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Interim Report On Status Of Containment Integrity Studies For Continued In-Tank Storage Of Hanford High-Level Defense Waste

P. F. Mercier

September 1979

Prepared for the United States
Department of Energy
Under Contract DE-AC06-77RL01030

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INTERIM REPORT ON STATUS OF CONTAINMENT INTEGRITY STUDIES FOR CONTINUED IN-TANK STORAGE OF HANFORD HIGH-LEVEL DEFENSE WASTE

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ABSTRACT

This interim report supplements technical information reported in RHO-LD-52, "Status of Containment Integrity Studies for Continued In-Tank Storage of Hanford Defense High-Level Waste", September 1978. Only new data from the continuing laboratory programs and those studies initiated in the past year are included.

Analyses of waste tank concrete integrity continued through the year. Laboratory tests to determine the effect of long-term elevated temperatures on the strength and elastic properties of concrete showed that the modulus of elasticity, compressive strength, and splitting tensile strength continued to decrease as a function of temperature; Poisson's ratio was relatively unchanged. The durability tests of reinforced concrete specimens exposed to simulated waste chemicals showed no evidence of deterioration after 6 months exposure. Temperature cycling effects after 17 cycles showed little change in the compressive strength but a large reduction in the modulus of elasticity.

A structural failure mode analysis was initiated to estimate the effect of constant dead load, elevated temperature, and aggressive chemicals on tank structural integrity after 100 years of waste storage. No results are presently available. A report is scheduled for completion in early 1980.

An electron microscopy analysis was initiated to determine if microstructural changes in concrete can be detected which would provide a key for correlating relatively short-term laboratory data to predicting long-term structural behavior. Documented results are scheduled for late 1980.

CONTENTS

1.0 INTRODUCTION

1.1 BACKGROUND

High-level radioactive wastes resulting from the chemical processing of spent reactor fuel for the recovery of plutonium, uranium and other radioisotopes have been accumulating at Hanford since 1944; these wastes have been stored in underground steel-lined reinforced concrete tanks. A solidification program was initiated in 1960 to reduce the liquid inventory and mobility of the waste.

Alternative storage modes were discussed in a final environmental statement of waste management operations at Hanford.(1) One of the alternatives considered was deferring retrieval of the waste and continuing in-tank storage with engineered improvements until a permanent disposal mode is selected. A report issued in 1978(2) summarized the work accomplished in developing a technical basis for assessing the storage tank containment integrity.

The purpose of this report is to update the 1978 report, publish results of work accomplished in the past year, and reconsider the previously made assessment of storage tank integrity.

1.2 SCOPE

This report documents an additional year of technical studies and laboratory tests to provide a basis for estimating how long the defense high-level waste can be safely stored in the existing single-shell tanks. The information in this and the preceding report(2) is generic in its application to all of the reinforced concrete waste tanks.

2.0 SUMMARY

2.1 TANK INTEGRITY ASSESSMENT

This report provides technical information from continuing studies carried out since publication of an earlier status report.[2] These new data have been examined to determine the effect on the previous conclusion that "the single-shell tanks are serviceable for high-level waste storage for decades."[2]

The concrete integrity analysis program continued through the past year. Some chemicals in the stored waste are capable of attacking reinforced concrete. However, laboratory tests designed to simulate a leak in the carbon steel tank liner have shown no deleterious effect on either the concrete or reinforcing steel after 6 months exposure. Testing will be continued with specimens tested at 6-month intervals until the 3-year program is completed.

The effect of elevated temperatures on the elastic and strength properties of concrete continues to show reduction with time at a rate dependent on the temperature and the design mix. The rate of change for the 3000-psi compressive strength concrete is less than that for the 4500-psi mix. In contrast, the control specimens maintained in a moist atmosphere at 70°F increased in strength with time. Poisson's ratio varied little with either temperature or time.

The effects of cyclically varying temperature on the strength and elastic properties of Hanford aggregate concretes showed a large reduction in the modulus of elasticity but a negligible reduction in either Poisson's ratio or compressive strength after 17 cycles.

2.2 CONCLUSION

Elevated temperatures continue to be the dominant factor in the reduction of concrete strength. Waste management standards limit tank concrete temperatures.[3] Only 17 of the 149 single-shell tanks require auxiliary cooling to maintain the temperature limit. Because of the aging and decreasing decay heat of the waste, resulting in lower temperatures, current and future operating conditions will not subject the tanks to the thermal loads experienced in the past. The results of the elevated temperature tests show that temperatures within the waste management standards have little effect on elastic and strength properties of concrete. Unlike surface structures that are exposed to a variety of conditions, the underground tanks are in a stable moisture and temperature environment. Precipitation normally penetrates less than 13 feet and returns to the atmosphere by evaporation during the dry summer.

Laboratory test data and analyses completed to date support the earlier conclusion that the tanks will provide safe storage for salt cake and sludge for decades.

3.0 CONCRETE INTEGRITY ANALYSIS

3.1 CONCRETE DATA BASE STUDIES

3.1.1 Objective

The objective of this analysis is to develop a technical basis for evaluating the integrity of the underground storage tanks. Published literature is not available to predict the behavior of reinforced concrete exposed to a highly alkaline solution (pH $\cong$ 9.0) while subjected to elevated temperatures (250 to 450°F) for decades. A 4-year laboratory test program, initiated in 1975, to develop the unknown data has been in progress at the Construction Technology Laboratories of the Portland Cement Association, Skokie, Illinois. All tests were made on 6-inch-diameter by 12-inch-long cyclinders using aggregates from Hanford and the design mixes used in constructing the tanks (3000- and 4500-psi minimum compressive strength).

3.1.2 Concrete Durability Tests

The objective of this test is to determine the effect of a simulated waste solution on laboratory constructed concrete specimens made with Hanford aggregates. The 36-inch-long specimens contain three reinforcing bars and are maintained under stress while exposed to the waste solution at a temperature of 180°F. The waste solution was applied in a manner that simulates a leak in the tank's steel liner, as shown in Figure 3.1

Examination of the specimens after 6 months of exposure showed no evidence of chemical attack. The reinforcing steel showed no evidence of rusting, cracking, or disruption of the mill scale; a petrographic examination of the concrete showed no evidence of corrosion.

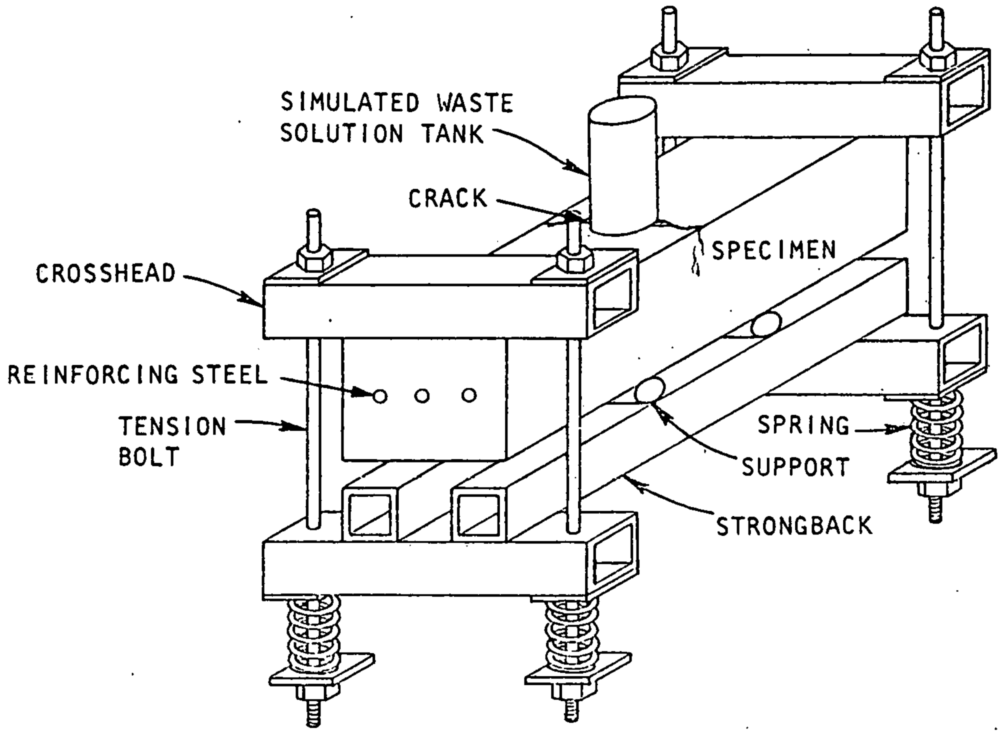

FIGURE 3.1. Concrete Durability Test Setup.

3.1.3 Elevated Temperature Effects

Concrete test specimens were made with Hanford aggregate in accordance with the two specified mix designs used in building the storage tanks. Tests were made to determine the effect of elevated temperatures on the modulus of elasticity, Poisson's ratio, compressive strength, and splitting tensile strength. Specimens were held at 250, 350, and 450°F with a control specimen held at 70°F in a moist atmosphere. Nearly 2-1/2 years (900 days) of exposure have been completed. Details of the test and results are reported in a separate document.(4)

Figures 3.2 and 3.3 show the change of the modulus of elasticity with time and temperature for each of the two mix designs. The modulus of the moist-cured control specimens at 70°F increased with time. At elevated temperatures, the modulus of both design mixes decreased with increasing temperature and time.

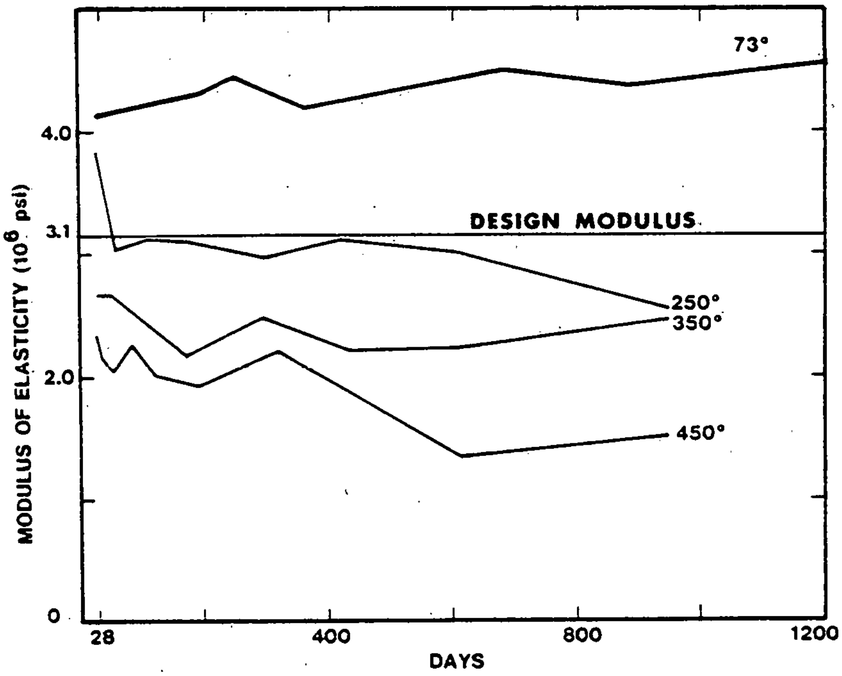

FIGURE 3.2. Modulus of Elasticity Versus Temperature and Time (3000-psi concrete).

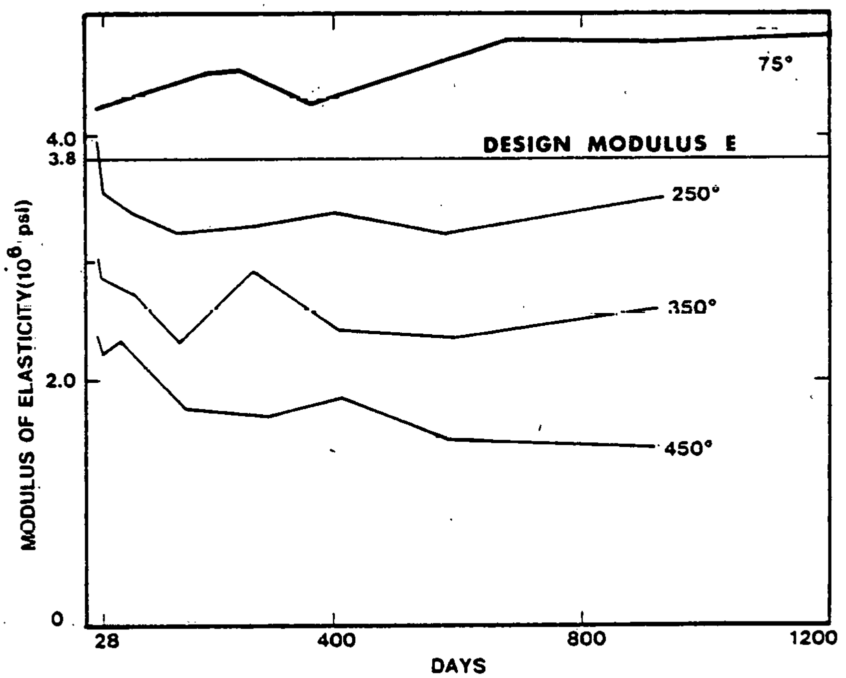

FIGURE 3.3. Modulus of Elasticity Versus Temperature and Time (4500-psi concrete).

Poisson's ratio varied little with time and temperature; for the moist-cured specimens at 70°F, using the static test method, it ranged from 0.15 to 0.19 while at elevated temperatures, it varied between 0.10 and 0.14 for both design mixes.

In general, the compressive strength of both design mixes at elevated temperatures decreased with time and increased temperatures while the moist-cured control specimens at 70°F increased with time; Figures 3.4 and 3.5 show these changes. The values for the 3000-psi concrete remained above the minimum design value; the 4500-psi concrete values were below at 450°F and approached the minimum design value at 350°F after 900 days.

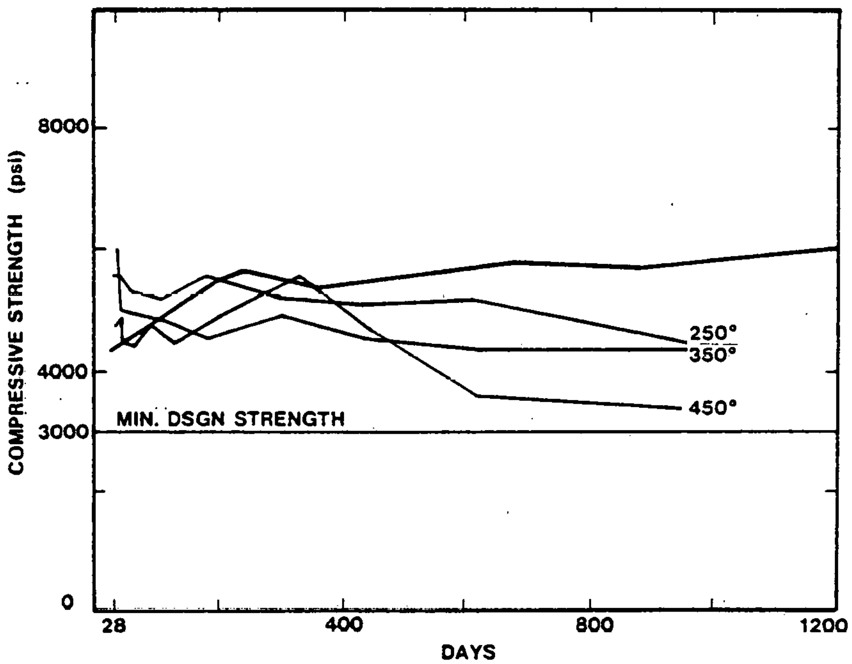

FIGURE 3.4. Compressive Strength Versus Temperature and Time (3000-psi concrete).

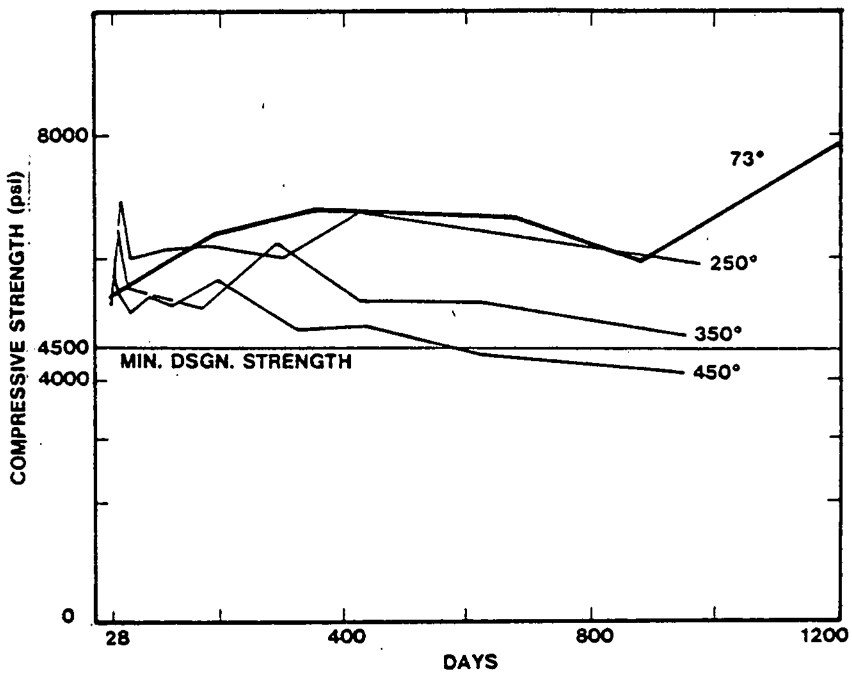

FIGURE 3.5. Compressive Strength Versus Temperature and Time (4500-psi concrete).

3.1.4 Temperature Cycling Effects

The effects of cyclically varying elevated temperatures on strength and elastic properties of concrete have been studied in connection with reactor shielding. Results indicate four factors strongly influence the degree of deterioration: temperature, rate of heating and cooling, presence of moisture, and load applied during heating. Studies have not been undertaken to determine the effect of a large number of thermal cycles on strength and elastic properties.

Tests have been completed and reported in a separate document[5] to evaluate the effects of cyclically varying temperature on the strength and elastic properties of Hanford aggregate concretes. The specimens were cast and testing conducted by the Portland Cement Association Construction Technology Laboratories., Skokie, Illinois. Two design mixes were used, 3000- and 4500-psi minimum compressive strength. A thermal cycle was 14 days. Maximum rate of heating was 140°F per day to a maximum temperature of 350°F and maintained for 10 of the 14 days of the cycle. Compressive strength and elastic properties were determined for unheated cylinders, and for specimens subjected to 1, 3, 5, 8, 12 and 17 thermal cycles.

Unheated cylinders from the 3000- and 4500-psi mix had average strengths of 6195 and 7595 psi, respectively. Repeated thermal cycling caused a gradual decline in strength values. After 17 thermal cycle, the strength of the 3000-psi mix cylinders averaged 5755 psi, while that of the 4500-psi mix averaged 6775 psi.

Modulus of elasticity of unheated 3000-psi mix cylinders was 4.9 million psi and the 4500-psi mix averaged 5.63 million psi. After one thermal cycle, modulus of elasticity values were higher than those of unheated specimens. Continued thermal cycling caused a decline in modulus values below that of unheated cylinders. After 17 thermal cycles, modulus of elasticity of 3000-psi mix cylinders averaged 3.39 million psi. Values for the 4500-psi mix specimens averaged 3.41 million psi.

Poisson's ratio for the unheated 3000-psi mix cylinders was 0.16 and for the 4500-psi, 0.18. After three temperature cycles, Poisson's ratio from these series were reduced to 0.14 and 0.13, respectively. After 17 thermal cycles, Poisson's ratio of the 3000-psi cylinders averaged 0.17, while the 4500-psi specimens averaged 0.16.

3.1.5 Conclusions

The results of 6 months exposure of concrete test specimens to a simulated waste solution to determine the effect on durability showed no evidence of corrosion of the concrete or reinforcing steel. Testing is continuing and the effects of 18 months and 2 years exposure will be tested in 1980.

The results of the elevated temperature tests show that the modulus of elasticity, compressive strength, and the splitting tensile strength generally decrease with increasing temperature and continue to decrease with time at steady-state temperatures. Poisson's ratio is not significantly affected. Control specimens at 70°F in a moist atmosphere increased in strength and elastic properties.

Temperature cycling had a minimal effect on concrete compressive strength but significantly reduces the modulus of elasticity. The reduction is greatest after three cycles.

3.2 WASTE TANK CONCRETE EXAMINATION

3.2.1 Objective

The objective of this examination is to provide concrete samples from existing tanks for testing and comparison with data from the laboratory tests. The results of the comparison will be one of the factors used in estimating the integrity of the tanks and the length of continued safe storage.

3.2.2 Tank Concrete Sampling

The tank dome supports a soil load of 250 tons per foot of depth and transmits the load to the sidewalls through the heavily reinforced haunch (junction of dome and sidewall). Structural analyses have shown that the dome is dependent on the haunch for support and rigidity. The effects of creep and elevated temperatures could ultimately jeopardize the structural integrity of the tank. Hence, it is necessary that the quality of the concrete in the haunch area, the sidewall, and the dome be determined.

Rotary drills were used to provide openings in the dome for equipment additions to the tanks. Some of the resulting concrete cores were tested in the laboratory and showed a compressive strength well above the minimum design value. No concrete from the haunch or sidewall has been removed to date. Figure 3.6 shows a proposed method for removing a concrete core from the haunch and sidewall of a tank.

Rotary drilling in basalt with diamond-studded bits was shown to be controllable. The return water from the cutter is metered and monitored for radioactivity. Loss of the return water indicates penetration of the sidewall and a reduction in flow indicates that penetration into a crack or failed area has occurred. Contaminated return water can be readily confined to the caisson for removal and cleanup. The vertical core hole can be easily plugged to maintain confinement.

A "cold" demonstration is planned for 1980 to determine the controllability and safety of the method. If acceptable, a safety review would be initiated to remove a core from one of the "empty" tanks with only a few inches of sludge in the bottom.

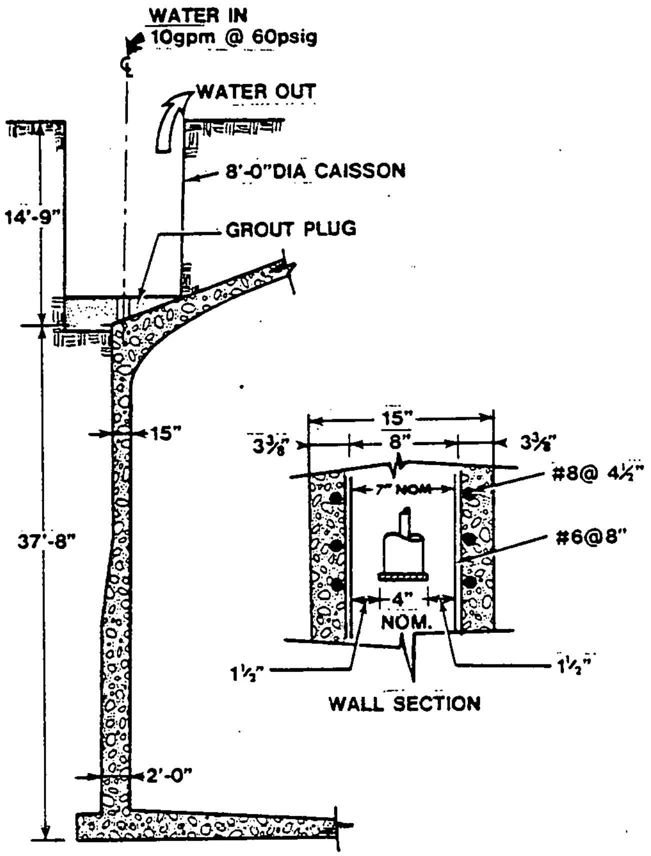

FIGURE 3.6. Proposed Concrete Sampling Method.

3.2.3 Electron Microscopy Examination

The laboratory studies of factors affecting concrete integrity are of miniscule duration compared to the length of the waste storage period. A fundamental question is, "How much confidence can be placed in the results of a relatively short-term study for predicting long-term concrete structural behavior?"

Technical direction for this analysis is provided by Pacific Northwest Laboratory - Battelle, Richland, Washington. Their equipment and capabilities for microstructural examination of certain materials via scanning electron microscopy are highly regarded. Development of this technical competency was achieved through liaison with the U. S. Army Corps of Engineers Waterways Experiment Station. The laboratory has been active in providing applied research in massive concrete structures, such as locks and dams, for more than 25 years. A contract for their assistance has been established and samples of concrete from tank domes, Purex canyon wall, and laboratory test specimens are being examined. The goal is to identify characteristic aging changes as a possible means of predicting long-term structural behavior. A final report of their study is scheduled for early 1980.

4.0 STRUCTURAL FAILURE MODE ANALYSIS

4.1 OBJECTIVE

The purpose of the analysis is to determine the structural change and failure mode of a reinforced concrete tank subjected to a constant dead load, elevated temperature, and aggressive chemicals for 100 years. The identification of possible failure zones in the storage tank structure could indicate modifications for improving containment integrity for long-term storage.

4.2 STUDIES

The analysis, initiated during the past year, is being conducted by the Pacific Northwest Laboratory, Engineering Physics Department. The Nonlinear Stress Analysis Program (NONSAP-C)[6] developed for reinforced concrete containments was selected for use, with a graphics package added to aid in debugging the mesh geometry.

The finite element model of the waste tank includes the effects of soil backfill and overburden loads, and the hydrostatic loads due to tank contents. Radially located truss elements with appropriate nonlinear stiffnesses are used to model the static soil-wall interaction. Backfill, overburden, and fluid hydrostatic pressures are input as element pressure loads.

The original modeling plan included three (three-dimensional) finite element models:

- One-eighth section model to serve as a baseline study, using the 100-year concrete properties without tank defects.
- One-eighth section model which will include a circumferential (deteriorated region of concrete) defect and the 100-year concrete properties.
- One-half section model with a growing through-wall hole and the concrete 100-year properties.

The baseline one-eighth section model contains approximately 3400 nodes. Time and cost considerations have led to program modifications so that the current three-dimensional finite element models will consist of:

- One element circumferentially to serve as a baseline study, using the 100-year concrete properties without tank defects.
- One element circumferentially which will include a circumferential defect and the 100-year concrete properties with tank defects.
- One element circumferentially which will include a circumferential defect, 100-year concrete properties, and variations in overburden pressure to model the effects of an over dome concrete slab and overburden cover.
- One element circumferentially and radially (through thickness) to serve as a mesh convergence test.
- One-half section model with coarser resolution (one element radially) to determine the effect of a through-wall hole, 100-year concrete properties, and variations in overburden pressure and defect growth.

The analysis has progressed to completion of the first three models. Coding of the convergence test and one-half model is completed. A report of the analysis is expected by late 1979.

5.0 TANK DOME SURVEILLANCE

5.1 OBJECTIVE

When loaded, concrete deforms in two steps: (1) a deformation which occurs immediately, and (2) a time-dependent deformation which begins immediately but continues for years. This latter deformation is called "creep", and its rate is affected by load and temperature. Under continuous load, creep continues for many years but the rate decreases with time.

A waste storage tank dome supports a soil cover load that varies in depth from 6 to 9 feet at temperatures as high as 200°F. The tank dome is a relatively flexible part of the tank structure and can be expected to experience sag as storage time increases.

The objective of this surveillance procedure is to monitor changes in tank dome elevation with time.

5.2 SCOPE

A surveillance program is being initiated for the single-shell tanks containing salt cake, sludge, and interstitial liquid.

5.3 PROGRAM DESCRIPTION

Tank dome surveillance will be conducted by periodically monitoring changes in dome elevation and by establishing a photographic record of the appearance of the underside surface of the dome.

Elevation reference points are established on tank dome risers after the tanks are isolated to prevent liquid intrusion, and the liquid in the waste has been removed as completely as is technically achievable. Measurements are taken from an established bench mark in the tank farm, recorded, and maintained for periodic measurements. Comparison with previous measurements will indicate stability of the dome. Indication of a change or rate of change would be the basis for initiating more frequent measurements.

Reduction of the soil cover as the need for radiation shielding is reduced will reduce the rate of creep in the dome. The creep rate due to temperature will decrease also as the waste ages and radiolytic heat decays and will eventually have a negligible effect.

Photographing the underside of the tank dome has been performed with difficulty and distortion because the camera system in use was designed to view the surface of the waste. Modifications have been made and recent photographs are improved. A new camera has been designed to allow a full view of the underside of the dome and remote focusing. The use of this camera will provide an accurate photographic record that can allow comparison with later photographs to determine if changes in the dome surface are occurring.

The elements of the tank dome surveillance are: soil cover removal, tank dome elevation monitoring, and dome underside photographs. These provide a basis for assuring continued safe containment. If measurements indicate a dome sag is progressing, a preplanned method of assuring containment integrity can be initiated.

6.0 REFERENCES

1. ERDA-1538, December 1975, "Final Environmental Statement, Waste Management Operations, Hanford Reservation, Richland, Washington," U. S. Energy Research and Development Administration, Richland, Washington.

2. RHO-LD-52, September 1978, R. G. Baca, et al., "Status of Containment Integrity Studies for Continued In-Tank Storage of Hanford Defense High-Level Waste," Rockwell Hanford Operations, Richland, Washington.

3. RHO-MA-151, March 1979, G. T. Dukelow, "Specifications and Standards for the Operation of Radioactive Waste Tank Farms and Associated Facilities," Rockwell Hanford Operations, Richland, Washington.

4. RHO-C-28, March 1979, M. S. Abrams, M. Gillen, D. H. Campbell, "Elastic and Strength Properties of Hanford Concrete Mixes at Room and Elevated Temperatures", Construction Technology Laboratories of the Portland Cement Association, Skokie, Illinois.

5. RHO-C-23, December 1978, M. Gillen, "Effects of Temperature Cycling on Strength and Elastic Properties of Hanford Concretes," Construction Technology Laboratories of the Portland Cement Association, Skokie, Illinois.

6. NUREG/CR-0416, October 1978, P. D. Smith and C. A. Anderson, Los Alamos Scientific Laboratory, "NONSAP-C: A Nonlinear Stress Analysis Program for Concrete Containments Under Static, Dynamic, and Long-Term Loadings", Los Alamos, New Mexico.

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