DEFENSE NUCLEAR FACILITIES SAFETY BOARD

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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

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.