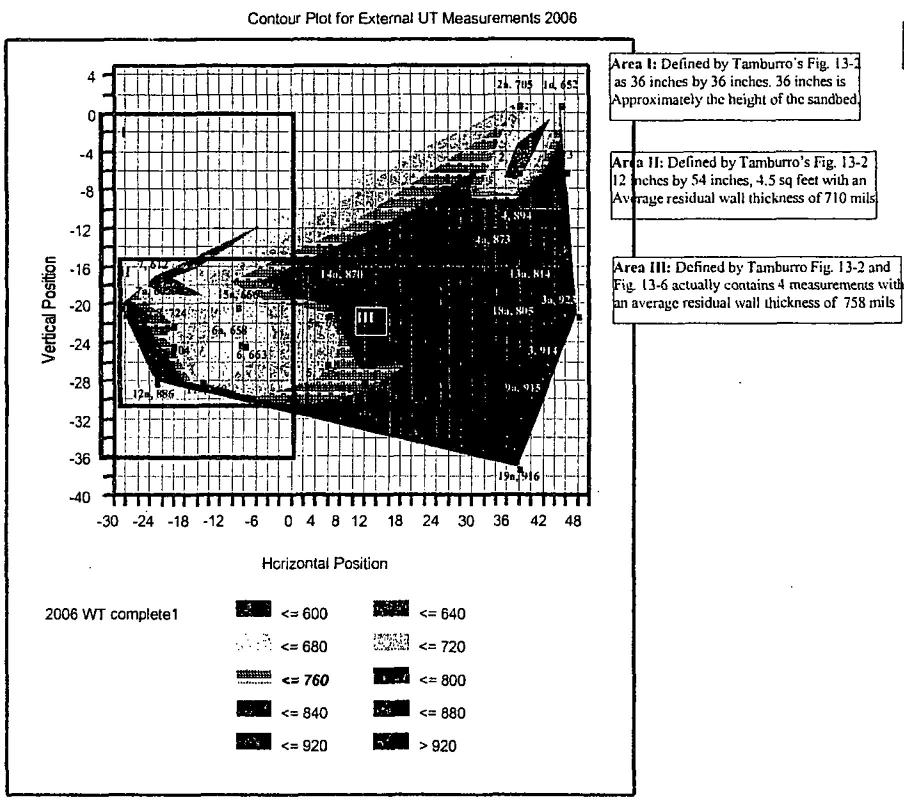

Contour Plot for External UT Measurements 2006
Vertical Position
Horizontal Position
4
0
-4
-8
-12
-16
-20
-24
-28
-32
-36
-40
-30 -24 -18 -12 -6 0 4 8 12 18 24 30 36 42 48
III
2006 WT complete1
<= 600
<= 640
<= 680
<= 720
<= 760
<= 800
<= 840
<= 880
<= 920
> 920
Area I: Defined by Tamburro's Fig. 13-2 as 36 inches by 36 inches. 36 inches is Approximately the height of the sandbed.
Area II: Defined by Tamburro's Fig. 13-2 12 inches by 54 inches, 4.5 sq feet with an Average residual wall thickness of 710 mils
Area III: Defined by Tamburro Fig. 13-2 and Fig. 13-6 actually contains 4 measurements with an average residual wall thickness of 758 mils

Figure 3

Figure 4

Predicted Response Surface for area of Bay 13
Contiguous Areas which are less than 725 mils about 12 sqft
Bordered by the dark green areas.

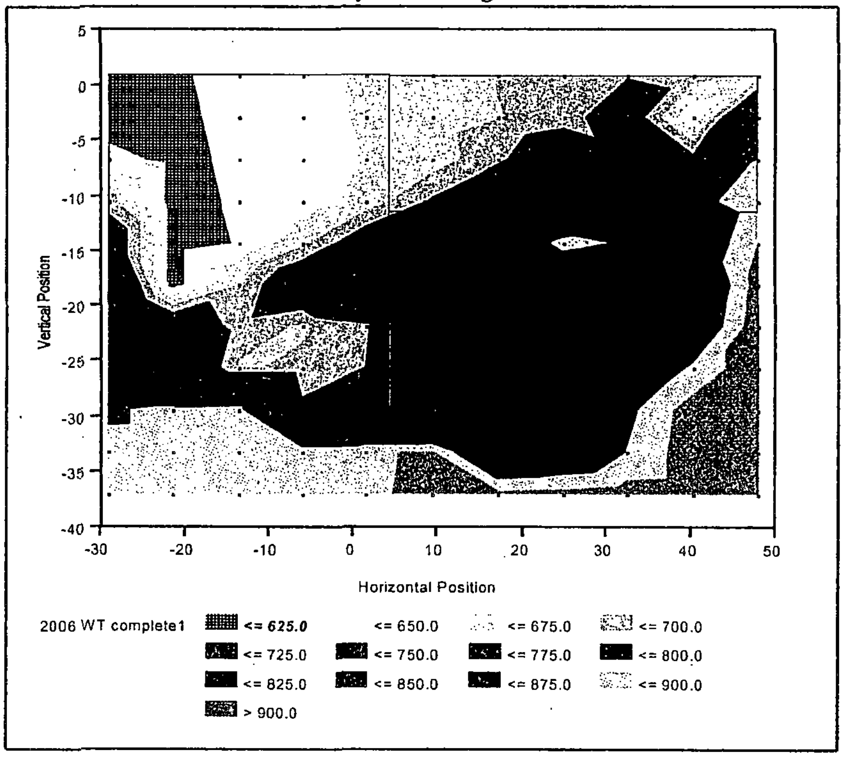
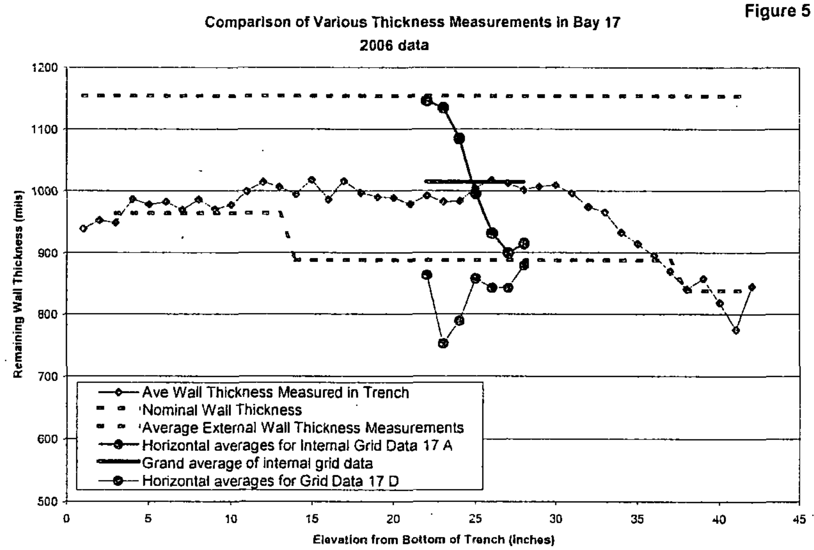


Figure 5



Comparison of Various Thickness Measurements in Bay 17
2006 data
Remaining Wall Thickness (mils)
Elevation from Bottom of Trench (inches)
1200
1100
1000
900
800
700
600
500
0
5
10
15
20
25
30
35
40
45
Ave Wall Thickness Measured in Trench
Nominal Wall Thickness
Average External Wall Thickness Measurements
Horizontal averages for Internal Grid Data 17 A
Grand average of internal grid data
Horizontal averages for Grid Data 17 D