John T. Conway, Chairman
A.J. Eggenberger, Vice Chairman
John W. Crawford, Jr.
Joseph J. DiNunno
Herbert John Cecil Kouts

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

625 Indiana Avenue, NW, Suite 700, Washington, D.C. 20004
(202) 208-6400

October 9, 1997

The Honorable Alvin L. Alm
Assistant Secretary for Environmental Management
Department of Energy
Washington, D.C. 20585

Dear Mr. Aim:

Defense Nuclear Facilities Safety Board (Board) staff review teams have visited the Savannah River Site several times this year to review implementation of Recommendation 96-1 at the In-Tank Precipitation (ITP) Facility, and to assess the authorization basis and safety programs for the high-level waste tank farms. The Board requested Mr. R. Tontodonato of the Board's staff to review the reports of these visits and to summarize these findings for us. The enclosed report is his summary of the issues identified during each site visit and the progress made in resolving each open item.

There are several key issues the Board would like to draw to your attention. The numerous observations made by our staff regarding the ITP nitrogen inerting systems make it clear that great care must be taken to ensure these systems are rigorously effective and reliable. Furthermore, the staffs observations regarding controls on ITP pump operations highlight the fact that ITP appears to be developing an undue reliance on administrative controls. Engineered controls would be preferable, to the extent that they are practical, for a facility facing such a long and technically demanding mission. Finally, the prolonged discussions that have taken place regarding the accident analyses and controls for hydrogen deflagrations in waste tanks and waste tank overheating indicate that closure of these issues is proving difficult and may warrant increased scrutiny from the Department of Energy. The Board is closely following the progress of the research on the chemistry of the ITP process, and the results that continue to come in with bearing on the safety of the process.

The enclosed reports provide a synopsis of the observations made during the reviews conducted by the Board's staff and are forwarded for your consideration. If you have any questions, please feel free to call me.

Sincerely,

John T. Conway
Chairman

c: Mr. Mark Whitaker

Enclosures

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

September 5, 1997

MEMORANDUM FOR: G. W. Cunningham, Technical Director
S. Krahn, Deputy Technical Director

COPIES: Board Members

FROM: R. Tontodonato

SUBJECT: Status of Open Issues Identified in Recent Trip Reports for Savannah River Site Waste Management Facilities

This memorandum documents the current status of the issues related to Savannah River Site (SRS) waste management facilities that were identified in recent trip reports by the staff of the Defense Nuclear Facilities Safety Board (Board) and for which Board action is pending. The following reports are addressed:

- *Review of Adequacy and Reliability of In-Tank Precipitation Facility Safety Systems, Savannah River Site, January 23–24, 1997*, D. Napolitano, February 5, 1997
- *Review of Technical Safety Requirements for High-Level Waste Tank Farms, Savannah River Site, March 31–April 1, 1997*, D. Napolitano, April 15, 1997
- *Review of Savannah River Site In-Tank Precipitation Facility, April 2–3, 1997*, D. Drop and R. Tontodonato, April 15, 1997
- *In-Tank Precipitation Facility and Tank Farm Instrumentation and Control Systems*, T. Davis, May 7, 1997
- *Review of Savannah River Site Waste Management Facilities, June 9–11, 1997*, R. Tontodonato, June 16, 1997

Recommendation 96-1 and the In-Tank Precipitation Facility. The staff reports discussed the following issues.

Reliability of Nitrogen Inerting System—The February 5, 1997, report identified that numerous problems were causing the primary inerting system for Tanks 48 and 49 to trip off line far too frequently, and that a comprehensive evaluation of the system's failure modes could help identify ways to improve reliability. Westinghouse Savannah River Company (WSRC) has subsequently worked to identify and eliminate vulnerabilities in the nitrogen system, and has made further upgrades, as documented by the April 15, 1997, staff report on the In-Tank Precipitation (ITP) Facility. The staff will continue to monitor the system's reliability to ensure that unplanned outages are reduced to a minimum.

Vapor Space Mixing—The February 5, 1997, and April 15, 1997, staff reports identified that test results used by WSRC to show that mixing in the Tank 48 vapor space was sufficient to eliminate pockets of air and benzene were not conclusive. The February 5, 1997, report stated that modeling of fluid flows and worst-case pockets would help resolve this issue. WSRC is currently performing this work and plans to prepare a white paper summarizing these calculations in September 1997.

Oxygen In-Leakage Calculations—The February 5, 1997, report identified weaknesses in WSRC's calculation of how long the Tank 48 ventilation system could be inoperable before the oxygen concentration would exceed operating limits. WSRC is now preparing an improved calculation. The staff will review the calculation as soon as it becomes available.

Positive-Pressure Inerting—The February 5, 1997, report stated that it seemed prudent to continue evaluating a positive-pressure inerting system, based on the issues associated with the reliability and adequacy of the existing negative-pressure system. Also, the May 7, 1997, report identified that lack of fuel control during operation of the planned low-flow positive-pressure backup nitrogen system was a potential concern, particularly if oxygen monitoring was not required in that mode of operation. This issue will be reviewed further once the draft Safety Analysis Report (SAR) and Technical Safety Requirements (TSRs) are available (November 1997).

Controls on Pump Operations—WSRC is headed toward the development of a complicated administrative program that will use numerous plant parameters to calculate the maximum allowable time before the next mixer pump runs for Tanks 48 and 49. The June 16, 1997, staff report identified that simple Limiting Conditions for Operation specifying pump run intervals for major phases of the ITP process would be simpler and easier to implement effectively. The staff is still pursuing this issue and will discuss it further with the Department of Energy Savannah River Operations Office (DOE-SR) when the draft SAR and TSRs for ITP become available (November 1997).

Backfit Analyses—WSRC has developed a backfit analysis process for determining whether upgrades or compensatory measures are needed for existing equipment that is designated as safety class or safety significant in the new SAR. The March 15, 1997, and June 16, 1997, staff reports identified that there were some systematic problems in the methodology used and in the resulting backfit analyses. WSRC subsequently agreed to correct specific problems with particular backfit packages, to correct the generic problem that alternatives evaluated (e.g., new equipment vs. added administrative controls) were not being documented, and to make it clear that the methodology was not intended to be applied routinely to new facility design and construction in lieu of appropriate standards. It is still not clear that the methodology will ensure that the periodicity of surveillances used as compensatory measures has a technical basis. The staff will check the updated backfit packages, as well as any new packages, and will evaluate the equipment, controls, and compensatory measures identified in the draft SAR and TSRs (November 1997). Backfit analyses for other high-level waste facilities will be checked once they have been completed.

Cooling Systems for ITP—The April 15, 1997, staff report on ITP identified that it was unclear how temperatures in Tanks 48 and 49 would be kept low enough to avoid excessive benzene generation from tetraphenylborate in the tanks. Further discussions with WSRC and DOE-SR indicate that controls on the tanks' radionuclide loading and on pump operations should adequately prevent unacceptable temperature increases.

Other—The May 7, 1997, report also identified the need for lightning protection for the safety-class backup nitrogen system and the benefits of improving ITP instrument trending, test, and surveillance programs. WSRC is installing lightning protection throughout ITP, and had previously planned to do so. The staff will revisit the instrumentation programs before ITP resumes operations.

High-Level Waste Tanks. The staff reports discussed the following issues.

TSR Implementation and Backfit Analyses—The March 15, 1997, report on high-level waste tanks identified that a concern identified in a February 3, 1997, staff trip report (that WSRC planned to implement new TSRs for the tank farms before performing backfit analyses for the required equipment) had not yet been addressed. The February 3, 1997, report was forwarded to DOE by the Board on April 18, 1997. The issue was revisited during the August 20–22, 1997, staff visit to SRS. DOE-SR and WSRC now plan to prioritize the backfit analyses to ensure that the most important evaluations (e.g., adequacy of the flammable gas monitors in the waste tanks) are completed before the TSRs are implemented in the spring of 1998. As is being done for ITP, the staff will review the backfit analyses as they are completed.

Unreviewed Safety Question Process—The April 15, 1997, report on high-level waste tanks identified that WSRC was referring some potential unreviewed safety questions (USQs) to a "New Information" process, and spending months attempting to resolve the safety issues without entering the formal USQ process or implementing formal interim controls. DOE-SR subsequently acted to impose a limit on how long potential USQs could be evaluated before entering the formal USQ process.

Tank Overheating—The April 15, 1997, report on high-level waste tanks identified that WSRC calculations showed that a tank overheating event could have significant off-site consequences, and that WSRC was developing improved analyses and controls. This issue was revisited during the August 20–22, 1997, staff visit to SRS; it is still unresolved. The staff will continue to follow WSRC's efforts to adequately address the potential for tank overheating.

Hydrogen Deflagration in a Tank—The April 15, 1997, and May 7, 1997, reports on high-level waste tanks identified that WSRC was planning to eliminate the existing requirement to ventilate the high-level waste tanks routinely to prevent hydrogen from accumulating. WSRC planned instead to implement TSRs that would require monitoring flammable gas concentrations. The proposed TSRs required ventilation only if elevated flammable gas concentrations were detected. The basis for this requirement was a probabilistic analysis that concluded that the new control scheme would result in an annual deflagration probability slightly less than 10^{-6}. The April 15, 1997, report identified that WSRC could not technically justify the frequency assumed in the probabilistic analysis for tanks exceeding the lower flammability limit. On April 18, 1997, the Board expressed its concern regarding this issue to DOE in a letter forwarding a February 3, 1997, report of an earlier staff visit to SRS.

This issue was revisited during the August 20–22, 1997, staff visit to SRS, and is still unresolved. WSRC now plans to require tank ventilation, but not in the form of a Limiting Condition of Operation or a TSR. The staff will continue to follow this issue.

Siphon Breaks—The April 15, 1997, report on high-level waste tanks identified that WSRC had not completed calculations demonstrating the adequacy of siphon breaks for the high-level waste transfer lines.

The calculation was received at the Board during the week of September 1, 1997, and will be reviewed shortly.

Other—The May 7, 1997, report also identified the benefits of improving ITP instrument trending, test, and surveillance programs, and the potential need for lightning protection in the tank farms. The staff will revisit the instrumentation programs prior to TSR implementation in early 1998. The staff will continue to follow lightning protection issues in the tank farms.

Consolidated Incinerator Facility (CIF). The June 17, 1997, report identified that continued problems caused by inadequate conduct of operations indicated the need for further improvements. The staff is monitoring operational occurrences at CIF, and will conduct a focused review of conduct of operations if improvement is not evident.

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

February 5, 1997

MEMORANDUM FOR: G. W. Cunningham, Technical Director

COPIES: Board Members

FROM: D. S. Napolitano

SUBJECT: Review of Adequacy and Reliability of In-Tank Precipitation Facility Safety Systems, Savannah River Site, January 23–24, 1997

1. Purpose

This report documents a visit by Defense Nuclear Facilities Safety Board (Board) staff members D. S. Napolitano, J. D. Roarty, and R. E. Tontodonato to the Savannah River Site (SRS) on January 23–24, 1997. The purpose of this visit was to examine the adequacy and reliability of the safety systems for the In-Tank Precipitation (ITP) Facility.

2. Summary

The negative-pressure nitrogen purge system is the first line of defense against a deflagration in the ITP Facility. Thus its reliability and adequacy are important elements. The Board staff has identified two issues with this system:

- Vulnerabilities affecting the system's reliability have not been comprehensively examined. There continue to be frequent unplanned outages. Each problem is dealt with as it occurs. There has not been an attempt to identify and correct weaknesses in the system proactively.

- Test results that support the well-mixed assumption seem inconclusive. This assumption underlies the technical basis of the nitrogen purge system. The *ITP Safety Strategy* acknowledges that uncertainty about vapor mixing is a concern, but states that the risk of a deflagration will be reduced to an acceptable level through the use of a safety-class nitrogen purge system and safety-significant fuel controls.

A high-flow positive-pressure nitrogen purge system might increase ITP's safety margin against deflagrations. This option introduces worker hazards and may require a significantly greater nitrogen supply. However, in light of the issues with the negative-pressure system and the possibility that uncertainties will remain in the chemistry test program, it seems prudent to continue to evaluate the use of such a system.

3. Background

In accordance with Board Recommendation 96-1, the Department of Energy (DOE) will develop safety measures to prevent benzene deflagrations in ITP. DOE plans to continue using oxygen control as the primary defense against accidents. Fuel control will provide defense in depth. The effectiveness of fuel control will be validated by the test program for Recommendation 96-1. A January 17, 1997, trip report authored by R. E. Tontodonato details the present safety strategy for ITP.

4. Discussion

Recognizing the importance of ITP's nitrogen purge system, the Board staff is examining the system's technical basis and reliability. Key observations are summarized below.

Reliability of the Nitrogen Purge. The negative-pressure nitrogen purge system, ITP's first line of defense against a deflagration, is subject to frequent failures (approximately once per week). However, SRS personnel have not taken a rigorous look at the system's weaknesses. Each operational problem is dealt with on a case-by-case basis.

Between September 1995 and late January 1997, the system tripped off line 60 times. These outages are usually corrected quickly; since November 1996, the system has been down less than 200 minutes per month. However, since outages are frequent, ensuring this availability requires vigilant attention.

Upgrades to the purge system are in progress. About half the outages are attributed to cold weather. As such, improvements are largely directed at weather-proofing. Although cold is an important factor, there are still many other reasons for outages. Cold weather was not a primary factor in the four most recent outages, between December 20, 1996, and January 17, 1997. The reasons for these outages ranged from a suspected short circuit to operator error.

The Board staff notes that a comprehensive review of the system, such as a Failure Modes and Effects Analysis, could provide valuable information. A list of the principal problem sources could help determine whether upgrades are needed and how to prioritize them. Additionally, it could help operators quickly find the reason for an outage, and indicate which replacement parts are good to have in inventory.

Adequacy of the Nitrogen Purge. The staff discussed two elements of ITP's technical basis: the assumption that the tank vapor space is well-mixed, and the calculations that support the time to reach the minimum oxygen concentration (MOC) for combustion.

<u>Well-mixed Assumption</u>—Fundamental to the technical basis for ITP is the assumption that the vapor space is well mixed. A large body of empirical data has been collected to validate this assumption. The test results presented to the Board staff focus on conditions during normal operation and after a loss of ventilation. The data set suggests that the vapor space is well mixed during both of these times. However, the results relate to the bulk vapor space and do not preclude the possibility of air pockets. Measurements are taken from two gas sampling poles and two closely spaced oxygen analyzers in an 85 ft diameter tank. If an

air pocket is present, it may not be detected.

Mixing in the tank occurs from a variety of processes, including forced convection, natural convection, and diffusion. In large tanks, forced flow from a ventilation system may not affect the entire tank equally. However, the combination of mixing mechanisms may still adequately stir the tank vapor space. Since the test results suggest that the tank bulk vapor space is well mixed even without forced ventilation, it is suspected that natural convection accounts for much of the mixing in the vapor space. Therefore, it seems important to understand which liquid levels, temperature differences, and other conditions allow natural convection to mix the tank effectively. This information should help determine whether the test results are valid for all conditions. In addition, it might be possible to set operating limits on these parameters to ensure bulk vapor space mixing.

When conditions allow for a well-mixed bulk vapor space, they may simultaneously allow air pockets to form. Local oxygen concentration differences might exist for at least two reasons. First, if the rate at which air infiltrates into the tank is greater than the combined processes of diffusion and natural convection, oxygen concentrations can be larger locally. It may be possible to characterize the extent of this problem by determining the size of the worst-case air pocket. This can be found analytically by comparing the infiltration and mixing rates. If the resulting air pocket is small, it may not present a combustion propagation hazard. Based on this type of analysis, operating limits can be set to ensure that mixing will prevent air pockets of some critical size. Second, the secondary flow created by the nitrogen purge nozzle might allow vortices to form. These low-pressure vortices could retard the egress of air after it enters the tank or any air already in the tank when the ventilation system starts up. Modeling the fluid flow could provide valuable information regarding this aspect of air pocket formation.

Local differences in concentration are especially important when transitioning from an air-based to an inerted state. If the ventilation system does not affect the entire vapor space equally, a preferred flow path can be set up, and large air pockets can be left at the waste surface. Since the test results are based only on a few sample locations, they do not preclude this situation. As a safety measure, SRS intends to purge the tank slurry of benzene before entering an air-based mode. However, the chemistry program has not progressed to the point where this can be guaranteed. Assuming secondary flow does not create additional air pockets, the concern with transitioning can be alleviated by simple diffusion calculations. If the bulk vapor space is well mixed, these initial air pockets should eventually dissipate by diffusion. The calculations can help define an operating limit to ensure that the air pockets dissipate before activities that may produce benzene are resumed.

<u>MOC Calculations</u>—Presently, calculations that support the time to MOC are spread throughout many documents. Some of these calculations supported the previous safety strategy of fuel control, but are now used to support oxygen control. There are identified weaknesses in the calculations that SRS personnel are actively working to correct. The specific concerns of the Board staff include the following: (1) some conservatisms assumed for fuel control are not necessarily conservative for oxygen control, and (2) the empirical air-infiltration data set does not include results for the small pressure differences.

The Board staff is encouraged that all work supporting the time to MOC is being collected into two new calculations. These new calculations are supposed to remove the nonconservatisms and introduce improved air-infiltration data. These are important issues to resolve for ITP operation.

Safety Strategy. The nitrogen purge system normally operates at a negative pressure, drawing in both air and nitrogen. The system is intended to provide both oxygen control and fuel control by inerting the vapor space and also removing flammable vapors. This requires that the system operate reliably and that the tank headspace be well mixed.

A positive-pressure nitrogen system is an alternative to negative pressure. As used in the petrochemical industry, positive pressure is a low-flow system that is a superior way of minimizing oxygen infiltration. However, it does not prevent the accumulation of flammable gases. If ITP adopted a positive-pressure design, it would need to increase its present nitrogen flow rate in order to maintain fuel control. An evaluation has not been done to determine how large the flow rate would have to be or whether that rate can be achieved. Additionally, both the low- and high-flow systems create worker asphyxiation hazards and may result in tank-top contamination.

Given the issues associated with the negative-pressure system's reliability and adequacy, it seems prudent to continue examining the positive-pressure alternative. The high flow rate may be attainable, and there may be inexpensive ways to minimize or eliminate worker hazards. It is not clear whether the low-flow system, as used in the petrochemical industry, can improve the overall safety margin of the current ITP system. However, if the ITP chemical test program demonstrates that fuel control is not effective, the low-flow system would be an improved, though perhaps not adequate, method to prevent deflagrations.

5. Future Staff Actions

The ITP technical basis and the ventilation system's reliability will continue to be evaluated as part of the Board staff's Recommendation 96-1 reviews.

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

April 15, 1997

MEMORANDUM FOR: G.W. Cunningham, Technical Director

COPIES: Board Members

FROM: D. Napolitano

SUBJECT: Review of Technical Safety Requirements for High-Level Waste Tank Farms, Savannah River Site, March 31–April 1, 1997

1. Purpose

This report discusses the development and implementation of new Technical Safety Requirements (TSRs) for the high-level waste tank farms at the Department of Energy's (DOE) Savannah River Site (SRS). The observations presented are the result of a March 31–April 1, 1997, site visit by Defense Nuclear Facilities Safety Board (Board) staff members D. Drop,
D. Napolitano, and R. Tontodonato.

2. Summary

The SRS tank farms are making progress toward developing new safety controls. Salient points resulting from the Board staff's visit are as follows:

- The rigor of the Critical Lift and Tank Overheating Programs has improved since the last visit by the Board staff.

- The program to prevent hydrogen deflagrations in tanks still lacks a firm technical basis.

- Evidence suggests that SRS tank wastes retain hydrogen. The safety analysis assumes hydrogen is not retained. As of now, SRS is determining whether this issue should enter the Unreviewed Safety Question (USQ) process.

3. Background

There is currently an approved Basis for Interim Operations (BIO) document for the SRS tank farms. TSRs associated with the BIO are being implemented in phases. A previous Board staff trip report, dated February 3, 1997, identified issues in three safety programs (Critical Lift, Tank Overheating, and Hydrogen Deflagration) and suggested that the current TSR implementation schedule might lower the present tank farm safety margin.

4. Discussion

The following subsections document the staff's observations related to the analysis of hazards, the development and implementation of safety controls, and the methodology for backfitting facilities to support these controls.

Analysis of Hazards. The current tank farm safety analysis assumes hydrogen is not retained by SRS high-level waste. However, experience with the currently active waste tanks—the In-Tank Precipitation (ITP) Facility and the Extended Sludge Processing (ESP) Facility—indicates otherwise. Data sets show that small amounts of hydrogen are released when the ITP pumps run. When the ESP tank was slurried in 1993 after having been stagnant for years, the hydrogen level rose sharply from 1 to 6 percent of the lower flammability limit (LFL) and continued to rise until the pumps were shut off. At least one stagnant tank, Tank 35, has also exhibited retention. In 1990, when a valve misalignment caused steam to bubble through the waste, the tank's vapor space hydrogen concentration increased.

The Westinghouse Savannah River Company (WSRC) is using the New Information (NI) process to resolve this issue. This is a contractor-defined process that allows them a "reasonable amount of time" to research an issue and determine whether there is a potential inadequacy in the safety basis. If there is a potential inadequacy, the USQ process is entered. The hydrogen NI evaluation has been ongoing since October 1996. While this research is being conducted, the DOE field office (DOE-SR) has imposed no operational restrictions on agitating the tanks. Since the NI process has been ongoing for some time, SRS' actions do not seem consistent with DOE Order 5480.21, *Unreviewed Safety Questions*. It states that if a situation involves an accident of a different type than previously considered, the USQ process should be entered, and appropriate operational restrictions should be put in place until the issue has been resolved to DOE-SR's satisfaction. Subsequent to the Board staff visit, DOE-SR stated that it is attempting to expedite the NI process and possibly enter the USQ process.

Development and Implementation of Controls. Updates to the three accident-prevention programs discussed in the February Board staff trip report are presented below, along with new issues in other programs.

Critical Lift Program—Previously, the Board staff identified that WSRC does not know whether its special lifting devices meet safety factor requirements. Archive searches are being performed to resolve this issue, but have not produced results to date. The Rigging Manager has decided to perform design calculations before using equipment without documented factors of safety; this is encouraging.

Tank Overheating—The original dose calculations for this event indicated that off-site consequences could be significant. WSRC has taken the initiative to complete new analyses. These refined calculations are preliminary, but they show that tank overheating remains a problem for certain waste configurations. The analyses conclude that present controls on high-efficiency particulate air (HEPA) filter changeout are adequate to mitigate overheating consequences for current waste conditions, but that programs are needed to track waste temperature, heat load, and distribution when transfers begin to alter tank inventories.

Hydrogen Deflagration in a Tank—The present safety basis states that a tank deflagration is a Beyond Design Basis Event (BDBE), and therefore the predicted off-site consequences —approximately 1000 rem at the site boundary—can be neglected. The BDBE categorization is the result of a Probabilistic Risk Assessment (PRA) that credits redundant monitoring controls. However, SRS has not been able to justify the accuracy of an assumed PRA value for the frequency at which tanks reach the LFL. As a result, WSRC has now taken the position that the PRA and BDBE categorization are not important because they have already put as many controls in place as is reasonable. The Board staff notes that the new controls eliminate a former requirement to ventilate the tanks proactively. Ventilation, in addition to the new monitoring controls, might increase the safety margin and also ease the PRA analysis burden.

Waste Transfer Program—Air holes in pipelines are credited as passive siphon breakers. However, WSRC does not have calculations to show that the breakers are adequate. This issue was raised by the Board staff in December. At that time, WSRC committed to preparing a calculation; this calculation is still being worked on.

Implementation Schedule—In its February trip report, the Board staff stated that the tank farm safety margin might be reduced by the plan to implement new TSRs before determining whether equipment upgrades are necessary to support them. The Board staff cited hydrogen deflagration controls as a potential problem area since SRS' new safety strategy eliminates former operational requirements. The DOE field office has still not addressed this issue.

Backfit Methodology. The DOE-SR approved *WSRC Backfit Methodology* outlines a procedure for determining whether equipment upgrades and compensatory measures are needed to support TSRs. This document might be used at facilities across SRS. Both the ITP Facility and the F- and H-Canyons have already expressed interest in using it. The Board staff has the following concerns with the backfit methodology:

- The methodology allows compensatory measures to substitute for equipment upgrades, but it does not require that these measures be judged against standards for adequacy. The preliminary backfit for new conductivity probes (leak detectors) is a good example. To compensate for their lack of redundancy**,** SRS may rely on periodic walkdowns to double check for leaks. This type of compensatory measure has no benchmark standard, and thus sufficiency is largely a subjective decision.

- DOE-SR and WSRC have not formally defined how compensatory measures will be linked to the authorization basis.

- The methodology allows a user to pick and choose which parts of an individual standard will be followed. For example, an engineer may use the *American Society of Mechanical Engineers Boiler and Pressure Vessel Code* (B&PV) design section to find a minimum vessel wall thickness, but neglect the testing, fabrication, and inspection sections. However, the B&PV Code, like many standards, is an integrated document in that all of its parts must be used together to create a conservative design.

- The backfit methodology may be used for new facility construction. The aim here is to promote consistency among facilities. However, the end result might be new facilities that rely on compensatory measures instead of new equipment designed to industry standards.

5. Future Staff Actions

The staff will continue to follow the development and implementation of TSRs at the SRS tank farms. Specific issues to be followed include (1) adequacy of instrumentation and electrical controls, (2) hydrogen retention and deflagration in a tank, (3) deflagration in a transfer facility, (4) justification for siphon breakers, (5) performance of critical lift work, and (6) outstanding NI and USQ issues.

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

April 15, 1997

MEMORANDUM FOR: G. W. Cunningham, Technical Director

COPIES: Board Members

FROM: D. Drop
R. Tontodonato

SUBJECT: Review of Savannah River Site In-Tank Precipitation Facility,
April 2–3, 1997

1. Purpose

This report documents a visit by Defense Nuclear Facilities Safety Board (Board) staff members D. Drop, D. Napolitano, and R. Tontodonato to the Savannah River Site (SRS) on April 2–3, 1997. The purpose of this visit was to review the implementation of Board Recommendation 96-1 regarding process safety at the In-Tank Precipitation (ITP) Facility.

2. Summary

ITP Equipment Upgrades. Several equipment upgrades are currently being installed at ITP. Insulation is being installed on the exhaust systems and instrument air lines for Tanks 48 and 49 to improve cold-weather reliability, instrument air will be replaced with dry nitrogen, and a new safety-class backup nitrogen system is being constructed. A new pipeline is being constructed for transfers from Tank 49 to Tank 48, to bypass transfer facilities shared with non-ITP tanks. Westinghouse Savannah River Company (WSRC) plans to replace the manually operated variable-depth sampler in Tank 48 with a fluidic diode sampling system that can draw samples without opening a tank riser.

Tank 48 Vapor Space Mixing. Based on operational data, WSRC believes the Tank 48 vapor space is well mixed both during normal operations with a nitrogen purge flow and during standby conditions when the purge is lost. Computational fluid dynamics modeling will be used to assess further whether this is true for the normal operational mode, but not for loss-of-ventilation conditions. The Board staff is concerned that the data obtained during loss-of-ventilation conditions (1) may not be representative of the entire vapor space, and (2) may not have been taken under bounding temperature conditions.

ITP Chemistry Program. WSRC has made significant progress in understanding the chemistry associated with the ITP process. Initial results show that copper, organic compounds, dissolved oxygen, and noble metals all play a role in the decomposition of soluble tetraphenylborate and its degradation products. Progress has also been made in understanding how benzene is retained in the ITP slurry. Further testing in both areas is planned.

3. Background

Board Recommendation 96-1, issued on August 14, 1996, recommends that the Department of Energy (DOE) not proceed with large-scale process testing at ITP until the mechanisms for benzene generation, retention, and release are better understood, and adequate safety measures to prevent benzene deflagrations have been developed. DOE's implementation plan for this recommendation, transmitted to the Board on November 12, 1996, commits to conducting a testing program that will develop an improved understanding of ITP chemistry and appropriate process controls. The Board staff conducted reviews at SRS to assess the implementation of Recommendation 96-1 in December 1996 and January 1997. The key issues discussed during these reviews were the need for improving the reliability of the Tank 48 ventilation system, and the safety strategy and technical basis for future ITP operations.

4. Discussion

During the site visit, the Board staff discussed DOE's progress in implementing Recommendation 96-1, including equipment upgrades planned for ITP, investigations into vapor space mixing in Tank 48, progress in the ITP chemistry program, and the reliability of tank cooling systems. Key observations in these areas are summarized below.

ITP Equipment Upgrades. WSRC is installing several equipment upgrades to improve the ventilation system reliability for Tanks 48 and 49, and to improve and simplify ITP operations. Since about half the ventilation outages in the past year were attributed to cold weather, insulation and heat tracing have been installed on exhaust and instrument air lines on Tank 48. WSRC also plans to supply instrument air lines with dry nitrogen to avoid condensation and freezing. Similar upgrades will be installed on Tank 49. Additionally, WSRC is attempting to identify and correct vulnerabilities in ITP's electrical system, such as single circuit breakers supplying power to an excessive number of unrelated components.

Several new systems are also being installed. Construction of the new safety-grade backup nitrogen system is under way. In addition, a new pipeline is being constructed for transfers from Tank 49 to Tank 48, to bypass transfer facilities shared with non-ITP tanks. Lastly, WSRC plans to replace the manually operated variable-depth sampler in Tank 48 with a fluidic diode sampling system that can draw samples without opening a tank riser.

Tank 48 Vapor Space Mixing. One of the key assumptions of the ITP safety strategy is that mixing of nitrogen, oxygen, and benzene in the Tank 48 vapor space is adequate to prevent localized flammable mixtures from forming. Furthermore, it is important that measurements of oxygen and benzene concentrations be representative of the entire vapor space, since the planned Technical Safety Requirements will require maintaining those concentrations below specified levels. WSRC is working to validate the assumption of a well-mixed vapor space for both the normal operating mode and loss-of-ventilation conditions. Experimental data were taken by two oxygen analyzers and two gas chromatograph poles at two radial positions in Tank 48 during both modes of operation. These data show little difference in gas composition at the different locations measured. WSRC is currently documenting these experiments and drafting a report summarizing relevant vapor space mixing calculations. Work that remains to be done and Board staff comments are summarized below.

Normal Operating Mode—WSRC will use steady-state computational fluid dynamics modeling to verify that the data obtained during the normal operating mode in Tank 48 are representative of the entire vapor space. These calculations include steady-state results from the COMPACT-3D computer code, used in 1995 to model the forced convective flow in Tank 48. This code did not model transient effects well (e.g., it predicted that residual momentum effects would persist to a limited degree for 3 days after the purge flow had been shut off), but WSRC believes the steady-state results are valid. The COMPACT-3D results will be verified by FLUENT, another computational fluid dynamics code.

Loss-of-Ventilation Conditions—WSRC believes that the available data, representing air in-leakage rates ranging from the expected low range to very high rates, adequately demonstrate that the vapor space remains well mixed during loss-of-ventilation conditions. WSRC does not plan to verify by calculations (e.g., with computational fluid dynamics modeling) that the data are representative of the entire vapor space. It is not clear how WSRC plans to determine whether there is a potential for poorly mixed regions to form in uninstrumented regions of the tank.

Furthermore, it is not clear that these measurements were taken during worst-case conditions for mixing. Based on the reported tank dome and liquid temperatures, the loss-of-ventilation test data appear to have been taken during conditions favorable to natural convective mixing. It is possible that mixing would be less complete during periods less conducive to natural convection (e.g., temperature inversions where the tank top is warmer than the waste surface). The potential for temperature inversions in Tank 48 has not been evaluated, and such events could become more likely if WSRC decides to maintain a lower waste temperature to minimize tetraphenylborate decomposition rates. It would be prudent to obtain a better understanding of vapor space mixing during loss-of-ventilation conditions, especially during worst-case temperature conditions. It could then be determined under what conditions oxygen and benzene measurements will be representative of the entire vapor space and whether there may be conditions where these measurements will not be representative.

ITP Chemistry Program. The Savannah River Technology Center (SRTC) has made significant progress in the ITP chemistry program. The status of the test program is summarized below.

Tetraphenylborate Decomposition—Initial test results show that copper, organics, dissolved oxygen, and noble metals all play a role in the catalytic decomposition of soluble tetraphenylborate and its degradation products. Dissolved oxygen appears to act by affecting the oxidation state of the copper catalyst, and it may affect other catalysts as well. Copper exists as Cu(II) in an oxygen-rich (aerobic) environment, whereas it takes the form of Cu(I) in an oxygen-deficient (anaerobic) environment. The current data suggest that Cu(I) is an important catalyst in the decomposition of soluble tetraphenylborate. However, Cu(I) catalysis alone does not explain the tetraphenylborate decomposition rates observed in Tank 48; other constituents, most likely noble metals and organics, are also catalyzing decomposition processes.

Similarly, Cu(I) catalysis alone does not explain the maximum decomposition rates observed for the degradation products of tetraphenylborate. SRTC believes the observed rate for triphenylborane adduct may be a result of either (1) increased salt/hydroxide concentrations (which have been observed to increase decomposition rates) or (2) an unidentified alternate catalyst. Cu(II) appears to be the key catalyst for both diphenylboronic acid and phenylboronic acid decomposition.

The effects of dissolved oxygen, as well as those of organics and other suspected catalysts, will continue to be studied in a set of statistically designed catalyst identification tests. Constituents no longer suspected of being catalysts will be included in these tests to ensure that they have been properly classified. Testing to characterize the degradation of tetraphenylborate solids is also under way, but results are not yet available.

Benzene Retention and Release—Several tests have been performed in an effort to determine visually where benzene is retained in tetraphenylborate slurries. In these tests, benzene was tinted using a red dye and then added to a tetraphenylborate slurry. It was found through these tests that when benzene is first added, it adsorbs onto the tetraphenylborate solids. As larger amounts of benzene accumulate in the slurry, "suspended benzene" is observed, trapped between agglomerated tetraphenylborate particles. The suspended benzene was observed to evaporate quickly upon contact with air. SRTC suspects that this suspended benzene is the source of the "readily releasable benzene" released to the vapor space in Tank 48 when the mixer pumps are operated after a quiescent period.

Further benzene retention and release testing is under way, including large-scale demonstrations using 6-foot-tall columns with in-situ benzene generation and a floating solid layer similar to that in Tank 48. The columns have sample ports that allow benzene to be detected over a range of heights. To date, benzene has been detected exclusively in the floating solids layer. Smaller-scale tests will explore the effects of single parameters such as temperature, weight percent solids, and sodium concentration on benzene retention and release.

ITP Tank Cooling Systems. The ITP chemistry program has found that tetraphenylborate decomposition rates increase dramatically with increasing temperature. Accordingly, temperature controls are an important component of the safety strategy for future ITP operations. However, cooling-water systems have suffered outages in the past, so their reliability for future ITP operations is questionable. Although tank temperatures can be regulated to some degree by controlling heat inputs, such as the duration and speed of mixer pump operations, it is not yet clear how WSRC intends to control temperatures in Tanks 48 and 49 once full-scale ITP operations begin. The Board staff will evaluate how WSRC plans to implement reliable temperature controls for ITP.

5. Future Staff Actions

The Board staff will continue to review the implementation of Recommendation 96-1 at SRS, particularly with regard to ITP's safety systems, resolution of the vapor mixing issue, and the ITP chemistry program.

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

May 7, 1997

MEMORANDUM FOR: G. W. Cunningham, Technical Director

COPIES: Board Members

FROM: T. Davis

SUBJECT: In-Tank Precipitation Facility and Tank Farm Instrumentation and Control Systems

1. Purpose

This report documents observations regarding instrumentation and control (I&C) systems at the In-Tank Precipitation (ITP) Facility and tank farms at the Savannah River Site (SRS). These observations were made by members of the Defense Nuclear Facilities Safety Board's (Board) staff T. Davis and D. Napolitano during a visit to SRS on April 29–May 1, 1997.

2. Summary

The following observations summarize the conclusions of the review by the Board's staff:

- The current ITP safety strategy does not limit the length of time for which the standby nitrogen purge system is used. Because fuel control is not maintained while the standby system is in use, the tank vapor could reach the lower flammability limit (LFL). Additionally, oxygen monitoring is not required to confirm that the standby system is properly inerting the vapor space.

- Based on instrument uncertainty and surveillance frequency, the tank farms may exceed the guidelines of National Fire Protection Association (NFPA) 69, *Explosion Prevention Systems*, for hydrogen concentration in the tank vapor space.

- For some safety-class equipment, Westinghouse Savannah River Company (WSRC) is performing analyses to determine whether safety-class requirements can be relaxed, which could reduce equipment reliability.

- The accuracy and reliability of I&C systems could be improved at ITP and the tank farms by implementing an instrument calibration trending program, and by improving the flammability analyzer testing and surveillance program.

- The safety-class nitrogen system at ITP is not fully protected by the lightning protection system. Additionally, there has not been an evaluation of the potential effects of lightning at the tank farms.

3. Background

Based on Recommendation 96-1, WSRC is conducting testing to understand ITP chemistry and identify the appropriate process controls. The current ITP schedule is to begin readiness reviews in September 1997 and processing operations in December 1997. The tank farms plan to replace the current Operational Safety Requirements with new Technical Safety Requirements (TSRs) by September 1997.

4. Discussion

ITP Safety-Class Nitrogen Purge. Under the current ITP safety strategy, a seismically qualified safety-class nitrogen system (standby system) provides oxygen control when the normal system is not available. Unlike the normal purge system, the standby system does not provide for control of flammable vapors. Therefore, the tank could reach the LFL if this system were used for an extended time. TSR guidance limiting the time in standby mode may be appropriate. Additionally, there is no requirement to maintain oxygen monitoring capability when using the standby system. Monitoring of oxygen concentration would provide assurance that the tank vapor space is adequately inerted.

ITP and Tank Farm LFL Analyzers. At both ITP and the tank farms, only a single analyzer is permanently installed, and a portable analyzer is used periodically to verify its readings. The Board's staff noted the following issues:

- At the tank farms, the uncertainty of the LFL analyzers (approximately 10 percent LFL) and the surveillance frequency could allow tanks to reach 30–40 percent LFL. This does not appear to meet the requirements of NFPA 69, which requires monitoring programs to ensure that vapors do not exceed 25 percent LFL.

- The portable monitors are maintained by a site-wide organization, which does not normally handle safety-related instruments. Because these portable analyzers are used to perform a safety function, additional requirements for calibration and testing are necessary; however, this testing is not controlled by an appropriate safety-related procedure.

- LFL analyzers are currently calibrated with 50 percent LFL gas, as recommended by the vendor. However, alarms and interlocks are set at 10–25 percent LFL. Using a calibration gas closer to the alarm and interlock set points in addition to the vendor- recommended gas would ensure that these instruments are properly calibrated in the range of interest.

Safety-Class Equipment Design. The WSRC backfit methodology allows some design requirements for existing and new equipment to be relaxed. Instead, compensatory measures or a probablistic analysis is used to justify the adequacy of equipment design. Specifically, this approach is being considered for the new safety-class oxygen analyzers because of the excessive cost identified by the vendor for fully qualified equipment. WSRC is negotiating with the analyzer vendor to determine whether removing Institute of Electrical and Electronics Engineers (IEEE) standards would reduce the cost of the analyzers. Additionally, the analyzers will not have a safety-class power supply, and therefore would not be operable during an extended power outage (i.e., when the standby nitrogen system was operating). A final decision on equipment design has not been made. The impact on equipment reliability will be reviewed on a case-by-case basis as WSRC completes its backfit analyses and equipment designs.

Trending of Instrument Calibrations. Safety-related instruments are calibrated periodically to ensure that they have not drifted out of the required tolerance band. However, there is no program for trending instrument performance and predicting failures based on calibration results. A formal trending program in accordance with DOE Order 4330.4B to track instrument performance and predict failures would increase instrument accuracy and reliability.

Lightning Protection Systems. The safety-class nitrogen system at ITP has not been evaluated for the effects of lightning. The electrical systems that initiate and control this system are located near the new nitrogen tanks and are not protected by ITP lightning protection. Because of the importance of this system, it would be prudent to evaluate the effects of lightning on the standby nitrogen system.

There is currently no lightning protection system at the tank farms. Additionally, an evaluation of the potential effects of lightning in accordance with NFPA 780, *Lightning Protection Code*, has not been performed.

5. Future Staff Actions

The Board's staff will perform an additional review of ITP I&C systems prior to startup to ensure that these systems adequately support the ITP safety basis.

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

June 16, 1997

MEMORANDUM FOR: G. W. Cunningham, Technical Director

COPIES: Board Members

FROM: R. Tontodonato

SUBJECT: Review of Savannah River Site Waste Management Facilities, June 9–11, 1997

This memorandum documents a visit by members of the staff of the Defense Nuclear Facilities Safety Board (Board) L. Jellett and R. Tontodonato to the Savannah River Site (SRS) on June 9–11, 1997. The purpose of this visit was to review implementation of Board Recommendation 96-1 at the In-Tank Precipitation (ITP) Facility, hydrogen retention in SRS high-level waste tanks, and operational problems at the Consolidated Incineration Facility (CIF).

Recommendation 96-1. Technical Safety Requirements being developed for ITP will impose safety-class and safety-significant reliability criteria on certain existing systems, structures, and components. Westinghouse Savannah River Company (WSRC) is performing backfit analyses to determine whether upgrades are needed to ensure that such equipment will function as assumed by the safety analysis. Six backfit analyses have been completed to date. Design deficiencies identified by the analyses include vulnerability to single failures, inadequate electrical design (particularly lack of redundant sources of power), inadequate protection against environmental conditions, and failure to meet modern quality assurance standards for procurement. WSRC responses include a mix of equipment upgrades and compensatory actions such as improved surveillance and new administrative controls. The Board's staff will evaluate these analyses to assess whether the WSRC methodology results in appropriate backfit decisions. The initial conclusions of the Board's staff are that there is little basis for the surveillance frequencies specified in the compensatory actions, and that the feasibility and merit of potential compensatory actions were not thoroughly evaluated in some cases (e.g., performing functional testing of check valves instead of relying on periodic inspections and operator response to valve failure).

WSRC is evaluating the potential for hydrogen retention in ITP tanks. Tank data show that small hydrogen releases occur when the slurry pumps in Tank 48 are started. Future operations involving more waste and higher curie loadings could significantly increase the size of these releases. Laboratory studies have shown that simulated tetraphenylborate slurries can retain over 3.5 volume percent hydrogen. Release of such a quantity of hydrogen from a large volume of slurry would create a flammable atmosphere in the tank. WSRC is working to define additional authorization basis controls to prevent hazardous quantities of hydrogen from accumulating during full-scale ITP operations, without relying on continuous (or near-continuous) slurry pump operations. Continuous pump operations are not feasible using the existing pumps and power supplies.

The potential exists for ITP operations to become very complex if too many variables are factored into the determination of pump operating frequencies, especially when both hydrogen and benzene accumulation are considered. Using conservative values for some parameters (such as nitrate and nitrite concentrations) instead of recalculating the maximum allowable quiescent time for the precise tank conditions that exist at any given time could greatly simplify operations. It could also make operator compliance with the controls easier. Ideally, the authorization basis will identify a simple set of Limiting Conditions of Operation providing mixing frequencies for each major phase of the ITP process (e.g., precipitation, concentration, washing).

Hydrogen Retention in Other Waste Tanks. Hydrogen retention in non-ITP tanks is much less severe than at the Hanford Site because high-level waste at SRS contains only small quantities of organic compounds. Spontaneous gas release events have not been observed. However, a significant hydrogen release was observed in 1993 during slurry pump operations in Tank 51. WSRC plans to address the potential for induced releases by estimating the size of such releases and developing controls on ventilation, mixing frequency, and/or the intensity of agitation. Interim controls on waste-disturbing activities have been implemented to ensure that operations will remain safe while these investigations are pursued.

Consolidated Incineration Facility. Several operational problems have occurred at CIF since it started operating in late 1996. Significant events include a pump leak that contaminated a facility worker and a small fire involving waste boxes jammed in the feed unit for the rotary kiln. Corrective actions being taken by CIF management appear to address both the immediate problems and the broader implications of each incident adequately. However, an incident that occurred the day after the review by the Board’s staff (spill of radiologically contaminated liquids due to an improper valve line-up) shows that conduct of operations at CIF needs further improvement.