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TANK ASSESSMENT STUDIES FOR CONTINUED IN-TANK STORAGE OF HANFORD DEFENSE WASTE

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EXECUTIVE SUMMARY

This report provides technical information on a 7-yr study evaluating the underground single-shell waste tanks for the continued storage of radioactive waste at the Hanford Site. Status reports were issued in September 1978, October 1980, and October 1982. This effort is concluded with the issuance of this report. The data are generic to all the underground reinforced concrete waste storage tanks at Hanford and include study results and evaluation methods. Any future work would be directed to very specific final disposal alternatives that might affect the structural integrity during implementation. The work was conducted as part of the U.S. Department of Energy (DOE) Waste Tank Assessment Task, WG End Function (AR-05-15-20).

The objectives of this task established in ERDA-1538, 1975,* were to determine the period of time during which salt cake, sludge, and terminal liquor can continue to be safely stored in underground tanks, and to determine the engineered improvements that might be used to extend the safe storage period. Though an exact life cannot be established using present-day analysis techniques, results of the analyses indicated that the tanks are capable of supporting all loads specified under presently proposed operating conditions. These proposed operating conditions provide greater soil and equipment loads, higher specific gravity, and higher temperatures than allowed earlier. The tanks should continue to function structurally if there are no changes in operating conditions.

It was also determined that, under present conditions, dome support methods are not warranted with respect to continued structural integrity. Though dome filling would be important to reduce subsidence if problems occurred in the future, it is unlikely that a system could be designed to prevent dome cracking, as the domes do not deflect significantly under soil or equipment loads.

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*ERDA-1538 (UC-70), 1975, Final Environmental Statement, Waste Management Operations, Hanford Reservation, Richland, Washington, U.S. Energy Research and Development Administration, (2 Volumes), NTIS, Springfield, VA.

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INTRODUCTION

Radioactive defense waste, resulting from the chemical processing of spent nuclear fuel for recovery of special nuclear materials (primarily plutonium), has been accumulating at Hanford since 1944. This defense waste is stored in underground waste tanks and in storage capsules in water basins. Based on current planning, waste will remain in existing underground tanks at Hanford until final waste disposition is completed. To ensure safe storage of the waste, the use of underground waste storage tanks for continued service is being investigated.

BACKGROUND

Technical studies were initiated in 1973 to provide a basis for evaluating the structural integrity of the defense waste single-shell storage tanks. A waste management solidification program, initiated in 1960, has reduced the liquid waste in the single-shell tanks to a relatively immobile salt cake (precipitated soluble salts), sludge (insoluble hydrous metal oxides), and interstitial liquor (partly held by capillary attraction).

Preliminary work was aimed at characterizing the basic structural properties of the concrete used in the waste tanks. In 1977 studies were completed on various ways to add extra dome support. An initial status report (Baca et al., 1978) summarized the work accomplished in developing a technical basis for assessing the storage tank containment integrity.

More recent work has centered on potential failure modes of the waste tanks and the present condition of the tanks. Updated reports discussed the effects of elevated temperatures on the structural properties of reinforced concrete (DeFigh-Price and Mercier, 1980) and the results of the single-shell tank structural analyses and heat transfer analyses of long-term disposal options (DeFigh-Price, 1982).

This final report summarizes the results of the structural analyses and the tanks' response to the applied loads, the material properties, and the possible failure modes.

SCOPE

The Waste Tank Evaluation Task (WG6AA) was undertaken to evaluate the structural integrity of concrete single-shell waste tanks at Hanford.

The objectives of this task were to:

- Develop a technical data base on parameters important to the structural integrity of the waste tanks
- Develop and demonstrate methods for inspecting and evaluating the structural integrity of the tanks
- Support the engineered barriers work, as needed.

The original purpose of the 7-yr study was to determine if the tanks could be used beyond their specified design life. Design life is not a realistic method for determining the condition of a structure, however. Variability in construction materials and methods, loading histories, and environmental conditions, for example, affects a structure's durability or longevity. The quality of the concrete at the time of construction and the loads to which the structure has been subjected over a period of time are extremely important in determining its durability or longevity (Neville, 1981; Hansen, 1982). Therefore, the tank integrity studies emphasized:

- The present condition of the tanks
- The possible damage of the concrete due to the stored waste forms
- The magnitudes of the stresses experienced by various structural components as compared to present American Concrete Institute design limits.

STRUCTURAL ANALYSIS

Five waste tank designs are used at Hanford for underground liquid waste storage (Fig. 1). Four of these are single-shell; the fifth is a double-shell tank design. This report addresses only the single-shell tank

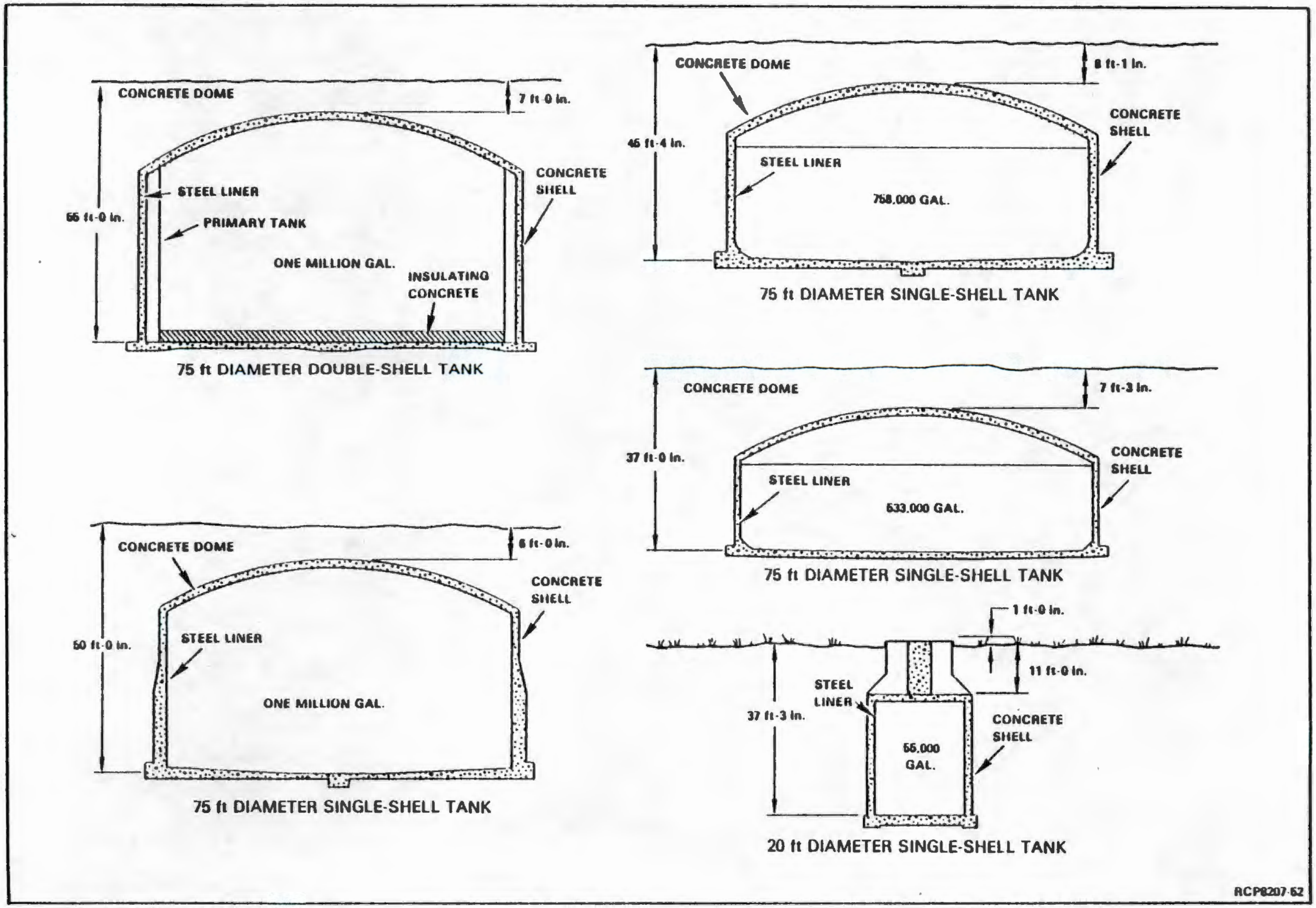

FIGURE 1. General High-Level Waste Tank Designs Used at Hanford.

designs, which will be categorized according to their inside diameters: a 20-ft-diameter tank design for a capacity of 55,000 gal and three 75-ft-diameter tank designs for capacities of 533,000, 758,000, or 1 million gal.

Each single-shell tank design was analyzed for soil, equipment, hydrostatic, and thermal loads. The sensitivity of a particular tank design to each of the loads was determined by varying each load, one at a time, and calculating the resulting stresses.

BASE LOADING CASE

A base-loading case for the present standard operating conditions was established for each tank design. The base value for each load variable is given below.

Soil Load

The base line soil load results from the normal and lateral soil pressures due to the minimum soil covers measured at the tank's crown. Minimum soil covers for the four tank designs are illustrated in Figure 1. The soil pressure loads are based on a soil weight of 115 lb/ft^3 and a lateral soil pressure coefficient of 0.4.

Equipment Load

The base line equipment or live load is considered to be a 100,000-lb or 50-ton crane located at the surface directly above the crown of the tank and distributed over a 10-ft-diameter circle.

Hydrostatic Load

The base line hydrostatic load results from the pressure due to a tank filled with liquid of specific gravity 2.0. Vapor pressures from -6 in. to +60 in. of water were also included.

Thermal Load

The base line thermal load is based on a maximum specified concrete temperature of 350°F, representing a heat load of approximately 30,000 to 50,000 Btu/hr depending on tank type and size, waste depth, backfill material, and the presence of overburden material.

SENSITIVITY TO BASE LOADS

The sensitivity of a particular tank design to each base load was determined by varying each load, one at a time, and calculating the resulting stresses. Loads were increased either until an unacceptable stress level was reached, as defined by the American Concrete Institute (1977) code requirements, or until a maximum practical level was reached (such as a tank filled to capacity).

Soil Loads

The soil load was analytically increased in several steps (i.e., 6 ft, 15 ft, 25 ft, 30 ft, as measured from the crown of the tank dome) until dome or wall failure stresses were reached. Failure was defined as the maximum compressive stress in the concrete dome or wall exceeding 3,200 psi (a conservative limit based on a statistical analysis of a number of tank concrete core samples).

The footing designs were found to be the governing factor in determining the amount of soil that could be placed over a tank before allowable stresses were exceeded. Exact values varied somewhat with the six different footing designs, but maximum allowable soil covers (based on American Concrete Institute acceptable limits, not failure criteria) varied from 10 ft 2 in. to 16 ft 0 in., as measured from the tank crown (Table 1). If the footing were allowed to crack, the wall and dome could withstand 20 to 30 ft of soil (as measured from the tank crown) before unacceptable stresses (not necessarily failure stresses) were reached (Table 2).

TABLE 1. Footing Evaluation for 75-ft-Diameter Tank.

Tank farm designation	Tank capacity (gal)	Maximum allowable soil cover (ft - in.)*	Soil load factor*
241-A	1,000,000	10 - 2	1.5
241-AX	1,000,000	16 - 0	2.3
241-SX	1,000,000	10 - 3	1.5
241-BY,S,TX,TY	758,000	12 - 6	1.8
241-BX,B,C,T,U	533,000	10 - 7	1.5

*Based on ACI acceptable loads, not failure.

TABLE 2. Thermal-Creep and Ultimate Load Analyses for 75-ft-Diameter Tank.

Tank type	Capacity (gal)	Soil depth at crown (ft)		Analysis length (day)	Maximum wall temp (^oF)	Heat-up rate (^oF/day)
		As built	Maximum			
241-BX	533,000	7	20	33	387	21.1
241-U	533,000	7	20	3,650	315	4.9
241-BY	758,000	7	N/A*	900	250	3.7
241-SX	1,000,000	6	27	3,752	387	10.4
241-AX	1,000,000	8	29	2,000	350	2.9
241-A	1,000,000	6	20	15	511	48.4

*N/A - Not analyzed.

Equipment Loads

Equipment or live loads of 100,000, 200,000, and 400,000 lb were analyzed. These include the largest sized crane that could possibly be driven over a tank.

The tank designs were very insensitive to equipment loads. A negligible change in maximum concrete or steel stress was calculated for the fourfold increase in loads.

Hydrostatic Loads

Hydrostatic loads varied from zero (for an empty tank) to maximum (for a tank filled to capacity with liquids of specific gravity 2.0). Vapor pressures varying from -6 in. to +60 in. of water were included.

For the 20-ft-diameter tank design, changes in hydrostatic loads had negligible effects on the stresses in the dome and tank wall.

For the 75-ft-diameter tank designs, changes in hydrostatic loads had negligible effects on the longitudinal and circumferential stresses in the dome and haunch areas. Removal of the hydrostatic load increased the longitudinal compressive stresses in the wall at the junction of wall and footing and also increased the circumferential compressive stresses in the lower third of the wall. Since neither of these regions is critical for the combined loading, the effect on the overall margin of safety is negligible.

Thermal Loads

Thermal loads for all but the 20-ft-diameter tanks varied from none (for an ambient temperature analysis) to a worst-case temperature distribution (based on thermocouple measurements of the 241-A-106 Tank that experienced almost 600°F in the sludge layer for about 1 yr in the early 1960s).

The small 20-ft-diameter tanks have not been and will not be subjected to thermal loads.

Thermal loads had the largest effect on the deflections and stresses in the 75-ft-diameter tank designs. Tank dome deflections are very sensitive to thermal changes. Actual measurements indicated changes in elevation of up to 0.3 in. between January and July due to variations in ventilation air temperature. Several inches of change in dome elevation can be expected due to the addition of hot (250°F) liquids to the tank. Heat-up rates varied from 2.9° to 48.4°F/day in the computer analyses of the tanks (Table 2). In some computer models the concrete was allowed to creep (i.e., deform continuously under constant load), but the displacements stabilized once the steady-state temperature was reached.

Detailed stress analyses indicated the haunch region to be critical. Both concrete and steel stresses reached a maximum, and extensive cracking of the concrete was predicted. However, stresses in the reinforcing steel were calculated to be well below yield, and the total load-carrying capacity of the critical tank cross section was not exceeded. Further, the effects of the concrete cracks are to release some of the thermal strains and to relax the circumferential stresses in the reinforcing steel.

In the worst-case analysis, the maximum vertical wall temperature gradient was 112°F/ft near the junction of wall and footing, and was 78.2°F/ft on the inside surface, averaged over the critical elements at the haunch. The maximum concrete temperature in the wall was calculated to be 511°F just above the footing at the sludge layer. Results of the analysis indicated cracking of the concrete at the haunch and in the wall near the footing. Some of the reinforcing steel yielded near the footing in the high-temperature gradient area. The tank could withstand additional soil loads but may not be able to carry additional seismic loads at this extreme temperature. However, upon cooling, the stresses in the reinforcing steel returned to normal levels.

SEISMIC ANALYSIS

A seismic analysis was made of the 20-ft-diameter (55,000 gal) tank for the 0.25-g safe shutdown earthquake. Results indicated that the tank is capable of successfully resisting this earthquake.

A separate seismic analysis was performed for the 75-ft-diameter 241-AX (1 million gal) tanks for the 0.25-g safe shutdown earthquake. The results of this analysis were combined with those of the thermal creep analyses (dead, thermal, and hydrostatic loads) by constructing axial load-bending moment (P-M) interaction diagrams. Structural integrity of the tank due to a combination of all loading conditions was demonstrated by not exceeding the reserve capacity of any tank section. A P-M curve for a typical tank section with the superimposed results of the seismic analysis is shown in Figure 2.

MATERIAL PROPERTIES

WASTE SOLUTION EFFECTS

Technical studies and laboratory tests have been conducted to determine the effects of the simulated waste chemicals at operating temperatures on Hanford reinforced concrete. Chemically aggressive waste solutions could come into contact with the reinforced concrete tank wall and bottom through breaches in the steel liner.

An earlier (1976) study explored the effects of caustic solutions of various concentrations and temperatures (122°, 212°, and $301^{\circ}F$) on concrete samples for 30 different exposure conditions. The study was terminated after 6 mo because the highly alkaline solutions aggressively attacked the concrete specimens, as indicated by the recorded excessive expansions. All deterioration developed along the peripheral areas of the test specimens, and no test solution had penetrated to the reinforcing steel. Temperature was the predominant factor in the development of expansion and cracking, with higher temperatures causing greater effects.

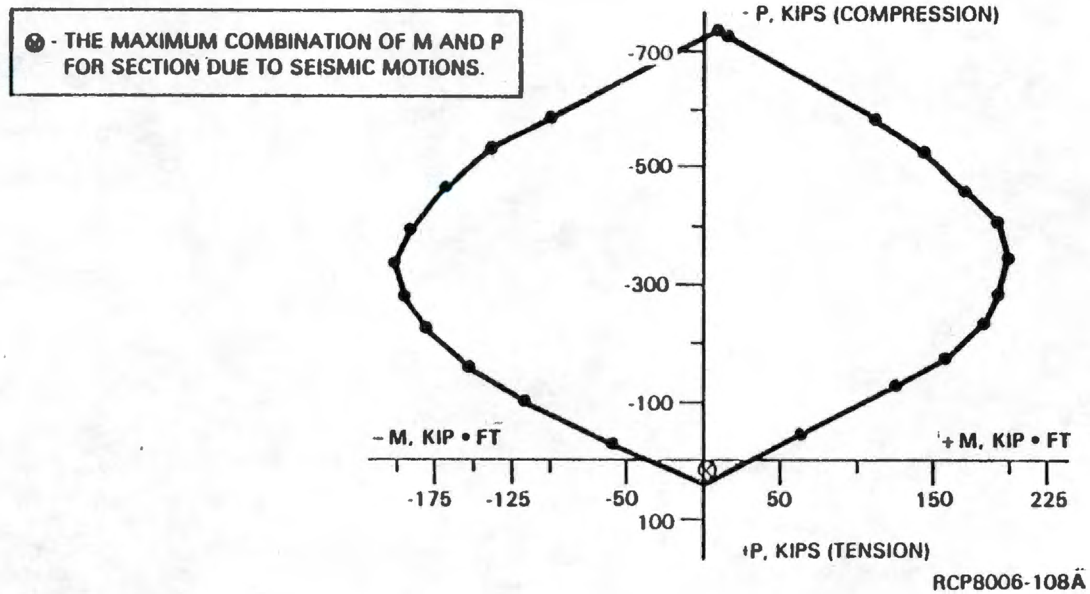

FIGURE 2. A P-M Curve for a Typical Tank Section.

This test was not considered representative of actual conditions, so a new laboratory test was established. Large reinforced concrete samples were loaded to simulate bending and compressive loads, similar to those expected in the tank walls. The flexure specimens were loaded so that the concrete was cracked to the reinforcing steel. Cans with slits in the bottom and filled with waste solution were then placed on the specimens. Details are shown in Figures 3 and 4. This allowed the solution to contact the concrete and gradually seep into the crack, simulating the case of a tank with a crack or break in the steel liner. In no tank was the liner so damaged that large areas of concrete were directly exposed to the waste solution. The entire test setup was then placed in a temperature-controlled environment maintained at $180^{\circ} \pm 10^{\circ}$F. The specimens were exposed to two types of solution from 3 to 36 mo: double-shell slurry and simulated salt cake. Performance was evaluated by determining the stress-strain characteristics of the reinforcing steel and by performing petrographic analyses of the concrete. Test results, as well as a detailed description of laboratory procedures and setup, can be found in Daniel et al. (1983). It was concluded, after the tests were completed, that no discernible signs of degradation were found in either the reinforcing steel or the concrete. Therefore, further testing of these two solutions was not warranted. If significantly different solutions are proposed for storage in the waste tanks, their effects on the concrete and reinforcing steel should also be determined. The 180°F concrete temperature is typical for the majority of the tanks. Even for Tank 241-A-106, which had waste temperatures up to almost 600°F in 1963-64, the concrete walls at the time of high temperatures were generally below 300°F. Historical records show only five tanks that had waste (not wall) temperatures above 350°F.

SAMPLING AND TESTING

Extensive laboratory studies were made on the effects of moderate (250° to 450°F) temperatures on concrete and were reported earlier (DeFigh-Price, 1982; Portland Cement Association, 1981). This laboratory work indicated that some loss in strength and elastic properties could be expected. Test results of actual samples taken from waste tanks (dome, wall, haunch, and

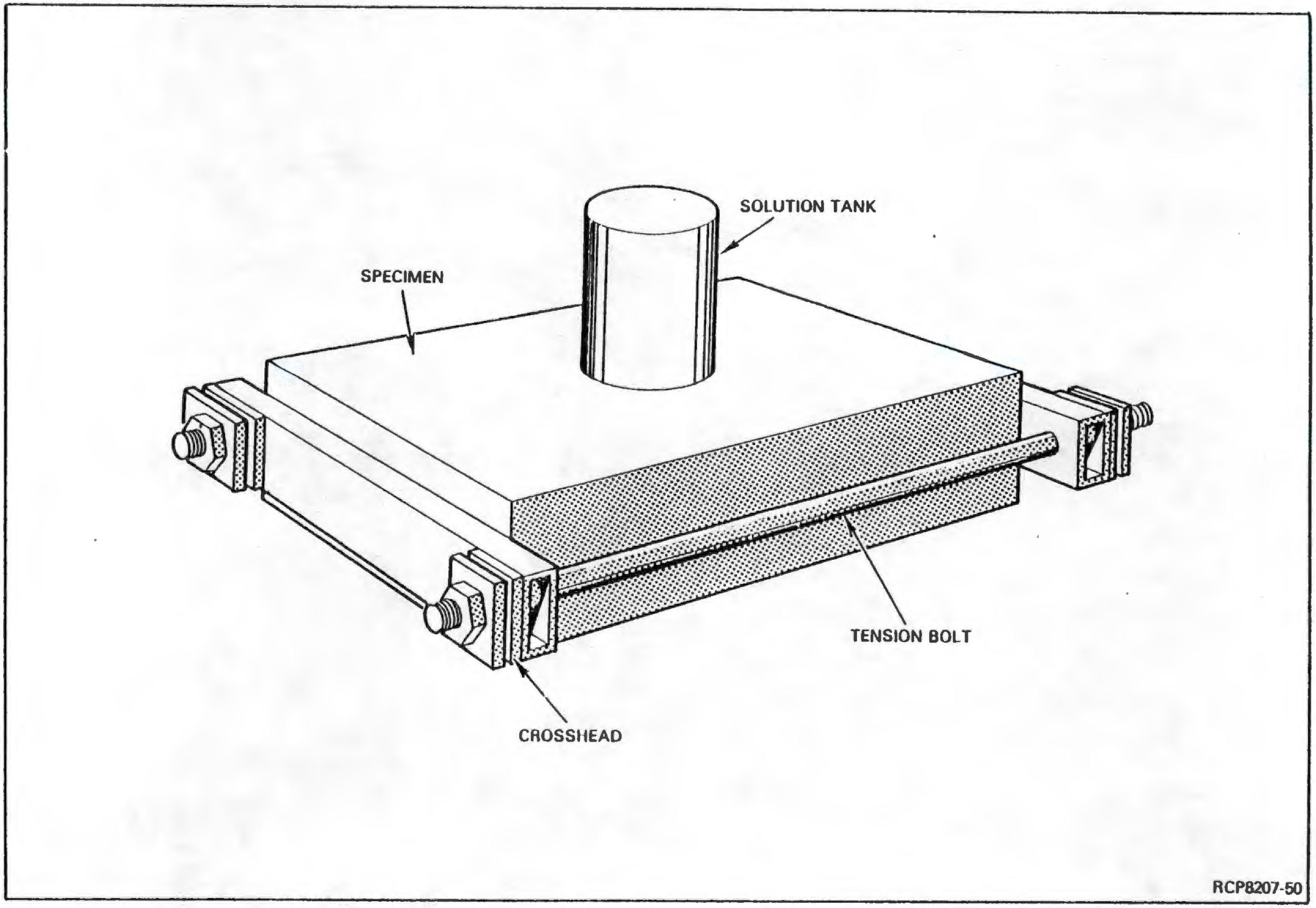

FIGURE 3. Compressive Specimen Under Load.

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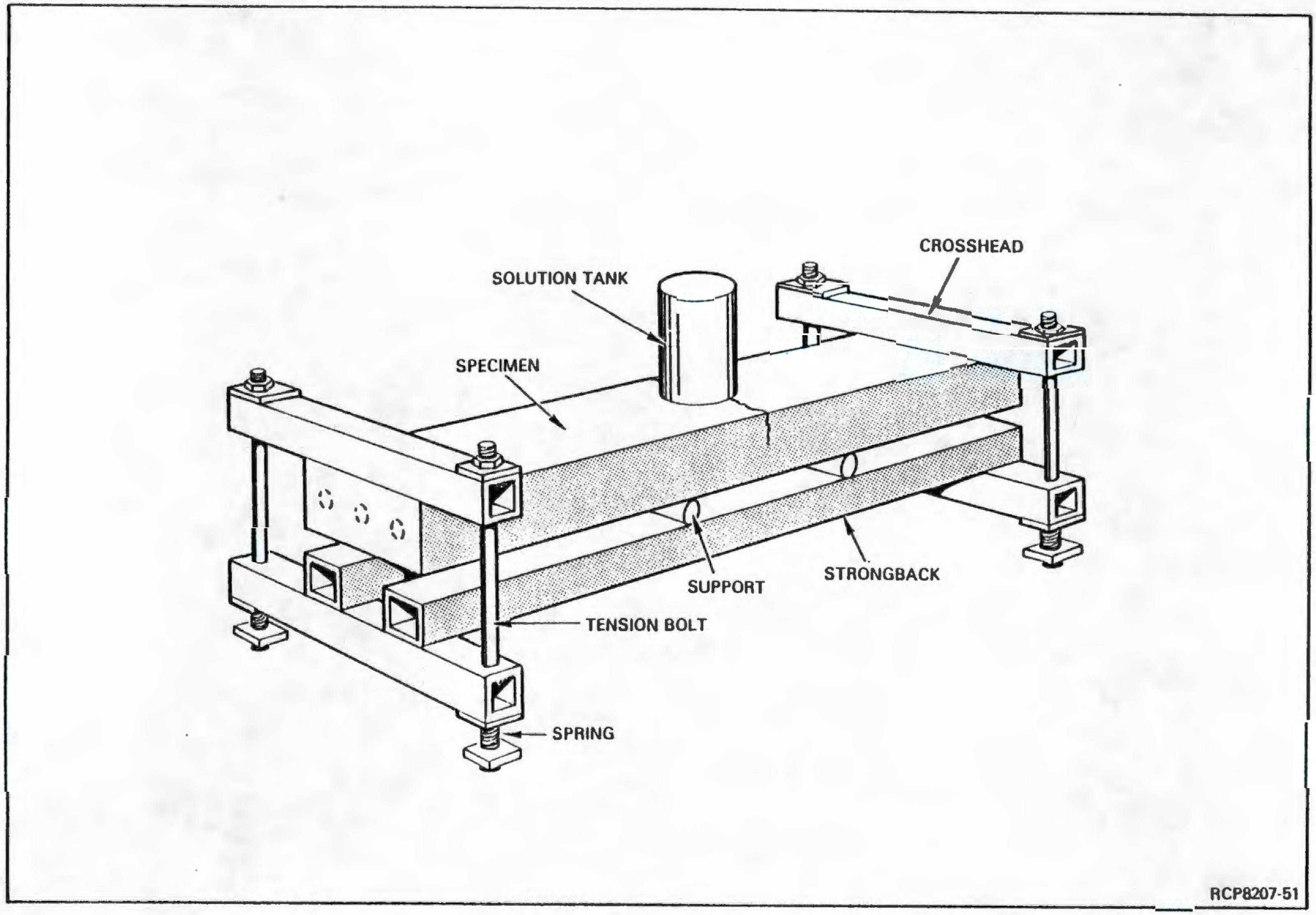

FIGURE 4. Flexural Specimen Under Load.

footing areas) were significantly above expected values. Comparison to concrete samples taken from buildings constructed using the same concrete mix design at about the same time period (1953) but not exposed to temperature extremes showed about the same variation in strength and elastic properties (DeFigh-Price, 1982).

No radiolytic effects have been identified in samples at Hanford or by others in the 400 to 500 R/hr field to which the tanks were subjected. Test results of core samples taken from tank domes that had been exposed to these radiation fields showed no degradation due to radiation effects.

To determine acceptable material properties of the reinforced concrete for analytical purposes, a statistical method based on American Concrete Institute (1977) Standard ACI 214-77 was used. This standard specifies three criteria for evaluating the concrete's compressive strength, of which the most conservative was chosen. Since the standard deviation of the Hanford concrete sample tests exceeded 700 psi (considered poor for present-day concretes, but not uncommon for concrete of the 1940-50 period), the criteria were modified somewhat according to the recommendations of the chairman of ACI Committee 214. Results from the three criteria are given in Table 3.

TABLE 3. Concrete Properties According to ACI 214-77.

Criterion	Compressive strength (psi)	Tensile strength (psi)	Modulus of elasticity (10^6 psi)
1	3,716	553	2.67
2	4,877	540	2.59
3	3,160	485	2.27

EXPECTED FAILURE MODES

A number of conditions, separately or in combination, could lead to failure of a waste tank at Hanford. Failure can be either functional or structural. A functional failure is defined as an inability of the waste tank to contain or isolate the waste from the surrounding environment. A number of the tanks have had functional failure with liquid waste, but not with solid waste. Hence, a functional failure depends both on the condition of the tank and on the waste form in the tank.

A structural failure occurs when the waste tank cannot support additional applied loads. For example, a tank may appear to be adequate but may not be capable of withstanding future loads, such as the safe shutdown earthquake.

Excluding very low probability events, such as a plane crashing into the site, the tanks are expected to withstand all present operating loads plus the safe shutdown earthquake. If the tanks should be exposed to large soil overburdens, the footings would crack prior to the dome or wall cracking. If the tanks are allowed to heat up well past their present operating limits, the concrete in the walls could crack and the reinforcing steel could yield in the areas of highest thermal gradients. If, along with such heat, an earthquake should occur simultaneously, the walls could not withstand the additional lateral loads. Severe heating could result in damage to the concrete or reinforcing steel that could, in itself, lead to failure. Equipment or hydrostatic loads are not of sufficient magnitude to affect the probable failure modes.

INDIVIDUAL TANKS

An extensive review of past thermal and operating history records was completed. Only in five single-shell tanks did waste temperatures exceed 350°F, according to the records. These, along with their maximum temperatures, are:

Tank	Temp (°F)
241-A-101	399
241-A-106	594
241-A-104	430
241-A-102	420
241-SX-107	390

Tank 241-A-106 not only reached the highest temperature but was also at elevated temperatures the longest. Calculations have shown that even this tank, now that it has cooled, was not sufficiently damaged to restrict its present use. Some tanks have, at times, had soil cover or equipment loads in excess of the approved operating limits. However, the latest analyses have indicated that these operating limits were overly conservative with respect to soil cover, equipment load, and temperature. None of the tanks have had soil cover or equipment loads that exceeded the presently recommended operating limits. Uncontrolled boiling in the early 1960s occasionally caused large vibrational loads in certain tanks. This may have led to early liner failures, but these should not have been of a magnitude to have damaged the concrete or reinforcing steel. Photographs have shown fine cracks in the dome and haunch area of certain tanks. Excavation along the outside wall down to the footing of one tank showed fine cracks, especially in the footing. These were primarily due to shrinkage and thermal cracking and should not affect the overall performance of the tanks. At this time, no one tank appears less safe than any other from a structural point of view.

CONCLUSIONS

The tanks were found to have an adequate margin of safety against failure, given present and planned future operating limits plus the safe shutdown earthquake. Past and present waste solutions do not appear to affect either the concrete or the reinforcing steel. Dome support scenarios cannot be justified under present operating conditions. Surveillance should be maintained until final disposal of the tanks has taken place and should consist of dome elevation measurements, tank dome underside photography (if sudden elevation changes or other signs of possible degradation are noticed), and occasional tank concrete sampling and testing to supplement available information. It is recommended, though not essential, that the tanks be kept as full as possible, as this provides lateral support to the walls.

Though an exact life of the waste tanks cannot be established using present-day analysis techniques, results of the analyses indicated that the tanks are capable of supporting all loads specified under presently proposed operating conditions. The tanks should function at least 40 more years (i.e., equal to their present age) if there are no changes in operating conditions; more likely they will perform adequately for hundreds of years. Dramatic changes in operating limits (such as going to an acid waste form or large increases in soil loads) could, however, change this estimate.

REFERENCES

American Concrete Institute Standard 214-77, (1977), Recommended Practice for Evaluation of Strength Test Results of Concrete, American Concrete Institute, Detroit, Michigan.

American Concrete Institute Standard 318-77, (1977), Building Code Requirements for Reinforced Concrete, American Concrete Institute, Detroit, Michigan.

Baca, R. G., G. A. Beitel, P. F. Mercier, E. L. Moore, and F. R. Vollert, (1978), Status of Containment Integrity Studies for Continued In-Tank Storage of Hanford High-Level Defense Waste, RHO-LD-52, Rockwell Hanford Operations, Richland, Washington.

Daniel, J. I., D. C. Stark, and P. H. Kaar, (1983), Long-Term Effects of Waste Solutions on Concrete and Reinforcing Steel, RHO-RE-CR-8 P, Rockwell Hanford Operations, Richland, Washington.

DeFigh-Price, C., (1982), Status of Tank Assessment Studies for Continued In-Tank Storage of Hanford High-Level Defense Waste, RHO-RE-ST-4 P, Rockwell Hanford Operations, Richland, Washington.

DeFigh-Price, C. and P. F. Mercier, (1980), Status of Tank Assessment Studies for Continued In-Tank Storage of Hanford High-Level Defense Waste, RHO-LD-142, Rockwell Hanford Operations, Richland, Washington.

Hansen, J., (December 1982), "The Delicate Architecture of Cement," Science 82, American Association for the Advancement of Science, Washington, D.C., pp. 49-55.

Neville, A. M., (1981), Properties of Concrete, 3rd ed., Pitman, London.

Portland Cement Association, (1981), Effects of Long-Term Exposure to Elevated Temperature on Mechanical Properties of Hanford Concrete, RHO-C-54, Rockwell Hanford Operations, Richland, Washington.

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