UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO THE REFUELING WATER

STORAGE TANK AT WOLF CREEK GENERATING STATION

WOLF CREEK NUCLEAR OPERATING CORPORATION

DOCKET NO. 50-482

## BACKGROUND

Surveys of damage during past earthquakes (NUREG/CR-4776) have repeatedly pointed out the damage susceptibility of large, above-ground, vertical tanks under earthquake loads. The basic cause of damage has been identified as the inadequacy of the seismic analysis methods used for design of the tanks. A number of safety-related, above-ground vertical tanks exist at operating nuclear power plant sites. The earlier commonly used method of analyzing tanks for seismic response was based on the "Housner-Method," contained in TID-7024, "Nuclear Reactors and Earthquakes," dated August 1963.

During the discussions related to the resolution of Unresolved Safety Issue (USI) A-40 "Seismic Design Criteria," the method of analysis of above ground, flexible, vertical tanks was identified as an important topic requiring technical resolution. The resolution of the USI is contained in Revision 2 of Standard Review Plan (SRP) Sections 2.5.2, 3.7.1, 3.7.2, and 3.7.3. The guidelines related to the seismic analysis of the above-ground vertical tanks are included in SRP Section 3.7.3.II.14. Thus a number of tanks at nuclear power plant sites are required to have confirmatory checks to ensure that the safety related above-ground vertical tanks are adequately designed. Most of the licensees of newer plants have incorporated the flexible tank concept in the design of their above-ground tanks. Some licensees have committed to make confirmatory checks of their designs using the procedures developed by Seismic Qualification Utility Group (SQUG) under the resolution of USI A-46, "Seismic Qualification of Equipment in Operating Plants." Wolf Creek Nuclear Operating Corporation (WCNOC) is one of the four licensees requested to provide information regarding the above-ground vertical tank as contained in Reference 1.

## EVALUATION

This evaluation addresses the seismic adequacy of the Refueling Water Storage Tank (RWST), and is based on the information provided in the responses to the staff's requests for additional information (Refs. 2,3,4).

A typical tank evaluation consists of confirming: (1) the appropriateness of the seismic analysis, (2) the adequacy of the tank shell and the roof supports, (3) the adequacy of the anchor bolts to hold the tanks against uplift, and (4) the adequacy of the foundation or the floor-slab.

The RWST is located on a 5 ft 6 inch thick reinforced concrete (RC) pad which is constructed on rock foundation media. The inside diameter of the stainless steel tank is 40 ft and its height to the springline is 45 ft. The inside radius of the shallow dome is 32 ft. The thickness of the cylindical shell varies from 1/2-inch at the bottom to 3/16-inch at the spring line. The thickness of the dome shell is 1/4-inch. The cylinder is connected to the dome by means of a welded angle. The tank is anchored to the RC pad by means of 74 two-inch diameter cast-in-place anchor bolts. For seismic loadings, the tank was originally analyzed using the methods of TID-7024.

To account for the tank flexibility, the tank was completely reanalyzed. The seismic input for the reanalysis at the grade level (1 ft below the top of the pad) was in accordance with Regulatory Guide 1.60 with the Operating Basis Earthquake (OBE)-zero period ground acceleration (ZPGA) of 0.12g and the Safe Shutdown Earthquake (SSE)-ZPGA of 0.20g in the horizontal and vertical directions. The seismic reanalysis incorporated the lumped-mass model of the structure (shell and fluid) foundation system. The damping factors used were in accordance with Regulatory Guide 1.61 for the shell and the impulsive fluid mass. For the convective fluid, the damping was considered to be 1/2 percent of critical damping. Thus, the parameters and methods used for seismic reanalysis are in accordance with the accepted practice and are acceptable.

The responses (loads) from the impulsive, sloshing and vertical modes in the two horizontal directions are combined by the square root of the sum of the square method and the results were combined with hydrostatic loads by the absolute sum method. The spatial combinations were performed by the method recommended by Newmark using 100 percent of the horizontal response in one direction combined with 40 percent of the response due to the other (perpendicular) direction and 40 percent of the response due to the vertical seismic excitation. The nozzle loads were computed from the separate seismic analysis and were combined with the total tank responses around the nozzle locations. Thus, the method of combining responses from the seismic analyses are acceptable.

For computing stresses in the roof shell and the connecting angle welds, the sloshing height and resulting forces were computed using the formula in NUREG/CR-1161 (Ref. 5).

The shell stresses are computed for each course of the shell thickness and compared against the allowables. The allowable stresses are computed using the provisions of Subsection NC of the ASME Boiler & Pressure Vessel Code Section III. The staff accepts the licensee's procedure. The computed compressive stresses are within the corresponding allowables. The compressive stresses in the dome-shell due to sloshing of fluid are less than the ones computed for snow load and they are significantly lower than the allowables. The calculated maximum forces on the circumferential fillet weld connecting the dome to the angle is substantially lower than the allowable force. The maximum tension load in any anchor-bolt under the three components of earthquake is less than 10 kips, while the allowable is 50 kips. Actual construction indicates the hole-size of 3-1/4 inch diameter for 2-inch diameter anchor-bolts ensures that there will not be any shear force transferred to the anchor-bolts due to lateral loads. Also, utilizing the static friction between the tank bottom and the concrete pad, the licensee demonstrated that there will not be any sliding of the tank due to the lateral loads.

The licensee also performed calculations to demonstrate that the RC pad is capable of withstanding the calculated maximum forces due to the reanalyzed applied loads. For example, at the weakest section (i.e., the strip around the sump-pit) the maximum design shear under load combination incorporating SSE is 74.5 kips per foot, while the allowable shear computed using the provision of ACI 318-83 is 79.35 kips per foot. The staff accepts the licensee's results of the reanalysis ensuring that the tank will retain its integrity under the postulated seismic loadings.

## CONCLUSION

Based on the review of the licensee responses to the staff requests for additional information, audit of sample calculations and subsequent teleconferences, the staff has concluded that the check of the RWST performed by the licensee is in accordance with the guidelines provided in Revision 2 of the Standard Review Plan Section 3.7.3, the Updated Safety Analysis Report (USAR) commitments, and other acceptable procedures, and therefore the tank is acceptable.

## REFERENCES

1. F.J. Hebdon, U.S. Nuclear Regulatory Commission, letter to B. D. Withers, Wolf Creek Nuclear Operating Corporation, dated May 25, 1989.

2. F.T. Rhodes, Wolf Creek Nuclear Operating Corporation, letter to U.S. Nuclear Regulatory Commission, dated September 22, 1989.

3. B.D. Withers, Wolf Creek Nuclear Operating Corporation, letter to U.S. Nuclear Regulatory Commission, dated July 5, 1990.

4. B.D. Withers, Wolf Creek Nuclear Operating Corporation, letter to U.S. Nuclear Regulatory Commission, dated December 28, 1990.

5. U.S. Nuclear Regulatory Commission, "Recommended Revisions to Nuclear Regulatory Commission Seismic Design Criteria," NUREG/CR-1161, May 1980.