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SES Project No.: 131377

Subject: Cursory Check of Structural Analyses, Oyster Creek Drywell Vessel

Dear Mr. Webster:

Recently, you requested that Stress Engineering Services, Inc. consider several documents that you provided and others that were made available to us through internet link references from the U. S. Nuclear Regulatory Commission. These documents concern the license renewal of the Oyster Creek Nuclear Generating Station.

One issue of contention in the license renewal at hand is whether the corroded drywell shell retains adequate strength for continued service. Your specific instructions were to review the structural analyses and comment on the approach used to assess their adequacy. Thus, we did not address any issues related to either the preexisting corrosion damage or potential ongoing corrosion of the vessel, unless it was salient to our review of the structural analysis work.

This report contains two sections. The first section addresses the general structural analysis methods and results. The second section addresses the ASME Code provisions. In both sections, it is important to note that our comments and opinions are based on a severely limited review that only touches the highlights of the respective subjects. A more detailed review is needed to address these subjects with the depth of study necessary to uncover the fundamental differences between the work that was done in support of the license and the state-of-the-art in structural analysis.

Structural Analyses
At issue is the structural adequacy of the drywell shell, which has the shape of an inverted light bulb. The primary structural concern is the drywell shell's ability to resist buckling with an adequate margin for continued safe operation.

The structural analysis results offered by AmerGen were obtained using typical techniques for the period of time in which the analyses were performed. Due to the limited computational power that was readily available at the time, the computer-aided analysis performed by General Electric (GE) utilized relatively small slices of the vessel, idealized geometries (perfect spheres, cylinders, etc.), and required computationally efficient calculation techniques. Calculated buckling load behaviors for the idealized geometries were subsequently adjusted using assumptions or "capacity reduction factors" for surface irregularities, plasticity, and local buckling; and the resulting adjusted values were taken as representative of the actual buckling load. GE compared the calculated buckling loads with the imposed loads, and safety margins were determined for comparison to ASME Code minimum requirements. Primarily because of these computational limitations, the finite element analysis performed by GE on the drywall vessel may not be adequate to capture its global behavior, which may be some combination of symmetrical and anti-symmetrical buckling.

The state-of-the-art has progressed far beyond the methods available to structural analysts in the early 1990s. Today, when reconstructing or reverse engineering existing structures, it is routine to use laser devices to generate "point clouds" that fully define the surfaces of pressure vessels, including any irregularities. The point clouds are digitalized, and the digitized information is converted into a mathematical representation of the actual surface shape, which is subsequently utilized for full three-dimensional modeling. Since the resulting models account for actual surface waviness, unevenness, bulges, facets, and other potentially deleterious geometric surface conditions, there is no longer any need to resort to the use of "capacity reduction factors" to determine buckling loads, as the GE analysts were forced to do.

The digitized surface is converted into a form suitable for meshing and further processing using finite element analysis (FEA). The mesh areas are then assigned the corroded thicknesses at the specific areas where they actually occur, and any future corrosion allowance is subtracted from the thickness at this time. The FEA mesh density would then be generated as fine as needed to capture the stiffness that resists buckling. The simulated loads are then applied and the buckling load and shape are directly calculated without needing imposed perturbations or anything except the measured geometry and thicknesses.

Utilization of point cloud surface mapping techniques along with measurements that represent the actual wall thickness is thought to give the most accurate structural analysis results possible, with the fewest assumptions, using current technology. Three-dimensional thin shell analyses can be done today with few assumptions concerning stiffness and in a way that complies with Case N-284-1-1320.

ASME Code[1] Provisions

At issue is whether the Code is the best tool available for determining the drywell's fitness for continued service.

In general, the Code establishes rules of safety relating only to pressure integrity and governing the construction[2] of boilers, pressure vessels, transport tanks, and nuclear components. Its

[1] ASME Boiler and Pressure Vessel Code, Section III, *Nuclear Components*, and Section VIII, *Rules for Construction of Pressure Vessels,* American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016

[2] *Construction*, as used in the Code, is an all-inclusive term comprising materials, design, fabrication, examination, inspection, testing, certification, and pressure relief.

wording allows for some latitude in design and analysis methods, anticipates that deterioration of pressure vessels will occur, requires the use of engineering judgment, and recognizes the inevitability of technological progress in design and analysis methods. The following statements, which we excerpted from the FOREWORD of the current edition of the ASME Boiler and Pressure Vessel Code, support this contention.

"*The Committee's function is to establish rules of safety, relating only to pressure integrity, governing the construction of boilers, pressure vessels, transport tanks and nuclear components, and inservice inspection for pressure integrity of nuclear components and transport tanks, and to interpret these rules when questions arise regarding their intent... With few exceptions, these rules do not, of practical necessity, reflect the likelihood and consequences of deterioration in service relating to specific service fluids or external operating environments. Recognizing this, the Committee has approved a wide variety of construction rules in this Section to allow the user or his designee to select those which will provide a pressure vessel having a margin for deterioration in service so as to give a reasonably long, safe period of usefulness. Accordingly, it is not intended that this Section be used as a design handbook; rather, engineering judgment must be employed in the selection of those sets of Code rules suitable to any specific service or need... The Committee recognizes that tools and techniques used for design and analysis change as technology progresses and expects engineers to use good judgment in the application of these tools.*"

Clearly, the authors of the Code never intended that its rules be used as the only arbiter of pressure vessel structural integrity. Neither did the authors intend the rules be used to extend, possibly unreasonably, the useful life a significantly corroded nuclear pressure vessel such as the drywell. Nonetheless, some continue to rely on Code construction rules for these purposes. They continue to do so despite the existence of tools such as three-dimensional thin shell analysis that have proven to be more than adequate for nuclear applications when applied in the presence of seasoned engineering judgment.

Respectfully Submitted,

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