May 23, 1989

Docket No. 50-483

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Mr. Donald F. Schnell
Senior Vice President - Nuclear
Union Electric Company
Post Office Box 149
St. Louis, Missouri 63166

Dear Mr. Schnell:

SUBJECT: SEISMIC DESIGN CONSIDERATION FOR CERTAIN SAFETY-RELATED VERTICAL STEEL TANKS (REQUEST FOR INFORMATION)

As a result of activities related to the technical resolution of Unresolved Safety Issue (USI) A-40, "Seismic Design Criteria," a preliminary determination has been made that a potential safety issue exists with regard to the ability of certain safety-related above-ground vertical liquid storage tanks at your facility to maintain their structural and functional integrity during postulated earthquake events. To make a final determination as to the safety significance of this issue, the NRC staff requests the information identified below. The following is a brief description of the technical basis for the staff concern.

There has been a significant evolution in the seismic design practice for tanks. In the past, the method used for tank analysis (Ref. 1 of the enclosure) did not account for tank flexibility. As a result, some large tanks were designed for significantly lower loads compared to current practice (Ref. 2 of the enclosure). The Lawrence Livermore National Laboratory (LLNL), an NRC contractor, has estimated this difference to a factor of 2 to 2.5. That is, the past design practice led to tanks being designed for loads that could be a factor of 2 to 2.5 less than current practice. The source of this factor is the amplification of spectra at typical tank frequencies. Coupling the above with the observation of tank failures at non-nuclear facilities during past earthquakes (most recently, at Coalinga, California in May 1983, in Chile in 1984 and in Mexico in 1985), the staff considers this a potentially significant safety issue.

In order to make a final determination on this issue, you are requested to provide within 120 days of receipt of this letter, the information identified below.

1. If tank wall flexibility was considered in the seismic design of the Refueling Water Storage Tank and the safety-related Condensate Storage Tank/Auxiliary Feedwater Storage Tank at your facility as outlined in

DF01
1/1

the enclosure to this letter, provide a summary of the analyses sufficient to show how steps a. through i. of the enclosure were considered and the results of these analyses.

2. If tank wall flexibility was not considered as outlined in the enclosure to this letter for the above tanks, in view of the new information described above, provide the basis for continued confidence in the ability of the tanks to withstand the seismic event specified as a design basis for your facility. One option may be to use the procedures developed by the Seismic Qualification Utility Group (SQUG) under the resolution of USI A-46, "Seismic Qualification of Equipment in Operating Plants," to check the adequacy of the above-mentioned tanks for seismic events.

The reporting and/or recordkeeping requirements contained in this letter affect fewer than 10 respondents; therefore, OMB clearance is not required under Pub. L. 96-511.

Sincerely,

/s/

John N. Hannon, Director
Project Directorate III-3
Division of Reactor Projects - III, IV, V and Special Projects
Office of Nuclear Reactor Regulation

Enclosure:
NRC Staff-Recommended Method for Seismic Analysis of Above-Ground Tanks

cc w/enclosure:
See next page

[Vertical Steel Tanks]

Office:	LA/PDIII-3	PM/PDIII-3	ESGB	PD/PDIII-3
Surname:	PKreutzer	TAlexion/mr	GBagchi	JHannon
Date:	5/19/89	5/29/89	5/2/89	5/23/89

Mr. D. F. Schnell
Union Electric Company

Callaway Plant
Unit No. 1

cc:

Dr. J. O. Cermack
CFA Inc.
4 Professional Dr., Suite 110
Gaithersburg, MD 20879

Gerald Charnoff, Esq.
Thomas A. Baxter, Esq.
Shaw, Pittman, Potts & Trowbridge
2300 N Street, N. W.
Washington, D. C. 20037

Mr. T. P. Sharkey
Supervising Engineer,
Site Licensing
Union Electric Company
Post Office Box 620
Fulton, Missouri 65251

U. S. Nuclear Regulatory Commission
Resident Inspectors Office
RR#1
Steedman, Missouri 65077

Mr. Alan C. Passwater, Manager
Licensing and Fuels
Union Electric Company
Post Office Box 149
St. Louis, Missouri 63166

Manager - Electric Department
Missouri Public Service Commission
301 W. High
Post Office Box 360
Jefferson City, Missouri 65102

Regional Administrator
U. S. NRC, Region III
799 Roosevelt Road
Glen Ellyn, Illinois 60137

Mr. Ronald A. Kucera, Deputy Director
Department of Natural Resources
P. O. Box 176
Jefferson City, Missouri 65102

Mr. Bart D. Withers
President and Chief
Executive Officer
Wolf Creek Nuclear Operating
Corporation
P. O. Box 411
Burlington, Kansas 66839

Mr. Dan I. Bolef, President
Kay Drey, Representative
Board of Directors Coalition
for the Environment
St. Louis Region
6267 Delmar Boulevard
University City, Missouri 63130

Enclosure

NRC Staff-Recommended Method for Seismic Analysis of Above-Ground Tanks

Most above-ground fluid-containing vertical tanks do not warrant sophisticated, finite element, fluid-structure interaction analyses for seismic loading. However, the commonly used alternative of analyzing such tanks with rigid wall assumption (Ref. 1) may be inadequate in some cases. The major problem is that direct application of this method is consistent with the assumption that the combined fluid-tank system in the horizontal impulsive mode is sufficiently rigid to justify the assumption of a rigid tank. For the case of the flat-bottomed tanks mounted directly on their bases, or tanks with very stiff skirt supports, the assumption leads to the usage of a spectral acceleration equal to the zero-period base acceleration. Recent evaluation techniques (Ref. 3 and 4) have shown that for typical tank designs the frequency for this fundamental horizontal impulsive mode of the tank shell and contained fluid is generally between 2 and 20 Hz. Within this regime, the spectral acceleration is typically far greater than zero-acceleration. Thus, the assumption of a rigid tank could lead to inadequate design loadings.

The acceptance criteria below are based upon the information contained in References 1-4. These references also contain acceptable calculational techniques for the implementation of these criteria.

a. A minimum acceptable analysis should incorporate at least two horizontal modes of combined fluid-tank vibration and at least one vertical mode of fluid vibration. The horizontal response analysis should include at least one impulsive mode in which the response of the tank shell and roof are coupled together with the portion of the fluid contents that moves in unison with the shell. Furthermore, at least the fundamental sloshing (convective) mode of the fluid should be included in the horizontal analysis.

b. The frequency of fundamental horizontal impulse mode of the tank and the fluid system should be estimated. It is unacceptable to assume a rigid tank unless the assumption can be justified. The horizontal impulsive-mode spectral acceleration is then determined using this frequency of fundamental horizontal impulsive mode and tank-shell damping. The maximum horizontal spectral acceleration associated with the tank support at the tank-shell damping level may be used instead of determining frequency of fundamental horizontal impulsive mode.

c. Damping values used to determine the spectral acceleration in the impulsive mode should be based upon the values for tank shell material as specified in the current SRP Section 3.7.1.

d. In determining the spectral acceleration in the horizontal convective mode the fluid damping ratio should be 0.5% of critical damping unless a higher value can be substantiated by experimental results.

e. The maximum overturning moment M_B at the base of the tank should be obtained by the modal and spatial combination methods discussed in the SRP Section 3.7.2.II. The uplift tension resulting from M_B should be resisted either by tying the tank to the foundation with anchor bolts, etc., or by mobilizing enough fluid weight on a thickened base skirt plate. The latter method of resisting M_B must be shown to be conservative.

f. The seismically-induced hydrodynamic pressures on the tank shell at any level can be determined by the modal and spatial combination methods in the SRP Section 3.7.2. The hydrodynamic pressure at any level should be added to the hydrostatic pressure at the level to determine the hoop tension in the tank shell.

g. Either the tank top head should be located at an elevation higher than the slosh height above the top of the fluid or else should be designed for pressures resulting from fluid sloshing against this head. The method in current design codes for calculating slosh height is not necessarily conservative. Formulas given in Ref. 1 can be used to calculate slosh height.

h. The tank foundation (see also SRP Section 3.8.5) should be designed to accommodate the seismic forces imposed by the base of the tank. These forces include the hydrodynamic fluid pressures imposed on the base of the tank as well as the tank shell longitudinal compressive and tensile forces resulting from M_B.

i. In addition to the above, consideration should be given to prevention of buckling of tank walls and roof, failure of connecting piping, and sliding of the tank.

References:

1. "Nuclear Reactors and Earthquakes," TID-7024, prepared by Lockheed Aircraft Corporation and Holmes & Narver, Inc., for the Division of Reactor Development, U.S. Atomic Energy Commission, Washington, D.C., August 1963.

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. A. S. Veletsos and J. Y. Yang, "Dynamics of Fixed-Base Liquid-Storage Tanks," U.S.-Japan Seminar for Earthquake Engineering Research with Emphasis on Lifeline Systems, Tokyo, Japan, November, 1976.

4. A. S. Veletos, "Seismic Effects in Flexible Liquid Storage Tanks," Proceedings of Fifth World Conference on Earthquake Engineering, Rome, 1974.