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SAFETY ANALYSIS APPROACH TO TANK 241-SY-101 REMEDIATION ACTIVITIES

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March 2000

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SAFETY ANALYSIS APPROACH TO TANK 241-SY-101 REMEDIATION ACTIVITIES

ABSTRACT

An Unreviewed Safety Question was declared related to the unexplained waste surface level growth in high-level radioactive waste storage Tank 241-SY-101 at the Hanford Site in Richland, Washington. Because the waste surface level in Tank 241-SY-101 was growing in a manner inconsistent with previous behavior, the following issues of concern were recognized:

- The continually rising surface level had the potential to reach physical encumbrances or limits within the tank (e.g., instrumentation, cameras, established Authorization Basis limits, and the double containment boundary) and the potential to significantly change the consequences of previously analyzed accidents (e.g., flammable gas deflagrations).

- The presence of new hazards because of significant quantities of flammable gas retained in the crust (e.g., crust collapse gas-release events).

- The potential to inhibit information gathering related to the existing hazards in the tank (e.g., unable to determine surface level to assess the potential for large gas releases).

In response to this situation, a Contractor Project Team, which included Department of Energy representation, was formed to constructively address the issue. The team was responsible for developing and evaluating remediation options and executing the chosen option for remediating the surface level rise issue for Tank 241-SY-101. From an Authorization Basis perspective, the following important aspects will be discussed in this paper:

- The integrated nature of the Project Team. The team consisted of all the organizations necessary to ensure that the time available to remediate Tank 241-SY-101 was effectively used. Most notable is the connectivity of the Nuclear Safety & Licensing organization with the Engineering, Design, and Operations organizations.

- The ability of the safety analysis support to adjust to and address evolving Project Team goals and dynamic tank conditions.

- Due to the urgency to mitigate this developing issue, supplemental controls to ensure safety during remediation operations and activities were developed and approved at the Contractor level with DOE cognizance through their participation as an integral part of the Project Team. This approach was selected as the most expedient to meet the aggressive project schedule and changing tank conditions.

This project has been successful in meeting established goals because of the effectiveness of an integrated project team that included Nuclear Safety & Licensing at the start, the integral involvement of DOE during each phase of the project, and the ability of the Contractor to develop, approve, and implement the supplemental controls necessary to safely perform operations and activities.

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List of Terms

BD	buoyant displacement
DOE	U.S. Department of Energy
GRE	gas release event
LFL	lower flammability limit
PHA	preliminary hazard analysis
SSC	structure, system, or component
TSR	Technical Safety Requirement
USQ	Unreviewed Safety Question

1.0 BACKGROUND

Highly radioactive and chemically hazardous waste from past reactor fuel processing and other waste management activities is stored in 177 underground tanks at the Hanford Site.[1] Tank 241-SY-101 is a double-shell tank (DST) consisting of a steel primary tank to contain high-level radioactive waste and an outer reinforced concrete confinement structure with a steel liner to provide secondary confinement (see Figure 1). Tank 241-SY-101 has a nominal storage capacity of 3.8 million liters (1 million gallons). Construction of Tank 241-SY-101 was completed in 1976.

Tank 241-SY-101 contained approximately 3.8 million liters (1 million gallons) of the most highly concentrated radioactive and toxic waste stored in the DSTs at the Hanford Site. The first waste put into the tank came from the first double-shell slurry campaign in 1977. Double-shell slurry is a concentrated waste produced by evaporators and is high in sodium hydroxide, sodium nitrate, and sodium aluminate. Tank 241-SY-101 received subsequent transfers of double-shell slurry and concentrated complexant waste, an evaporator product similar to double-shell slurry (although not as concentrated) that contained significant organic complexant concentrations. The last slurry transfer into Tank 241-SY-101 was in November 1980.

Degradation of organic complexants and radiolysis of water in the Tank 241-SY-101 waste generated a flammable mixture of gases that included hydrogen, nitrogen, nitrous oxide, and ammonia. Until 1993, the settled solids waste layer at the bottom of Tank 241-SY-101 retained the gas and periodically released large volumes in sudden, buoyant displacement gas release events (BD GREs). These periodic BD GREs occurred approximately every 100 days. Two of these BD GREs resulted in measured flammable gas concentrations in the tank headspace above the lower flammability limit (LFL). In July 1993, a mixer pump was installed in Tank 241-SY-101. Operation of the mixer pump stirs up the settled solids in the bottom of the tank releasing the gas. The mixer pump has prevented the periodic, large BD GREs by inducing a more continuous release of gas.

Starting in September of 1996, the waste surface level in Tank 241-SY-101 began rising in a manner inconsistent with previous behavior (i.e., post mixer pump installation). That is, the mixer pump was unable to release the gas because the gas was being retained in the waste crust at the top of the tank where the mixer pump could not affect it. Safety issues posed by the rising waste surface level included the following.

1. Extrapolations of the rising waste surface level (see Figure 2) showed the potential of reaching physical encumbrances or exceeding established Authorization Basis limits within the tank[2]. That is, the increasing waste surface could affect installed instrumentation, video cameras, etc., and could rise above the double containment boundary, thereby, causing the waste to be contained only by a single barrier, which would violate the existing double-shell tank waste permit.

2. The rising waste surface level decreased the tank head space volume available to dilute released flammable gases or absorb combustion energy in case of a deflagration, thereby increasing the likelihood and consequences of potential flammable gas hazards. New flammable gas hazards were also created by the retention of a significant amount of gas in the crust on the waste, which, in fact, was the cause of the waste surface level rise. Gas retention in the crust is not controlled by operation of the mixer pump and several scenarios were postulated that could cause flammable

[1] There are 149 single-shell tanks (SSTs) and 28 double-shell tanks (DSTs) located at the Hanford Site.
[2] The waste surface level actually peaked at approximately 434 inches.

gas releases from the crust (e.g., mechanical disturbance, dissolution by water additions to the tank).

3. The waste surface level rise affected existing mixer pump Technical Safety Requirement (TSR)-level controls that were based on tank level. (DOE suspended these controls and approved supplemental controls for mixer pump operation to prevent BD GREs.) In addition, growth of the crust created the potential for interference with operation of the mixer pump, a Safety-Class structure, system, or component (SSC). That is, continued growth of the crust thickness and/or lowering of the crust as the result of waste transfer out of Tank 241-SY-101 could cause the bottom of the crust to encroach on the mixer pump suction inlet, thus degrading pump effectiveness at preventing BD GREs.

These safety issues resulted in DOE declaring an Unreviewed Safety Question (USQ) in February 1998, and approving a revision to the USQ in April 1999.

Figure 1. Cross-Sectional View of Tank 241-SY-101.

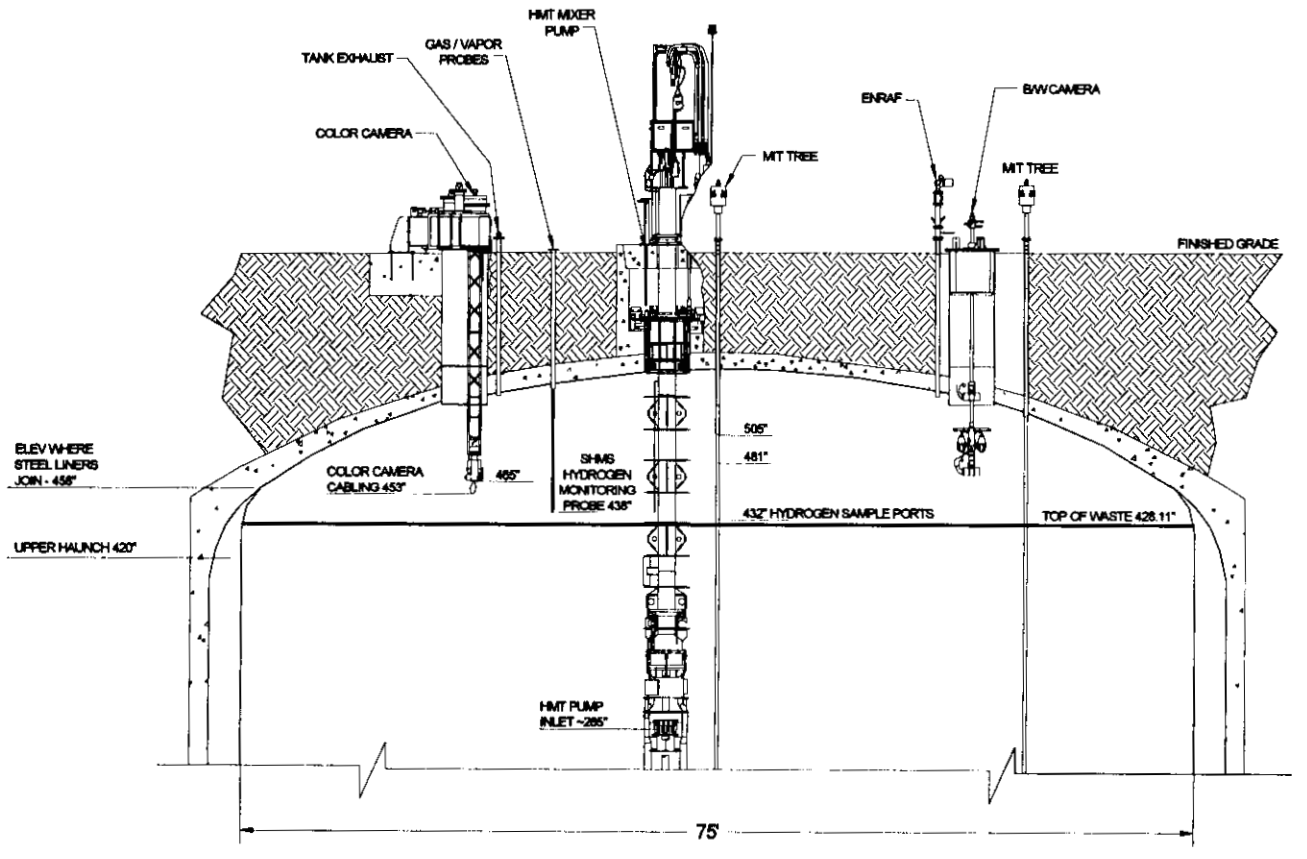
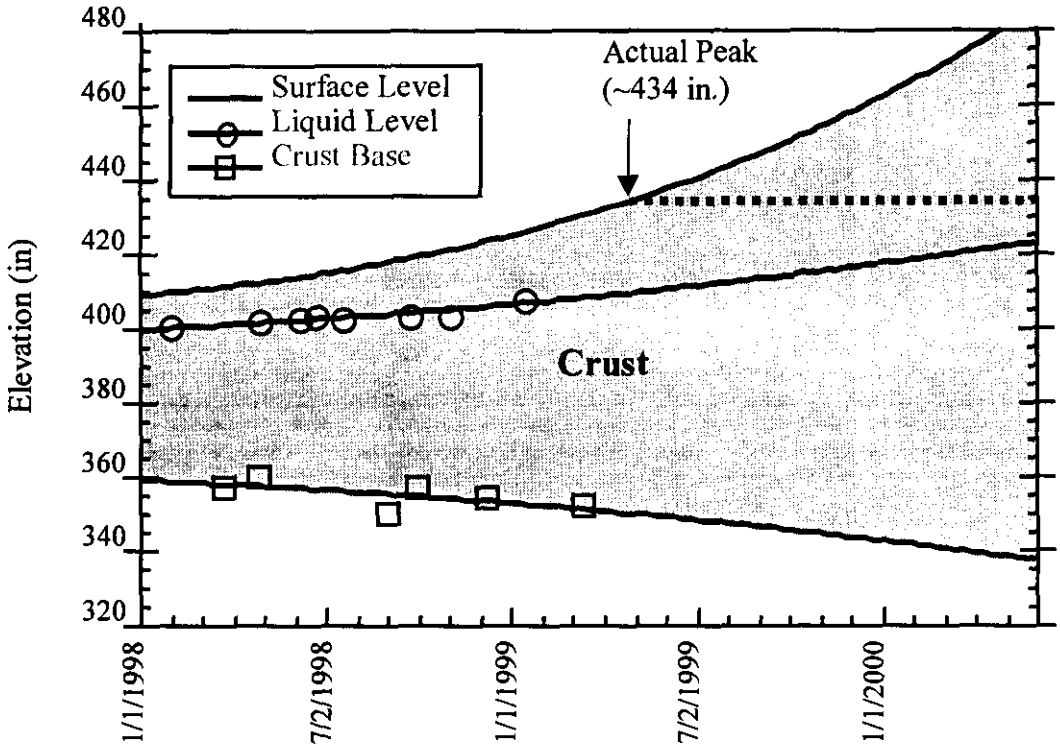


Figure 2. Extrapolation of Crust Thickness Shows Potential for Waste Surface to Exceed Double-Containment Boundary and Impact Installed In-Tank Equipment.



2.0 SY-101 PROJECT TEAM APPROACH

To address the USQ and the escalating hazards in Tank 241-SY-101, a focused project team (i.e., the SY Farm Project Team) was established to develop, evaluate, and execute options for remediating the surface level rise in the tank. The SY Farm Project Team used a systems engineering, logic-based project planning approach. Dedicated members of the Project Team were selected from the following organizations:

- Department of Energy – Office of River Protection
- Operations
- Environment, Safety, and Health
- Engineering
- Process Engineering
- Systems Engineering
- Nuclear Safety and Licensing
- Construction and Installation
- Business Management
- Pacific Northwest National Laboratory

In addition to the direct members of the Project Team, external interfaces were also managed. These external interfaces included the U.S. Congress/Defense Nuclear Facilities Safety Board, Washington State Department of Ecology, Washington State Department of Health, and the Hanford Advisory Board.

The most significant point to note in this paper is that Nuclear Safety and Licensing was involved with the Project from the start and was able to assist Engineering and the other organizations by providing a clear understanding of the safety analysis and Authorization Basis aspects of the remediation activities. Nuclear Safety & Licensing provided support to the Project by providing safety analysis input to the remediation options selected and to the planning and design processes. This provided the Project with a clear definition of how to maintain the design and operation within the established safety envelope and also provided an estimate of the impacts if design and operations decisions would move the Project outside the bounds of the established Authorization Basis. In addition, the safety analysis and control selection provided insight into Project decisions where areas of potential risk reduction might be achieved. More robust designs, additional safety analysis and more expansive controls, or more extensive testing had to be compared to the risk increase of delaying remediation actions to accommodate more design, analysis, testing, and training efforts. This risk-balancing approach served the Project well, by helping guide engineering and operations decisions, and was essential to the Project's success.

3.0 SY-101 PROJECT SAFETY ANALYSIS STRATEGY

The Nuclear Safety & Licensing organization was responsible for developing the licensing strategy to enable remediation activities and operations, and to recommend closure of the USQ to DOE. As a starting point for this activity, a preliminary hazard analysis (PHA) was conducted to understand the potential hazards associated with the waste level growth. It is important to note that the PHA did not focus on specific remediation methods, however, it was conducted to try and understand the underlying phenomena that may be causing the waste level increase. Gas retention by the solid particles within the waste crust at the top of the tank was determined to be the most plausible cause for the waste level growth. This study identified several hazardous conditions associated with gas retention and release from the crust that were investigated further in the accident analysis.

In addition to the PHA, the Project commissioned a Value Engineering study to develop a ranked list of options to mitigate or remediate the Tank 241-SY-101 level growth. Each of the options developed in the Value Engineering study and the preferred approach with supporting estimates, schedules, and path forward were presented to DOE and Contractor management at the conclusion of the study.

The Value Engineering teams' recommendation was to remediate the level rise phenomena by diluting the waste and dissolving most of the solids through a series of waste transfers from Tank 241-SY-101 to Tank 241-SY-102 followed by back dilution of Tank 241-SY-101 with water, as required. In parallel, short-term options to mitigate the level growth (i.e., water jet and/or mechanical disturbance of the crust) were developed.

The short-term mitigation options were designed to release some of the trapped gas and to gather operational experience related to the crust. The data gathered were used to better understand the behavior of the crust for remediation by waste transfer and back dilution. The crust was directly disturbed by inserting a Mechanical Mitigation Arm via open risers. Additionally, a water jet was used to cut a hole in the crust to insert the waste transfer pump in Tank 241-SY-101. Each of these short-term methods of crust mitigation provided a pathway for trapped gas to be released and allowed more information to be gathered regarding the crust growth phenomenon.

Using the preferred approach defined by the Value Engineering study, the Project proceeded to design the equipment necessary to perform the transfer and back dilution. Integrated with this process was the Nuclear Safety & Licensing organization providing insight and guidance during the design process. To evaluate the hazards associated with the design and operation, a HazOp and supporting accident analyses were conducted and documented. The hazard and accident analyses largely found that the design selected was within the established Authorization Basis. This was not surprising because there is much accumulated experience in transferring waste at Hanford and a large variety of waste transfer approaches have been utilized. The Authorization Basis is structured in a manner that supports a large variety of waste transfer approaches.

In response to changing Project requirements, alternate designs were subsequently considered. Each of these alternatives was explicitly evaluated in supplemental hazard analyses and/or accident analyses and the final design chosen for construction. A confirming analysis of this design was documented as proof that the design was within the Authorization Basis.

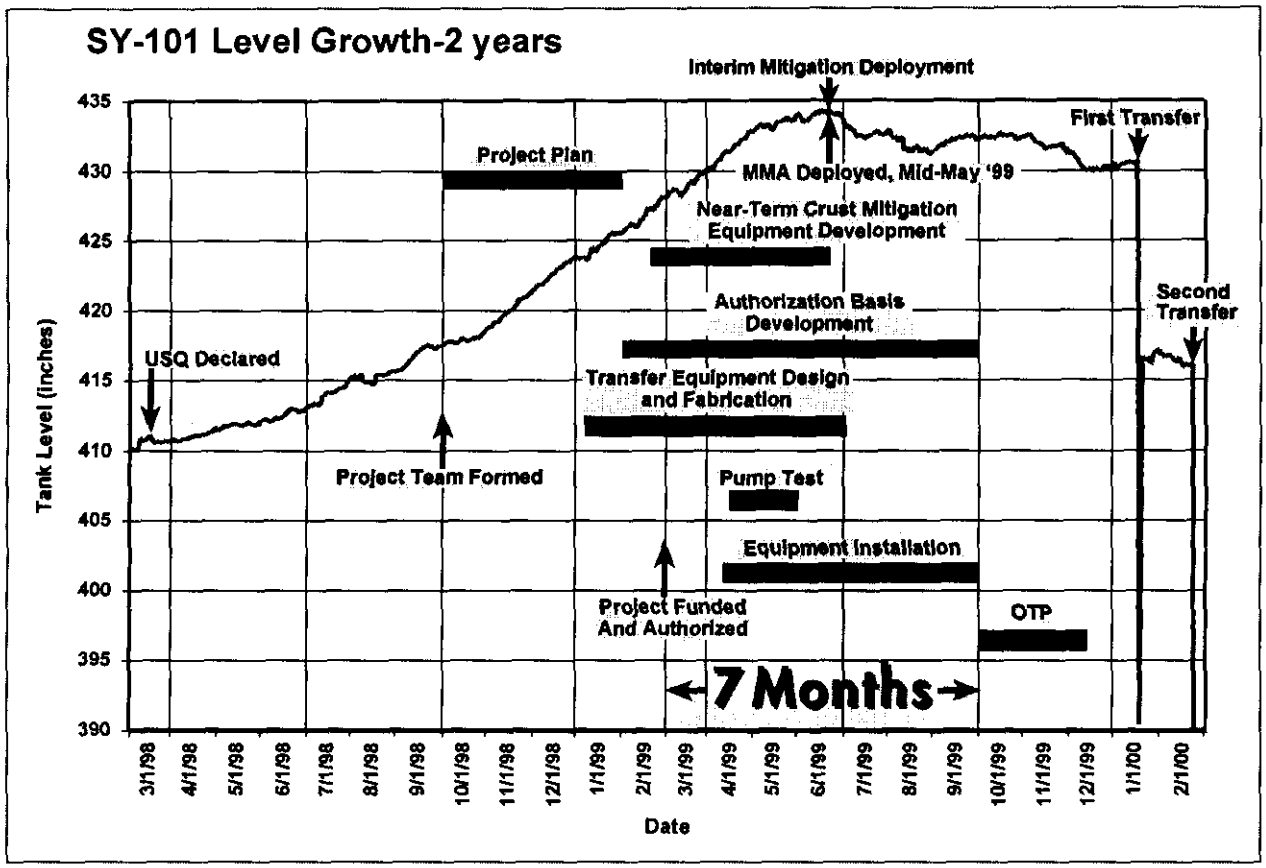
Throughout the design and engineering analysis of the transfer system, unique aspects in the design were identified (e.g., the potential for waste siphoning while the transfer pump was not operating, use of an aboveground pre-fabricated pump pit, and use of an aboveground hose-in-hose waste transfer line). Nuclear Safety & Licensing was able to respond quickly to these issues and use focused safety analysis to provide timely resolution. The results of the focused safety analysis were used to help define specific design criteria and also to support control decisions for items not considered already addressed within the Authorization Basis envelope.

Because of uncertainties associated with predictions of how the crust would respond to waste transfers and back dilution with water, it was recognized that a single Authorization Basis modification to address the entire project at the beginning would not be sufficient (i.e., too many unknowns). Therefore, it was necessary to adopt a stepwise strategy of analyzing, authorizing and controlling each step. Through the use of feedback (i.e., using field data and operational information), the Authorization Basis for each subsequent step was refined to ensure that the operations being conducted were always within the established Authorization Basis envelope.

In practice, conservative contractor prudent controls were placed on the initial quantity of waste that could be transferred, and on the quantity and location for inserting back dilution water following the first waste transfer. Based on information gathered during the first transfer and back dilution, the safety analysis was updated, and contractor prudent controls were revised to allow a second and third set of waste transfers and back dilutions to safely proceed. Again, the presence of Nuclear Safety & Licensing as part of the SY-101 Project Team facilitated the integration of organizations involved in obtaining and analyzing tank data, and applying it to the development and approval of revised controls.

The timeline of the Project (see Figure 3) shows the aggressiveness of the schedule that was required to address the safety issues. In a period of only seven months from the time the Project was funded and authorized, the equipment necessary to perform remediation activities and operations was designed, installed, and tested and an Authorization Basis to conduct the activities was developed and approved.

Figure 3. Timeline of Tank 241-SY-101 Remediation Activities and Operations.



4.0 DOE/CONTRACTOR AUTHORIZATION BASIS INTERFACE

With the approval of the USQ concerning the Tank 241-SY-101 waste surface level change, DOE recognized that the hazards in the tank were increasing, and that the frequencies and consequences of potential accidents were increased over those previously accepted by DOE. In the case of tank waste storage there is no "safe shutdown" option. In addition, DOE recognized that these increased risks could not be reasonably quantified at the time. In view of the urgent need to mitigate the growing hazards with Tank 241-SY-101, DOE authorized the conduct of remediation activities and operations, which exceeded previously accepted risk, so long as:

1. The Contractor imposed an operational restriction that requires verification that flammable gas concentrations in the tank dome space do not exceed 25% of the LFL before commencing any discretionary activities, and further, when unanticipated exceedances of the 25% LFL limit occur, all discretionary activities will be halted until the tank dome space is below 25% of the LFL.

2. The Contractor imposed ***additional prudent controls*** necessary to safely conduct such activities and operations.

In effect, DOE defined the safety envelope for Tank 241-SY-101 remediation activities and operations as the existing Authorization Basis with the addition of the 25% LFL limit, and directed the

contractor to develop additional specific implementing controls (i.e., prudent contractor controls) that previously would have been subject to DOE review and approval.

Figure 4 illustrates the work authorization process developed for Tank 241-SY-101 remediation activities and operations to identify, prepare, review, and approve additional prudent contractor controls. This process contains the same safety analysis and review elements required for development of the Authorization Basis [i.e., hazard analysis, accident analysis, control decisions, Tier I (Safety Review Board) review]. Prudent contractor controls are approved by the Contractor Plant Review Committee, rather than DOE, thus shortening the review and approval cycle time. It should be noted, however, that because of DOE's involvement as a integral member of the Tank 241-SY-101 Project team, and extensive overview of the Plant Review Committee process, the safety analysis supporting prudent contractor controls and the controls themselves were always open to DOE review and comment. This unique approach to safe control development and approval allowed the safety basis and controls to respond to changing tank conditions and remediation project steps in a more timely manner.

5.0 CONCLUSIONS

Through the dedication of a focused Project Team and the flexibility provided by DOE, crust growth in Tank 241-SY-101 has been safely remediated. This project progressed with a strategy of taking small steps followed by data collection and re-analysis and demonstrated that through diligent teamwork and communication, the most serious hazard associated with the Hanford Site's Tank Farms could be remediated in a safe, timely, and fully documented manner. Work is currently in process to observe the effect of these actions on the waste in the tank and determine if predictions are correct based on field data. Analysis results are expected to show that BD GRE's are no longer a credible hazard in Tank 241-SY-101. If this is the case, then the mixer pump will no longer be needed as a safety control and Tank 241-SY-101 will be returned to service as a useful DST providing operational flexibility and possible acceleration of the longer-term waste retrieval and disposal mission.

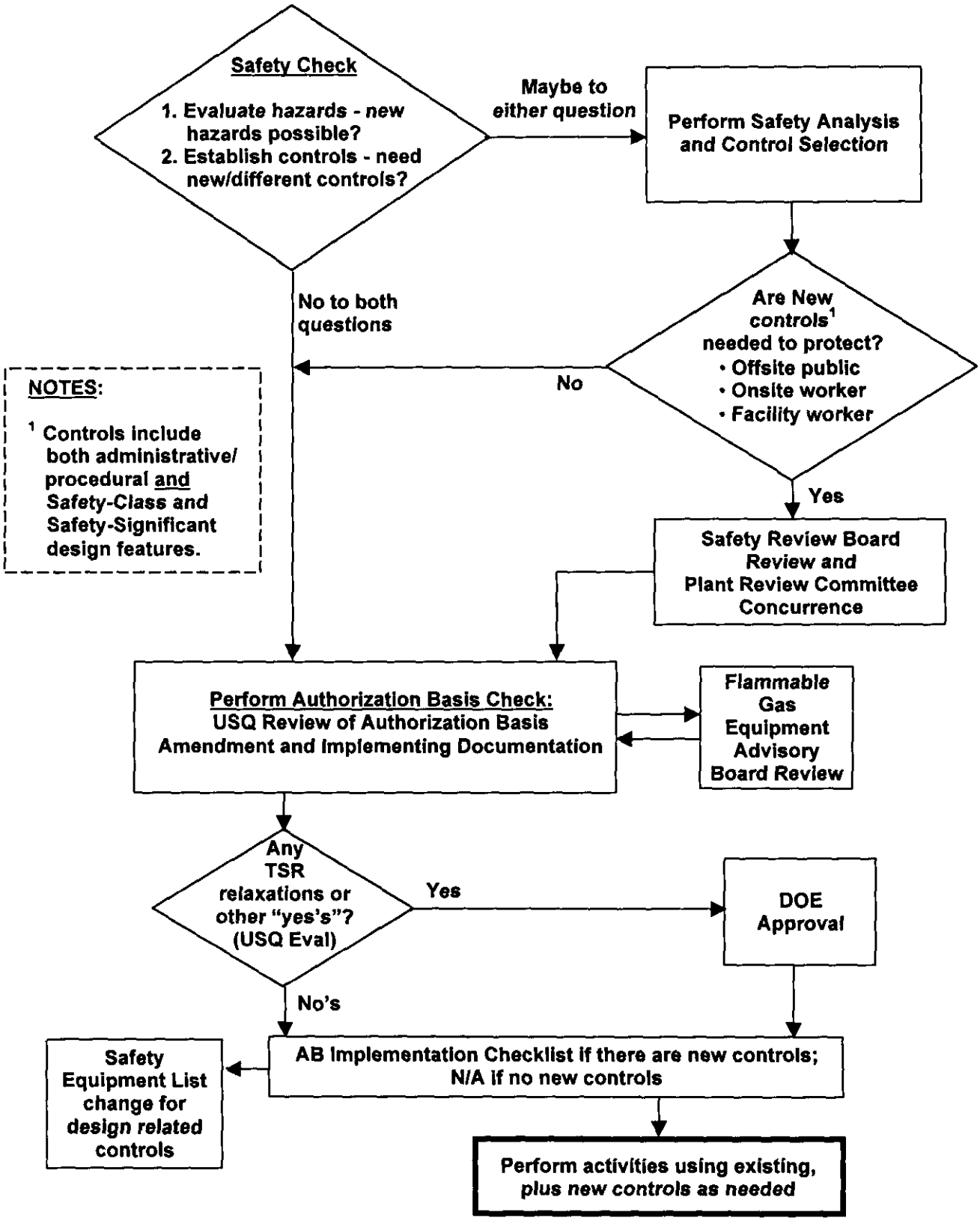



Figure 4. Tank 241-SY-101 Work Authorization Process.