Citizens Exhibits 39

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Memorandum

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August 16, 2007

Subject: **Further Discussion of the Nature of the Corroded Surfaces and The Residual Wall Thickness of the Oyster Creek Dry Well**

I. Introduction

It is understood from the NRC testimony that …"the license renewal safety review process focuses on the 'potential detrimental effects of aging that are not routinely addressed by ongoing regulatory oversight programs'" [1)]. This is an extremely important statement with respect to the efforts by 'citizens' to contribute constructively to the discussion of the integrity of the Oyster Creek drywell shell. The statement in essence urges "thinking out of the box" and focuses on future potential events that are difficult to predict. NRC and AmerGen both have stated that the aging processes in question are slow and can be monitored within relatively long intervals, without risking an undesirable event. It is, however, a well-established fact and acknowledge by those skilled in the art that "rate to failure", i.e. the rate of the aging process, be it corrosion, degradation of coatings, fatigue etc., is not constant with time (often also said to be non-linear). While almost imperceptibly slow in the beginning, the processes accelerate later in the life of the structure and my lead to failure

[1)] NRC Staff Initial Statement of Position on the Drywell Contention, pg. 7, July 20, 2007

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exponentially with time. **It is also a well established correlation that the logarithm of the cumulative failure rate of complex aging structures is linear with time, i.e. failures accumulate exponentially as time goes on** [2]. In discussing, therefore, the processes and the monitoring of aging one has to be acutely aware that the rates of these processes are not constant with time but can and often do, after a slow initiation period, accelerate exponentially. **Monitoring intervals therefore cannot be judged by past performance.**

We also try to guard against using terminologies, which tend to create in one's mind images with conflict with the real world. It has, for instance, been said all through these proceedings that "the thinnest spots in the drywell wall in the sandbed area were identified visually (and by micrometer readings). This is utterly impossible, because just by looking at the corroded surface one cannot guess at the remaining wall thickness because one has no reference point back to the original surface. Micrometer readings can establish pit depth, but only with reference to the remaining surface, not the original one. Similarly, 2-inch plugs had been removed from the drywell wall in order to verify the UT measurement at that location. One such plug was examined by a third party [3] corrosion expert and assessed as showing *uniform corrosion*. While the assessment may have been correct for the surface of the 2-inch plug, it certainly was not representative for the drywell surface in the sandbed area in general, because here corrosion was highly non-uniform, as one would expect from the corrosion mechanism. It has also been said that the corrosion damage was caused by *galvanic corrosion*. Galvanic corrosion is defined as occurring between dissimilar metals. There were no dissimilar metals present in the sandbed area. The prevailing corrosion phenomenon is generally identified as differential aeration cell occurring under a deposit. As such, for a number of reasons, the corrosion will be highly non-uniform and characterized by pitting and trough formation, as was indicted by the term golf ball like pimpled surface (which is not what is commonly understood by uniform corrosion).

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[2] This correlation was discussed by Professor Dr. Roger Staehli in a Plenary Lecture during the NACE Convention of 2004 in New Orleans with special reference to the Nuclear Industry

[3] AmerGen's Pre-filed direct testimony Part 6, Future Corrosion, Barry Gordon, pg 4.

Another terminology, which causes a great deal of confusion relates to the removal of air from the reactor cavity during normal operation. Inerting, presumably with nitrogen has been said to make "the likelihood of corrosion very low" [4]. The fact, however, is that the oxygen content in the atmosphere is reduced only from 20% to 5% [5]. Corrosion, therefore, will continue however, at a reduced rate [6]. In fact, it appears that several instances of carbon steel corrosion have been identified in the RBCCW system inside the containment [7].

These examples, which are only a few of many, demonstrate that it is important not to use words, expressions, sentences, which create imagery not consistent with reality. The containments do not contain *an inert atmosphere;* rather they contain a reduced oxygen atmosphere for the purpose of preventing the formation of an explosive one.

It has been said, and this is obviously not in dispute, that the outside steel surface of the drywell in the former sandbed area had been thoroughly coated with a primer and two epoxy paint coats. Additionally, the concrete floor of the former sandbed had been built up with epoxy, etc, etc. This of course creates the image of a well-protected structure where the protective coating would have to be destroyed or damaged before corrosion could take place. **However, what had not been highlighted until recently [8] is the fact that there are concerns about areas that were not accessible to cleaning and/or coating.**

These comments, some of which will be discussed in more detail below, bear directly on the question of "how well do we really know the condition of the drywell", i.e. the uncertainties, which surround this entire project. AmerGen has repeatedly indicated both the UT measurements using the internal grids and particularly the external

4) NRC Staff Initial Statement of Position on the Drywell Contention, July 20, 2007 pg. 15, A12(a)

5) e-mail from T. Quintenz to K. Muggleston, 2/1/2006.

6) See also expert opinion by Dr. R. M. Latanision, letter to Mr. Ron Zak, NJDEP-Bureau of Nuclear Engineering, March 26, 2007.

7) e-mail from K. Muggleson to G. Beck 1/31/07 (RAI regarding corrosion of carbon steel mechanical components in containment atmosphere).

8) e-mail from W. T. Russell to F. Polaski, 11/30/06

measurements gave conservative results because they were obtained from areas that were most corroded. For the external measurements, the only evidence for this statement stems from visual observation of the corroded surfaces. Presenting the data AmerGen had generated in contour plots [9)] seemed to suggest that corrosion could, at least in certain cases, be more severe outside the areas that had been examined by UT. At minimum, the contour plots showed that the most severely corroded areas in the sandbed region are very poorly defined spatially. There is therefore tremendous uncertainty about the extent and the thickness of these areas. Instead of merely making optimistic or pessimistic assumptions, statistics may be used to attempt to quantify that uncertainty and illustrate the limits of our current knowledge about the corrosion of the drywell shell. At this point there are two principles one must be acutely aware of. These are: a) the larger the variability of a particular measurement, the larger will be the confidence limits within which the real value might be found. (For example: the reproducibility (s) of wall external thickness measurements is of the order 0.03 inch. The 95% confidence limits within which the wall thickness at that particular spot might be found is therefore approximately +/- 0.06 inch.); b) if it becomes necessary to estimate the thicknesses within tighter confidence limits it will be necessary to perform a larger number of measurements, because the mean will have tighter confidence limits than individual measurements. Indeed, if the null hypothesis is well demonstrated, then successive data sets may be pooled to increase certainty. Thus, a requirement for increased certainty could initially drive a higher monitoring frequency than proposed. However, in areas where there are no measurements, one is reduced to conjecture, and the question in the end is whether AmerGen can show that the drywell meets safety requirements, despite the large uncertainty associated with the proposed monitoring program.

II. Background

The purpose of this discussion is to systematically establish the confidence levels associated with the various wall thickness measurements and the conclusions drawn from them. In reviewing the various documents dealing with these subjects it became

[9)] R. H. Hausler Memorandum to R. Webster, Esq., July 18, 2007 apparent that the methodology of measurement and interpretation was not always consistently applied and hence it is necessary to get back to the basics of what can be validly concluded from the data we have. This discussion is therefore not intended to be a critique of the methodology of UT measurements, nor the evaluation procedures of the data, but rather a further attempt to extract additional information from the existing data, and establish a reasonable perspective for the conclusions.

III. A thought about Confidence limits

I believe everybody can agree that the *realistic assessment* of the extent of the corrosion damage on the external wall of the drywell in the former sandbed area is crucial for the establishment of the current fitness for service condition of this vessel. Additionally it will set realistic limits to the margins, which may still exist regarding further allowable corrosion.

Since fitness for service is determined on the basis of various model calculations (buckling calculation) and specific codes, such as the ASME pressure vessel code, the question boils down to the definition of "realistic" in "realistic assessment". Here is of course where experts begin to disagree because some may assess a given situation as less "severe" than others would.

For instance, NRC and AmerGen have at times practiced a statistical approach to the interpretation of measured data, and applied the 95% confidence limits to the reported results. I believe this to be prudent, since corrosion rates, for instance, determined from residual wall thicknesses as a function of time should be seen both in the as correlated form as well as in the extreme form based on the 95% confidence limits, since particularly the upper 95% confidence limit would result in more rapid deterioration or a faster elimination of still available margins [10)].

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10) See for instance Calc. C-1302-187-5300-20 (various revisions)

The 95% confidence limits embrace 95% of all data belonging to a specific family of data, which have been experimentally determined. The limits are defined as the mean of the data +/- approximately two (2) standard deviations (s) (depending on the degrees of freedom). Hence if a data point lies outside any of the 2 s limits it is said not to belong to the same family and is often characterized as atypical [11)]. As an example, a location of corrosion damage in Bay 13 has been identified with a residual wall thickness of 0.602 inches. The standard deviation of this particular measurement has been identified from a series of duplicate measurements as being approximately 0.03 inches. Therefore, if the data are normally distributed, there is a 2.5% probability that the remaining wall thickness at this particular location could in fact be lower than 0.542 inches (the normal distribution is symmetric so the upper and lower tails beyond the 95% confidence limits each contain 2.5% of the data). If this result characterizes an area of 1 sq. ft. around it, the result should be compared to the acceptance criterion of either 0.636 inches or 0.536 inches for localized corrosion damage This comparison indicates that there could be 2.5% probability that the remaining margin is zero or less than 0.006 inches, depending on which acceptace criterion the Board decides is appropriate. It is of course within the purview of NRC or the ASLB to determine whether 2.5% probability for a certain event not to happen is or is not sufficiently conservative. (Parenthetically it may be interesting to note how over the years the statistical confidence limits have changed since in 1992 99% confidence was still considered appropriate for nuclear safety considerations and here the lower 99% confidence limit would have eliminated the remaining margin completely. [12)]. To avoid this result, AmerGen's Testimony has argued that statistics should not be applied to the external measurements. Nevertheless, this residual wall thickness has been reported by AmerGen. The duplicate measurements also have been reported by AmerGen and calculating the standard deviation for a single UT wall thickness measurements on the outside of the drywell from these duplicate measurements is a simple exercise in Statistics 101 [13)]. Are we therefore resigned to

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[11)] See for instance also Calc. 1302-187-5320-24 Rev. 0

[12)] Calc. No. C-1302-187-5300-19 at page 37 for instance

[13)] *It should be remembered that there are actually two types of "standard deviations" in the set of* measurements presented by AmerGen. The series of 49 measurements made by means of a grid on the live with a 2.5% or 0.5% probability that in the event of a nuclear accident the drywell may not serve as a primary containment and may release radioactive emanations into the environment? Not necessarily: the well-known resolution of large uncertainties caused by large standard deviations of single measurements is to repeat the measurement a few times because the standard deviation of the mean of multiple measurements is reduced according to the well know *central value theorem.*

While the standard deviation for single measurements is quite large and tends to lead to the conclusion that at least in one area the limit for local wall thickness reduction has been reached, the spread of the measurements leads to the same conclusion as has been shown in Figure 6 of R. H. Hausler Memo of 4/25/07 [14)]. In this latter case, however, additional measurements would not reduce the spread of the data since in heavily corroded areas the pit distribution is systemic and could not be made tighter by additional measurements, only the mean would get better defined.

Since very few external wall thickness measurements have been repeated, which holds in particular for those measurements resulting in low residual wall thicknesses, one is saddled with large uncertainties in the interpretation of the UT wall thickness measurements. This is neither a criticism of AmerGen's UT measurement methodology nor of their interpretation of the data, but simply a statement of fact, which AmerGen and NRC could have arrived at themselves if they had pushed their data analysis to the same insights.

IV. Residual Wall Thickness Measurements and the Buckling Criteria (Fitness for Service Criteria)

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inside of the vessel presents a certain spread of wall thicknesses which can be represented by a standard deviation if the distribution of the measurements is indeed Gaussian. (Similarly, the external measurements are somehow distributed). However, there is another standard deviation, which originated from repeated measurements at the same spot. This standard deviation represents the repeatability of the measurement proper. This standard deviation could actually be determined from duplicate wall thickness measurements made on the outside of the drywell in the sandbed area.

[14)] R. H. Hausler Memorandum to R. Webster, Esq., April 15, 2007 at 17.

The analyses of the UT residual wall thickness measurements in combination with the various fitness for service criteria is intended to arrive at a reliable estimate of the remaining margin, if any. The remaining margin together with an estimate of the potential corrosion rate will determine the frequency of inspection. It has been said that the remaining margin is at least 64 mils (800 mils minus 736 mils) and that the estimated corrosion rate is at most 2 mils per year (mpy). It will be shown that these statements, even if not totally grabbed out of thin air, cannot stand up to detailed scrutiny.

The remaining margin of 64 mils is based on the lowest average for the 49 point 6 inch by 6 inch internal grid measurement in one Bay (Bay 19A). It should be remembered here that the NRC had wisely requested that "the grids shall be one square foot except unless justified otherwise" [15). Apparently the total area of the dry well in the former sand bed is 701.5 square feet. Of this only 115.6 square feet would be accessible for UT measurements from the inside. However, the total surface area that was and will be inspected by UT is only 3.9 square feet [16) or about 0.5% of the total area of interest. If it had been established that corrosion was spread uniformly through the sandbed area one could let the grid measurements stand as being representative. However, quite the contrary is the case. Corrosion based on UT measurements varies from bay to bay from almost nothing to 30% (on average) of wall thickness in the horizontal direction at the elevation of the grid measurements. More importantly, corrosion also varies over the approximately 3 foot height of the sandbed area in the vertical direction. This had been conclusively shown in my Memo of April 25, 2007 [17). ***The UT wall thickness measurements by means of and at the locations of the internal grids therefore cannot be considered representative of what may be going on in the lower parts of the sand bed region.***

A large number of UT measurements were performed in the sandbed areas after removal of the sand. It has been said that these measurements were conservative

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[15) NRC Notice 71 FR 67923, Nov. 24, 2006

[16) e-mail from P. Tamburro to A. Ouaou, Surface area of the Drywell in the sandbed, 4/3/06

[17) R.H. Hausler Memorandum to Richard Webster, Esq., April 25, 2007 because they had been accomplished in areas, which were, by visual examination and micrometer measurements, identified as the thinnest areas. It should be obvious to all skilled in the art that neither visual examination of nor micrometer measurements on a corroded surface can identify or even estimate the thinnest remaining wall thickness. Visual examination will identify the corroded areas but the degree of wall thinning cannot be determined because of the absence of a reference point, i.e. the original surface was corroded away and one does not know a priori by how much. Indeed, the inspector who did the assessment of the extent of corrosion in the sandbed area stated that: *"I could not visually determine which of the thin spots are the thinnest"*.[18)]. Furthermore, what this inspector (not a corrosion engineer) interpreted as "thin spots" were really the corroded areas, because that was all he could see. He also stated that: *"the thin spots comprise about 20% of the total area of the corroded portion of the shell. They are spread throughout the bay, but are closer together (about 1 ft apart) in the vicinity of the vent pipe and further apart toward the frame"*. It is clear from the above that the visual inspection may have identified areas, which may have appeared more heavily corroded than others, however, the claim that these were the thinnest areas is untenable. **Moreover, the Whitmore document [(5)] makes it clear that the heavily corroded areas extended into the bays away from the vent pipes, areas, which were not examined by UT.** This was indeed suspected from the contour plots established from AmerGen's external UT measurements [19)]. There is therefore great uncertainty with respect to the extent as well as the severity of corrosion in the sandbed area, and we contend that recent efforts at AmerGen to in essence downplay this state of affairs in their attempts to obtain yet another structural analysis is ill advised [20)]. While previously the most corroded Bay, Bay 13, was said to have an average thickness of 0.8 +/- 0.04 (2s) inches and a margin of 0.064 inches was derived there from, this same bay is now said to have an average thickness of 0.907 inches.

[18)] Memorandum from K. L. Whitmore to J. C. Flynn, January 28, 1993, re. Inspection of Drywell sandbed region and access holes.
[19)] R. H. Hausler Memorandum to Richard Webster Esq., 7/18/07
[20)] AmerGen Tech Eval. 330592-27-27, 4/20/07

V. The Nature of the Corroded Surface

Much of the confusion as to which data set to use for comparison with the acceptance criteria stems from the manner in which the data have been acquired. The corroded metal surface in the sandbed region after removal of the sandbed is said to have the appearance of a "golf ball" in terms of a dimpled surface, except of course for the fact that the dimensions of the corrosion features are larger than the dimples on the surface of a golf ball. Since it was necessary to assess the remaining wall thickness in the external regions because there appeared to be corrosion more severe than reflected by the inside grid measurements, UT measurements were made only in those areas of the sand bed which were easily accessible.

It has been said time and again that these measurements were conservative and reflecting only the thinnest areas, which had been identified visually and by micrometer readings. Now, we submit that it is utterly impossible to assess the remaining wall thickness of a corroded area by looking at it or in fact by making micrometer measurements. The fundamental reason for this is a lack of knowledge regarding the extent of the total recess of the surface due to "general corrosion" rather than pitting. We have prepared a simple graph to illustrate the difficulty **(Figure 3)**. Clearly, even the highest dimple may not be at the height of the original surface. The micrometer only gives a measure of the pit depth relative to the remaining surrounding surface. Hence micrometer measurements cannot possibly reflect the remaining wall thickness at that location. As illustrated in Figure 3 the pit depth may be deceiving relative to the remaining wall thickness as a comparison between measurement 2 and measurement 3 indicates – clearly depending on the point of reference. It is of course even more difficult to identify the remaining wall thickness visually. In fact, reviewing the contour plots we have presented in Ref. 21 below [21)] one can see that a majority of the measurements had been made in areas of moderate or no corrosion.

[21)] R. H. Hausler Memorandum to Richard Webster July 18, 2007

We therefore submit that the statement that the areas of least remaining wall thickness were selected for external measurements and the results are therefore conservative is erroneous and misleading. The ramification of this conclusion affect the way data are treated down the line and finally the assessment or uncertainties of the remaining margins.

Because of the rough external corroded surface it was recognized that UT measurements might be difficult. For this reason in some cases the areas around the deeper pits are said to have been ground flat to accommodate the UT probe. Does this mean that the resulting measurements are overly conservative or invalid? We think not. These measurements represent to the best of everybody's knowledge the true state of the remaining wall thickness, and the fact that maybe more metal had been ground away than corresponded to the pit depth was never demonstrated and is really irrelevant because the UT measurement of the remaining wall thickness is what it is.

However, not all areas chosen for external remaining wall thickness measurements were ground down. It was therefore felt that the roughness of the surface was falsifying the measurements and that a correction for the roughness was indicated. In order to achieve this, epoxy imprints were made of two one square foot areas in Bay 13. Twenty micrometer-readings were made on each of these imprints in order to characterize the roughness of the corroded area.

These roughness data were subsequently used to "*correct*" some UT measurements[22]. In order to better understand the procedure, we have prepared the following graphs:

- **Figure 4** shows a schematic of the epoxy imprint of the remaining corroded surface. On that epoxy surface replica 20 micrometer measurements of the "pit depth" were made in order to characterize the roughness of the surface.

[22] In fact we understand that only those measurements which indicated a remaining wall thickness of less than 0.736 inch were also assessed by micrometer and then subject to correction for roughness.

(Note that the replica was actually a negative of the surface. Therefore each depression on the replica related to a raised area on the surface. The twenty measurements were averaged and the standard deviation calculated. This was done for both replicas. It turns out that there is no statistical difference between the average micrometer readings from both replicas, hence a grand average and pooled variance could be calculated. The average "roughness" (dimple height) is 125 mils with a pooled standard deviation of 70 mils. This number reflects the average variation in height from valley to peak and in essence characterizes the roughness of the surface.

- It should be mentioned that that kind of roughness is also reflected in Fig. 2 of the April 25 Memorandum [6], derived from the UT grid measurement in the Trench of Bay 17.

- **Figure 5** shows how the average roughness correction is being used to correct the UT measurements. The UT measurements reflect the residual wall thickness (UT). Additionally micrometer measurements were made at each location where a UT measurement had been performed. Now the UT result and the micrometer result are added and the average roughness is subtracted from the sum in order to obtain the so called "*evaluation thickness*". It is observed that with this correction every UT measurement, except for one, which had been below 736 mil is moved to above 736 mils and therefore into the acceptable range.

- In discussing this procedure one has to remember that the correction was made because the UT measurement was said to be inaccurate because of the air gap between the probe and the metal surface caused by the inherent roughness. Now it was never established to what extent the accuracy of the UT measurement suffered because of this air gap. Did it over- or underestimate the remaining wall thickness? Similarly, the micrometer measurement is affected by the roughness of the remaining surface as well.

There is no guarantee, nor was this discussed at all, that the reference point for the UT measurement and the micrometer measurement are the same. As Figure 3 suggest, the reference can be high or low. Finally, adding the micrometer measurement to the UT measurement might have made some sense if the sum were to reflect the original wall thickness where upon the roughness could have been subtracted to indicate a possible correction. This was however not the case since in addition to pitting there was general reduction of wall thickness. (This is supported by the description of the "bathtub ring".

- This entire procedure is extremely fraught with uncertainties. There is the perceived uncertainty of the UT measurement, never established but postulated. There is the uncertainty of the micrometer measurements, and then there is the correction for which there does not seem to be a justification.

- That there really was no justification for this type of manipulation of the UT data became clear in 2006. Now the surface was coated and flat to accommodate the UT probe. The UT probe compensated for the thickness of the coating. Hence the UT measurements in 2006 should indeed reflect the true remaining wall thickness at the point of measurement. Comparing the uncorrected 1992 with the 2006 means for all measurements (200 d.f.) one finds an average small bias of 20 mils which, however, statistically is non significant (s_{mean} = 11 mils). Therefore it is highly unlikely that the surface roughness had any effect in biasing the UT measurements prior to coating the surface. There was therefore no need to calculate the so-called *evaluation thickness*. Furthermore, the evaluation thickness was also calculated for other bays which were less corroded and for which the surface roughness had not been determined (i.e. using the value obtained from the Bay 13 epoxy replicas).
- It was never made clear why in the calculation of the "*evaluation thickness*" the mean micrometer depths plus 1 standard deviation was used. In fact Mr.

Tamburro realized the arbitrariness of the algorithm when he indicated a lack of established procedure [23], and the absence of a justification of why it should be justified to compare the evaluation thickness to the design basis required minimum wall thickness of 0.736 inches. Yet, even though AmerGen was aware of the lack of clarity and justification, it continued the practice in Rev. 2 [24]

- Therefore, the evaluation thickness should be disregarded (as has been done at times) in favor of the actual measurements.

VI. Establishing the Available Margins

If for any reason corrosion in the sandbed area should continue, the question remains as to how much margin there is still available. The acceptance criteria, both for general wall thinning as well as localized corrosion have been discussed before, and their inconsistent and arbitrary application highlighted. AmerGen and NRC nonetheless have consistently maintained that there is sufficient margin remaining such that even under the worst possible circumstances a 4-year inspection cycle can assure the continued integrity of the drywell.

We shall in the following take a look at the data on the basis of which such decisions were made. We are readily prepared to stipulate that the grid UT measurements "on average" returned residual wall thickness values above 800 mils, and if representative would therefore reflect a remaining margin for general corrosion of 64 mils above the average thickness criterion (It should be noted that 800 mils is an average and no confidence limits have been reported for this number. Therefore, this could only be the margin at 50% confidence, even if the grids were representative). But we also know:

[23] AR Report 00461639, P. Tamburro to H. Ray, Calc C-1302-187-5320-024 is not clearly documented. 3/3/2006
[24] Calc. C-1302-187-5320-024-Rev.2, 3/21/07, P. Tamburro reviewed by J. Abramovici

- That because of the location of the internal grid measurements they are not representative of the overall corrosion damage (as discussed above). This is demonstrated by way of an example in Figures 1 and 2 for Bay 13.
- That for Bay 1, where only a strip grid was used for internal UT measurements (1 inch by 7 inch for only 7 UT locations), the results returned by the internal measurements in no way reflect the overall corrosion in that Bay [25)]
- That therefore the external UT measurements have to be used for the assessment of the severity of corrosion and the residual margins.

Calc. 24 [26)] is the first manifestation of how the external UT data were to be dealt with. Here Table 1 lists all the measurements that were below 736 mils and shows that when the "evaluation thickness" was computed, as shown above, all but two of these data points were above 736 mils, but all were judged "acceptable". It is interesting to note that all points with residual wall thickness less than 736 mils were found in an area dubbed the bathtub ring. This area was said to be 18 inches wide and 30 long for a total surface area of 3.5 square feet [24)]. Without the correction, i.e. without calculating the "evaluation thickness" this area would have been out of compliance [27)]. But the evaluation thickness did not make any sense, and in 2006 it was shown that the UT measurements across the epoxy coating were essentially the same as those made before the coating had been applied. This presented a serious problem, because it essentially obviated the correction, which led to the "evaluation thickness".

A number of different approaches were taken to in effect rescue the drywell from being condemned. NRC commissioned a new buckling analysis *using advanced techniques for modeling and analyzing the complex shell structure to determine the*

[25)] see Figure 3 R. H. Hausler Memorandum to R. Webster, Esq., July 18, 2007
[26)] Calc. No. C-1302-187-5320-024, Rev. 0 4/16/93
[27)] The GE compliance criterion stipulated that if an area was thinner than 736 mils it had to thicker than 536 mils and no larger than 1 square foot. (This formulation of the criterion for localized corrosion was subsequently modified several times in various ways).

controlling loads [28]. It turns out that the input data for this study were the degradation data contained in Cal. 24, Rev 0 (see 24). Sandia found a safety factor against buckling of 2.15 for the degraded shell, based on the Calc. 24 data. As discussed in my companion Memorandum on statistical procedures, the standard deviation of the UT measurements was of the order of 0.03 inch or 95% confidence limits of 0.06 inches, which corresponds to about 7.5% of residual wall thickness. This at least puts the remaining margin corresponding to 7.5 % of the safety factor in question. This, coupled with other deficiencies that I have discussed elsewhere, may well mean that there is no remaining margin left. In addition, there are equally alarming concerns, such as the fact that there may be areas, which have not been cleaned or in fact coated because of their inaccessibility.

VII. Discussion of Future Uncertainties

Future degradation of the drywell may occur because of a number of factors. These will be discussed below. In all of this it must be remembered that because something has not happened in the past does not mean it cannot happen in the future. And because something that happened in the past and was presumably corrected does not mean the correction will hold in the future. However, more seriously are those things, which could have (or should have) been anticipated but were not.

- Pinholes in the Coating: When the coating was qualified in extensive model tests and model applications, constant attention paid to the inclusion of dust and residual pinholes in the coating [29]. Test coatings prepared on a life-size Bay mock-up were routinely tested for dust inclusions and pinholes. Such were indeed detected on the test panels prepared in a clean environment. It is therefore all the more surprising that no such tests were ever done after the coatings had been applied to the steel surfaces of the drywell in the sandbed areas.

[28] NRC Staff initial statement of position on the drywell contention, July 20, 2007 page 15

[29] MPR Associates, Inc.: *Results of Painting Process Qualification Tests for Drywell Exterior In the Sandbed area at Oyster Creek*, 11/9/92, GPU Nuclear Document 133825.

Admittedly pinholes are rare where two coats of paint (epoxy coating) have been applied, however, tests with the wet sponge techniques as described earlier and as standardized by NACE are quite simple to carry out and it is unclear why these tests were not done.

- The Nature of Epoxy Coatings and the Question of Aging: Epoxy coatings are the reaction product of two ingredients: a) the epoxide itself, which is a phenol derivative containing two ethylene oxide groupings and b) a di-functional amine compound generally designated as the curing agent. When the two ingredients react with each other, the viscosity of the mixture increases until eventually a hard substrate is obtained. Once the coating (or cast) has hardened is it commonly assumed that the reactions have terminated. In fact, unreacted functionalities keep reacting for a long time, even when the product has become solid. Granted these solid state reactions are excruciatingly slow, but the contribute to the product's becoming brittle with time, contracting and cracking. These processes are slow and the results can be spontaneous. Visual inspection cannot discern internal stresses. Residual stresses, however, can lead to spontaneous cracking, particularly under conditions of constant vibration and fatigue and elevated temperature. Hence we think that the assurances, brought forth by Mr. John Cavallo [30], that the coating will last the life of the plant (even including the expanded operation of the plant), are overly optimistic. In view of the fact that failures of the coating can occur spontaneously and that the resulting corrosion could be as rapid as it was in the presence of the sand, we cannot rely on a coating inspection program that only reviews the coating once every four years.

- Some Properties of Epoxy Coatings: All coatings (organic substrates) exhibit a certain permeability to uncharged molecules. Oil field experience, for instance has shown that epoxy coatings are subject to spontaneous de-lamination as a consequence of abrupt pressure drops. The phenomenon

[30]) Affidavit John Cavallo, at 22: 3/26/2007

clearly demonstrates that CO_2 for instance, but other gases as well (CH_4) can defuse through the coating. More detailed investigation have shown that both water and H_2S can diffuse as well. Granted, these diffusion rates are slow, in fact approximately 3 orders of magnitude slower than diffusion of these same species in water. However, the slow diffusion of water and oxygen through the coating can cause formation of a thin oxide layer on the surface of the metal, which destroys the coating's adherence properties. Combined with the residual stresses in the coating de-lamination will cause cracking and of course will then provide access to water and the atmosphere. These processes are slow and will be accelerated by elevated temperature. None of this is predictable, however, one knows that it has happened, and therefore can infer that it could happen again. For these reasons we think the coating could fail in between the four year inspection cycles.

- Comments regarding Visual Observations: Essentially all epoxy coatings contain a filler. It has been said repeatedly that the coating used at Oyster Creek in the sandbed area is whiteish-grey indicating that the filler may be an oxide like possibly titanium oxide (this had never been specified). The filler functions as an agent to make the coating less brittle with aging, but it also opens up pathways for the diffusion of uncharged particles. Visual observation cannot detect what may go on underneath the coating until the coating fails. Similarly, corrosion at pinholes can proceed slowly until the pressure caused by the corrosion products leads to cracking of the coating. John Cavallo is wrong when he posits that the corrosion product occupies from 7 to 10 times the volume of iron from which it originates [30)]. A quick search in the Handbook of Chemistry and Physics teaches that iron has a density of 7.9 gm/cc (depending on the specific alloy) while iron oxide (Hematite) has a density of 5.24, and the hydrated iron oxide (rust) has a density of about 3.6. The iron oxide, which can form underneath the coatings, will therefore cause stresses, which will eventually lead to cracking. Similarly, corrosion occurring due to diffusion of water and oxygen through possible pinholes will eventually lead to cracking and blistering. While the results of these processes can be seen by visual inspection the onset cannot. Once blistering has occurred it may be too late because the margins here are, at best, tiny.

- Water, Origin and Frequency: There is universal agreement that without water no corrosion damage will occur. However, water has in the past leaked into the sandbed area, and even after the sand had been removed, water leakage was observed at times. The sandbed floors are supposed to be shaped such that water accumulations are not supposed to occur. Even if water should reach the sandbed area it is supposed to drain away, however, the drains were observed to be plugged. Finally, it is being said that even if water should for some reason accumulate in the sanded area it would evaporate quickly without being able to do a lot of harm. Specifically, Mr. Barry Gordon [31)] tries to convince us that water accumulations in the space of the former sandbed would evaporate quickly. In order to support the argument Mr. Gordon uses an engineering equation applicable to the evaporation of water from a pond or pools, in which wind velocity controls the evaporation rate. The former sandbed area, however, is a totally stagnant space where water might evaporate until the atmosphere above it is saturated with water vapor. Hence the equation used by Mr. Gordon describes a steady state, while the rate of evaporation in the confined space of the sandbed area would have to be described by a transient equation.

  Where does the water come from? There clearly are many possibilities all of which point to some sort of a leak. Leaks are not predictable (otherwise they would be prevented). When possible they are repaired in the hopes that they would not occur again. However, it is impossible to rule out further leakage. The situation, however, is reminiscent of earlier incidences. "The core samples validated the UT measurements and confirmed that the corrosion of the exterior of the drywell was due to the presence of oxygenated wet sand

[31)] Barry Gordon Affidavit 3/26/2007

and exacerbated by the presence of chloride and sulfate in the sandbed region [32]. The origin of the chloride and sulfate was to our knowledge never firmly established, but was attributed to impurities dissolved into the water along the leakage path.

- Summary: Clearly a number of factors must come together in order for continued damage to occur in the former sandbed area on the exterior or the interior. The most important one is the presence of aerated aggressive water. In addition, on the exterior, the coating has to have failed in some manner at the location where water is present. And finally the corrosion has to occur at a location where the drywell has already been damaged. It has already been shown that only a very small fraction of the entire sandbed area has been surveyed with respect to corrosion damage. There is no guarantee that other areas have not experienced similar or worse corrosion damage. It has also been argued that at this advanced stage in the aging process of the coating, failure is to be expected. And finally, the presence of stagnant water cannot be ruled out. Therefore, if AmerGen can establish that it has some margin, I believe it prudent to use UT techniques to monitor the thickness of the drywell frequently. At this time, because AmerGen has not shown that there is any margin, I am unable to set forth an exact frequency. The corrosion rate from the interior could be a multiple of 0.002 mils per year and the corrosion rate from the exterior could be as high as 0.039 inches per year. Thus, even if the mean margin were 0.064 inches as AmerGen has alleged, the proposed monitoring frequency of once every four years is insufficient.

[32] AmerGen Letter to NRC 12/3/2006, 92130-06-20426, Enclosure, page 12 of 74

Figure 1

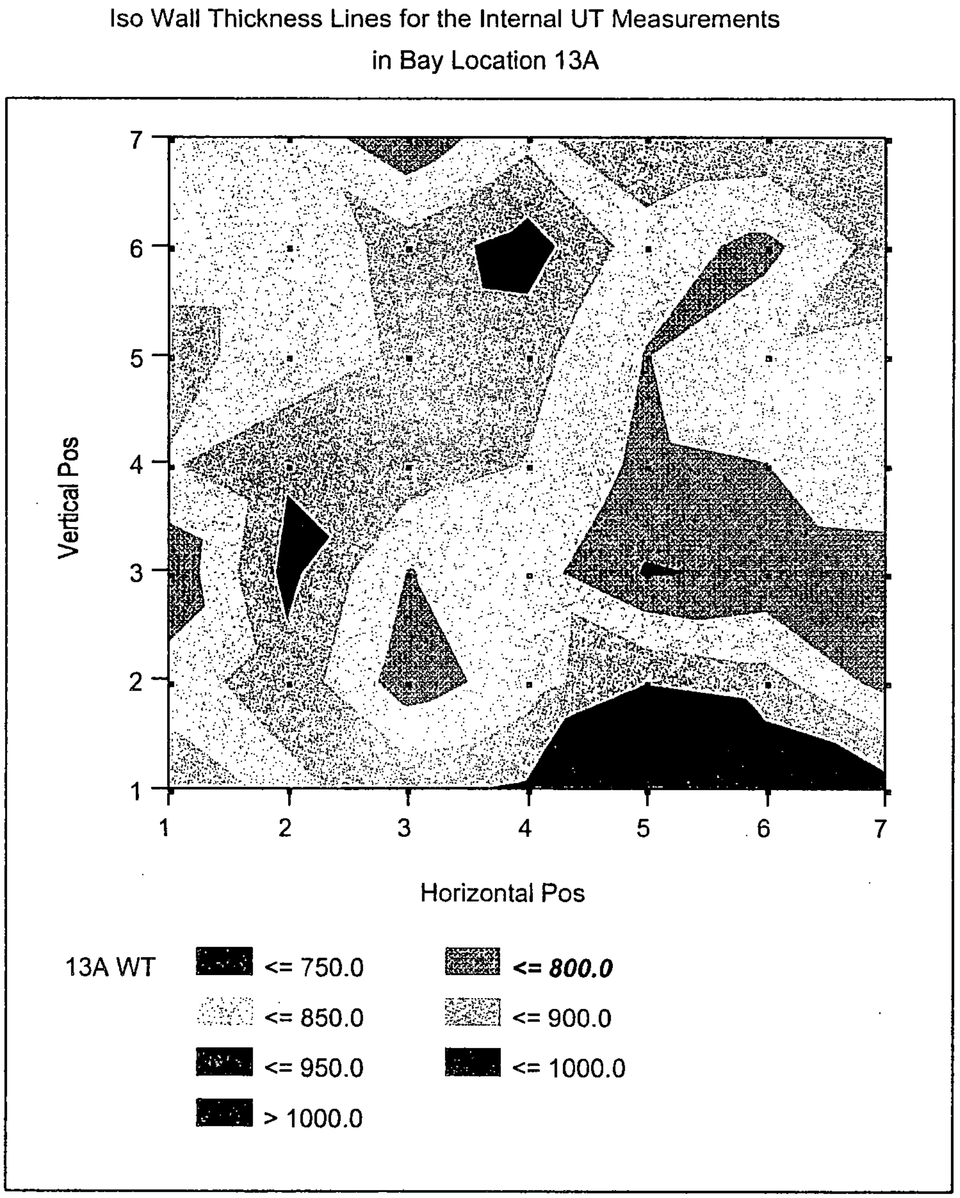

Iso Wall Thickness Lines for the Internal UT Measurements
in Bay Location 13A
Vertical Pos
Horizontal Pos
1
2
3
4
5
6
7
13A WT
<= 750.0
<= 800.0
<= 850.0
<= 900.0
<= 950.0
<= 1000.0
> 1000.0

Figure 2

Contour Plot for External UT Measurements in Bay 13

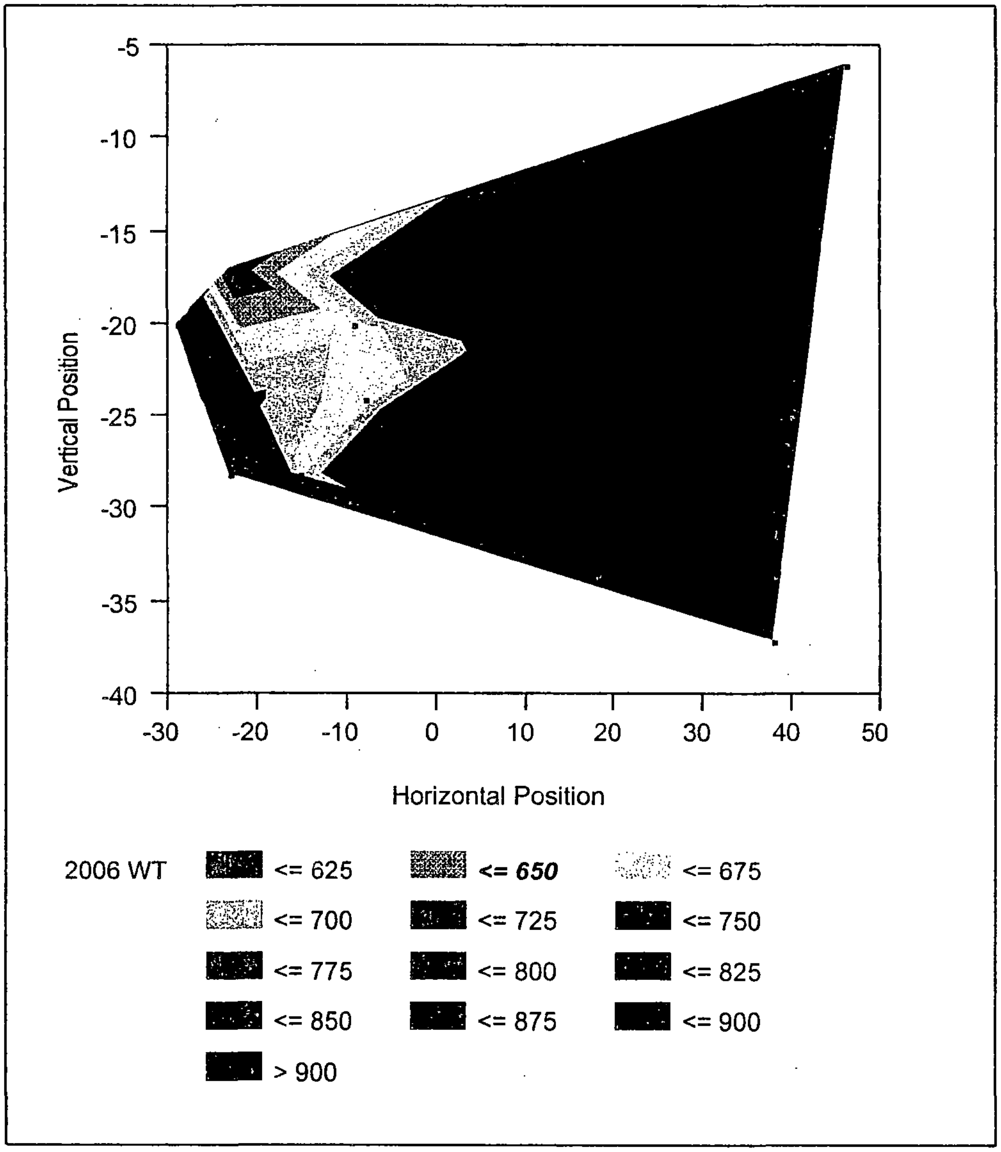
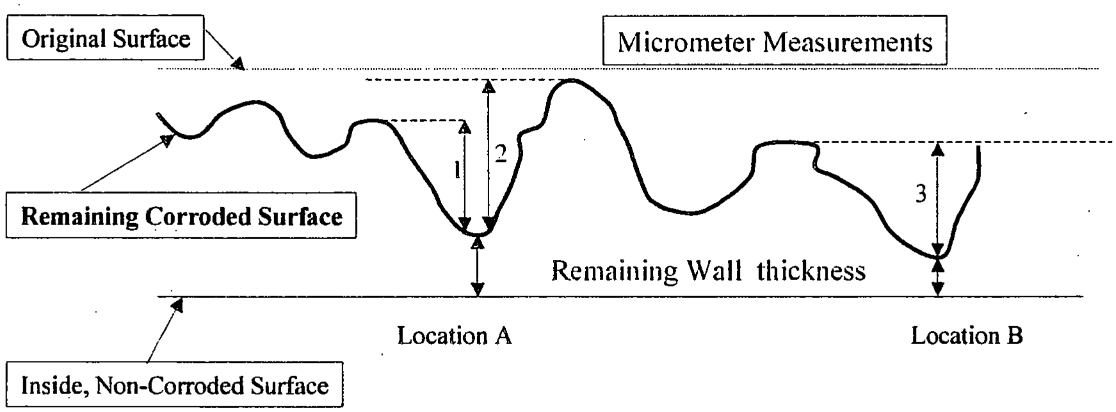


Figure 3

The Problem of Identifying the Thinnest Remaining Wall Thickness by ***Visual Observation*** or by ***Micrometer Measurements.***



Location A: Since the remaining, corroded surface is "dimpled", the *Micrometer Measurement* clearly depends on the point of reference. However, the point of reference is not, cannot be, the ***Original Surface,*** hence the *Micrometer Measurement* is in no relationship to the remaining wall thickness.

Location B: Here the "Pit Depth" obtained by micrometer measurement (3) is smaller than (2) in location A but the remaining wall thickness here is the least. Visual observation would identify Location B as less corroded because visually one has no reference point, in particular, one cannot refer back to the original surface area.

Figure 4

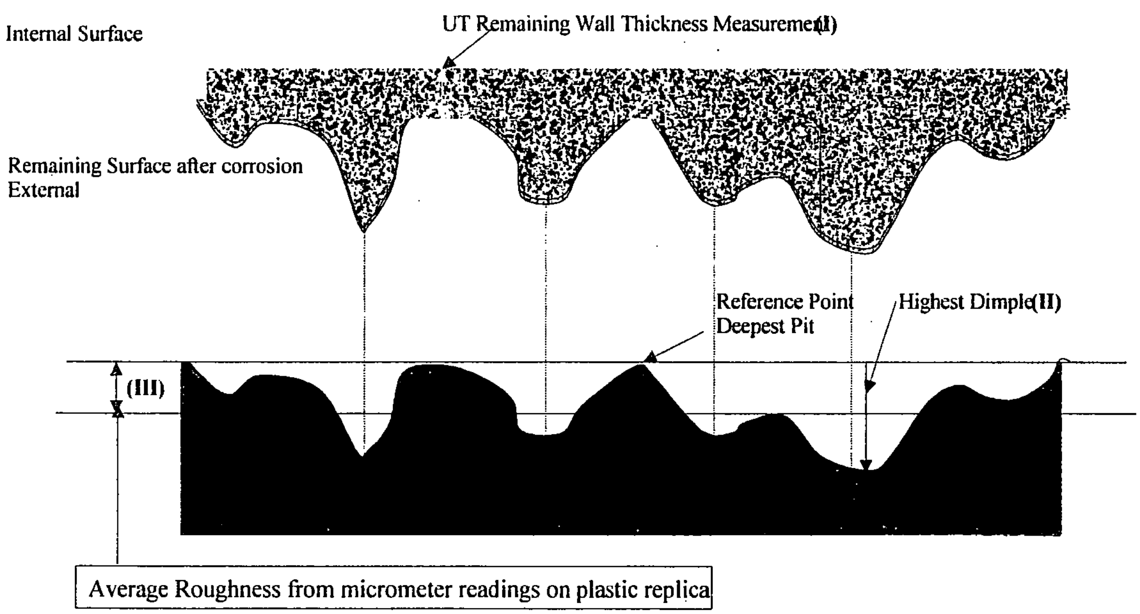
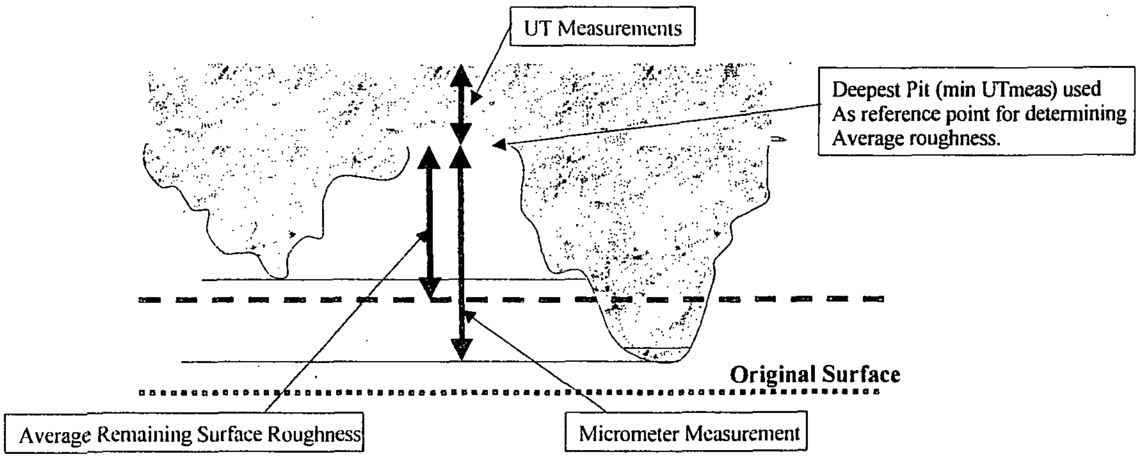


Figure 5

Schematic Presentation of Drywell External Surface – State of Corrosion



Evaluation Thickness = UT Measurement + Micrometer Measurement – Average Surface Roughness