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7. Abstract

This document presents alternatives and recommendations for a Moisture Monitoring and Control System to be utilized in waste tanks at the Hanford site.

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MOISTURE MONITORING AND CONTROL

ENGINEERING STUDY

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1.0 INTRODUCTION

During the past 50 years, a wide variety of chemical compounds have been placed in the 149 single-shell tanks (SSTs) on the Hanford Site. The chemical wastes stored in the tanks are byproducts of processes used to recover valuable heavy metals from spent nuclear fuel.

The waste in SSTs generally forms in two or three regions. In most SSTs, a layer of sludge occupies the bottom of the tank, with a layer of liquid waste on top of the sludge. In some SSTs, a layer of saltcake is found on top of the sludge, and the potential exists for capillary-held liquid throughout the saltcake lattice. A concern relating to chemical stability, chemical control, and safe storage of the waste is the potential for propagating reactions as a result of ferrocyanide-oxidizer and organic-oxidizer concentrations in the SSTs.

1.1 SAFETY ISSUE

Condensed-phase, propagating reactions of fuels (ferrocyanide compounds and/or organic salts) with nitrates in the SSTs could lead to structural failure of the tanks, with resulting releases of radionuclides and toxic materials. Propagating reactions in fuel-nitrate mixtures are precluded if the amounts of fuel (potential chemical energy release) and moisture present in the waste are within specified limits (Webb 1995). Waste that has total organic carbon and moisture values within these defined limits cannot sustain a propagating reaction (FAI 1995). When waste moisture exceeds 20% by weight, no propagating reaction is possible for any fuel concentrations. Maintaining waste moisture at such high levels, however, may present environmental contamination risks due to potential tank leaks, if this moisture is in the form of drainable liquids.

Because a fuel-nitrate combustion accident requires reactive waste and an ignition source, and most credible ignition sources occur near the waste surface (Meacham et al. 1995), the main emphasis of this study is toward monitoring and controlling moisture in the top 14 cm ($\approx$5.5 in.) of waste. Safe storage of SST waste requires that the waste be shown to meet fuel-nitrate safety criteria. Therefore, either fuel concentrations must be shown to be below threshold criteria, or waste moisture concentrations must be shown to be above minimum criteria. If fuel-moisture combinations are less than required by safety criteria, waste moisture may need to be increased to acceptable levels.

1.2 MOISTURE LOSS FROM TANK WASTE

High waste moisture content significantly reduces the potential for fuel-nitrate propagating reaction accidents. However, waste moisture can be reduced by drainage and evaporation. The wastes that were transferred to the SSTs for storage were all either slurries or liquids, and most of the solids (sludge particles or salt crystals) settled to the bottom of the tanks, with supernatant liquids above. To minimize the impact of tank leaks, the drainable liquids (interstitial and supernatant) are removed from selected

SSTs and transferred to double-shell tanks during interim stabilization. To maximize liquid removal, interim stabilization is often performed by draining and pumping liquid tank wastes using a saltwell screen and a jet pump. Draining could also occur due to tank leaks. The amount of liquid drained depends on the waste height and its capillary height, which is a function of particle size, void fraction, and liquid properties.

Moisture is lost from the tank waste as evaporative and convective processes remove heat from the waste surface. The relative proportion of heat removed by each process (evaporation or convection) depends strongly on the salt concentrations in the pore fluid (which suppress evaporation), waste temperature as determined by the heat flux, and natural or forced convective exchange with the environment.

1.3 OBJECTIVE

The purpose of this engineering study is to recommend a moisture monitoring and control system for use in SSTs containing sludge and saltcake. The recommendations were obtained by evaluating existing technologies for monitoring and controlling moisture concentrations in various materials. The recommended moisture monitoring and control system (MMCS) will be applicable for use in SSTs with low moisture concentrations and high fuel (ferrocyanide and/or organic fuels) concentrations.

1.4 SCOPE

This study includes recommendations for: 1) monitoring and controlling moisture in SSTs; 2) the fundamental design criteria for a moisture monitoring and control system; and 3) criteria for the deployment of a moisture monitoring and control system in Hanford Site SSTs.

To support system recommendations, technical bases for selecting and using a moisture monitoring and control system are presented. Key functional requirements and a conceptual design are included to enhance system development and establish design criteria.

2.0 SUMMARY AND CONCLUSIONS

There are many methods to monitor and control moisture. Some methods are better suited for one type of environment, test condition, or measurement range. All of the moisture monitoring alternatives discussed in Section 3.3 are viable for use in the SSTs at Hanford, and have distinctive advantages. Moisture measurement apparatus should provide a comprehensive waste moisture profile both at and below the surface of the waste. The neutron probe described in Section 3.3.1 is the most effective means of monitoring tank waste moisture concentrations. However, instrumentation capable of producing representative direct surface moisture measurements must be developed.

Methods for increasing the moisture content of SST waste (especially the saltcake lattice) are discussed in Section 3.2. Moisture control systems using direct water injection into the tank vapor space (Section 3.2.1) would be the most effective for waste tank applications, because water might be absorbed by the tank saltcakes, the system is easily controllable, and water is clearly not hazardous or difficult to handle.

Ideally, the moisture monitoring and control system would be low in cost, easy to maintain and calibrate, and would provide real-time data for waste moisture concentrations.

3.0 DESCRIPTION OF ALTERNATIVES

To obtain a better understanding of the mission for the moisture monitoring and control system, Sections 3.1.1 and 3.1.2 discuss moisture phenomena in sludge and saltcake waste. Introductory system description and criteria are included in Section 3.1.3. Specific alternative listings for the MMCS components are given in Sections 3.2 and 3.3, followed by a discussion of the considerations for candidate demonstration tank selection in Section 3.4.

3.1 CRITERIA

3.1.1 Moisture in Sludge Waste

As the result of solids precipitating from the tank waste contents, a layer of sludge is found at the bottom of many SSTs. Organic salts and ferrocyanide compounds (constituents of the waste streams from the processing facilities and scavenging processes) are contained in much of the Hanford Site SST sludge (Hanlon 1994). The sludge region on the tank bottom typically has a high moisture content (35% to 80% by weight) (FAI 1994b). Due to electrostatic forces between the sludge particles and constituent water (Epstein et al. 1994), an inherent property of the SST sludge is moisture retention. Moisture, however, is removed from the sludge through evaporation and consolidation (FAI 1994b).

Typical sludge particle sizes are on the order of 10 μm and the associated capillary height is on the order of 6.1 m (20 ft) (Atherton 1974). Sludge drainage is very limited and has a negligible effect on moisture loss compared to consolidation and evaporation. Consolidation is a mechanism by which the waste is compressed under its own weight, reducing the pore volume and driving out moisture. Sludges will consolidate under their own weight, driving moisture from shrinking pore space, and the extent of consolidation may be estimated by consolidation theory and assumed sludge properties (FAI 1994b). The loss of moisture in weight percent was shown (FAI 1994b) to be rather small, between 10% by weight (for sludge with high initial moisture) and 3% by weight (for deep sludge with low initial moisture). Consolidation alone is only important for sludge with a very low initial moisture content, below 30% by weight, for which the maximum consolidation-driven moisture loss is not expected to exceed 3% by weight.

Sludges, therefore, are predicted to retain adequate moisture even after draining, and moisture loss beyond drainage must result from evaporation. Evaporative moisture loss rates for each SST have been developed (FAI 1994a and 1994b) and are discussed further in Section 3.1.2. Evaporative losses might be replaced by the addition of water to the waste surface, with subsequent adsorption into the sludge matrix.

3.1.2 Moisture in Saltcake Waste

To reduce waste volume, supernate from various waste tanks was processed by evaporators (and/or evaporator-crystallizers) to boil off excess water. The evaporator operations were successful in reducing waste volume, but when the residual waste was put back into the SSTs, a crystalline material (saltcake) formed in some tanks. Due to the lack of knowledge concerning current waste fuel concentrations, the minimum moisture required to meet fuel-nitrate safety criteria is not defined for each tank. When waste moisture exceeds 20% by weight, propagating reactions are not possible for any fuel concentrations, and this value can be conservatively applied as a minimum required moisture content for all tanks until better fuel values are determined. Saltcake is not expected to retain moisture concentrations higher than 20% by weight (Meacham et al. 1995).

Various aspects of saltcake properties relevant to moisture concentrations in drained wastes have been evaluated by Dickinson (Dickinson 1995a and 1995b). It has been shown that moisture transport to the waste surface is a function of local evaporation and heat flux. Of the mechanisms that contribute to upward migration of moisture (i.e., diffusion, convection through the material voids, capillary flow), diffusion alone could transport more water vapor through the unsaturated saltcake than the amount of water that could be lost by surface evaporation, given an ideal case with uniform surface crust (based on the surface and headspace water vapor removal rates per Epstein [1994]).

Drainage from saltcakes may be significantly higher than from sludges. Salt particles are expected to be larger (in the 100 to 1000 μm range) than sludge particles (Atherton 1974). Drainage from saltcakes has historically been evaluated assuming porous media behavior. Based on this model, saltcakes have been predicted to have a low capillary height (Atherton 1974) compared to that of sludge, on the order of 0.30 to 0.60 m (1 to 2 ft). Note that limited sample results from drained saltcakes indicate significantly more moisture retention than predicted by porous media models. Saltwell pumping experience indicates that the saltcake drainable void volume is in the range of 30% to 48% (Kirk 1980), although the higher numbers may be a result of large, liquid-filled voids below the waste surface, or a floating crust on top of a liquid layer. In contrast to sludge, in which void space is filled with water, drained saltcake has air and water in the void space. A figure of 7.5% by volume (Atherton 1974) has been cited for the expected water fraction in the void space of a drained zone. Thus, based on the historically applied porous media model, saltcake is expected to retain less than 20% by weight moisture above the capillary zone. This will be verified through further waste characterization efforts.

Models for estimating the evaporative moisture loss rate for each SST (both sludge and saltcake) have been developed (FAI 1994a and 1994b). Waste dryout has been estimated based on these calculated moisture loss rates and estimated initial waste moisture content (Webb 1995). High evaporation rates are calculated for wastes with high decay heat loads stored at high temperatures, or wastes provided with high ventilation rates. Yearly evaporative loss rates range from very small (< 0.1 metric ton/yr) for cool, passively ventilated tanks to quite high (> 50 metric ton/yr) for warm, actively ventilated tanks. Given the yearly loss rate, and an estimated, initially drained waste moisture content, approximately 20 tanks are predicted to dry below 5% by weight water over 50 years of storage, another 25 below 10% by weight, and all but 45 below 20% by weight. Note that this prediction is for both sludge and saltcake tanks.

Because of their composition and the inherent moisture gradient through the saltcake layers, saltcakes do not naturally retain liquid (FAI 1994b). Moisture replacement might not be adequate to make up for local evaporative losses at all waste surface locations; therefore, saltcake moisture may vary across the waste surface. However, evaporative losses from the unsaturated zone (above the capillary zone) might be replenished by the careful addition of moisture. The moisture concentration levels in the unsaturated zone might be gradually increased back to the original, post-drained state, without allowing liquid to drain to the lower regions of the saltcake. The addition of too much water would add to the drainable liquids and could jeopardize interim stabilization status.

3.1.3 System Description and Criteria

An efficient MMCS would monitor and maintain required moisture levels in SST waste. The MMCS could be used in any waste tank where dry waste conditions pose threats to safe interim storage.

Conceptually, the MMCS would be comprised of components that adequately monitor the moisture content of tank waste and effectively control waste moisture content above any required level. To meet this objective, the MMCS must include equipment to precisely control moisture additions as dictated by decreasing moisture levels. Moisture additions must be controlled to prevent altering the chemical composition of tank waste (other than increasing the moisture content), and jeopardizing tank stabilization criteria (i.e., raising interstitial liquid levels). Moisture additions must be performed precisely enough to ensure that tank saltcakes remain in equilibrium. Additionally, moisture additions must provide uniform waste coverage and effectively raise and maintain required moisture concentrations.

Specific criteria for the MMCS include protective design features for adverse ambient conditions, in-tank conditions, and radioactive environments. The MMCS must be designed per applicable codes and standards, and installed in a manner that maintains the structural integrity of the tank. The MMCS must operate within the existing safety envelope for SSTs (e.g., pressure and temperature limits, dome loading limits, interstitial liquid levels, required waste moisture concentrations), without extensive modifications to the existing tanks.

3.2 CONTROLLING MOISTURE

To assist in maintaining the prescribed moisture concentrations in waste tanks, a moisture control system must be developed and installed. The control system should be composed of equipment that can add moisture to the entire waste surface without jeopardizing any tank stabilization or operational safety requirements. The primary task for the moisture control system is to maintain adequate moisture levels in the top 14 cm ($\approx$5.5 in.) of saltcake waste. The control system could be designed to increase moisture concentrations at various depths. A typical mitigation of low moisture concentrations in saltcake waste is shown graphically in Appendix A. Assuming a negligible tank heat load (and that water is added at a rate of 100 gpm), it would take approximately 20 minutes to elevate water concentrations in tank saltcakes from 6% to 15% by weight for the top 14 cm ($\approx$5.5 in.). Note that a demineralized (and/or de-ionized) water supply may be necessary.

3.2.1 Water Injection

A water injection system could be used to add moisture in specified quantities over the entire surface of tank waste. The system would consist of a water supply tank, water pumps and/or air compressors, spray nozzle(s) (designed for any specific riser location), and necessary interface piping. The water droplet size would be dependent upon the application; however, for saltcake waste, a droplet diameter between 1/1,000 (mil) and 1/10,000 (tenth mil) of an inch would be required for complete absorption and reasonable settling periods. Small droplet size would allow appropriate entrainment time intervals so that water droplets could migrate to all portions of the saltcake surface before settling. Water injected into the vapor space would be controlled at temperatures lower than vapor space temperatures to preclude condensation on in-tank structures, and to force the tank to "breathe" in during moisture additions. Though the density and global temperature in the vapor space may be affected during moisture additions, this will not have significant impact on tank negative pressure.

Advantages:

- Controllable operating parameters.
- Off-the-shelf technology.
- Relatively inexpensive ($\approx$\$20K per tank for capital equipment).
- Uniform waste coverage.
- Any tank riser could be used if spray pattern and spray angle are designed for specific riser locations.

Disadvantages:

- May require a blower in the vapor space to properly disperse moisture medium.

- Off-the-shelf equipment may require further development to produce needed particle sizes (given desired flow rates, and required waste coverage).
- May require induced frequency vibrations at the spray nozzle(s) to maintain consistent particle sizes and optimize nozzle performance.

3.2.2 Ultrasonic Humidifiers

Ultrasonic humidifiers are an industry standard for applications requiring sub-micron particle sizes. Ultrasonic frequencies are used to achieve a consistent and very small particle size for humidification purposes. A typical ultrasonic humidifier system for use in the waste tanks would consist of system controller(s), ultrasonic humidifiers (up to 40), and a de-ionized water supply. If the system were placed outside of the waste tank, extensive tank inlet and outlet ducting would be required, as well as additional motive forces for humidity dispersion.

Advantages:

- Controllable operating parameters.
- Off-the-shelf technology.
- Uniform waste coverage.
- Could be deployed in or out of tank.

Disadvantages:

- Expensive for tank application ($\approx$\$100K capital equipment per tank).
- Tank location dependent (could require in-tank air blowers).
- Extensive ducting and air movement required if deployed outside the tank.
- Excessive number of controllers required for tank application.
- De-ionized water required for operation.

3.2.3 Evaporative Cooling

Evaporative cooling is a method used extensively at the Hanford Site to reduce the residual heat load in some waste tanks. A scaled system for specific applications would consist of a standard tank ventilation system (centrifugal fan[s], ducting, filtration, psychrometric instrumentation) coupled with a moisture addition system designed to allow periodic or continuous moisture additions (the water injection method described in Section 3.2.1 could be used). In order to not "short-circuit" the tank waste, moisture additions would be completed when the exhaust fans are idle.

Advantages:

- Controllable operating parameters.
- Proven/effective technology for heat removal.
- Can be designed to perform several functions for tank safety.

Disadvantages:

- Expensive for tank application (≈$150K capital equipment per tank)
- Low heat load may not require evaporative cooling.
- Could require extensive interlocks between cooling fans and moisture addition equipment.

3.2.4 Steam Injection

Steam injection, which uses a batch process of steam mixed with cold and/or compressed air, could be used for tank waste moisture control. The system would consist of steam jets or steam electrode humidifiers with controllers to limit temperatures. Extensive development to obtain definitive moisture addition volumes would be required.

Advantages:

- Steam supply available at most tanks.
- Off-the-shelf technology.
- Uniform waste coverage.

Disadvantages:

- Particle size (steam) may be too large for specific applications.
- Must control phase change (vapor to liquid) pressure drop precisely.
- May require in-tank blower system for effective waste coverage.
- Expensive for tank application (≈$100K capital equipment per tank).

3.3 MONITORING MOISTURE

In order to understand the moisture conditions inside SSTs, a moisture monitoring system must be employed. The monitoring system should be composed of components that can adequately monitor waste moisture. The monitoring system should be capable of providing an accurate moisture profile of the top 14 cm (≈5.5 in.) of saltcake waste, although an entire waste moisture profile may be necessary depending upon specific applications. Additionally, the monitoring system should monitor moisture concentrations below the top 14 cm to verify that any moisture added to the tank is not draining too far below the surface, and that the interstitial liquid level does not increase during or after moisture additions. Ancillary moisture monitoring devices may be necessary to operate the moisture control system within the desired parameters, or to verify moisture data. Note that all methods to monitor moisture in SSTs are not presented in this study; however, viable existing technologies are represented.

3.3.1 Neutron Probe

For several years a neutron probe has been used in the Hanford Site waste tanks to monitor the air/liquid interface or interstitial liquid level. A proof of principle report for in-tank moisture monitoring using an active neutron probe (Watson 1993), provided evidence that a modified neutron probe could be used to monitor moisture at different tank waste elevations. Further studies (Finfrock et al. 1994) have been performed concerning material anomalies and geometric uncertainties surrounding a liquid observation well (LOW) (used to insert the neutron probe into the waste tanks), and how in-tank conditions can be modelled by laboratory experience. A neutron probe capable of producing representative direct surface moisture measurements must be developed.

Advantages:

- Would provide effective waste moisture monitoring if probe is sufficiently below the waste surface and the waste being monitored is relatively close to the LOW. (NOTE: Characteristic detector responses can identify anomalies around LOWs, make corrections to the moisture measurement, and place bounds on the corrections).

- Is presently used in waste tanks for liquid level monitoring.

- Could assist in determining the effectiveness of a near-surface moisture control system.

- Modified probe could monitor waste permeation by moisture control medium and determine interstitial liquid level.

- Modified probe could be deployed inside a cone penetrometer or other devices designed for waste penetrations.

Disadvantages:

- Prototype for moisture monitoring must be developed and tested further. (NOTE: Is presently scheduled for completion by June 1995)

- Additional calibration and instrument modifications required to obtain accurate waste moisture profiles. Use of an empirical calibration curve for all tanks may not be practical due to air gap size variation around each LOW and variations in the LOW tube material. (NOTE: Calibration facility presently scheduled to be operable by June 1995)

- Limited radius of observation or measurement (≈30 cm [76 in.] at ≈20% moisture; ≈40 cm [101 in.] investigation radius at lower moisture levels).

- Tanks must have a LOW installed for probe insertion.

- Multiple waste scans using multiple probe configurations could be necessary to identify irregular waste surface geometries and provide corrections for moisture content.

- Numerical modeling for each SST/LOW configuration may be required to identify and correct moisture content in the waste.

3.3.2 Electromagnetic Induction

The electromagnetic induction (EMI) method to monitor waste moisture content has been developed at the Hanford Site by Pacific Northwest Laboratories, and is being readied for tank use by Westinghouse Hanford Company. Using impedance measurements from a coil inserted into a LOW (or cone penetrometer), the moisture content of the surrounding waste can be determined. The EMI is currently being developed for use in a LOW; however, a flat probe may be developed for direct surface measurements outside a LOW.

Advantages:

- Effective waste moisture monitoring if coil is sufficiently below the waste surface and the waste being monitored is relatively close to the LOW.

- Has the potential to monitor waste permeation by moisture control medium and to help determine effectiveness of moisture control system near the waste surface.

- Could be used to determine air/liquid interface in waste tanks, thereby providing limits for moisture additions.

Disadvantages:

- Technology must be further developed and tested in different waste environments.

- No documented technical bases.

- Small radius of investigation (≈61 cm [24 in.]).

- Tanks must have a LOW installed for probe insertion and for obtaining comprehensive waste moisture profiles.

3.3.3 Hygrometers

Hygrometers are capable of monitoring the humidity or psychrometric state of air. Electrical hygrometers are an industry standard having many heating, ventilation and air conditioning applications, and may be used in both forced or passively ventilated environments. Dewpoint hygrometers use a surface, which can be cooled as required, to record the dewpoint temperature of any vapor passed over the surface. If it can be shown that a hygrometer system would provide required waste moisture information, then a system for SSTs could be developed to correlate vapor space humidity to waste moisture concentrations.

Advantages:

- Effective vapor space humidity monitoring.
- Could provide connection between waste moisture monitoring equipment (neutron probe or EMI) and vapor space conditions.
- Provides efficient operating parameters for moisture control system.

Disadvantages:

- Does not provide direct waste monitoring (would require testing with direct waste monitoring equipment to provide a baseline for required humidity levels).
- Remote calibration difficult if hygrometer installed in tank.
- Relatively expensive if installed directly above waste surface (shielding required).
- Equilibrium humidity may approach 100% (saturated atmosphere) in tanks containing saltcakes, thereby making humidity measurements useless.
- Sample tubing atmosphere (dewpoint hygrometer) must be meticulously controlled to avoid possible condensation or drying of vapor sample.

3.3.4 Near-Infrared Spectroscopy

Near-infrared spectroscopy measurement of water-absorption bands in porous solids is another method for moisture monitoring. A technique using fiber optic probes is currently being investigated and developed. The development work (Reich et al. 1995) is primarily directed toward moisture measurements in high-level waste environments situated in laboratories.

Advantage:

- Very accurate moisture measurements obtained using waste simulants. (Uncertainties on the order of 0.5% to 1.5% by weight, using simulants in a moisture range of 0% to 25% by weight)

Disadvantages:

- No accuracy or reliability data available for systems installed in SSTs.
- Radiation protection must be further developed.

- Sensitive/fragile components in the waste space could lead to continuous monitoring difficulties.
- Limited depth of observation or measurement ($\approx$1.5 mm).

3.4 DEMONSTRATION TANK SELECTION

An SST is the preferred tank to use for a demonstration of the MMCS. Using all Ferrocyanide and Organic Watch List tanks as a baseline for tank selection (see Appendix B), criteria were developed to determine which Ferrocyanide and/or Organic Watch List tanks could provide quantitative results for monitoring and controlling moisture. Of the six tanks that survived the initial investigation for the demonstration project (A-101, BY-104, BY-112, S-102, S-111, and TX-118), three are also listed on the Flammable Gas Watch List. Due to the many work restrictions placed on intrusive work in flammable gas tanks, these three tanks (A-101, S-102, and S-111) were not considered suitable for the moisture monitoring and control demonstration project.

Tank selection criteria may be altered to allow the use of any "sound" tank containing considerable amounts of saltcake for the MMCS demonstration project. The three remaining candidate tanks (BY-104, BY-112, and TX-118) all contain large volumes of saltcake and are the most desirable tanks to use for a demonstration of the MMCS. If any "sound" saltcake tank could be used for a demonstration, then selection criteria would be expanded to emphasize historical temperature data, waste surface condition, and riser availability.

4.0 DISCUSSION OF PREFERRED ALTERNATIVE

The moisture monitoring and control system will be comprised of equipment that can adequately monitor and control moisture concentrations in Hanford Site waste tanks. As shown in the conceptual design in Appendix C, the moisture monitoring equipment will consist of a modified neutron probe (Section 3.3.1) installed in a LOW (a LOW is a small-diameter composite tube, closed at its lower end, that is placed through a tank riser and waste, and used for the purpose of inserting instrument probes) or, as development progresses, a neutron probe designed specifically to provide a larger radius of investigation and direct surface measurements. The conceptual moisture controlling equipment shown in Appendix C (Water Injection, Section 3.2.1) consists of a water supply tank (ASME Section VIII rated if used with pressurized headspace), water temperature controller, staged motive force, interconnecting piping, and high-efficiency spray nozzle(s). It would be economical to position the spray nozzles as close to the center of the tank as possible; however, a nozzle assembly could be designed for full tank coverage, regardless of the riser location.

During development of the MMCS, a scaled prototype could be designed, assembled, and installed in small test tanks available on the Hanford Site. The purpose for the design prototype would be to provide a method to test moisture monitoring and controlling equipment in a simulated waste tank environment. The end product of the prototype development would be a defensible, comprehensive design basis, which could be used to produce a full scale MMCS targeted for specific SST installations.

Controlling costs will be emphasized throughout development of the moisture monitoring and control system. Using existing engineering practices, the design process would be controlled by the Cognizant Engineer for design, providing a disciplined engineering process to produce a useable product. As shown in Appendix C, development and definitive design costs for the MMCS total $240K ($160K for personnel and $80K for equipment). These costs are estimated and could change, depending upon where the development process takes place.

5.0 UNCERTAINTIES

Several uncertainties are associated with installing new equipment into the SSTs at Hanford. One of the most significant or limiting factors concerning monitoring and controlling tank moisture is the availability and location of tank penetrations (risers). Systems that require multiple tank entries would necessitate the need for more than one available riser providing access to the tank vapor space. The MMCS recommended for use will require at least two risers; one for the monitoring equipment (LOW), and one for the controlling equipment (assumed need is a 10-cm [4-in.] or larger riser). Riser availability will probably dictate which tanks are targeted for a demonstration, and future installations, of the MMCS.

It is known that after prolonged exposure to high levels of radioactivity, components will fail and require replacement. All systems, however, are subject to damage from radiation exposure, and could be designed with radiation shielding if necessary.

There are additional uncertainties concerning moisture addition. These include the need for moisture addition, the amount of moisture addition required, and the chemical changes in the waste constituents during moisture addition. For tanks containing saltcake, the present need for moisture addition has been established, although future waste characterization campaigns may indicate sufficient moisture concentrations remain in saltcake waste to prevent propagating reactions. Moisture additions are also related to various conditions inside the SSTs, and, assuming worst case, definitive design will dictate required moisture levels. Finally, specific criteria for the MMCS will ensure the waste environment is not chemically altered more than what is occurring naturally due to atmospheric conditions and the aging process of tank waste. Initial testing may be required on waste simulants to ensure the MMCS will properly monitor and control prescribed moisture concentrations.

6.0 RECOMMENDATIONS

To assist the ongoing activities of storage, characterization, and retrieval of tank waste at the Hanford Site, a method to control moisture concentrations in tank waste is needed. The moisture monitoring and control system could be used to maintain safe conditions during any in-tank activity, but its primary purpose is to monitor and maintain safe moisture concentrations in the waste. After a thorough review of existing technologies to monitor and control tank waste moisture, it is recommended that water injection (Section 3.2.1) be used in conjunction with a modified neutron probe (Section 3.3.1) to comprise the moisture monitoring and control system. This decision is based on several factors, including cost effectiveness, safety considerations, design simplicity, and engineering experience. It is also recommended that the MMCS be developed in a two- or three-step process which, in the end, might result in a definitive design with enough flexibility to be used at any location, in any waste tank.

Additionally, it is recommended that tank 241-BY-104 (Section 3.4) be used for the first in-tank demonstration of the MMCS. This decision would be finalized after confirming, with a modified neutron probe, that the waste surface is relatively dry. Although BY-104 is not listed on both the Organic and Ferrocyanide Watch Lists (as is tank TX-118), the saltcake present in the tank, high waste temperatures ($\approx$52 °C [126°F]), and an available thermal-hydraulic analysis (McLaren 1993) provide sufficient justification for its selection.

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APPENDIX A

MOISTURE PROFILES

As shown by the following three moisture profiles, the moisture control system would be designed to increase moisture concentrations in tank saltcakes to acceptable levels. The first moisture profile (Figure A-1) represents assumed initial moisture conditions found in a recently interim-stabilized SST. The second moisture profile (Figure A-2) depicts an assumed condition where the waste has partially dried by evaporation, and moisture concentrations at the surface of the waste are too low. The third moisture profile (Figure A-3) shows the condition during moisture additions, whereby the moisture concentrations are increased to acceptable levels for safe interim storage. The feasibility of reestablishing a waste moisture profile similar to that shown in Figure A-1 (moisture conditions found in a recently interim stabilized SST), by direct water addition to a partially dried waste surface, needs to be demonstrated.

Figure A-1. Moisture Profile - Recently Interim Stabilized Single-Shell Tank.

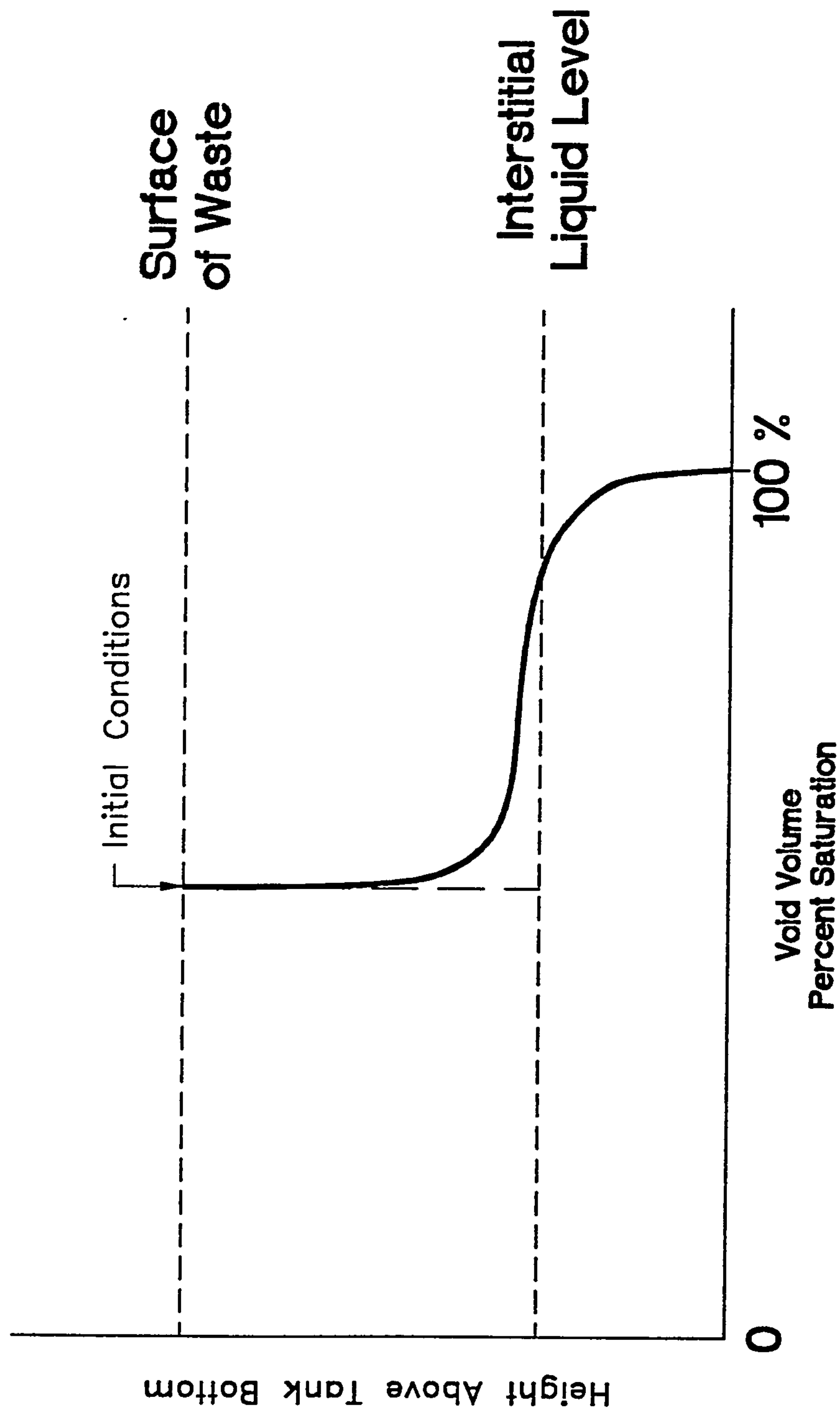


Figure A-2. Moisture Profile - Low Moisture at Waste Surface.

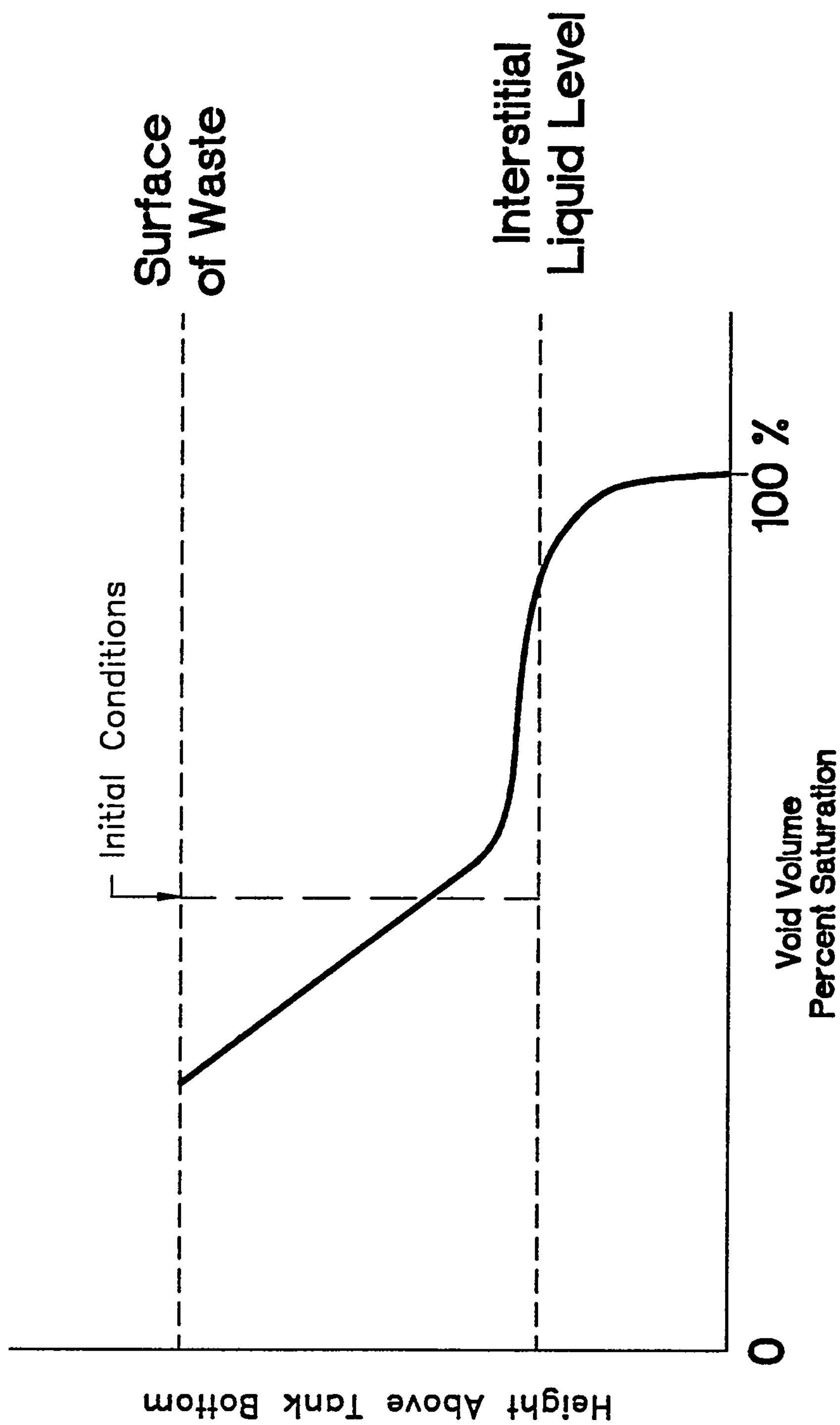
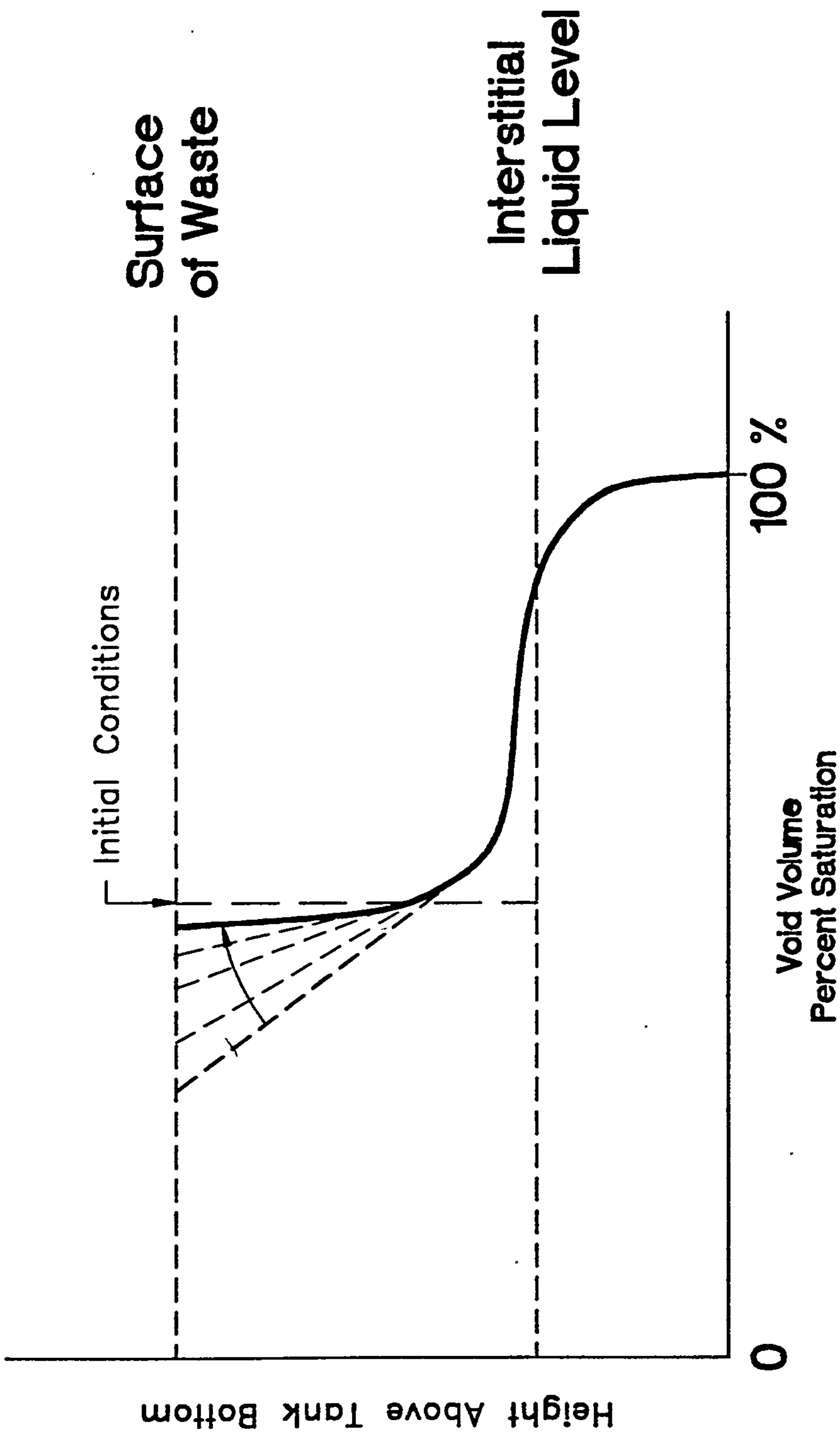


Figure A-3. Moisture Profile - Mitigation in Progress.



APPENDIX B

TANK SELECTION CRITERIA

The following table provides preliminary tank selection criteria for the moisture monitoring and control demonstration project. All tanks that are assumed leakers, per the July 1994 summary report (Hanlon 1994), are not considered acceptable for the project. Tanks that are shaded in the table are being deleted from selection; justification for the tank deletions follows the table.

WASTE TANK #	FERROCYANIDE WATCH LIST	ORGANIC WATCH LIST	LOW	DRAINABLE LIQUID (gallons)	TOTAL SOLIDS (gallons)	MAX. WASTE TEMPERATURE (°F)	MOST RECENT SAMPLE
A-101(1)	N	Y	Y	413,000	953,000	152	1984
BY-104(2)	Y	N	Y	18,000	406,000	126	1992
BY-110	Y	N	Y	9000	398,000	118	1992(5)
BY-111	Y	N	Y	0	459,000	87	1994(5)
BY-112	Y	N	Y	8000	291,000	88	1972
C-102	N	Y	N	37,000	423,000	83	1975
C-103	N	Y	N	39,000	175,000	119	1986
C-108	Y	N	N	0	66,000	75	1994
C-109	Y	N	N	4000	62,000	80	1992
C-112	Y	N	N	32,000	104,000	81	1992
S-102(1)	N	Y	Y	230,000	549,000	107	1979
S-111(1)	N	Y	Y	205,000	586,000	91	1978
SX-103(1)	N	Y	Y	233,000	536,000	173(3)	1976
SX-106(1)	N	Y	Y	255,000	477,000	117(3)	1979
TX-118(4)	Y	Y	Y	27,000	347,000	75	1977

(1) Waste tank is also on the Flammable Gas Watch List.
(2) Thermal-hydraulic analysis performed 1993 (McLaren 1993).
(3) Waste tank is actively ventilated.
(4) Only "SOUND" tank that is on both the Ferrocyanide and Organic Watch Lists.
(5) Tank has been vapor sampled only, waste sampling planned (Homi 1994a and 1994b).

Tanks BY-110 and BY-111 would need current sampling information to be used for the demonstration project. A baseline waste moisture content is desirable for the selected tank.

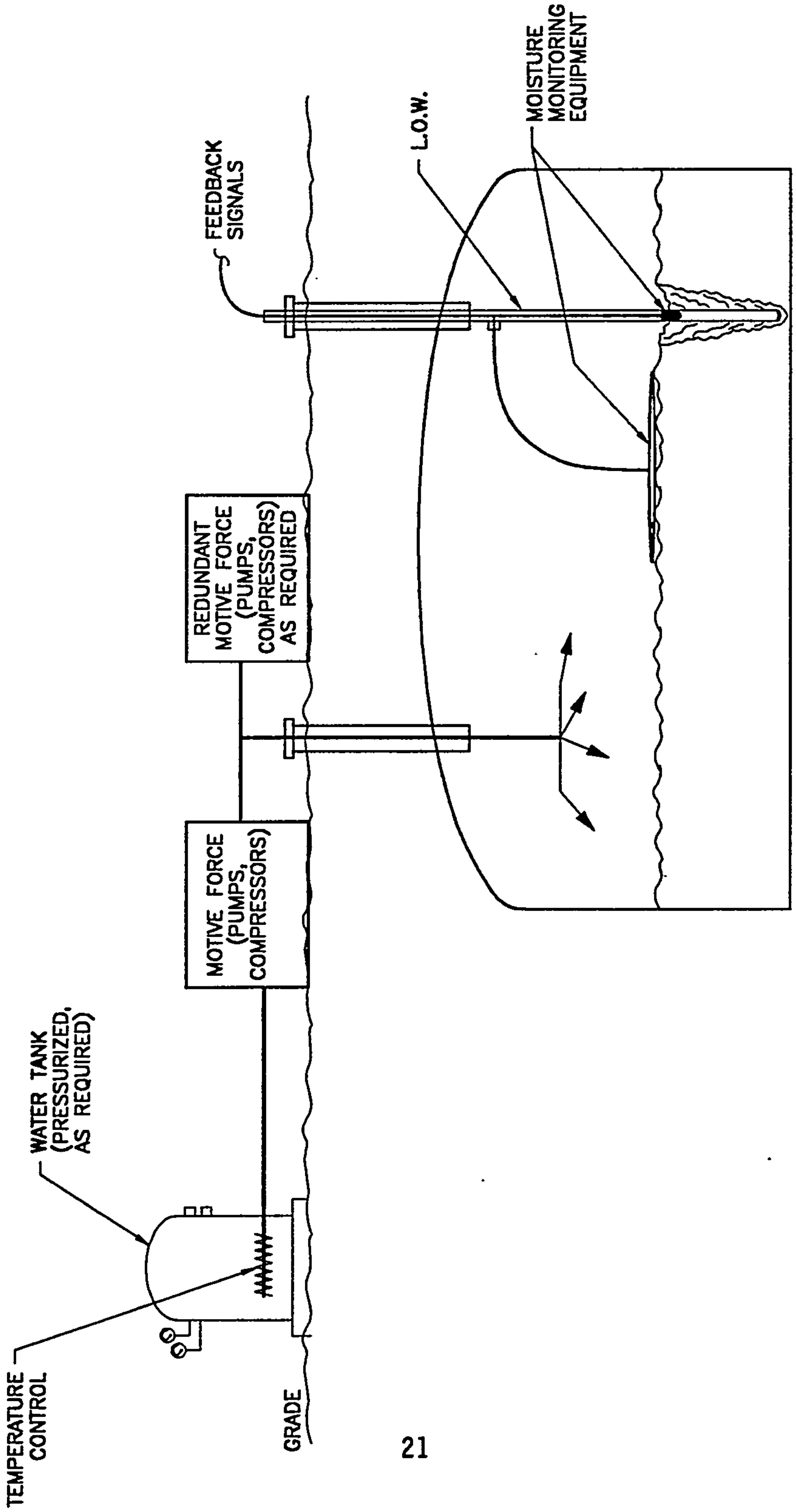
All listed tanks from 241-C Tank Farm would need a LOW installed for the demonstration project. The moisture monitoring equipment would be inserted into the LOW to verify waste moisture content.

It is recommended that real-time psychrometrics (relative humidity, flow rate, dry bulb) be pursued for tanks which are actively ventilated (SX-103, SX-106).

APPENDIX C

CONCEPTUAL DESIGN

Figure C-1. Moisture Monitoring and Control System Conceptual Design.



The following table provides Rough Order of Magnitude costs associated with the development and definitive design of the MMCS.

COST ELEMENT	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	**TOTAL**
WHC Non-Exempt	0.1	0.1			0.1	0.2	0.5
WHC Exempt	1.5	1.5	1.5	1.5	1.5	1.5	9.0
Job Shoppers		0.1	0.1	0.1	0.1	0.1	0.5
Kaiser	0.5	0.5	1.0	1.0	1.5	1.5	6.0
LABOR TOTAL (FTE*)	2.1	2.2	2.6	2.6	3.2	3.3	16.0 = $160K*
Material Costs for Control Equipment		$20K		$20K	$30K	$10K	$80K
TOTAL $ - LABOR AND MATERIAL	$21K	$42K	$26K	$46K	$62K	$43K	$240K

*One FTE calculated as $10K/man-month.

FTE = full-time equivalent