

RAS 14222

U.S. NUCLEAR REGULATORY COMMISSION

DOCKETED  
USNRC

APPLICANT'S EXH. 15

In the Matter of AMERGEN ENERGY CO. LLC  
 Docket No. 50-0219-LR Official Exhibit No. 15  
 OFFERED by Applicant/Licensee Intervenor \_\_\_\_\_  
 NRC Staff \_\_\_\_\_ Other \_\_\_\_\_  
 IDENTIFIED on 9/20/07 Witness/Panel N/A  
 Action Taken: ADMITTED REJECTED WITHDRAWN  
 Reporter/Clerk DM

October 1, 2007 (10:45am)  
 OFFICE OF SECRETARY  
 RULEMAKINGS AND  
 ADJUDICATIONS STAFF

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# Safety Evaluation Report

Related to the License Renewal of Oyster Creek  
 Generating Station

Docket No. 50-219

AmerGen Energy Company, LLC

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U.S. Nuclear Regulatory Commission  
 Office of Nuclear Reactor Regulation  
 March 2007



the drywell shell in the inspection trenches in drywell bays #5 and #17. AmerGen will monitor the two trenches for the presence of water during each refueling outage. The staff identified this commitment item as a license condition.

#### Ultrasonic Testing Measurement Issues

In the sand pocket region of the drywell shell, the most susceptible bays are incorporated in the sampling. However, the staff believes that readings should be taken at vulnerable locations and that UT techniques are reliable. The first issue is addressed as part of Open Item 4.7.2-1.2 and the second issue is addressed below.

The second item is that a review of UT data indicates that the UT measurements taken from inside the drywell after 1992 show a general increase in the metal thickness. In some cases, the average increase is as much as 40 mils in a 2-year timeframe. In general, it appears that the UT measurements taken after 1992 require proper calibration, considering the coatings on both sides of the drywell shell. The staff requested that the applicant address this issue during a public meeting held June 1, 2006.

In its response dated June 20, 2006, the applicant provided the following discussion of sensitivities involved with the UT measurement process and how they will be minimized in the future:

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UT Instrumentation Uncertainties. The UT instrumentation, which includes the transducer, cable and ultrasonic unit, will be calibrated to within approximately +/- 0.010 inches. Exelon Procedure (ER-AA-335-004) step 4.1.3 requires that the UT instruments must be checked within 2% of the calibration standard (block) prior to use. For the sand bed region, which is nominally 1" thick, a 1-inch thick calibration standard block is used. This results in checking the UT instrument to within 0.020" inches or +/- 0.010". UT instrumentation accuracy is verified under controlled conditions where UT thickness readings are performed on calibration blocks. The calibration blocks have been precisely machined to prescribed thicknesses, which are then verified by micrometer readings.

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Actual Drywell Surface Roughness and UT Probe Location Repeatability. Due to the corrosion, the outside surface of the Drywell Vessel is not smooth and uniform. The surface condition is indicative of general corrosion, which is rough with high and low points spaced very closely together. This profile was verified when the sand was removed in 1992. The UT Instrumentation probes are 7/16" in diameter and are dual element transducers (i.e. half transmits sound and the other half receives). The probes emit a focused beam that measures an area significantly smaller than 7/16" diameter and will record the thinnest reading within that area.

Because the surface roughness of the drywell within this 7/16" diameter can vary, the probe must be placed at precisely the same location to precisely repeat a thickness reading. A slight shift of the probe will result in a reading which is correct, but different from a previous reading.

The variability associated with this factor is reduced by the use of the stainless steel template. The template has been manufactured with holes in a 7 by 7 pattern on 1 inch centers. Each of the 49 holes has been machined with a diameter so that the UT probe fits within each hole snugly. The templates are machined with 1/16" wide slits on each

edge of the template at 0, 90, 180, and 270 degrees. During inspections the slits in the template are lined up with permanent marks that were placed on the drywell shell when the location was originally inspected. The UT readings are then taken by placing the probe inside each hole in the template.

Inspection procedures require that NDE personnel performing the inspection place the template precisely on the permanent markings.

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Actual Drywell Surface Roughness and UT Probe Rotation. The UT probe sends the signal from one side of the probe and receives the signal on the other side. The probe must be oriented in the same plane in order to measure exactly the same point. Test data taken on a mock up with similar roughness showed that a variance up to 0.016 inch was noted when rotating the probe 360 degrees over the same spot. Therefore, a slight rotation of the probe will result in a reading, which is correct, but different from a previous reading.

Inspection procedures require that NDE personnel performing the inspection place the probe in the same orientation.

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Temperature Effects. Significant temperature differences between inspections may result in a shift in the material thickness. Therefore, the inspection specification will require that NDE personnel performing the inspection record the surface temperature of the area that is inspected.

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Batteries. Inspection specifications require the installation of new batteries prior to each series of inspections.

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NDE Technician. Inspection specifications require that personnel conducting UT examinations be qualified in accordance with Exelon Procedure ER-AA-335-004.

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Calibration Block. Exelon Procedure ER-AA-335-004 requires that calibration blocks used during the inspection be inspected to verify that the ultrasonic response equals the physical measurement.

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Internal Surface Cleanliness. The inspection areas are covered with a qualified grease to protect the examination surface from rusting between inspection periods. The grease must be removed prior to the inspection and reapplied after the inspection. Tests performed in April and May of 2006 show that the presence of the grease will increase the readings as much as 12 mils. In 1996, the governing specification did not clearly specify the requirement to remove the grease prior to the inspection. 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.

The inspection procedures will clearly require that personnel conducting UT examinations remove the grease prior to performing the examination.

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UT Unit Settings. 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. Future inspections will use modern "state of the art" UT units that do not have gain

settings.

Identification of the Physical Inspection Location. There is a potential that inspection locations may be mislabeled on the data sheets. The inspection procedures uniquely and clearly identify each inspection location and provide the specific instruction as to the area's location.

Data Analysis. The above potential variables will be considered in the analysis of the data. The analysis not only determines a mean for each grid or sub-grid, but also the variance of the means. These variances will be compared to past inspections to ensure consistency. The mean and the variance are compared to the acceptance criteria.

In addition, the mean UT thickness values for a current inspection will be computed and compared to the previous inspection prior to restarting from an outage. If data anomalies similar to 1996 are identified corrective actions will be taken, including new UT measurements, as necessary, to ensure accuracy of measurements.

Based on the applicant's discussion of the variables involved in the UT results, the staff finds it reasonable to conclude that the anomalous readings of 1994 and 1996 could be attributed to one or more of the factors enumerated in the discussion. The staff was concerned about systematic corrections to the UT measurements and could not determine the basis for the applicant's use of the anomalous readings nor systematic corrections. The applicant could not isolate the factors that contributed to these anomalous results; therefore, it plans to utilize the lessons learned from the experience for the future UT examinations. On the basis of the applicant's written response, the staff determined that its concerns have been resolved.

#### 4.7.2.2.2 Minimum Drywell Thickness

In RAI 4.7.2-1 dated March 10, 2006, the staff requested that the applicant provide a summary of the factors considered in establishing the minimum required drywell thickness.

In its response dated April 7, 2006, the applicant explained that the factors considered in establishing the minimum required drywell thickness at various elevations of the drywell are described in detail in engineering analyses documented in two GE reports, Index Nos. 9-1, 9-2, and 9-3, 9-4. Report Index No. 9-1, 9-2 was generated for the drywell condition with sand in the sand bed region and Report Index No. 9-3, 9-4 addressed the drywell condition without sand in the sand bed region. The two reports were transmitted to the staff in December 1990 and 1991, respectively. Report Index No. 9-3, 9-4 was revised later to correct errors identified during an internal audit and was resubmitted to the staff in January 1992. The analysis described in Report Index No. 9-3, 9-4 (i.e., without sand) is the current applicable analysis for the drywell.

In its response the applicant also noted that it based the analysis on the original code of record, ASME Code, Section VIII, and Code Cases 1270N-5, 1271-N, and 1272N-5. The ASME Code and its Code Cases do not provide specific guidance in two areas. The first relates to the size of a region of increased membrane stress due to thickness reductions from local or general corrosion effects, and the second pertains to the allowable stresses for Service Level C or post-accident conditions. In the first case, guidance was sought from ASME Code Section III, NE-3213.10. For Service Level C or post-accident conditions, the SRP-LR was used as guidance to develop the allowable stresses. Additionally, the applicant summarized the analysis efforts in the following paragraphs:

The analysis is based on a 36-degree section model that takes advantage of symmetry of the drywell with 10 vents. The model includes the drywell shell from the base of the sand bed region to the top of elliptical head and the vent and vent header. The torus is not included in this model because the vent bellows provide a very flexible connection, which does not allow significant structural interaction between the drywell and the torus. The analysis considered drywell geometry and materials, thickness reduction from corrosion, test loads, normal operating loads, design basis accident loads, seismic loads, refueling loads, and design basis load combinations. Pressure and temperature were in accordance with approved Technical Specification Amendment No. 165, which established a revised design bases accident pressure of 44 psig and accident temperature of 292°F. The results of the analysis show that the minimum required ASME Code thickness of the drywell shell above the sand bed region is controlled by membrane stresses and the minimum drywell shell thickness in the sand bed region is controlled by buckling. The minimum required ASME Code thicknesses above the sand bed region are shown in Table 1 (attached to the response). For the sand bed region, the analysis conservatively assumed that the shell thickness in the entire sand bed region has been reduced uniformly to a thickness of 0.736 inches. This thickness satisfies ASME Code requirements and is considered the minimum required thickness.

As described above, the buckling analysis was performed, assuming a uniform general thickness of the sand bed region of 0.736 inches. However, the UT measurements identified isolated, localized areas where the drywell shell thickness is less than 0.736 inches. Acceptance for these areas was based on engineering calculation C-1 302-1 87-5320-024. The calculation uses a "Local Wall Acceptance Criteria." This 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. However, the calculation does not provide additional criteria as to the acceptable distance between multiple small areas. For example, the minimum required linear distances between a 12" by 12" area thinner than 0.736" but thicker than 0.536", and another 12" by 12" area thinner than 0.736" but thicker than 0.536", were not provided.

The actual data for two bays (13 and 1) shows that there is more than one 12" by 12" area thinner than 0.736" but thicker than 0.536". Also the actual data for two bays shows that there is more than one 2½ in. diameter area thinner than 0.736" but thicker than 0.490". Acceptance is based on the following evaluation. The effect of these very localized wall thickness areas on the buckling of the shell requires some discussion of the buckling mechanism in a shell of revolution under an applied axial and lateral pressure load.

To begin the discussion, we will describe the buckling of a simply supported cylindrical shell under the influence of lateral pressure and axial load. As described in chapter 11 of the Theory of Elastic Stability, Second Edition, by Timoshenko and Gere, thin cylindrical shells buckle in lobes in both the axial and circumferential directions. These lobes are defined as half wave lengths of sinusoidal functions. The functions are governed by the radius, thickness and length of the cylinder. If we look at a specific thin walled cylindrical shell, both the

length and radius would be essentially constants and if the thickness was changed locally, the change would have to be significant and continuous over a majority of the lobe so that the compressive stress in the lobe would exceed the critical buckling stress under the applied loads, thereby causing the shell to buckle locally. This approach can be easily extrapolated to any shell of revolution that would experience both an axial load and lateral pressure as in the case of the drywell. This local lobe buckling is demonstrated in the GE Letter Report "Sandbed Local Thinning and Raising the Fixity Height Analysis" where a 12 x 12 square inch section of the drywell sand bed region is reduced by 200 mils and a local buckle occurred in the finite element eigenvalue extraction analysis of the drywell. Therefore, to influence the buckling of a shell, the very local areas of reduced thickness would have to be contiguous and of the same thickness. This is also consistent with Code Case 284 in Section-1700 which indicates 'that the average stress values in the shell should be used for calculating the buckling stress. Therefore, an acceptable distance between areas of reduced thickness is not required for an acceptable buckling analysis except that the area of reduced thickness is small enough not to influence a buckling lobe of the shell. The very local areas of thickness are dispersed over a wide area with varying thickness and as such will have a negligible effect on the buckling response of the drywell. In addition, these very local wall areas are centered about the vents, which significantly stiffen the shell. This stiffening effect limits the shell buckling to a point in the shell sand bed region which is located at the midpoint between two vents.

The acceptance criteria for the thickness of 0.49 inches confined to an area less than 2½ inches in diameter experiencing primary membrane + bending stresses is based on ASME Boiler and Pressure Vessel (B&PV) Code, Section III, Subsection NE, Class MC Components, Paragraphs NE-3213.2 Gross Structural Discontinuity, NE-3213.10 Local Primary Membrane Stress, NE-3332.1 Openings not Requiring Reinforcement, NE-3332.2 Required Area of Reinforcement and NE-3335.1 Reinforcement-of Multiple Openings. The use of Paragraph NE-3332.1 is limited by the requirements of Paragraphs NE-3213.2 and NE-3213.10. In particular, NE-3213.10 limits the meridional distance between openings without reinforcement to 2.5 x (square root of Rt). Also, Paragraph NE-3335.1 only applies to openings in shells that are closer than two times their average diameter. The implications of these paragraphs are that shell failures at these locations from primary stresses produced by pressure cannot occur provided openings in shells have sufficient reinforcement. The current design pressure of 44 psig for the drywell requires a thickness of 0.479 inches in the sand bed region of the drywell. A review of all the UT data presented in Appendix D of the calculation indicates that all thicknesses in the drywell sand bed region exceed the required pressure thickness by a substantial margin. Therefore, the requirements for pressure reinforcement specified in the previous paragraph are not required for the very local wall thickness evaluation presented in Revision 0 of Calculation C-1302-187-5320-024.

Reviewing the stability analyses provided in both the GE Report 9-4 and the GE Letter Report, "Sand bed Local Thinning and Raising the Fixity Height Analysis," and recognizing that the plate elements in the sand bed region of the model are 3" x 3", it is clear that the circumferential buckling lobes for the drywell are

substantially larger than the 2½ inch diameter very local wall areas. This, combined with the local reinforcement surrounding these local areas, indicates that these areas will have no impact on the buckling margins in the shell. It is also clear from the GE Letter Report that a uniform reduction in thickness of 27 percent to 0.536" over a one square foot area would only create a 9.5 percent reduction in the load factor and theoretical buckling stress for the whole drywell resulting in the largest reduction possible. In addition to the reported result for the 27 percent reduction in wall thickness, a second buckling analysis was performed for a wall thickness reduction of 13.5 percent over a one square foot area which only reduced the load factor and theoretical buckling stress by 3.5 percent for the whole drywell, resulting in the largest reduction possible. To bring these results into perspective, 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 used in GE Report 9-4, which cover a conservative total area of 0.68 square feet of the drywell surface with an average thickness of 0.703" or a 4.5 percent reduction in wall thickness.

Therefore, to effectively change the buckling margins on the drywell shell in the sand bed region a reduced thickness would have to cover approximately one square foot of shell area at a location in the shell that is most susceptible to buckling with a reduction in thickness greater than 25 percent. This leads to the conclusion that the buckling of the shell is unaffected by the distance between the very local wall thicknesses, in fact these local areas could be contiguous provided their total area did not exceed one square foot and their average thickness was greater than the thickness analyzed in the GE Letter Report, and provided the methodology of Code Case N284 was employed to determine the allowable buckling load for the drywell. Furthermore, all of these very local wall areas are centered about the vents, which significantly stiffen the shell. This stiffening effect limits the shell buckling to a point in the shell sand bed region, which is located at the midpoint between two vents.

In summary, the applicant noted that the minimum required drywell shell thickness is based on an analysis conducted in accordance with ASME Code. Factors considered include drywell geometry, material of construction, reduced wall thickness due to corrosion, and applicable design-basis loads and load combinations. Accident pressure and temperature are 44 psig and 292 °F, respectively, in accordance with the approved technical specification amendment No. 165.

In a letter dated April 7, 2006, the applicant responded to RAI 4.7.2-1. In its response the applicant stated that the minimum required thicknesses of the drywell shell above the sand bed region shown in Table-1 of the response are controlled by membrane stresses. The minimum required general drywell shell thickness in the sand bed region of 0.736 inch is controlled by buckling. Localized areas in the sand bed region where the thickness is less than 0.736 inch are evaluated against a local thickness acceptance criteria (0.49 inch) developed based on ASME Code, Section III, Subsection NE, Class MC Components, Paragraphs NE-3213.2, "Gross Structural Discontinuity," NE-3213.10, "Local Primary Membrane Stress," NE-3332.1, "Openings Not Requiring Reinforcement," NE-3332.2, "Required Area of Reinforcement," and NE-3335.1, "Reinforcement of Multiple Openings." Application of these ASME Code sections is justified as discussed above, and specific buckling sensitivity analysis results support the conclusion that, on an average wall thickness basis, buckling of the shell is unaffected by local wall thickness areas

as these are distributed over the sand bed region.

The staff reviewed the cited analysis reports to ensure that the parameters used and the assumptions made in the analysis are valid for the period of extended operation. However, based on the review conducted, the staff requested that the applicant provide additional information to address certain gross assumptions.

Attachment 1A of the GPU letter dated November 26, 1990, makes a statistical evaluation of the UT measurement data taken up to 1990. On the cover page of the report, GPU Nuclear Corporation states a disclaimer, "the work is conducted by an individual(s) for use by GPU. Neither GPU nor the authors of the report warrant that the report is complete or accurate ...." In view of this disclaimer, the staff at a public meeting on June 1, 2006, asked the applicant to provide a detailed description of the way the UT measurement data, whether taken as part of the 6-inch by 6-inch grid, or isolated readings, were evaluated and used in performing the analysis.

In its response dated June 20, 2006, the applicant clarified the use of the statistical evaluation as follows:

The disclaimer noted by the NRC staff is on the cover page of Technical Data Report (TDR) No. 948 Revision 1, "Statistical Analysis of the Drywell Thickness Data." The disclaimer statement is a standard clause that was placed on TDRs developed in accordance with the applicable GPUN procedure at the time. AmerGen points out that TDR No. 1027, which is also a part of Attachment 1A includes the same disclaimer. The disclaimer was intended to reinforce that TDRs are not design basis documents and were not design verified in accordance with the GPUN QA Program. In this case TDR 948 was developed to summarize the initiative that surveyed the drywell and that assessed initial corrosion rates based on data collected from 1986 through December 1988. However this TDR did not serve as the design basis document, which demonstrated the drywell shell met design basis requirements. The TDR in Section 1 (Introduction/Background) explains that the TDR documents the assumptions, methods and results of the statistical analysis used to evaluate the corrosion rates. The section then states that the complete analysis is documented in calculation C-1302-187-5300-005.

Calculation C-1302-187-5300-005, "Statistical Analysis of Drywell Thickness Data Thru 12-31-88" did serve as the design basis document, which demonstrated the drywell shell met design basis requirements. This calculation was developed and design verified in accordance with the GPUN QA Program and is approximately 200 pages long. A review of the information contained in the TDR Section 4.6 (Summary of Conclusion) shows that it is consistent with the information in Section 2 (Summary of Results) in calculation C-1302-0187-5300-005. Thus, the information in the TDR No. 948 represents design quality information.

In response to the NRC's question on how the UT measurement data were evaluated and used in the drywell analysis, AmerGen provided a description of how the 49-point array statistical analysis was performed in response to NRC Q&A #AMP-356, item (4). In that response, AmerGen stated that the methodology and acceptance criteria that are applied to each grid of point thickness readings, including both global (entire array) evaluation and local (subregion of array) are

described in engineering specification IS-328227-004 and in calculation No. C-1302-187-5300-011, "Statistical Analysis of Drywell Thickness Data Thru 4-24-90". This calculation is the more recent version of calculation C-1302-187-5300 and has been submitted by AmerGen to the NRC.

These two documents were submitted to the NRC in a letter dated November 26, 1990 and provided to the Staff during the AMP/AMR audit. A brief summary of the methodology and acceptance criteria is described below.

The initial locations identified in 1986 and 1987 where corrosion loss was most severe were selected for repeat inspection over time to measure corrosion rates. For locations where the initial investigations found significant wall thinning, UT inspection consisted of 49 individual UT data points equally spaced over a 6"x 6" area. Each new set of 49 values was then tested for normal distribution. If the data was normally distributed, then the mean value of the 49 points was calculated and used to represent the general drywell shell thickness in the tested area. If the 49 points were not normally distributed, then the grid was subdivided into datasets (usually 2, top and bottom) that were normally distributed. The mean value for each dataset was then calculated. The minimum mean value was compared to the minimum required thickness as described below.

The mean values of each grid were then compared to the required minimum uniform thickness criteria of 0.736 inches. In addition each individual reading was compared to the local minimum required criteria of 0.490 inches. The basis for the required minimum uniform thickness criteria and the local minimum required criteria is provided in response to NRC Question #AMP-210. A decrease in the mean value over time is representative of corrosion. If corrosion does not exist, the mean value will not vary with time, although random variations in the UT measurements as a result of such factors as variables in the inspection process and in environmental conditions may occur. If corrosion is continuing, the mean thickness will decrease linearly with time. Therefore the curve fit of the data is tested to determine if linear regression is appropriate, in which case the corrosion rate is equal to the slope of the line. If a slope exists, then upper and lower 95% confidence intervals of the curve fit are calculated. The lower 95% confidence interval is then projected into the future and compared to the required minimum uniform thickness criteria of 0.736 inches.

A process similar to that described above is applied to the thinnest individual reading in each grid. The lowest reading taken is also verified against the local minimum thickness requirement. Then the curve fit of the data is tested to determine if linear regression is appropriate. If a slope exists, then the lower 95% confidence interval is then projected into the future and compared to the required minimum local thickness criteria of 0.490 inches.

The staff finds that the applicant has provided an explanation of the documents used for the design basis calculations. Furthermore, the applicant provided the process used in establishing the minimum thickness of the drywell used in the 1991 GE analysis. Based on the discussion provided above, the staff finds the applicant's historical method of determining the minimum required wall thickness acceptable because these processes use recognized industry standards for performance and evaluation of results. On the basis of the applicant's written response, the