APPLICANT'S EXH. C

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:
E. Roy Hawkens, Chair
Dr. Paul B. Abramson
Dr. Anthony J. Baratta

In the Matter of:	)	August 17, 2007
AmerGen Energy Company, LLC	)	
(License Renewal for Oyster Creek Nuclear Generating Station)	)	Docket No. 50-219

AMERGEN'S PRE-FILED REBUTTAL TESTIMONY PART 1 INTRODUCTION, DRYWELL PHYSICAL STRUCTURE, HISTORY, AND COMMITMENTS

I. WITNESS BACKGROUND

Q. 1: Please state your names and current titles. The Board knows that a description of your current responsibilities, background and professional experience was provided in Part 1 of AmerGen's Pre-Filed Direct Testimony on July 20, 2007, so there is no need for you to repeat that information here.

A. 1: (JFO) My name is John F. O'Rourke. I am a Senior Project Manager, License Renewal, for Exelon, AmerGen Energy Company, LLC's ("AmerGen") parent company.

(FWP) My name is Frederick W. Polaski. I am the Manager of License

Renewal for Exelon.

(MPG) My name is Michael P. Gallagher, and I am the Vice President for License Renewal for Exelon.

Q. 2: Would you please summarize the purpose of this Rebuttal Testimony?

A. 2: (All) The purpose is to respond to the Pre-Filed Direct Testimony of Dr. Rudolf Hausler (A.16) that discusses the "industry standard" for "monitoring intervals" of potentially corroding components. In summary, the applicable ASME Code requirements authorize AmerGen to use engineering evaluations to determine the inspection frequency. Those evaluations are specific to the component being evaluated and the conditions/environment to which it is exposed. In other words, inspection frequency is determined under the ASME code on a case-by-case basis. That is the industry standard.

II. COMPLIANCE WITH THE ASME CODE IS THE INDUSTRY STANDARD

Q. 3: Dr. Hausler has stated, in Answer 16 of his Direct Testimony, that,

> The margin AmerGen has claimed to have is 0.064 inches . . . . *The industry standard is to measure at half the interval in which it is possible to have lost margin.* Given a total corrosion rate of 0.041 inches per year, a margin of 0.034 inches could be lost in less than a year. Thus, the monitoring interval would have to be more than once every six months.

Do you agree with Dr. Hausler's statement about the "industry standard"?

A. 3: (All) No. Dr. Hausler's statement is incorrect as applied to the drywell shell. Under 10 C.F.R. § 50.55a, the drywell shell is governed by ASME Code, Section XI, Subsection IWE-3512.3, which requires the following:

> Containment vessel examinations that reveal material loss exceeding 10% of the nominal containment wall thickness . . . shall be documented. Such areas shall be accepted by engineering evaluation or corrected by repair or replacement . . . . Supplemental examinations . . . shall be performed when specified as a result of the engineering evaluation.

AmerGen's regulatory commitments in its Primary Containment Inspection Program comply with these ASME Code requirements because, if sand bed region UT thickness examinations reveal statistically-significant deviations from previous results, then AmerGen will conduct an engineering evaluation to assess the extent of condition and to determine if additional inspections are required to assure drywell integrity. In other words, the engineering evaluation determines whether the inspection frequency is adequate, or if it needs to be accelerated. For example, following AmerGen's engineering evaluation of the 2006 external data, AmerGen further enhanced its ASME Section XI, Subsection IWE Program to require UT measurements of the locally thinned areas in 2008 and periodically throughout the period of extended operation. (Applicant's Exhibit 3, p. 6-18).

Q. 4: Does this conclude your testimony?

A. 4: (All) Yes.

In accordance with 28 U.S.C. § 1746, I state under penalty of perjury that the foregoing is true and correct:

John F. O'Rourke	8-15-2007
John F. O'Rourke	Date
	8/15/2007
Frederick W. Polaski	Date
Michael P. Gallagher	8-15-2007
Michael P. Gallagher	Date

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AMERGEN'S PRE-FILED REBUTTAL TESTIMONY PART 2 ACCEPTANCE CRITERIA

I. WITNESS BACKGROUND

Q. 1: Please state your names and current titles. The Board knows that a description of your current responsibilities, background and professional experience was provided in Parts 1 and 2 of AmerGen's Pre-Filed Direct Testimony on July 20, 2007, so there is no need for you to repeat that information here.

A. 1: (MPG) My name is Michael P. Gallagher, and I am Vice President of License Renewal for Exelon.

(AO) My name is Ahmed Ouaou, and I am a registered Professional Engineer specializing in civil structural design. I am an independent contractor.

(HM) My name is Dr. Hardayal S. Mehta, and I am a Chief Consulting Engineer-Mechanics with GE-Hitachi Nuclear Energy Co. My résumé is attached as Applicant's Exhibit 36.

Q. 2: Would you please summarize the purpose of your testimony?

A. 2: (All) The purpose of our testimony is to respond to Question 12 of the Atomic Safety and Licensing Board's ("Board") Memorandum and Order of August 9, 2007. We are not responding to Citizens' Direct Testimony because we believe AmerGen's Direct Testimony addresses Citizens' misconceptions about the acceptance criteria.

II. RESPONSE TO QUESTION 12

Q. 3: In Question 12 of its Order, the Board states:

> It is the Board's understanding that the original GE analysis of the response of the drywell shell to loads that might lead to buckling failure employed a model that broke the shell into elements of certain discrete sizes and shapes over which physical properties (such as shell thickness) are averaged.

Is the Board's understanding correct?

A. 3: (All) Yes, with the exception that the shell thickness was not averaged over each element. Rather, a uniform thickness of 0.736" was assumed and the analysis was performed using this assumed uniform thickness. GE used a finite element model that modeled one 36 degree, pie-slice of the entire vertical length (*i.e.*, height) of the drywell shell. The pie-slice is representative because the drywell shell and sand bed are symmetrical with respect to the 10 torus vent lines. A discussion of GE's modeling is in Applicant's Exhibit 3, beginning on page 6-7.

Q. 4: Question 12 includes five discrete parts. Part A asks the parties to describe the sizes and shapes of the elements used in the GE analysis. Please provide this information.

A. 4: (All) The elements used to confirm the stability of the drywell in the sand bed region are 3" x 3" in size and quadrilateral in shape, with a uniform thickness of 0.736" for the entire sand bed region model. The other element properties, such as yield strength, density, Poisson's ratio, and modulus of elasticity, are as specified in ASME Code for the drywell material of construction, SA-212 grade B carbon steel plate.

GE's sensitivity analyses included the 3" x 3" quadrilateral elements in modeling a local area of 12" x 12" having an assumed thickness of 0.536" with a transition to the uniform thickness of 0.736" on all sides as shown on Applicants' Exhibit 11. GE modeled this 12" x 12" area in the location of the highest buckling stress, which is midway between the torus vent lines.

Q. 5: Part B asks the parties to "indicate whether the average properties used in any of those elements would be different if the corrosion pattern had been as described by the contour plots proposed by Dr. Hausler (see Hausler Direct Testimony, Att. 4), and if so, the magnitude of those differences." Please provide this information.

A. 5: (All) No. The average properties such as element size and material properties, as described above, would not be different. The only difference would be thickness of the element because GE conservatively modeled the shell with a uniform thickness of 0.736" in the sand bed region.

Q. 6: Part C asks the parties to "indicate the source and sizes of the conservatisms built into the original properties used for those elements and whether any of those conservatisms would be reduced if the elements' properties were computed based on the pattern of corrosion indicated by the contour plots rather than those used by AmerGen." Please provide this information.

A. 6: (All) We used 0.736" for each element. Accordingly, the conservatism "built into the original properties used for those elements" is the use of the conservative value of 0.736" because it was known from UT thickness measurements that the shell was on average significantly thicker than 0.736". This conservatism would not be reduced by Dr. Hausler's modeling which, for reasons demonstrated in Part 3 of AmerGen's Rebuttal testimony, is based on an inappropriate statistical treatment of the external UT data.

There are other sources of conservatism for the modeling on a whole. First, the Torus vent pipes, which are present in each Bay, and the reinforcing plates for their penetrations, stiffen the shell. This results in a stress reduction of the shell in their influence zone which would allow uniform and local shell thickness to be below the values modeled by GE and still satisfy ASME requirements. The areas of most significant corrosion are beneath or near the torus vent pipes.

The second area of conservatism is that the local buckling criterion assumes that the rest of the drywell shell in the sand bed region has a uniform thickness of 0.736". This is because the local buckling criterion was derived through sensitivity analyses using the 0.736" uniform thickness modeling. Thus, an area could thin to 0.536" (as shown in Applicants' Exhibit 11) and still meet the ASME code so long as the remainder of the shell was uniformly thicker than 0.736".

The third area of conservatism is driven by the ASME Code itself, and is related to how the allowable buckling stress is calculated. The theoretical elastic instability stress, based on the grade of the plate material used for the OCNGS drywell is 46,590 psi; but the ASME Code allowable buckling stress is 15,180 psi. The reduction is required by the Code to account for potential geometric imperfections and non-linear material behavior. In addition, the Code requires a factor of safety of 2 for the controlling load combination (refueling).

Q. 7: Part D asks, "If the elements' properties would be affected by the contour of corrosion as depicted by the contour plots, assuming the contour plots presented by Dr Hausler are accurate (and if they are not, so state), how should the existing buckling failure criteria be applied to the indicated extent of sub-threshold area in those bays?" Please answer this question.

A. 7: (All) The contour plots presented by Dr Hausler are not accurate. The contours generated by Dr. Hausler show drywell shell thinning that has not been observed or measured by AmerGen. In addition, there will be no change on how the existing criteria are applied. The general buckling criterion remains valid and will be compared to the average thickness calculated based on internal grid UT measurements. The local buckling criterion will be used to evaluate local thinning.

Q. 8: Part E asks "Because Oyster Creek's current licensing basis (CLB) is based on the GE methodology and explicit elementization of the model for the drywell shell (see Licensing Board Memorandum and Order (Denying Citizens' Motion for Leave to Add a Contention) at 3 n.6 (Apr. 10, 2007) (unpublished)), discuss whether consideration of a different modeling or elementization would constitute, under NRC regulations, a challenge to the CLB." Please answer this question?

A. 8: (All) Yes, the use of different modeling would constitute, under NRC regulations, a challenge to the CLB. The GE analysis is the basis for acceptance of the drywell shell under the CLB. Any new analysis that alters the acceptance criteria, if adopted by AmerGen, will constitute a change to the CLB and require NRC approval.

Q. 9: Does this conclude your testimony?

A. 9: (All) Yes.

In accordance with 28 U.S.C. § 1746, I state under penalty of perjury that the foregoing is true and correct:

Michael P. Gallagher — 08-16-07

Michael P. Gallagher — Date

Ahmed Ouaou — 08-16-07

Ahmed Ouaou — Date

Dr. Hardayal S. Mehta — Date

In accordance with 28 U.S.C. § 1746, I state under penalty of perjury that the foregoing is true and correct:

______________________________ ______________
Michael P. Gallagher Date

______________________________ ______________
Ahmed Ouaou Date

______________________________ Aug. 16, 2007
Dr. Hardayal S. Mehta Date

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NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:
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AmerGen Energy Company, LLC	)	
	)	Docket No. 50-219
(License Renewal for Oyster Creek Nuclear Generating Station)	)	

AMERGEN'S PRE-FILED REBUTTAL TESTIMONY
PART 3
AVAILABLE MARGIN

I. WITNESS BACKGROUND AND CONCLUSIONS

Q. 1: Please provide the Licensing Board with your names and current titles. The Board knows that a description of your current responsibilities, background and professional experience was provided in Parts 1, 2 and 3 of AmerGen's Pre-Filed Direct Testimony on July 20, 2007, so there is no need for you to repeat that information here.

A. 1: (FWP) My name is Frederick W. Polaski. I am the Manager of License Renewal for Exelon.

(DGH) My name is Dr. David Gary Harlow. I am a Professor in the Mechanical Engineering and Mechanics Department at Lehigh University located in Bethlehem, Pennsylvania.

(JA) My name is Julien Abramovici. I am a consultant with Enercon Services, Inc. located in Mt. Arlington, New Jersey, but formerly worked for the Oyster Creek Nuclear Generating Station ("OCNGS").

(PT) My name is Peter Tamburro. I am a Senior Mechanical Engineer in the OCNGS Engineering Department.

(MEM) My name is Martin E. McAllister. I am an American Society of Mechanical Engineers ("ASME") Non-Destructive Examination ("NDE") Level III Inspector at Oyster Creek Nuclear Generating Station ("OCNGS").

Q. 2: Please summarize the purpose of your testimony and overall conclusions.

A. 2: (All) The purpose of our testimony is to respond to the Pre-Filed Direct Testimony of Dr. Rudolf Hausler that discusses available margin and statistical treatment of the ultrasonic testing ("UT") data taken from the drywell shell in the sand bed region. Our overall conclusions, as stated below, are that Dr. Hausler's statistical treatment of the UT data is inappropriate and that Citizens are using the wrong acceptance criteria for buckling.

<u>Internal UT Data Conclusions.</u> For the internal UT grid data – upon which AmerGen determines available margin – Dr. Hausler inexplicably ignores the averages of the data. For example, the average of the 49 UT measurements from grid 19A was 0.800" in 1992. Therefore, 0.800" is deemed to be representative of that 6" x 6" grid. Dr. Hausler, however, throughout his testimony focuses on the

lowest values from the 49 points and inexplicably assumes that those values are representative of the grid. There is no valid scientific support for this approach, which ignores reality. We believe that Dr. Hausler applies a type of "extreme value" statistics which is improper here because he uses extreme value statistics to look at the thinnest single points, whereas buckling is not a phenomenon that is dependent on very local thickness, but instead on the average thickness over a larger area. Thus, the averages of these data, not the thinnest extremes, are representative of each grid.

Dr. Hausler also argues that the internal grid data are not representative of the condition of the drywell shell in the sand bed region, and that the external single-point UT data should be used instead. (Citizens' Exhibit 12, at 3-4.) Dr. Hausler's argument is based on a comparison of internal, external, and trench UT data from Bay 17. (Citizens' Exhibit 12, at 3-4.) Whether on purpose or by error, his underlying calculation ignores an entire grid of 49 UT data points from Bay 17. (Citizens' Exhibit 12, at 3-4.) Dr. Hausler's argument falls apart when those data points are included. In other words, the internal UT data are indeed representative of the condition of the drywell shell in the sand bed region.

<u>External UT Data Conclusions.</u> Dr. Hausler also inappropriately statistically treats the external UT data. These data cannot represent the thickness of the drywell shell. First, there are too few of them for the points to be statistically representative of the shell as a whole. Second, they are biased toward the thin side (*i.e.*, they historically were selected as the thinnest locations). Dr. Hausler, however, ignores the limited number of data points and performs his

calculations and computer "contouring" assuming that these external locations were selected at random and, thus, are representative of the condition of the drywell shell in the sand bed region. (Citizens' Exhibit 13, at 5-6, 9-11.)

Finally, Dr. Hausler relies upon an incorrect local buckling criterion. (Citizens' Exhibit 13, at 11-12.) He then improperly applies that criterion and the general buckling criterion to the single-point UT data collected from the exterior surface of the drywell shell to erroneously conclude that the drywell shell thickness currently is not in compliance with the ASME code.

Q. 3: What is your ultimate conclusion?

A. 3: (All) The bounding remaining available margin of the OCNGS drywell shell in the sand bed region for the period of extended operation remains 0.064".

II. BACKGROUND NEEDED TO UNDERSTAND CITIZENS' STATISTICAL ARGUMENTS

Q. 4: Please define the terms (a) "population mean," (b) population variance," (c) "sample mean," and (d) "sample variance" as used in the presented statistical analyses [Board Question 1].

A. 4: (DGH, JA, PT) In order to understand "population mean," you must first understand the term "population." "Population" is the set of all possible outcomes. In the case of the thickness of the drywell shell in the sand bed region, the "population" is a range that could be zero—if there was a hole in the shell—up to approximately 1.154", which is the nominal designed thickness.

(a) For the drywell shell thickness, the "population mean" can only be estimated, not actually measured. The more precise answer is that "population mean," which is symbolized by "μ", is the expected value for the population being considered. For random variables defined on real numbers, the technical definition is as follows:

$$\mu = \int_{-\infty}^{\infty} x f(x)\, dx,$$

where $f(x)$ is the probability density function that characterizes the randomness of the random variable. The "population mean" cannot be determined unless you know the probability of each of the values in the population.

(b) Variance is the amount of scatter that characterizes the randomness in the variable, for example, thickness of the drywell shell. The more precise answer is that "population variance," symbolized by "σ^2", is the expected value of the second moment about the population mean μ for the population being considered. For random variables defined on the real numbers, the technical definition is as follows:

$$\sigma^2 = \int_{-\infty}^{\infty} (x-\mu)^2 f(x)\, dx,$$

where $f(x)$ is the probability density function that characterizes the randomness of the random variable.

(c) "Sample" is the set of all observations, for example, UT measurements. The "sample mean," symbolized by "$\bar{x}$" or more appropriately the "sample average," is the arithmetical average of the physical measurements made from a population being considered. If the observations are $x_1, x_2, \ldots, x_n$, where n is the sample size or number of measurements, then the technical definition is as follows:

$$\bar{x} = \sum_{k=1}^{n} x_k / n.$$

This is analogous to measuring a limited amount of points over a 6" by 6" area (*i.e.*, 49 points), summing each measured value, and then dividing by the number of measurements that were taken. It is impossible to measure the thickness of the entire surface of the 6" by 6" area, or for that matter, the drywell shell, even by scanning the entire area. However, the more measurements that are taken, the better the sample average will approximate the population mean.

(d) The "sample variance," symbolized by "s^2" is the second arithmetical moment about the sample average $\bar{x}$ for the measurements from a population being considered. If the observations are $x_1, x_2, \ldots, x_n$, as above, where n is the sample size, then the technical definition is as follows:

$$s^2 = \sum_{k=1}^{n} (x_k - \bar{x})^2 / (n-1).$$

This is analogous to measuring a limited amount of points over a 6" by 6" inch area (*i.e.*, 49 points), summing the square of the difference between each measured value minus the sample average, and then dividing by the number of measurements minus one. As above, it is impossible to measure the thickness of the entire surface of the 6" by 6" area, or for that matter of the drywell shell. However, the more measurements that are taken, the better the sample variance will approximate the population variance.

If you knew the population mean and the population variance for the drywell shell thickness, no measurements would be needed. Because they are not known, however, measurements are needed to estimate them. It should also be noted that the "standard deviation" for either the population σ or sample s is the square root of the variance.

Q. 5: Where does the term "uncertainty" fit into all this?

A. 5: (DGH, JA, PT) "Uncertainty" refers to the level of assurance that a measurement is accurate. Uncertainty is caused by things that are typically outside of your control. For example, the UT technicians are competent and qualified but cannot locate the *exact* measurement location each time; the accuracy of the UT equipment is excellent but still not 100%; and different technicians take the measurements in very slightly different ways.

Q. 6: The Board has asked the following question regarding uncertainty: "The SER lists ten sources of systematic error (SER at 4-53 to 4-55), but AmerGen's direct testimony does not appear to discuss all ten sources (AmerGen's Prefiled Direct Testimony Part 3, Available Margin at 21-23). Estimates and explanations for the all ten sources should be provided, or, if they are insignificant, it should be so stated." Please respond to this question. [Board Question 7]

A. 6: (PT, FWP) We provide each of the ten sources of systematic error (*i.e.*, uncertainty) below, with a brief explanation as to their significance.

a) **UT Instrumentation Uncertainties.** The uncertainty for each UT measurement is approximately +/- 0.010". However, as described below, this uncertainty is not significant for the internal UT grid data once these data are averaged over multiple sampling events.

b) **Actual Drywell Surface Roughness and UT Probe Location Repeatability.** The uncertainty associated with this factor is not quantifiable. It is not significant for the internal UT grid data due to the use of a template that constrains the UT probe and because these data are averaged.

c) **Actual Drywell Surface Roughness and UT Probe Rotation.** The uncertainty associated with this factor is not considered significant because inspection procedures require that NDE personnel performing the UT inspection place the probe in the same orientation.

d) **Temperature Effects.** The uncertainty associated with this factor is not considered significant. Significant temperature differences between inspections may result in a shift in the material thickness. Therefore, the inspection procedure ER-AA-335-004 requires that NDE personnel performing the inspection record the surface temperature and verify that the temperature is within manufacturer tolerances. The procedure also requires that the calibration block be within 25°F of the surface which is being inspected.

e) **Batteries.** The uncertainty associated with this factor is not considered significant. The inspection procedure requires the technician to install new batteries prior to each series of inspections.

f) **NDE Technician.** The uncertainty associated with this factor is not considered significant. Inspection specifications require that personnel conducting UT examinations be qualified in accordance with Exelon Procedure ER-AA-335-004.

g) **Calibration Block.** The uncertainty associated with this factor is not considered significant. Exelon Procedure ER-AA-335-004 requires that the UT technician use only calibration blocks that meet applicable specifications.

h) **Internal Surface Cleanliness** – The uncertainty associated with this factor is not considered significant. The interior UT grid locations are protected by grease between UT inspections. The failure to remove grease from the interior drywell shell surface may have affected the internal UT data measurements collected during the 1996 refueling outage. The UT inspection protocol at that time did not specify the removal of the grease prior to performing UT measurements. Therefore it is possible that the requirement to remove the grease was not communicated to the contractor, and that the contractor who performed the 1996 inspection may have not removed the grease. Tests performed in April and May of 2006 show that the presence of the grease could increase the readings as much as 0.012".

i) **UT Unit Settings**. The uncertainty associated with this factor is not considered significant. It is possible that the ultrasonic unit can be set in a "high gain" setting which may bias the machine into including the external coating as part of the thickness. AmerGen used modern "state of the art" UT units that do not have gain settings during the 2006 refueling outage, and intends to use the same or similar equipment for future inspections.

j) **Identification of the Physical Inspection Location.** The uncertainty associated with this factor is not considered significant. This is not an issue for the internal UT grid locations which are marked on the drywell itself. However, the external UT locations are identified by the area that was prepared (*i.e.,* ground) to make them suitable for UT measurements. The exact location within that prepared area is identified on the UT data sheets by X and Y coordinates from known plate welds, but locating the exact point within the prepared area over the uneven drywell surface is difficult.

Q. 7: Please explain why the systematic error (*i.e.*, uncertainty) is not significant for the internal UT grid data after those data are averaged over multiple sampling events (*i.e.*, 1992, 1994, 1996 and 2006).

A. 7: (DGH, PT, JA) The short answer is that systematic error is negligible for sufficiently large numbers of measurements collected over time. So the more measurements you have, for example, 49 points within a 6" x 6" area, and the more times you collect those measurements, the less significant systematic error becomes.

The more precise answer is that "systematic error" may be considered to be part of the overall uncertainty encountered in measuring the drywell thickness. Although it is not taken into account directly, it is considered indirectly as follows. Let x_k be the thickness measurement at position k, and let ε_k be the error associated with that position. Since ε_k is difficult to quantitatively characterize, the common practice is to assume that it is a normal random variable with mean zero and variance σ^2, which is typically small because the measurement error is minimized by constantly improving the techniques for observations. Thus, the average should be written as

$$\bar{x} = \sum_{k=1}^{n} (x_k + \varepsilon_k) / n$$
$$= \sum_{k=1}^{n} x_k / n + \sum_{k=1}^{n} \varepsilon_k / n,$$

where the last sum is the cumulative error per measurement. The Law of Large Numbers in probability theory implies $\sum_{k=1}^{n} \varepsilon_k / n$ approaches zero as n increases. Thus, the effect of the systematic error is negligible for sufficiently large numbers of measurements. Furthermore, assuming that the errors ε_k, for all k, are statistically independent, then the variance of $\sum_{k=1}^{n} \varepsilon_k / n$ is σ^2/n, which also approaches zero as n increases.

Consequently, the overall effect of systematic error is assumed to be negligible.

Q. 8: Please explain the relationship between "population mean and sample mean" and "population variance and sample variance." [Board Question 2]

A. 8: (DGH, JA, PT) The population mean (μ) and population variance (σ^2) cannot be computed explicitly. They must be estimated, *i.e.*, expressed by a function of the observations $x_1, x_2, \ldots, x_n$ from the population. There are several ways to estimate μ and σ^2; however, the best estimates statistically are the sample average and the sample variance, respectively. In technical jargon,

$$\hat{\mu} = \bar{x} \text{ and } \hat{\sigma}^2 = s^2,$$

where the carat (^) indicates estimate.

Most of the statistical analysis in this discussion focuses on the normal distribution which is completely characterized by two parameters μ and σ^2 which are the mean and variance of the normal distribution. It can be proven, using maximum likelihood estimation, that the best estimates for μ and σ^2 are

$$\hat{\mu} = \bar{x} \text{ and } \hat{\sigma}^2 = (n-1)s^2 / n.$$

It should be noted that if n is sufficiently large, $(n - 1)/n$ is essentially one.

Therefore, for 49 points that are normally distributed, the sample variance is essentially the best estimate for the population variance.

The confidence interval, defined below, for the population mean is a measure of how well the sample average estimates the population mean.

Q. 9: Please define "confidence" as used in the 41 Calc. [Board Question 3]

A. 9: (DGH, JA, PT) "Confidence," symbolized by "$(1 - \alpha)$" is the degree of assurance that a particular statistical statement is correct under specified conditions. The confidence in the data used for the statistical analyses in the 41 Calc is 0.95. However, as stated in A.10 and A.13 below, there is a difference between confidence in the data and a "confidence interval."

Q. 10: Please discuss "confidence interval" and how the interval relates to the sample and population and means and variances. [Board Question 4]

A. 10: (DGH, JA, PT) First, we note that the term "confidence interval" implies that you can statistically treat the data. If the data cannot be statistically treated—such as the external UT data from the drywell shell in the sand bed region—then you cannot determine a confidence interval for that data.

A confidence interval bounds an unknown parameter, such as the population mean μ, so that its probability is the desired level of confidence, $1 - \alpha$. Assuming a normal distribution, the interval is estimated by including the uncertainty and variability in the data. The more uncertainty and variability in the data, the greater is the range of the confidence interval for the parameter.

The technical answer to the question is as follows: Let $f(x; \theta)$ be the probability density function for a population where θ is a parameter in the density function which is unknown. In order to estimate θ observations $x_1, x_2, \ldots, x_n$ must be collected from the population. The statistics L and U, *i.e.*, functions of the samples $x_1, x_2, \ldots, x_n$, determine the $100(1 - \alpha)\%$ confidence interval (L, U) for the parameter θ, if $\Pr\{L \leq \theta \leq U\} \geq 1 - \alpha$. In order to compute the probability $\Pr\{L \leq \theta \leq U\}$ which defines the confidence interval, the probability density for the parameter θ must be known.

By far the usual assumption is that θ is well characterized by a normal distribution. It is for the normal distribution that formulae are given in textbooks for statistics. If any other distribution is operable for a parameter, then the standard textbook formulae are not applicable. Note that all of the internal UT grid data were normally distributed as analyzed in the 41 Calc.

Most often θ is to be taken as the mean μ. For the drywell statistics, this is the primary parameter for which a confidence interval is required. The first task was to establish that the data for drywell thickness were well characterized by a normal distribution for areas defined by the sampling grid. Furthermore, the Central Limit Theorem of probability theory indicates that the sample average can be characterized by a normal distribution for sufficiently large numbers of data. Thus, the confidence interval of concern is

$$\Pr\{L \leq \mu \leq U\} \geq 1 - \alpha.$$

Again, the population mean μ is not known. It is estimated by the sample average $\bar{x}$. Furthermore, the population variance σ^2 is unknown, and an estimate for it is also needed. Under these conditions the interval estimate for μ is computed by the following statistic:

$$t = \frac{\bar{x} - \mu}{s / \sqrt{n}},$$

where the statistic t has the t-distribution with $n - 1$ degrees of freedom. Specific values for the t-distribution are contained in standard statistical tables. The confidence interval for the statistic t is

$$\Pr\{-t_\alpha \leq t \leq t_\alpha\} \geq 1 - \alpha,$$

where $\pm t_\alpha$ are the two-tail α values, for the upper U and lower L interval values. Substituting for t and doing straightforward algebraic manipulation leads to the confidence interval for population mean μ when the population standard deviation σ is unknown. Thus,

$$\Pr\{\bar{x} - \frac{s t_\alpha}{\sqrt{n}} \leq \mu \leq \bar{x} + \frac{s t_\alpha}{\sqrt{n}}\} \geq 1 - \alpha,$$

$$\text{and } L = \bar{x} - \frac{st_\alpha}{\sqrt{n}};\ U = \bar{x} + \frac{st_\alpha}{\sqrt{n}}.$$

Thus, L and U are the upper and lower confidence intervals.

Q. 11: What is a "standard deviation"?

A. 11: (DGH, JA, PT) A standard deviation is the square root of the variance. Confidence intervals for the mean μ for the normal distribution are determined as a multiple of the sample standard deviation. A standard deviation provides an estimate of the variability of readings within the measured UT grid. It does not provide a reasonable estimate of the uncertainty of the average of that grid, and it can not provide an estimate of the uncertainty or variability of the data outside the grid.

Q. 12: How does a 95% confidence interval relate to "standard deviation"?

A. 12: (DGH, JA, PT) Citizens refer to a 95% confidence interval for the mean μ (for example, in A.11). A 95% confidence interval is almost equal to two standard deviations divided by the square root of the sample size, *i.e.*, the standard error, defined below, higher and lower than the difference in the sample average and the population mean μ, assuming the data are normally distributed. We say *almost* equal, because 1.96 standard errors produce a 95% confidence interval; two standard errors produce a 95.5% confidence interval.

Q. 13: Is there a difference between a "confidence interval" and simply having "confidence" in the data?

A. 13: (DGH, JA, PT) Yes. For example, there is a difference between a 95% confidence interval for the population mean in UT data and the fact that 95% of a particular UT grid's data, when normally distributed, falls within +/- two standard deviations of the average. The latter 95% value is not a confidence interval and has nothing to do with statistical confidence interval estimation for the mean.

Q. 14: What is the student's "t distribution" and what is its significance relative to estimation of the mean thickness? [Board Question 5]

A. 14: (DGH, JA, PT) The significance is that this method is necessary if you are trying to calculate the confidence interval, and if you do not know the population variance (which we do not), you must use the "t test" to compute the confidence interval for the mean. The "student t-distribution" or simply "t-distribution" is the distribution function for the random variable $t = \dfrac{\bar{x} - \mu}{s / \sqrt{n}}$. It is used primarily for interval estimation of the population mean μ when the data are normally distributed and when the population variance σ^2 is unknown.

Specifically, for the drywell thickness the confidence is 0.95, and the degrees of freedom depend on the sample size. The most frequent sample sizes used in the analyses are grids of 49 and 7 points, so that the corresponding degrees of freedom are 48 and 6, respectively. The values of t_α for these cases are 2.010 and 2.447, respectively.

To illustrate this computation, let $\bar{x} = 800$ mils, $s = 62.4$ mils, for 49 observations, then

$$\Pr\{\bar{x} - \frac{st_\alpha}{\sqrt{n}} \le \mu \le \bar{x} + \frac{st_\alpha}{\sqrt{n}}\} \ge 1 - \alpha$$

$$\Pr\{800mils - \frac{(62.4mils)(2.010)}{\sqrt{49}} \le \mu \le 800mils + \frac{(62.4mils)(2.010)}{\sqrt{49}}\} \ge 1 - 0.05$$

$$\Pr\{781.3mils \le \mu \le 818.7mils\} \ge 0.95.$$

Even though the population variance σ^2 is unknown, often investigators will use the two-tail α values z_α from the normal distribution, which are not dependent on sample size. For α equal to 0.05, z_α is 1.96. For practical purposes using a value of 2 is adequate except for small sample sizes where the degrees of freedom have a significant impact on the estimation of the confidence interval.

Q. 15: Is there a more reasonable estimate of the uncertainty of the average of the UT grid data than the standard deviation?

A. 15: (DGH, JA, PT) Yes. A more reasonable estimate (than standard deviation) of the variability of the average of the UT grid data is the "standard error." Assuming a normal distribution, the standard error estimates the variability of the average thickness by accounting for the standard deviation of the distribution *and* the number of samples. The standard error is calculated by dividing the standard deviation by the square root of the number of data points. Thus, the more data you have, the less the variability and the lower the standard error.

Q. 16: Can you provide an example?

A. 16: (DGH, JA, PT) Yes. An understanding of the UT grid averages over time can be developed by reviewing the standard error after the 1992 outage, when corrosion was arrested. At the bounding grid (19A), the 1992, 1994, 1996 and 2006 refueling outage averages (and standard errors) were 0.800" (0.0084"), 0.806"

(0.0099"), 0.815" (0.0096"), and 0.806" (0.0086"), respectively. This illustrates that the average thickness of this 6" by 6" grid has varied between 0.800" and 0.815" in four inspections over about 15 years, and the standard error has varied between 0.0084" and 0.0096".

But you can refine the sample variability even further, assuming no corrosion, through the standard error. AmerGen calculated the sample variability of the average of the data from this grid (through the standard error) over the four sampling events to achieve about +/- 0.005". (Applicant's Exhibit 25)

Q. 17: The Board requested that we provide a table of the location, mean thickness (by date), and the 95% confidence interval of the internal UT grid data. [Board Question 9]

A. 17: (PT, FWP) That table is provided as Applicant's Exhibit 25. Note, however, that AmerGen estimates the 95% confidence interval only for the internal UT grid data, and does so only for the 2006 data because the previous calculations (for 1992, 1994 and 1996) did not include these intervals.

Moreover, as explained above, the 95% confidence interval for each sampling event is not the best estimate of the uncertainty in the data. That is captured by the standard error, which is an estimate of the uncertainty corrected for multiple sampling events (referred to in the Table as the "Grand Standard Error"). Accordingly, AmerGen is also supplying the Grand Standard Error for each grid as calculated using the data from the 1992 through the 2006 refueling outages.

Q. 18: What is the "F statistic" used in the regression model of corrosion and its significance to the corrosion data? [Board Question 6]

A. 18: (DGH, JA, PT) The primary use of the "F statistic" is to test the ratios of two sample variances when it is reasonable to assume that (a) the population variances are equal and (b) the data are normally distributed. Specifically, the F statistic is

$$F = s_1^2 / s_2^2,$$

where s_1 and s_2 are sample standard deviations from the two samples with sample sizes of n_1 and n_2, respectively. Note that there are two degrees of freedom, one for each sample size. The specific values for the F distribution are found in standard statistical tables.

The application of the F test for the drywell is to determine if the variances from two samples of thickness measurements are equal.

Q. 19: Does AmerGen use the "F test," and if so, for what purposes?

A. 19: (PT, DGH, JA) AmerGen has only used the "F test" to evaluate potential corrosion rates. In the 41 Calc., AmerGen used the "F test" in an attempt to identify a corrosion rate. The data, however, failed that test because there were too few inspections (*i.e.*, only 1992, 1994, 1996, and 2006) and the data variability was too large.

Therefore, AmerGen modeled what corrosion rate would be required to pass the "F test" with the existing limited data and large variability. Based on these results, as stated in Applicant's Exhibit 3, page 6-17:

> AmerGen cannot statistically confirm that the sandbed region has a corrosion rate of zero. This is because of the high variance in UT data within each 49-point grid (standard within a range of

deviation 60 to 100 mils), the relatively limited number of data sets that have been taken and the time frame over which data has been collected since the sand was removed in 1992. The high variance in UT data within the grids is a result of the drywell exterior surface roughness caused by corrosion that occurred prior to 1992. However, AmerGen continues to believe that corrosion of the exterior surface of the drywell shell in the sandbed region has been arrested as evidenced by little change in the mean thickness of the 19 monitored (grid) locations and the observed good condition of the epoxy coating during the 2006 inspection.

Q. 20: Explain how systematic error is accounted for in estimating the thickness and corrosion rate. [Board Question 8]

A. 20: (DGH, JA, PT) Systematic error is not accounted for in estimating the thickness of the UT data for the reasons described above in Answer 7. Systematic error equals uncertainty. The ten sources of uncertainty were provided in Answer 6.

Q. 21: Please describe in detail how the term "reasonable assurance" has been defined and applied in the instant case. [Board Question 11]

A. 21: (All) AmerGen has demonstrated reasonable assurance through its aging management program for the drywell shell as a whole. For the UT inspection component of that program, AmerGen has demonstrated that: (a) the average, as an estimate of the mean, of the normally distributed UT data from each internal grid, is thicker than the general buckling criterion, (b) no grouping of external UT data points exceed the local buckling criterion, and (c) no single UT reading from either inside or outside the drywell shell exceeds the pressure criterion. AmerGen does not need to meet its burden to demonstrate reasonable assurance under 10 C.F.R. § 54.29(a) with 95% confidence.

ASME Code, Section XI, Subsection IWE, provides rules for inspection and evaluation of the drywell shell. The Code requires that UT measurements be taken in grids established by the Owner. There is no requirement that the data be evaluated using 95% confidence. The current approach was reviewed by the NRC Staff. The methodology is appropriate for UT data evaluation and is part of the current licensing basis.

Having said that, AmerGen has calculated the 95% confidence interval for the data collected from the internal UT grids in 2006. These intervals are presented in Applicant's Exhibit 25, in response to Board Question 9.

Q. 22: On page 28 of their Initial Statement, Citizens have interpreted the Board's July 11, 2007, Order as requiring AmerGen to demonstrate that "it currently has margin with 95% confidence." Dr. Hausler says the same thing in A.11. Alternatively, Citizens believe they can prevail "either by showing that at 5% confidence the drywell thickness is already below the established acceptance criteria, or that the thickness could go beyond any established margin within four years." Are Citizens correct?

A. 22: (DGH, JA, PT) Citizens are not correct. First, Citizens appear to be confused about what a confidence interval really does. The confidence interval does not provide any information about failure of a component, or compliance with a Code or regulation. Second, Citizens appear to be arguing that AmerGen is required to show that that it has 95% confidence that the drywell shell thickness meets acceptance criteria. (See A.11 "there is less than 95% confidence that the drywell shell currently meets the area acceptance criteria and other acceptance criteria.")

This is inappropriate. AmerGen is primarily interested in the data within a grid which are between ± two sigma about the sample average because this region accounts for 95% of normally distributed data. If there is relatively little scatter in these data, which has been demonstrated elsewhere, so that they are also reasonably close to the sample average, then the sample *average* is the quantity that should be used in comparison to the general buckling criterion. The 5% of the data outside ± two sigma about the sample average pose no threat to buckling; however, these data are considered relative to the pressure criterion.

Q. 23: Is there anything else you would like to add about these statistical issues?

A. 23: (All) Yes. AmerGen's statistical evaluations have been internally and externally reviewed by qualified people, in accordance with objective industry standards. The 41 Calc., for example, was reviewed internally by another senior mechanical engineer, and reviewed externally by consultants. This level of review provides a greater degree of certainty that the data are treated appropriately. Dr. Hausler's statistical treatment of the data does not appear to have been subject to any review, either internal or external, until now. And the many problems we will discuss later in this testimony demonstrate that Dr. Hausler has not treated the data appropriately.

III. DR. HAUSLER USES THE WRONG DATA AND THE WRONG METHODS TO EVALUATE THE INTERNAL UT GRID MEASUREMENTS

Q. 24: Citizens conclude that 0.064" is not the bounding available margin for the OCNGS drywell shell in the sand bed region. How do they arrive at that conclusion?

A. 24: (All) They appear to rely solely upon the opinion of Dr. Hausler, and Dr. Hausler reaches that conclusion only by manipulating the internal and external UT data in a manner that is not statistically appropriate. He also makes some mathematical errors.

Q. 25: Please explain how Dr. Hausler manipulates the data, and why his approach is inappropriate.

A. 25: (All) We will discuss the internal UT grid data first. In order to understand how Dr. Hausler manipulates the data, some background discussion is required. As we previously discussed in Part 3, Answer 12 of AmerGen's Direct Testimony, the internal UT data are collected from nineteen "grids" located throughout all ten drywell bays. Twelve of these grids are six inches square, each consisting of a total of forty-nine individual UT thickness measurement points. The remaining seven grids are rectangular—one inch by seven inches—consisting of a total of seven individual UT points.

As discussed in Part 3, Answer 24, the normally-distributed data from these grids are averaged and compared to the general buckling criterion of 0.736". As discussed in Part 3, Answer 31, the bounding margin of the drywell shell in the sand bed region of 0.064" is based on a 49-point grid in Bay 19 (19A), which had a general average thickness in 1992 of 0.800".

For the internal UT grid data – upon which AmerGen determines available margin – Dr. Hausler inexplicably ignores the averages of the data.

Q. 26: Can you provide some examples?

A. 26: (All) Yes. The average of the 49 UT measurements from grid 19A in 1992 was 0.800." The averages from this UT grid have varied little over time: 0.800" (1992), 0.806" (1994), 0.815" (1996) and 0.807" (2006). As part of the license renewal review process, AmerGen conservatively reported the smallest of these four values (0.800") to the Advisory Committee on Reactor Safeguards (ACRS) to document the minimum available margin in the sand bed region (*i.e.*, 0.800" - 0.736" = 0.064"). (Applicants' Exhibit 3, page 6-2)

Q. 27: Do Citizens agree?

A. 27: (All) No. Citizens claim that the remaining margin for buckling should not be 0.064" but rather 0.034". (Dr. Hausler Answer 16; Citizens Initial Statement at 2). They claim that AmerGen must subtract 0.030" from the measured average of 0.800" in grid 19A (0.064" – 0.030" = 0.034") in order for the average to be compared to the general buckling criterion (*i.e.*, 0.736"). Citizens derive the 0.034" value from an AmerGen response to an NRC Information Request in which AmerGen agreed to take action if the future average of any of the internal grid data collected during an outage was +/- 0.021" different than previous readings. (See Citizens' Direct Answer 16; Citizens' Initial Statement at 11 citing Ex. 10 at 2 and SER at 3-121). This 0.021" value was based on the standard deviation of internal UT data of 0.011" plus uncertainty associated with instrument accuracy of 0.010".

But Citizens believe this value is too low. They claim that 0.011" is based on only one standard deviation and that AmerGen is required to achieve two standard deviations (which, as explained above approximately equals 95% of the distribution for normally distributed data). Citizens conclude that the uncertainty should be approximately 0.030". Dr. Hausler's testimony does not show how he derived that value. We can only assume that Citizens derived this uncertainty as follows, (which would be the proper way to derive the uncertainty): assuming that the randomness in thickness and the measurement error are independent, then the overall standard deviation is $\sqrt{(0.011in)^2 + (0.01in)^2} = 0.0149in$. Two standard deviations would be 0.0297", which Citizens appear to have rounded up to 0.030". To determine the lower limit of the 95% interval for the data, they argue that AmerGen must subtract 0.030" from the available margin of 0.064", thus concluding that only 0.034" remain.

Q. 28: What are your concerns with how Dr. Hausler manipulated these data?

A. 28: (All) There are several problems with Dr. Hausler's manipulation of the data. First, Citizens miss the point of AmerGen's response to the NRC. AmerGen was identifying an action limit. If AmerGen had selected two standard deviations as Citizens suggest, then it would not take action until the difference in the average of data was approximately +/- 0.030". For an action limit, however, it is appropriate and conservative to assume only one standard deviation. Again, Citizens demonstrate that they do not understand basic information relevant to AmerGen's Aging Management Program.

Second, the actual standard error for grid 19A over time is about 0.005", not 0.030". The standard error for the grid 19A data is about 0.010" *each time* this 49-point grid was measured. (Applicant's Exhibit 25.) But AmerGen has four data sets to work with. If we assume no corrosion, then we can combine the four data sets for 1992, 1994, 1996 and 2006, which results in a standard error of about 0.005". Accordingly, the variability in the grid 19A data is an order of magnitude lower than cited by the Citizens (*i.e.*, 0.005" vs. 0.030"). That is no surprise, since the uncertainty that Citizens cite was taken out of context in the first place.

Q. 29: Doesn't Citizens' method ignore thicker metal that AmerGen has actually measured?

A. 29: (All) Yes. Subtracting 0.030" from the calculated grid average thickness ignores data. For example, the bounding grid (19A) had an average thickness of 0.800" in 1992. If you subtract 0.030" and conclude that the average is 0.770", then review of the 1992 data (41 Calc., Appendix 10, page 6) shows that Dr. Harlow ignores 32 of the 45 UT valid readings from that grid (because 32 were greater than 0.770"). (Four of the readings in 19A are located over a newer metal plug and are not considered valid for calculating the grid average).

The best confidence for the thickness is from the internal UT data. More specifically, it is the repetitive and consistent results for the internal grids in 1992, 1994, 1996 and 2006, and the known standard error which is an order of magnitude lower than that irresponsibly identified by Citizens.

Finally, the ASME Code and acceptance criteria do not require AmerGen to bound the condition of the drywell shell with 95% confidence. AmerGen has to determine a reasonable and conservative measure of the drywell and compare it to the Code-based criteria. By assuming that the bounding available margin is uniformly 0.800" thick, AmerGen has demonstrated that it has developed a conservative measure of the actual condition.

Q. 30: Does AmerGen ignore the lowest readings?

A. 30: (All) No. Each single point within the grid was compared with the pressure criterion to assure that it surpassed that test.

Q. 31: Is there anything else you would like to add before we move on to the topic of whether the internal UT data are representative of the drywell shell?

A. 31: (DGH) Yes. On page 7 of his April 25, 2007 memorandum, Dr. Hausler states that "if an average of ten measurements over a specific area results in a thickness of 0.750 inches with a variability (standard deviation) for the average of 0.03 inches, the lower 95% confidence limit for this average would be 0.690 (0.75 – 0.06)." In other words, Dr. Hausler concludes that the 95% confidence interval would be +/- 0.060".

I have attempted to replicate this value and can only do so if, within basic statistical equations, I fail to divide the standard deviation by the square root of n = 10. If Dr. Hausler had calculated the statistical equation properly, then the 95% confidence interval for the difference between the sample average and the population mean would have been approximately +/- 0.019", not 0.060". This means that the confidence interval in Dr. Hausler's example is much tighter than Dr. Hausler states.

IV. THE INTERNAL UT DATA ARE REPRESENTATIVE OF THE BOUNDING DRYWELL SHELL CONDITION IN THE SAND BED REGION

Q. 32: Dr. Hausler spends much of his April 25, 2007 memorandum alleging that the internal grid data are not representative of the condition of the drywell shell in the sand bed region, and that the external single-point UT data should be used instead. He compares the trench, internal grid, and external point data from Bay 17 to support his allegation. What is your response to that allegation?

A. 32: (All) Whether on purpose or by error, Dr. Hausler's underlying calculations ignore an entire grid of 49 UT data points from Bay 17. Dr. Hausler's argument falls apart when those data points are included. In other words, Dr. Hausler reaches his conclusion by conveniently ignoring data that contradict his position. Moreover, it is the omitted data that AmerGen relies upon for purposes of calculating the available margin in Bay 17. Accordingly, Dr. Hausler's calculations do nothing to undermine the fact that the internal UT data are indeed representative of the bounding condition of the drywell shell in the sand bed region.

Dr. Hausler's conclusion on page 4 of his April 25, 2007 memorandum (Citizens' Exhibit 12) states that "only the trench measurements and outside measurements come close to represent [sic] the most severe corrosion at the highest elevations." Dr. Hausler also concludes that the internal data are not representative of the worst corrosion in the sand bed. (Citizens' Exhibit 12, at 3-4.) Dr. Hausler's conclusion is based on evaluation of the data as presented in figures 3 and 4 on pages 15 and 16 of his memorandum. The figures attempt to show the relationship between the internal Bay 17 thickness data, the external Bay 17 data points of which there were only 10 points, and the Bay 17 trench data. All of these data were collected during the 2006 refueling outage.

Q. 33: What are the data that Dr. Hausler ignored that contradict his position?

A. 33: (PT FP) AmerGen routinely monitors only two internal grids that are entirely within Bay 17: 17A and 17D. 17A had a 2006 average thickness of 1.015". 17D had a 2006 average thickness of 0.818". Dr. Hausler uses the data from the 17A grid, but ignores the data from 17D.

Q. 34: What grid from Bay 17 does AmerGen use for license renewal?

A. 34: (PT FP) Oyster Creek considers grid 17D—not 17A—as the representative thickness value of the worst corrosion for Bay 17, and has used the average from that grid for purposes of license renewal. For example, the following values have been reported to the NRC and the ACRS as part of the license renewal process for grid 17D: 1992 – 0.817", 1994 – 0.810", 1996 – 0.848", and 2006 – 0.818" (page 94 of the January 18, 2007 ACRS Presentation – Applicant's Exhibit 26. The 1994 value of 0.810" was used in the ACRS presentation to document 0.074" of margin in Bay 17 (page 95 of the January 18, 2007 ACRS Presentation). It is also shown in Applicant's Exhibit 3 at 6-2 & Table 18. That value was achieved by subtracting the 0.736" general buckling criterion from 0.810".

Therefore, using Dr. Hausler's methodology and grid 17D supports the conclusion that this internal grid is representative of the worst corrosion in Bay 17. This should not be a surprise since the internal grids were originally selected based on a much more extensive set of UT inspections in the mid 1980's which identified the thinnest areas.

Q. 35: Before we move on to discuss the external UT data, there is one other issue that Citizens raise regarding the uncertainty of the internal UT data. Citizens claim that AmerGen uses an uncertainty for the internal UT data of 0.020", and that AmerGen "subtracted 0.020 inches before it compared the mean to the acceptance criterion." (Citizens' Initial Statement at 13.) Citizens cite to AmerGen's Exhibit 19, page 8, for support. Does AmerGen subtract 0.020" from the mean/average of the internal UT grids before comparing the mean to the general buckling criterion?

A. 35: (PT, FP) No. The document that Citizens rely upon (Applicant's Exhibit 19.) is Technical Evaluation AR A2152754 E09, which documented AmerGen's *preliminary* evaluation of the UT data collected in 2006 from the *internal* surface of the drywell shell in the sand bed region. The purpose of that Technical Evaluation was not to support license renewal. Rather, the Technical Evaluation documented why there was adequate margin of the drywell shell in the sand bed region to operate until the next refueling cycle in 2008, to support exiting the 2006 refueling outage.

Q. 36: Is this Technical Evaluation conservative in nature?

A. 36: (PT, FP) Yes. The Technical Evaluation reviewed the internal UT grid data as well as data collected from the two internal trenches. It was a preliminary analysis because we had not at that time had the opportunity to perform statistical analyses of those data. AmerGen, therefore, used extremely conservative factors, including an uncertainty of +/- 0.020", for its preliminary evaluation. Systematic error (*i.e.*, uncertainty) is not accounted for in estimating the final thickness of the UT data for the reasons described above in Answer 7.

V. DR. HAUSLER USES THE WRONG DATA AND THE WRONG METHODS TO EVALUATE THE EXTERNAL UT GRID MEASUREMENTS

Q. 37: Does AmerGen statistically treat external UT data for purposes of demonstrating compliance with the acceptance criteria?

A. 37: (All) No. As we testified in Direct Part 3 Answer 27, AmerGen does not statistically treat the external UT data for purposes of demonstrating compliance with the acceptance criteria. Rather, the raw UT data are compared against the relevant acceptance criteria without any statistical treatment.

Q. 38: Why?

A. 38: (All) Because AmerGen does not use the external UT data points to determine margin. AmerGen only uses that data to demonstrate compliance with the ASME Code. As stated in Part 3, A.29, the single-point UT measurements can tell you that you meet the applicable ASME Code, but not by how much. This is the case because there are an insufficient number of UT measurements over large areas to evaluate a representative average thickness over each area. So Citizens are performing statistical analyses on the external UT data that AmerGen does not perform.

Q. 39: Citizens claim in their response to AmerGen's Motion in Limine, however, that external UT data have in the past been used to estimate available margin.

Citizens cite to Applicant's Exhibit 17, p. 7, which is the original 24 Calc performed in 1993. What is your response to this allegation?

A. 39: (PT, FWP, JA) Citizens are taking that discussion out of context. The top of page 7 confirms that the external UT locations inspection "focused on the thinnest areas of the drywell . . . [thus] the inspection did not attempt to define a shell thickness suitable for structural evaluation." You cannot calculate available margin from a buckling perspective using biased thin points. Second, the evaluation *assumed* a *uniform thickness* of 0.800" for purposes of evaluation against the general buckling criterion. As stated on page 8, however, "In reality, the remainder of the shell is much thicker than 0.800" inches." This external UT data provide useful information that can help you determine that you meet the applicable ASME Code, but they cannot tell you by how much.

Q. 40: Please explain how Dr. Hausler manipulates the external UT data, and why it is inappropriate to do so.

A. 40: (All) As we will demonstrate below, Dr. Hausler statistically treats the external UT data in an inappropriate manner. These data cannot represent the average thickness of the drywell shell because there are too few of them and they are biased toward the thin side (*i.e.*, they historically were selected as the thinnest locations). Dr. Hausler, however, ignores the limited number of external data points and performs his calculations and computer "contouring" assuming that these external locations were selected at random and, thus, are representative of the condition of the drywell shell in the sand bed region. This is an improper assumption which necessarily leads to inappropriate conclusions. (Note that Dr.

Hausler does not appear to account for the UT thickness measurements from internal grids that overlap his contour map area. These are actual measurements that, if considered, would demonstrates that he has significantly underestimated the thickness of the shell).

We can best demonstrate Dr. Hausler's inappropriate techniques through an analogy. If you wanted to know the average weight of people walking along 5th Avenue in New York City, then you would make an inference that if you weighed enough people randomly from that street that their weights would be representative of all the people on that street (*i.e.*, you would have a statistically representative sample). You would not want to select only ten people (too few) or people who biased the sample population by, for example, purposefully selecting those who looked thin. You would then determine if you had a normal distribution of the individuals' weights. With a normal distribution, you would then calculate the average weight, which would be representative of the people on that street. You could then calculate the 95% confidence interval of those weights.

Dr. Hausler glosses over the fact that there are not enough UT measurements to statistically treat the external data in the first instance. He acknowledges there are not enough data when he states that "the paucity of data, particularly in the heavily corroded Bays makes definite conclusions very difficult and an assessment of the extent of the corroded areas somewhat intuitive," (July 18 memorandum at 2). We believe he goes beyond intuition, to speculation when he nevertheless statistically treats those data.

Q. 41: Are there any other reasons why Dr. Hausler is wrong?

A. 41: (All) Yes. Dr. Hausler also acknowledges, but then ignores the fact that the external UT data were selected because they were determined to be the thinnest points. For example, Citizens state on page 14 of their Initial Statement that "the best approach . . . is to regard the external readings as representative, even though they might actually be biased to the thin side by their method of selection." Dr. Hausler's rationale for this statement appears to be his April 25, 2007 memorandum on page 6: "I believe that when assessing the extent of severe corrosion, reviewers should assume that the measured points connect unless other measurements show this not to be the case."

Dr. Hausler then averages these thinnest points and improperly identifies a 95% confidence interval. He then focuses on the thinnest of these readings. Not surprisingly, he declares that the drywell shell, in some cases, already has exceeded the general and local buckling criteria.

Using our analogy, what Dr. Hausler does is similar to biasing the sample population from 5th Avenue by selecting too few people, and only those who are waif-like. Needless to say, it is statistically inappropriate to average biased thin measurements and treat them as representative of the population, whether it is the weight of people or the thickness of the drywell shell. These data simply are not representative of the average since the shell between these UT locations is thicker. It is similarly statistically inappropriate to take the thinnest of these biased thin areas (*i.e.*, the lower 2.5% of this biased sample) and claim that these extreme values could be representative of the average. Using our analogy, such statistics would lead to the absurd conclusion that only people with anorexic qualities walk on 5th Avenue.

Dr. Hausler is confusing extreme value behavior with averaging. If your sample population is biased thin, then the way to evaluate the data is through extreme value statistics. You would not use an averaging technique because averaging implies a normal distribution. Dr. Hausler argues that the average of the thinnest points is representative of the whole drywell shell, but it can only be representative of the extreme values.

Q. 42: What is the basis for your opinion that the external UT locations were selected because they were the thinnest locations?

A. 42: (JA, PT) During the 1992 refueling outage, OCNGS did not identify UT measurement points on the exterior of the drywell shell to identify the average thickness. Rather, it specifically looked for the thinnest areas. This is documented in Applicant's Exhibit 27 (TDR1108):

> The corroded vessel shell resembled a cratered golf ball surface. The areas where the heaviest corrosion had taken place appeared obvious from a visual inspection since the inside shell wall was relatively uniform. The GPUN metallurgist (S. Saha) identified on a sketch, areas to be prepared for UT readings. At a later time he reviewed the surface preparation and thickness data and identified additional locations to ensure that the thinnest areas were surveyed. [page 15]
>
> It was reasoned that since the inside surface of the vessel shell is smooth and not corroded, any thin area on the outer surface should represent the minimum thickness in that region. It was further reasoned that if six to twelve scattered spots, located in the area of worst corrosion, are ground smooth and the thickness of each spot is measured by UT method we will have a high level of confidence that we have identified the thinnest shell thickness for a bay. This approach is conservative since, (a) we are forcing

> a statistical bias in choosing only the thinnest areas and (b) grinding of the selected spots to obtain a flat surface for reliable UT readings will remove additional good metal. [page 16]

This is also discussed in other documents, including, Applicant's Exhibit 12 on p. 14, Applicant's Exhibit 16 on p.4, and Applicant's Exhibit 17 on page 7.

In addition, Dr. Hausler's own analysis has independently confirmed that these external points are biased thin. In Citizens' Exhibit 12 on page 4, Dr. Hausler states that "the average outside measurements are significantly lower at comparable elevations [than the interior measurements]. This is probably because the choice of location for the external measurements was deliberately biased towards thin spots."

The fact that the external UT locations are biased towards the thinnest locations is also demonstrated by comparison of those data to the data taken from the internal UT grids. Some of the external UT locations coincide with internal grid locations, as generally shown on the comprehensive map of all 2006 UT inspection results that AmerGen provided to the ACRS for a public meeting in February 2007. The map is located on Page 14 of AmerGen's presentation, which is attached as Applicant's Exhibit 28. We will refer to this map as the "2006 map" as we next discuss three illustrative examples.

Two of the thinnest external readings in Bay 19 (points 9 and 10) were 0.728" and 0.736", respectively, in 2006. The 2006 map shows that these points are located within inches of internal grids 19A and 19C, which had averages thicknesses of 0.807" and 0.824", respectively, in 2006.

One of the thinnest external readings from Bay 13 was point 15 at 0.666" in 2006. The 2006 map shows that this external point is located within inches of internal grid 13C, which averaged 1.142" in 2006.

One of the thinnest readings in Bay 17 (point 2) was 0.663" in 2006. This point is located within inches of internal grid 17A, in which the top half of the grid averaged 1.112" in 2006 and the bottom half of the grid averaged 0.935" in 2006.

One of the thinnest readings in Bay 1 in 2006 (point 5) was 0.680". This point is located within inches of internal grid 1D, which had an average thickness of 1.122" in 2006.

These data, from multiple bays, unambiguously demonstrate that the external locations are biased thin compared to their surroundings. To statistically treat these data as representative of the drywell shell in the sand bed region is, therefore, inappropriate.

Q. 43: But on Page 10 of their Initial Statement, Citizens discuss the measurements taken in 2006 from 0.25" around the coordinates for certain external UT points in Bays 7, 15, 17, and 19. They state that those measurements are thinner than the designated external UT data point. Are Citizens correct that these external measurement locations are, therefore, not the thinnest?

A. 43: (FP, PT, JA) No, they are not correct. They confuse the measured "points" with the "ground UT locations." The external measurement "point" is located within a 2-inch diameter area that was ground smooth during the 1992 refueling outage to allow for the UT probe to sit flat against the shell. Examples of these ground locations are shown in Applicant's Exhibits 29, which are two presentation slides from AmerGen's meeting with the ACRS in January 2007. These *locations* were selected because they were the thinnest locations in the sand bed region for each bay.

The coordinates on the UT data sheets direct the UT technician to a spot within a specific ground location. But that specific spot is not itself marked and UT data from that location is, therefore, not precisely reproducible from sampling event to sampling event. These nuances, however, in no way undermine that these ground *locations* are the thinnest locations in each bay. Indeed, the fact that UT readings 0.25" around the center reading were lower, further supports that these ground areas are the thinnest locations.

Q. 44: Did AmerGen ignore these thinner UT readings 0.25" around the center reading if they were lower?

A. 44: (PT) No. When I performed my evaluation of the external UT data, I used the thinnest UT value from each of the ground areas measured in 2006. This is shown in Rev. 2 of the 24 Calc. for data points from Bays 7, 15, 17, and 19.

Q. 45: Is there anything else wrong with Dr. Hausler's evaluation of the external UT data?

A. 45: (All) Yes. Dr. Hausler relies upon an incorrect local buckling criterion (*e.g.*, A.13). He compares the external UT data to a criterion consisting of a one square foot area with a thickness of 0.636", without any transition back to 0.736". The actual criterion—AmerGen's local buckling criterion—has a thickness of 0.536" in a tray configuration, with a transition back to 0.736". That criterion is shown on AmerGen's Exhibit 11. Using the wrong criterion compounds his errors, and affects his ultimate conclusions about whether the drywell shell thickness meets the ASME Code.

Q. 46: Dr. Hausler argues that there are severely corroded areas that are shaped "like long grooves" or are irregular in shape, that call into question AmerGen's use of a square-shaped, local buckling criterion. (A. 24) What is your response to this argument?

A. 46: (All) Dr. Hausler is wrong. This argument can only be based on Dr. Hausler's improper statistical treatment of the external UT data, and his assumption that "the measured points connect unless other measurements show this not to be the case." (April 25 memorandum, page 6) The bath tub ring is irregular in shape, but the corrosion in that ring is only relevant to buckling if the resulting thickness is less than 0.736". And AmerGen has evaluated as acceptable those locations within the bath tub ring with UT readings that are less than 0.736". Additionally, the thinnest average grid reading taken from inside the drywell is in the bath tub ring, supporting our position that there is adequate margin to buckling.

A. Uncertainty in External UT Data

Q. 47: Dr. Hausler claims that the uncertainty of each external point is approximately +/- 0.090". (A.15) The basis for this claim is from Section IV (page 3) and Section VII (pages 8 and 9) of his July 18, 2007 memorandum (Citizens' Exhibit 13). Is Dr. Hausler correct?

A. 47: (All) No. In order to understand why Dr. Hausler is wrong, you first need to understand how he derived his level of uncertainty. Dr. Hausler derives 0.090" as follows. He identifies locations in Bays 5, 15, and 19 where measurements were taken during the 2006 refueling outage in a 0.25"-diameter area around the designated external measurement point. (On Page 9 of his July 18 memorandum, Dr. Hausler refers to these measurement locations as "identical coordinates," when in fact, they were taken in an area 0.25" around the specified coordinate.)

He assumes that the external data are representative of the thickness of the shell in these three bays, so he averages the data from these locations. (See the last column of the table on page 9 of his July 18 memorandum.) He then assumes the external data are normally distributed, and calculates the standard deviations for each bay, arriving at 0.033", 0.050" and 0.043" for the points in Bays 5, 15, and 19, respectively. (Citizens' Exhibit 13, at 3.) He then inexplicably "pools" these three values to arrive at 0.045", which he argues applies as a representative thickness for all areas in all of the bays. He then doubles that value (0.045" x 2) to account for the two standard deviations required to identify the 95% confidence interval.

Q. 48: What is wrong with this use of the data?

A. 48: (All) In arriving at 0.090", Dr. Hausler completely ignores reality and proper statistical techniques. As discussed above, he ignores that the external data are biased thin and that the locations were deliberately chosen to be the thinnest locations in each bay; that the data are not normally distributed (as shown by Kurtosis of the three data sets); and that there are not enough data to establish a representative sample population of these very large areas. As to the last point, there are only eight external points in Bays 5 and 15, and nine in Bay 19, to represent three areas *each of which* is about 3.5 feet by 15 feet wide. He also conveniently ignores the Bay 7 standard deviation he calculates on the same table (page 9) which would have reduced his number from 0.090" to 0.075".

Dr. Hausler then assumes this 0.090" value can be applied globally to any one reading or set of readings throughout the sand bed region of the drywell shell. This is unsupported and suggests that Dr. Hausler's testimony in this area should be given little, if any, weight.

Using the analogy of people on 5th Avenue, what Dr. Hausler does by pooling these thin points is akin to selecting the thin-looking people from 1st Avenue, 3rd Avenue, and 5th Avenue, and concluding that everyone in New York City is underweight.

Q. 49: What do you mean by the use of the term "kurtosis" in your previous answer?

A. 49: (PT, DGH) For ease of discussion here, we have rescaled Kurtosis, so that it equals zero for a normal distribution. Distributions that are greater or less than zero are not normally distributed.

For Bay 5, the 2006 external points were 0.948, 0.955, 0.989, 0.948, 0.88, 0.981, 0.974, and 1.007 with a calculated Kurtosis of 2.43.

For Bay 15, the 2006 external points were 0.711, 0.777, 0.935, 0.791, 0.817, 0.715, 0.805, and 0.76, with a calculated Kurtosis of 1.65.

For Bay 19, the 2006 external points were 0.867, 0.85, 0.894, 0.883, 0.82, 0.721, 0.728, 0.736, and 0.721 with a calculated Kurtosis of -2.2.

B. Evaluation Thickness

Q. 50: On pages 6 and 7 of his July 18 memorandum, Dr. Hausler raises many allegations about the "Evaluation Thickness," which is discussed in the various revisions of the 24 Calc. He concludes on page 7 that, "We can, therefore, not accept the evaluation done by AmerGen using the 'evaluation thickness.'" Please explain what the "Evaluation Thickness" is and its use.

A. 50: (FP, PT) As explained on pages 17-19 of Rev 2 of the 24 Calc. (AmerGen's Exhibit 16), the Evaluation Thickness is a representative average thickness in an area of 2" in diameter surrounding the external points that were less that 0.736" as measured by UT in 1992. During the 1992 refueling outage, micrometer readings were taken in a 2" diameter area around each external UT point that measured less than 0.736" (*i.e.*, about 20 points). This uniform depth was generated from actual measurements which had surface roughness variability of 0.200" from the micrometer readings for the two thinnest points in Bay 13 (see 24 Calc, Rev 2, p. 19). The Evaluation Thickness method is the UT thickness reading, plus the average depth of the area relative to its surroundings, minus 0.200" (referred to in the Evaluation Thickness method as "T roughness").

Dr. Hausler assumes the Evaluation Thickness method is to "correct for the fact that due to the roughness the UT probe may not have 'coupled' well with the metal surface and therefore detect less metal (thinner wall) than was actually there." (July 18 memorandum, page 7). He also assumes that "T-roughness" was to correct for roughness under the UT probe, and that it therefore should *not* have been used in 2006 when the epoxy coating would have created a smooth surface for the probe.

Q. 51: Is Dr. Hausler correct?

A. 51: (PT, FP) Dr. Hausler is wrong. The purpose of the method—as stated in Applicant's Exhibit 16— is to evaluate a 2-inch diameter area around the UT location, and estimate the average thickness of that 2-inch diameter area, not to account for the ability of the UT probe to properly couple. The purpose of "T-roughness" is to account for the roughness under the micrometer's straight edge, not roughness under the probe.

In addition, Dr. Hausler does not understand the implication of his argument. If AmerGen had *not* used T-roughness in 2006, as Dr. Hausler suggests, then the value would have been *thicker* by 0.200", which would not have been conservative.

Q. 52: On page 7 of his July 18 memorandum, Dr. Hausler quotes a document that you, Mr. Tamburro, wrote in 2006, suggesting that the Evaluation Thickness ought not to be used. Can you please respond to this?

A. 52: (PT). Yes. I did indeed submit a document to the OCNGS corrective action system (Citizens Exhibit 3), raising a concern with Rev 0 of the 24 Calc. (Applicant's Exhibit 17). However, my concern was limited to inadequate documentation. I identified approximately 11 items that required additional documentation in that calculation. All of the items were related to *documentation* of assumptions, methods, and data. This included an item about documentation of the methodology and justification for the Evaluation Thickness method. In other words, the deficiencies could be resolved with additional documentation. My concern about the Evaluation Thickness method was properly and thoroughly resolved through AmerGen's corrective action process and pages 17-19 of Rev 2 of the 24 Calc. document the resolution of the deficiency that I had identified.

I believe the method is appropriate to use, and I employed that method to evaluate data from the 2006 refueling outage.

VI. AMERGEN'S EVALUATION OF THE LOCAL BUCKLING CRITERION IN THE 24 CALC. IS APPROPRIATE

Q. 53: Dr. Hausler calls into question AmerGen's evaluation of the external UT data in Rev. 2 of the 24 Calc by challenging AmerGen's assumptions about the size of the historically corroded areas. (A. 23) Please respond to this.

A. 53: (PT) I performed the evaluations that are documented in Rev. 2 of the 24 Calc., and am very familiar with the prior revisions. For Rev. 1 (which he calls the second revision), he states that AmerGen "assumed, contrary to the visual observation, that all the severely areas measured were less than 2" in diameter." Dr. Hausler does not cite a specific page in the calculation so I cannot determine what precisely he is referring to. However, he is not correct. AmerGen identified the thinnest areas within the severely corroded areas, and then ground the metal around those points for a 2" diameter.

Dr. Hausler also states that, for Rev. 2 (which he calls the third revision), "AmerGen has taken an approach of drawing squares by eye on plots of the external data points." (A.23). On page 5 of his July 17 memorandum, he states that this was a "one-dimensional analysis." These too are incorrect. I did not draw squares by "eye on plots." I entered each of the external UT points using the x and y coordinates provided on the UT data sheets into Microsoft Excel. I then used Excel to create a 36" x 36" square, to represent the boundaries of the tray configuration that comprises the local buckling criterion. For points that measured less than 0.736" in 2006, I used Excel to move the square around to ensure that it encompassed, *in three dimensions*, the external points that were thinner than 0.736". Some of the points that measured less than 0.736" were evaluated using the Evaluation Thickness method described above.

Q. 54: Please address the following Board question, "This Board understands that UT thickness measurements are commonly used to determine pipe wall thickness and plate thickness in other industries (see, e.g., Attachment to Citizens Answer (Selected Papers by Dr. Hausler)). To enhance the Board's general understanding and thereby enable it to make a more informed decision, the parties should discuss other applications of UT thickness measurement and identify the best practices recommended by National Association of Corrosion Engineers or other professional organizations, if any, with particular attention to the determination of the thicknesses of corroded plates and the rate of corrosion. The discussion should include use of mean versus extreme value statistics and the Analysis of Variance used in these cases." [Board Question 10]

A. 54: (MEM, PT, JA) The Board's understanding that UT thickness measurements are commonly used is correct. For power plant applications, UT inspection has been the predominant technique used to measure wall thickness and flaws in pressure vessels, piping, tanks and heat exchanger shells and tube sheets. It is the most widely used method in the power industry as well as the nuclear industry. Recommended practices are provided in codes and standards such as ASME Code Section V (NDE) and ASTM E797: Practice for Measuring Thickness by Manual Ultrasonic Pulse-Echo Contact Method.

The ASME codes used in power plants, ASME Section III (Nuclear), Section VIII (Unfired Pressure Vessels), and Section XI (Inservice Inspections) specify UT as the examination method of choice for thickness, particularly for operating plants. In a similar fashion, other codes such as American Petroleum Institute (API) also predominantly use the UT technique to determine thickness and flaws. National Association of Corrosion Engineers (NACE) in its "Corrosion Basics" publication identifies ultrasonics as a method to measure "metal losses caused by corrosion and erosion" and states that "the measurements can be made from the outside of the vessels or pipelines during operation."

In general, these codes and standards do prescribe rigid UT inspection methodology, but do not prescribe data evaluation methodology (including whether to evaluate the data using the mean, extreme values, or analysis of the variance). Rather, they recommend that the owner specify the methodology on a case-by-case basis. To our knowledge, NACE does not require or suggest that the data be statistically evaluated using any particular method.

Typical power plant applications of UT include:

- Evaluation of Degraded Piping. Evaluation Methodology is prescribed by ASME Section XI, and applicable code cases (such as Code Case N513). UT measurement and subsequent evaluations focus on the average thickness of the degraded areas and the size of the degraded areas and not on extreme thickness values.

- Erosion-Corrosion (FAC) Prone Piping. Inspection practices were developed to identify the problems in regard to Erosion/Corrosion monitoring programs as they relate to NRC Bulletin 87-01, "Thinning of Pipe Wall in Nuclear Power Plants" and NRC Generic Letter 89-08 "Erosion/Corrosion-Induced Wall Thinning, and EPRI TR-106611." Components are examined both to ensure equipment reliability and personnel safety. EPRI has developed software (TR-106611), and workgroups have been established to incorporate the best practices and to share industry experience and technology development. UT measurements and evaluations use grids of points to determine the average thicknesses of the piping. The average of these grid readings is used for evaluation and determination of corrosion rates.
- Pressure Vessel Shell Inspection. Components are examined in accordance with ASME Section VIII to identify degradation of the vessel shells in order to ensure both equipment reliability and personnel safety. Inspection practices for feedwater heaters, for example, are developed to identify the degraded area due to steam impingement wear. In this case, UT measurements and subsequent evaluation focus on the average thicknesses of pressure retaining sections of the Feedwater Heater Shell.

- Tanks. Inspection practices are developed to identify degraded tank walls and floors. Components are examined in accordance with ASME Code Section XI and/or API 650 and 653. UT measurements and subsequent evaluation focus on the average thicknesses of degraded areas and not extreme values.

Q. 55: Does this conclude your testimony?

A. 55: (All) Yes.

In accordance with 28 U.S.C. § 1746, I state under penalty of perjury that the foregoing is true and correct:

F. Polaski ______________________ 8/15/07 ______________

Frederick W. Polaski Date

______________________ ______________

David Gary Harlow Date

______________________ ______________

Julien Abramovici Date

______________________ ______________

Peter Tamburro Date

______________________ ______________

Martin E. McAllister Date

In accordance with 28 U.S.C. § 1746, I state under penalty of perjury that the foregoing is true and correct:

____________________________ ____________________

Frederick W. Polaski — Date

David Gary Harlow — August 14, 2007

David Gary Harlow — Date

____________________________ ____________________

Julien Abramovici — Date

____________________________ ____________________

Peter Tamburro — Date

In accordance with 28 U.S.C. § 1746, I state under penalty of perjury that the foregoing is true and correct:

______________________________ ______________________

Frederick W. Polaski Date

______________________________ ______________________

David Gary Harlow Date

______________________________ 8-15-07

Julien Abramovici Date

______________________________ ______________________

Peter Tamburro Date

______________________________ ______________________

Martin E. McAllister Date

In accordance with 28 U.S.C. § 1746, I state under penalty of perjury that the foregoing is true and correct:

______________________________ ______________________

Frederick W. Polaski Date

______________________________ ______________________

David Gary Harlow Date

______________________________ ______________________

Julien Abramovici Date

Peter Tamburro 8/16/07

Peter Tamburro Date

______________________________ ______________________

Martin E. McAllister Date

In accordance with 28 U.S.C. § 1746, I state under penalty of perjury that the foregoing is true and correct:

____________________ ______________

Frederick W. Polaski Date

____________________ ______________

David Gary Harlow Date

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Julien Abramovici Date

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Peter Tamburro Date

M McAllister 8-16-07

Martin E. McAllister Date

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:
E. Roy Hawkens, Chair
Dr. Paul B. Abramson
Dr. Anthony J. Baratta

In the Matter of:	)	August 17, 2007
AmerGen Energy Company, LLC	)	
	)	Docket No. 50-219
(License Renewal for Oyster Creek Nuclear Generating Station)	)	

AMERGEN'S PRE-FILED REBUTTAL TESTIMONY
PART 4
SOURCES OF WATER

I. WITNESS BACKGROUND

Q. 1: Please state your names and current titles. The Board knows that a description of your current responsibilities, background and professional experience was provided in Parts 1 and 4 of AmerGen's Pre-Filed Direct Testimony on July 20, 2007, so there is no need for you to repeat that information here.

A. 1: (JFO) My name is John F. O'Rourke. I am a Senior Project manager, license Renewal, for Exelon, AmerGen Energy Company, LLC's ("AmerGen") parent company.

(AO) My name is Ahmed Ouaou. I am a registered Professional Engineer specializing in civil/structural design and an independent contractor.

(FHR) My name is Francis H. Ray. I am the Engineering Programs Manager at Oyster Creek Nuclear Generating Station ("OCNGS").

II. KNOWN SOURCES OF WATER IN THE SAND BED REGION

Q. 2: What is the purpose of this Rebuttal Testimony?

A. 2: (All) The purpose of this Rebuttal Testimony is to respond to the information provided in Citizens' Initial Statement Regarding Relicensing of Oyster Creek Nuclear Generating Station ("Statement") and in the Pre-Filed Direct Testimony of Dr. Rudolf H. Hausler, regarding the sources of water in the sand bed region.

Q. 3: Please summarize your conclusion.

A.3: We have reviewed Citizens' Statement and Dr. Hausler's testimony. These documents conclude that "it has not been established that the only source of water is the reactor fueling cavity." (Citizens' Statement at 21). This conclusion is based on a lack of knowledge of the subject matter and a lack of understanding of the available documents. Nothing in Dr. Hausler's testimony or Citizens' Statement contradicts our previous conclusion that AmerGen has identified and eliminated the potential sources of water in the sand bed region.

Q. 4: What is the basis for your previous conclusion?

A. 4: (All) As we described in our Direct Testimony (Part 4, A.13) and discuss further in this Rebuttal Testimony, the evaluations that took place in the 1980s and 1990s essentially ruled out other components as potential sources of water. Thus, "the only known source of water on the exterior of the drywell shell in the sand bed region is the reactor cavity liner . . . ." (Part 4, A.4) Further, "[o]bservation of the exterior of the drywell shell in the sand bed region and the sand bed drains during the 2006 refueling outage[] confirms that the use of metal tape and strippable coating on the reactor cavity liner during outages can eliminate the presence of water from the exterior sand bed region." (Part 4, A.4)

Q. 5: Are there documents that support your conclusions?

A. 5: (All) Yes. Citizens' Exhibit 21, Attachment III; page 6-3 of Applicant's Exhibit 3; and portions of the transcripts of AmerGen's meetings with the ACRS license renewal subcommittee on October 3, 2006 and January 18, 2007, all discuss the historical investigations. The relevant portions of the ACRS transcripts are attached as Applicant's Exhibits 30 and 31.

Q. 6: Is there other evidence that the only known source of water is the refueling cavity?

A. 6: (All) Yes. During inspections, no new water has been found in the plastic bottles that are connected to the sand bed drains. This includes the quarterly inspections during operations that resumed in March 2006, and daily inspections while the reactor cavity was filled with water during the 2006 outage. Thus, these inspections provide additional confirmation that the only known source of leakage is the reactor cavity liner.

Q. 7: Citizens have submitted, as their Exhibit 21, a December 5, 1990 letter from OCNGS to the NRC. Attachment III to that letter describes past actions to "investigate, identify, and correct leak paths into the drywell gap . . . ." Are you familiar with this document?

A. 7: (All) Yes.

Q. 8: What does that document discuss?

A. 8: (All) It discusses the extensive investigations undertaken in the 1980s and early 1990s to identify the sources of water in the sand bed region and it reports the results of those investigations to the NRC.

Q. 9: On page 21 of their Statement, Citizens cite their Exhibit 21, Attachment III, at 4 in support of the claim that "the equipment pool has also leaked." What is your opinion regarding this statement?

A. 9: (All) The passage cited by Citizens has nothing to do with leakage on the drywell shell. The discussion of equipment pool leaks on page 4 of Citizens' Exhibit 21, Attachment III describes "[e]vidence of leakage" on both the floor and wall of the equipment pool and in the reactor cavity wall," and "water stains on the underside of the equipment pool." The leakage described is isolated from the drywell shell and, based on the physical configuration of OCNGS, there is no credible leakage path from the underside of the equipment pool to the drywell shell.

Tellingly, this passage is part of a discussion of "actions [that have] also been taken to address the potential impact of leakage on *other* structures and equipment." Citizens' Exhibit 21, Attachment III at 4 (emphasis added). The cited passage *comes after* a description of the licensee's "thorough program for managing leakage that could affect drywell integrity," and is not part of the cited description. Citizens' Exhibit 21, Attachment III, at 4.

Q. 10: Dr. Hausler also has testified on the topic of equipment pool leakage. He states, in A.17, that there "are a number of potential sources of water that have been identified by the reactor operator, including . . . the equipment pool." What is your opinion regarding this statement?

A. 10: (All) OCNGS historically identified a number of potential sources of water, including the equipment pool, but investigations in the 1980s and 1990s eliminated the equipment pool as a source of water leakage onto the external drywell shell. Further, to the extent Dr. Hausler is relying on the "reactor operator," then we can only assume that he relies on the conclusions documented in Citizens' Exhibit 21, Attachment III, which are that, with respect to leakage "into the drywell gap" (page 2), "no leaks have been found related to the equipment pool. Preventively, the equipment pool will be protectively coated similar to the refueling cavity. Drains from the leak detection system are monitored on a periodic basis to detect any changes" (page 3).

Further, there is no potential for water from the equipment pool to reach the external sand bed region. The equipment pool is filled with water during outages when it is utilized to store reactor components for shielding purposes during their disassembly. During this period, the water in the equipment pool can mix with the water in the reactor cavity. Prior to plant restart the equipment pool is drained down, eliminating the potential for water from the equipment pool to provide a source of leakage into the sand bed region.

Q. 11: Citizens also have submitted TDR 964, dated March 3, 1989, as Citizens' Exhibit 22. Are you familiar with this document?

A. 11: (All) Yes.

Q. 12: Please summarize the purpose and contents of the document.

A. 12: (All) TDR 964 describes the clearing of the sand bed drains that took place in 1988 and recommends further corrective actions to monitor sand bed leakage.

Q. 13: On page 21 of Citizens' Statement, Citizens cite to page 3 of TDR 964, to support the statement that "fuel pool water that did not originate from the reactor cavity has been found in the sand bed region." Does the citation support Citizens' Statement?

A. 13: (All) No. Citizens' conclusion is *not* supported by this citation. The cited passage in TDR 964 states,

> On Oct 26, 1988 during the cathodic protection core bore operation . . . it was noted that hole 2 in bay 11 was filled with standing water. This water when tested by O.C. chemistry was found not to be core bore water used during the drilling operation but rather it had the characteristics of "old" fuel pool water.
>
> Since the reactor cavity had not been filled with fuel pool water for the "upcoming refueling" it was postulated that this entrapped water could be "old" fuel pool water.

This document simply does not support the conclusion Citizens draw from it (*i.e.*, that fuel pool water that did not originate from the reactor cavity has been found in the sand bed region). The author of TDR 964 proposes that the water discovered might have been "old" fuel pool water, *i.e.*, water left over from a previous refueling outage, when the reactor cavity was filled with water. There is no basis upon which Citizens can then jump to the conclusion that there is some source of water in the sand bed region *other than the reactor cavity*. TDR 964 offers no support for this leap of logic. Ultimately, on page 5, the conclusion reached is that "[w]ater samples were collected from each bay drain and analysis proved to be inconclusive."

Also, following this TDR, the licensee conducted extensive investigations to determine the source of leakage into the sand bed region. As documented in Citizens' Exhibit 21, Attachment III, those investigations ultimately found no source of leakage other than the reactor cavity liner. There is nothing in TDR 964 that contradicts these later findings.

III. REFUELING CAVITY LEAKAGE

Q. 14: Dr. Hausler has testified, in A.17, that "AmerGen has not managed to devise a method to ensure that the refueling cavity will not leak in the future . . . ." Is this correct?

A. 14: (All) This is correct, but irrelevant. Leakage from the reactor cavity is not relevant unless it exceeds the capacity of the trough drain. As we explained in Part 4, A.9 of our Direct Testimony, the use of metal tape and strippable coating has "drastically reduced the amount of reactor cavity liner leakage" to a level that is "well within the capacity of the reactor cavity trough drain system." Moreover, the trough drain is inspected during each outage. Thus, it is mere speculation to assume that leakage at the trough drain equates to undetected water on the exterior of the drywell shell.

IV. CONDENSATION

Q. 15: Dr. Hausler has testified, in A.18, that "small droplets of condensation . . . would likely not cause observable flow in the sand bed drains." What is your response to this statement?

A. 15: (All) We would first point out that, as we testified on direct, "[c]ondensation on the exterior of the drywell shell in the sand bed region during normal operations is not credible," and even during outages, "the potential for condensation is entirely speculative." (Part 4, A.17) Direct visual observation during the 2006 outage in all ten bays did not identify condensation.

Next, relying on Ed Hosterman's testimony in Part 6 of AmerGen's Direct Testimony, we understand that any water that might condense on the drywell shell during an outage "would evaporate in a couple of hours" following start-up at the end of the outage. Also, the potential future corrosion calculations of Barry Gordon in Part 6 of AmerGen's Direct and Rebuttal Testimony conservatively assume that water from the reactor cavity is present for the entire 30-day period of a refueling outage, once every 24 months. Thus, even if Dr. Hausler's testimony is correct, condensation already is accounted for in AmerGen's potential future corrosion analysis.

Q. 16: Dr. Hausler has testified, in A.17, that "AmerGen has [not] been able to definitively trace the source of water found most recently in the drains from the drywell," so "it is not possible to rule out the potential for water from other sources to enter during operation."

A. 16: (All) Dr. Hausler is referring to the water found in early 2006 in three of the five plastic bottles in the Torus Room that collect leakage from the sand bed drains. As explained in Part 1 of AmerGen's Direct Testimony, water from the sand bed drains "is diverted through plastic tubing where it is collected in five-gallon plastic bottles." (A.10) There is no evidence that this water "enter[ed]" the sand bed region "during operation," as Dr. Hausler speculates. Instead, as we testified in Part 4, A.12, the presence of water in these bottles "is consistent with the failure to apply strippable coating during past refueling outages." The fact that AmerGen cannot "definitively trace the source" of this water does not mean that the water came from a source other than the refueling cavity. Again, the fact that no water has been identified in these bottles since inspections resumed in March 2006, and the fact that no water was found in any portion of the sand bed region during the 2006 outage inspections, provides additional support that there are no other sources of water reaching the sand bed region during operations or outages.

Q. 17: On page 21 of Citizens' Statement, they cite to Citizens' Exhibit 23 (an AmerGen e-mail) for the fact that "no activity" was detected in the water found in the plastic bottles in March 2006. They conclude, therefore, that "some water will result from condensation during outages." Are Citizens correct?

A. 17: (All) No. The reference to "no activity" refers to no gamma radioactivity. However, the sample was not analyzed for tritium. Analytical results from prior samples taken from the sand bed region, identified in Citizen's Exhibit 22, also have no gamma radioactivity but still exhibited tritium at concentrations that are consistent with water from the primary cooling system. Thus, the fact that "no activity" was detected in the water sample taken in March 2006 does not prove that the water came from condensation. In addition, no condensation was observed during visual inspections of the exterior sand bed region during the 2006 outage. At best, that analytical result is inconclusive.

Furthermore, as we testified on direct, the temperature differential between the "hotter drywell interior" and the "cooler external sand bed region. . . . will prevent condensation from forming on the exterior of the drywell shell." (Part 4, A.14.) Although condensation is "theoretically possible" during outages (Part 4, A.15.), "[t]here was no evidence of condensation on the exterior of the drywell shell" during the 2006 outage. (Part 4, A.16.) "Qualified NDE [non-destructive examination] visual inspectors examined each individual bay during the 2006 refueling outage and their reports did not identify any condensation or other moisture." (Part 4, A.16.)

V. CRACKS IN THE EPOXY FLOOR

Q. 18: Dr. Hausler has testified, in A.18, that if "defects in the floor coating recur, water could run down into those defects, rather than running to the [sand bed] drains" leading to "a failure to detect corrosive conditions." Do you agree with this statement?

A. 18: (All) No. Once again, Dr. Hausler is speculating and does not understand the facts. Dr. Hausler is assuming that water would run down the shell, onto the floor, and into cracks that would have to be present between each of the sand bed drains and the shell, thereby preventing water from reaching the sand bed drains. This is speculation. Past defects in the floor were not in locations that would permit the scenario Dr. Hausler assumes to take place. The defects were primarily at the interface between the concrete shield wall and the floor, on the opposite side of the sand bed floor from the drywell shell. Those that were not at this interface were small defects that could not prevent water from reaching the drains. Further, as described in Applicant's Exhibit 3, at 7-3, no defects were found in the seal between the drywell shell and the concrete floor. Thus, Dr. Hausler's statement is best characterized as speculation that is based on a misunderstanding of the geometry and drainage design of the external sand bed region and the configuration of the floor defects.

VI. CLOGGED DRAINS

Q. 19: Dr. Hausler has testified, in A.18, that "in the past the [sand bed] drains have clogged and it is reasonable to assume that this situation could recur." Do you agree?

A. 19: (All) No. Dr. Hausler argues that the drains could become totally blocked so that no water can pass through them. This is total speculation, because the sand bed region drains were historically clogged with sand. That sand was removed during the 1992 refueling outage. This is described in Applicant's Exhibit 3, at 6-3. In the 2006 outage, as described in Applicant's Exhibit 3, at 4-7, some solid debris was found in two of the sand bed drains, but the debris would not have prevented flow. The debris was removed from both of these drains. Further, the sand bed drains are verified to be clear during each refueling outage. Applicants' Exhibits 32 and 33. Thus, there is no reason to "assume" that the sand bed drains will ever prevent drainage.

Q. 20: Dr. Hausler concludes, in A.17, that "it appears likely that some water will be present on the surface of the drywell during refueling outages, and it is not possible to rule out the potential for water from other sources to enter during operations." Do you agree?

A. 20: (All) No. Leakage from the reactor cavity is the only known source of water on the exterior of the drywell shell in the sand bed region. Moreover, AmerGen's commitments effectively eliminate the potential for water leakage from the refueling cavity onto the drywell shell exterior, during the only time when the reactor cavity is filled with water. Furthermore, the 2006 outage inspections clearly demonstrate that with these commitments in place, water is not expected to enter the external sand bed region. Nothing in Dr. Hausler's Direct Testimony or Citizens' Statement demonstrates anything to the contrary.

Q. 21: Does this conclude your testimony?

A. 21: (All) Yes.

In accordance with 28 U.S.C. § 1746, I state under penalty of perjury that the foregoing is true and correct:

John F. O'Rourke   8-15-2007

John F. O'Rourke   Date

Ahmed M. Ouaou   8/15/2007

Ahmed Ouaou   Date

Francis H. Ray   Date

In accordance with 28 U.S.C. § 1746, I state under penalty of perjury that the foregoing is true and correct:

____________________	______________
John F. O'Rourke	Date
____________________	______________
Ahmed Ouaou	Date
F. Henry Ray	8/15/07
Francis H. Ray	Date

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:
E. Roy Hawkens, Chair
Dr. Paul B. Abramson
Dr. Anthony J. Baratta

In the Matter of:	)	August 17, 2007
AmerGen Energy Company, LLC	)	
	)	Docket No. 50-219
(License Renewal for Oyster Creek Nuclear Generating Station)	)	

AMERGEN'S PRE-FILED REBUTTAL TESTIMONY PART 5 THE EPOXY COATING

I. WITNESS BACKGROUND

Q. 1: Please state your names and current titles. The Board knows that a description of your current responsibilities, background and professional experience was provided in Parts 4 and 5 of AmerGen's pre-filed Direct Testimony on July 20, 2007, so there is no need for you to repeat that information here.

A. 1: (JRC) My name is Jon R. Cavallo. I am Vice President of Corrosion Control Consultants and Labs, Inc., and Vice-Chairman of Sponge-Jet, Inc.

(AO) My name is Ahmed Ouaou. I am a registered Professional Engineer specializing in civil/structural design and an independent contractor.

Q. 2: What is the purpose of this Rebuttal Testimony?

A. 2: (All) The purpose of this Rebuttal Testimony is to specifically address the information provided in Citizens' Initial Statement of Position Regarding Relicensing of Oyster Creek Nuclear Generating Station ("OCNGS"), and in the Pre-Filed Direct Testimony of Dr. Rudolf H. Hausler, regarding the epoxy coating system installed on the exterior of the OCNGS drywell shell in the sand bed region.

Q. 3: Please summarize your conclusions.

A. 3: (All) We have reviewed Citizens' Statement and Dr. Hausler's testimony. First, we conclude that the Board should accord very little, if any, weight to Dr. Hausler's testimony on the epoxy coating system, because his professional expertise and qualifications are lacking with respect to such systems. Second, we address the specific allegations in Dr. Hausler's testimony. These include, among other things, his allegations that visual inspections will not detect the early stages of coating failure, and that the lifespan of the coating system is ten to twenty years. We show that those allegations are either speculative or incorrect, and were in most cases addressed in our Direct Testimony.

II. DR. HAUSLER IS POORLY QUALIFIED TO TESTIFY ABOUT THE EPOXY COATING SYSTEM

Q. 4: Mr. Cavallo, what is your opinion regarding Dr. Hausler's qualifications in the field of epoxy coating systems?

A. 4: (JRC) I have reviewed the materials that Citizens have submitted related to Dr. Hausler's professional qualifications, and I have found no clear evidence or documentation to support his specific expertise on the subject of epoxy coatings or the use of coatings to protect carbon steel substrates from corrosion.

In particular, I have reviewed Dr. Hausler's description, in his July 29 memorandum (at 2), of his work on "oil field tubulars" which "are frequently internally coated." He implies that he is familiar with coatings "based on epoxy chemicals (Tuboscope's TK-7, for instance)." July 29, 2007 Memorandum at 2.

Q. 5: Is Dr. Hausler's experience relevant to the OCNGS exterior drywell shell epoxy coating system?

A. 5: (JRC) It does not appear to be. The experience Dr. Hausler describes is fundamentally inapplicable to the issue of exterior drywell shell corrosion in the sand bed region for two reasons. First, the operating environment of the external drywell shell in the sand bed region is entirely different from that of the "oil field tubulars" that Dr. Hausler describes. Based on Dr. Hausler's own publications, such oil field applications generally involve continuous immersion service with highly corrosive pressurized fluids, corrosive gases and continuous fluid flow. In contrast, the sand bed region is exposed to a relatively benign non-immersion environment. As described by Barry Gordon in his Direct Testimony (Part 6, A.10), any fluids which may occasionally be present in the sand bed region would be relatively non-corrosive. Such fluids also would not be pressurized. In addition, there is no potential for high-velocity fluid-flow across the external OCNGS drywell shell in the sand bed region.

Second, Dr. Hausler's primary area of expertise is clearly in the field of chemical corrosion inhibitors, *i.e.*, fluid additives, and specifically in oil and gas production facilities – – and not in epoxy coating systems. The Tuboscope TK-7 product that he describes (July 29, 2007 Memorandum at 2) is a thin-film, modified phenolic coating specifically formulated for use in high-temperature and high-pressure gas production environments containing carbon dioxide and hydrogen sulfide. (Applicant's Exhibit 34). It is not chemically similar to the epoxy coating system applied to the OCNGS drywell shell. Thus, in my opinion Dr. Hausler has shown little, if any, expertise or experience applicable to the OCNGS epoxy coating system.

III. COATING SYSTEM ROBUSTNESS AND EXPECTED LIFE SPAN

Q. 6: Dr. Hausler states, in A.21, that, "it is not reasonable to assume that visual inspection could detect the early stages of coating failure." Do you agree?

A. 6: (All) No. There is no factual support for this statement. The use of visual inspections to detect coating failures is not based upon simple "assumptions" but is based, instead, on established industry practice. Dr. Hausler's statement contradicts current industry and regulatory practices for in-service inspections of nuclear power plant coatings, including ASME Code Section XI requirements and practices. ASME Section XI, Subsection IWE is mandated by 10 CFR 50.55a. ASME Section XI, Subsection IWE recognizes that containments are coated and requires a visual inspection of the coating to identify ongoing corrosion of the containment vessel under the coating. NRC has endorsed these practices in the GALL Report (NUREG-1801, Vol. 2, Appendix xi.S8).

(JRC) Thus, as I described in my Direct Testimony, "VT-1 inspections performed by qualified inspection personnel are the ASME Code-approved means of assessing the condition of a coating system." (Part 5, A.11) Further, as I previously testified (Part 5, A.3), I also have served as principal investigator in a recent Electric Power Research Institute ("EPRI") study which confirms that visual inspections would detect the early signs of coating system failure, contrary to Dr. Hausler's opinion.

Q. 7: How are the early stages of coating failure detected?

A. 7: (JRC) I would expect early indications of epoxy coating failure to include pinpoint rusting and rust staining, long before widespread coating failure in the form of cracking and delamination. In a benign non-immersion environment, such as the OCNGS external sand bed region, such indications would develop at a very slow rate, over a period of years. Thus, based on my years of experience analyzing failure in epoxy coating systems, Dr. Hausler's speculation about the inability of visual inspections to "detect the early stages of coating failure" is simply not technically credible. Instead, I would expect visual inspections, at the four-year interval required by AmerGen's commitments, to detect the early stages of coating failure.

Q. 8: Citizens claim that the "lifespan of the coating has been estimated at anything from ten to twenty years." (A.21) For support, Citizens cite to your testimony (Mr. Ouaou) before the Advisory Committee on Reactor Safeguards ("ACRS") License Renewal Subcommittee. (Dr. Hausler testimony, Attachment 5, page 17) Do you agree with Citizens' estimate of the epoxy coating system lifespan?

A. 8: (AO) No. The estimated coating system life of ten to twenty years that I provided in my ACRS testimony was based on conservative engineering judgments undertaken by OCNGS personnel in the 1990s, around the time that the epoxy coating was installed. (Citizens' Exhibit 16 at 61:12-22). As I also explained to the ACRS, further research, including discussions with the coating system vendor, led AmerGen to the conclusion that the life span limit for the epoxy coating system is not limited to ten to twenty years in the sand bed region environment. (Citizens' Exhibit 16 at 61:12-22).

Jon Cavallo's Direct Testimony (Part 5, A.8 and A.9) addresses the life span of the epoxy coating system and reaches the same conclusions. First, based on my engineering experience, I agree with Mr. Cavallo that the OCNGS "epoxy coating system is in a relatively benign environment in terms of exposure to elevated temperature, mechanical damage, submersion in water, radiation, and UV light. Thus, none of the factors that would be most likely to contribute to deterioration of the coating over time are present." (Part 5, A.9) Second, I agree that the "short life-span estimates [provided in the 1990s], particularly in this environment, are overly conservative." (Part 5, A.9) Third, I also agree that "AmerGen's inspection program" should "identify the early signs of deterioration, long before widespread coating failure could take place." (Part 5, A.9)

(All) Thus, based on our experience, we both believe that "[t]he epoxy coating system should last for the life of the plant, including the extended period of operation, provided that proper inspections are conducted and, in the unlikely event that defects are identified, necessary corrective maintenance is performed. With appropriate inspections and proper maintenance, the coating system should last decades." (Part 5, A.8)

Q. 9: Dr. Hausler, in A.21, and Citizens, on page 21 of their Statement, draw an analogy between the defects discovered in the sand bed region epoxy floor in 2006 and the potential for deterioration of the epoxy coating system covering the exterior drywell shell. Specifically, Citizens state that these defects show "that the potential for the epoxy coating [on the exterior drywell shell] to deteriorate is not mere speculation." What is your opinion of this analogy?

A. 9: (JRC) It is Dr. Hausler and Citizens who are speculating as to the cause of the deterioration of the floor coating, based on limited understanding of the evidence. In order to explain why their statements lack a factual basis, some background on the application of epoxy to the sand bed region floor is required.

When the sand was removed in the early 1990s, the sand bed concrete floor was found to be cratered and unfinished. The concrete floor was repaired, finished, and built up to permit proper drainage of the sand bed region, using the same epoxy that was used to coat the drywell shell. This is described in Applicant's Exhibit 3, at 4-3 and 6-13.

During the 2006 outage, OCNGS personnel discovered that in isolated areas, the epoxy coating on the sand bed region floor had separated from its interface with the concrete shield wall. This discovery and repair is described in Applicant's Exhibit 3, at 7-3. These defects have no bearing on the epoxy coating system covering the drywell shell. First, the curing of epoxy poured thickly onto the concrete floor of the exterior sand bed to build up the floor, and the mechanism behind isolated cracking of that thickly poured epoxy are different than for the comparatively thinly-coated drywell shell. Second, the adherence of the epoxy to concrete is different than for prepared metal. Finally, the epoxy coating system applied to the carbon steel shell includes a pre-prime sealer that "soaks and penetrates into the semi-irregular surface of the steel substrate and promotes coating system adhesion." (Part 5, A.6) No such pre-primer was applied to the concrete. Thus, no analogy can be drawn between the defects discovered at the concrete shield wall and on the sand bed region floor and speculative deterioration of the epoxy coating system on the drywell shell.

IV. APPLICATION OF THE COATING SYSTEM

Q. 10: Dr. Hausler has testified that "[i]t is likely that there were defects in the coating when it was applied, because no electrical testing of the applied coating was performed." (Part 5, A.21) In previous testimony, he has claimed that "there are always holidays present, albeit perhaps few." (Citizens' Exhibit 12 (April 25, 2007 Memorandum at 8)) Do you agree with these statements?

A. 10: (JRC) No. First, it must be noted that the mere fact that there was no electrical testing does not *cause* defects in the coating, nor does it make such defects "likely." Also, as I explained in my Direct Testimony, the "three-layer system chosen by OCNGS and the techniques and tools used in the application provide reasonable assurance that such potential pinholes or holidays would not extend through the three layers to expose the underlying metal substrate." (Part 5, A.14)

Second, as I further explained in my direct testimony, Part 5, A.14:

> [P]inholes or holidays would have existed since the coating was applied during the 1992 refueling outage. And water was reported to be present in the external sand bed region when strippable coating was not used on the reactor cavity liner during the 1994 and 1996 refueling outages. The

> corrosion that would have resulted from that water entering pinholes or holidays would be visible today due to the volume of corrosion products (iron oxides) and surface rust staining caused by the corrosion process.

Q. 11: In Part 5, A. 7 of your direct testimony, you state that "as described in the manufacturer's data sheet, [the epoxy coating] is designed for continuously submerged environments such as water tank bottoms." What data sheet were you referring to?

A. 11: (JRC) I was referring to the Devoe Coatings data sheets for the "Devran 184, 100% Solids Epoxy Tank Coating" and "Pre-Prime 167, Rust Penetrating Sealer" that were attached to the materials that AmerGen submitted to the ACRS in December 2006. The specific data sheets are available on the NRC's website (ML063490343, beginning at page 299). They are also attached as Applicant's Exhibit 35. That Devran 184 data sheet clearly describes that the coating—two coats of which were applied to the exterior of the drywell shell in the sand bed region—is designed for continuously submerged environments.

V. OSMOTIC DIFFUSION

Q. 12: Dr. Hausler also alleges it is possible for "slow diffusion of water and corrosive gases across the epoxy boundary" that could cause "delamination, blister formation and subsequent breaking of the bubble and rapid attack of the metal." (Letter from R. Hausler to R. Webster, July 29, 2007). He makes a similar allegation in Citizens' Exhibit 12 (April 25, 2007 Memorandum) at 7. Can water or corrosive gases diffuse through the drywell shell epoxy coating system to cause corrosion in this manner?

A. 12: (JRC) No. The osmotic diffusion phenomenon Dr. Hausler describes is inapplicable to the present situation, because there is no potential for long-term or continuous immersion of the epoxy coating system in the OCNGS exterior sand bed region. Without such continuous immersion, osmotic diffusion and blistering cannot occur. And there are no corrosive gases present in the exterior OCNGS sand bed region, so diffusion of such gases is not an issue here.

Q. 13: Does this conclude your testimony?

A. 13: (JRC, AO) Yes.

In accordance with 28 U.S.C. § 1746, I state under penalty of perjury that the foregoing is true and correct:

Jon R. Cavallo

August 15, 2007
Date

Ahmed Ouaou

Date

In accordance with 28 U.S.C. § 1746, I state under penalty of perjury that the foregoing is true and correct:

____________________________ __________________

Jon R. Cavallo Date

Ahmed M Ouaou 8/15/2007

Ahmed Ouaou Date

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UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD

Before Administrative Judges:
E. Roy Hawkens, Chair
Dr. Paul B. Abramson
Dr. Anthony J. Baratta

In the Matter of:	)	August 17, 2007
AmerGen Energy Company, LLC	)	
	)	Docket No. 50-219
(License Renewal for Oyster Creek Nuclear Generating Station)	)	

AMERGEN'S PRE-FILED REBUTTAL TESTIMONY
PART 6
FUTURE CORROSION

I. WITNESS BACKGROUND

Q. 1: Please state your names and current titles. The Board knows that a description of your current responsibilities, background and professional experience was provided in Parts 1, 2 and 6 of AmerGen's Pre-Filed Direct Testimony on July 20, 2007, so there is no need for you to repeat that information here.

A. 1: (BG) My name is Barry Gordon. I am an Associate with Structural Integrity Associates, Inc. ("SIA"), located in San José, California.

(MPG) My name is Michael P. Gallagher, and I am Vice President of License Renewal for Exelon.

(PT) My name is Peter Tamburro, and I am a Senior Mechanical Engineer in the Engineering Department at the Oyster Creek Nuclear Generation Station ("OCNGS").

Q. 2: Would you please summarize the purpose of this Rebuttal Testimony?

A. 2: (All) The purpose of this testimony is to respond to the Pre-Filed Direct Testimony of Dr. Rudolf Hausler that discusses the potential for future corrosion of the exterior drywell shell in the sand bed region, and to address the potential for corrosion of the interior embedded surface of the drywell shell.

Q. 3: What is your overall conclusion?

A. 3: (All) Our overall conclusion is that Dr. Hausler's experience and expertise is extremely limited in this area. His testimony is based on inapplicable analyses and mistaken assumptions about corrosion mechanisms. Dr. Hausler appears to be using analyses developed from his experience in oil field applications that, from the limited information he provides, appear inapplicable to the actual conditions of the drywell shell in the sand bed region at OCNGS. In addition, potential corrosion on the interior embedded surface of the drywell shell is insignificant for purposes of license renewal.

II. DR. HAUSLER IS POORLY QUALIFIED TO TESTIFY ABOUT POTENTIAL CORROSION MECHANISMS

Q. 4: What is your opinion regarding Dr. Hausler's expertise in corrosion? In particular, please address his expertise in corrosion of carbon steel in environments similar to the exterior sand bed region at OCNGS.

A. 4: (BG) I have reviewed Dr. Hausler's résumé and the other materials submitted in support of his qualifications, and some of his publications. From that review, it appears that Dr. Hausler's experience is primarily in oil-field applications, where the corrosion mechanism may be pitting corrosion, erosion-corrosion, corrosion fatigue, etc. in high temperature, highly aggressive environments containing hydrogen sulfide, carbon dioxide, organic acids, etc. This contrasts with general corrosion of carbon steel in stagnant wet oxygenated environments, such as the historical conditions in the exterior sand bed region at OCNGS, where the corrosion rate is expected to decrease with time, for the reasons I describe below.

Q. 5: Dr. Hausler has testified that "the corrosion rate (rate of deterioration) in pitting situations as well as on coated materials, increases exponentially with time. Hence, past performance is no indication of what may happen in the future." (A.21) Why is that statement incorrect for the exterior sand bed region at OCNGS?

A. 5: (BG) It is incorrect because the relevant corrosion mechanism for the drywell shell in the OCNGS sand bed region is general corrosion not pitting corrosion. Dr. Hausler's misconception that the OCNGS corrosion rate "increases exponentially with time" appears to be based on experience that is simply inapplicable to the exterior sand bed region.

Q. 6: What is the relevant difference between general and pitting corrosion?

A. 6: (BG) General corrosion is a form of corrosion that occurs fairly uniformly over a metal surface, while pitting is localized corrosion experienced only on materials that form a protective passive film on the surface. The rate of general corrosion typically decreases exponentially over time, *i.e.*, in proportion to the square root of time. This is due to the diffusion-limiting control of the kinetics of the corrosion reaction, *i.e.*, the outward diffusion of metal ions and/or the inward diffusion of dissolved oxygen through the corrosion film to the metal surface. In other words, the corrosion products formed on the surface form a barrier film that inhibits the corrosion reaction. Thus, as well documented in the laboratory and in the field, the general corrosion rate of carbon steel in oxygenated water will decrease, not increase with time.

Q. 7: So, Dr. Hausler has confused pitting vs. general corrosion?

A. 7: (BG) Yes. Dr. Hausler incorrectly describes the corrosion mechanism associated with the drywell shell as "pitting." Pitting corrosion is the localized, accelerated dissolution of metal that occurs as a result of a breakdown of the otherwise protective passive film on the metal surface. Many alloys, such as stainless steel and aluminum alloys, are useful for industrial purposes because of the passive films (which are thin, nanometer scale, oxide layers) that form naturally on the metal surface. Such passive films, however, are often susceptible to localized breakdown resulting in accelerated dissolution of the underlying metal. If the attack initiates on an open surface, it is called pitting corrosion and if the attack initiates at an occluded site, it is called crevice corrosion. The corrosion film formed on carbon steel exposed to low-temperature oxygenated water is not passive, and so the drywell shell is susceptible to general corrosion, *not* pitting corrosion. And the rate of general corrosion does not increase with time, much less increase at an exponential rate.

Finally, in pitting corrosion, the change in pit depth usually slows with time. A typical exponent for pit growth is the same for general corrosion, *i.e.*, 0.5, which is the ideal value for pit growth. Sometimes the exponent is greater than 0.5, but it is often less than 0.5, and usually between 0.3 and 0.5.

Additionally, I reviewed core samples from the OCNGS drywell shell taken during the 1980s when I worked at GE, and the corrosion mechanism was classic general corrosion.

Q. 8: If pitting corrosion would not occur on the carbon steel drywell shell, can you explain the reference to minor "pitting" on the interior of the drywell in the AmerGen email which was attached to Citizens' Direct Testimony as Citizens' Exhibit 26?

A. 8: (BG) General corrosion often has the general appearance of "pitting," *i.e.*, a bunch of overlapping indentations or "pits," especially to someone who is not a corrosion engineer. The statements by the person characterizing the corrosion in Citizens' Exhibit 26 do not support a conclusion that pitting corrosion is occurring or has occurred on the inside of the drywell shell.

III. INTERNAL DRYWELL SHELL SURFACE

Q. 9: Is there a potential for corrosion on the interior embedded drywell surface?

A. 9: (BG) Not anything that would be significant for purposes of license renewal. Any corrosion would be vanishingly small and of no engineering concern.

Q. 10: What is the basis for that opinion?

A. 10: (All) First, AmerGen removed the concrete from a portion of the embedded drywell shell in the sand bed region in Bay 5 during the 2006 outage. This portion of the shell had been embedded in concrete since construction of OCNGS. There was no measurable corrosion on the surface of this newly-exposed shell. This demonstrates that the conditions inside the drywell will not lead to significant corrosion during the period of extended operation because interior drywell conditions over the next 22 years are expected to be the same as over the past 38 years.

(BG) Second, any water that would be in contact with the interior surface of the embedded drywell shell would have a high pH caused by its contact with the concrete and/or concrete pore water. This high pH is caused by the abundant amounts of calcium hydroxide, and relatively small amounts of compounds of alkali elements sodium and potassium, in the concrete. Water samples collected from the inside of the drywell shell during the 2006 outage were measured to have a pH of approximately 8.4 to 10.2 and low levels of chloride and sulfate, which is consistent with NRC Generic Aging Lessons Learned (GALL) Report (Vol. 2, Rev. 1, at II A.1 through 5) and EPRI embedded steel guidelines for an environment that poses no aging management concerns. These water samples also had high levels of calcium which indicate slow migration through the concrete. Any subsequent water ingress into the concrete floor will also become high pH concrete pore water. That is why, based on commonly accepted scientific principles and my decades of experience, any corrosion of the embedded carbon steel drywell shell due to this water would be vanishingly small and of no engineering concern.

(PT, MPG) In addition, the air inside the drywell shell is inerted with nitrogen during operations, severely reducing the oxygen available to allow corrosion.

Q. 11: What do you mean that the inside of the drywell is inerted with nitrogen during operations?

A. 11: (PT, MPG) The interior of the drywell is air tight during operations. Ambient air is present in the drywell during outages, but is replaced with nitrogen for operations. AmerGen is permitted to operate OCNGS with up to 4% oxygen inside the drywell (which is slightly lower than the value provided in Citizens Exhibit 27). However, the drywell is typically operated with an oxygen concentration of less than 2%.

Q. 12: What is the impact on potential corrosion of the interior embedded drywell shell of this reduced oxygen concentration?

A. 12: (BG) There would be an order of magnitude less oxygen available to support corrosion. In any event, oxygen is not the limiting factor for potential corrosion of the interior embedded drywell shell surface where the presence of the concrete itself provides a protective pH of any water that would be adjacent to the drywell shell. Thus, the amount of oxygen has less importance here than it would for carbon steel not embedded in concrete.

Q. 13: Citizens' Exhibit 36, which includes an email from MPR Associates to AmerGen, states that "the protective pH cannot be presumed to exist during outages anywhere below 10'3" level in the [drywell]. [Structural Integrity] should evaluate the effect of combined oxygen and lower pH on corrosion during outages to estimate how much corrosion will occur during each outage, and show by calculation that it is insignificant." Can you explain what you did, if anything, in response to this recommendation?

A. 13: (BG) I do not recall performing any additional analyses in response to MPR's comment. In fact, I disagree with the comment that protective pH cannot be assumed to exist during outages beneath the interior drywell floor. In my opinion, the concrete will leach calcium hydroxide shortly after the water comes into contact with the concrete floor. Significant corrosion during outages or operations is not expected and has not been observed. If it had occurred, those who observed the internal surface of the drywell shell for the first time (it had previously been embedded in concrete) would have noticed it. Rather, their descriptions of the condition of the shell, as provided in Citizens' Exhibit 26, for example, do not support significant corrosion over the operating history of OCNGS, let alone just during outages.

IV. POTENTIAL CORROSION RATE

Q. 14: Dr. Hausler estimates a potential future corrosion rate for both sides of the drywell shell of 0.041" per year (A.16). Is this reasonable?

A. 14: (BG) No. I would first point out that Dr. Hausler appears to entirely ignore the limited exposure period (time of wetness = T_w) which, as I previously estimated based on Part 6 of my Direct Testimony, is limited to "approximately 30 days every 24 months." (A.13)

In my Direct Testimony, I applied the rate cited by Citizens of 0.017" per year to derive a total amount of potential corrosion expected during a month-long refueling outage at approximately 0.001". (A.15) Even if I were to adopt Dr. Hausler's speculative assumption that 0.002" per year of interior corrosion can take place (Hausler Direct, A.16), it would only result in a total expected corrosion of 0.005" (0.001" + 0.002" + 0.002") over two years. I must emphasize, however, that 0.002" per year interior corrosion is unrealistic for the reasons I describe above.

That being said, Dr. Hausler's Direct Testimony now estimates the potential total corrosion rate to be 0.039" per year, which I previously cited in my Affidavit Supporting Summary Disposition as the highest estimate of historical corrosion ever measured in the exterior OCNGS sand bed region.

Q. 15: Is it realistic to use a corrosion rate of 0.039" per year?

A. 15: (BG) No. In my Affidavit, I did not state that a future annual corrosion rate of 0.039" is realistic. In fact, I described a future scenario using this high rate as "unrealistic and overly conservative." This is because the conditions that existed at the time of this measurement are no longer present and would not be replicated there again. So even if the epoxy coating were to fail and water were to contact the underlying metal drywell shell, I would not expect corrosion to take place at the highest rate measured historically.

Nevertheless, if I assumed that the highest levels of corrosion ever experienced in the sand bed region could recur, the total potential corrosion during a refueling outage would be calculated as follows: I would divide 0.039" by 365 days to get a daily corrosion rate of 0.0001069" per day. I would then multiply this corrosion rate by 30 days to compute the total corrosion expected during a month-long refueling outage over two years, which is about 0.003". Even if we also account for Dr. Hausler's speculation about corrosion from the interior, we still only have slightly more than 0.007" (0.003" + 0.002" + 0.002") of potential corrosion over two years.

Q. 16: Dr. Hausler claims, in A.22, that AmerGen has not accounted for the high historical corrosion rates experienced in the sand bed region in its "latest acceptance calculations." Is this correct?

A. 16: (All) He is correct. However, the historical conditions that permitted these levels of corrosion are no longer present at OCNGS. It would be unreasonable and contrary to existing conditions to apply the high historical corrosion experienced when there was sand and essentially standing water in the sand bed.

Further, Dr. Hausler's analysis assumes that the exterior coating fails *and* that water would be present at all times. (A17, A21). Since AmerGen has taken multiple steps to mitigate water ingress into the region, the probability of water entering the sand bed region is very low. And the probability of such water entering the sand bed region undetected is even lower.

More importantly, Dr. Hausler fails to address the possible exposure period of the water, *i.e.*, the time of wetness. Since the known source of water on the exterior drywell shell occurs only when the reactor cavity is filled, the possible time of wetness is limited to approximately 30 days every 24 months. And Mr. Hosterman explained in his Direct Testimony that any water that might exist on the surface of the drywell shell at the end of an outage "would evaporate in a couple of hours." (Part 6, A.19)

Thus, there is no credibility to Dr. Hausler's analysis.

Q. 17: What future corrosion of the drywell shell in the sand bed region would you expect?

A. 17: (BG) Near zero. For the external surface, as I explained in my Direct Testimony: "[t]here can be no future corrosion unless the epoxy coating system fails in some manner . . . . The epoxy coating will prevent water with its dissolved cathodic reactant oxygen from coming into contact with the underlying metal shell." (Part 6, A.11) Even if the epoxy coating system fails, "I still need the ongoing presence of water . . . to have corrosion of the underlying carbon steel drywell shell." (Part 6, A.12) For the internal surface, the presence of concrete adjacent to a wetted drywell shell in the sand bed region limits corrosion to insignificant levels.

V. CONCLUSIONS

Q. 18: Please summarize your conclusions regarding Dr. Hausler's analysis of potential future corrosion in the sand bed region.

A. 18: (All) In summary, Dr. Hausler's testimony on the topic of potential future corrosion is based on inapplicable analyses and incorrect assumptions. Accordingly, Dr. Hausler's testimony should be given little weight. AmerGen has taken into account the actual conditions of the drywell shell in the sand bed region, and the actual potential corrosion mechanisms. Based on this, we conclude that AmerGen has established an appropriate aging management program.

Q. 19: Does this conclude your Rebuttal Testimony regarding the potential for future corrosion of the drywell shell in the sand bed region?

A. 19: (All) Yes.

In accordance with 28 U.S.C. § 1746, I state under penalty of perjury that the foregoing is true and correct:

______________________	8/14/07
Barry Gordon	Date
______________________	______________
Michael P. Gallagher	Date
______________________	______________
Peter Tamburro	Date

In accordance with 28 U.S.C. § 1746, I state under penalty of perjury that the foregoing is true and correct:

Barry Gordon	Date
Michael P. Gallagher	08-15-07
Michael P. Gallagher	Date
Peter Tamburro	Date

In accordance with 28 U.S.C. § 1746, I state under penalty of perjury that the foregoing is true and correct:

Barry Gordon — Date

Michael P. Gallagher — Date

Peter Tamburro — 8/16/07 — Date