RAS 14387

Staff Exhibit C

STAFF REBUTTAL TESTIMONY

Template=SECY-027

SECY-02

August 17, 2007

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
AMERGEN ENERGY COMPANY, LLC	)	Docket No. 50-219-LR
	)	
(Oyster Creek Nuclear Generating Station)	)	

NRC STAFF REBUTTAL TESTIMONY OF HANSRAJ G. ASHAR, DR. JAMES A. DAVIS, DR. MARK HARTZMAN, TIMOTHY L. O'HARA, AND ARTHUR D. SALOMON AND ANSWER TO BOARD QUESTIONS

Q1. Please state your name, occupation, and by whom you are employed.

A1(a). My name is Hansraj G. Ashar ("Ashar").[1] I am employed as a Senior Structural Engineer in the Division of Engineering, Office of Nuclear Reactor Regulation ("NRR"), U.S. Nuclear Regulatory Commission ("NRC"). A statement of my professional qualifications is attached to prefiled testimony I provided on July 20, 2007.

A1(b). My name is Dr. James A. Davis ("Davis"). I am employed by the NRC as a Senior Materials Engineer in the Office of Nuclear Reactor Regulation ("NRR"), Division of License Renewal. A statement of my professional qualifications is attached to prefiled testimony I provided on July 20, 2007.

A1(c). My name is Dr. Mark Hartzman ("Hartzman"). I am employed by the NRC as a Senior Mechanical Engineer in the Division of Engineering, Office of Nuclear Reactor Regulation ("NRR"). A statement of my professional qualifications is attached to prefiled testimony I provided on July 20, 2007.

---

[1] In this testimony, the sponsors of each numbered response are identified by their last name; no such designation is provided for paragraphs which are sponsored by all witnesses.

A1(d). My name is Timothy L. O'Hara ("O'Hara"). I am employed by the NRC as a Reactor Inspector in the Division of Reactor Safety, Region I Office. A statement of my professional qualifications is attached to prefiled testimony I provided on July 20, 2007.

A1(e). My name is Arthur D. Salomon ("Salomon"). I am employed by the NRC as a Research (Mathematical) Statistician. My duties include statistical consulting and technical project management for national laboratory contracts involving reactor operating experience data for risk analysis; industry trends for systems and component reliability and common cause failures; and performance indicators for mitigating systems at operating nuclear power plants. A statement of my professional qualifications is attached.

Q25. What is the purpose of your testimony?

A25. The purpose of this testimony is to rebut statements made by the other parties in testimony filed July 20, 2007, and to answer questions posed by the Atomic Safety and Licensing Board ("ASLB" or "Board") in a Memorandum and Order (Ruling on Motions in Limine and Motion for Clarification) (Aug. 9, 2007) ("August 9 Order") (unpublished).

Q26. Dr. Hausler (Testimony at 6; Citizens Exhibit 13 at 12) suggests that his contour plots of the Oyster Creek UT data indicate that a long groove of corrosion is present in Bays 1, 15 and 19. Did you observe such degradation on the exterior of the drywell?

A26. (O'Hara) No. My visual observation of Bays 11 and 13 (which I physically entered during the 2006 outage) did not show the existence of "long grooves of corrosion." I also reviewed all of AmerGen's visual inspection data sheets from 2006 for all bays. The data sheets did not document the presence of "long grooves of corrosion" on the exterior of the drywell in the former sand bed elevations. During the 2006 inspection, I also reviewed all of Oyster Creek's video and photographic records from 1992, 1994 and 1996 and did not note the presence of a "long groove" of corrosion.

Q27. Dr. Hausler (Testimony at 6; Citizens' Exhibit 13 at 19-21) suggests that some bays have long, thin, grooved areas thinner than 0.736 inch that could have a greater effect on the buckling capacity of the drywell shell. Do you agree?

A27. (Hartzman) No. Dr. Hausler used 1992 and 2006 UT wall thickness data to develop contour plots which he believes depict long, thin (almost horizontal) grooves that could affect the stability of the drywell more than square areas of corrosion of the same size.

The Staff examined the contour plots in Hausler Testimony, Attachment 4 at 19-21 (also Citizens Exhibit 13), and concluded that Figure 3, "Contour Plot for Bay 1, 2006, External UT Measurements," depicts an area that could resemble a "long, thin groove". Dr. Hausler claims that the entire bathtub ring area extending from 40 to -40 inches on the horizontal axis and from about -3 to -20 inches on the vertical axis is below the 0.736 inch criterion for general thinning and is much larger than the one square foot acceptance criterion. Citizens Exhibit 13 at 10. Dr. Hausler speculates that the contoured areas below 750 mils are of the order of 4 to 7 square feet all together. Citizens Exhibit 13 at 10. An evident limitation of these contour plots is that they do not show the exact boundary of the areas where the thickness is below the threshold value of 0.736 inch. It is therefore difficult to discern an accurate estimate of the area that is thinner than 0.736 inch.

Assuming, for the sake of analysis, that the contour plots are accurate, the contour plot of Bay 1 shows a local area that contains a horizontal thin elongated area in the shape of a trapezoid, that is shown on the contour plot as a region where the wall thickness is less than 0.725 inches. *See* Citizens Exhibit 13 at 19. This area could be described as a long, narrow groove. The dimensions of this trapezoid were measured off from the contour plot as 44 inches horizontal and 4.12 inches vertical. Based on these measurements, this area was calculated to be approximately 0.63 sq. ft. and increased by 10%, to account for the uncertainty of the location of the 0.736 inch threshold. Therefore, the area of this groove is estimated to be 0.69 sq. ft. A box on this contour plot states that the area less than 725 mils is about 6" to 7" wide and 80" long. This constitutes an area of 3.6 sq. ft. The elongated area is considerably smaller than the 3.6 sq. ft. given on the figure. Thus, the corroded areas shown on these contour plots may be significantly overestimated. In addition, the area of the sand bed shell in a bay is approximately 73 sq. ft. The elongated shape in this case constitutes less than 1% of the total Bay 1 sand bed area. A corroded area less than 1% of the total bay area will most likely have a negligible effect on the buckling capacity of the drywell shell in the sand bed region.

To ascertain the effect of the groove, or elongated shape, in the contour plot for Bay 1 on the local buckling capacity, or conversely, on the effective factor of safety (EFS) -- the theoretical stress divided by the actual stress -- in this area of the shell, the Staff estimated the EFS for the elongated area in the Bay 1 contour plot by first estimating the theoretical buckling stress for this geometry. Although this is a complicated geometry, an *estimate* of the local theoretical buckling stress for this geometry may be obtained by assuming that the elongated groove is a rectangular strip of infinite horizontal length and 4.12 inches vertical length, and is uniformly thinned to 0.665 inch. This is the minimum wall thickness of all the 2006 wall thickness data for Bay 1, as reported and used by Dr. Hausler to form the contour plot for this bay. *See* Haulser Testimony, Attachment 4 at 15. The strip is loaded horizontally in tension and vertically in compression. The vertical stress acting on this strip may be assumed to be the same as the compressive stress in the shell. The theoretical buckling stress for this strip is determined by considering a centrally loaded column with built-in ends of unit horizontal length, 4.12 inches in vertical length and a uniform thickness of 0.665 inch, constrained from lateral expansion in the horizontal direction. Calculations classify this column as a "short column;" such a column will not buckle either elastically or inelastically. It will simply deform in compression. The theoretical critical stress for this column was determined as 37,870 psi (99.6% of the yield stress of the material, 38,000 psi (as reported by GE)). The compressive stress in the refueling condition reported in the GE stability analysis is 7,588 psi. The compressive stress in the column is estimated as approximately 8,400 psi. Therefore, the EFS for the strip, and by extension for the finite groove, is approximately 4.5. This is more than twice that specified by the American Society of Mechanical Engineers ("ASME") Code. Similar calculations were also performed with column thickness of 0.636 inch and 0.536 inch. In both cases the EFS changed minimally, because the column remained classified as a "short column." On this basis, the Staff concluded that Bay 1 of the sand bed region containing the corroded shallow groove will not buckle or exceed the compressive yield stress of the material.

The Staff therefore concludes that Dr. Hausler has not provided sufficient evidence to support his assertion that the effect of long, narrow, shallow grooves on the local stability of the drywell shell will be greater than square areas. The above-described analysis is an approximate estimation of the EFS for this type of geometry. An exact determination requires a highly sophisticated and complex analysis. However, approximate calculations of this nature can inform staff decisions about reasonable assurance of structural integrity and operability under various service conditions.

Q28. Dr. Hausler asks (Citizens Exhibit 13 at 12) how much of a reduction in safety factor can be tolerated if there are local areas with thinner wall thicknesses? Do you have an opinion?

A28. (Hartzman) Yes. Physical local buckling of the sand bed shell may occur only when the EFS for sand bed shell approaches 1.0, by definition of the EFS. This would happen only if the entire drywell shell wall in the sand bed region were corroded to some uniform wall thickness. This wall thickness has not as yet been determined.

Assuming that the corrosion is as extensive and severe as Dr. Hausler's contour plots in Exhibit 13, the Staff estimates that the EFS in the sand bed shell is 1.9. Although this EFS is less than the FS of 2.0 specified by ASME Section III Code Case N-284-1, the Staff believes that the sand bed shell, with the current or potential corrosion, would not be susceptible to buckling.

However, should local buckling of the sand bed shell hypothetically occur, the consequences are believed to be minimal, for the following reasons. The basic function of the drywell shell during refueling operations is to provide structural support for the water-filled reactor refueling cavity, and to withstand an earthquake, should one occur simultaneously during refueling. The latter is a low probability event, so the loading on the drywell shell during refueling consists essentially of the load due to the water in the refueling cavity and its self weight. The limiting loads for buckling are only present during the short periods of time (less than a month) during a refueling outage, which at Oyster Creek occurs at a frequency of every two years. Under such a scenario, no containment function is necessary, since the plant is in cold shut down and the reactor system is unpressurized. Because the stresses in the shell reported by GE under refueling loads were significantly below the yield stress, hypothetical buckled areas within the drywell shell will not affect either the structural integrity of the drywell nor the ability of the drywell shell to perform its intended function. In addition, under normal operating conditions, the reactor refueling cavity is not filled with water, so the load caused by the water would not be present.

Q29. What are the statistical methods used to analyze Oyster Creek's UT data in Calculation No. C-1302-187-5300-011, Rev. 0 (6/13/1990) ("Calc 11") (AmerGen Exhibit 23)?

A29. (Salomon) Calc 11 uses the mean value of the thickness measured over a 6"x6" grid generally containing 49 data points. (Invalid points are set to zero and excluded from further use in the computations.) The variance is also determined. A Chi-squared ($\chi 2$) goodness-of-fit test is used to verify the assumption of normality. The $\chi 2$ test is performed at both the 5% and 1% levels of significance. *See* Exhibit 23 at 13 of 454.

An Analysis of Variance (ANOVA) F-test was used to determine if there is a significant difference among the means of the data sets. *Id.* at 11 of 454. Generally, an ANOVA F-test would be used when more than two means are being compared. A t-test is used when only two means are being compared.

The coefficient of determination, R-squared, is computed to show the percentage of total error explained by the regression, the higher the better. *Id.* at 12 of 454. Regression analysis is used to determine corrosion rates, where the slope of the regression line represents the corrosion rate and the upper limit of a 95% one-sided confidence interval is used to provide an estimate of the maximum probable corrosion rate. However, regression analysis is not appropriate when there are only two data points (as is the case in 1990) since the two points are sufficient to determine a straight line and no regression is needed. In that case, Calc-11 indicates that a t-test is used to determine if the difference in two mean thicknesses is statistically significant. Exhibit 23 at 13 of 454.

Tolerance limits (99%/99%) are computed in order to determine whether low thickness measurements are outliers or are statistically significant. F-tests are used to determine if variances are equal at the 5% and 1% levels of significance.

The use of regression analysis to estimate the (remaining) mean thickness is appropriate when there is enough data and using the lower limit of the one-sided 95% confidence interval (CI) as an estimated lower bound of the thickness is reasonable. The use of the corresponding lower limit for a CI under the Mean Model is also appropriate as an estimate of the lower bound of the thickness.

The F-ratio approach to assessing the degree of confidence in the predicted corrosion rate is a standard practice. The use of the "upper bound of the 95% one-sided confidence interval about the computed slope ... [as] an estimate of the maximum probable corrosion rate at 95% confidence" is also appropriate.

Q30. Are the statistical methods used in Calculation No. C-1302-187-E310-041, Rev. 0 (12/15/06) ("Calc 41") (Exhibit 20) the same as those used in Calc-11?

A30. (Salomon) Generally, yes. In Calc 41, AmerGen uses many of the same statistical computations and methods as were used in Calc 11 – mean, variance, standard deviation, standard error, linear regression, F-test, and F-ratio – and uses the skewness (which measures the relative positions of the mean, median and mode) and kurtosis (which measures the heaviness of the tails of distribution) of the data and normal probability plots to verify normality of the data. *See* Exhibit 20 at 12 of 55.

The biggest difference between Calc 11 (1990) and Calc 41 (2006) is that Calc 41 includes regressions because there are four data points (1992, 1994, 1996, and 2006) rather than just two as in Calc 11.

Although the methods used in Calc 11 (1990) and Calc 41 (2006) are generally consistent, there are changes. The increased reliance on regression analysis in Calc 41 (likely due to the increased number of data points) goes beyond what was actually done in Calc 11, but is understandable due to the increased number of data points.

Q31. Can the corrosion rate in the sand bed region be determined using the available UT data?

A31. (Salomon) In my opinion, only the average corrosion rate from 1992 through 2006 can be determined. Using regression analysis to make projections into the future is generally not advised unless there is very good evidence that there is a linear relationship with respect to time (i.e., with time as the independent input variable). Although only two points are needed to determine the equation of a straight line (regression equation), even four points are probably not enough to make precise estimates (i.e., estimates with narrow 95% confidence intervals) because of the limited sample size and due to the large interval between the last two measurements. Thus, there may not be a sufficient number of measurements to determine whether the corrosion rate is linear or constant.

Q32. In Citizens Exhibit 13 (at 3), Dr. Hausler states that "there are two kinds of number [sic], absolute ones and estimates." Do you agree?

A32. (Salomon) No. There are several kinds of numbers, among them real, rational, irrational, algebraic, and transcendental, natural numbers, and integers.

Q33. In Citizens Exhibit 13 (at 3), Dr. Hausler states that a number derived from a model is an absolute number and numbers derived from measurements are only estimates. Do you agree?

A33. (Salomon) No. While it is true that measurements are generally considered to be approximations, in that a measurement of 5 ⅛ inches is only a representation of a measurement which is between 5 1/16 inches and 5 3/16 inches, or between 5 inches and 5 1/4 inches, depending on the level of calibration of the measuring device (*i.e.*, whether the ruler is divided into sixteenths of an inch, eighths of an inch, or quarters of an inch), numbers derived from models may be estimates as well, especially if the coefficients of the model(s) are measurements or the input data to the models are measurements.

If the input data to model(s) include estimates, then the results or output of the model(s) must be considered estimates as well.

Q34. In Citizens Exhibit 13 (at 5), Dr. Hausler states, "A simple statistical principle says there is 'power in data' and the more data one can bring to bear on a statistical analysis, the more confidence one can have in the results." Do you agree?

A34. (Salomon) No. This statement is an oversimplification of a generally accepted statistical principle. In cases where there is difficulty in obtaining reliable data or the additional data may be subject to more variability, the analyst is charged with the task of balancing the need for data with the difficulty of collecting the data. Certainly, in cases where the act of collecting the data changes the data (*e.g.,* perhaps because of grinding a surface to enable use of a measuring device), collecting more data may not be advisable.

Q35. In his pre-filed testimony, Dr. Hausler stated in A21 that "it is not reasonable to assume that the [epoxy] coating [on the drywell exterior] will not fail during any period of extended operation." Do you agree with this statement?

A35. (Davis) No. It is difficult to predict the lifetime of these types of epoxy coatings. What is known is that poorly or improperly applied coatings tend to fail early in life, while coatings applied to surfaces that are properly prepared and coatings that are properly applied can survive for many years. The fact that visual inspections have determined that this coating system is in very good condition after 15 years of service, indicates that the surface was properly prepared and that the coatings were properly applied. *See* SER at 5-5 (visual inspection of the coating during the 2006 outage revealed the epoxy coating was in "very good condition with no evidence of degradation"). Another consideration for these coatings is they are not subjected to the stressors that may shorten the life of coatings, such as exposure to ultraviolet light, mechanical damage, exposure to high radiation areas, and exposure to high temperature. The coated surface is surrounded by the concrete containment and is not exposed to ultraviolet light, mechanical damage or high temperature. Furthermore, this coating system is commonly used for service where the coating is continuously under water. Thus, the absence of a continually wetted surface leads me to expect that the coating would have a prolonged service life.

Q36. In A21 of his prefiled testimony, Dr. Hausler states, "It is also not reasonable to assume that visual inspection could detect the early stages of coating failure." Do you agree with this statement?

A36. (Davis) No. When a steel surface corrodes, the oxide film that is generated has a higher volume than the original volume of the steel because iron in the steel is converted to iron oxide that is then hydrated. The film will be rust colored and will be obvious against the grey colored epoxy coating. Thus the early stages of coating failure would be apparent during a VT-1 inspection.

Q37. In A21 of his prefiled testimony Dr. Hausler states, "It is important to remember 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." Do you agree with this statement?

A37. (Davis) No. Dr. Hausler provides no rationale for his statements. Discussion of pitting situations is not relevant here. Pitting is a completely different corrosion mechanism that is not relevant to the alleged corrosion in pin holes in coating. In addition, the corrosion rate will not increase, but decrease over time.

When corrosion starts at defects in a coating on a steel substrate, the following reaction is the most common reaction to occur:

$2Fe + 9H_2O + 2O_2 = 2Fe(OH)_2 \cdot 6H_2O + H_2$, overall reaction

The overall reaction can be divided into half cell reactions that describe what occurs at the anode and cathode as follows:

$2Fe = 2Fe^{+2} + 4e$, anodic reaction

$9H_2O + 2O_2 + 4e = 4(OH)^{-} + 6H_2O + H_2$ cathodic reaction

The hydrated ferrous hydroxide (rust) that forms is much larger than the original iron atom on the surface of the steel and would be readily visible on the surface of the epoxy. In order for the reaction to continue once it begins, the water and oxygen atoms must diffuse through the rust and the hydrogen generated during the reaction with the water molecules and oxygen atoms must escape. As more rust is generated, it becomes more and more difficult for the water molecules and oxygen atoms diffuse to the steel surface and for the hydrogen gas to escape. In addition, as the drywell heats up to between 120 °F and 135°F while the reactor is operating, the solubility of oxygen in the water decreases, reducing the rate of corrosion.

Q38. In Attachment 5 (at 2) to Dr. Hausler's Testimony, Citizens note that the SER (Staff Exhibit 1) at 4-56 states that "UT measurements identified isolated, localized areas where the drywell shell thickness is less than 0.736 inches," that the Local Wall Acceptance Criterion "can be applied to small areas (less than 12" by 12"), which are less than 0.736" thick so long as the small 12" by 12" area is at least 0.536" thick," and that AmerGen indicated that measured locally thin areas totalled less than 0.68 sq. ft. Was the Staff's acceptance of the local acceptance criterion for thin areas less than 0.736 inch, for the extended period of operation, based upon an assumption that locally thin areas totalled less than .68 sq. ft.?

A38. (Ashar) No. In Request for Additional Information (RAI) 4.7.2-1, the Staff asked AmerGen to provide a summary of the factors considered in establishing the minimum required drywell thickness. *See* SER at 4-55. AmerGen's response provided information regarding various criteria used in evaluating the locally thin areas less than 0.736 inch. Acceptance for these areas was based on engineering calculation C-1 302-1 87-5320-024 (Rev. 0 and Rev. 1) ("Calc 24") (AmerGen Exhibits 17 and 18). One of the criteria is applied to small areas which are less than 0.736 inch thick, but greater than 0.536 inch in a square area of 12 inches by 12 inches. *See e.g.,* AmerGen Exhibit 17 at 6 of 54. AmerGen also describes the methods by which it met the ASME code provisions for buckling and primary membrane stresses. The Staff's acceptance of the criterion for the renewal period was based on the Staff's review of Calc 24, Revs. 0 and 1, and the relevant ASME Code sections to ensure that the parameters used and the assumptions made in the analysis were valid for the period of extended operation. *See* SER at 4-59.

AmerGen also described the impact of using these criteria for buckling and primary membrane stresses. AmerGen also commented that a review of the nondestructive examination (NDE) reports indicates that there are 20 UT measured areas in the whole sand bed region that have thicknesses less than the 0.736 inch and that the total measured area was 0.68 sq. ft. of the drywell surface with an average thickness of 0.703 inch or a 4.5 percent reduction in wall thickness. *Id.* at 4-58. Thus, the Staff's acceptance of the locally thin area criteria was not based on the locally thin areas measurements totalling 0.68 sq. ft.

However, AmerGen's statement that 0.68 sq. ft. is the total area of all measured locations having a thickness less than 0.736 in. indicates that locally thin areas are small in comparison to the total sand bed surface area of more than 700 sq. ft, and indicates that such areas are isolated and their effects on the buckling safety factor are not significant in the Staff's judgment.

Q39. In A15 of his prefiled testimony, Dr. Hausler concludes that areas thinner than 0.736 inch in Bays 1 and 13 are long grooves and not squares. Were the Staff's conclusions regarding the frequency of UT inspections based on the shape of AmerGen's acceptance criteria for local thin areas less than 0.736 inch?

A39. (Ashar) No. For structural modeling, engineers make a number of (conservatively biased) assumptions to estimate the sensitivity of certain parameters. In this case, Oyster Creek made a lower bound (conservatively biased) assumption that though the lowest UT measurement in 1992 was 0.618 inch (in 2006, it was 0.602 inch), it would bound all such degradation by assigning 0.536 inch thickness in one sq. ft. area with a one foot transition length to 0.736 inch thickness on all four sides, and estimated how the buckling safety factor would change as a function of modeling the areas less than 0.736 inch. *See* AmerGen Exhibit 18 at 10-11 of 117; AmerGen Exhibit 17. The Staff found Oyster Creek's approach for simulating the actual degradation acceptable. SER at 4-56 to 4-61. As part of the sensitivity analyses, Oyster Creek also performed a finite element analysis assuming 0.636 in. in one sq. ft. area. It resulted in a higher bucking safety factor than the accepted analysis. *Id.* at 4-58.

The Staff's acceptance of the frequency of UT monitoring was not based on the shape of the acceptance parameter. The Staff's acceptance was based on AmerGen's aging management program that includes periodic monitoring of the sand bed region for existence of new water, the functionality of sand bed drains, and the condition of the epoxy coating, as well as precautions to be taken during refuelling activities (including use of strippable coating). *See* SER (Staff Exhibit 1) at Appendix A, Commitment 27. The Staff also based its acceptance on the results of AmerGen's 2006 outage inspection which indicated the epoxy coating is in a good condition and no significant additional corrosion in the sand bed region.

Q40. Dr. Hausler implies (Exhibit 12 at 3) that Staff conclusions regarding the extent of corroded areas on the drywell shell in the sand bed area are based on grid measurements from the interior of the drywell shell. Do you agree?

A40. (Ashar) No. The Staff's judgment regarding the extent of corrosion was based on a number of considerations.

External measurements were taken at locations that were ground down to provide a flat surface for the UT probe. Citizens' use of only external measurements without regard to internal measurement is not representative of degradation of the drywell because it relies on the conservatively biased measurements and incomplete information regarding surrounding thicknesses.

As noted in the SER at 3-424, the coated surfaces of the former sand bed region were inspected during refueling outages of 1994, 1996, 2000, and 2004. These inspections showed no coating failure or signs of deterioration. Therefore, AmerGen concluded that corrosion in the sand bed region had been arrested, that no further loss of material would occur, and that monitoring of the coating in accordance with the protective coating monitoring and maintenance program will continue to ensure that the containment drywell shell maintains its intended function during the period of extended operation. *See* SER at 3-424.

In a letter dated December 3, 2006 (Citizens Exhibit 35, Enclosure), AmerGen provided information concerning the drywell inspections and ultrasonic (UT) measurements performed during the 2006 refueling outage. On the basis of visual inspections that indicated no visible deterioration, AmerGen confirmed that no further corrosion of the drywell shell is occurring on the exterior of the epoxy-coated sand bed region and, based upon UT measurement taken in the sand bed region from inside the drywell, concluded that corrosion on the exterior surfaces of the drywell shell in the sand bed region has been arrested. *See* SER at 3-424; Citizens' Exhibit 35.

From UT measurements taken in the trenches in drywell bays 5 and 17, AmerGen concluded that wall thinning of approximately 0.038 in. had taken place in each trench since 1986. On the basis of 106 UT measurements taken on the outside of the drywell in the sand bed region in 2006, AmerGen determined that the measured local thickness is greater than the local acceptance criteria of 0.49 in. for pressure and 0.536 in. for local bucking.

Based on AmerGen's above assertions, and commitments listed in the SER, Appendix A, the Staff concluded that the effects of aging will be adequately managed and the drywell shell will be able to perform its intended functions during the period of extended operation. Thus, the

Staff's conclusion regarding the extent of corrosion was not based solely on AmerGen's internal grid measurements.

Answers to Board Questions Posed in August 9 Order

Question 1: Define as used in the presented statistical analyses (a) population mean, (b) population variance, (c) sample mean, and (d) sample variance.

Response 1(a): (Salomon) A population in the statistical sense is the entire collection of items (or the entire collection of data) to be studied or analyzed. Assume the number of items in the population is N. A sample is a subset of the population. If the number of items in the sample is n, then $n \leq N$ (*i.e.*, the sample size n is less than or equal to the population size). Usually $n < N$ (*i.e.*, n is strictly less than N).

The population mean (usually denoted by μ) is the arithmetic average of all of the data in the population (the sum of all of the data items divided by the number of data items). That is, if each item in the population is denoted by x_i and there are N items in the population, then $\mu = (x_1 + x_2 + x_3 + \ldots + x_N)/N = \Sigma\, x_i/N$, where the sum is from i =1 to i = N.

Response 1(b): (Salomon) The population variance (usually denoted by σ^2) is the mean of the squared differences between each item in the population and the population mean (*i.e.*, $\boldsymbol{\sigma}^2 = \Sigma\,(x_i - \mu)^2/N$, where the sum is from i =1 to i = N).

Response 1(c): (Salomon) The sample mean (usually denoted by $\bar{x}$) is the mean of all of the items in the sample (the sum of all of the items in the sample divided by the number of items in the sample. That is, $\bar{x} = (x_1 + x_2 + x_3 + \ldots + x_n)/n = \Sigma\, x_i/n$, where the sum is from i =1 to i = n.

Response 1(d): (Salomon) The sample variance (denoted by s^2) is the sum of the squared differences between each item in the sample and the sample mean divided by n-1 — i.e., $\mathbf{s}^2 = \Sigma\,(x_i - \bar{x})^2/(n-1)$, where the sum is from i =1 to i = n.

Question 2: Explain the relationship between (a) population mean and sample mean, and (b) population variance and sample variance.

Response 2(a): (Salomon) In situations where it is impossible, impractical, or not sensible to collect data from each member of the population, the sample mean is used as an estimate of the population. In fact, the sample mean $\bar{x}$ of a random sample from a population is an unbiased estimator of the population mean μ.

Response 2(b): (Salomon) Similarly, the sample variance s^2 is computed when a sample is selected and the population variance σ^2 is unknown. In fact, the sample variance s^2 of a random sample from a population is an unbiased estimator of the population variance σ^2.

Question 3: Define "confidence" as used in the analysis of the thickness data in AmerGen's prefiled Exhibit 20, Calculation No. C-1302-187-E310-041, Statistical Analysis of Drywell Vessel Sandbed Thickness Data 1992, 1994, 1996, and 2006.

Response 3: (Salomon) The term "confidence" as used in the analysis of the thickness data in AmerGen's prefiled Exhibit 20, Calculation No. C-1302-187-E310-041, Statistical Analysis of Drywell Vessel Sandbed Thickness Data 1992, 1994, 1996, and 2006 denotes a statistical measure of the assurance that the constructed interval covers or includes the (population) parameter of concern or interest. Statistical "confidence" is expressed in terms of a probability (e.g., 0.95 or 0.99) or a percentage (e.g., 95% or 99%). The term "confidence" is often paired with an interval to define a concept (construct) known as a confidence interval (described in more detail in response 4, below).

Question 4: Discuss confidence interval and how the interval relates to the sample and population means and variances.

Response 4: (Salomon) Population means and variances are known as parameters in the sense that they are "true" measures of population characteristics. Sample means and variances are known as statistics in that they are used to estimate the respective population parameters when the parameters are unknown. In most cases the true population values – the population parameters – are unknown and are estimated by the corresponding sample statistics. (That is, in some sense, the sample statistics $\bar{x}$ and s^2 are used as proxies for the population parameters μ and σ^2.)

These estimates — the sample statistics $\bar{x}$ and s^2 — are known as "point" estimates because each is just one individual value to be used as an estimate for the desired unknown population parameter. Since $\bar{x}$ and s^2 are sample values, they may vary from one sample to another even though the population parameters they estimate remain constant. In order to assess how well the sample statistics $\bar{x}$ and s^2 are as estimators of the population parameters the concept of an interval estimate is used. In particular, the cited computations use a specific type of interval estimate known as a confidence interval (CI). More specifically, CI's about the mean are used. A CI about the mean comprises an interval and a level of confidence often expressed as a percent — e.g., 95% or 99%. Most of the CI's used in the relevant calculations are 95% CI's.

A confidence interval about the mean of a population assumed to be normal with unknown mean and variance, μ and σ^2, and sample mean and variance, $\bar{x}$ and s^2, is constructed as follows assuming a 95% confidence level and sample size n:

Let $\alpha = 1 - .95 = .05$ and, therefore $\alpha/2 = .025$. Let df equal the number of degrees of freedom, where df = n-1. Then $1 - \alpha/2 = 1 - .025 = 0.975$ and t(0.975, df) = t(.975, n-1) is the 97.5th percentile of a t-distribution with n-1 degrees of freedom (i.e., n-1 df).

The 95% CI is then defined as $\bar{x} \pm t(.975, n-1)\, s/\sqrt{n}$ where $\bar{x} - t(.975, n-1)\, s/\sqrt{n}$ is the lower limit (lower bound) of the 95% CI and $\bar{x} + t(.975, n-1)\, s/\sqrt{n}$ is the upper limit (upper bound) of the 95% CI.

Consider an example. Suppose $\bar{x} = 70$, $s^2 = 25$, and n = 49. Then a 95% CI for the mean is given by $70 \pm t(.975, n-1)s/\sqrt{49}$ is $70 \pm (2.011)(5/7)$ or 70 ± 1.436. This is an interval from 70 − 1.436 to 70 + 1.436 — i.e., an interval from 68.564 to 71.436.

How shall this be interpreted? Prior to computing the actual end points of the 95% CI, the endpoints of the intervals are random variables and it can be said that there is a 95% chance of getting a sample such that the interval constructed as above will contain the population mean μ.

However, once the interval is actually numerically determined (computed), the interval either contains the population mean μ, or it does not. Thus the probability will either be 1 or 0. But what the above procedure does is allow us to say that if we repeat the above procedure (for the same sample size), say 100 times, 95 of those intervals should contain the population mean μ.

Question 5. What is the students [sic] "t distribution" and what is its significance relative to estimation of the mean thickness?

Response 5: (Salomon) The student's "t distribution" is a distribution very similar to the standard normal distribution in that its mean is zero, it is symmetric about its mean, and it extends to "- ∞" on the left and to " + ∞" on the right. However, it depends on its number of "degrees of freedom" (d.f.) which is equal to the sample size minus one (i.e., d.f. = n-1, where n is the sample size). This means that the Student's t-distribution has a lower peak (mode) and fatter 'tails" than the standard normal distribution. The Student's t-distribution is used in place of the normal when the distribution is approximately normal and the sample size is small (n < 30), or when the distribution is (approximately) normal and the population variance (σ^2) is unknown. As the sample size n increases (and d.f. = n-1 increases correspondingly) the t-distribution approaches the normal distribution.

The significance of the t-distribution relative to the estimation of the mean thickness is that the t-distribution is used in the construction of a confidence interval (CI) about the mean because the true value of the population variance is unknown. The expression for a 95% CI about the mean (when the variance is unknown) is $\bar{x} \pm t(.975, n\text{-}1)\, s/\sqrt{n}$. Because the value of the t-variate t(.975, n-1) is larger than the corresponding value of the variate of the normal distribution z(.975) — often denoted $z_{.975}$ — a 95% CI for the mean based on a t-distribution (unknown population variance) is larger than the corresponding 95% CI for the mean based on a normal distribution (known population variance). This is the correct statistical approach despite the fact that the larger CI's mean slightly less precision in the estimates.

Question 6: What is the "F statistic" used in the regression model of corrosion and its significance relative to the corrosion data?

Response 6: (Salomon) The "F-statistic" (F-ratio) is a statistic based on the F distribution and is used to test the difference of two variances and also used to test whether there are "statistically significant differences among several sample means." Chris Sptaz & James O. Johnson, *Basic Statistics: Tales of Distributions*, (4th Ed. 1989).

The F-statistic or F-ratio is expressed as the ratio of two variances — $F = \sigma^2(1)/\sigma^2(2)$ — where the two variances being compared are $\sigma^2(1)$ and $\sigma^2(2)$. If the two variances are close to each other in magnitude, then the F-ratio is close to 1, implying that the null hypothesis H_0: $\sigma^2(1) = \sigma^2(2)$ is true. In this case the alternate hypothesis would be H_a: $\sigma^2(1) \neq \sigma^2(2)$ or more likely, $H_a = \sigma^2(1) \geq \sigma^2(2)$. According to work by J.M. Wetz in a dissertation prepared under Professor George E. P. Box at the University of Wisconsin in 1964 and cited in *Applied Regression Analysis* (Second Edition) by N. R. Draper and H. Smith, published in 1981 by John Wiley & Sons, the F-ratio "should exceed not merely the selected percentage point of the F-distribution, but at least *four times* the selected percentage point . . . for the fitted equation to be rated as a satisfactory prediction tool." This leads to the approach that the F-ratio should be at least 4 or 5 for a strong result and 8 or 9 for a very strong result.

Thus, the approach used in the calculations is consistent with generally accepted statistical practice.

Question 7: 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 all ten sources should be provided, or if they are insignificant, it should be so stated.

Response 7: This question is directed to AmerGen.

Question 8: Explain in greater detail how systematic error is accounted for in estimating the thickness and corrosion rate.

Response 8: (O'Hara) With respect to systematic error in data collection, AmerGen took steps in the 2006 drywell inspection to minimize and control potential sources of systematic error in their collection of the UT and visual inspection data. Steps taken by AmerGen to reduce and control systematic error were: 1) Use of procedures qualified to industry standards and AmerGen approved data collection procedures; 2) Use of qualified technicians specifically trained to perform these data collection activities; 3) Use of additional dedicated NDE Level 3 qualified personnel to supervise the data collection technicians in the drywell, providing continual NDE supervision to ensure that the procedure and the data collection were performed correctly and consistently in the field; and 4) Use of an external drywell thickness measurement technique (wave-skip methodology) to calibrate the UT instrument and to record the UT data, thus eliminating the need to manually measure the epoxy coating thickness separately.

By taking these steps, AmerGen was able to provide consistent application of their qualified procedures by trained technicians, supervised by dedicated Level 3 NDE personnel. These steps thus provided consistently reliable data (both UT and visual) for analysis, minimizing the potential for systematic error.

I did not observe the prior UT and/or visual inspections performed in 1992, 1994 and 1996 and cannot comment about steps taken by the plant owner, at that time, to minimize sources of systematic error.

(Salomon) Based on my reading of Calculation 41, systematic error in the 1996 measurements (i.e., the unexplained increase in the thickness data at previously measured sites) has not been accounted for in estimating the thickness and corrosion rate.

Question 9: (Directed to AmerGen)

Question 10: 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.

Response 10. (O'Hara) Ultrasonic thickness gauging consists of passing an ultrasonic wave, generated by a piezo-electric element, into a conducting material, such as a steel vessel or pipe wall, and timing the round trip of the sound pulse reflecting from the opposite wall. The functional components of the ultrasonic thickness gauging equipment is an electric pulse generator, timing circuit, and transducer containing the piezo-electric sound generator. Refinement has lead to digital circuits that can pulse and time ultrasonic pulses with a high degree of precision for very short durations. This increased accuracy allows modern instruments to capture the second set of reflections compensating automatically for coating thicknesses.

The digital ultrasonic instrument however is not able to determine from where the reflecting sound wave has originated. Some instruments add an oscilloscope display representing the sound path, called an 'A' scan, in order to allow the technician to determine where the reflecting signal originated. This allows for manual manipulation of the timing gate so that spurious signals can be excluded.

For convoluted reflecting surfaces, such as those corroded to a degree that causes a pitted surface, a special transducer is used, with the thickness gauging instrument, to increase the likelihood the returning signal from the nearest surface, bottom of the pit, is measured. This transducer is called a pitch-catch and consists of two piezo-electric elements set at angles to each other similar to the pitch of a roof. The elements are separated by an acoustic barrier to minimize cross talk. One element is optimized to send a signal and the other is optimized to receive a signal.

On smaller diameter (less than approximately 2 ft. radius) pipes, vessels or tubes, the transducer may rock side-to-side allowing the couplant under the edge of the transducer to cause higher or thicker readings than actually exist. This problem can often be corrected by making sure the divider in the transducer is oriented perpendicular to the axis of the pipe so that the major point of contact will include both sides of the transducer. This problem does not generally occur on larger diameter surfaces such as the Oyster Creek drywell shell, which has a radius significantly greater than two feet.

One advantage obtained by using a dual element transducer is the tendency of the unit to trigger from the nearest reflector, such as internal corrosion or pitting. Single element transducers tend to read the reflector with the largest surface area. For example, a deep farside pit with a small surface area may not be picked out from the larger backwall signal. As a result, single element transducers may result in thicker readings than what may actually exist at that point in the part or may miss small reflectors. *See* TNT The NDE Technician A Quarterly Publication for the NDT Practitioner, Jim Houf and Bill Svekric January 2004.

Once the aforementioned variables are compensated for procedurally by adequate calibration, appropriate settings of the equipment, and training of the technician, one can assume an accurate reading for thickness. AmerGen's procedure was written to compensate for the inherent variables and its personnel were adequately trained. A high degree of reliability is normally achieved by using UT for thickness measurements.

The National Association of Corrosion Engineers (NACE) recommends practices, and certifies coating inspectors in the processes needed for measuring ambient conditions and surface temperature, measuring surface profile depth, assessing surface cleanliness, sampling and testing for soluble salt contamination, calculating and measuring wet film thickness, measuring coating thickness, testing of coating adhesion, and detecting pinholes and holidays in coatings and linings. NACE does not address the determination of wall thickness and corrosion loss by ultrasonic testing. NACE does not have a report or specification related to this subject.

There are, however, other sources that address this subject. One familiar to anyone in the nuclear power industry is the program originally sponsored by the Electric Power Research Institute for the monitoring of Flow Assisted (or Accelerated) Corrosion. A common use of UT thickness measurements in the nuclear field is to monitor piping for Flow Accelerated Corrosion. This program was devised and computerized by Checzal and Horowitz and is known as the CHECWORKS system, a proprietary software code. The program uses the thickness derived from ultrasonic methods in order to determine the current wall thickness of a component, and, based on the difference between the current and last measurements, predicts the life of the component. The program uses this input, along with flow, temperature, and fluid phase. Generally, the industry practice is to use two methods to take measurements on a grid. One method is to lay out the grid and take a reading at each intersection. The other is to lay out the grid and scan the grid box for the minimum reading. No preconditioning of the data is necessary because the computer program uses the inputs directly. Statistical treatment of the data is not required (or provided in) the program because a safety factor is applied.

The ASME Code does not contain provisions regarding thickness gauging and does not specify the statistical treatment of statistical data.

The only prescriptive system for taking data is the grid descriptions in the Lloyd's of London and U.S. Coast Guard requirements for determining the seaworthiness of a steel ship. To my knowledge, those entities do not prescribe methods to reduce the data.

Based on my industry experience with using UT thickness gaging (i.e., wall thickness measurement) of flat, or essentially flat, plate, an accuracy of in the order of several mils is routinely achieved when proper training and procedures are used, however, accuracy is very dependent on the specific application.

In sum, while statistical analysis, whether mean or extreme value analysis, can be performed for a certain data set, there is generally no requirement or industry practice that required such analysis of UT data.

Question 11. One criterion for issuance of the renewal license is that the Commission must find that there is "reasonable assurance that the activities authorized by the renewed license will continue to be conducted in accordance with the [current licensing basis]" (10 C.F.R. § 54.29(a)). In the NRC Staff's prefiled testimony, it explains that the objective of the GE analyses performed in 1991-1992 was "to provide reasonable assurances that the structural integrity of the as-built shell would be maintained under refueling conditions, by showing that the stresses do not exceed ASME Section III Subsection NE limits" (NRC Staff Initial Statement at 14).

(a) The parties shall describe in detail how the term "reasonable assurance" has been defined and applied in the instant case. They shall also explain whether the NRC has a practice or policy for applying the "reasonable assurance" standard in cases where there are measurements of a particular physical condition that vary over a particular component or system and, therefore, must be statistically interpreted. In particular, the parties shall address whether a mean or average has been traditionally used by the NRC to determine "reasonable assurance," and whether a mean or average was used in the instant case. If neither is used, what criteria has been (and, in the instant case, is) actually applied. [footnote omitted]

A11. (Ashar) In order to assess the ability of a structure or component (SC) to perform its respective intended functions during the period of extended operation, the Staff reviews how the SC meets the current licensing basis (CLB), and whether the aging management program and/or the time-limited aging analysis is adequate to ensure its functional characteristics during the period of extended operation. The CLB includes the Updated Final Safety Analysis Report (UFSAR), engineering calculations, technical reports, engineering work requests, licensing correspondence (including Staff safety evaluations and licensee commitments), and applicable vendor reports.

Applicants for license renewal are also required to identify the components that would be subjected to time limited aging analysis (TLAA) (10 C.F.R. § 54.3). The proposed TLAAs are reviewed by the Staff to confirm that with the implementation of the identified TLAA, there is reasonable assurance that the SC will perform its intended function during the period of extended operation.

For the structures and components identified as requiring TLAA, 10 C.F.R. § 54.21(c)(1) provides that an applicant must demonstrate that (i) the analyses remain valid for the period of extended operation, (ii) the analyses have been projected to the end of the period of extended operation, or (iii) the effects of aging on the intended function(s) will be adequately managed for the period of extended operation.

In case of the Oyster Creek drywell shell, AmerGen identified "Drywell Shell Corrosion" as a TLAA and discussed it in section 4.7.2 of the License Renewal Application (LRA). AmerGen chose option (iii) for complying with the rule, and proposed an aging management program based on Subsection IWE of Section XI of the ASME code. During the course of the Staff's review, based on the actual condition of the shell, as well as the discovery of water in plastic bottles and in the trenches, AmerGen revised its program. The important features of AmerGen's aging management program are captured in Commitments 27 and 33 (Appendix A of the SER). Commitment 27 contains 21 items that include the monitoring of upper drywell shell, epoxy coating in sand bed area, and inside trenches. Item 21 of Commitment 27 provides that AmerGen will perform full scope of drywell, sand bed region inspections prior to the period of extended operation and then every other refueling outage thereafter. Full scope is defined as (1) UT measurements from inside the drywell, (2) visual inspections of the drywell external shell epoxy coating in all 10 bays, (3) inspection of the seal at the junction between the sand bed region concrete and the embedded drywell shell, and (4) UT measurements at the external areas inspected in 2006. AmerGen also plans to perform the inspections during the 2008 outage. Commitment 33 provides that AmerGen will monitor the epoxy coating periodically.

Thus, based on the Staff review performed and documented in Sections 3.0.3.2.23, 3.0.3.2.7, 3.5.2.2.1, 3.5.2.3.1, and Section 4.7.2 of the SER, the Staff concluded that the applicant has demonstrated that the aging effects associated with the primary containment components will be adequately managed so that the intended functions will be maintained consistent with the CLB for the period of extended operation, as required by 10 C.F.R. § 54.21(a)(3).

As part of the TLAA, when there are measurements of a particular physical condition, the Staff reviews any reasonable means (*e.g.*, trending based on the past experience, regression analysis based on the past data, documented industry experience, requirements of National Standards, e.g., AMSE, or statistically derived parameter) that would demonstrate to the Staff that the process is relevant and would maintain the structure or a component in a safe configuration. For example, for the evaluation of the grid data taken from inside the sand bed, the Staff has accepted the quasi-statistical process summarized in SER at 4-60. The October 2006 UT results were evaluated by AmerGen in Citizens Exhibit 35 and most of them met the criteria. In the two trenches, the UT evaluation process discovered thinning of the drywell shell as 0.039 inch between 1986 and 2006. The corrosion rate from this thinning can be derived in a number of ways. If it is assumed that most of the corrosion occurred from 1986 to 1992 (a reasonable assumption), from 1992 to 2006 there would be a low corrosion rate of 0.5 to 0.6 mils per year. If a linear corrosion rate is established considering 39 mils to have occurred in 20 years, the corrosion rate would be about 2 mils per year.

The UT measurements taken from outside the shell are not at random locations. They are taken at the locations judged to be the thinned areas. These locations were selected by qualified NDE inspectors, just after cleaning up the drywell shell, but prior to the application of three layer epoxy coating in the sand bed region. The results of the UT measurements in these areas have to be evaluated individually, and collectively to determine how they would affect the safety factor against buckling.

Assurance of adequately managing the effects of corrosion on the drywell shell (*see* 10 C.F.R. § 54.21(c)) is provided by compliance with NRC regulations. In order for the Staff to conclude that an aging management program or TLAA proposed by an applicant are adequate to ensure that a structure or a component will perform its intended function consistent with the

CLB during the period of extended operation, AmerGen has to propose the programs that provide assurance that it will adequately manage the effects of aging during the renewal period. Although the Staff accepts the use of regression analysis of the averages or means or a trend of averages or means to project particular parameter in the period of extended operation as part of the information which could show reasonable assurance, a pure statistical analysis is not a prerequisite for review and acceptance.

Question 12. 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 the physical properties (such as shell thickness) are averaged. Assuming the Board's understanding is correct (if the Board's understanding is incorrect, the parties should so state):

(a) The parties shall describe the sizes and shapes of those elements.

Response A12(a). (Hartzman). In GE's analysis, the sand bed region is represented mostly by 3"x3" quadrilateral elements and some triangular elements. The original model of the sand bed region assumed all elements representing the shell wall were uniformly 0.736 inch thick. The elastic material properties for all elements were assumed to be the same as those of the shell. The Board's statement that the original GE analysis employed a model that "broke" the shell into "elements" of discrete size and shape, with average material properties is not entirely correct. The shell was not "broken" up; it was represented conceptually by a discrete mathematical model for analytical purposes, in which thickness, material properties and physical continuity of the shell were maintained just as in the actual body.

Question 12(b). [I]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, and if so, the magnitude of those differences.

A12(b). (Hartzman) Elements properties are characterized by their shape, dimensions and material properties. The number of elements would need to be increased (and the size of those elements reduced) locally to capture some of the small areas in the pattern of corrosion depicted on the contour plots. The dimensions and size of the elements would also need to change to match the shape of the contours. The material properties listed above would remain the same, since these are not affected by corrosion. The current GE mesh would not be adequate to capture the very fine detail in some of the patterns of corrosion indicated on the contour plots. However, very fine details generally are not modeled in engineering design unless there is a specific need, such as studies in fracture mechanics, which was not the intent of the GE study.

Question12(c). [I]ndicate 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 that those used by AmerGen.

Response 12(c). (Hartzman) Conservatism may be viewed in terms of the ability of a finite element mesh to bound a desired response. The conservatism of the GE analysis used by AmerGen to define wall thickness acceptance criteria may be judged by the capability of the model to capture the fundamental buckling mode shape in the reduced thickness regions. This, in turn, depends on the fineness of the mesh used to represent the finite element model of the region. The conservatism of this model, i.e., the sizes of the elements and the number of elements, is considered adequate based on the fact that GE was able to determine the fundamental buckling mode shape.

The current mesh would not accurately capture the fine details in some of the patterns of corrosion depicted on the contour plots.

Question 12(d). 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 (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?

Response 12(d). (Hartzman) The Staff has concluded that the corroded areas shown on the contour plots may be significantly overestimated. This conclusion is based on an evaluation of the contour plot of the Bay 1 contour plot in Exhibit 13 (at Fig. 3). Hausler Testimony, Attachment 4 at 19. This plot depicts a long, narrow groove, measuring less than or equal to 0.725 in. thick and approximately 44 inches long by 4.12 inches high. Based on these measurements, the Staff has estimated the area of this groove as 0.69 sq. ft. This area is considerably smaller than the 3.6 sq. ft. stated on the contour plot as being less than 725 mils. On the basis of this evaluation, the Staff believes that this is also representative of the other plots (*i.e.*, extent of the corroded areas may be significantly overestimated.

To ascertain the effect of the groove in the contour plot for Bay 1 on the local buckling capacity, or conversely, on the effective factor of safety (EFS) of the shell, the Staff estimated the EFS for an equivalent rectangular strip representing the long groove. The strip was assumed to be of infinite horizontal length and 4.12 inches vertical length, uniformly thinned to 0.665 inch. This is the minimum wall thickness of all the 2006 wall thickness data for Bay 1, as reported and used by Dr. Hausler to form the contour plot for this bay. Citizens Exh. 13 at 15. Hausler Testimony, Attachment 4 at 15. The Staff determined that the failure mechanism of the strip is not buckling but axial compression. The theoretical critical stress for the strip was determined as 37,870 psi. Based on an estimated compressive stress in the refueling condition of approximately 8,400 psi, the EFS for the strip, and by extension for the finite groove, was determined as 4.5. This is more than twice the safety factor specified by the ASME Code. Similar calculations performed with column thickness of 0.636 inch and 0.536 inch determined that the EFS changed minimally. On this basis, the Staff generally concludes that the effect of long, narrow, shallow grooves, as represented by the dimensions of the elongated shape on the contour for Bay 1, on the local stability of the drywell shell will be less than square areas, provided the wall thickness is greater than 0.536 inch. Where the wall thickness of such long, narrow, shallow grooves is smaller than 0.736 inch, the current local buckling criteria are most likely also applicable.

An exact determination of the EFS for this type of geometry requires a highly sophisticated and complex analysis. However, approximate calculations of this nature performed by the staff during reviews often form part of the basis for obtaining "reasonable assurance" of structural integrity and operability under various service conditions.

Question 12(e). Because Oyster Creek's current licensing basis (CLB) is based on the GE methodology and explicit elementization of the model for the drywell shell, discuss whether consideration of a different model or elementization would constitute, under NRC regulations, a challenge to the CLB.

Response 12(e). (Ashar, Hartzman) The CLB for Oyster Creek is in part based on acceptance criteria derived from 1991-92 GE analyses. A consideration of a different model or elementization in an attempt to impose different acceptance criteria would be a challenge to the CLB as it would not be encompassed by the safety analysis of record. For example, if AmerGen wants to revise its acceptance criteria to values that are not encompassed by the GE analyses (e.g., less stringent drywell shell thickness criteria) based on the results of the three-dimensional finite element analysis referenced in Commitment 27, Item 18, AmerGen would have to submit that analysis for NRC review and approval. If approved, it would become part of the CLB.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
AMERGEN ENERGY COMPANY, LLC	)	Docket No. 50-219-LR
	)	
(Oyster Creek Nuclear Generating Station)	)	

AFFIDAVIT OF HANSRAJ G. ASHAR

I, Hansraj G. Ashar, do hereby declare under penalty of perjury that my statements in the foregoing rebuttal testimony are true and correct to the best of my knowledge and belief.

Hansraj G. Ashar

Executed at Rockville, MD
this 17th day of August, 2007

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
AMERGEN ENERGY COMPANY, LLC	)	Docket No. 50-219-LR
	)	
(Oyster Creek Nuclear Generating Station)	)	

AFFIDAVIT OF JAMES A. DAVIS, PH.D

I, James A. Davis, do hereby declare under penalty of perjury that my statements in the foregoing rebuttal testimony are true and correct to the best of my knowledge and belief.

James A. Davis, Ph. D

Executed at Rockville, MD
this 17th day of August, 2007

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
AMERGEN ENERGY COMPANY, LLC	)	Docket No. 50-219-LR
	)	
(Oyster Creek Nuclear Generating Station)	)	

AFFIDAVIT OF MARK HARTZMAN, PH. D

I, Mark Hartzman, do hereby declare under penalty of perjury that my statements in the foregoing rebuttal testimony are true and correct to the best of my knowledge and belief.

Mark Hartzman PhD.

Mark Hartzman, Ph. D

Executed at Rockville, MD
this 17th day of August, 2007

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
AMERGEN ENERGY COMPANY, LLC	)	Docket No. 50-219-LR
	)	
(Oyster Creek Nuclear Generating Station)	)	

AFFIDAVIT OF TIMOTHY L. O'HARA

I, Timothy O'Hara, do hereby declare under penalty of perjury that my statements in the foregoing rebuttal testimony are true and correct to the best of my knowledge and belief.

Timothy L. O'Hara

Executed at Medford, NJ
this 17th day of August, 2007

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
AMERGEN ENERGY COMPANY, LLC	)	Docket No. 50-219-LR
	)	
(Oyster Creek Nuclear Generating Station)	)	

AFFIDAVIT OF ARTHUR D. SALOMON

I, Arthur Salomon, do hereby declare under penalty of perjury that my statements in the foregoing rebuttal testimony and my statement of professional qualifications are true and correct to the best of my knowledge and belief.

Arthur D. Salomon

Executed at Rockville, MD
this 17th day of August, 2007

Arthur D. Salomon
Statement of Professional Qualifications

CURRENT POSITION:

Research (Mathematical) Statistician
Probabilistic Risk Analysis Branch, Division of Risk Analysis and Applications
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission, Rockville, MD

EDUCATION

B.S. (with distinction), Mathematics	University of Michigan, April 1968
M.A., Mathematics	University of Maryland, June 1971
Ph.D. Candidate	University of Maryland, 1971 - 1974 Completed all requirements for Ph.D. in Mathematics, except for dissertation.
D.Sc. Candidate	George Washington University, 1974- 76, 1979- 87 Part-time study in statistics and operations research; completed all requirements for D.Sc. in operations research, except for dissertation.

EXPERIENCE

July 2002 – present **Research (Mathematical) Statistician**

Responsible for review of the statistical uncertainty analysis part of the nuclear risk analysis for the Light Weight Radioisotope Heater Units (LWRHU) fueled with Pu-238 and containing other sealed sources of radionuclides used in the Mars Exploration Rover (MER) — 2003 project (with NASA and DOE).

Responsible for review of techniques used in parameter estimation for probabilistic risk assessment (PRA), and for coordination and reconciliation of comments on the PRA parameter estimation handbook. I participated in a verification and validation of SAPHIRE — a set of computer programs code used for PRA analysis, mainly for nuclear power plants.

Developed procedure for determining adverse trends in unidentified leakage rates — in support of Davis-Besse Lessons Learned Task Force.

Preparation of SOW tasks to support NRR for development of approach to construction sampling (ITAAC) for combined operating license (COL) for nuclear reactors.

Reviewed and provided comments on a strategy for hydro-geologic modeling and uncertainty analysis for nuclear facilities and sites.

Reviewed and commented on a framework for risk informing regulation of nuclear reactors using PRA methods, and reviewed a standard developed by The American Society of Mechanical Engineers (ASME) for PRA assessment for nuclear power plant applications. Provided internal statistical consulting on uncertainty analyses. Also involved in consultation on aviation risks associated with dry cask storage at nuclear power plant sites.

May 1990 – July 2002 **Electronics Engineer, Deputy Program Manager, Management and Program Analyst, General (Systems) Engineer, and Statistician**
Federal Aviation Administration, Washington, DC

Feb. 2000 – July 2002 Responsible for the General Aviation (GA) survey — including review of sample design, sample allocation, estimation procedures, review of survey results, and coordination of other issues related to the survey. Responsible for other GA issues, including GA forecasts, preparation of GA point papers for the FAA Administrator, and development of the GA chapters of the annual FAA forecast documents. Received cash award for the GA survey work and was granted a retention allowance by the FAA.

Provided statistical consulting to the analysts and economists in my office and throughout the agency. Served as a member of several GA related aviation subcommittees of the Transportation Research Board (TRB) and briefed them on the status of GA at annual and semi-annual meetings.

March 1998 – Feb. 2000 Served as a general (systems) engineer in the Concept Development Branch, responsible for developing a white paper on issues involving National Airspace System (NAS) modernization and its impact on airports. Significant participant in the FAA process improvement (PI) program and in the development of the FAA integrated Capability Maturity Model (FAA-iCMM); co-authored the FAA-iCMM Appraisal Method. Participated in CMM assessments and development of training for process improvement; involved in the development of metrics for program management. (Received awards for work related to the PI effort and the metrics development.)

July 1995 – March 1998 Served as a management and program analyst on the National Airspace System (NAS) Planning Team where I was responsible for development of (economic) service life data to be used in the preparation of needs-based resource requirements for the Long Range Resource Allocation Plan. I also began my involvement in systems engineering assessments as a member of the Systems Engineering Capability Maturity Model (SE-CMM) evaluation team.

In late 1996, the office was realigned, my branch was eliminated and I was reassigned to the NAS Concept Development Branch where I continued to serve as a management and program analyst until I was reclassified as a general (systems) engineer in March of 1998.

May 1992 – July 1995 Served as the deputy program manager (DPM) for terminal automation and DPM for en route, tower, and training automation — responsible for acquisition and installation of airport traffic control tower display and automation equipment, automated terminal radar display systems, and en route systems software development. Performed an active role in technical reviews, technical interchange meetings, deployment readiness reviews, and development of program budgets and schedules. As a result of a reorganization in late 1994, my office was combined into the Office of Air Traffic Systems Development (AUA). I was reassigned to the AUA Business and Financial Staff (AUA-10) where I served on that from late 1994 through July 1995. I was responsible for special projects – office business plan development as a member of the business plan team; AUA technical assistance contract (TAC) as a member of the source evaluation board and chairman of the technical evaluation team.

May 1990 – May 1992 Served as an electronics engineer on the Voice Switching and Control System (VSCS), and as lead FAA systems engineer on VSCS —responsible for engineering requirements and system reliability and availability requirements for the technical evaluation team and for the acquisition team after the contract was awarded. Responsible for assembling (from industry and academia) the members of the VSCS Independent Fault Tolerance Assessment Team (VIFTAT) and for acting as advisor to the team.

March 1986 – May 1990 **Senior Engineer Specialist**
Stanford Telecommunications, Inc. (STel)
Washington, DC

As a senior engineer specialist (automation/reliability), served as the reliability/ maintainability/availability (RMA) task leader for the systems engineering support contractor to the FAA's Advanced Automation System (AAS) design competition phase (DCP) and acquisition phase (AP). Had primary responsibility for reviewing all fault tolerance and RMA activities and efforts — related to system design and performance – of the DCP contractors and AP prime system contractor. I reviewed reliability designs, reliability data collection, hardware and software reliability modeling and estimation, fault tolerance design specifications, and RMA planning and improvement. I also performed a similar role on the VSCS program just prior to joining the FAA.

Conducted an independent software reliability (probabilistic) risk assessment of the AAS software development. Provided suggestions for improving reliability modeling and estimation — based on advances in reliability research, including incorporation of expert opinion and Bayesian techniques.

Oct. 1985 – March 1986 **Senior Statistician**
Science Applications International Corporation (SAIC),
McLean, VA

Served as the senior statistician of this SAIC group, which provided technical support to the Ground Launched Cruise Missile (GLCM) program office of the Johns Hopkins University/

Applied Physics Laboratory (JHU/APL) and to the Pershing missile program office. Participated in developing data collection methods; responsible for reviewing statistical procedures used for missile reliability and accuracy analysis. Provided recommendations for improvements to statistical analyses based on current research, and was responsible for apprising the group of advances in statistics research, operations research, and reliability.

Oct. 1983 – Dec. 1985 **Systems Engineer**
The MITRE Corporation, McLean, VA

Provided support to FAA air traffic control systems development by developing functional and performance requirements (and specifications) for Automated En Route Air Traffic Control (AERA) capabilities for the FAA AAS System Level Specification (SLS). I developed a set of performance measures for AERA capabilities and prepared a series of technical papers discussing issues involved in AERA function validation.

Served as a member of the Host Computer system (HCS) Independent Technical Assessment Group — responsible for evaluating system reliability, reliability growth, and other RMA issues. Developed a set of reliability growth requirements for the HCS which led to the successful deployment and operational performance of the HCS.

Oct. 1978 – Oct. 1983 **Mathematical Statistician**
Bureau of Labor Statistics (BLS), Washington, DC

As a (senior) mathematical statistician with BLS, was responsible for sample size determination and sample allocation for BLS Area Wage Surveys, Industry Wage surveys, and Service Contract Act Surveys. Responsible for all statistical aspects of these surveys including weighting and non-response adjustment; was also responsible for annual development of the universe file/sampling frame used in BLS surveys.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
AMERGEN ENERGY COMPANY, LLC	)	Docket No. 50-219-LR
	)	
(Oyster Creek Nuclear Generating Station)	)	

AFFIDAVIT OF HANSRAJ G. ASHAR

I, Hansraj G. Ashar, do hereby declare under penalty of perjury that NRC Staff Exhibits B (Staff Initial Testimony), C (Staff Rebuttal Testimony) and C.1 (Staff Sur-Rebuttal Testimony), as corrected, are true and correct to the best of my knowledge and belief.

Hansraj G. Ashar

Executed at Rockville, MD
this 20th day of September, 2007

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
AMERGEN ENERGY COMPANY, LLC	)	Docket No. 50-219-LR
	)	
(Oyster Creek Nuclear Generating Station)	)	

AFFIDAVIT OF JAMES A. DAVIS, PH. D

I, James A. Davis, Ph. D, do hereby declare under penalty of perjury that NRC Staff Exhibits B (Staff Initial Testimony), C (Staff Rebuttal Testimony) and C.1 (Staff Sur-Rebuttal Testimony), as corrected, are true and correct to the best of my knowledge and belief.

James A. Davis, Ph. D

Executed at Rockville, MD
this 20th day of September, 2007

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
AMERGEN ENERGY COMPANY, LLC	)	Docket No. 50-219-LR
	)	
(Oyster Creek Nuclear Generating Station)	)	

AFFIDAVIT OF MARK HARTZMAN, PH. D

I, Mark Hartzman, Ph. D, do hereby declare under penalty of perjury that NRC Staff Exhibits B (Staff Initial Testimony), C (Staff Rebuttal Testimony) and C.1 (Staff Sur-Rebuttal Testimony), as corrected, are true and correct to the best of my knowledge and belief.

Mark Hartzman
Mark Hartzman, Ph. D

Executed at Rockville, MD
this 20th day of September, 2007

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
AMERGEN ENERGY COMPANY, LLC	)	Docket No. 50-219-LR
	)	
(Oyster Creek Nuclear Generating Station)	)	

AFFIDAVIT OF TIMOTHY L. O'HARA

I, Timothy L. O'Hara, do hereby declare under penalty of perjury that NRC Staff Exhibits B (Staff Initial Testimony), C (Staff Rebuttal Testimony) and C.1 (Staff Sur-Rebuttal Testimony), as corrected, are true and correct to the best of my knowledge and belief.

Timothy L. O'Hara

Timothy L. O'Hara

Executed at Rockville, MD
this 20th day of September, 2007

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
AMERGEN ENERGY COMPANY, LLC	)	Docket No. 50-219-LR
	)	
(Oyster Creek Nuclear Generating Station)	)	

AFFIDAVIT OF ARTHUR D. SALOMON

I, Arthur D. Salomon, do hereby declare under penalty of perjury that NRC Staff Exhibits C (Staff Rebuttal Testimony) and C.1 (Staff Sur-Rebuttal Testimony), as corrected, are true and correct to the best of my knowledge and belief.

A D Salomon

Arthur D. Salomon

Executed at Rockville, MD
this 20th day of September, 2007