TECHNICAL EVALUATION REPORT

REVIEW OF ANO-1 CONDENSATE STORAGE TANK
SEISMIC DESIGN

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MARCH 1991

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1. INTRODUCTION

Around May 1986, Arkansas Power and Light Company (APL) submitted to the Nuclear Regulatory Commission (NRC) a technical specification change regarding the installation of a new condensate storage tank (CST) at Arkansas Nuclear One, Unit 1 (ANO-1). APL claimed that the new tank was designed and installed under the provisions of 10CFR50.59 and therefore the design adequacy of the tank should be treated separately from the requested technical specification change (Reference 1). NRC felt that the seismic design and analysis methods used for the new CST are different from those related to the Category I structures in the ANO-1 Final Safety Analysis Report (FSAR). Consequently, the seismic adequacy of the new CST was subjected to a review process by the NRC.

Brookhaven National Laboratory (BNL) was requested by the NRC to provide technical assistance in determining the seismic adequacy of the CST (FIN L-1521, Task 3). This Technical Evaluation Report (TER) presents BNL's review and findings concerning the design and analyses methods employed by APL for the seismic qualification of the new CST.

2. REVIEW PROCEDURES

BNL's review and evaluation of the models, analytical methods and results obtained by APL for demonstrating the seismic adequacy of the new CST at ANO-1 nuclear facility can be chronologically divided into two phases as follows:

Phase-1 covers the activities which took place during 1987 which include:

(a) BNL's review of APL's initial submittal to NRC (Reference 1).

(b) Meeting at APL's engineering offices to discuss details pertaining to the analysis and design procedures and review of APL's seismic calculations for the tank (April 7-8, 1987).

(c) BNL's site visit to the ANO-1 nuclear facility with the objective to observe the CST configuration. (April 9, 1987).

As a result of the above activities, BNL raised several questions with respect to the seismic models and input parameters utilized by APL in their seismic calculations for the CST. NRC requested APL to address these questions. This concluded Phase-1 of BNL's review of CST's seismic design.

The above review activities were followed by approximately a three year waiting period. On June 18, 1990 APL submitted to NRC responses to the BNL questions which were raised on April 1987 during the audit and site visit regarding the seismic design of CST (Reference 2). This was followed by another submittal by APL on October 25, 1990 which provided responses to NRC's request for additional information (Reference 3).

Phase-2 of BNL's review and evaluation of CST's seismic design started on December 21, 1990 after NRC's request for BNL's assistance (FIN L-1521, Task 3) in reviewing the June and October 1990 submittals by APL. The objective of Phase-2 was for BNL to review these submittals and provide resolutions to the open issues so that a final assessment can be made with regard to the seismic adequacy of the ANO-1 condensate storage tank.

3. APL'S SEISMIC ANALYSIS

The ANO-1 CST is a steel tank which consists of a 42 ft. diameter cylindrical shell of variable thickness (0.310 to 3/16 inch). The height of the cylindrical shell is 32 ft. The tank has a 0.210 inch thick steel cap roof which was designed by CBI for a 39 psf dead plus live load in addition to earthquake loads. The tank design specifications assume zero internal gas pressure as well as zero negative internal pressure (vacuum). One of the main characteristics of the ANO-1 CST is its foundation system. Since the top clay layer at the site is relatively soft and in order to achieve adequate bearing capacity, a drilled pier foundation system was employed by APL to support the tank. Specifically, the CST foundation consists of a 30 inch RC base slab supported by a system of 27 RC drilled piers 42 inches in diameter. The average length of the drilled piers is about 29 ft, and they are embedded into the underlying bedrock. In addition, as part of the tank base mat, an 18 inch thick and 5 ft. high RC wall around the tank was designed to provide a partial tornado protection for the CST.

The seismic analysis of the CST is based on the dynamics of the tank and its supporting foundation configuration. Specifically, NUTECH (San Jose, CA) carried out for APL a soil-structure interaction analysis of the CST with the objective to generate design response spectra for the tank-foundation-pile-soil system utilizing the FLUSH approach. The seismic loads generated from this analysis were subsequently used by CBI (tank vendor) in the load combinations employed for the design of the tank.

The FLUSH model of the CST incorporates the tank, the foundation system (mat plus drilled piers) and the soil layers overlying the bedrock. The soil deposit above the bedrock is 30 ft, deep and it was subdivided in the mathematical model by eight horizontal layers. Due to symmetry, only half of the tank

foundation system was modeled in the FLUSH analysis. The mat and the drilled piers were modeled with beam elements. The FLUSH model employed by APL for performing the seismic analysis of the CST follows the general modeling procedures of the direct approach of soil-structure interaction.

As a result of BNL's review of APL's FLUSH model, several concerns were identified with respect to the soil input data as well as the specification of the input ground motion. These concerns are discussed in Section 4 of this report. In response to BNL's concerns, APL made several changes with respect to the input parameters of the FLUSH model and a reanalysis of the CST was performed. The reanalysis resulted in a set of revised seismic loads for the CST. Subsequently, CBI used the revised seismic loads to recompute the stresses at the tank and determine its design adequacy. The conclusion of this reanalysis was that the tank is still adequate for the revised loads without modification.

4. BNL'S EVALUATION

As a result of BNL's audit of APL's seismic design calculations of the CST at ANO-1, a total of nine open issues (OI's) were identified. In response to BNL's concerns regarding the seismic response analysis of CST, APL revised the original analysis by taking into account the specific issues which were raised by BNL. APL's reanalysis of the tank-foundation system forms the basis of the resolution of the open issues (ROI's). The specific OI's are presented in Subsection 4.1 while the basis for the corresponding ROI's is presented in Subsection 4.2 of this report.

4.1 Description of Open Issues

The specific OI's resulted form BNL's review and evaluation of APL's seismic analysis of the ANO-1 CST are:

OI-1: NUTECH used a soil shear wave velocity of 1100 fps for the FLUSH runs. A review of the geophysical data indicates that this is perhaps closer to the compression wave velocity. In general, it appears that there is a lack of good data for the clay upon which to base the selection of an appropriate wave speed.

OI-2: Poisson's ratio of 0.2 was used in the FLUSH runs for the clay. A review of the soil data indicates that the clay is saturated. One would expect the Poisson's ratio for a saturated clay to be larger than 0.2.

OI-3: The motion developed from the criteria design spectra was assumed at the surface and

deconvolution methods were used to calculate a consistent bedrock motion. This bedrock motion was then used as input to the FLUSH program. Since the primary support of the tank (especially for vertical and rocking motions) is the caissons which are founded on bedrock, a more consistent application of NRC guidelines would be to use the criteria motion as input to the base of the caissons (at bedrock).

OI-4: A 10-second duration pulse was used as input to the FLUSH model. Response spectra developed from the FLUSH results were then used by CBI to calculate the effects of water sloshing. The frequency of the sloshing mass was calculated to be about 0.25 cps. It is questioned whether the input spectra, developed form a ten-second duration pulse, is adequate to evaluate the response of a 0.25 cps system.

OI-5: Response spectra were reported at the foundation level. These spectra were then used by CBI to evaluate stresses in the tank. This approach neglects any inertial that would occur as a result of rocking of the tank. Some rational for neglecting this effect is required.

OI-6: The CBI calculations do not seem to account for an increase in fluid pressure as a result of the vertical seismic input. This increase in pressure would result in higher hoop stresses in the tank walls.

OI-7: CBI calculates a wave height due to sloshing effects which is higher than the available freeboard in the tank. No consideration is given as to the potential impact this may have on the tank design.

OI-8: The seismic loads used to design the foundation and caissons are not consistent with the latest seismic analysis.

OI-9: The CBI report uses a Rayleigh-Ritz procedure to calculate tank frequencies. No detail on the assumed shape function is given and should be provided.

4.2 Basis For Resolution of Open Issues

In response to BNL's concern regarding the seismic analysis of the ANO-1 CST, APL performed a seismic reanalysis by refining the original mathematical models of the tank. The reanalysis resulted in a set of revised seismic loads for the tank which were subsequently used to compute total stresses and perform code checks to verify the design adequacy of CST. According to APL, the new stresses which were obtained from the reanalysis of the tank were accommodated within the stress margins existed in the original analysis. Therefore, no modifications were necessary to be made in order to satisfy the design requirements of the CST.

BNL performed a detailed review of APL's response (Reference 2) to the OI's which were presented in Subsection 4.1 of this report. As indicated above, APL's response is primarily based on the results of the seismic reanalysis of the tank. On this basis, all open issues are considered by BNL to be closed. Specific details pertinent to the resolution of the open issues (ROI's) are given next.

ROI-1: According to APL's response, a geophysical survey was performed by Weston Geophysical and Bechtel to evaluate site properties. In addition, Grubbs, Garner & Hoskyn, Inc. supported the soil testing program for APL. The results of these studies indicate that the shear wave velocity of the supporting media is a function of depth below surface and ranges between 580 and 700 fps. This range seems to be more appropriate than the value of 1100 fps used by APL in the original FLUSH analysis of the tank-foundation configuration. On this basis, this open issue is considered closed.

ROI-2: As a result of BNL's concern regarding the validity of the Poisson's ratio employed in the original soil-structure interaction analysis of the tank-foundation system, APL performed a geophysical survey complemented by a soil test program. The results of this program indicate that the Poisson's ratio of the supporting soil is in the range of 0.45 to 0.42. BNL believes that the later values are more realistic for the site as compared to the value of 0.2 which was originally used in the FLUSH analysis. Specifically, the range of 0.45-0.42 obtained from the recent tests is typical to saturated clays, while the value of 0.2 is rather representative of stiffer soils. According to APL, the Poisson's ratio values used in the soil-structure interaction reanalysis of the tank-foundation system in the range of 045-0.42. On this basis BNL considers this issue to be resolved.

ROI-3: BNL considers that the specification of the design ground motion employed in the soil-structure interaction evaluation of the tank-foundation is one of the most critical issues raised with respect to APL's seismic analysis of the CST. During the April 1987 audit of APL's calculations, it was concluded that the seismic design criteria motion was applied at the surface and then deconvolved down to bedrock. Subsequently, the deconvolved motion was used as input to the FLUSH mathematical model for computing the seismic response of the tank and its foundation. BNL questioned the appropriateness of specifying the control motion at the surface since it was not clear from discussions with APL that site-specific conditions were met for the site considered. In response to BNL's concern regarding the specification of the free-field motion for the seismic analyses of the tank, APL, in consultation with Professor J. Lysmer of University of California at Berkeley, revised its original free-field analysis of the CST. According to APL, in the revised analysis the control motion was specified at a rock outcrop and a free-field analysis for the site was performed using SHAKE. In BNL's opinion, this approach is more appropriate than that employed by APL in the original analysis of the CST. Therefore, this issue is considered closed.

ROI-4: According to APL's response, the reanalysis of the CST was carried out using a duration of 24

seconds for the input acceleration time history. This duration is about twice that used in the original analysis. Accordingly, it is considered to be adequate for computing responses at lower frequencies, e.g., at about 0.25 cps. APL's response is considered acceptable. Therefore, this issue is considered closed.

ROI-5: According to APL, rocking effects are included in the soil-structure interaction analysis of the tank foundation system. In addition, they pointed out that based on CBI's experience with similar studies, more sophisticated seismic investigations generally indicate an increase in damping and decrease in loads. The above responses, either individually or in combiration, do not seem to provide a clear justification to support APL's conclusion that the inertia associated with rocking was adequately accounted for in evaluating the seismic stresses of the CST. BNL's concern deals clearly with the fact that only the foundation translational response spectra obtained from the SSI analysis were utilized by CBI for subsequent computation of the seismic stresses at the tank. The corresponding rotational components of the foundation motion from the SSI analysis were not utilized for the same purpose. In general, the impact of neglecting the rotation components of the foundation motion could be significant in terms of the tank response. It is reasonable, however, to expect such an

impact to be practically negligible for the case of the CST since the system of the 27 drilled piers extending down to the bedrock would tend to minimize the rocking motion of the tank foundation. On this basis, this issue is considered closed.

ROI-6: According to APL's response, the reanalysis of the CST is based on consideration of both horizontal as well as vertical seismic response calculations. In the stress reevaluation of the tank, the seismic stresses due to the horizontal and vertical earthquake components were combined by SRSS. BNL believes that the seismic reanalysis of the CST performed by APL is more appropriate than the original analysis in which the contribution of the vertical seismic input was not properly accounted for. Accordingly, this issue is considered closed.

ROI-7: APL performed stress calculations assuming a wave height of 1.6 feet due to sloshing effects during the design earthquake. The resulting stresses at the junction between the cylindrical shell and the tank reef was found to be 1,760 psi which is well below the allowable stresses of 18,055 psi. On this basis, this issue is considered closed.

ROI-8: APL indicated that a comparison was made between the loads and moments obtained from the FLUSH reanalysis of the tank-foundation system and the corresponding loads and moments used to design the RC foundation and caissons. From

this comparison it was concluded that the design specification loads envelop those obtained from the FLUSH reanalysis. Since the later is considered to be the latest seismic analysis of the ANO-1 CST, APL's response is acceptable and this issue is considered closed.

ROI-9: According to APL's response the Rayleigh-Ritz method was used to determine the natural fundamental frequency of vibration of the tank (fixed base frequency) for the full and half condition of the contained fluid. For this purpose the assumed shape function was of the cantilever shear beam type. This assumption is appropriate for computing approximately lateral modes of vibration. Accordingly, this issue is considered closed.

5. SUMMARY AND CONCLUSIONS

BNL completed a detailed review and evaluation of the seismic analysis performed by APL for the CST at ANO-1 facility. As a result of this review a total of nine open issues were identified by BNL with respect to the adequacy of APL's seismic analysis and results. The key issues raised by BNL questioned the appropriateness of the soil data, as well as, the deconvolution procedure used to determine the free-field motion in APL's soil-structure interaction analysis. The overall conclusion reached by BNL as a result of the April 1987 audit was that APL's seismic analysis of the tank-foundation system was inadequate.

In response to BNL's concerns, APL performed a reanalysis of the CST. A geophysical survey was also performed to determine the site properties which were employed in the reanalysis of the tank-foundation FLUSH model. BNL considers that the data from the geophysical survey are more appropriate than those of the original analysis. In addition, in the reanalysis of the tank-foundation system, the control motion was applied at a rock outcrop. BNL believes that the later approach is more consistent than that of APL's original analysis. On the basis of the input parameters, modeling approaches and analytical methods used in the reanalysis of the tank-foundation system, BNL considers that APL's responses to the open issues are acceptable. Accordingly, all of the nine issues raised with respect to the seismic adequacy of the ANO-1 CST are completely satisfied.

6. REFERENCES

1. "Arkansas Nuclear One-Unit 1, Docket No. 50-313, License No. DPR-51, Request for Information on the New Condensate Storage Tank," letter from APL (J.T. Enos) to NRC (J.F. Stolz), dated July 31, 1986.

2. "Arkansas Nuclear One-Unit 1, Docket No. 50-313, License No. DPR-51, Response to Remaining NRC Questions on QCST Seismic Qualification," letter from APL (J.J. Fisicaro) to NRC (Document Control Desk), dated June 18, 1990.

3. "Arkansas Nuclear One-Unit 1, Docket No. 50-313, License No. DPR-51, Response to Requested Additional Information - QCST Seismic Qualification," letter from APL (J.J. Fisicaro) to NRC (Document Control Desk), dated October 25, 1990.