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Gentlemen: ULNRC-2077

DOCKET NUMBER 50-483
CALLAWAY PLANT
SEISMIC DESIGN OF SAFETY-RELATED ABOVE-GROUND
VERTICAL LIQUID STORAGE TANKS

Reference: NRC Request for Information letter, J. N. Hannon to D. F. Schnell, dated 5-23-89

The referenced letter raised an issue regarding the seismic design of the Refueling Water Storage Tank (RWST) and Condensate Storage Tank (CST) at Callaway Plant. As requested, the attachment provides a summary of the RWST seismic analysis which includes the effects of tank wall flexibility and is consistent with the nine acceptance criteria given in the reference. This issue is not applicable to the CST at Callaway since it is non-seismic and has no safety function (i.e., the essential service water system provides the safety-related water supply for the auxiliary feedwater system at Callaway as discussed in FSAR Table 3.2-1 item 5.11, Section 9.2.6, and Section 10.4.9).

If you have any questions regarding the attachment, please contact us.

Very truly yours,

Al Passwater for
Donald F. Schnell

GGY/pkn
Attachment

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STATE OF MISSOURI)
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CITY OF ST. LOUIS)

Alan C. Passwater, of lawful age, being first duly sworn upon oath says that he is Manager, Licensing and Fuels (Nuclear) for Union Electric Company; that he has read the foregoing document and knows the content thereof; that he has executed the same for and on behalf of said company with full power and authority to do so; and that the facts therein stated are true and correct to the best of his knowledge, information and belief.

By Alan C Passwater
Alan C. Passwater
Manager, Licensing and Fuels
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SUBSCRIBED and sworn to before me this 21st day of September, 1989.

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I. INTRODUCTION

The original seismic analysis of the Callaway Refueling Water Storage Tank (RWST) was based on the "Housner Method", discussed in Reference 1, and a rigid tank wall assumption. Recent analytical techniques (Reference 2), however, have indicated that the previous design methods may not be appropriate and/or conservative for the majority of tank structures. Specifically, the recent technical developments have shown that for typical tank designs the fundamental frequency associated with the combined fluid-tank shell system in the horizontal impulsive mode is not sufficiently rigid to justify the assumption of a rigid tank.

The NRC subsequently issued draft revision 2 of Standard Review Plan (SRP) Section 3.7.3 identifying this concern and adopting these new analytical techniques. In addition, draft revision 2 also identified the need to consider soil-structure interaction (SSI) effects when evaluating such structures.

In order to address these concerns, a complete reanalysis of the RWST structure and foundation was completed incorporating these newly adopted analytical techniques. Additionally, in accordance with the acceptance criteria of SRP Section 3.7.3, Subsection II.14, the effects of this analysis on the connected piping, tubing, and associated supports were also evaluated. This report provides a summary of the design approaches and corresponding results, accounting for tank flexibility and SSI effects.

II. REANALYSIS METHODOLOGY

The RWST structure was evaluated using a lumped mass stick model depicting the seismic system. Response Spectrum Analyses (RSA) were performed for both the design OBE and SSE earthquakes, using the Bechtel Structural Analysis Program (BSAP) (CE800) and BSAP Dynam (CE207) computer programs. See FSAR Appendix 3.8A and Table 3.9(B)-1 for a discussion of these programs (BSAP Dynam is a subprogram of BSAP). The analyses were conducted for all three orthogonal directions using ground accelerations of 0.12g OBE and 0.20g SSE. Design loads were calculated per the Reference 2 methodology using the BSAP runs to determine seismic responses (frequencies, mode shapes, accelerations, etc.).

(a.) Fluid Parameters

The design fluid parameters were developed in accordance with the procedures outlined in Reference 2. Specifically, the fluid was modeled considering the appropriate breakdown between the rigid (impulsive) and oscillating (sloshing/convective) portions associated with this mass.

(b.) Soil-Structure Interaction Effects

In order to include the effects of soil-structure interaction, the tank stick model was coupled with the foundation medium using a lumped mass parameter, elastic half-space, representation. The soil parameters (springs & dampers) were computed in accordance with the procedures outlined in Reference 3. In order to account for the sensitivity associated with these parameters, pertaining to the resulting responses, the soil shear modulus value was varied by +/-50 percent in the analysis. As such, this resulted in three cases (i.e. lower bound, average & upper bound) being investigated.

The lumped parameter, elastic half-space, representation was selected, in lieu of a finite element representation, based on the results of previous SNUPPS studies and the shallow embedment (i.e. only 4.5 feet or less than 10%) of this structure as compared to its overall height of 53 feet.

(c.) Nozzle Loads

The nozzle loads used in this tank/foundation reanalysis were taken from the original seismic analysis. This approach was deemed acceptable considering the insignificant contribution of the nozzle loads to the overall moments and forces on the tank and foundation. The validity of this approach was subsequently confirmed by calculating new nozzle loads for all six RWST nozzles and comparing them with the old nozzle loads. The effects on the tank/foundation reanalysis were found to be insignificant.

III. DISCUSSION OF NRC ACCEPTANCE CRITERIA

The following discussions are presented in the same order as listed in Reference 4.

(a.) Per Reference 2, a minimum of two horizontal modes of combined fluid-tank vibration (one impulsive and one convective) and one vertical mode of fluid vibration must be considered. However, this reanalysis was performed considering all modes below 50 Hz. The fundamental sloshing (convective) mode of the fluid was included in the horizontal analysis.

(b.) The frequency of the fundamental horizontal impulsive mode of the tank and fluid system was determined by the BSAP computer program runs. For the impulsive mass, several dominant modes occurred before the ZPA. Per Reference 2, only the first fundamental impulsive mode needs to be considered. The horizontal impulsive mode spectral acceleration, as well as the horizontal convective mode and vertical mode spectral accelerations, were determined by the BSAP computer code runs as discussed previously.

(c.) Material properties used in the reanalysis included damping values for the RWST shell that were taken from Regulatory Guide 1.61 listings corresponding to welded steel structures (i.e. 2% of critical damping for OBE, 4% for SSE).

(d.) The convective fluid damping value of 1/2% of critical damping was used, as specified in Reference 2.

(e.) The maximum overturning moment at the base of the RWST was obtained by the square-root-sum-of-squares (SRSS) combination of the impulsive and convective horizontal overturning moments, pursuant to Reference 2. Anchor bolts are discussed under item (h) below.

(f.) The seismically-induced hydrodynamic pressures on the RWST shell at a given level were determined by the SRSS combination of the horizontal impulsive, horizontal convective, and vertical hydrodynamic pressures which were calculated per the Reference 2 methodology. Since SSI effects are to be considered, the spectral acceleration corresponding to the fundamental vertical mode was used, rather than the vertical ZPA value, in equation 2.2.5.1 of Appendix C to Reference 2. The hydrodynamic pressure at a given level was added to the hydrostatic pressure at that level to determine the hoop stresses in the RWST shell courses. It was confirmed that the membrane hoop stresses were within the normal allowable limits and that the shell thicknesses satisfied the Reference 5 requirements.

(g.) The fluid slosh height was calculated per the Reference 2 methodology (d=3.36 feet). The roof and top angle design is adequate to accommodate the pressures resulting from fluid sloshing effects.

(h.) The tank foundation was verified to be able to accommodate the seismic forces imposed by the base of the tank. Soil pressure allowables were met. Anchor bolts were verified to adequate; no net tension was demonstrated to exist in the anchor bolts and the maximum shear load per anchor was calculated to be less than the allowable working stress. As such, the primary function of the foundation slab is to provide additional dead weight to resist overturning and/or sliding. Overturning requirements, including the 1.50 FSAR factor of safety, were satisfied. Sliding requirements, including the 1.10 FSAR factor of safety, were also satisfied. The foundation slab design moment and shear loads were verified to satisfy allowables.

(i.) Design reactions and moments at the base of the six tank shell courses were calculated as follows.

Reactions included dead weight loads, loads due to the vertical mode spectral acceleration (OBE or SSE) acting on the dead weight loads, and nozzle shear loads.

Moments about the shell courses' horizontal axes were calculated from nozzle loads and the overturning moment discussed under item (e) above. The nozzle load contributions to these moments included the effects of nozzle moments and radial stresses inducing a moment about one horizontal axis (y-axis) as well as the effects of nozzle torsional moments and shear stresses inducing a moment about the other horizontal axis (x-axis). The effect of the overturning moment was included in calculating the shell course moment about the y-axis. To account for the second horizontal direction, forty percent of the effect of the overturning moment was also included in calculating the shell course moment about the x-axis. A shell course resultant moment was then calculated by the SQSS combination of these horizontal moments.

These reactions and moments were then used to calculate the maximum longitudinal compressive stresses in the six shell courses. These maximum stresses were subsequently compared to allowables computed per Article NC-3133.6 of Reference 5. It is noted that the calculated compressive stresses do not include the effects of roof snow loads. This follows from FSAR Section 3.8.3.3.4.d (i.e. live loads for seismic analyses do not include the 100-year recurrence snowpack load discussed in FSAR Section 2.4.2.3.2 since this load is not expected to occur concurrently with seismic loads).

The maximum longitudinal compressive stresses were shown to be acceptable with consideration given to the actual tank shell plate yield strength of 37 ksi per the certified material test reports (CMTRs) for the SA240, type 304 stainless steel shell plates.

This demonstrated that buckling of the tank will not occur.

The connected piping, instrument tubing, and their supports were also reviewed and verified to be adequate as a part of this reanalysis effort. This included the generation of several new stress calculations.

Tank sliding was verified to not occur, as discussed in item (h) above.

IV. RESULTS

(a.) Seismic Responses of Tank/Foundation System

1. Horizontal Impulsive Mode(s)

Several dominant modes occurred before the ZPA frequency; however, the first dominant horizontal impulsive mode occurred between the frequencies of 4.60 and 5.55 Hz, depending on the soil shear modulus used. This mode represented approximately 70% of the total system horizontal mass.

2. Horizontal Convective/Sloshing Mode

The fundamental horizontal convective/sloshing mode occurred at a frequency of 0.22 Hz and represented approximately 15% of the total system horizontal mass. Note that only one convective mode was applicable since all of the convective mass responded during the first mode.

3. Vertical Mode

In the vertical direction, only one dominant mode occurred before the ZPA frequency. Depending on the shear modulus used, this mode was determined to occur between 8.38 and 11.08 Hz and represented approximately 93% of the total system vertical mass.

(b.) Design Forces and Moments for Tank/Foundation Reanalysis

Revised seismic forces and moments for the tank and foundation were computed for the licensed OBE and SSE earthquakes. The maximum values of these revised seismic loads were then combined with the appropriate nozzle forces and moments from the original analysis, as discussed above, and utilized to reanalyze the various structural components per the applicable requirements of References 5-7.

(c.) Connected Piping Evaluation

The effects of the new RWST analysis on the connected piping, tubing, and associated supports were also evaluated and all items were found to be structurally adequate.

V. CONCLUSIONS

The results of the tank/foundation reanalysis confirm that the Callaway RWST structure meets the licensed FSAR requirements. Specifically, the structure and its foundation are acceptable, based on the Reference 2 design methodology, for both the licensed 0.12g OBE and 0.20g SSE seismic design ground response spectrum inputs.

Additionally the existing piping, tubing, and support analyses, including tank nozzles, have also been reviewed and reanalysis performed as necessary. All components were found to be adequate for the effects of the new analysis.

VI. REFERENCES

1. TID-7024, "Nuclear Reactors And Earthquakes", Prepared by Lockheed Aircraft Corporation and Holmes & Narver, Inc. for the Division Of Reactor Development, U.S. Atomic Energy Commission, Washington, D.C., 8/63.

2. D. W. Coats, "Recommended Revisions to Nuclear Regulatory Commission Seismic Design Criteria", Prepared by Lawrence Livermore National Laboratory For The U.S. Nuclear Regulatory Commission, NUREG/CR-1161, May 1980.

3. Topical Report BC-TOP-4A, "Seismic Analyses Of Structures And Equipment for Nuclear Power Plants", Revision 3, November 1974.

4. NRC Request for Information Letter, J.N. Hannon to D. F. Schnell, dated 5-23-89.

5. ASME Boiler and Pressure Vessel Code, 1974 Edition up to and including Winter 1975 Addenda.

6. SNUPPS Civil and Structural Design Criteria, 10466-C-0(Q), Revision 12.

7. Union Electric, Callaway Plant Final Safety Analysis Report.