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7. Abstract

This document reports the results of an evaluation of the safety issues associated with Tank 241-C-106: the continued cooling required for high heat generation in tank 241-C-106.

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High-Heat Tank Safety Issues Evaluation

1.0 INTRODUCTION/SUMMARY

Subsection (b) of Public Law 101-510, Section 3137, "Safety Measures for Waste Tanks at Hanford Nuclear Reservation" (PL 101-510), requires the Secretary of Energy to "identify those tanks that may have a serious potential for release of high-level waste due to uncontrolled increase in temperature or pressure". One of the tanks that has been identified to meet this criteria is single-shell tank (SST) 241-C-106 (Wilson and Reep 1991).

This report presents the results of an evaluation of the safety issue associated with tank 241-C-106: the continued cooling required for high heat generation in tank 241-C-106. If tank 241-C-106 should start leaking, continued addition of water for cooling could possibly increase the amount of leakage to the soil column. In turn, if the current methods of cooling tank 241-C-106 are stopped, the sludge temperatures may exceed established temperature limits, the long term structural integrity of the tank liner and concrete would be jeopardized, leading to an unacceptable release to the environment.

In summary, this evaluation has determined that:

1. Tank 241-C-106 contains at the present time enough heat generating wastes to justify retaining this tank on the list "Single-Shell Tanks With High-Heat Loads (>40,000 Btu/H)" (Hanlon 1993).

2. There is insufficient data available at this time to determine that the addition of water, or active ventilation or both, should be terminated to tank 241-C-106.

3 For a period of approximately five months the active ventilation system for tank 241-C-106 was unavailable. In addition, water was not added. During this period, both the dome and waste temperature experienced an increase. No structural damage to the concrete from high temperatures was expected. The data does not indicate that this temperature transient ever attained an equilibrium.

4. To confirm the structural integrity necessary for the retrieval of the contents of tank 241-C-106, an updated structural analysis, in conjunction with a thermal analysis as a boundary condition, will be conducted.

2.0 BACKGROUND

Tank 241-C-106 was constructed in 1943-1944 as 75 feet diameter concrete structure lined with 1/4 inch thick carbon steel, ASTM A 7, with a concave bottom. 241-C-106 was equipped with air-cooled condensers of the multi-tube air-fin type vented directly to the atmosphere which were adequate for the waste temperatures and vapor loads encountered in the original operations.

Tank 241-C-106 was placed into active service in 1947, and remained in active use until 1979. The tank was first used to store metal waste from the Bismuth Phosphate Process. The metal waste was removed from the tank during 1953-1954 by sluicing to recover Uranium. After removing the Uranium, Tributyl Phosphate (TBP) waste was stored in the tank. Most of this waste was removed in 1956 to make room for PUREX Coating Waste. The tank remained full until 1963 when some of the material was pumped out to make room for PUREX Neutralized High Level Waste. At that point, tank 241-C-106 contained 62,000 gallons of sludge. From 1969 to 1971 tank 241-C-106 was used in conjunction with 244-AR Vault for PUREX sludge processing. The wash solution from AR Vault was decanted to tank 241-C-106. The supernatant liquid from tank 241-C-106 was pumped to 241-C-105. After a sludge temperature of 212°F was observed in tank 241-C-106 in late 1971, the tank was placed on an active ventilation system in early 1972. Its function as receiver for wash solution was immediately terminated. B-Plant cesium recovery waste was directed to the tank from 1974 to 1978. The active ventilation of tank 241-C-106 is supplemented by the periodic addition of water to maintain a liquid cover (supernate) over the sludge for enhanced thermal conductivity and evaporative cooling (Dukelow 1979).

Tank 241-C-106 is ringed with six dry wells sunk approximately 75 feet below grade. Each dry well is located approximately 10 feet from the tank. These dry wells are equipped with scintillation detectors and neutron detection devices. These dry well are monitored on a bi-weekly basis (Schofield 1993).

Based on data from various types of tests conducted on Hanford concrete mixes, some conclusions can be made about the long-term effects of elevated temperatures on the thermal and mechanical properties of Hanford concrete mixes:

- The mechanical properties of Hanford concrete are susceptible to degradation when exposed to elevated temperatures in the range from 250° to 450°F. The amount of degradation is dependent on the length, heat up rate, and degree of elevated temperature exposure.

- Heat induced strength losses did not reduce Hanford concrete mixes' compressive strengths below minimum design levels.

- Relative sensitivity of mechanical properties to degradation by concrete heat exposure are: most sensitive - modules of elasticity, splitting tensile strength, compressive strength and lease sensitive - Poisson's ratio. Most severe properties losses were measured with concrete at 450°F.

- Long-term tests at elevated temperature produced properties losses that were more severe than those measured with short term tests of heated concrete. Moreover, at maximum test temperature, 450°F, losses did not appear to approach limiting values even after more than 1 1/2 years heating. (DeFigh-Price 1981)

The minimum depth of soil cover on the dome is approximately 6 feet which represents a total load of 1500 tons supported by the dome and transmitted to the tank walls. The dynamic dome loading (live loads) specification limit is to be a maximum of 100 tons (Boyles 1992).

Operational Safety Requirements (OSR) have specified a maximum waste temperature of 350°F, to be monitored every 45 days (Borsheim 1989). This OSR was written to ensure that the structural integrity of 241-C-106 is not jeopardized due to excessive waste temperatures transmitted to the tank structure.

Tank 241-C-106 has a requirement for weekly temperature surveillance to determine if an increasing temperature trend exists from the established baseline (Schofield 1993). Monitoring of temperatures is accomplished by means of thermocouples arranged in thermocouple trees. There are presently two thermocouple trees installed directly in the tank. One thermocouple tree is located in riser number eight and consists of six ungrounded, type E thermocouples. The other thermocouple tree is located in riser number 14 and consists of 12 grounded, type J thermocouples.

Monitoring of tank 241-C-106 surface level indicates possible changes of conditions within the tank. The device used for measuring surface level, manufactured by the Food Instrument Company (FIC), consists of a conductivity electrode (plummet) connected to a calibrated steel tape, a steel tape reel housing, and a controller that automatically raises and lowers the plummet to obtain a waste surface level reading. The controller provides digital display of the data and transmits hourly readings to the Computer Automated Surveillance System (CASS).

3.0 SAFETY ISSUE DISCUSSION

To evaluate this safety issue the following topics are discussed:

3.1. Structural integrity

3.2. Drainable water

3.3. Leak verification

3.4 Interim Stabilization/Interim Isolation

3.1. Structural integrity

Any reduction in the structural integrity of any SST at the Hanford Site is an unacceptable event. The hazard associated with heat-induced structural damage to any SST is related to the residual strength of the tank's concrete after the accumulation of wastes for 40 to 50 years.

Any future degradation of the structural strength of the concrete can be mitigated by control of the temperature within the tank waste to the following temperature criteria, the Operational Specification Document (OSD) limits, (Boyles 1992):

Temperature

The temperature of the waste shall not exceed 300°F.
The temperature of the tank dome shall not exceed 250°F.
The maximum temperature change shall be 20°F per day.

It should be noted that these temperature criteria are conservatively lower than the Operational Safety Requirements (OSR). The OSR states that the "tank waste temperatures shall not exceed 350°F" (Borsheim 1989).

Thermocouple Trees

Thermocouple trees shall be installed in any SST containing a demonstrated heat load of greater than 40,000 Btu/Hr. If two or more probes on a thermocouple tree fail, operability shall be restored as soon as practical.

Temperature Readings

Temperature readings from thermocouple trees shall be recorded at least once every 38 days in tanks required to have thermocouple trees installed.

Tank 241-C-106 presently has two operable thermocouple trees. In January, 1993, the thermocouples in both trees were field checked for loop resistance, leads to ground, and continuity. At the present time all of the thermocouples have passed these field checks.

Tank 241-C-106 is the only SST that requires more than active ventilation to keep the temperature below 300°F (Pauly and Torgersen 1987). An earlier heat transfer analysis determined that if the tank waste is allowed to dry out, and forced ventilation is continued, the tank base could exceed 510°F and dome temperatures of 335°F. As a design basis, a heat generation rate of 200,000 Btu/hr was used in this heat transfer analysis (Campbell 1980). A comparison of transient calculated temperature with thermocouple measurements during the ventilation outage in 1992 denotes that the total heat source in Tank 241-C-106 is 110,000 Btu/hr (Bander 1993). Tank 241-C-106 is designated as sound, defined as "the integrity classification of a waste storage tank for which surveillance data indicate no loss of liquid attributed to a breach of integrity" (Hanlon 1993).

The active ventilation system was unavailable for waste temperature control for tank 241-C-106 from the period January 24, 1992 until June 7, 1992. During this period the dome temperature increased from 84°F to 148°F, the waste temperature increased from 161°F to 195°F with a 0.2°F change per day for the waste temperature and a 0.5°F change per day for the dome temperature. It should be noted that water was available but was not added because of lack of adequate evaporation. It is suspected that since the active ventilation was unavailable, what water that was heated to evaporation, was not taken away but remained in the tank. An Unreviewed Safety Question Evaluation determined that

these temperatures were well below the established OSR temperature limits of 300°F (waste) and 250°F (dome) with a maximum change of 20°F per day (Borsheim 1989). Therefore, no structural damage to the concrete from high temperatures during that period is expected (Richardson 1992).

3.2. Drainable water

The fraction of the liquid content in a tank that exceeds the interstitial holdup (liquid) is defined as the drainable liquid. The amount of drainable liquid is reported as 48,000 gallons: 32,000 gallons of supernatant, 12,000 gallons of interstitial holdup, and the remaining as raw water added for evaporative cooling purposes (Hanlon 1993). Based on a 12.5% assumed sludge porosity, an estimated 16,000 gallons of drainable interstitial liquid is present in the tank. It can be readily seen that the amount of drainable cooling liquid that is maintained in tank 241-C-106 exceeds the interstitial holdup of the tank's sludge.

The periodic addition of water is required in order to maintain a liquid cover (supernate) over the sludge for enhanced thermal conductivity and evaporative cooling (Dukelow 1979). The minimum operational surface level measurement limit is 74.5 inches, the maximum is 79 inches, with a maximum permissible change of 2.00 inches from baseline values established by Tank Farm Surveillance & Support (Godfrey 1992). Liquid levels for tank 241-C-106 are monitored weekly (Schofield 1993).

This practice of maintaining drainable liquid in the tank presents a dilemma in the event of a tank leak. Water would continue to be added to make up for the water that leaked out and to control the temperature within limits. Water additions could be terminated and the waste would heat up and dry out, which potentially could result in structural damage.

One of the solutions to the problem of maintaining the drainable liquid in the tank is to determine the minimum liquid addition required. A method to do this is to develop a thermal model from which could be projected the minimum water addition and liquid level needed to maintain the waste temperature below the maximum allowable limit.

Parallel to this effort, an updated structural analysis is being developed which will take the output from the above thermal analysis as a boundary condition and confirm the structural integrity. This activity is in support of the planned retrieval of the contents of tank 241-C-106. A process test is also being considered that would determine the minimum quantity of cooling liquid required to maintain the structural integrity of the tank concrete (DeFigh-Price, Wang 1993).

3.3 Leak verification

One of the postulated safety hazards for waste tanks at the Hanford Site is the potential for the release of high-level nuclear waste as a result of structural damage due to overheating the tanks reinforced concrete. Drywell radiation monitoring is one method of detecting a leak in 241-C-106. Surface-level measurement is another means of leak detection. This method of leak detection is not generally reliable because of its slow response and accuracy, principally in the case of a small leak.

If there is a change in tank liquid levels or drywell radiation levels and the liquid loss values are not comparable (a tank leak is confirmed), a contingency plan has been prepared (DeFigh-Price 1993). This plan states that in the case of a leak in tank 241-C-106 the following corrective actions shall be initiated immediately:

(1) Increase Surveillance - surveillance frequencies will be increased for parameters

(2) Reduce Supernatant Liquid - the liquid cover will be reduced by evaporation to reduce drainable liquid

(3) Accelerate Removal of Waste Sludge - the removal of the sludge will be accelerated under close coordination with Washington State and DOE-HQ.

This plan states that in the case of a leak in tank 241-C-106 the following corrective actions shall be initiated for the long term (more than one month):

(1) Monitor soil temperatures

(2) Install thermocouples

(3) Maximize ventilation

(4) Photograph tank interior

(5) Install surface sprinkler

(6) Retrieve high-heat waste

3.4 Interim Stabilization/Interim Isolation

The *Hanford Federal Facility Agreement and Consent Order*. Ecology, et.al., 1990 (Tri-Party Agreement) mandates the interim stabilization of tanks 241-C-105 and 241-C-106 by September 1996 (milestone M-05-08), and the interim isolation of all single-shell tanks by the same date (milestone M-05-09). Interim stabilization limits the amount of supernatant and pumpable interstitial liquid that can be present in the tank. Interim isolation requires physical isolation of the tank. Interim stabilization prevents leakage or minimizes the quantity of leakage to the ground. Interim isolation prevents or reduces additions of liquid to the

tank that might contribute to a liquid leak source. Interim isolation and stabilization criteria would require cessation of the current practice of adding to the leak source through periodic cooling water additions (Squires 1991).

An estimated 65 percent of the strontium-bearing sludge must be removed from the tank to leave approximately 40,000 Btu/Hr of high heat sludge in the tank. At this level the tank may be placed in a safe, interim isolated state. Removal of 65% of the sludge will reduce the heat source sufficiently so that the tank can be cooled solely by conduction to the soil. Following completion of the waste retrieval actions, water additions can be halted, and standard tank isolation actions can be completed.

The Tri-Party Agreement (TPA) Milestone M-05-12 states that a plan will be provided to the Washington State Department of Ecology the Environmental Protection Agency (EPA) which evaluates actions, schedules, and cost impacts for removing tank contents (retrieval) from a single-shell tank. Demonstration of single-shell tank waste retrieval is required under the TPA milestone M-07. Tank 241-C-106 has been recommended as the retrieval demonstration tank and hydraulic retrieval (sluicing) has been proposed as the method to demonstrate this retrieval.

To support the retrieval activity an updated structural analysis is being developed. This analysis will use the output from a recent thermal analysis as a boundary condition and confirm the structural integrity of tank 241-C-106.

4.0 CONCLUSIONS

In conclusion, this evaluation has determined that tank 241-C-106 contains at the present time enough heat generating wastes to justify retaining this tank on the list "Single-Shell Tanks With High-Heat Loads (>40,000 Btu/H)" (Hanlon 1993).

There is insufficient data available at this time to determine that the addition of water, or active ventilation or both, should be terminated to tank 241-C-106.

For a period of approximately five months the active ventilation system for tank 241-C-106 was unavailable. In addition, water was not added. During this outage, the dome and waste temperatures both experienced an increase. No structural damage to the concrete from high temperatures was expected. The data does not indicate that this temperature transient ever attained an equilibrium.

To confirm the structural integrity necessary for the retrieval of the contents of tank 241-C-106, an updated structural analysis, in conjunction with a thermal analysis as a boundary condition, will be conducted. The retrieval actions will reduce the heat generation load of this tank so that water additions can be halted, and standard tank isolation actions can be completed.

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