HANFORD HIGH-ACTIVITY WASTE TANK SAFETY ISSUES

Harry Babad and John L. Deichman
Westinghouse Hanford Company
Richland, Washington

ABSTRACT

A description of seven primary safety issues associated with continued storage of high-activity wastes in Hanford single- and double-shell storage tanks is presented. Extensive management controls are employed to assure that the tanks continue to be maintained in a safe manner. In addition, comprehensive monitoring, characterization and applied research efforts have been initiated to support resolution of issues and to prevent creation of future problems associated with potentially incompatible wastes or actions related to the planned disposal of the wastes in these storage tanks. Such efforts will also provide the basis for safe near future remediation of tanks and define the envelope of safety to support the disposal of all high-activity waste in the Hanford tanks.

INTRODUCTION

This paper provides a summary discussion of eight priority safety issues related to the storage of high-activity mixed tank waste at the Hanford Site. Major initiatives for evaluating the technical issues leading to solving waste tank safety issues, are initially being focused on the hydrogen and ferrocyanide tanks, are ongoing and are reported.

BACKGROUND

Between 1943 and 1964, 149 single-shell tanks (SSTs) (capacity 94 million gallons) were built for the storage of liquid radioactive wastes at the Hanford Site. Today, they hold about 37 million gallons of liquids and solids from a variety of reprocessing and waste processing activities. No wastes have been added to any of these tanks since November 1980. Half of the tanks, 66 of the 149, are assumed to be leaking.

Between 1968 and 1986, 28 double-shell tanks (DSTs) were built for storage of liquid radioactive wastes at the Hanford Site. Their total capacity is about 28 million gallons. The DSTs are a tank-in-tank design and were placed into service beginning in 1973. They presently contain about 22 million gallons of liquid radioactive waste.

To prevent or diminish impacts from future leaks from SSTs, a program to remove pumpable liquids from these tanks was started about 1968. Pumpable interstitial liquid and supernatant wastes were removed from SSTs and transferred to DSTs. A total of 3.5 million gallons of liquid waste was removed from 98 SSTs between 1979 and 1989. The remaining 51 tanks are scheduled to be pumped by September 1996. Not all liquid can be pumped from the SSTs since some is bound interstitially in the tank solids and the remainder drains too slowly to pump effectively.

SAFETY ISSUES

Safety issues are the primary present focus of the Waste Tank Safety Program. Issues of concern include cyclic hydrogen release, ferrocyanide accumulation, the presence of organic chemical nitrate-nitrite mixtures, and outdated instrumentation and control systems associated with the waste tank system. Specifically, there are seven primary safety issues associated with the Hanford waste tanks.

A. Twenty-three tanks generate, store, and periodically release significant quantities of flammable gases, primarily hydrogen and nitrous oxide. If a spark were to be present, this gas could ignite and burn, potentially causing filters in the vent system to fail with resulting spread of contamination.

B. Twenty-four tanks contain insoluble ferrocyanide salts in quantities greater than 1,000 gram-moles mixed in a sodium nitrate/sodium nitrite matrix. If subjected to high temperatures these materials could become explosive. However, there is a low probability for any heating mechanism to occur.

C. Eight tanks contain organic chemicals at a concentrations believed to be greater than 10 mole percent sodium acetate equivalent mixed in a sodium nitrate-sodium nitrite matrix. Three of the hydrogen and ferrocyanide tanks also appear on the organic list.

D. One tank requires periodic addition of water to maintain its temperature within the permissible limits determined by structural considerations

E. The actual composition and distribution of chemicals in most tanks is not well characterized, but it is known that most tanks contain appreciable oxidants (mostly sodium nitrate and sodium nitrite) as well as flammable or potentially explosive materials.

F. The instrumentation to monitor and control tank temperature or to detect the presence of flammable gas is old, and needs to be updated to current waste management design requirements.

G. Determination of the safe operating life of the SSTs and DSTs needs to be made to assess their ability to safely store wastes until waste disposal decisions are implemented (estimated to be 25-30 years)

The hazardous characteristics of the existing wastes, leading to their identification and control, were estimated on the basis of general information from the chemical literature, expert peer judgement, and limited historical and actual sampling data. Mitigating factors such as moisture content, presence of inert diluents (e.g., sodium carbonate, sodium aluminate, and/or sodium phosphate), and conditions that could lead to a lack of reactivity of the wastes were purposely understated.

Scenarios of significant concern associated with waste in tanks include:

- Potential for ignition of flammable gases such as hydrogen-air, hydrogen-nitrous oxide and or air-organic vapor mixtures.
- Potential for secondary ignition of organic-air and/or organic-nitrate mixtures initiated by the burning of flammable gases.
- Potential for ignition of organic-nitrate and/or ferrocyanide-nitrate mixtures initiated by the radiolytic or chemical heating of dry salt cake or by localized heating.

Administrative and technical controls are in place to restrict activities which could cause undesirable exothermic reactions. For example, pumping of interstitial liquid from ferrocyanide tanks has been stopped in order to maintain present moisture levels (e.g., to maintain present thermal conduc-tivity and heat capacities). Nonsparking tools and use of electrical bonding techniques on instrumentation are used around hydrogen tanks. So-called "normal" activities for tanks at issue are limited to surveillance. Special safety analysis documents, which are extensively peer reviewed, are prepared for all work inside the tank.

A. Hydrogen Tanks. Flammable gas generation in tank 101-SY is a top priority waste tank safety issue at Hanford because average peak concentrations above the lower flammability limit (LFL) for hydrogen occur periodically. Such venting of gases is expected to keep reoccurring until some form of remediation is taken. In addition, it is likely that a greater-than-LFL concentration exists at times within the waste. In the unlikely event an ignition source were present during these periods, a hydrogen burn or explosion could occur with a possible release of nuclear waste to onsite and offsite personnel.

There are 22 other tanks also suspected of potentially containing smaller accumulations of hydrogen or other flammable gases. There is however, a significant difference in severity between those tanks and tank 101-SY. Evidence of venting, surface level behavior, and knowledge of the other tank contents suggests a much lower likelihood of potentially dangerous gas concentrations in these other tanks.

This paper will center on tank 101-SY because it is currently the focus of our efforts to understand and then ultimately to remediate the problem.

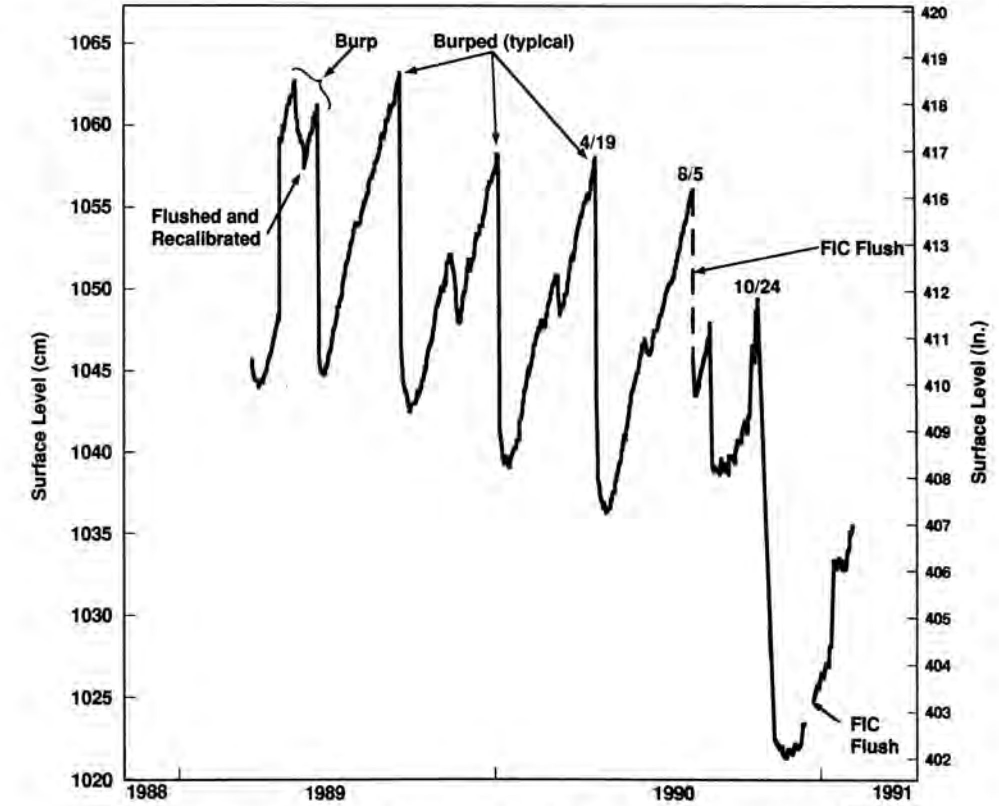
Figure 1 illustrates the cyclic behavior, the rise and fall of the tank crust surface, of tank 101-SY. Episodic vent cycles have ranged from 42 to 110 days. Each drop in surface level, while gas is rapidly venting, takes from a few hours to a few days to reach surface level equilibrium. Informa-tion from the most recent and more heavily instrumented events are shown in Table I.

Figure 2 shows an illustration of the vertical distribution of the tank contents and the temperature profiles associated with the October 24, 1990 vent cycle. Tank 101-SY contains about 50 inches of solid crust floating on a convective layer of mostly liquid waste. The convective layer sits on top of an approximately 150 inch layer of settled solids that is essentially nonconvective in fluid behavior. At the bottom of the tank, there appears to be a layer of compacted solids that is about 50 inches deep.

Based on analysis of the offgas stream, a mixture of hydrogen, nitrous oxide and nitrogen gas appears to form as the product of radiolysis and/or the chemical decomposition of the organic chemicals in tank 101-SY. Insight into tank chemistry and the processes associated with gas generation requires information obtained from taking a full core sample of the tanks contents. According to our current hypothesis, tank gases appear to be formed continuously in the whole tank, but appear to be formed and stored preferentially in the nonconvective sludge layer in the bottom, settled solids portion, of the tank. The storage phenomenon creates a supersaturated "solution" of gas in the tank. Unknown instabilities trigger a thermal rollover to occur, releasing the stored gas.

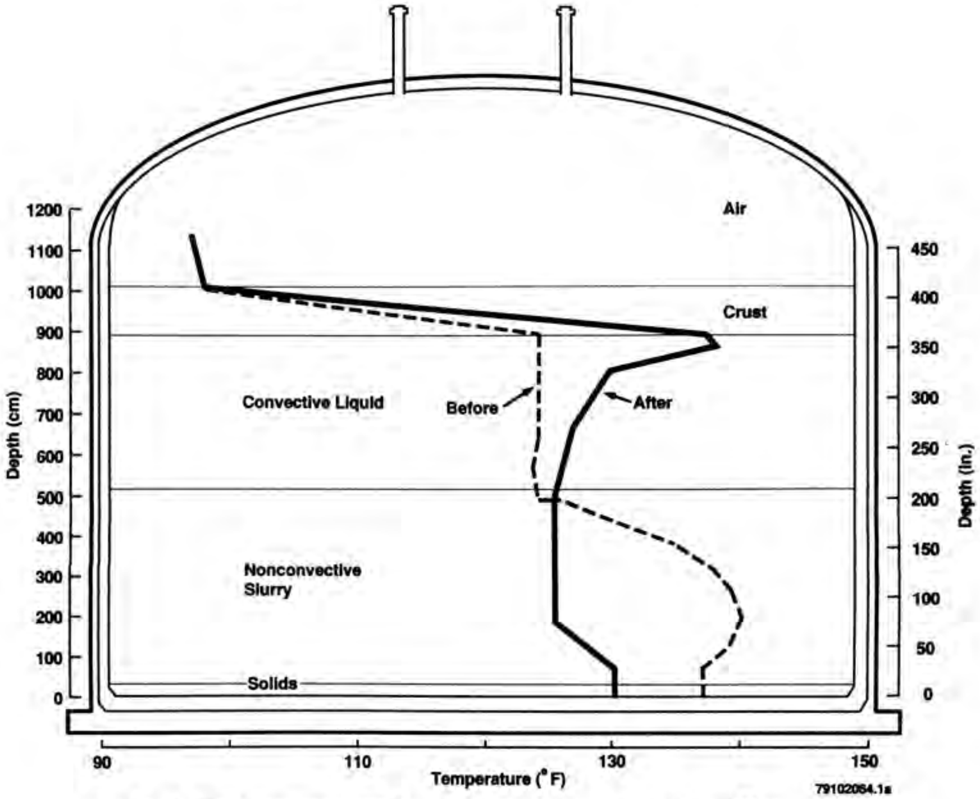
During the October 24th vent, thermal rollover occurred in about 120 seconds, as predicted by modeling done by Pacific Northwest Laboratory, Westinghouse Hanford and Los Alamos staffs. After rollover, it takes from one day to one week for the crust level to stabilize and the surface rise to begin to occur again. Presently, it takes about 100 days for the cycle to repeat itself. Because of this cyclic behavior, Westinghouse Hanford limits intrusions into the tank to a 20 to 30 day "window of safety" that starts after a gas release event. The length of the window varies depending on whether the intrusion is to penetrate the crust (20 days) or restricts activity to the tank dome space (30 days).

A number of hypotheses have been proposed to explain the mechanisms of gas creation, but more information from characterization, modeling, and laboratory simulation studies is needed before we can fully understand and plan to mitigate the tank hazards. Work is in progress by Westinghouse Hanford, Argonne National Laboratories, and Pacific Northwest Laboratory staff to determine the exact mechanism of gas generation and release. Because the cause of the cycle is not yet known, cyclic hydrogen generation and release is an unreviewed safety question.



79102064.2a

Fig. 1. Recent tank 101-SY crust levels.



79102064.1a

Fig. 2. Tank content configuration and temperature profiles.

TABLE I

Vent Information

Date	Duration (hours)[1]	Pressure spike duration (minutes)	Plenum pressure (water gage)	Hydrogen volume calculated (cu ft)	Gas volume calculated (cu ft)[2]	Peak hydrogen concentration[3]	Crust level drop (inches)	Shape of pressure spike
04-19-90	37	35	+0.1"	3,600	12,000	3.5%	9.3	Sharp peak
08-05-90	18	250	-1.96"	1,600	5,400	1.2%	5.2	Multiple small peaks
10-24-90	14	30[4]	+2.3"	3,200	10,600	4.7%	10.2	Sharp peak

Note:

[1] Vent duration is defined as the time to flush all the hydrogen released during the effort from the tank based on thermal conductivity gauge data.

[2] Assumes gases generated are 30% hydrogen in composition.

[3] Lower flammability limit H_2/Air = 4%; H_2/N_2O = 3%.

[4] The duration of tank overpressurization (positive pressure) was less than five minutes.

The primary risks associated with tank 101-SY and related tanks result from a potential for hydrogen gas ignition, with or without a secondary ignition of the crust. Secondary crust ignition depends on the magnitude and duration of a hydrogen burn, and the characteristics of the crust. Four factors that could prevent such a crust burn are:

1. Presence of only limited quantities or concentrations of combustible gases in the dome space
2. The presence of significant quantities of moisture in the crust
3. The absence of large quantities of organics in the crust
4. The presence of large quantities of noncombustible (inert) material such as sodium carbonate, sodium sulfate, and inorganic aluminum salts and oxides in the crust.

Early results from grab samples taken after the October 24th vent, of materials accumulated on the crust surface and from sludge level monitoring are encouraging. Analytical results from a "sludge weight" sample (the largest amount of material recovered) are reported in Table II. They are compared with assay results reported in 1986 on a sample of very fluid slurry taken from the nonconvective layer of tank 101-SY. It should be noted that these results represent a statistical sample of one and additional samples will be taken in February to enhance our knowledge of crust surface composition.

While the probability of a crust burn is very low, the level of risk from such an event remains unacceptable. Therefore, after initial, but detailed characterization of the contents of tank 101-SY (and other tanks that undergo cyclic venting) steps to remediate the tanks will be evaluated and ultimately implemented. The characterization efforts are being paralleled by the studies to support remediation, so that an understanding of the root cause can be developed to avoid creating cyclicly venting tanks in the future. Activities planned for the next three windows are summarized in Table III. These focus on enhancing monitoring, obtaining statistically significant assays of tank contents in support of laboratory studies, and planning remediation efforts.

Potential remediation methods, all aimed at minimizing or eliminating "burp" cycles, include dilution of the wastes and/or stirring them to allow the gases that are formed by the chemicals and radionuclides to vent continuously. Other alternatives being explored include ultrasonic methods for forcing continuous release of the gases as formed.

B. Potentially Explosive Mixtures of Ferrocyanide in Tanks. Ferrocyanide tanks were selected as a safety issue since it is not known whether concentrations and distribution of ferrocyanide and nitrate-nitrite materials in the tanks would allow an uncontrolled exothermic reaction or explosion if tank contents were allowed to heat up. Although the measured tank temperatures are far below the temperature required to cause an exothermic reaction, the consequences of an event could be at a level potentially exceeding the safety envelope defined in the 1987 environmental impact statement (EIS) (1).

These tanks store radioactive wastes containing ferrocyanide resulting from the process used in the 1950's to scavenge radioactive cesium from waste liquids stored in the tanks. To obtain additional storage volume within a short

TABLE II

Assay Information

Analyte	Sludge weight (wet center)	Sludge weight (dry outer)	Center slurry (1986)	Notes
Percent moisture	26%	15%	33%	By TGA analysis (estimated 20% of moisture lost on handling in lab)
DSC (endotherm)	132 cal/g	58 cal/g	NA	Exotherm starts at 200 - 250 °C Tank temperature: <57 °C
DSC (exotherm	-61 cal/g	-56 cal/g	NA	
Total organic carbon as wt% sodium acetate	1.6% 6%	2% 7%	5%	Total organic carbon 3.4% or as sodium acetate equivalent is considered flammable above 10% in nitrate/nitrite mixtures
Wt% sodium nitrate/nitrite	31%	40%	36%	
Wt% inerts (w/o water)	29%	33%	31%	
Recovery (wt%)	92%	94%	104%	Expresses mass balance
Carbonate:OH (ratio wt%)	7:5	11:3	3:8	Carbonate:OH ratio. The crust seems richer in carbonate than slurry.

Legend:

NA = Not available.

Inerts = These include sodium aluminate, sodium carbonate, sodium hydroxide, sodium chloride, sodium sulphate, and "metals".

TABLE III

Tank 101-SY Near-Term Instrument Installation and Sampling Plans

Window	Instrumentation	Characterization
October 24, 1990 (Window A)	Enhance temperature data logger Initiate gamma scans in annulus	Monitoring instrument grab samples
February (Window B)	Install dome gas monitoring equipment Listen to vent in annulus (microphones) Perform gama scans in annulus Install digital pressure readout pressure and flow equipment Obtain gamma levels in tank (TLD)	Obtain five crust surface grab samples for analysis Interpret gamma field data
Window C	Install TV camera Install new instrument tree	Monitor gas in dome during vent episode Obtain deeper crust samples with auger system Run penetrometer tests on crust Obtain core sample (drill push mode) for analysis
Window D	Install high-resolution gamma scanner Remove old thermocouple tree	Monitor gas in dome Obtain another full core sample (drill rotary mode) for analysis Run more penetrometer tests on crust

period of time and to avoid additional storage tanks, Hanford scientists developed a process to reduce radionuclide levels in tank supernatants to levels low enough for disposal to cribs. The process scavenged radioactive cesium from waste liquids stored in the tanks by the carrier precipitation of cesium, nickel, and ferrocyanide along with an excess of sodium or potassium nickel ferrocyanide. In implementing this process, up to 150 metric tons of ferrocyanide were added to a group of high cesium SSTs.

In early 1990, a study by the U.S. General Accounting Office reported a major safety issue, that a worst case accident, a ferrocyanide explosion in certain SSTs in the Hanford tank farms, could result in a subsequent short-term radiation dose to the public one to two orders of magnitude greater than the 200 mrem projected in the 1987 EIS (1). This resulted in declaring the tanks to be an unreviewed safety question because of their potential to explode at elevated temperatures.

Ferrocyanide salts in the presence of nitrate and/or nitrite constituents can be made to react and explode under certain conditions, which include dryness, favorable stoichiometry, and elevated temperatures, or a high-energy spark. These exothermic reactions can start to take place in the range of 180-200 °C (356-392 °F), and an explosion can occur at 285 °C (545 °F). Maximum tempera-ture measured inside the ferrocyanide tanks at the Hanford Site are at or below 57 °C (135 °F).

Records at the Hanford Site currently show that there are 24 SSTs that contain appreciable ferrocyanide precipitates (1,000 g-moles or greater). The ferro-cyanide content of the tanks ranges from 1,000 gram-moles (465 lb) up to approximately 200,000 gram-moles (93,000 lb in tank BY-104) calculated as the ferrocyanide anion. Other wastes in these tanks probably include significant quantities of sodium nitrate and sodium nitrite; a variety of silicate, aluminate, hydroxide, phosphate, sulfate, carbonate, and nitrate salts; as well as salts or oxides of uranium, copper, and calcium. In addition, fission products are also present from the processing of irradiated fuel. Some tanks may also contain quantities of organic materials that cause exother-

TABLE IV

Fiscal Year 1991 Plans: Ferrocyanide Tanks

Action focus	Monitoring instrumentation	Modeling and analysis	Characterization and R&D
Aerosol behavior modeling		Burn propagation modeling Aerosol generation modeling Agglomeration modeling	Explosion tests for aerosol characterization
Near-term safety analysis		Develop accident scenarios PRA/consequence analysis	Calorimetry screening tests
Near-term planning 10/90 - 9/91 (Tank 104-BY)	Infrared mapping of tank surface New instrument trees (thermocouples and sensors)	Safety analysis for all planned actions	Dome space gas sampling Tank surface samples Penetrometer tests Core drill sampling
Expanded tank monitoring, characterization, and modeling	Thermocouple system accuracy and readout Continuous monitoring and alarms Multifunctional instrument trees on FeCn tanks Alternate monitoring technology	Historical database (documentation systems)	101-TY analysis (archive FeCN sample) Dome space gas samples - all FeCN tanks Flowsheet tests (to replicate FeCN solids at beaker scale) Core sample all FeCN tanks Adiabatic calorimetry on real and synthetic samples)

mic reactions to start at the low end of the temperature range listed above.

A program plan has been completed that will provide the primary technical analysis and modeling required to analyze the ferrocyanide explosion potential in a supplemental EIS, as well as providing for characterization work and remediation efforts. The probability of a ferrocyanide explosion is considered very low because currently measured maximum temperatures in the ferrocyanide tanks (57 °C [135 °F]) falls significantly below the lowest threshold temperature 180-200 °C (356-392 °F) for ferrocyanide nitrate-nitrite reactions found in the laboratory. Table IV summarizes plans for addressing the ferrocyanide issue in fiscal year 1991. Efforts are focused on enhancing monitoring capability, characterizing tank 104-BY and gaining information on the mechanism and propagation and radionuclide release characteristics of a ferrocyanide explosion.

A recent review of the practice of drying out SSTs to avoid potential leakage of radioactive and hazardous materials into the soil disclosed that additional analysis of this practice for the ferrocyanide tanks is needed. For tanks that contain large quantities of ignitable materials (tanks containing ferrocyanide and organics) such pumping has been discontinued until safety evaluations of liquid removal can be completed.

C. Organic Tanks. Concentrations of organics may be present in some tanks that could cause an exothermic reaction given a sufficient driving force, such as high temperature. However, the difference between ignition temperatures and actual tank temperatures measured, as discussed previously for the ferrocyanide tanks, is so large that the probability of such a reaction is considered very low. The consequences of the postulated reaction is about the same as that for some scenarios for an explosion in a "burping" hydrogen tank Although work on this issue is just beginning, consideration of hazards associated with heating nitrate-nitrite mixtures containing organic materials is an integral part of both the hydrogen and ferrocyanide tank efforts.

High concentrations of organic compounds have been inferred (from tank transfer, flow sheet records, and limited analytical data) in eight SSTs. Many organic chemicals, if present in concentrations above 10 dry wt% (sodium acetate equivalent), have the potential to react with nitrate-nitrites constituents at temperatures above 200 °C (392 °F) in an exothermic manner. The concentrations of organic materials in the listed SSTs and their chemical identity is not accurately known at present. A tank sampling program is being developed to provide more information on the contents of these tanks and to serve as a basis for laboratory testing and safety evaluations.

These tanks were identified as potential hazards on the premise that litera-ture information suggested that mixtures of organic chemical and sodium nitrate and sodium nitrite could deflagrate at temperatures above 200 °C (392 °F). Initial small scale work (2) on organic-nitrate reactions performed in the past suggest that waste mixtures containing more then 10 wt% (dry salt basis) of nitrite-nitrate organic mixture are safe at temperatures below 200 °C (392 °F).

Additional work is planned to better define the initiation point for the organic-nitrate reactions. Work is also planned to demonstrate that in-tank temperature measurements are representative of the tank contents. Even with the removal of most free liquids (and possible attendant decrease in thermal conductivity), temperatures in the SSTs will be maintained below that necessary for an uncontrolled reaction. In-tank temperatures are stable or decreasing and have been for years. The measured in-tank temperatures of the organic SSTs are approximately 110 °C (equivalent to 200 °F) and below the laboratory observed minimum exotherm initiation temperatures.

Evaluation of the records related to material transfers to the remaining SSTs and DSTs continues, and may uncover additional tanks that meet the organic concentration requirements, placing them on "watch list" status.

D. Continued Cooling Required for High Heat Generation in Tank 106-C. Single-shell tank 106-C (530,000 gallon capacity), has been used for radioactive waste storage since mid-1947 and currently contains about 250,000 gallons of waste. During the late 1960s, a program to recover strontium and cesium from aging stored waste in the A and AX tank farms started at the Hanford Site. Sludge washing/decanting steps in this process inadvertently transferred heat-generating strontium-rich sludge to tank 106-C.

Continued cooling by water addition is required to prevent structural damage to tank 106-C. This tank is currently considered to be sound. If the current methods of cooling tank 106-C are stopped, the sludge will heat to tempera-tures greater than established tank limits and may cause tank structural problems. The tank generates enough heat that water is periodically added to prevent overheating. This is an anomaly among the SSTs. In the event of a leak, the need for cooling water to be added to the tank would remain. Existing interstitial liquid could not be removed from the tank, in accordance with existing practice, to prevent unacceptable leakage to the environment.

E. Insufficient Tank Contents Characterization to Support Evaluations. For many tanks, there are sufficient uncertainties in tank chemistry, a possible source of a yet unidentified hazard. Based on flow sheet considerations, the probability of additional possible hazardous chemical combinations occurring is believed to be low.

The nature of the chemicals used in past chemical processing, the waste management operations leading to the waste in the tanks, and the alkaline condition of the tanks appears to limit the range of new possibilities.

In general, knowledge of the contents of the SSTs and DSTs is necessary to ensure appropriate safety precautions and preventative measures are taken in operating the tank farms. Characterization is required to assess the flammable/explosive potential and the chemical and radiological hazards which may be present in the tanks for continued storage and final disposal. For operating tanks, it is imperative to know what is in the tank and how that waste will interact with other wastes before they are mixed.

F. Monitoring and Control Systems. Many of the waste tank farm facilities are old, degraded, and unreliable. For example, the electrical distribution equipment needs upgrades to provide a reliable source of power as well as backup power. Ventilation systems are wearing out and require high maintenance, which results in outages that are longer than acceptable. Instrumentation, such as liquid-level gauges, leak-detection systems in process pits, and radiation monitors require high maintenance and are out of service or fail often. Spare parts are unavailable. In addition, many of the waste tank farm facilities do not meet current design requirements. One example would include the lack of redundant high-efficiency particulate air filtration in many facility ventilation systems.

A major upgrade (repair and/or replace) effort is required to return existing equipment to an acceptable condition, as well as bringing all equipment and facilities into compliance with current regulatory requirements.

G. Tank Safe Operating Life. The SSTs at the Hanford Site have exceeded their original operating life and the early DSTs are fast approaching their operating life (20 years). However, all these tanks will be required to contain chemically and radioactively materials well beyond their design lives (50 years) under present operational and disposal plans. The primary liners of about half of the SSTs have already leaked. No DST liner has leaked to date, but original corrosion studies would indicate that a strong possibility exists that a liner could start leaking before disposal operations are completed.

The condition of the SST concrete structure was evaluated in the late 1970s and early 1980s, to determine structural conditions. At that time, it was concluded that the SST concrete structure was adequate to support the disposal plans, though the tanks could not be expected to contain any liquid materials. In the 1970s and 1980s the expectation was that the SSTs were to be disposed by the late 1990s. The cleanup of the SSTs is now scheduled to be completed by the year 2018 (3).

The SSTs were designed using industry standard codes in the 1940s and 1950s. The ability of the SSTs to safely store their solid waste contents, particularly their ability to withstand natural forces and the added stresses due to contained waste forms and planned remediation activities will be reevaluated.

The DSTs at Hanford are planned to remain operational past the year 2030 to support site cleanup, including the disposal of SST wastes. The DSTs were designed in the 1960s and 1970s to existing design codes and standards. The condition of the tanks will be reviewed to determine their capacity to support the extended cleanup mission.

Finally, the potential for nuclear criticality in waste tanks was recently reviewed and determined not to be a safety issue.

SUMMARY

Evaluating the safety issues identified previously and defining appropriate remedial action to correct these safety concerns is being actively pursued at the highest possible priority. Risk to the operating staff, the Hanford Site environment, and to the general public appears to be low; this is being reaffirmed. We are working both to quantify the risk and to take appropriate corrective actions to support continued safe storage of the waste as well as the eventual permanent disposal of Hanford's SSTs and DSTs.

REFERENCES

1. U.S. Department of Energy-Headquarters, "Final Environmental Impact Statement, Disposal of Hanford Defense High-Level, Transuranic, and Tank Waste, Hanford Site, Richland, Washington," DOE/EIS-0113, (1987).
2. G.A. BEITEL, "Chemical Stability of Salt Cake in the Presence of Organic Materials," ARH-LD-119, Atlantic Richfield Hanford Company (1976).
3. Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, "Hanford Federal Facility Agreement and Consent Order," as amended (1990).