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1	1	Cog.Eng. J. M. Grigsby	[signature]	7/31/96	A3-37						
1	1	Cog. Mgr. C. E. Leach	[signature]	7/31/96	A2-34						
1	1	QA	[signature]	7/31/96							
1	1	Nuclear Safety M. N. Islam	[signature]		R3-08						
		Env.									
1	1	Auth Basis Mgr. J. J. Klos	[signature]		R2-54						
1	1	TF PRC Chairman J. E. Truax	[signature]	7/31/96	R2-50						

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C. E. Leach [signature] 7/30/96 Signature of EDT Originator / Date	J. E. Truax [signature] 7/31/96 Authorized Representative for Receiving Organization / Date	J. J. Klos [signature] 7/31/96 Cognizant Manager / Date	Ctrl. No. [] Approved [] Approved w/comments [] Disapproved w/comments

Flammable Gas/Slurry Growth Unreviewed Safety Question: Justification for Continued Operation for the Tank Farms at the Hanford Site

J. M. Grigsby
G & P Consulting, Inc., Richland, WA 99352

C. E. Leach
Westinghouse Hanford Company, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-87RL10930

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Abstract: This Justification for Continued Operation (JCO) provides a basis for continued operation in 176 high level waste tanks, double contained receiver tanks (DCRTs), catch tanks, 244-AR Vault, 242-S and 242-T Evaporators and inactive miscellaneous underground storage tanks (IMUSTs) relative to flammable gas hazards. Required controls are specified.

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EXECUTIVE SUMMARY

This Justification for Continued Operation (JCO) and accompanying Unreviewed Safety Question Evaluation (TF-96-0433) provide clarification of the facilities, hazards, and controls associated with the flammable gas Unreviewed Safety Question (USQ) as it is currently defined, and presents the basis for continued tank farm operation.

The purpose of the USQ Evaluation addressed by this JCO is to reevaluate and redefine the flammable gas USQ (Lawrence 1990) with respect to currently available data and methodology, clarify the applicability of this USQ to additional tanks and other engineered structures within the Tank Waste Remediation System (TWRS), and consider additional flammable gas hazards not adequately addressed in the Authorization Basis. The purpose of the JCO is to determine if continued operation is justified and under what controls. The Implementation Plan will provide the schedule and cost associated with revising equipment and work procedures as needed to justify continued operation.

The scope of the JCO covers any engineered structure, container or receiver managed and operated by the contractor at TWRS which may store Hanford's high level waste in a condition and for a period of time which permits generation, accumulation and/or release of flammable gas. These structures include all single-shell tanks, double-shell tanks, aging waste facilities, double-contained receiver tanks, TWRS-managed inactive miscellaneous underground storage tanks, catch tanks, and waste transfer systems. The scope of this evaluation also includes the 244-AR Facility and the 242-S and 242-T Evaporators.

Since the original identification of the USQ in 1990, understanding of the hazards associated with flammable gas in tanks has expanded considerably. Current understanding of flammable gas has expanded the USQ to envelope the following hazards:

- Generation of potentially flammable concentrations of hydrogen, ammonia and methane

- Steady state release of flammable gas from the waste
- Accumulation of flammable gas in ex-tank intrusive areas such as sealed pits and risers and connected ventilation spaces
- Accumulation of flammable gas in the dome space
- Retention of flammable gas within the waste, allowing spontaneous and induced releases
- Deflagration in the waste
- Plume burns
- Accumulation of flammable gas in waste-intrusive equipment such as drill strings and liquid observation wells.

The current TWRS Authorization Basis does not adequately evaluate these hazards or the frequency and consequences associated with related accidents. Specific inadequacies in the current Authorization Basis are described in the associated USQ evaluation (TF-96-0433). Until an adequate treatment of flammable gas hazards is incorporated into the Authorization Basis via the Basis for Interim Operations and/or Final Safety Analysis Report, this JCO will identify the set of controls required to ensure safe storage and operations with three exceptions: (1) salt well pumping of certain tanks is being evaluated in separate safety documents being submitted for U.S. Department of Energy (DOE) approval to amend the Authorization Basis; (2) adequate controls for safe storage and operations in Tank 241-SY-101 exist within the current Authorization Basis in LANL (1995), and are not superseded by this document; and (3) addition and removal of tanks from the flammable gas watch list is not within the scope of this JCO.

Rather than specifically identifying any normal or anticipated operations that should be excluded, the JCO simply states the controls that must be applied (from a flammable gas perspective only) to perform any tank intrusive work. The JCO does not categorically exclude or allow any specific activity as it does not address any other hazards than flammable gas. The overall acceptability of performing activities in and around the TWRS facilities affected by this USQ must therefore still be evaluated to ensure all nonflammable gas Authorization Basis requirements are also met. The USQ process is used to perform this function.

The control strategy developed within this JCO is twofold. To manage risk associated with steady state accumulation of flammable gas in the dome space, sealed pits and risers, and other ex-tank intrusive areas, the JCO requires adequate passive and/or active ventilation to ensure gas concentrations do not exceed 25% of the Lower Flammability Limit (LFL). To manage risk associated with retention of flammable gas within the waste, the JCO requires equipment and work controls intended to prevent spark sources in the tanks when flammable conditions may exist. The JCO also groups the tanks according to those which are postulated to be subject to large versus small gas release events (GREs), i.e., tanks whose releases may cause the dome space concentration of flammable gas to exceed 25% of the LFL (global impact) versus tanks whose releases may elevate the concentration of flammable gas beyond 25% of the LFL in a localized area of the tank only (local impact).

For the purpose of assigning graded control sets, each TWRS-managed tank has been placed into one of three distinct Facility Groups depending on the types of gas release events associated with the tank. Tanks which have demonstrated a propensity for large spontaneous and induced GREs are placed in Facility Group 1 while those tanks which are postulated to be susceptible to large induced GREs but only small spontaneous GREs are placed in Facility Group 2. All of the remaining tanks are assigned to Facility Group 3 for which it is judged that spontaneous releases do not occur but small induced release may be possible. The hazards and associated control sets for each group are clearly highlighted and summarized in matrices.

The grouping of the tanks is based, in part, on a published methodology to estimate quantities of releasable gas in each tank (Hopkins 1996).

Although this methodology cannot provide precise, quantitative results, it does provide a qualitative indication of the presence of flammable gas. This matter is thoroughly discussed in WHC-SD-WM-ER-594, Rev. 0, *Evaluation of Recommendation for Addition of Tanks to the Flammable Gas Watch List*. Despite the technical uncertainty associated with this methodology, it is the only one currently available and will continue to be used, albeit cautiously. The only alternative in this case would be placing tight controls on all tanks which would place unnecessary operational restrictions on many tanks.

The JCO controls required to manage the risk of flammable gas hazards during storage and operations may not always be consistent with existing procedures and/or equipment associated with each activity and facility. Under these circumstances, the alternatives to compliance with the JCO control strategy include the following:

- Curtailment of those operations and activities which are not in compliance until implementation of controls as specified in the JCO can be achieved

- Justification for alternative yet functionally equivalent controls, as identified in the JCO Implementation Plan, that are reviewed through the USQ evaluation process and are approved by the newly formed Flammable Gas Equipment Advisory Board

- Facility and/or activity-specific justification that the hazards posed by waste-generated flammable gas merit no particular controls or less stringent controls than specified in the JCO. This alternative requires preparation of authorization and safety basis documentation compliant with DOE 5480.23 and quantitative comparison of accident frequencies and consequences with the radiological and toxicological risk guidelines found in WHC-CM-4-46. This approach requires a change to the TWRS Authorization Basis, and hence, DOE approval.

This document concludes that compliance with the JCO control strategy, or adoption of the accepted alternatives outlined above, provides prudent risk management for storage and operations with respect to the flammable gas hazard. The JCO and associated documents are expected to remain in place until superseded by a revised Authorization Basis which is viewed by DOE to sufficiently address flammable gas hazards.

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LIST OF TERMS

AWF	aging waste facility
CGM	combustible gas monitor
DCRT	double-contained receiver tank
DOE	U.S. Department of Energy
DST	double-shell tank
FIC	Food Instrument Corporation (level gage)
FSAR	final safety analysis report
GRE	gas release event
HECB	Hanford Electric Codes Board
HLW	high-level waste
IC	ignition source control
IMUST	inactive miscellaneous underground storage tank
IOSR	Interim Operational Safety Requirements
JCO	justification for continued operation
LFL	lower flammability limit
LOW	liquid observation well
LPF	low pressure weather front
NFPA	National Fire Protection Association, Inc.
OSD	operation specification document
OSR	operational safety requirements
RL	DOE-Richland Operations Office
SHMS	Standard Hydrogen Monitoring System
SST	single-shell tank
T/C	thermocouple
TWRS	Tank Waste Remediation System
USQ	unreviewed safety question
WHC	Westinghouse Hanford Company

DEFINITIONS OF TERMS

Gas Release Events. Gas release events are flammable gas releases that occur at a relatively high rate. The released gas must include gas that has been generated but then retained in the waste, as the gas release rates far exceed the gas generation rates. These gas release events are distinctive events although in some tanks such releases may be a part of a larger series of such events (i.e., episodic). These gas release events are generally described by a sudden onset, a sharp increase in gas release rate above steady state rates, and have a short duration compared to the ventilation dilution time constants. Gas release events may occur spontaneously, be caused by outside natural phenomena such as seismic events, or be induced by operations or activity related to disturbances of the waste. The release rate can be sufficiently high that dilution by mixing with vapor space air and dilution with ventilation can not prevent flammable conditions from occurring, at least for some duration of time, in some portion of the vapor space.

Steady State Releases. Steady state release is used to describe the ongoing release of generated flammable gases such that the rate of release changes only negligibly over time. The release rates are relatively slow (compared to gas release events) as the generation rates are relatively low.

These releases are a concern only if the released gases are allowed to accumulate to flammable concentrations in tank system vapor spaces. Such an accumulation takes a relatively long time (hours to months) and can be managed by dilution using ventilation. All of the radioactive tank wastes generate flammable gases on an ongoing basis, and therefore these releases and their potential accumulation are a chronic problem for all waste-containing vessels.

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FLAMMABLE GAS/SLURRY GROWTH UNREVIEWED SAFETY QUESTION: JUSTIFICATION FOR CONTINUED OPERATION FOR THE TANK FARMS AT THE HANFORD SITE

1.0 PURPOSE

This Justification for Continued Operation (JCO) provides clarification of the Flammable Gas/Slurry Growth Unreviewed Safety Question (USQ) (flammable gas USQ) and seeks concurrence from the U.S. Department of Energy (DOE) on the understanding of the hazards as described in USQD TF-96-0433, and seeks approval of the controls required to perform operations and activities for facilities where this USQ applies. Continued operation of the Tank Waste Remediation System (TWRS)-managed tanks is necessary to continue waste characterization sampling, tank waste stabilization, and Site deactivation and remediation support.

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2.0 SCOPE

This JCO provides a basis for allowed conditions, operations and activities in 176 high-level waste (HLW) tanks and associated waste transfer systems, double-contained receiver tanks (DCRTs), catch tanks, the 242-T and 242-S Evaporators, 244-AR Vault, and inactive miscellaneous underground storage tanks (IMUSTs) relative to flammable gas hazards. Required controls are specified. The plan to implement required modifications to equipment and work controls is included in a companion implementation plan.

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3.0 DEFINITION OF THE FLAMMABLE GAS UNREVIEWED SAFETY QUESTION

Nuclear waste stored at the Hanford Site has been proven to generate flammable gases, principally hydrogen, in most tanks. Hydrogen is generated by radiolysis of water, thermolytic decomposition of organics, and corrosion. Radiolysis also generates ammonia in nitrate and/or nitrite bearing waste while thermolytic decomposition generates methane. The produced gas is either released continually to the tank vapor spaces (i.e., steady state) or is retained by the waste matrix. This retained gas may be released in either a spontaneous or induced gas release event that can significantly increase the flammable gas concentration of the tank vapor space. The various aspects of the flammable gas hazard and the control strategy is summarized below.

3.1 ORIGINAL UNREVIEWED SAFETY QUESTION DECLARATION

The flammable gas issue was first declared a USQ in May 1990 (Lawrence 1990). The original statement (Dougherty 1990) said, in part, "Recent Westinghouse reviews of the tank vapor space flammability identified that the gas under the crust is potentially flammable because nitrous oxide and hydrogen can create flammable mixtures. This is considered an Unreviewed Safety Question." The phenomenon of gases being generated and entrapped within the waste slurry and beneath the crust was termed "slurry growth." The DOE Richland Operations Office (RL) sent notification (Lawrence 1990) to DOE-Headquarters, which stated in part, "RL has determined that the matter of hydrogen and nitrous oxide evolution within the material in certain waste tanks and subsequent hypothetical ignition is an Unreviewed Safety Question."

3.2 REFINEMENTS TO THE UNREVIEWED SAFETY QUESTION DEFINITION

Since 1990, new information has been obtained from tank samples, monitoring data, laboratory experiments, and theoretical modeling and analysis. This information has led to an increased understanding of the flammable gas and "slurry growth" phenomena and refinements in the definition of the flammable gas USQ as summarized below.

3.2.1 Flammable Gas Composition

Radioactive waste generates hydrogen through the radiolysis of water, thermal breakdown of organic components, and corrosion of the waste tank's carbon steel walls. Radiolysis also generates ammonia in tanks where nitrate and/or nitrite ions are present. Additional flammable gases such as methane and nitrous oxide are generated by chemical reactions between various degradation products of organic chemicals originally present in the tanks. Volatile or semi-volatile organic chemicals present in some tanks also produce organic vapors in the tanks.

3.2.1.1 Hydrogen. Hydrogen gas has been identified through sampling as one of the major components of flammable gas in the waste tanks. The principal source of hydrogen gas is the thermolysis of organic components which is a function of the total organic carbon, the liquid volume of the waste, and the waste temperature. Radiolytic decomposition of water is the other principal source of hydrogen gas in the waste tanks and is proportional to the radionuclide content or decay heat load of the tank. Corrosion of the waste tank walls also produces hydrogen gas, but it is an insignificant portion of the overall generation rate.

Although the hydrogen is a major component of gas samples and hydrogen generation mechanisms are known, there are still uncertainties in the parameters of the equation used to calculate generation rates. Bounding calculations have estimated a worst-case hydrogen production rate of 3.53 scf per day per tank (based on 101-SY) (Hopkins 1995). However, it is important to note that measured hydrogen concentrations in the tanks that have been sampled to date have been lower (sometimes much lower) than the calculated values.

3.2.1.2 Ammonia. In October 1993, Occurrence Report RL-WHC-TANKFARM-1993-0090 was issued because of the measurement of ammonia gas in the vapor space of Tank SY-101 during release event "I," and also because of the measurement of increased ammonia background level in the tank following mixer pump operation. The presence of ammonia gas was judged to increase the fuel content, however, it did not reduce the ignition energy. This JCO includes the available data, hazard conditions and controls for the consideration of ammonia as an additional hazard.

3.2.1.3 Methane. In December 1993, Occurrence Report RL-WHC-TANKFARM-1993-0105 was issued because of the measurement of methane gas (in the amount of 1,000 parts per million [ppm]) in the vapor space of Tank SY-101 during Window I activities which occurred in June 1993. The presence of methane was judged to increase the fuel content of released gases, however, it did not reduce the ignition energy. This JCO includes the available data, hazard conditions and controls for the consideration of methane as an additional hazard.

3.2.1.4 Other Gases. Other flammable gases and oxidizers have been identified in the various waste tanks. Nonmethane organic compounds from past chemical processing operations have been found at very low concentrations (less than 0.1% of the lower flammability limit [LFL]) in the vapor spaces of most tanks. By using a conservative concentration for methane in the LFL calculations, the contribution of nonmethane organic is assumed to have negligible impact. Therefore no additional hazards or controls for organic vapors are identified in this JCO.

3.2.1.5 Hydrogen Concentration in Slurry Gas at 25 Percent of the Lower Flammability Limit. Slurry gas is composed of a number of fuel gases and nitrous oxide as an oxidizer. A major component is hydrogen, and hydrogen concentration is often the only gas measurement available for tank conditions. These measurements are obtained with a Standard Hydrogen Monitoring System (SHMS). Therefore, some evaluation and assumptions are needed to establish the correlation between the measured hydrogen concentration and the percent of the LFL for the mixture in the tank where the measurement was taken. In addition to variations in slurry gas composition, many measurements are taken in the tank headspace where the slurry gas has been mixed with the headspace air, and oxygen is available as the predominant oxidizer. An evaluation to establish a reasonable hydrogen concentration measurement that represents 25% of the LFL is described in Appendix A. This evaluation concludes that a hydrogen measurement of 7500 ppmv is a reasonable, yet conservative value to use as representing 25% of the LFL for slurry gas and slurry gas in headspace air mixtures (10,000 ppm would represent 25% of the LFL for a mixture that contained only hydrogen as the fuel, mixed with air). This 7500 ppmv hydrogen concentration is used in this JCO to convert SHMS hydrogen measurements to a percent of the LFL, as well as to define the SHMS hydrogen monitoring limit that represents 25% of the LFL when an SHMS is used for work activity flammable gas monitoring.

3.2.2 Vapor Space Accumulation of Flammable Gas Because of Steady State Releases

Flammable gases are constantly generated by all of the radioactive wastes. While a fraction of the gas is retained in the waste, a portion of this generated gas is continuously released at a very low rate. This JCO terms such gas releases as steady state releases to differentiate them from the acute, episodic release of retained gas discussed later (gas release events). Steady state gas releases are managed by diluting and removing the gases from the tank dome space through active or passive ventilation to prevent a steady accumulation of gas to flammable concentrations. Concentrations are maintained as low as practical with the existing ventilation configuration. In addition, maintaining low concentrations in the vapor spaces reduces the severity of gas release events by providing relatively clean air in which to dilute the released gases.

For tanks with a combination of small waste volumes, low-decay heat loads, small concentrations of organic chemicals, and relatively large dome spaces steady state gas releases can be maintained at low concentrations with passive ventilation. Passive ventilation is provided by atmospheric breathing and an unquantified combination of: (a) convective flow through tank openings and tank-to-tank connections because of buoyancy effects from gas temperature differences, (b) bernoulli flow caused by wind blowing past the tank exhausts, or (c) Food Instrument Corporation (FIC) instrument purge flow. Currently, the passive ventilation rates have not been accurately measured.

Double-shell tanks (DSTs) and some single-shell tanks (SSTs) (in the SX-Farm and C-Farm) are provided with active ventilation via exhausters and breather filters. Although the ventilation for each tank is established by procedure and the flow rate can be estimated by design parameters or measured occasionally with portable instruments, actual tank ventilation flow rates are not monitored because of the lack of installed instrumentation.

Although the calculation of the steady-state gas concentration is simple and straightforward, the actual concentration is difficult to precisely calculate. Given a gas generation rate (G) and ventilation rate (V) we can define the steady state gas concentration as G/V. However, because of various uncertainties in the calculation of the hydrogen generation rates and the lack of accurate ventilation data, it is not possible to sufficiently postulate the steady state flammable gas concentrations (WHC-SD-WM-ER-594).

Furthermore, these ventilation effects may be reduced in the high points of sealed risers and sealed pits thus allowing flammable gas to accumulate in concentrations that are higher than in the unobstructed dome space. Buoyancy effects cause flammable gases to migrate upwards into risers or pits that are isolated from the tank's ventilation. Combustible gas monitor (CGM) readings taken in risers have indicated higher readings at the top of some risers than are measured at lower elevations.

Formal gas samples have been taken from approximately 42% of the SSTs as of July 1, 1996. An additional 31% of the SSTs have grab sample results. These data are included in Appendix A. DSTs have been sampled as a matter of course during work activities, but the measurements have not been recorded in the gas sample results database. It is very important to note that the actual steady state gas concentrations measured to date are consistently below 25% of the LFL. Furthermore, these measurements have demonstrated that the measured values are significantly lower than the calculated values for passively ventilated tanks (Hodgson 1996). It is therefore concluded that for the purposes of this JCO, the current ventilation procedures should be continued. It must be noted, however, that these existing procedures were not originally conceived to address the flammable gas issue, and the current Authorization Basis does not identify the specific ventilation controls that are needed for continued safe storage in light of flammable gas hazards.

3.2.3 Gas Accumulation Within the Waste

Some portion of the gas that is generated is retained within the waste. Retained gases can include fuel (e.g., hydrogen, ammonia, methane) and an oxidizer (e.g., nitrous oxide) and therefore be in flammable concentrations. The retained gas presents a flammability hazard in the following ways. The retained gas may burn below the waste surface if ignited. The amount of gas, bubble type, size, and distribution allow for flame propagation. The gases can be released from the waste and burn in the tank vapor spaces (tank dome, connected vapor spaces such as pits and outside of tank openings such as ventilation inlet paths) if ignited. And finally, the retained gases can be released inside of equipment that is inserted into the waste, such as core sample drill strings, and burn if ignited.

3.2.3.1 Deflagrations Below the Waste Surface. The original USQ (Lawrence 1990) acknowledged that a flammable mixture of gases may exist within the waste creating the possibility of a combustion event below the waste surface. The likelihood and consequences of such an event are not analyzed in the Tank Farm Authorization Basis (with the exception of 101-SY), and therefore the hazard of igniting flammable gases that may be retained within the waste (below the waste surface) is covered by the flammable gas USQ and this JCO.

3.2.3.2 Gas Accumulation in Equipment That Penetrates the Waste. On September 28, 1995 an Occurrence Report (RL-WHC-TANKFARM-95-0078) was issued because of the presence of flammable gas in excess of the LFL inside the drill string used for core sampling Tank 241-S-107. Another incident occurred one month later in Tank 241-BY-110. In both incidents the cause was attributed to encountering gas pockets within the waste which caused flammable gases to enter and accumulate within the drill string in concentrations that were measured to be in excess of the LFL. Flammable gases have accumulated in drill strings in several more tanks. Accumulation of flammable gases in waste intruding equipment is considered to be a facet of the flammable gas USQ, and the controls in this JCO address this hazard.

It is noted that Tank 241-BY-110 was not listed as a flammable gas USQ tank at the time of the occurrence. The USQ evaluation for these incidents concluded that even though a tank may not contain sufficient trapped gas to warrant flammable gas controls because the potential is low for high vapor space flammable gas concentrations, it still could be a concern for waste intruding equipment. There may be gas pockets encountered under the waste surface which have a high concentration of flammable gas. A somewhat similar situation occurred in the liquid observation well (LOW) in Tank SX-104. The LOW in SX-104 accumulated flammable gases that were measured to be in excess of the LFL (102% of the LFL as read with a CGM). This event is described in Occurrence Report RL-WHC-TANKFARM-1994-0073. The high gas concentrations were attributed to a breach in the LOW below the waste interstitial liquid level. This allowed gases to enter and accumulate in the LOW as it is sealed at the top so no ventilation flow is provided. The dome space in SX-104 was sampled at the time and measured to be 0% of the LFL with no ammonia.

This JCO specifies controls to be used with waste intruding equipment in all waste tanks. These controls are judged to be adequate to manage risk from potential flammable gas accumulation in waste intruding equipment.

3.2.3.3 Gas Release Events. Many of the wastes have demonstrated the ability to retain a substantial fraction of generated gases in the waste matrix. Periodically the waste may spontaneously release large volumes of the trapped gas that can raise the gas concentrations in the vapor space to flammable levels in a very brief period of time (Hopkins 1995). The performance of many activities also may trigger an induced release of retained gas. These prompt spontaneous and induced gas release events (GREs) are in sharp contrast to the continuous steady state releases described earlier.

For the purpose of applying controls, each DST, SST, DCRT, aging waste facility (AWF), IMUST, and catch tank has been placed in one of three distinct facility groups depending on the types of GREs associated with each tank. Five tanks within the scope of this JCO (i.e., excluding SY-101) that have undergone observed significant GREs are conservatively postulated to have the potential for large spontaneous and large induced GREs and have been assigned to Facility Group 1. If a tank is postulated to have the potential for a large induced GRE but only a small spontaneous GRE then it is placed in Facility Group 2. Finally, the remaining tanks that show no propensity for spontaneous GREs but might still produce a small induced GRE are placed in Facility Group 3. All facility groups assume that the subject tanks undergo steady state gas generation at all times.

The grouping of the tanks reflects a conservative approach given the admitted uncertainties in the underlying methodology. It also allows a graded application of controls based on perceived hazards while freeing less hazardous tanks from unnecessarily restrictive or burdensome controls. This method also allows a degree of simplicity in applying control sets to specific tanks.

Measured Gas Releases: Information regarding spontaneous gas release events has been gathered by SHMSs that continuously sample the tank vapor space hydrogen concentrations. SHMSs have been installed on 6 DSTs and 22 SSTs. Data obtained from the DSTs and 18 of the 22 SSTs for which the SHMS has been operating is summarized in Tables 1, 2, and 3, along with dome space concentration predictions from the GRE evaluation found in Hodgson (1996).

DSTs: Data have been documented for the six (of 28) DSTs that have been instrumented. As indicated in Tables 1 and 2, of these six tanks, Tank SY-101 has had dome space concentrations measured that exceed the LFL. Tanks AN-105 and AW-101 have had measured hydrogen concentrations that exceed 25% of the LFL for slurry gas in air. The measured hydrogen concentrations for the other instrumented tanks have all been less than 25% of the LFL. The measured concentrations are all significantly less than the concentrations predicted by the GRE evaluation (Hodgson 1996). The data for Table 1 is obtained from Wilkins 1996a through Wilkins 1996d. The data for Table 2 is obtained from Wilkins 1995.

SSTs: Studies by Gauglitz (1994, 1995) and Bredt (1996) into the growth of bubbles in settled solids have demonstrated that the presence of a supernatant liquid layer allows for large, buoyancy-induced rollovers that trigger large, spontaneous GREs. Since SST's do not usually contain a supernatant layer (or at most a very small one) large buoyancy-induced rollovers are not possible. Therefore, there is no serious potential for large spontaneous GREs from the waste in SSTs.

The available SHMS data for SSTs is summarized in Brown (1996) and confirms this hypothesis. This indicates small gas releases that appear to coincide with low-pressure barometric fronts (LPF) but no other phenomena. In addition to SHMS data, some vapor grab sample data has been obtained during the calibration and baselining effort of SHMS start up. The release events are summarized in Table 3 for tanks where SHMS data is available. As indicated in Table 3, however, the highest measured concentrations are all well below 25% of the LFL even accounting for instrument errors and calibration drift in the SHMS Whittaker cells.

3.2.3.3.1 Spontaneous Gas Release Events. Five DSTs within the scope of the JCO (241-AN-103, 241-AN-104, 241-AN-105, 241-AW-101, and 241-SY-103) have been observed to release large gas quantities when no operations or activities are disturbing the waste. In addition, Tank 241-SY-101 exhibited spontaneous GREs before the operation of the mixer pump in this tank. Tank 241-SY-101 has an approved safety analysis and is, therefore, not within the scope of this JCO. The large "spontaneous" gas releases in these tanks are believed to be caused by instabilities that result from density differences between the gas retaining waste and the overlying supernatant liquid. As the waste entrains more gases it becomes more buoyant until at some point the density differences are large enough to overcome the forces keeping the gas retaining wastes in place and a waste rollover occurs, releasing gas.

All DSTs with significant sludge to retain gas are considered to have the potential for spontaneous releases as they all have significant amounts of supernatant and therefore may be able to create instabilities that result from density differences between the gas retaining waste and this supernatant. However, DSTs (other than the five mentioned above, and excluding 241-SY-101) have not shown evidence of large spontaneous GREs based on historical monitoring of waste surface level rise and falls, tank vacuum levels, and waste temperature profiles. Instead, these remaining DSTs may be prone to small spontaneous GREs.

As previously noted, SSTs are unlikely to exhibit a large, spontaneous GRE, but have exhibited small spontaneous releases typically associated with LPFs.

3.2.3.3.2 Induced Releases (Waste Disturbing Operations and Activities). Retained gas may be released during many waste disturbing operations or activities. It is hypothesized that waste disturbing operations may release gas by either directly releasing gas from the waste in the local volume where the waste in disturbed or by triggering a release from a larger volume, such as by triggering a rollover.

3.2.3.3.3 Experience During Waste Disturbing Activities. Forty-nine waste sampling activities and 38 LOW installation activities have been evaluated to determine if these activities caused a gas release (Schofield 1996a). These evaluations concluded that no gas releases were evident based upon temperature data from the 87 activities; however, waste level data could not rule out the possibility of two gas releases in the 1980's. Surface level data showed the waste level reading dropped several inches about the same time as one LOW installation and one sampling event occurred during the 87 activities. It is not possible at this time to reconstruct whether the level reading drop was because of an FIC or manual tape adjustment or plummet flush, or how close to the waste intrusion event the level reading change occurred. One of the level reading changes may have occurred a day or two before the intrusion.

Of the 17 recent waste core samples where gas monitoring was available, small gas releases were indicated by CGM readings from the tank vapor space during three of them. The gas release volume was estimated for two of the three events. Based upon CGM readings and conservatively assuming the entire tank head space was at the indicated CGM value, about 0.68 m^3 (24 ft^3) of H_2 was released during the sampling event in S-102, and 1.33 m^3 (47 ft^3) of H_2 was released in the U-109 sampling event (Schofield 1996b). Readings from SHMS cabinets on the same tanks showed negligible hydrogen increases at the same time the CGMs showed the increases. This provides evidence that the gas releases were small and did not fill the tank dome space to the CGM concentration. Thus, the volume of H_2 released in each event was likely to be less than the 0.71 to 1.42 m^3 (25 to 50 ft^3) range.

Although the fraction of retained gas that is released for each operation or activity has not been quantified, for the purposes of this JCO it is postulated that waste disturbing operations can be graded into local waste disturbing operations and global waste disturbing operations. Local waste disturbing operations can cause a small GRE in any tank while a global waste disturbing operation can cause a large GRE in those tanks that are postulated to retain a large amount of gas.

3.2.3.3.4 Large Versus Small Gas Release Events. Actively ventilated tanks (i.e, DSTs, AWFs, and some SSTs) normally are operated with the dome space at a slight vacuum. However, large gas releases can pressurize the dome space above atmospheric pressure and therefore the flow of dome space gases into pits, out open risers into the atmosphere, and through the ventilation system upstream towards other connected tanks must be postulated.

Tank 241-SY-101 has experienced several gas release events that were large enough to create flammable conditions in a large portion of the dome space and pressurize the dome space (pressure increased from 498 Pa (gauge) [-2-in. W.G.] to approximately 1,449 Pa (gauge) [+6-in. W.G.] in two events summarized in Table 2). Gas concentrations were not measured in pits, but concentrations were measured in the ventilation system about 4.9 m (15 ft) from Tank 241-SY-101 upstream of the connections to other tanks. During GREs the concentrations measured in the ventilation system are lower than in the dome space as demonstrated by the December 4, 1991 event. This GRE resulted in concentration in the dome space of 53,000 ppm while vent duct concentration remained below the LFL (maximum measured concentration was 26,000 ppm). The event also caused pressurization in the dome space that increased the ventilation flow rate from 0.23 m^3/s (500 cfm) to 1 m^3/s (2,125 cfm).

The dome space of passively ventilated tanks is normally at atmospheric pressure; therefore, large gas release events could cause a positive pressure and outflow of gases into pits, breather filters, and open risers. Large releases that can cause a significant portion of the dome space to exceed the LFL are therefore postulated to cause flammable conditions outside of the dome space in passively ventilated tanks.

Tanks estimated to retain relatively small amounts of gas are judged less likely to present a risk of creating flammable conditions outside of the tank. Small releases would likely be mixed and diluted by dome space air before exiting the tank dome space. For the purposes of this JCO, the tanks with estimated retained gas amounts that are too small to cause the dome space concentration to exceed 25% of the LFL (if 25% of the gas is released per Hodgson [1996]) are considered to have too little potential to create flammable conditions in vapor spaces located outside of the dome space (e.g., in pits, outside of open risers and breather filters) to warrant ignition source controls in these areas.

Small GREs pose some risk of creating localized flammable regions within the dome space (e.g., plumes) until mixing occurs with headspace air. However, they are unlikely to cause flammable conditions outside of the tank dome space.

Estimated Gas Release Potential: 177 tanks have been evaluated for gas retention and release potential and documented in Hodgson (1996). The first step was the application of the quick screen method to estimate the quantity of retained flammable gases in the tank waste. If the quick screen method predicted dome space concentrations less than 25% of the LFL, no further evaluation was done. If the quick screen method predicted dome space concentration greater than 25% of the LFL, then one of two additional methods was employed to estimate retained and releasable gas. One method uses waste surface rise to calculate the amount of retained gas. The second method uses the waste level variation with corresponding barometric pressure changes as an indication of retained gas. This screening process identified tanks where the released gas was calculated to cause hydrogen concentrations in a well-mixed tank dome space to exceed 25% of the LFL. As indicated in Tables 1 and 3, the predicted concentrations following a gas release event (Hodgson 1996) are much higher than the measured concentrations for GREs monitored to date.

3.3 FACILITY GROUP ASSIGNMENT

TWRS-managed facilities affected by this JCO have been divided into three facility groups to allow for grading of controls without undue complexity for implementation in the field. Control grading addresses the fact that flammable gas hazards are widely variable among individual tank farm facilities. There are three Facility Groups with associated controls which are logically based on the variable degrees of flammable gas hazards observed and postulated for the TWRS facilities. Limiting the control grading to three levels is a deliberate strategy to minimize operational complexity. At the same time, the use of three broad groups is an acknowledgement that technical uncertainties prevent "knife-edge" determinations regarding the hazard potentials of each individual facility.

3.3.1 Facility Group One

Facility Group 1 consists of those facilities which are acknowledged with little or no controversy to be of the greatest concern with respect to the flammable gas hazard. Specifically, the five tanks (241-AN-103, 241-AN-104, 241-AN-105, 241-AW-101, and 241-SY-103) within the scope of this JCO that have undergone observed, significant GREs are conservatively postulated to have the potential for large spontaneous and large induced GREs. The level of rigor selected for these tanks is judged to be the maximum possible to simultaneously manage the risk while continuing to perform essential waste storage functions and meet planned TWRS mission objectives.

3.3.2 Facility Group Two

If a tank is postulated to have the potential for a large induced GRE but only a small spontaneous GRE then it is placed in Facility Group 2. For the purposes of this JCO, the SSTs that fail the GRE evaluation (Hodgson 1996) (i.e., are estimated to retain gas amounts sufficient to cause the dome space concentration to exceed 25% of the LFL, if 25% of the gas is released) are considered to have the potential for large induced releases. However, as stated previously SSTs are not postulated to undergo large spontaneous releases.

The definition of Facility Group 2 is a reflection of the uncertainty that remains in fully understanding tank flammable gas hazards and characterizing tank specific contents and behaviors. Facility Group 2 contains all DSTs and AWFs not listed in Facility Group 1 plus all SSTs that are documented to "fail" the GRE evaluation as noted above.

The balance of the DSTs and AWFs are all within their design life and are integral to the safe waste storage and disposal mission. It is known that they will receive some amount of new wastes from other Hanford Site facilities and will undergo liquid reductions, waste consolidation, multiple transfers, and mixing. Procedures are in place to minimize the likelihood that these operations would create conditions resulting in large spontaneous gas release behavior. However, it is recognized that some of these operations may result in increased gas generation and retention capability. Therefore, it is appropriate to categorize these facilities in Group 2 or higher in recognition of this potential. In the unlikely event that significant GRE behavior develops, tank monitoring results will provide indication and the category of the facility will be changed to Group 1.

3.3.3 Facility Group Three

The most lenient set of controls is applied to those facilities assigned to Facility Group 3 which includes all of the remaining tanks not assigned to either Facility Groups 1 or 2. The controls for Facility Group 3 reflect the widely accepted judgement that many SSTs, particularly those that have been stabilized, pose a significantly lower risk from the standpoint of flammable gas hazards than those in either Facility Group 1 or Facility Group 2.

3.4 RESTRICTED OPERATION

3.4.1 Salt Well Pumping of Certain Tanks

The risk of flammable gas releases during the salt well pumping of tanks with large amounts of retained gas was judged to be sufficiently uncertain to warrant placing this operation on hold in certain tanks. The risk during salt well pumping and the required controls are being evaluated and will be addressed in separate safety documentation. Until this evaluation is complete and approved, salt well pumping is not allowed in the following tanks: 241-A-101, 241-BY-105, 241-BY-106, 241-S-101, 241-S-102, 241-S-103, 241-S-106, 241-S-107, 241-S-109, 241-S-111, 241-SX-102, 241-SX-103, 241-SX-105, 241-SX-106, 241-U-102, 241-U-103, 241-U-105, 241-U-107, 241-U-108, 241-U-109, 241-U-111. These tanks are suspected of retaining large amounts of gas based on a GRE evaluated result of greater than 50% of the LFL in the headspace (Hodgson 1996).

4.0 TANK CONTROL STRATEGY

To effectively manage the risk associated with steady state accumulation the JCO requires either passive or active ventilation for all tanks to ensure that steady state flammable gas concentrations are well below the LFL. In order to manage the risks associated with retained gases and GREs, specific ignition source controls and continuing monitoring requirements are applied on a graded basis to the facility groups depending on the work performed.

A summary of the application of these control strategies to address each of the flammable gas hazards discussed in Section 3.2 is provided in Table 4. Each strategy is discussed in detail in the following section.

4.1 TANK REGIONS

This JCO stipulates specific equipment and work controls for any TWRS-managed tank, container or receiver that could present a waste-related flammable gas hazard and lead to a fire or explosion. These controls shall apply to all facility group tanks unless the equipment or work meets the definition of nonintrusive, as follows.

Nonintrusive: This includes all equipment located in, and work done on, parts of the tank or ventilation system which are isolated from the tank air space by a "vapor-tight" barrier, and are not otherwise included in the definition of intrusive as described in this JCO. "Vapor-tight" barriers must meet the intent of such barriers as described in NFPA 497A as clarified in ANSI/API 500. For unventilated areas, the barrier must be "vapor-tight." For ventilated areas the strict vapor-tight requirements can be modified depending on ventilation conditions. There are no JCO related flammable gas controls for nonintrusive equipment or work, except for assurance that isolation exists.

Conversely, equipment and work which meet the definition of intrusive (either ex-tank, dome space or waste intrusive) shall be fully subject to the control strategy as specified in this JCO. These intrusive tank regions are defined in detail below:

Ex-Tank Intrusive (Region 1): Region including all vapor spaces with a direct connection to the tank dome space but which do not meet the definition of either dome or waste intrusive below. The ex-tank intrusive region includes pits (e.g., pump pits, transfer pits) that are not isolated from the tank dome by a vapor tight barrier. The ex-tank intrusive region also includes: (a) the environment outside of the tank opening, which is directly connected to the dome space, out to a distance of 18 opening diameters, (b) 4.92 m (15 ft), or (c) the boundary of temporary containment devices, whichever is shorter. Equipment located in these areas shall have ignition source control requirements as described below. Ex-tank intrusive work also includes all activities that are in direct contact with the outside of this boundary, such as welding or grinding, that could result in an ignition source inside the boundary. Ex-tank, dome space, and waste intrusive regions are shown in Diagram 1 for passively ventilated tanks, Diagram 2 for actively ventilated tanks, and Diagram 3 for tanks when the active ventilation system is not operating.

Diagram 1. Ex-Tank, Dome, and Waste Intrusive Region in Passively Ventilated Tank.

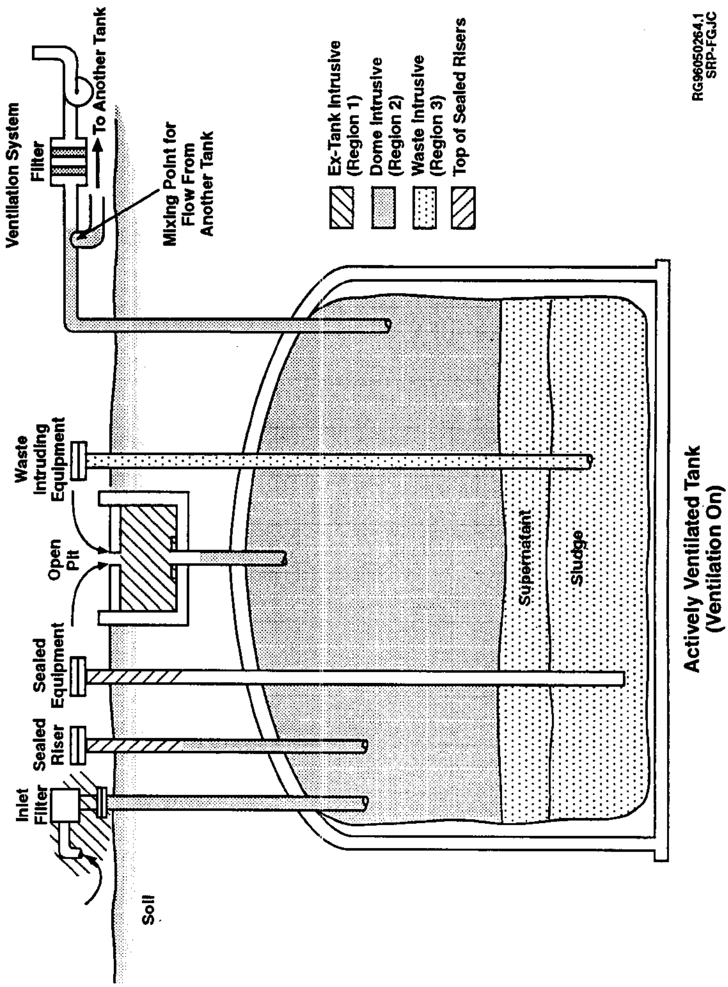


Diagram 2. Ex-Tank, Dome, and Waste Intrusive Regions in Actively Ventilated Tanks (Ventilation Active).

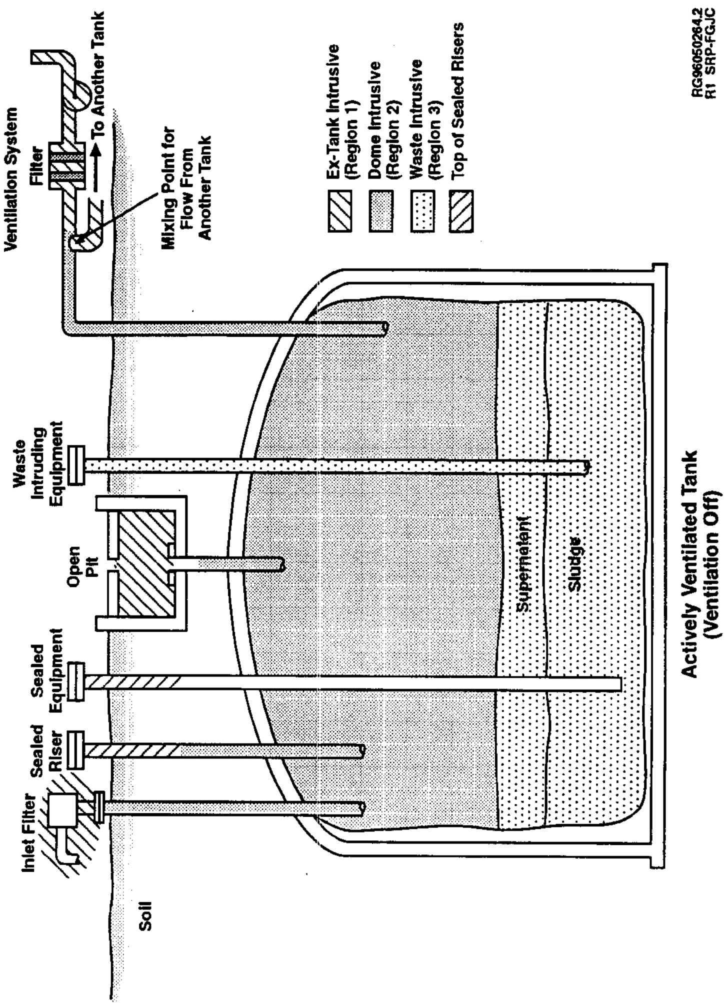
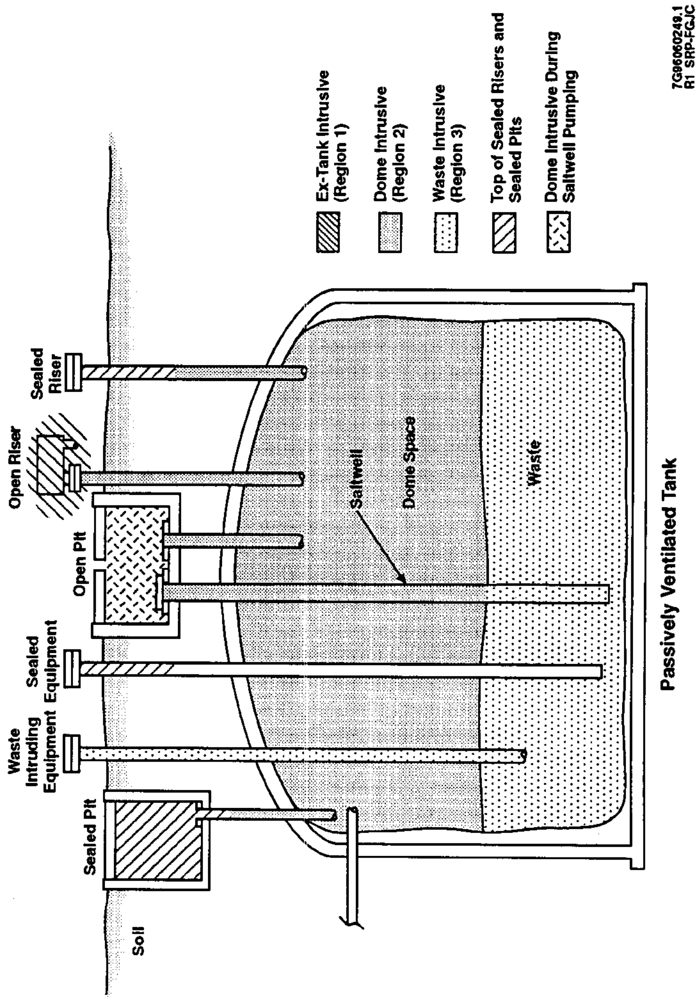


Diagram 3. Ex-Tank, Dome, and Waste Intrusive Regions in Actively Ventilated Tanks (Ventilation Off).



Dome Space Intrusive (Region 2): Any location within the tank between the top of the riser and the surface of the waste including ventilation ducting up to the first mixing point with flow from another tank. However, the entire ventilation system may need to be considered an ex-tank intrusive region if shutdown. Dome intrusive work also includes all activities that are in direct contact with the outside of this boundary, such as welding or grinding, that could result in an ignition source inside the boundary.

Salt well pits are considered to be part of the dome intrusive region during operation of salt well pumps. This designation (and accompanying control requirements) is made in light of analysis (Thurgood 1996) that concluded released gases could be channeled to the pit by the salt well thereby creating localized flammable conditions in the pit while the rest of the dome space may be well below the LFL.

Ignition source controls are applied to the region at the top of sealed risers and pits. These higher concentrations result from buoyancy effects and the reduced ventilation in these potentially stagnant areas.

Waste Intrusive (Region 3): Waste intrusive is the region below the waste surface. The vapor space inside equipment inserted into the waste (waste intruding equipment) is also considered part of the waste intrusive region.

Waste intruding equipment includes open ended and breached objects that are inserted below the waste surface and create an unvented vapor space where flammable gases retained in the waste may accumulate. Examples of waste intruding equipment include core sample drill pipe, pump suction legs, and weight factor dip tubes.

Equipment inserted below the waste surface and properly sealed (e.g., T/C trees, LOWs) is not considered to be waste intruding equipment; however, gas monitoring is required as an entry requirement for work inside such sealed equipment as a prudent precaution. For LOWs where entry is performed on a frequent basis, monitoring will be performed periodically (i.e., not required during every entry).

Waste disturbing operations or activities include all work that may result in significant motion under the waste surface. Activities considered waste disturbing include, but are not limited to, waste sampling (e.g., grab sampling, auger sampling, core sampling), water lancing, installing or removing instrument trees or liquid observation wells, waste transfers into or out of a tank, and the removal, installation or operation of mixer pumps. Operations and activities that disturb only a small, local portion of the waste, such as removal of air lances or T/C trees are quite different than operations that can cause a large global disturbance such as the operation of a mixer pump. Examples of global and local waste disturbing operations and activities are shown in Table 5.

Waste disturbances may also occur because of seismic events which are not addressed by this JCO.

4.2 VENTILATION CONTROLS

Requirements related to ventilation performance are documented in the Interim Operational Safety Requirements (IOSR) for the DSTs and AWFs. They are documented for SSTs in Operating Specification Documents (OSD) and OSRs. As stated above, in situ measurements have demonstrated that steady-state flammable gas concentrations are consistently below both calculated values and 25% of the LFL in passively and actively ventilated tanks (Hodgson 1996). Because the current ventilation methods maintain steady state gas concentrations significantly below 25% of the LFL, it is recommended that existing ventilation controls be maintained to manage the risk associated with gas added to the vapor space by steady state and small induced or spontaneous releases.

Although the current IOSR, OSR and OSD requirements related to ventilation were not established to control flammable gases, available gas sample results indicate all sampled tanks are less than 5% of the LFL. These controls require near constant operation of the exhausters with verification of the resulting tank vacuum for DSTs and AWFs. For passively ventilated tanks, the breather filters are verified to be operable at least every 12 months and the breather filter isolation valves are verified to be open weekly. Therefore, the current operating practices are judged to be adequate for controlling steady state flammable gas and may be used to support continued operation of these tanks. The specific IOSR, OSR, and OSD control requirements credited in this judgement are specified in Table 6.

4.3 IGNITION SOURCE CONTROLS

Ignition source controls are applied to equipment installed or used during work activities in tank intrusive locations per Facility Groups 1,2, and 3 on a graded basis. Additionally, controls shall be applied to all equipment used in waste intrusive locations at all times.

Most of the locations in and around the tanks within the scope of this JCO do not need to be classified in accordance with National Fire Protection Association (NFPA) guidelines. However, other tanks with a potential for achieving at least 25% of the LFL are NFPA classified but only during work activities that are considered waste intrusive (WHC-SD-WM-HC-017).

Although these requirements are intended to provide a prudent and conservative technical approach to facility designers and engineers, there may be situations that require additional controls based on the risk of the particular activity or location. When safety class or safety significant equipment are called for other referenced design requirements may be imposed by WHC-CM-4-46, Section 9, Appendix A as appropriate. Conversely, relaxation of requirements may be appropriate on a case by case basis because of mitigating circumstances or equivalent design methods. These deviations shall only be invoked after analysis or testing and with appropriate documentation, review, and approval. The Flammable Gas Equipment Advisory Board, consisting of the TWRS Design Authority and representatives from the Hanford Electrical Codes Board (HECB) and the contractor NFPA Interpretative Authority, will review the design based on equivalent safety and approve the equipment and its installation. Implementation of ignition source controls is discussed further in Section 6.1.2.

4.3.1 Ignition Source Control Set 1

This set is used for all equipment that is installed or used during work activities for that portion of the equipment that can contact the undiluted gases that are retained within the waste or are present in the vapor space of waste intruding equipment. The basis is that flammable conditions may be present always or often in these locations, and therefore the highest level of control, consistent with NFPA 70 (1993) Class I, Division 1 is appropriate.

1. Mechanical tooling, equipment and materials (including lubricants, adhesives, gaskets, corrosion inhibitors, epoxies, etc.) shall be constructed of spark-resistant material, or shall be rendered incapable of sparking, or shall have been analyzed and evaluated to not be capable of sparking under the applied conditions (Johnson 1990). Material compatibility shall be evaluated for thermite reaction potential (Raymond 1996).

2. Electrostatic ignition sources shall be controlled by providing bonding or grounding according to NFPA 77 (1993).

3. Exposed polymer materials shall be rendered incapable of electrostatic charge or discharge potential either by design or through acceptable workaround practices (e.g., slow deployment/removal, humidification, etc.) (NFPA 77 1993). Use of existing nonconductive polymer equipment and materials may be acceptable for temporary activities, through similar workarounds, provided required flammable gas control limits are employed (e.g., continuing monitoring, stop work if LFL reaches 25%).

4. The surface temperatures of heat-generating devices shall not exceed 80% of the autoignition temperature of the flammable gas or a maximum of 160 °C (320 °F) if the device can contact the waste and cause ignition by triggering exothermic reactions in the waste (i.e., organic-nitrate reactions). Internal temperatures of heat generating devices may exceed 80% of the autoignition temperature (NFPA 70 1993) if the heat source is either isolated (pressurized) from the gas environment, or if the design of the device enclosure meets the requirements for explosion-proof housings.

5. Electrical equipment shall be designed to meet NFPA 70 (1993), Class 1, Division 1, Group B criteria to the maximum extent practical. As a minimum, this shall be interpreted to mean that no single point failure of energized equipment can result in an arc or spark, or gas burn propagation to the environment external to the source enclosure (NFPA 70 1993). In the case of waste-submerged equipment containing potential ignition sources, demonstration by design that the equipment is nonsparking under normal operation <u>and</u> is designed to be isolated from the waste environment is an acceptable alternative.

6. Shutdown of purged and pressurized electrical equipment and purged and pressurized heat-generating equipment, upon loss of protective gas pressure or flow, shall be automatic by design as defined by NFPA 496 (1993) Type X pressurization.

7. Interlocked start-up of purged and pressurized electrical or purged and pressurized heat-generating equipment shall only be allowed upon system sensing of pre-set safety limits (e.g., adequate protective gas pressure established as defined by NFPA 496 [1993]). If pressurized enclosures are used to isolate energized components, a minimum of four enclosure volumes shall be purged through the enclosure for energized components, and/or 10 volumes shall be purged for enclosed motors prior to controlled start-up of the system components (NFPA 70 1996), (NFPA 496 1993).

4.3.2 Ignition Source Control Set 2

This set is applied to vapor space locations (ex-tank intrusive and dome-intrusive) when a GRE is postulated to create flammable conditions. Set 2 is similar to Set 1 except that requirements (6) and (7) are modified to allow the use of more readily available equipment. The basis is that the flammable conditions are unlikely and would persist for relatively short periods of time. Therefore, the use of equipment that meets the intent of NFPA 70 (1993) Class I, Division 2 is adequate. The requirements for implementation of this control set are specified in Table 7.

1. Mechanical tooling, equipment and materials (including lubricants, adhesives, gaskets, corrosion inhibitors, epoxies, etc.) shall be constructed of spark resistant material, or shall be rendered incapable of sparking, or shall have been analyzed and evaluated to not be capable of sparking under the applied conditions (Johnson 1990). Material compatibility shall be evaluated for thermite reaction potential (Raymond 1996).

2. Electrostatic ignition sources shall be controlled by providing bonding or grounding per NFPA 77 (1993).

3. Exposed polymer materials shall be rendered incapable of electrostatic charge or discharge potential either by design or through acceptable workaround practices (e.g., slow deployment/removal, humidification, etc.) (NFPA 77 1993). Use of existing nonconductive polymer equipment and materials may be acceptable for temporary activities, through similar workarounds, provided required flammable gas control limits are employed (e.g., continuing monitoring, stop work if LFL reaches 25%).

4. The surface temperatures of heat generating devices shall not exceed 80% of the autoignition temperature of the flammable gas or a maximum of 160 °C (320 °F) if the device can contact the waste and cause ignition by triggering exothermic reactions in the waste (i.e., organic-nitrate reactions). Internal temperatures of heat generating devices may exceed 80% of the autoignition temperature (NFPA 70 1993) if the heat source is either isolated (pressurized) from the gas environment, or if the design of the device enclosure meets the requirements for explosion-proof housings.

5. Electrical equipment shall be designed to meet NFPA 70, Class I, Division 2, Group B criteria to the maximum extent practical. As a

minimum, this shall be interpreted to mean the equipment is nonsparking under normal operation or, if normally sparking, the sparking component(s) shall be continuously isolated (purged and pressurized) from the potentially flammable gas environment, or the design of the device enclosure shall be of sufficient strength (explosion-proof) to prevent propagation of a gas burn to the environment external to the enclosure (NFPA 70 1993).

6. Either automatic shutdown or alarming with manual shutdown will be required upon loss of protective gas pressure or flow as defined by NFPA 496 (1993) Type Z pressurization. In ex-tank area applications, electrical equipment that does not meet Class I, Division 2, Group B may be used, if it is automatically shutdown by combustible gas detection systems.

7. Automatic or manual start-up of purged and pressurized electrical or purged and pressurized heat-generating equipment shall only be allowed upon system sensing of pre-set safety limits (e.g., adequate protective gas pressure established as defined by NFPA 496 [1993]). If pressurized enclosures are utilized to isolate energized components, a minimum of four enclosure volumes shall be purged through the enclosure for energized components, or 10 volumes shall be purged for enclosed motors prior to controlled start-up of the system components (NFPA 70 [1993], NFPA 496 [1993]). When combustible gas detection shut down systems are employed, start-up of equipment shall only be allowed once measured acceptable flammable gas levels are indicated.

4.4 MANNED WORK ACTIVITY ENTRY AND GAS MONITORING REQUIREMENTS

Flammable gas concentrations in intrusive work locations must be verified to be below the flammable gas work control limits prior to commencing any work. This requirement shall be applied to all manned work activities in waste containing vessels (i.e., when the manned work activity is near an opening in the vessel containment) to ensure that flammable conditions in the work space are not present because of steady state accumulation and/or recent GREs. Manned work shall neither commence nor proceed if flammable gas concentrations are greater than 25% of the LFL with an exception for gas sampling and necessary actions to reduce gas concentrations, deenergize ignition sources, etc. Installed qualified equipment may be allowed to continue to operate (i.e., not be deenergized) if greater than 25% of the LFL. If flammable gas concentrations are greater than 25% of the LFL a grab sample shall be taken and sent to the lab for analysis. Until gas concentrations less than 25% of the LFL are verified, the equipment and tools used to perform this verification (e.g., wrenches, equipment such as riser covers that must be removed, CGMs) shall meet the requirements of Ignition Source Control Set 2 with the following exceptions.

1. Electrical bonding is not required for openings less than or equal to 1 in. inside diameter.

2. Electrical bonding is not required for use of FIC level gauges, manual tape level gauges, and zip cords.

3. Spark resistant tools are not required for openings less than or equal to one inch inside diameter.

4. Spark resistant tools are not required for loosening nuts/bolts, etc. for the first nominal turn or for final tightening.

Because of the possibility of flammable conditions developing during work as a result of a GRE (particularly during waste disturbing operations), work space (ex-tank intrusive or dome intrusive) monitoring is continued as indicated in Table 7. Continuing monitoring means use of a continuous monitor (e.g., SHMS) or use of portable CGMs with readings recorded at least every 15 minutes. Ignition source controls are also imposed in these locations to prevent ignition in the unlikely event that flammable conditions develop. All manned work activities must immediately halt if flammable gas concentrations exceed 25% of the LFL with an exception for gas sampling and necessary actions to reduce gas concentrations, deenergizing ignition sources, etc.

4.4.1 Unmanned Operations

Unmanned operations such a waste transfers, operation of Air Lift Circulators (ALC) or mixer pumps in actively ventilated tanks do not require continuing monitoring as the installed equipment must meet ignition source control requirements and there are no workers in the vicinity. Gases released will be diluted and swept from the tank by the ventilation flow. Adequate protection is provided by ignition source control (IC) Set 2 for the short duration that flammable conditions may exist, in the unlikely event that a large GRE were to occur.

During unmanned global waste disturbing operation in passively ventilated tanks flammable gas concentrations from GREs may persist for a significant length of time because of the low ventilation flows provided. Continued operation in this condition is imprudent if the flammable gas concentration is greater than 25% of the LFL, therefore continuing monitoring is required. For long duration operations such as salt well pumping, continuing monitoring can be defined as follows:

1. Monitor dome space and/or salt well pit once per hour for 5 hours following initiation of pumping, then

2. Monitor dome space and/or salt well pit once per day for the next 3 days (or once per 24 nominal hours run time), then

3. Monitor weekly, (or once per 168 hours nominal run time). Revise sampling period:

    a. Less than 15% of LFL, sample every 7 days, not to exceed 10 days

b. Greater than 15% to ≤ 25% LFL, take daily samples

c. Waste disturbing operation to stop if greater than 25% LFL.

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5.0 APPLICATION OF CONTROLS TO FACILITY GROUPS

5.1 FACILITY GROUP ONE

Five tanks (241-AN-103, 241-AN-104, 241-AN-105, 241-AW-101, and 241-SY-103) within the space of the JCO that have undergone observed, significant GREs are conservatively postulated to have the potential for large spontaneous and large induced GREs that could create flammable conditions in the ex-tank region. For this reason, the most stringent controls are applied to these Facility Group 1 tanks. Ventilation controls as stipulated in Section 4.2 shall be maintained to mitigate steady state gas accumulation.

Because of the possibility of a large spontaneous GRE in Facility Group 1 tanks, Ignition Source Control Set #2 (Section 4.3.2) shall be applied to the ex-tank and dome intrusive regions at all times. Additionally, continuing flammable gas monitoring as defined in Section 4.4 shall be in place for both the ex-tank and dome regions during ex-tank intrusive and dome intrusive manned work activities. These controls are aimed at managing the risk of ignition in the event of a large spontaneous or induced GRE that causes flammable gas conditions and pressurization of the dome region with resultant outflow of flammable gases to ex-tank regions.

Ignition Source Control Set #1 (Section 4.3.1) shall be applied to all waste intruding equipment during all Facility Group 1 tank activities. These waste intruding equipment controls can be relaxed if the waste intruding equipment is purged with inert gas, flushed with inert liquids, or if ignition sources are normally nonsparking and isolated from the waste environment. Continuing monitoring is required if the above controls cannot be met. Further, if concentrations exceed 25% of the LFL, immediate deenergization is required.

5.2 FACILITY GROUP TWO

Facility Group 2 tanks differ from Facility Group 1 in that they are postulated not to be subject to large spontaneous GREs. Therefore, the only large GREs in Facility Group 2 tanks postulated to occur are induced releases triggered by global waste disturbing operations. Because the likelihood of dome pressurization and outflow of gas to the ex-tank region is less than that for Facility Group 1 tanks, the ignition source controls can be relaxed to a certain degree.

During nonwaste disturbing and local waste disturbing operations, Ignition Source Control Set #2 (Section 4.3.2) shall apply to the dome space only because of the decreased likelihood of gas release outside of the dome region. Similarly, continuing gas monitoring (Section 4.4) is required only in the dome space during manned work activities. These are judged to be sufficient controls to mitigate any hazards posed by small spontaneous and induced GREs.

Global waste disturbing operations are postulated to be capable of triggering a large induced GRE that could pressurize the dome space and force flammable gases out of the tank into ex-tank regions. Therefore, for the duration of the global waste disturbing operation Ignition Control Set #2 shall be extended to the ex-tank region. Continuing monitoring is also required for these regions during manned activities. Upon completion of the global waste disturbing activity and verification that flammable conditions do not exist these ex-tank controls can be relaxed.

Ignition Source Control Set #1 (Section 4.3.1) shall be applied to all waste intruding equipment during all Facility Group 2 tank activities. In parallel with the application of this control set, continuing monitoring in accordance with Section 4.4 is required to ensure that flammable gases do not accumulate inside of tools and equipment. These waste intruding equipment controls may be relaxed if the waste intruding equipment is purged with inert gas flushed with inert liquids, or if ignition sources are normally nonsparking and isolated from the waste environment. Continuing monitoring is required if the above controls cannot be met. Further, if concentrations exceed 25% of the LFL, immediate deenergization is required.

Finally, ventilation controls as dictated by current IOSRs and OSDs shall be maintained in Facility Group 2 tanks to mitigate steady state gas accumulation (Section 4.2).

5.3 FACILITY GROUP THREE

Because Facility Group 3 tanks are only expected to be subject to small induced GREs, the control set is the least restrictive of all. No event expected to trigger a GRE of sufficient size to either pressurize the dome or cause flammable gas to exit the dome region. Therefore, the control set is limited to the dome and waste regions.

During nonwaste disturbing operations, Ignition Source Control Set #2 with the specific exceptions delineated in Section 4.4, shall apply for initial entry of the tank. After flammable gas concentrations are verified to be less than 25% of the LFL, the ignition source controls may be removed. Continuing gas monitoring is not required for nonwaste disturbing activities if the initial sample is below 25% of the LFL.

Any waste disturbing operation (either local or global) could trigger a small induced GRE in the dome. For this reason Ignition Source Control Set #2 shall be applied to the dome space for the duration of the waste disturbing activity. In addition, continuing monitoring is required in the dome space during manned, waste disturbing activity. Upon completion of the waste disturbing activity and verification that flammable conditions do not exist these dome space controls can be relaxed.

Ignition Source Control Set #1 (Section 4.3.1) shall be applied to all waste intruding equipment during all Facility Group 3 tank activities. These waste intruding equipment controls may be relaxed if the waste intruding equipment is purged with inert gas, flushed with inert liquids or the ignition sources are normally nonsparking and isolated from the waste environment. Continuing monitoring is required if the above controls cannot be met. Further, if concentrations exceed 25% of the LFL, immediate deenergization is required.

Finally, ventilation controls as dictated by current IOSRs and OSDs shall be maintained in Facility Group 3 tanks to mitigate steady state gas accumulation (Section 4.2).

These Facility Group control sets are summarized in Table 7.

5.4 NONTANK WASTE TRANSFER SYSTEM COMPONENTS

Miscellaneous transfer system components (e.g., transfer lines, valve pits, diversion boxes, process pits, transfer line clean out boxes) not directly connected to the waste tank vapor spaces are judged to pose a low flammable gas deflagration risk. The potential for flammable gases to exist in these transfer system components is limited to the accumulation of gas from chronic generation and release from contained waste and corrosion. Risk is further reduced by the practice of flushing lines after use. There is historical evidence the risk posed by this hazard is small. In addition, gas concentrations are monitored during entry to all vapor spaces (e.g., process pits) that might be connected to transfer lines. This gas monitoring provides verification that risk is low. It is judged that additional controls are not warranted at this time.

5.5 DOUBLE-CONTAINED RECEIVER TANKS

DCRTs are used as lag storage facilities for supernatant and interstitial liquids for SSTs which are being pumped to complete the interim stabilization process. DCRT 244-BX currently contains a sludge heel approximately 1.2 to 1.8 m (4 to 6 ft) deep, of unknown composition.

The DCRTs consist of a steel tank located within an underground concrete vault. Mechanical exhausters provide ventilation flow through the vault as well as providing suction to the tank. Inlet flow from the vault to the tanks is only provided through leak paths at instrument connections with the tank (except for 244-U which has a filtered inlet path). Ventilation flow is provided by instrument air injected into the tank at an estimated 0.4 m^3/hr (1.5 ft^3/hr) as part of the waste level "dip tube" operation. Gas generation rates from the waste temporarily stored in the DCRT are generally low enough that ventilation flow rates of a few cubic feet per hour are judged to be adequate for continued operations. The flammable gas controls for the DCRTs are as follows.

Variable: Tank Ventilation Flow

Control Requirement:

1. Verify that two of three waste level dip tubes are supplying inlet air when there is waste in the tank.

2. Assess gas generation rates prior to placing waste in the tanks to verify that they will not cause gas concentrations to exceed 25% of the LFL for the dip tube air being provided. The assessment shall consider, as a minimum, gas release because of (1) radiolysis, (2) organic decomposition, and (3) generation and evolution of ammonia.

Recovery Action: On a loss or reduction of dip tube air flow take the following actions:

1. Restore dip tube air flow within the available recovery action time (i.e., time calculated for concentration to increase from 25% of the LFL to 100% of LFL for the stored waste), or

2. Pump sufficient waste out within the allowed recovery action time to reduce the calculated gas generation rate so that less than 25% of the LFL can be maintained, or

3. Provide a known tank inlet path and verify the vault exhauster is operating.

If adequate ventilation cannot be reestablished within the allowed recovery action time, then monitor the tank gas concentrations. If concentrations are greater than 50% of the LFL, stop transfer into the DCRT, remove waste from the tank if practical, then deenergize installed equipment which does not meet IC Set 2 requirements.

Because DCRT 244-BX contains a waste sludge heel, dip-tube air flow is constantly maintained in this tank. On a loss or reduction of dip tube flow, recovery actions as stated above shall be performed. 244-BX has been gas sampled recently (Goheen 1996a) and the measured hydrogen concentrations were 0.0015 mole% (or 15 ppmv) which is well below 25% of the LFL.

Because of the limited storage time and small amount of solids stored in DCRT wastes, DCRTs are judged not to have significant GRE potential and therefore are not subject to GRE controls. However, Facility Group 3 controls shall be prudently applied to 244-BX because of the significant sludge heel of unknown composition. This will ensure that sludge disturbing operations, if performed, will consider the hazards posed by the potential release of gas retained in the sludge.

The DCRTs are shown in Table 8 along with the ventilation requirements and Facility Control Grouping.

5.6 244-AR VAULT LAG STORAGE TANKS

The 244-AR Vault facility is an inactive canyon building that was used to handle transfers and provide lag storage for wastes en route from the Plutonium-Uranium Extraction (PUREX) Facility to B Plant and wastes en route from B Plant and the Waste Encapsulation Storage Facility (WESF) to the Tank Farms. Additionally, the facility was utilized during waste sluicing/transfer operations from the A and AX-Farms. 244-AR includes 4 storage tanks (TK-001, TK-002, TK-003 and TK-004).

The best estimate of the tank contents, the required flammable gas related ventilation controls, and facility grouping is shown in Table 9. TK-002 contains 87,000 L (23,000 gal) of radioactive waste which includes 2,300 L (600 gal) of neutralized current acid waste sludge left from the sluicing/waste transfer operations in AX-Farm. The estimated TK-002 source term is 120,000 Ci from ^{137}Cs and ^{90}Sr. The other three tanks in this facility are believed to contain very dilute liquids from flushing operations and collected from facility sumps and therefore have little potential for gas generation.

A vessel vent system (K4) was provided to control hydrogen buildup and provide confinement for the storage tanks when the facility was active. Because this system has been inactive for several years, ventilation flow is provided by dip-tube air flow to all four tanks. Recent vapor space gas sample results for these tanks are listed in Table 9. TK-002 had the only nonzero concentration measured which indicated a hydrogen concentration of 2,200 ppm, or the equivalent of 5.5% of the LFL (0.222 vol % H_2). For this tank, 4.0 %vol hydrogen can be used for total flammable gas concentrations since the measured concentrations of methane and ammonia are less than 0.001 %vol. Based on these sampling results, it is judged that continued operation of dip-tube air is adequate to control flammable gases in TK-002 until the waste can be removed while TK-001, TK-003, and TK-004 are judged to be safe without dip-tube air purging.

TK-002 may contains a 2,300 L (600 gal) heel of sludge from AX-104 and is therefore prudently treated with Facility Group 3 controls to ensure that flammable gas controls mitigate the hazards posed by potential release of gas retained within the sludge during sludge disturbing operations. The flammable gas-related ventilation controls for TK-002, therefore, are as follows.

Variable: Tank Ventilation Flow

Control Requirement:

1. Verify that a dip tube is supplying inlet air 0.08 m^3/hr (3 ft^3/hr).

Recovery Action: On a loss of dip tube air flow take the following actions:

1. Restore dip tube air flow within the available recovery action time (i.e., time calculated for concentration to increase from 25% of the LFL to 100% of LFL for the stored waste), or if ventilation cannot be reestablished.

2. Monitor the tank gas concentrations. If concentrations greater than 50% of the LFL, deenergize installed equipment which does not meet IC Set 2 requirements.

5.7 INACTIVE MISCELLANEOUS UNDERGROUND STORAGE TANKS

TWRS has the responsibility to manage 36 inactive miscellaneous underground storage tanks (WHC-SD-WM-PD-046) that have been physically isolated for at least 10 years. Knowledge regarding the contents of these tanks ranges from adequate to unknown, but these tanks are all suspected of containing radioactive wastes. Because many of the IMUSTs contain wastes similar in composition to waste in the SSTs, it is postulated that flammable gas behavior (gas generation, retention and release) is analogous to that in SSTs but on a much smaller scale because of the small amount of waste present.

Because of the inactive and sealed condition of the IMUSTs, even slow gas generation rates can create potentially hazardous flammable gas accumulation over a long period of time. The gas generation rates, seal quality, and any possible passive ventilation rates provided to the IMUSTs is unknown. Therefore this JCO imposes flammable gas ignition source and work activity monitoring controls for these facilities required by the Facility Group control set assigned in Table 10. The requirements for each Facility Group are shown in Table 7.

The IMUSTs have been evaluated for flammable gas generation and accumulation rate previously (Powers 1995) to obtain rough estimates of gas generation based on the radiolysis of water given the best available information regarding ^{137}Cs and ^{90}Sr inventories and the assumption of a completely sealed tank. Based on this estimate the IMUST was assigned a flammable gas relative hazard ranking as defined in Table 10. These rankings are provided for information purposes only and are not used to establish JCO flammable gas control requirements. Actual gas samples taken from three of the IMUSTs (241-C-301C, 241-TY-302A, 241-TY-302B) have all indicated flammable gas concentrations of less than 1% of the LFL.

The Facility Group control sets were assigned based on the amount of waste solids and overlying supernatant known or suspected to be contained within the tank. IMUSTs with significant solids but little supernatant (less than 378.5 L (100 gal) or less than 1% of the tank capacity) were assigned to Facility Group 3. Conversely, those IMUSTs with significant solids and a large supernatant layer were assigned to Facility Group 2. If the waste solid and liquid volumes of an IMUST were unknown, the tank was assigned to Facility Group 2 as a prudent measure until better waste contents knowledge is obtained. A Group 2 assignment to these tanks is judged to be conservative because the IMUSTs, in general, have been interim stabilized by removing as much liquid as technically and economically practical. Because it is unlikely that a significant supernatant exists in these tanks, a spontaneous GRE is judged to be very unlikely. Finally, those IMUSTs containing mostly liquids but only a small amount of solids (less than 378.5 L [100 gal]) are judged not to warrant GRE controls.

The IMUSTs generally do not have energized equipment installed, so the potential for ignition sources is judged to be very low. Liquid levels are monitored in four tanks: two tanks (241-A-302B and 241-TX-302B) are monitored for liquid level using a manual tape while two tanks (240-S-302 and 241-S-302A) are monitored with FIC level detectors in the intrusion mode. These level measurement systems meet Ignition Source Control Set #2 requirements.

5.8 CATCH TANKS

Catch Tanks are underground storage tanks used to collect small amounts of waste from diversions boxes, valve pits, and other waste transfer system equipment. Newer catch tanks are contained within concrete vaults which provide secondary containment while older catch tanks are buried directly in the ground. Generally, catch tanks are located below pits that contain pumps and leak detection equipment.

Ventilation is provided by tie-ins to tank ventilation systems, passive ventilation via breather filters, and/or passive ventilation through cracks in tank connections and pit cover blocks. Exact ventilation performance in each catch tank is difficult to quantify because of a lack of instrumentation. Furthermore, these tanks utilize manual tape, FIC or ENRAF level measuring devices rather than dip tubes so purge air is not provided to the catch tanks.

Because of the small amounts of waste solids stored in the catch tanks, not even small induced gas release events are postulated for these tanks. The flammable gas hazard for these tanks is thus limited to steady state release and accumulation. Therefore, unless adequate ventilation is verified, including gas sampling, the control strategy for catch tanks in this JCO is verification that equipment in the vapor spaces connected to the catch tanks meets the requirements of Ignition Source Control Set #2 (Section 4.3.2). Additionally, catch tanks shall be verified to be less than 25% of the LFL during work activities using standard work entry controls. Ignition source controls are only applied during work entry until flammable gas concentrations are verified to less than 25% of the LFL.

The catch tanks addressed in this JCO are listed in Table 11 along with the flammable gas control requirements.

5.9 242-S AND 242-T EVAPORATORS

5.9.1 242-S Evaporator

The 242-S Evaporator facility was placed in a shutdown/standby condition in 1985 as documented WHC-SD-WM-SSP-002. The facility was flushed and radioactive liquids removed. Water flushing of the aqueous makeup (AMU) tanks, feed and slurry lines, acid addition lines, tank C-100 and evaporator vessel CA1 was performed along with blanking the lines.

Additionally a "Fire Hazards Analysis for the 242-S Evaporator" WHC-SD-WM-FHA-022 was issued in July of 1996 which did a facility walkdown and found no reservoirs exceeding 3.7 L (1 gal) containing solely flammable or combustible liquids in the process areas.

Because of the inactive status of this facility additional controls beyond those required for normal industrial hazards are not needed.

5.9.2 242-T Evaporator

Operations in the process areas of 242-T Evaporator were discontinued in November of 1980. Document WHC-SD-HS-SAR-009, "242-T Evaporator Facility Shutdown/Standby to Condition V Safety Analysis Report" was issued to maintain the facility process areas in a safe shutdown mode until decommissioning work is initiated.

Facility records indicate that the drain and transfer lines from the facility have been cut and capped isolating the facility from any SST, DST or DCRT, but fail to describe the flushing or waste removal from the process tanks.

Hydrogen can arise from the corrosion of iron, as well as the radiolytic degradation of water and organics such as tributyl phosphate. However, hydrogen generation in aqueous solutions low in fission products, such as Plutonium Finishing Plant waste (the type of waste last received through the process tanks), is expected to be slow. This along with the fact that the evaporator tanks are passively ventilated, argues for a low hydrogen concentration.

Due to the uncertainties of the amount of residual waste remaining, it appears prudent that this JCO impose flammable gas ignition source and work activity monitoring controls for the blend tank (TK-B1) and the evaporator vessel in 242-T. Equipment installed in these tanks must meet Ignition Control Set #2 requirements or be deenergized and entry monitoring must be performed prior to performance of any work activities. These controls are justified based on the type of waste and how the waste was processed through these tanks.

6.0 JUSTIFICATION FOR CONTINUED OPERATIONS AND RESIDUAL RISK FROM CONDITIONS, OPERATIONS, AND ACTIVITIES IN FACILITIES INVOLVING THE FLAMMABLE GAS UNREVIEWED SAFETY QUESTION

6.1 EFFECTIVENESS OF CONTROLS FOR MANAGING THE RISK POSED BY FLAMMABLE GASES

The control strategy for flammable gas is three pronged: ventilation, ignition sources, and monitoring. Ventilation controls limit the risk of flammable gas accumulation by removing continuously evolved gases (i.e., steady state) and diluting gas release events. Monitoring flammable gas levels validates ventilation effectiveness and provides a basis for managing the risks posed by tank intrusive activities. In the event that flammable gas concentration exceeds the LFL, strict control of ignition sources introduced into intrusive environments limits the risk of igniting flammable gas mixtures.

6.1.1 Effectiveness of Ventilation

Control of Flammable Gases Released in a Steady State Manner. For purposes of this JCO, limited tank vapor space data is judged to infer that current ventilation procedures are generally effective to manage the risk of steady state flammable gas accumulation in the waste storage tanks. Actual measurements documented for 73% of the tanks and taken as part of vapor space characterization and flammable gas monitoring have all indicted that concentrations are well below flammable levels. Therefore, this JCO continues the current practices related to tank ventilation. The longer term effort to upgrade the Authorization Basis with respect to management of flammable gas hazards will benefit from additional vapor space sampling and quantitative bases for ventilation performance requirements.

The ventilation provided to the DCRTs by the vault ventilation system has not been verified to be adequate. Therefore, these tanks are now required to be purged with instrument air. Sample data for 244-BX indicates that instrument air purge is adequate for the sludge contained in this tank. The adequacy of instrument air purge will be verified prior to placing waste in the other DCRTs.

Instrument air purge of 244-AR TK-002 is now required and has been verified through sampling to be adequate. TK-001, TK-003, and TK-004 have been sampled for flammable gas concentration and judged not to require air purges.

Gas Release Events. During large GREs the ventilation rate through the tank has little effect on the peak concentration. Because the vapor spaces are generally quite large (850 to 2,830 m^3 [30,000 to 100,000 ft^3]) compared to even active ventilation rates (typically 0.85 to 5.7 m^3/min [30 to 200 ft^3/min]), the ventilation effects on the concentrations in the tank vapor space just following a GRE are not dramatic; however, increased ventilation rates can shorten the "time at risk" above the LFL. For releases that can cause concentrations that significantly exceed the LFL, the time at risk could easily exceed several hours, even with high ventilation rates (LANL 1996).

Ventilation controls cannot guarantee maintaining concentrations below the LFL during GRE scenarios. Ventilation system modifications and controls directly aimed at reducing the risk from GREs (i.e., tank vacuum levels, flow rates, mixing effects) are not included as part of this JCO. Refinements to ventilation controls are being developed as part of the final safety analysis report (FSAR)/technical safety requirement effort.

For GRE events, deflagration and combustion are prevented by controlling ignition sources through equipment design and properly monitoring vapor space concentrations during work activities. The controls described in this JCO provide these defensive measures.

6.1.2 Effectiveness of Ignition Source Controls

In the event that flammable gas concentrations accumulate above the LFL, the primary defense against the flammable gas hazard is the strict control of ignition sources. While such controls cannot eliminate all possible ignition sources, the controls selected meet the intent of industry standards while allowing continued tank farm operations and prudent use of TWRS resources.

Ignition source controls include modifications to installed electrical equipment, control of electro-static sparks, use of spark resistant materials for tools and equipment, use of nonsparking or intrinsically safe or purged equipment, and/or immediately placing the equipment in a "reduced ignition source potential mode" (e.g., de-energizing electrical circuits, stopping insertion or removal of equipment) as soon as a hazardous condition develops.

Installed electrical equipment - Most of the electrical equipment installed in the tanks and connected vapor spaces was in existence prior to the flammable gas USQ determinations. While the majority of equipment has been deemed adequate, some electrical equipment must be either replaced or modified to adequately manage the risk from flammable gases while allowing important waste management functions to continue.

Control of electrostatic sparks - Electrically conductive objects are bonded as per NFPA 77 (1993) during intrusive work, except ex-tank intrusive work, on lines that are less than 2.54-cm (1-in.) in diameter. The 2.54-cm (1-in.) diameter line is chosen to exclude most instrument tubing or small piping used on these tanks from bonding, but to include all gasketed flanges. This is justified because bonding is done to minimize static electrical buildup and discharge. The potential for static buildup on a screwed fittings should be less than for a flanged fitting, where there is a gasket in between the flange and the riser and where electrical contact may not be adequate through the bolts. A resistance of less than 1 megohm (required by NFPA 77 (1993) for static bonding) between the nut and the tubing is realistic for small screwed fitting in the service seen in tanks farms. Most screwed fittings will only be removed for a short period of time, which will minimize the time for static to build up on a removed fitting. For screwed fittings, the chance of a wrench causing a spark against a fitting while there is an opening to the tank vapor space is negligible.

The use of nonconductive materials for temporary activities, specifically plastic glove bags used over open risers or greenhouses is continuing, provided that constant (or nearly constant) monitoring is provided (if required by the material location and the tank's assigned Facility Grouping) and insertion and removal of this material is stopped if monitored concentrations reach 25% of the LFL or other workarounds are evaluated to be acceptable as described in Section 4.3. These glove bags and greenhouses are used to provide containment of contamination during sampling or equipment installation/removal. The use of replacement materials that are suitable for the containment function but minimize the buildup of static charge or dissipate any such charge is being investigated. Such material will be used if a suitable material can be located and the risk reduction benefits warrant the additional costs.

Spark Resistant Materials - Spark resistant materials are used for tools and some equipment used in an intrusive manner to reduce the likelihood of mechanical "impact sparks" and "thermite reactions". The use of such materials is not always practical (e.g., existing T/C trees, auger guide tubes, core drill strings). The use of nonspark resistant materials is justified provided that compensatory measures are provided to reduce the likelihood of creating mechanical sparks when and where flammable conditions might exist. Compensatory measures can include providing restraints to prevent dropping equipment, slow insertion and removal rates through risers, riser sleeves made of spark resistant materials, wetting down of risers during equipment insertion and removal.

Electrical equipment used during intrusive work - Equipment containing energized circuits that can come in contact with gases potentially above the LFL must be qualified as specified in Section 4.3.

Exceptions to NFPA design requirements are allowed under certain circumstances if the exception is judged to be prudent and compensatory measures are judged to be adequate. Compensatory measures include a requirement for constant monitoring or nearly constant monitoring (i.e., use of installed monitor, such as SHMS or measurement using a portable monitor at least every 15 minutes) to detect the onset of potentially flammable conditions and de-energizing electrical circuits, if concentrations exceed 25% of the LFL. Such exceptions are allowed if the equipment is located sufficiently away from gas release points to allow adequate time to detect the onset of flammable conditions and de-energize electrical circuits.

6.1.3 Effectiveness of Monitoring Controls

Flammable gas monitoring is the third aspect of the flammable gas control strategy. Prior to and during the performance of intrusive work, the vapor space is monitored for flammable gases in the environment where the work (or possible ignition sources) is located (i.e., in the pits, ventilation systems, the risers, and in the tank headspace). Under all circumstances, work shall immediately halt if flammable gas concentrations exceed 25% of the LFL.

Monitoring may be conducted using either CGM, SHMS, or installed combustible gas monitors. Consideration was given to a requirement for using continuing monitoring (SHMS) exclusively or even the use of two redundant continuous monitors. However, at the present time this was not judged to be warranted because the JCO provided ignition source controls as the primary defense against deflagrations. Monitoring is used as an additional control feature when there are workers in the vicinity. It is the premise of the JCO that it is not prudent to continue manned work if 25% of the LFL has been exceeded even though equipment ignition source control requirements are met. Installed, qualified equipment may be allowed to continue to operate (i.e., not be deenergized) if above 25% of the LFL.

6.2 UNCERTAINTIES AND RESIDUAL RISK

6.2.1 Tank Flammable Gas Categorization and Grading of Controls

The sorting of TWRS-managed tanks into three facility groups allows consistent application of control sets for similarly situated tanks providing a practical degree of consistency in controls. This method also permits the relaxation of controls to the maximum extent possible given the existing uncertainties in tank conditions and tank flammable gas hazards phenomena.

While the methodology used to estimate gas release volumes admittedly possesses some weaknesses, it is the only methodology currently available and will continue to be used (albeit cautiously) until a better methodology is developed. All errors associated with the underlying assumptions and calculation tend to be overly conservative thus not affecting safety. The use of the methodology in this JCO is limited to distinguishing Facility Group 2 and 3 SSTs. The flammable gas topical reports associated with the Basis of Interim Operation and FSAR are expected to address this issue more fully.

The risks associated with relaxing the controls on DCRTs, IMUSTs, catch tanks, and 244-AR relative to Facility Group 3 are judged to be small. These miscellaneous tanks generally contain very little waste solids and thus are not estimated to retain flammable gases in the waste matrix. Whenever a particular tank in this group is proven to contain a substantial quantity of waste solids, Facility Group 3 controls are applied to that particular tank.

6.2.2 Risk From Natural Phenomena

The risks of a flammable gas deflagration resulting from natural phenomena such as lightning and seismic events are under investigation as part of the TWRS FSAR upgrade effort.

6.2.2.1 Lightning. The lightning hazard has recently been addressed in WHC-SD-WM-ES-387, *Probability, Consequences and Mitigation for Lightning Strikes to Hanford Site High-Level Waste Tanks*. This analysis determined that it is not possible to demonstrate quantitatively that an unacceptable lightning-caused combustion (organic-nitrate, organic solvent, flammable gas) event is not credible. The lightning strike probability evaluation indicates the possibility of a strike within the tank farms within the remaining duration of the waste storage mission. The qualitative factors that are known, however, support the conclusion that the likelihood of igniting the waste is low. However, because of the uncertainty associated with this analysis, it has been concluded that it is appropriate to provide additional mitigation for the tank farms. It is planned to install lightning arresters on existing poles in the tank farms, and to better ground tank risers which have high riser-to-ground resistance measurements. These measures are expected to provide a reduced risk from lightning ignition of flammable gases and an acceptable basis for continued operation.

6.2.2.2 Seismic Events. The risk posed by seismic events is uncertain. A concern is for a common cause scenario where the seismic event induces a GRE while causing a spark within the dome space. Currently no near-term controls for such a scenario have been identified. The benefits of possible mitigation actions for such a scenario need to be evaluated and weighed against the penalties (i.e., possible loss of tank monitoring, waste management capability such as interim stabilization and transfer capability, etc.) before implementation.

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Figure 1. Tank 241-AN-103 Hydrogen Concentration.

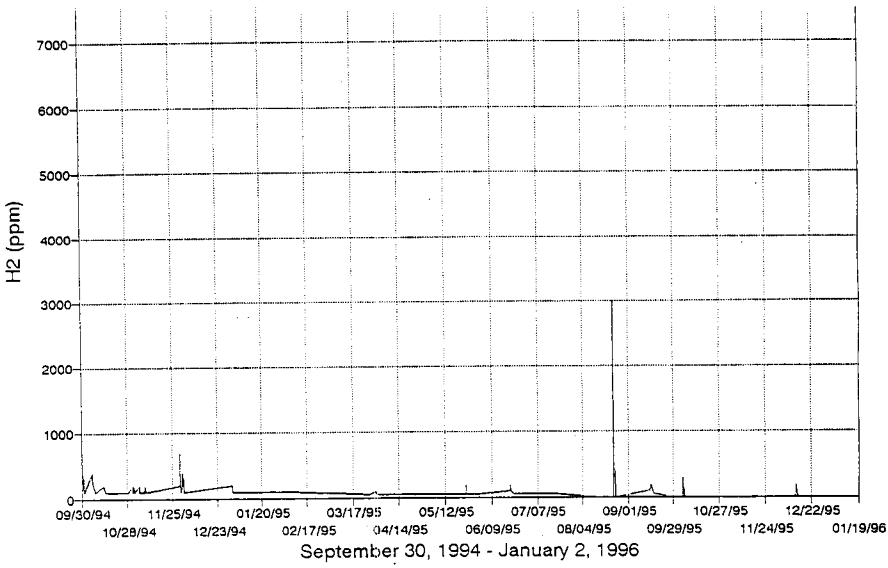

Figure 2. Tank 241-AN-104 Hydrogen Concentration (GC).

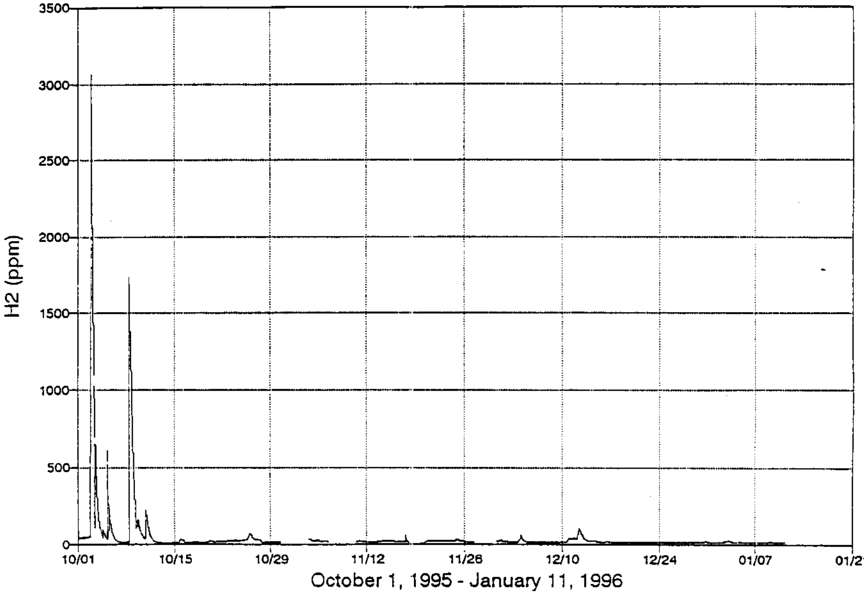

Figure 3. Tank 241-AN-104 Surface Level.

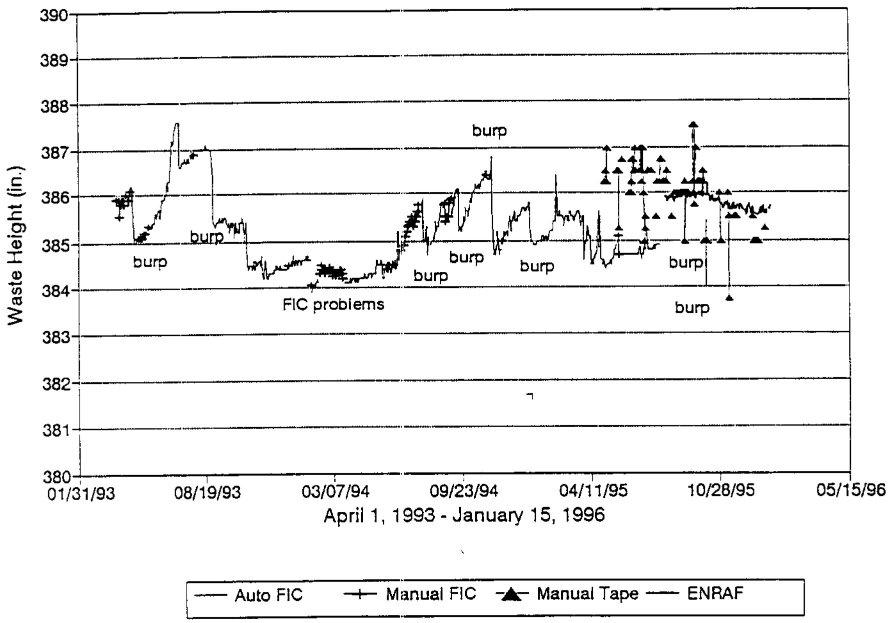

Figure 4. Tank 241-AN-105 Hydrogen Concentration.

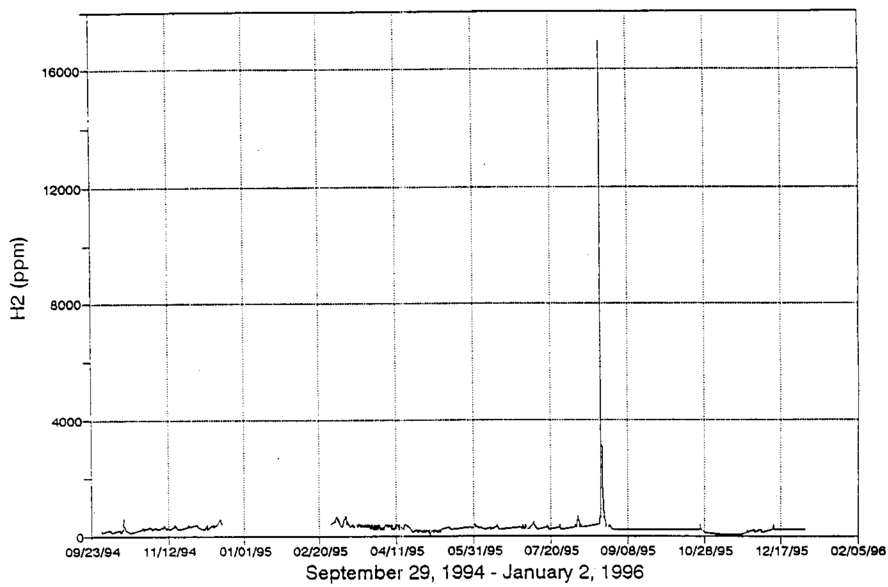

Figure 5. Tank 241-AN-105 Surface Level.

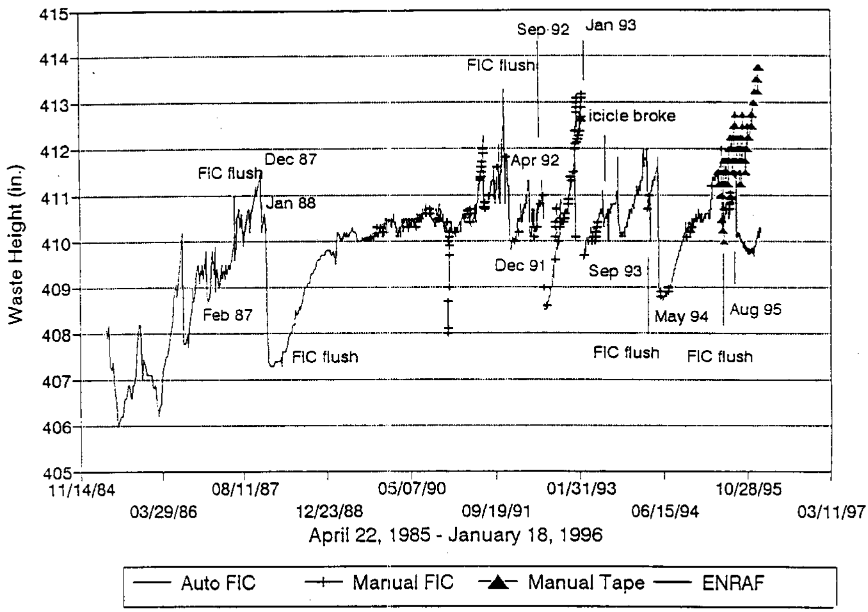

Figure 6. Tank 241-AW-101 Hydrogen Concentration.

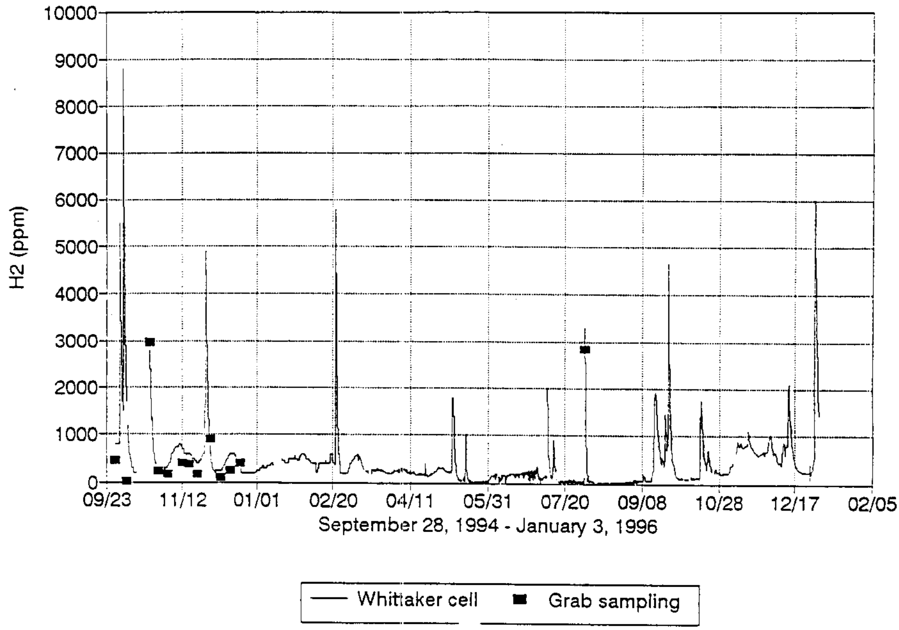

Figure 7. Tank 241-AW-101 Surface Level.

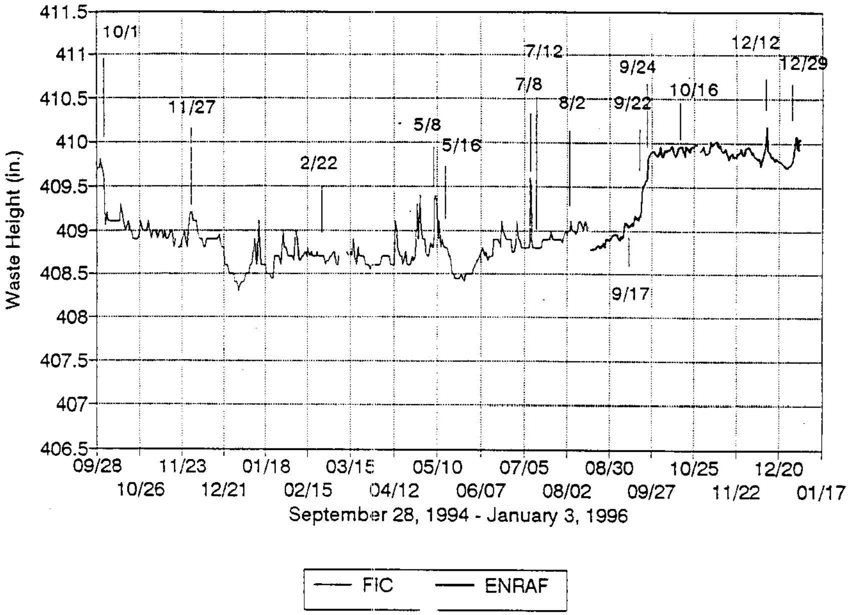

Figure 8. Tank 241-SY-103 Hydrogen Concentration.

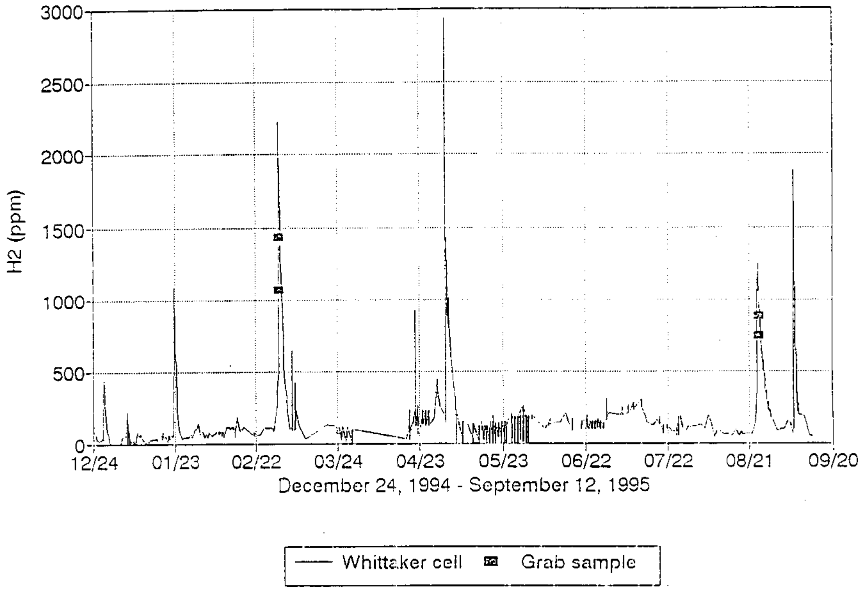

Figure 9. Tank 241-SY-103 Surface Level.

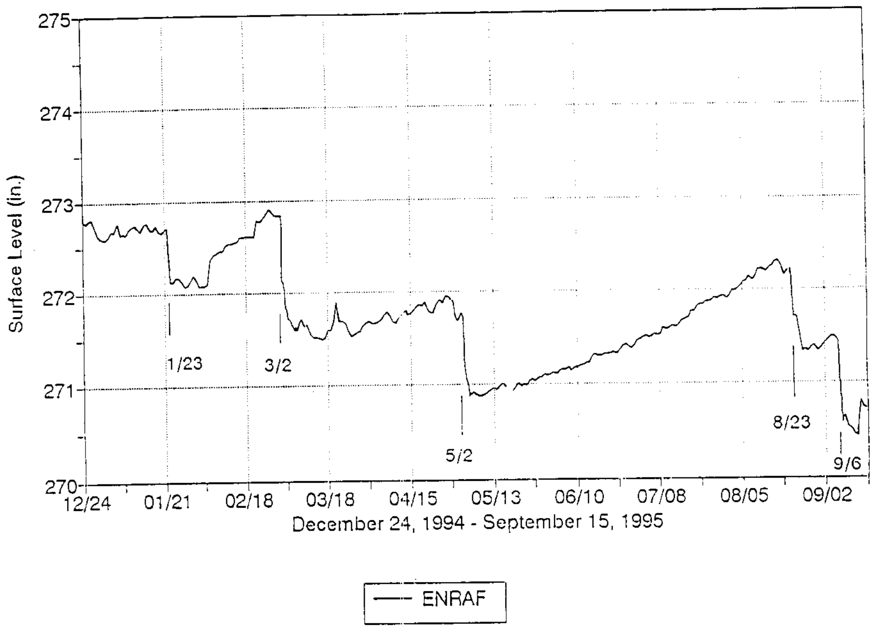

Figure 10. Tank 241-BY-103 Standard Hydrogen Monitoring System Data.

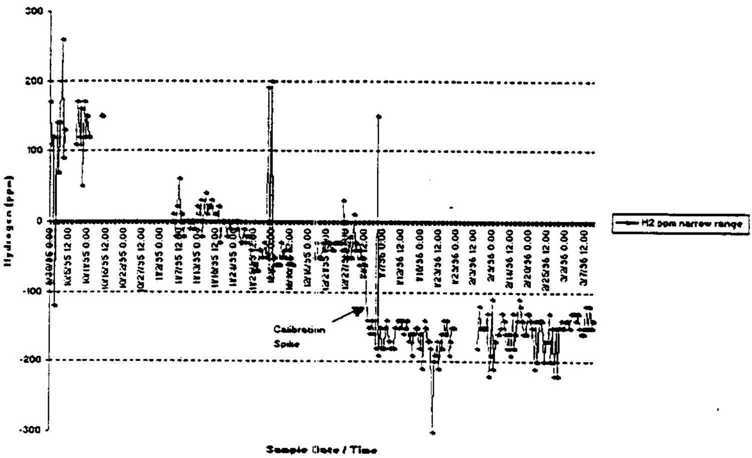

Figure 11. Tank 241-BY-106 Standard Hydrogen Monitoring System Data.

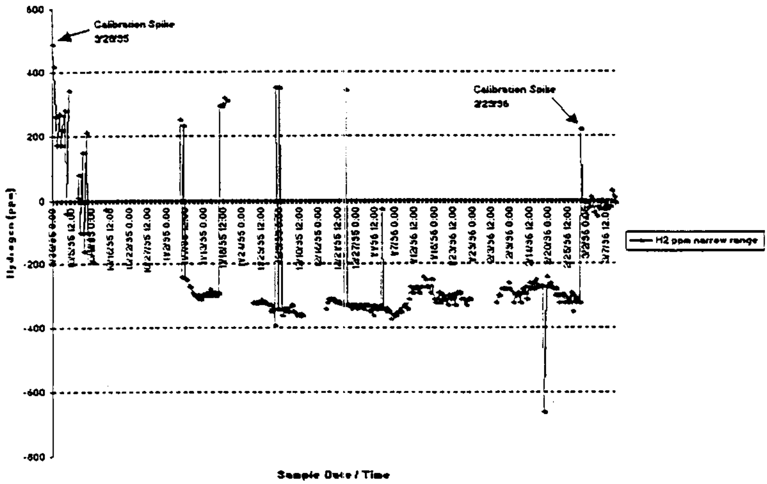

Figure 12. Tank 241-BY-109 Standard Hydrogen Monitoring System Data.

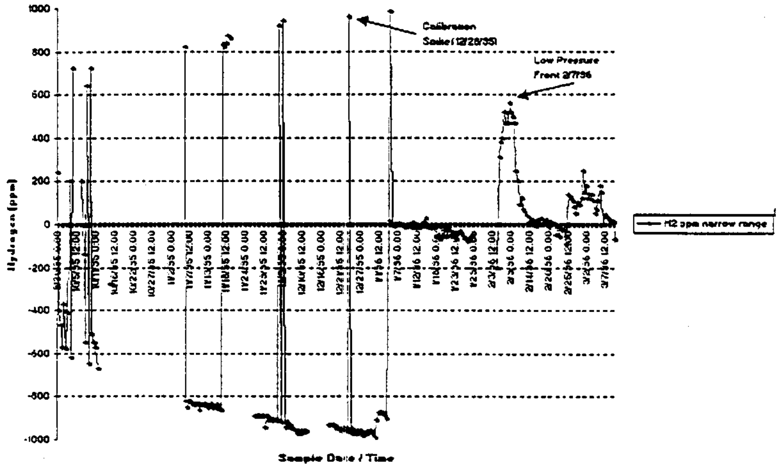

Figure 13. Tank 241-S-102 Standard Hydrogen Monitoring System Data.

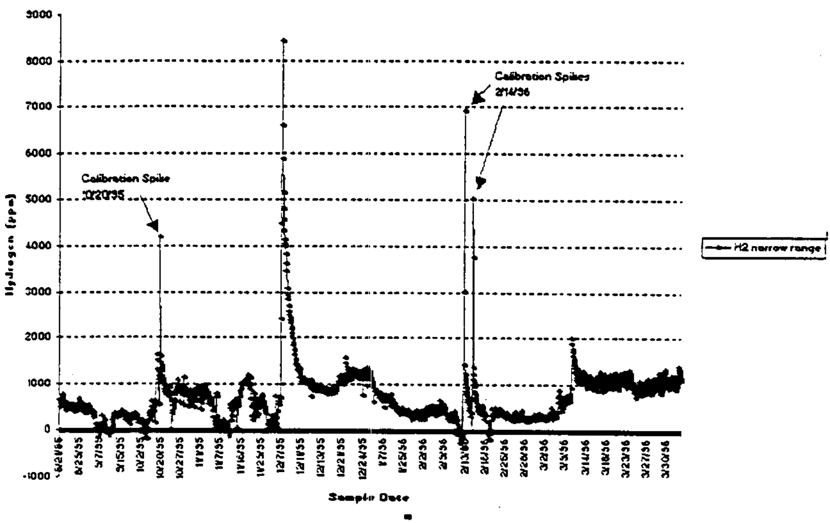

Figure 14. Tank 241-S-111 Standard Hydrogen Monitoring System Data.

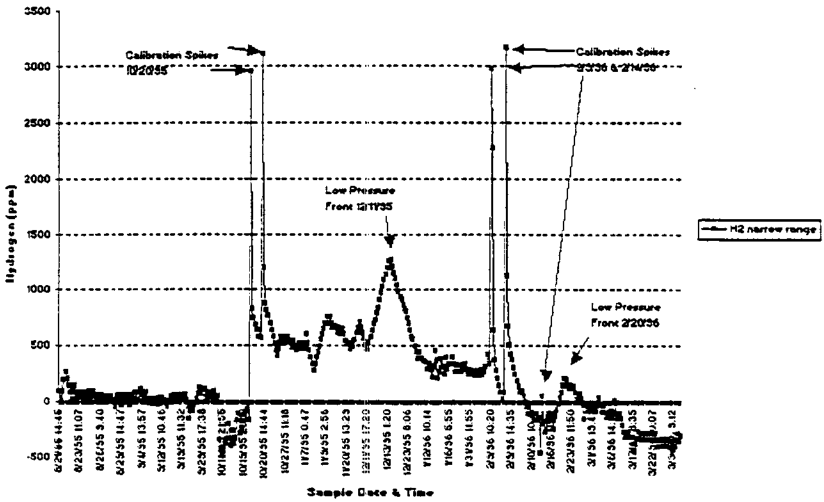

Figure 15. Tank 241-S-112 Standard Hydrogen Monitoring System Data.

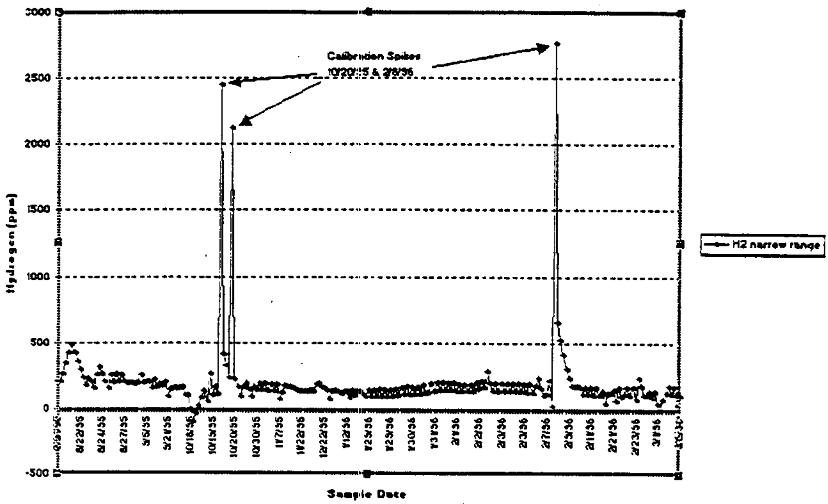

Figure 16. Tank 241-SX-101 Standard Hydrogen Monitoring System Data.

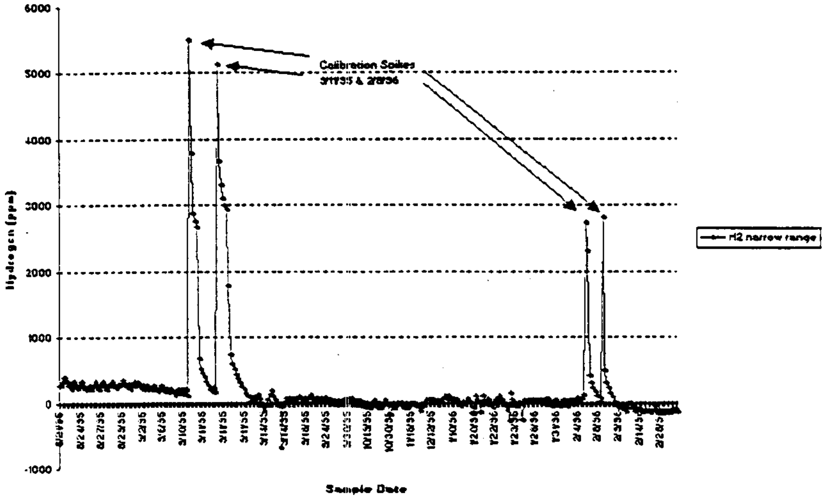

Figure 18. Tank 241-SX-103 Standard Hydrogen Monitoring System Data.

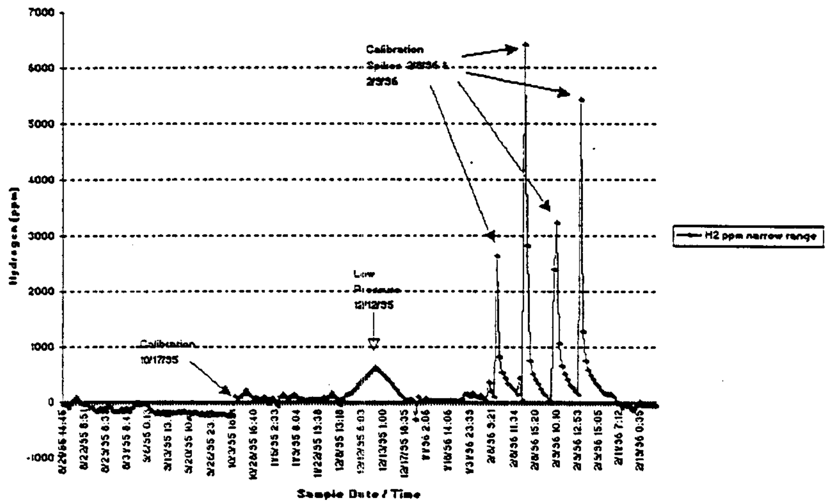

Figure 19. Tank 241-SX-104 Standard Hydrogen Monitoring System Data.

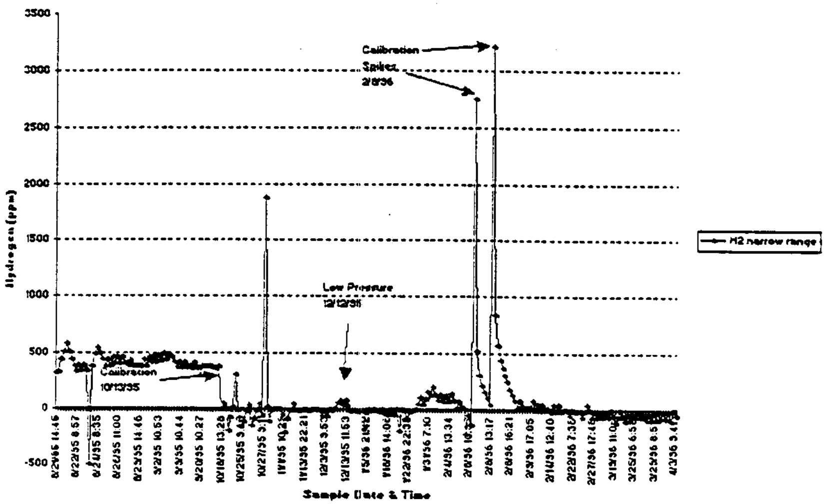

Figure 20. Tank 241-SX-105 Standard Hydrogen Monitoring System Data.

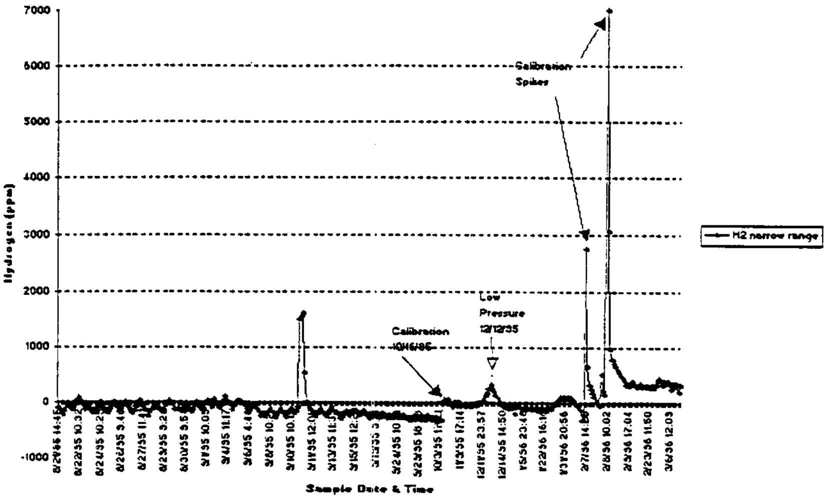

Figure 21. Tank 241-SX-106 Standard Hydrogen Monitoring System Data.

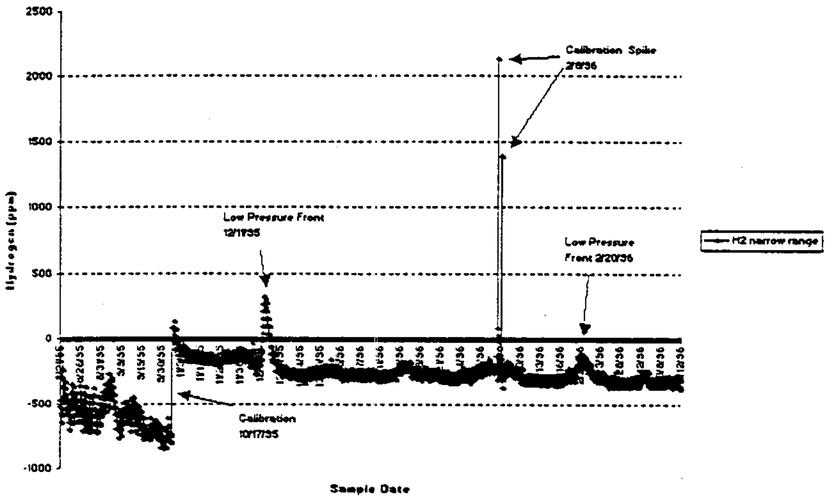

Figure 22. Tank 241-SX-109 Standard Hydrogen Monitoring System Data.

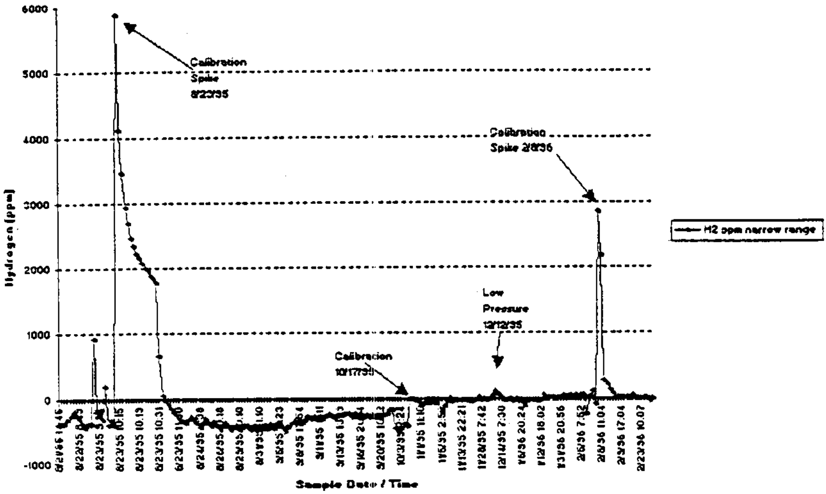

Figure 23. Tank 241-U-103 Standard Hydrogen Monitoring System Data.

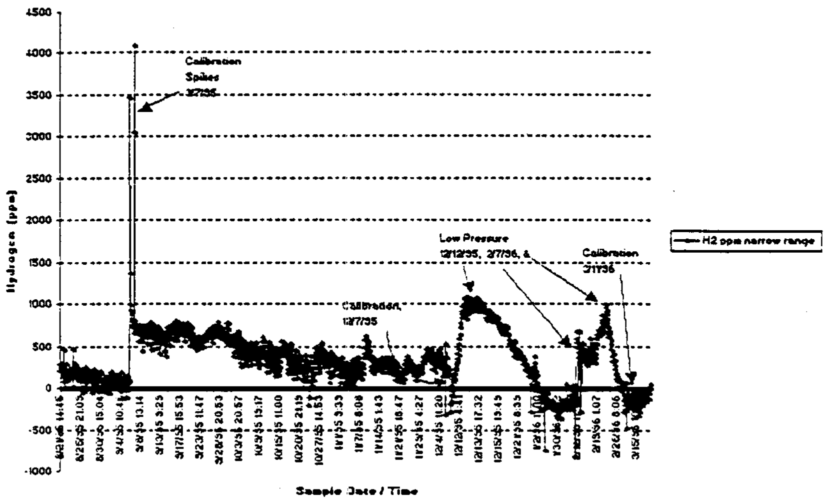

Figure 24. Tank 241-U-105 Standard Hydrogen Monitoring System Data.

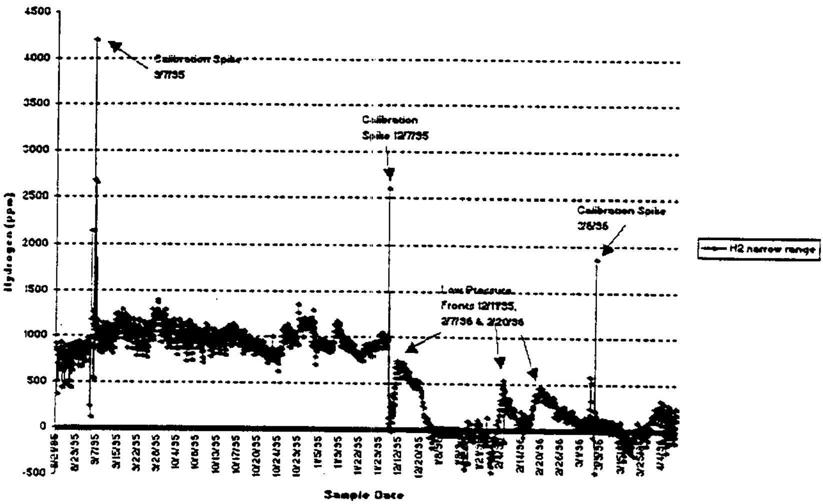

Figure 25. Tank 241-U-107 Standard Hydrogen Monitoring System Data.

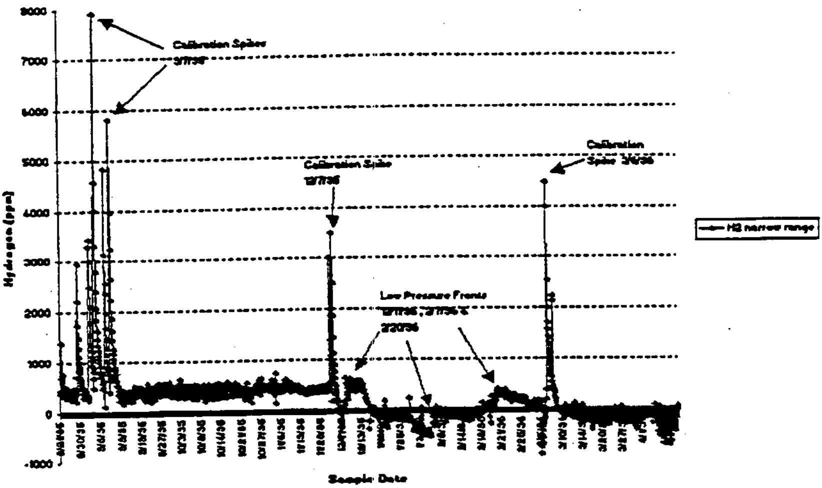

Figure 26. Tank 241-U-108 Standard Hydrogen Monitoring System Data.

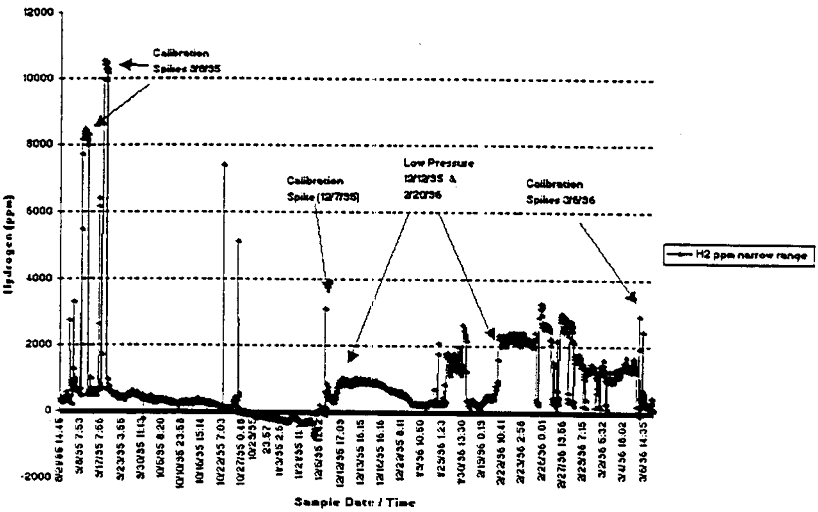

Figure 27. Tank 241-U-109 Standard Hydrogen Monitoring System Data.

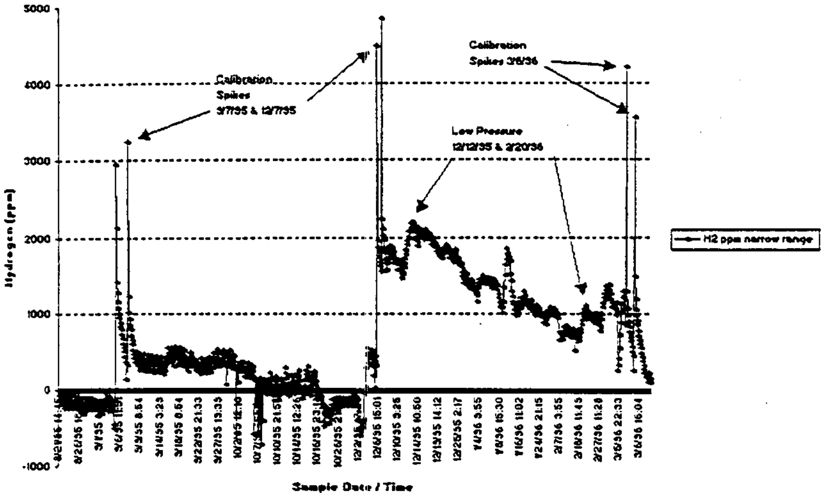

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Table 1. Summary of Gas Release Measurements for Six Instrumented Double-Shell Tanks.

Tank	Maximum measured H_2 concentration	When maximum was measured	Observed release periodicity	Release data	Predicted concentration following acute release (Hodgson 1996)
AN-103	3,000 ppm (10% LFL[1])	8/22/95	Once since 10/94	H_2 Conc. - Fig. 1	334% LFL (SLR[2]) 301% LFL (BPE[3])
AN-104	5,000 ppm (17% LFL)	10/8/95	Every 3-5 months	H_2 Conc. - Fig. 2 Surface Level - Fig. 3	505% LFL (SLR) 246% LFL (BPE)
AN-105	17,000 ppm (57% LFL)	8/21/95	Sporadic. 15 months between last two events	H_2 Conc. - Fig. 4 Surface Level - Fig. 5	743% LFL (SLR) 411% LFL (BPE)
AW-101	8,800 ppm (29% LFL)	10/94	About every 2 months	H_2 Conc. - Fig. 6 Surface Level - Fig. 7	231% LFL (SLR) 233% LFL (BPE)
SY-101	53,000 ppm (177% LFL) 51,200 ppm (174% LFL)	12/4/91 9/3/92	Every 3-4 months (none since mixer pump installation)	Table 2	825% LFL (SLR) 572% LFL (BPE)
SY-103	2,900 ppm (10% LFL)	5/95	About every 2 months	H_2 Conc. - Fig. 8 Surface Level - Fig. 9	79% LFL (SLR) 57% LFL (BPE)

[1]LFL - Value shown is based on the use of 30,000 ppm of H_2 being measured when the tank headspace reaches the LFL (see Section 3.2.1.5).
[2]SLR - Tank headspace concentration (as a percent of LFL) predicted using the surface level rise (SLR) methodology (Hodgson 1996).
[3]BPE - Tank headspace concentration (as percent of LFL) using the barometric pressure evaluation (BPE) methodology (Hodgson 1996).
DST = double-shell tank.

Table 2. A Comparison of Gas Release Events for SY-101.

Event date	08/27/91	12/04/91	04/20/92	09/03/92	02/02/93	06/26/93
Event start time	0933	1116	2002	1661	0124	1904
Days since event	102	99	138	136	152	144
S.L. drop. (in.[a])	5.5A	13.0M	7.2R	13.2R	8.5 (FIC)	9.75M
Estimated slurry-gas (ft^3)[b]	4043[b]	2565[b]	4600[c]	10480[f]	6500[f]	7000[b]
Estimated H_2 volume (ft^3)[c]	NA	2883[c] 1078[d]	1530[c]	3773	2340	3200
Maximum tank pressure (in w.g.)	-2.82	+6.84	-2.0	+5.37	-0.079	-0.93
Maximum exhaust flow (cfm)	550	1300	675	2125	1170	1512
Maximum H_2 concentration exhaust in (vol%)						
Whittaker	NA	NA	NA	NA	2.25	2.77
Teledyne	0.51	2.69	1.34	0.82	NA	NA
Chromatograph	NA	NA	NA	ND	0.21	3.4
Grab M.S.	NA	2.17	1.18	NA	NA	NA
Maximum H_2 concentration riser in 17B. (vol%)						
Wittaker	0.38	5.30	1.36	5.12	2.74	2.73
Cont. M.S.	0.28	08[e]	1.48	3.51	2.06	3.12
Grab M.S.	NA	NA	O/S	NA	NA	NA
Maximum N_2O concentration exhaust (vol%)						
Chromatograph	NA	NA	1.05	ND	NA	NA
Grab M.S.	NA	1.87	1.09	NA	NA	NA
FTIR	NA	NA	NA	NA	O/S	3.25
Maximum NH_3 concentration (ppm)						
OVM	NA	438	1507	1060	NA	NA
FTIR	NA	NA	NA	NA	NA	13,000

[a]A = Automatic FIC, M = Manual Tape, R = Radar.
[b]Using 736 ft^3/in. assuming the gas is under a pressure of 2 atmospheres.
[c]Using integrated Whittaker H_2 concentration and average exhaust flow.
[d]Using integrated Teledyne H_2 concentration and integrated exhaust flow.
[e]ND = not detected, NA = not available, OS = out of service.
[f]Using the method outlined in Internal Memo 7K210-93-502 (Reynolds).

Table 3. Summary of Gas Release Measurements for Instrumented Single-Shell Tanks.

Tank	Maximum H_2 concentration change	Date maximum release occurred	Periodicity	Gas release data (SHMS)	Predicted concentration following acute release (Hodgson 1996)
BY-103	No release evident	--	--	Fig 10	0% LFL (SLR[1]) 26% LFL (BPE[2])
BY-106	1060 ppm (grab sample)	9/22/95	None evident	Fig 11	123% LFL (SLR) nc[3] (BPE)
BY-109	790 ppm	2/7/96 (LPF[4])	None evident	Fig 12	0% LFL (SLR) 27% LFL (BPE)
S-102	1000 ppm	3/96	None evident	Fig 13	190% LFL (SLR) 226% LFL (BPE)
S-111	1750 ppm	12/11/95 (LPF)	None evident	Fig 14	80% FLF (SLR) 181% LFL (BPE)
S-112	No release evident	--	--	Fig 15	30% LFL (SLR) nc (BPE)
SX-101	No release evident	--	--	Fig 16	0% LFL (SLR) 28% LFL (BPE)
SX-102	No release evident	--	--	Fig 17	30% LFL (SLR) 93% LFL (BPE)
SX-103	700 ppm	12/11/95 (LPF)	None evident	Fig 18	2% LFL (SLR) 216% LFL (BPE)
SX-104	200 ppm	12/11/95 (LPF)	None evident	Fig 19	6% LFL (SLR) 11% LFL (BPE)
SX-105	400 ppm	12/11/95 (LPF)	None evident	Fig 20	87% LFL (SLR) nc (BPE)
SX-106	600 ppm	12/11/96 (LPF)	Small releases during LPFs	Fig 21	67% LFL (SLR) 78% LFL (BPE)
SX-109	200 ppm	12/11/95 (LPF)	None evident	Fig 22	0% LFL (SLR) nc (BPE)
U-103	1200 ppm	12/11/95 (LPF)	Small releases during LPFs	Fig 23	77% LFL (SLR) 161% LFL (BPE)
U-105	1000 ppm	2/7/96 (LPF)	Small releases during LPFs	Fig 24	270% LFL (SLR) 129% LFL (BPE)
U-107	600 ppm	12/11/95 (LPF)	Small releases during LPFs	Fig 25	42% LFL (SLR) 87% LFL (BPE)
U-108	1800 ppm	2/20/96 (LPF)	Small releases during LPFs	Fig 26	301% LFL (SLR) 179% LFL (BPE)
U-109	700 ppm	12/11/95 (LPF)	Small releases during LPFs	Fig 27	81% LFL (SLR) 118% LFL (BPE)

[1]SLR - Tank headspace concentration (as a percent of LFL) predicted using the surface level rise (SLR) methodology (Hodgson 1996).
[2]BPE - Tank headspace concentration (as percent of LFL) using the barometric pressure evaluation (BPE) methodology (Hodgson 1996).
[3]nc - Signifies that there was insufficient correlation between barometric pressure changes and waste level changes to use the methodology.
[4]LPF - Low pressure weather front.
SST = single-shell tank.

Table 4. Summary of Flammable Gas Controls Strategy.

FG Hazard	Control Strategy
Steady State Accumulation in Vapor Spaces	1. Dilution by ventilation, and 2. Gas monitoring (characterization sampling and work activity entry gas monitoring)
Accumulation in sealed risers and sealed pits	1. Ignition source controls (Set 2) at all times, and 2. Work activity entry gas monitoring
Ignition of FG retained within the waste	1. Ignition source controls (Set 1) at all times
Large spontaneous GREs	1. Ignition source controls (Set 2) in ex-tank and dome intrusive locations at all times, and 2. Continuing gas monitoring during work activity
Small spontaneous GREs	1. Ignition source controls (Set 2) for dome-intrusive locations at all times, and 2. Continuing gas monitoring during work activity
Large induced GREs	1. Ignition source controls (Set 2) in ex-tank and dome intrusive locations during waste disturbing operations and activities, and 2. Continuing gas monitoring during manned waste disturbing activities
Small induced GREs	1. Ignition source controls (Set 2) for dome intrusive locations during waste disturbing operations and activities, and 2. Continuing gas monitoring during manned waste disturbing activities
Accumulation in waste intruding equipment	1. Monitoring before energizing equipment inside the waste intruding equipment and continuing monitoring during use of equipment, or 2. Purge or flush prior to energizing equipment and during use of equipment, or 3. Ignition controls (Set 1) at all times

Table 5. Representative Tank Waste Remediation System Waste Management Operations and Activities. (2 sheets)

Representative Ex-Tank Intrusive Operations and Activities
• Vent and balance activities • Exhauster (maintenance/operations) • High-efficiency particulate air (HEPA) filter change out without primary tank isolation • De-entrainer pad change out • Operation of portable exhausters • Ventilation system modifications • Filter housing relocation • Filter inlet installation • Filter changing • Pit cover block/cover plate removal • Pit jumper setup and valve alignment for transfer • Pit leak detection • Pit activities • Gas sampling in pits and ventilation systems • Activities outside of open risers • Use of greenhouse/plastic sleeving around open risers • Drywell vans/on top of tanks, vehicle control* • Construction/tie-in activities*
Representative Dome Intrusive Operations and Activities
• Riser preps (asbestos removal) • Riser examination with high intensity lamp • Riser geometry measurements • Shield plug installation and removal • Swabbing risers for radiation readings • Flange work • Gauge plugs • Gas sampling with heated vapor probes • SHMS/GMS • Ammonia gas sampling • ENRAF/FIC/manual tape waste level measurements • Zip cord waste level measurements • ENRAF/FIC/manual tape repair, replacement, removal • DST high level detection and alarm • Use of camera, video, lights • Surface moisture monitoring system • Equipment removal (that is located in the dome space and not inserted below the waste surface) including retrieval devices and de-con • Water wands used to flush contamination from equipment in the tank dome space • Welding and grinding on the outside boundary or in a location where sparks or hot slag can enter the tank.

Table 5. Representative Tank Waste Remediation System Waste Management Operations and Activities. (2 sheets)

Representative Waste Disturbing Operations
Global Waste Disturbing Operations • Salt well pumping • Submersible pump operation • Emergency pumping of supernatant • Mixer pump operation • Transfer pump operation • Air lift circulator operation • Jet pump operation • Chemical additions • Large water additions • Waste addition/removal or transfers Locally Waste Disturbing Operations • Lancing • Hydraulic jetting (with ultra-high-pressure) • LOW installation • T/C tree installation • Salt well installation • MIT installation • Instrumentation Installation/Operation Void meter Viscometer Densitometer readings Sludge level (weight) measuring devices Penetrometer testing • Dip tube installation/operation/removal • Mixer installations • Transfer pump installation • Equipment removal if inserted below the waste surface, including retrieval devices and de-con Sludge weight removal Air lance removal Specific gravity probe removal LOW T/C tree MITs Pumps • Sampling Push mode core sampling Auger Grab Rotary mode core sampling

*Within 15 ft or 18 opening diameters from the tank opening, whichever is less.

Table 6. Ventilation Procedures Requirement.

Tank/Ventilation Configuration	IOSR or OSD Reference	Ventilation Parameter	Requirement
SSTs/Passively Ventilated (TO-OSD-T-151-00013)	13.2.2.D.2 Passive Ventilation	Passive breathing path	All SSTs shall be passively ventilated using HEPA breather filters even if active ventilation is temporarily installed
			Filter failure is checked by aerosol testing. Failed filters must be replaced within 7 days and the breather returned to service, or a cascaded path must be ensured.
	TF-or-WST-2 (Tank Farm Round Sheet)	Passive breathing path	Verify breather isolation valve is open weekly.
SST/Actively Ventilated	13.2.2.C - Active Ventilation Shutdown	Shutdown time	Tank Farm Engineering will determine the maximum time an active ventilation system can be shutdown. During this shutdown time, the passive HEPA breathers shall be operating.
DSTs/All are actively ventilated	SD-WM-SAR-016, Section 11.6	Tank Pressurization (tank vacuum is indication of ventilation operating)	Pressurization (e.g., ventilation system off) limited to 40 cumulative hours per 12 month period.
	(WHC-SD-WM-OSR-016, Rev. 0) LCO 3.3.2 - Primary Tank Pressure (partially implemented)	Primary tank pressure (vacuum) (indication of ventilation operating)	maintain pressure < 0 and ≥ -4 inches water gauge
	(WHC-SD-WM-OSR-016, Rev. 0) LCO 3.3.1 - Primary Tank Pressure Monitoring and Alarm System	Primary tank pressure (vacuum) (indication of ventilation operating)	Continuously monitored and alarmed or monitored every 2 hours manually)
AWF DSTs/All are actively ventilated	(WHC-SD-WM-OSR-004, Rev. 1) LCO 3.3.2 - Primary Tank Vapor Space Pressure (partially implemented)	Tank pressure (vacuum) (indication of ventilation operating)	Maintain pressure < 0 and ≥ -4 inches of water gauge
	(WHC-SD-WM-OSR-004, Rev. 1) LCO 3.3.1 - Primary Tank Pressure Monitoring and Alarm System	Tank pressure (vacuum) (indication of ventilation operating)	Continuously monitored and alarmed or monitored every 2 hours manually

Table 7. Facility Group Control Sets.

Facility Group	Affected Facilities	Postulated Gas Releases Which Drive Controls	Nonwaste Disturbing Operations	Locally Waste Disturbing Operations	Globally Waste Disturbing Operations	Waste Intruding Equipment
Group 1	AN-103, 104, 105 AW-101 SY-103	Large Spontaneous GREs, and Large Induced GREs, and Steady State releases at all times	IC Set 2 in ex-tank and dome intrusive locations at all times Continuing monitoring during manned activities for ex-tank and dome intrusive locations	Same as nonwaste disturbing	Same as nonwaste disturbing	Purge or Flush, OR IC Set 1 or Continuing Monitoring
Group 2	Balance of DSTs, SSTs: A-101, 103 B-201, 202 BX-107, BY-101, 102, 103, 105, 106, 109, C-104, S-101, 102, 103, 105, 106, 107, 109, 111, 112, SX-101, 102, 103, 105, 106, 109, T-110 201, 202, 204, TX-102, 111, 112, 113, 115, U-102, 103,105, 106, 107, 108, 109, 111	Small Spontaneous GREs, but Large Induced GREs, and Steady State releases at all times	IC Set 2 in dome intrusive locations only, but at all times Continuing monitoring during manned activities in dome intrusive locations only	Same as nonwaste disturbing	IC Set 2 in ex-tank and dome intrusive locations for duration of waste disturbance Continuing monitoring during manned work activities in ex-tank and dome intrusive locations for duration of waste disturbance	Purge or Flush, OR IC Set 1 or Continuing Monitoring
Group 3	Balance of SSTs	No Spontaneous GREs, but Small Induced GREs, and Steady State releases at all times	No IC after entry sniffing No continuing monitoring	IC Set 2 in dome intrusive locations for duration of waste disturbance Continuing monitoring during manned waste disturbing operations	same as locally waste disturbing	Purge or Flush, OR IC Set 1 or Continuing Monitoring

NOTE: SX-109 passes the GRE evaluation documented in Hodgson 1996. As such it would be placed in Facility Group 3; however, it is included in Facility Group 2 because a number of tanks in the SX farm are Facility Group 2 tanks and, because of the unique ventilation configuration of the S Farm, vent through the headspace of SX-109.

Table 8. Double-Contained Receiver Tank Flammable Gas Ventilation Controls and Gas Release Event Control Grouping.

DCRT	Use	Ventilation Requirements	GRE Control Grouping
244-A	Cross-site, B-plant and some evaporator feed transfers. Drainage from transfer lines.	Assess dip-tube flow requirements prior to placing waste in tank	n/a
244-BX	Lag storage of 241-B and 241-BY Tank Farm salt well liquids. Currently contains a significant sludge heel.	Dip-Tube operating to vent gases generated by sludge heel. Assess prior to placing additional waste in tank	Group 3
244-CR	Lag storage of 241-C Tank Farm salt well liquids	Assess dip-tube flow requirements prior to placing waste in tank	n/a
244-S	Lag storage of 241-S and 241-SX Tank Farm salt well liquids and miscellaneous plant wastes. Drainage from cross-site transfer line.	Assess prior to placing waste in tank	n/a
244-TX	Lag storage of 241-T Tank Farm salt well liquids. Drainage for PFP waste transfers.	Assess dip-tube flow requirements prior to placing waste in the tank.	n/a
244-U	Lag storage of 241-U Tank Farm salt well liquids. Drainage from 241-SY Tank Farm transfer lines.	Tank/vault ventilation provided during lag storage of wastes	n/a
241-A-350	Receives drainage from 241-A Tank Farm. Lag storage for transfers from 207-A Retention Basin to 241-AW-102.	Assess dip-tube flow requirements prior to placing waste in tank	n/a

Table 9. 244-AR Storage Tank Flammable Gas Information

244-AR Tank	Contents	Gas Sample Results (Goheen, 1996b)	Ventilation Control Requirements	Facility Group
TK-001	2400 gals of mostly water from flushing and sump collection	0% of LFL	None	n/a
TK-002	600 gals of AX-104 sludge and 22,400 gals of mainly water from flushing and sump collections	5.4% of LFL	Continued dip-tube air flow	Group 3
TK-003	2,000 gals of mainly water from flushing operations and sump collections	0% of LFL	none	n/a
TK-004	100 gals of mainly water from flushing of AX-014 sludge to TK-002	0% of LFL	none	n/a

Table 10. Tank Waste Remediation System Inactive Miscellaneous Underground Storage Tank Flammable Gas Control Information. (3 sheets)

FACILITY	CAPACITY (gallons)	INVENTORY		Relative Flammable Gas Accumulation Hazard[1] (Sample results if available, % LFL)	Flammable Gas Control Requirements	Facility Group
		MATERIAL	VOLUME (gallons)			
216-BY-201	no data	no data	no data	---	IC Set 2 Entry Monitoring	Group 2
216-TY-201	no data	no data	no data	---	IC Set 2 Entry Monitoring	Group 2
231-W-151-001	4,000	floor drainage from 231-Z	Solids: 0 Supernatant: 1,430 Total waste: 1,430	Low	IC Set 2 Entry Monitoring	none
231-W-151-002	1,000	floor drainage from 231-Z	Solids: 12 Supernatant: 955 Total waste: 967	Low	IC Set 2 Entry Monitoring	none
240-S-302	17,684	HLW [2]	Total waste: 2,276	Low	IC Set 2 Entry Monitoring	Group 2
241-A-302B	13,500	HLW	Total waste: 3,600	Low	IC Set 2 Entry Monitoring	Group 2
241-AX-151	11,000	no data	no data	---	IC Set 2 Entry Monitoring	Group 2
241-B-301B	36,000	HLW	Solids: 21,660 Supernatant: 590 Total waste: 22,250	Low	IC Set 2 Entry Monitoring	Group 2
241-B-302B	17,684	HLW	Solids: 690 Supernatant: 4,240 Total waste: 4,930	Low	IC Set 2 Entry Monitoring	Group 2
241-BX-302A	17,684	HLW	Solids: 835 Supernatant: 0 Total waste: 835	Low	IC Set 2 Entry Monitoring	Group 3
241-BX-302B	11,389	HLW	Solids: 950 Supernatant: 94 Total waste: 1,044	Low	IC Set 2 Entry Monitoring	Group 3
241-BX-302C	11,378	HLW	Solids: 635 Supernatant: 228 Total waste: 863	Low	IC Set 2 Entry Monitoring	Group 2
241-C-301C	36,000	HLW	Solids: 9,016 Supernatant: 1,470 Total waste: 10,486	Low (< 0.06% LFL)	IC Set 2 Entry Monitoring	Group 2
241-ER-311A	no data	no data	no data	-	IC Set 2 Entry Monitoring	Group 2
241-S-302A	17,684	HLW	Total waste: 5,130	Low	IC Set 2 Entry Monitoring	Group 2
241-S-302B	14,314	tank considered empty	probably empty	Low	IC Set 2 Entry Monitoring	none
241-SX-302	17,684	HLW	Solids: 1,050 Supernatant: 305 Total waste: 1,355	Low	IC Set 2 Entry Monitoring	Group 2

Table 10. Tank Waste Remediation System Inactive Miscellaneous Underground Storage Tank Flammable Gas Control Information. (3 sheets)

FACILITY	CAPACITY (gallons)	INVENTORY		Relative Flammable Gas Accumulation Hazard[1] (Sample results if available, % LFL)	Flammable Gas Control Requirements	Facility Group
		MATERIAL	VOLUME (gallons)			
241-T-301	36,000	HLW	Solids: 21,658 Supernatant: 588 Total waste: 22,246	Low	IC Set 2 Entry Monitoring	Group 2
241-TX-302A	17,684	HLW	Solids: 2,450 Supernatant: 30 Total waste: 2,480	Low	IC Set 2 Entry Monitoring	Group 3
241-TX-302B	17,684	HLW	Total waste: 1,320	Low	IC Set 2 Entry Monitoring	Group 2
241-TX-302B(R)	12,000	HLW	no data	-	IC Set 2 Entry Monitoring	Group 2
241-TX-302X	14,314	HLW	Solids: 108 Supernatant: 245 Total waste: 353	Low	IC Set 2 Entry Monitoring	Group 2
241-TY-302A	17,684	HLW	Solids: 450 Supernatant: 0 Total waste: 450	Low (< 0.01 % of LFL[3])	IC Set 2 Entry Monitoring	Group 3
241-TY-302B	14,314	tank is empty	tank is empty	none (<0.01% of LFL[4])	Entry Monitoring	none
241-Z-8	15,435	backflush of feed filters for the RECUPLEX process	Solids: 500 Supernatant: 0 Total waste: 500	Low	IC Set 2 Entry Monitoring	Group 3
242-T-135	no data	no data	no data	---	IC Set 2 Entry Monitoring	Group 2
242-TA-R1	4,200	no data	no data	---	IC Set 2 Entry Monitoring	Group 2
243S-TK-1	550	no data	no data	---	IC Set 2 Entry Monitoring	Group 2
244-BXR-001	50,000	metal waste slurry from BX and BY tanks	Solids: 7,215 Supernatant: 0 Total waste: 7,215	High	IC Set 2 Entry Monitoring	Group 3
244-BXR-002	15,000	metal waste slurry from BXR-001 mixed with nitric acid	Solids: 1,805 Supernatant: 380 Total waste: 2,185	Low	IC Set 2 Entry Monitoring	Group 2
244-BXR-003	15,000	metal waste slurry from BXR-001 mixed with nitric acid	Solids: 1,449 Supernatant: 356 Total waste: 1,805	High	IC Set 2 Entry Monitoring	Group 2

Table 10. Tank Waste Remediation System Inactive Miscellaneous Underground Storage Tank Flammable Gas Control Information. (3 sheets)

FACILITY	CAPACITY (gallons)	INVENTORY		Relative Flammable Gas Accumulation Hazard[1] (Sample results if available, % LFL)	Flammable Gas Control Requirements	Facility Group
		MATERIAL	VOLUME (gallons)			
244-BXR-011	50,000	metal waste slurry and nitric acid from BXR-002 & BXR-003	Solids: 7,020 Supernatant: 98 Total waste: 7,118	High	IC Set 2 Entry Monitoring	Group 3
244-TXR-001	50,000	bismuth phosphate metal waste from T and TX tanks	Solids: 2,291 Supernatant: 49 Total waste: 2,340	Low	IC Set 2 Entry Monitoring	Group 3
244-TXR-002	15,000	waste slurry from TXR-001 mixed with nitric acid	Solids: 2,945 Supernatant: 0 Total waste: 2,945	Low	IC Set 2 Entry Monitoring	Group 3
244-TXR-003	15,000	waste slurry from TXR-001 mixed with nitric acid	Solids: 6,460 Supernatant: 0 Total waste: 6,460	Low	IC Set 2 Entry Monitoring	Group 3
270-W	3,780	neutralized process condensate from 224-U	no data	---	IC Set 2 Entry Monitoring	Group 2

[1]The criteria for determining the priority rank of high, moderate, or low with regard to hydrogen generation and buildup as a potential safety issue are listed as follows:

Priority rank	Criterion
High	Hydrogen accumulation reaches more than 1 volume percent of the tank vapor space (25 percent of the lower flammability limit) within 10 years or less.
Moderate	Hydrogen accumulation reaches more than 1 volume percent of the tank vapor space within 10 to 25 years.
Low	A tank is either empty, or hydrogen accumulation reaches more than 1 volume percent of the tank vapor space in more than 25 years.

If there are no data to calculate hydrogen generation, and there is less than a 50 percent void space ratio, the tank is ranked moderate. If there are no data to calculate hydrogen generation, and there is greater than or equal to a 50 percent void space ratio, the tank is ranked low.

[2]HLW indicates waste contents could be any or a mixture of a number of typical High Level Wastes similar to those found in the SSTs. More details are contained in Powers (1995).

[3]Goheen, M. W., 1995a, "Gas Sample Analysis from Tank TY-302-A," (letter to W. B. Barton, Westinghouse Hanford Company) Pacific Northwest Laboratory, Richland, Washington.

[4]Goheen, M. W., 1995b, "Gas Sample Analysis from Tank TY-302-B, (letter to W. B. Barton, Westinghouse Hanford Company) Pacific Northwest Laboratory, Richland, Washington.

Table 11. Catch Tank Flammable Gas Control Information.

Catch Tank	Use	Flammable Gas Control
241-S-304	Drainage from Diversion Box DB-241-S-151, precipitation and run-off	IC Set 2 and entry monitoring
241-TX-302-B	Drainage from DB-241-TX-155, precipitation and run-off	IC Set 2 and entry monitoring
241-TX-302-C	Drainage from DB-241-TX-154, precipitation and run-off	IC Set 2 and entry monitoring
241-U-301-B	Drainage from DB-241-U-151, DB-241-U-152, DB-241-U-153 and DB-241-U-252	IC Set 2 and entry monitoring
241-UX-302-A	Drainage from DB-241-UX-154, 291-U stack, precipitation and run-off	IC Set 2 and entry monitoring
241-A-302-A	Drainage from DB-241-A-151	IC Set 2 and entry monitoring
241-A-417	Drainage from 241-AY/AZ ventilation condensate system and possibly steam condensate from 241-AX-501 valve pit and 241-AZ-154	IC Set 2 and entry monitoring
241-AX-152	Drainage from 241-AX-152 diverter station, DB-241-AX-155, AY-501 and 702-A seal pot	IC Set 2 and entry monitoring
241-AZ-151	Drainage from DB-241-AZ-152, AZ ventilation lop seals, leak detection pits, 801-AZ Instrument Building, precipitation and run-off	IC Set 2 and entry monitoring
241-AZ-154	Condensate from 241-AZ-101, 102 steam coils, precipitation and run-off	IC Set 2 and entry monitoring
241-ER-311	Drainage from DB-241-ER-151 and DB-241-ER-152	IC Set 2 and entry monitoring
241-EW-151	Vent station for cross site transfers	IC Set 2 and entry monitoring
204-AR-TK-1	204-AR Waste Unloading Facility catch tank	IC Set 2 and entry monitoring

APPENDIX A

FLAMMABLE GAS SAMPLE RESULTS AND SLURRY GAS LOWER FLAMMABILITY LIMIT

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FLAMMABLE GAS SAMPLE RESULTS AND SLURRY GAS LOWER FLAMMABILITY LIMIT

A1.0 FLAMMABLE GAS CONTROL LIMIT BASIS

This section outlines the basis for the flammable gas control limit of 25% of the LFL. A hydrogen concentration value which is expected to conservatively be within the control limit for tank vapor spaces or other working areas is derived. An evaluation of how monitoring is done to ensure compliance with the limit is provided.

The National Fire Protection Association (NFPA 30) recommends that processes be controlled so that flammable gas concentrations are <25 percent of the lower flammability limit (LFL), when relying upon vapor space flammability levels to preclude the possibility of an ignition. DOE Order 5480.4 requires Hanford waste tanks to be operated within NFPA guidelines. Thus, a control of <25% of the LFL has been established for performing manned activities in and around the facilities identified in this JCO.

Because of the uncontrollable nature of GREs, it is currently not possible to ensure that 25% of the LFL is never exceeded. Procedures and controls are in place to minimize the potential for a tank to exceed 25% of the LFL, and to cease work in areas common with the tank vapor space when the flammable gas concentration exceeds this value.

A2.0 FLAMMABLE GAS COMPOSITIONS AND ASSUMPTION REGARDING THE LFL

The flammable gas limit is currently stated as a percent of the LFL rather than a specific gas concentration. The primary flammable gas generated in the Hanford waste tanks is hydrogen (H_2), which has an LFL of 4.0 volume percent (40,000 ppmv) in air. In addition to hydrogen, there are frequently other flammable gases present. The ones of potential concern for determination of LFL are ammonia (NH_3), methane (CH_4) and carbon monoxide (CO).

A2.1 AVAILABLE GAS COMPOSITION AND CONCENTRATION DATA

Table A-1 summarizes the readily available flammable gas and organic vapor results for combustible gas monitor (CGM) readings and vapor samples (Type 2, 3 or 4) taken from single shell tank vapor spaces. Also included is the result from one IMUST (C-301) taken to date.

The CGM samples were taken in the tank vapor space a nominal 20 feet down from the riser top or a minimum of 3 feet below where the riser enters the tank. Of the 46 samples taken, 41 (89%) read 0% of the LFL. The five samples showing positive values were all small, ranging from 1-7% of the LFL, and averaged 2.6%. As the CGM values read high by approximately 100% (see Section A.4), the average reading for the samples showing a positive reading was about 1.3% of the LFL, based upon hydrogen in air.

The Type 2, 3 and 4 vapor samples were all taken from the tank vapor space using approved procedures. The percent LFL calculations were done using Le Chatelier's rule for the flammable gases, and excluding organic hydrocarbons other than methane. The highest hydrogen, ammonia and methane values were used, where a range is given. Where below detection limit "<" values are reported, the "<" value was used in the calculations. Carbon monoxide was not included in the table as the values were insignificant.

Of the 63 samples reported in the table, 43 (68%) either reported a < value for hydrogen, or when the reported values for hydrogen, ammonia and methane were used to calculate a percent of the LFL, the result was ≤0.5% of the LFL. For the 20 samples which did not have a < value reported for hydrogen, and which resulted in a calculated concentration greater than 0.5% of the LFL, the values ranged from 0.54 to 2.51%, and averaged 1.48% of the LFL.

The total nonmethane organic hydrocarbon percent LFL was calculated separately assuming that 45,000 mg/m^3 is equivalent to 100% LFL. A concentration of 46,000 mg/m^3 is the LFL for the kerosene hydrocarbons used as an organic diluent in PUREX and some B-Plant processing operations (Reference A-1). Further a value of 45,000 mg/m^3 is normally used as the LFL for the range of organic vapors occasionally found in the Hanford waste tanks. Only four tanks showed greater than 0.49% LFL for organic vapors and mists. The four values ranged from 0.49% - 3.80%.

The CGM reading and Type 3 sample result for one IMUST was taken from approximately the middle of the tank vapor space. No detectable flammable gas was found.

Thus, readily available vapor space sample results for SSTs indicate that approximately 70-90 percent of the tanks show negligible or nondetectable flammable gas levels when no waste intrusive work is being done, and the remaining nominal 10-30 percent of the tanks average about 1.2-1.5% of the LFL. The highest CGM reading (7%) equates to approximately 3.5% of the LFL. The highest vapor sample was calculated to correlate to 2.51% of the LFL. One IMUST tank sampled showed no flammable gas present. The highest organic concentration, 3.8% of the LFL, was found in C-103. This is the one waste tank known to have a significant floating organic layer on top of the waste.

Organic compounds other than methane are found in the vapor spaces of most tanks, but at very low concentrations, usually <0.1% of the LFL. Only two tanks to date (C-103 and BY-108) have shown the presence of any nonmethane organics above 1% of the LFL in the tank vapor space; although, other hydrocarbons have shown up in undiluted waste gas samples (see Table A-4). These organics are mostly kerosene type hydrocarbons associated with past chemical processing operations which have entered the waste tanks in minor quantities along with aqueous waste streams. Methane is normally found in concentrations <0.1% of the LFL, and is believed to be formed from degradation of some organic chemicals present in the waste in some tanks. By using a conservative concentration for methane (about 0.5 vol% in the undiluted waste gas) in the following LFL calculations, the contribution of other organics to the LFL can be assumed to have negligible impact on the LFL.

The flammable gases of concern in the waste tanks require the presence of an oxidizer to burn. The primary oxidizer in the tank vapor space is oxygen (O_2), which is present in air at about 20.95 vol%. Nitrous oxide (N_2O) is present in the waste slurry gas, at a concentration estimated to be about 85% of the hydrogen concentration for Tank 101-SY (Reference 2). The presence of nitrous oxide (N_2O) in the waste gas can affect the LFL as it acts as an oxidizer in addition to any oxygen (O_2) present.

A2.2 TECHNICAL BASES FOR LFL

The potential reactions between flammable gases and oxidizers in the waste tanks are given in (References 3 and 4) and repeated below in Table A-2.

The internal energy of the combustion reaction is defined as the enthalpy of the combustion reaction minus any pressure-volume work done by the process. Mathematically this is:

$$U_{RP} = h_{RP} - RT(n_P - n_R)$$

where h_{RP} is the enthalpy of combustion, R is the ideal gas constant, T is the temperature of the vapor space after mixing (34°C assumed) n_P is the number of moles of products and n_R is the number of moles of reactants. Based upon Table A-2, the reaction of hydrogen with oxygen generates the least heat per mole of the reactions given. Because of the predominance of hydrogen and ammonia as flammable gases, the majority contributor to the total energy released in an ignition event in a tank vapor space would be either hydrogen or ammonia combining with oxygen.

<u>Waste Slurry Gas Composition</u> - In order to calculate a LFL for a waste gas mixture, it is necessary to know the waste gas concentration. The waste gas composition has been evaluated fairly extensively for Tank 101-SY, and to a lesser extent for other tanks by analyzing the diluted off gas and backing out the contribution from nitrogen and oxygen in air.

Table A-3 summarizes the values used in References 2, 3, 4 and 5 as conservative gas mixtures in calculations of tank LFLs. These compositions were largely based upon DST releases for which sample results are available, as there have been negligible significant releases from SSTs since concerns with flammable gases in Hanford tanks were brought up in the late 1980s.

In the fall of 1995, two samples were taken from inside the drill strings used for core sampling. These samples were undiluted by air from the tank vapor space, although for S-107 the sample was diluted to an unknown amount by air in the drill string and for BY-110 the sample was diluted by nitrogen used as a purge gas in the drill string. In January 1996, a third sample was obtained from the drill string quill rod on Tank U-109.

In early 1996, the first retained gas samples (RGS) were taken from Tank 101-AW. These samplers are designed to trap waste gases along with the liquid/solid wastes taken during core sampling operations. This will enable the analysis of concentrated waste gases and thus provide more information on waste gas makeup. Four RGS samples taken from 101-AW have been analyzed to date. These samples were taken at heights of about 29, 67, 105 and 275 inches from the bottom of the tank. The tank contains approximately 410 inches of waste. The preliminary sample results were reported in Reference 6. Because of the highly soluble nature of ammonia, it is difficult to analyze for it in the trapped waste gases associated with the RGS samplers. The total amount of ammonia (on a mole basis) in the RGS sample liquid and gas phases from Tank 101-AW was 0.5-2 times the total volume of insoluble gases. The gases in the RGS samples are extracted in the laboratory by evacuating the sample and trapping the off gas. This is done repeatedly. Since ammonia in the gas phase is in equilibrium with ammonia in solution, when a sample is evacuated more ammonia is drawn out of solution to return to equilibrium. Therefore, RGS sample results for ammonia in the gas phase will be biased high, which in turn will bias the concentration of other constituents low.

Table A-4 gives the drill string sample results, the 101-AW RGS sample results and includes the ratios of other gases to hydrogen. The results for the RGS samples are shown as "<" (less than) values for ammonia as these are biased high. The results for all other constituents are shown as ">" (greater than) values as they are biased low.

A2.4 ASSUMPTIONS FOR THE LFL

The LFL as used in this JCO is the lowest concentration of a flammable gas mixture which will support combustion in the presence of a given oxidizer. The LFL will vary with the oxidizer. Table A-5 summarizes values from the referenced sources of the lower flammability limits for the flammable gases of concern in air, and in nitrous oxide.

Using Le Chatelier's rule, the LFL of an ideal gas mixture can be calculated by:

$$LFL_{mix} = \frac{1}{\frac{f_{fg1}}{LFL_{fg1}} + \frac{f_{fg2}}{LFL_{fg2}} + \frac{f_{fg3}}{LFL_{fg3}} + \ldots \frac{f_{fgn}}{LFL_{fgn}}}$$

where: f_{fg1} = mole fraction of flammable gas #1
LFL_{fg1} = LFL of flammable gas #1

The LFL_{mix} and the mole fractions of flammable gas 1, 2 etc. are based upon the flammable gases present only, i.e. all non flammable constituents are excluded.

Assumptions, evaluations and results of other available estimates for hydrogen concentrations that represent the LFL, or 25% of the LFL, are summarized for consideration in establishing the values for use in this JCO.

a) Reference 2, Appendix B This reference estimated the LFL for Tank 101-SY waste gases based upon Le Chatelier's rule and using the concentrations given in column 2a of Table A-3 (after revising to a flammable gas constituent only basis) with the LFL in air values in column 2 of Table A-5.

The LFL value of the mixture calculates to 5.3 vol% in the tank vapor space based upon the flammable gas constituents only, or 11.1 vol% if all waste gas constituents are included. This means 11.1% of the tank dome space would have to be filled with all the gases in the ratios given in Table A-3, with the remaining 88.9% being air, in order for the tank dome space to be at 100% of the LFL. As it is impractical to monitor for all the waste slurry gases in the tank dome space, the hydrogen concentration at 100% of the LFL is calculated and used as a basis for monitoring. The hydrogen concentration at the LFL of the waste gas in the tank vapor space calculates to 3.5 vol%. Reference 2 thus gives 3.5% H_2 in the tank vapor space as a conservative value which would indicate waste gas at 100 percent of the LFL was present in the tank vapor space, with 25% of the LFL being 8750 ppm. Reference 2 recommends using 8750 ppm as 25% of the LFL, but using an administrative control of 7500 ppm hydrogen as a monitoring limit to account for instrument uncertainties.

Reference 2 discusses the effect of nitrous oxide on the LFL. The wording isn't too clear but appears to indicate that it will have only a small impact when diluted by tank gases.

b) Reference 3 and 4, Appendices B, Reference 5 These references used Le Chatelier's rule to arrive at a ppm hydrogen limit that could be used for the vapor space of all tanks. The method included the effect of nitrous oxide on the LFL, and looked at varying the hydrogen level in the waste gas. These documents recommended using a 6250 ppm hydrogen level as the alarm point for hydrogen monitoring systems to indicate when 25% of the LFL may have been reached in a tank vapor space.

The 6250 ppm limit is very conservative because the following assumptions were used:

1. A LFL of 3.5% was used for hydrogen in air

2. A LFL of 8% was used for ammonia in air

3. A plot was presented of the waste gas LFL vs. the hydrogen concentration in the waste slurry gas excluding noncombustibles. Interpretation of the plot was based upon assuming a hydrogen concentration in the waste slurry gas of about 30-70%. This would either mean the noncombustibles were assumed present, or that the gas was assumed similar to that in some of the chronic releases which have shown a very low hydrogen:ammonia ratio.

c) Limit As Applied To This JCO The above references calculated hydrogen concentrations that give 25% of the LFL for a conservative waste gas composition, but may have some limitations. The method in Reference 2 is for 101-SY only, and doesn't include an adjustment for the presence of nitrous oxide. The other references vary the hydrogen content of the waste slurry gas to provide a range of LFLs and appear to include an adjustment for nitrous oxide, but they use conservative values for the LFLs for hydrogen and ammonia in air, and a conservative assumption is used in interpretation of the results.

The LFL calculations were redone for this JCO using the following assumptions:

1. The ratios of ammonia:methane:carbon monoxide were kept constant and equal to those in column 2b of Table A-3.

2. The values for LFL in air were assumed equal to those in column 7 of Table A-5 (CRC Handbook, Reference 7) and for LFL in nitrous oxide were assumed equal to those in column 6.

3. The LFL values used in subsequent calculations were based upon a gas of 92.6% air/7.4% nitrous oxide, as was done for References 3 and 4. A linear interpretation was made between the values for LFL in air and in nitrous oxide for hydrogen, ammonia and methane, and the value for LFL in air was used for carbon monoxide. These resulted in using LFL values of 3.84 for hydrogen, 14.5 for ammonia, 4.69 for methane, and 12.5 for carbon monoxide in the air/nitrous oxide mix.

4. The LFL was calculated for a waste slurry gas consisting of the four flammable constituents, with the hydrogen concentration varying but the other three constituents kept in the same ratio. The percent hydrogen in the tank vapor space at the LFL for the waste slurry gas was then plotted as a function of the percent hydrogen in the waste slurry flammable gases, (i.e., excluding all noncombustible constituents).

This plot is provided as Figure A-1 for this JCO. The conservative hydrogen concentration in the 101-SY waste slurry gas (and as used in References 3 and 4), from Table A-3 column 2a, is 31.41% hydrogen, which is 66.3% of the flammable gases. From Figure A-1, this equates to a vapor space hydrogen concentration of about 3.4% hydrogen, which is essentially the same as the 3.5% recommended in Reference 2.

Estimates of the actual hydrogen concentration in the tank waste gases ranges from 30-70% (References 3 and 4) but this range includes the presence of noncombustibles for significant releases. Including just the combustibles, the hydrogen concentration is expected to range from 60% on up. The "best estimate" gas composition makeup from References 2, 3, 4 and 5 are given in Table A-6.

Per this table, the percent hydrogen based upon the flammable gases in the waste slurry gas only is 71-61%. Per Table A-1, the ratio of hydrogen to ammonia found in tank vapor spaces from chronic releases shows hydrogen could range from <10% to greater than 90% of the flammable gases in a tank at very small (<3% of the LFL) concentrations. Experience with monitoring from larger DST releases (the basis for Tables A-3 and A-6), and as shown by the waste gas drill string sample results in Table A-4, high quantities of flammable gases aren't expected without the majority of the flammable gas released being hydrogen. The RGS sample results from 101-AW indicate hydrogen is only 7-41% of the flammable gases in the tank, but this is because of the ammonia results being biased high.

Using Figure A-1, and assuming 60% of the flammable gas in a waste slurry gas is hydrogen, the hydrogen concentration at 100% of the LFL in a tank vapor space conservatively calculates to 3.22%. Setting a monitoring limit of 25% of the LFL based upon this reasoning calculates to approximately 8000 ppmv.

A3.0 SUMMARY

Reference 2 recommends using 8750 ppm hydrogen as 25% of the LFL for TK 101-SY waste slurry gas in the tank dome space, and that a monitoring limit of 7500 ppm be established to account for instrument deficiencies. References 3, 4 and 5 recommended using a 25% of the LFL monitoring limit of 6250 ppm hydrogen for all tanks, and References 3 and 4 state that a value of 7375 ppm hydrogen could be used for all tanks if an LFL for ammonia of 15% was assumed. The calculations done for this JCO indicate that 6250 or 7375 ppm may be conservative, and that a value of 8000 ppm hydrogen is a reasonable value to use as a monitoring limit for 25% of the LFL.

In order to be conservative, and keep the same limit for all tanks, for this JCO it is recommended that 7500 ppm be used as the 25% of the LFL monitoring limit for hydrogen in a tank vapor space.

A4.0 FLAMMABLE GAS MONITORING METHODS

Several methods are used to monitor for various flammable gases or vapors within tank farms. These include combustible gas meters (CGMs), organic vapor monitors (OVMs), Drager tubes, standard hydrogen monitoring systems (SHMS), gas chromatographs, combustible gas monitors, and taking Type 2/3/4 vapor samples. Because the subject of this section is monitoring for hydrogen to demonstrate compliance with the 25% of the LFL control limit, and the recommended 7500 ppm hydrogen concentration monitoring limit, this section will be limited to a discussion of CGMs, SHMS and Belhaven monitors.

A4.1 COMBUSTIBLE GAS METERS

The combustible gas meter normally used within tank farms is the Industrial Scientific Corporation model LTX 310. This unit is calibrated on pentane, and the manufacturer provides a table of conversion factors to use when monitoring for other gases. Per the manufacturer's information the CGM reading should be multiplied by a correction factor of 0.5 when monitoring for hydrogen. Per the manufacturer, this conversion factor is accurate to about ±25%.

Reference 8 evaluated the response of the CGMs to hydrogen in air, and in the presence of nitrous oxide and ammonia. The data showed that below about 3% of the LFL for hydrogen in air (about 1200 ppm) the units were unable to accurately measure the LFL as the concentrations were too low. Around 1200 ppm the units were fairly accurate (after applying the 0.5 correction factor) and as the percent hydrogen increased above 1200 ppm, the indicated LFL (after applying the 0.5 correction factor) was 5-40% above the actual. The presence of ammonia and/or nitrous oxide also resulted in the indicated LFL reading higher than actual.

Thus, the CGMs used for flammable gas monitoring can be relied upon to indicate an LFL value that is high by a factor of two or more. Thus these units can be conservatively used for LFL monitoring to an indicated 25% of the LFL, and are expected to read high regardless of what gas mixture is present. Therefore, no lower (i.e., less than 25% of the LFL) monitoring setpoint is required when using these instruments. When 25% of the LFL is indicated, response shall be as required by the flammable gas specification limit of this JCO.

A4.2 STANDARD HYDROGEN MONITORING SYSTEMS

These monitors are installed on many of the tanks currently on the flammable gas watch list in OSD-T-151-0030 Appendix A. They operate using a Whittaker cell to detect hydrogen only. These monitors currently have a 6250 ppm hydrogen set point. This setpoint is below the recommended value of 7500 ppm hydrogen given in this appendix, but is on the conservative side.

A4.3 CONTINUOUS INSTALLED COMBUSTIBLE GAS MONITORS

These monitors are currently used to monitor the salt well pit vapor space of several tanks being salt well pumped. These units are calibrated on methane on approximately a on month basis. Per the manufacturer there is a 1:1 correlation (no correction factor) when monitoring hydrogen. Based upon a test gas mixture of hydrogen, ammonia and methane in air, the unit read about 1.5% higher for hydrogen than actually present. When measuring a gas with an LFL of 2.5% for hydrogen in air, a value of 3.2% was indicated. Below 5% of the LFL the units appear to read high. The units work best on a concentration of 5-30% of the LFL. Based upon the experience to date, the installed combustible gas monitors can be used to adequately monitor for compliance with the 25% LFL limit using the monitoring limit recommended in this appendix.

A4.4 OTHER HYDROGEN/FLAMMABLE GAS MONITORS

Some tanks have gas chromatographs installed to analyzed the vapor space. There may be other hydrogen monitors selected for use in the future. Any such monitor may be used for monitoring for compliance with the flammable gas specification limit as long as it is shown to read conservatively at less than 25% of the LFL for a conservative waste gas mixture.

A5.0 REFERENCES

1. SD-RE-TI-103, *Bases for PUREX Solvent Tank Temperature Limits*, S. M. Stordeur, Rockwell Hanford Operations, July, 1983

2. LA-UR-92-3196, Rev 14, *A Safety Assessment for Proposed Pump Mixing Operations to Mitigate Episodic Gas Releases in Tank 241-SY-101: Hanford Site, Richland, Washington*, L. Harold Sullivan, Los Alamos National Laboratory, March 31, 1995

3. WHC-SD-WM-SARR-002, Rev 1, *Safety Basis for Activities in Double-Shell Tanks with Flammable Gas Concerns*, R. L. Schlosser, Westinghouse Hanford Company, February, 1996

4. WHC-SD-WM-SARR-004, Rev 1, *Safety Basis for Activities in Single-Shell Tanks with Flammable Gas Concerns*, R. L. Schlosser, Westinghouse Hanford Company, February, 1996

5. WHC-SD-WM-ES-346, *Flammable Gas Tank Safety Program: Technical Basis for Gas Sampling and Monitoring*, D. J. Sherwood, Westinghouse Hanford Company, September 8, 1995

6. Letter, *TRANSMITTAL of Letter Report "Preliminary Retained Gas Sampler Results for Tank 241-AW-101"*, J. M. Bates, Battelle Pacific Northwest Laboratories, to R. E. Bauer, Westinghouse Hanford Company, May 24, 1996

7. *CRC Handbook of Chemistry and Physics*, 68th Edition, R. C. Weast et al, 1987

8. WHC-SD-WM-TRP-256 (Draft), *Test Evaluation of Industrial Hygiene Hand Held Combustible Gas Monitor*, N. W. Wilkins and R. E. Bauer, Westinghouse Hanford Company, May, 1996

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Figure A-1.

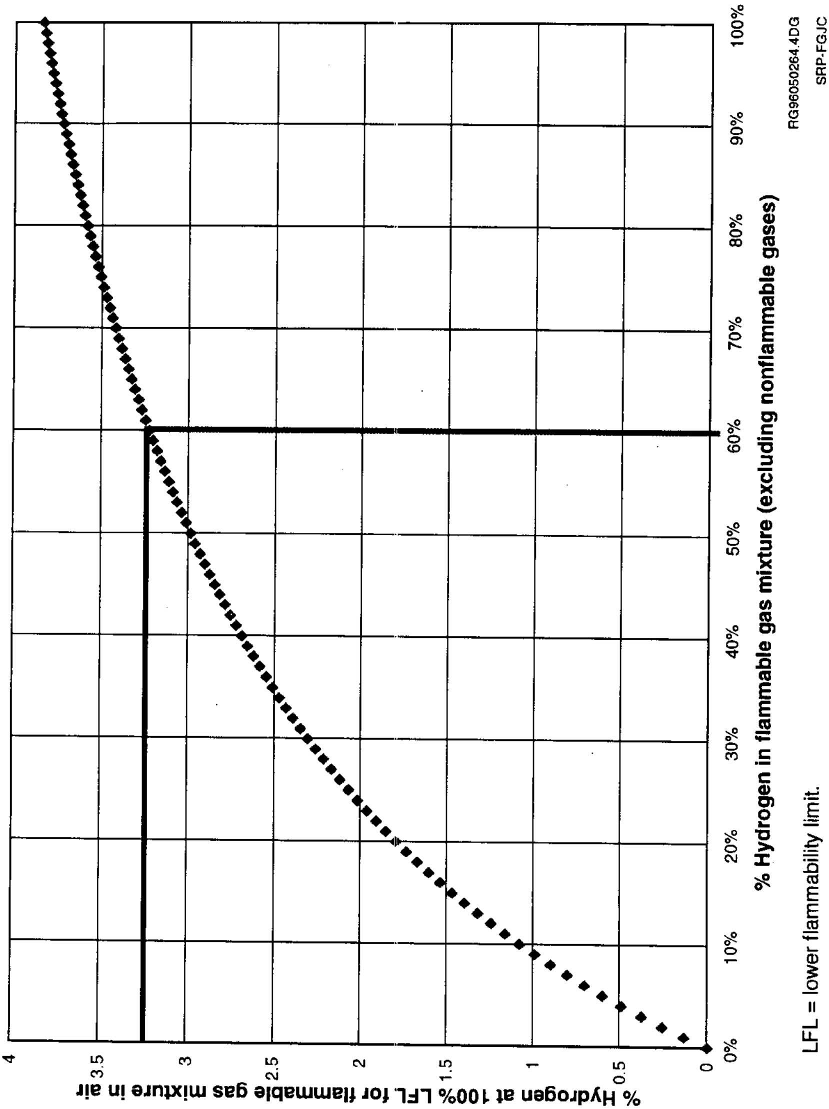
% Hydrogen at 100% LFL for flammable gas mixture in air
0
0.5
1
1.5
2
2.5
3
3.5
4
% Hydrogen in flammable gas mixture (excluding nonflammable gases)
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
LFL = lower flammability limit.
RG96050264.4DG
SRP-FGJC

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Table A-1. Single-Shell Tank and Inactive Miscellaneous Underground Storage Tank Vapor Sample Data. (5 sheets)

Tank	Date Sampled () = Type	TYPE 2/3/4 Sample Results				Grab Sample Results			% LFL c = calc oc = organic calc r = CGM
		Hydrogen (ppmv)	Ammonia (ppmv)	Methane (ppmv)	Other Organics (mg/m^3)	% LFL	Ammonia (ppmv)	TOC (ppmv)	
A-101	6/9/95 (3)	743-786	728-800	<12	21.9				2.51 (c)
A-102	11/10/95 (3)	294-302	248-263	<4	6.1				0.93 (c)
A-103	4/6/95 (3)	271-278	256-273	<4	8.2				0.88 (c)
A-104	1/14/96					0	<5	0	0 (r)
A-105	1/19/96					0	30	2.5	0 (r)
A-106									
AX-101	6/15/95 (3)	102-103	39-44	<12	2.6				0.31 (c)
AX-102	6/29/95 (3)	<98	30-37	<12	9.0				<0.29 (c)
AX-103	6/27/95 (3)	<98	37-44	<12	1.5				<0.30 (c)
AX-104									
B-101	3/26/96					0	20	10.7	0 (r)
B-102									
B-103	2/8/95 (3)	<99	7.7-10	<61	12.8				<0.38 (c)
B-104	3/26/96					0	0	1.8	0 (r)
B-105	6/6/96					1	12	3	1 (r)
B-106	4/26/96					0	0	0	0 (r)
B-107	6/6/96					2	25	3	2 (r)
B-108	4/26/96					0	30	2.4	0 (r)
B-109	6/12/96					0	35	1.8	0 (r)
B-110	4/26/96					0	50	5.5	0 (r)
B-111	3/19/96					0	25	0	0 (r)
B-112									
B-201	6/4/96					0	<5	0	0 (r)
B-202	6/4/96					0	<5	0	0 (r)
B-203									
B-204	4/26/96					0	<5	0	0 (r)
BX-101	4/24/96					0	50	3.3	0 (r)
BX-102	6/24/96					0	0	0	0 (r)
BX-103	3/26/96					0	70	6.4	0 (r)
BX-104	12/30/94 (3)	<94	229-238	<61	77.9				<0.51 (c)
BX-105									
BX-106	12/9/95					0	50	6.7	0 (r)

Table A-1. Single-Shell Tank and Inactive Miscellaneous Underground Storage Tank Vapor Sample Data. (5 sheets)

Tank	Date Sampled () = Type	TYPE 2/3/4 Sample Results				Grab Sample Results			% LFL c = calc oc = organic calc r = CGM
		Hydrogen (ppmv)	Ammonia (ppmv)	Methane (ppmv)	Other Organics (mg/m^3)	% LFL	Ammonia (ppmv)	TOC (ppmv)	
BX-107	11/16/95 (3)	10-14	76-89	<4	2.5				<0.10 (c)
BX-108									
BX-109	4/24/96 (G)					0	20	1.7	0 (r)
BX-110	10/2/95 (G)					0	50	3.8	0 (r)
BX-111	4/24/96 (G)					0	45	2.2	0 (r)
BX-112									
BY-101									
BY-102	11/20/95 (3)	33-37	170-180	<4	18.3				0.22 (c)
BY-103	11/1/94 (3)	21-22	24-30	<61	10.7				<0.12 (c)
BY-104	6/24/94 (3)	204-312	242-255	8-9	54.7				0.96 (c)
BY-105	7/7/94 (3)	84-87	41-44	3.8	11.6				0.25 (c)
BY-106	7/8/94 (3)	40-104	72-78	3.6	12.7				0.32 (c)
BY-107	10/26/94 (3)	687-698	963-978	<20	151.9				2.42 (c)
BY-108	10/27/94 (3) 1/26/96 (3/4) 3/28/96 (3/4)	335-647 (all data not available)	941-1140	<61	527				2.48 (c) 1.17 (oc)
BY-109					18.1				
BY-110	11/11/94 (3)	<160	385-426	<61	43.8				<0.80 (c)
BY-111	11/16/94 (3)	65-69	57-61	<61	8.5				0.33 (c)
BY-112	11/18/94 (3)	<94	54-71	<61	12.6				<0.40 (c)
C-101	9/1/94 (3)	434-439	96-99	12	221.6				1.19 (c) 0.49 (oc)
C-102	8/23/94 (3)	131-165	183-192	12	279.5				0.57 (c) 0.62 (oc)
C-103	4/15/94 (3)	676-894	308-349	13.2-17.7	1709.6				2.50 (c) 3.80 (oc)
C-104	3/3/94 (3)	60-76	44	neg	25.4				0.26 (c)
C-105	2/16/94 (2)	20-24	1.9-2.7	neg	1.4				0.10 (c)
C-106	2/15/94 (2)	8-12	0.2-8.8	neg	0.4				0.08 (c)
C-107	9/29/94 (3) 1/17/96 (3/4) 3/26/96 (3/4)	110-239 (all data not available)	81-87	<20	5.3				0.69 (c)
C-108	8/5/94 (3)	14-16	2.4-3.3	0.1	0.3				0.04 (c)
C-109	8/9/94 (3)	124-125	9.1-11.4	0.9	1.4				0.32 (c)
C-110	8/24/94 (3)	12	120-130	<61	20.5				<0.24 (c)

Table A-1. Single-Shell Tank and Inactive Miscellaneous Underground Storage Tank Vapor Sample Data. (5 sheets)

Tank	Date Sampled () = Type	TYPE 2/3/4 Sample Results				Grab Sample Results			% LFL c = calc oc = organic calc r = CGM
		Hydrogen (ppmv)	Ammonia (ppmv)	Methane (ppmv)	Other Organics (mg/m³)	% LFL	Ammonia (ppmv)	TOC (ppmv)	
C-111	9/13/94 (3)	10-14	4.7-6.8	0.3	1.0				0.04 (c)
C-112	8/11/94 (3)	200-210	22-23	1.0	3.0				0.54 (c)
C-201									
C-202									
C-203									
C-204	6/3/96					0	0	13.7	0 (r)
S-101	4/3/96					7	600	31	7 (r)
S-102	3/6/95 (3) 1/26/96 (3/4)	668-670 (all data not available)	402-418	<12	18.5				1.97 (c)
S-103	5/17/96					0	300	2.6	0 (r)
S-104	3/19/96 (G)					0	25	0	0 (r)
S-105	12/13/95 (3)	20-22	34-38	<4	2.6				0.09 (c)
S-106	5/17/96 (G)					0	40	1.6	0 (r)
S-107									
S-108	12/15/95 (3)	21-23	24-27	<4	2.9				0.08 (c)
S-109	5/17/96 (G)					0	80	3	0 (r)
S-110	12/4/95(3)	132-139	141-153	<4	4.2				0.45 (c)
S-111	3/13/95 (3)	390-392	115-124	<23	3.7				1.11 (c)
S-112	7/11/95 (3)	<25	86-90	<25	5.5				<0.17 (c)
SX-101	7/19/95 (3)	<25	3.4-4.2	<25	1.5				<0.12 (c)
SX-102	7/21/95 (3)	<25	15-16	<25	1.6				<0.12 (c)
SX-103	3/20/95 (3)	<23	71-80	<23	2.0				<0.16 (c)
SX-104	7/25/95 (3)	<25	24-26	<25	1.6				<0.13 (c)
SX-105	7/26/95 (3)	<25	25-30	<25	1.7				<0.13 (c)
SX-106	3/27/95 (3)	<98	171-188	<12	2.4				<0.39 (c)
SX-107									
SX-108									
SX-109	8/1/95 (3) (Duct)	<25	16-18	<25	1.6				<0.12 (c)
SX-110									
SX-111									
SX-112									
SX-113									

Table A-1. Single-Shell Tank and Inactive Miscellaneous Underground Storage Tank Vapor Sample Data. (5 sheets)

Tank	Date Sampled () = Type	TYPE 2/3/4 Sample Results				Grab Sample Results			% LFL c = calc oc = organic calc r = CGM
		Hydrogen (ppmv)	Ammonia (ppmv)	Methane (ppmv)	Other Organics (mg/m^3)	% LFL	Ammonia (ppmv)	TOC (ppmv)	
SX-114									
SX-115	3/8/96					0	0	0	0 (r)
T-101									
T-102	5/9/96					0	0	0	0 (r)
T-103	2/15/96					0	0	0	0 (r)
T-104	2/7/96 (3/4)	4-17 (all data not available)	102-110	<4	1.9				0.12 (c)
T-105	5/9/96					0	150	4.9	0 (r)
T-106	5/9/96					0	100	2.4	0 (r)
T-107	1/18/95 (3)	<94	122-127	<61	3.8				<0.44 (c)
T-108	5/9/96					0	20	1.2	0 (r)
T-109	5/9/96					0	5	1.2	0 (r)
T-110	8/3/95 (3)	<25	108-109	<25	1.6				<0.18 (c)
T-111	1/20/95 (3)	<94	225-227	<61	22.5				<0.50 (c)
T-112	5/9/96					0	40	1.2	0 (r)
T-201									
T-202									
T-203	3/19/96					0	0	1.6	0 (r)
T-204									
TX-101	6/14/96					0	20	6.8	0 (r)
TX-102	6/20/96					0	100	15.5	0 (r)
TX-103	6/17/96					0	100	14.9	0 (r)
TX-104									
TX-105	12/20/94 (3)	<99	19-21	<61	4.6				<0.38 (c)
TX-106									
TX-107									
TX-108									
TX-109									
TX-110									
TX-111	10/11/95 (3)	107-110	588-638	<25	13.1				0.74 (c)
TX-112									
TX-113	6/18/96					0	20	2	0 (r)

Table A-1. Single-Shell Tank and Inactive Miscellaneous Underground Storage Tank Vapor Sample Data. (5 sheets)

Tank	Date Sampled () = Type	TYPE 2/3/4 Sample Results				Grab Sample Results			% LFL c = calc oc = organic calc r = CGM
		Hydrogen (ppmv)	Ammonia (ppmv)	Methane (ppmv)	Other Organics (mg/m³)	% LFL	Ammonia (ppmv)	TOC (ppmv)	
TX-114	6/18/96					0	150	8	0 (r)
TX-115									
TX-116	3/19/96					0	0	6	0 (r)
TX-117	3/19/96					0	25	0	0 (r)
TX-118	12/16/94 (3)	96-98	31-36	<61	10.7				0.39 (c)
TY-101	4/5/95 (3)	<93	15-17	<12	1.7				<0.27 (c)
TY-102									
TY-103	4/13/95 (3)	<93	47-50	<12	55.6				<0.29 (c)
TY-104	4/26/95 (3)	<49	57-62	<23	2.8				<0.21 (c)
TY-105									
TY-106									
U-101	2/14/96					1	100	7.4	1 (r)
U-102									
U-103	2/15/95 (3)	552-557	720-761	<61	20.9				2.01 (c)
U-104	5/10/96					0	<5	0	0 (r)
U-105	2/24/95 (3)	<49	275-354	<23	7.9				<0.40 (c)
U-106	2/26/95 (3)	203-214	931-1013	<61	19.1				1.31 (c)
U-107	2/17/95 (3)	496-505	425-474	<12	15.4				1.59 (c)
U-108	8/18/95 (3)	518-524	679-701	<25	14.5				1.81 (c)
U-109	8/10/95 (3)	724-770	556-608	<25	14.4				2.37 (c)
U-110	3/19/96					2	450	26	2 (r)
U-111	2/20/95 (3)	244-250	671-682	<12	12.3				1.09 (c)
U-112									
U-201									
U-202									
U-203	8/9/95 (3)	<25	0.8-1	.25	13.4				<0.11 (c)
U-204	8/7/95 (3)	<25	0.1-0.2	<25	6.5				<0.11 (c)
C-301 (IMUST)	9/29/95 (3)	<25	NA	NA	2.1	0	0	0	0 (r) <0.06 (c)

Table A-2. Combustion Reactions and Internal Energy of Reaction.

Reaction	U_{RP} kJ/mole fuel
$H_2 + 0.5\ O_2 \rightarrow H_2O$	-240.55
$H_2 + N_2O \rightarrow H_2O + N_2$	-323.80
$NH_3 + 0.75\ O_2 \rightarrow 1.5\ H_2O + 0.5\ N_2$	-317.44
$NH_3 + 1.5\ N_2O \rightarrow 1.5\ H_2O + 2\ N_2$	-442.45
$CH_4 + 2\ O_2 \rightarrow H_2O + CO_2$	-798.31
$CH_4 + 4\ N_2O \rightarrow 2\ H_2O + CO_2 + 4\ N_2$	-1,132.10
$CO + 0.5\ O_2 \rightarrow CO_2$	-281.72
$CO + N_2O \rightarrow CO_2 + N_2$	-365.04

Table A-3. Conservative Estimates of Waste Gas Composition Used in LFL Calculations.

Gas	LA-UR-92-3196, Rev 14, App B WHC-SD-WM-SARR-002/004 Rev 1, App B		WHC-SD-WM-ES-346 Rev 0	
	Composition	Gas/H_2 Ratio	Composition	Gas/H_2 Ratio
Hydrogen	31.41 vol %	1	28.42 vol %	1
Ammonia	14.95 %	0.48	22.15 %	0.78
Methane	0.53 %	0.017	0.48 %	0.017
Others	0.5 %	0.016	0.50 %	0.018
Nitrous Oxide	26.69 %	0.85	24.16 %	0.85
Nitrogen	23.51 %	0.75	21.23 %	0.75
Water	2.4 %	remainder	3.07 %	remainder

Table A-4. Waste Gas Sample Results From Drill String Grab Samples and Initial Retained Gas Samples.

Gas	S-107 (9/26/95)	BY-110 (10/24/95)	U-109 (1/18/96)	AW-101[4]				S-107	BY-110	U-109	AW-101[4]			
				275 in. RGS	105 in. RGS	67 in. RGS	29 in. RGS				275 in. RGS	105 in. RGS	67 in. RGS	29 in. RGS
	Composition							Gas:Hydrogen Ratio						
Hydrogen	0.68 vol%[1]	24 vol%	0.65 vol%	>5.1 vol%	>12.1 vol%	>25.6 vol%	>19.5 vol%	1	1	1	1	1	1	1
Ammonia	-	0.28[2]	not reported	<64.2	<48.7	<35.0	<31.7	-	0.012	-	<12.5	<4.0	<1.4	<1.6
Methane	0.011[1]	0.83[3]	0.011	>0.2	>0.72	>0.76	>1.0	0.016	0.035	0.017	0.042	0.06	0.03	0.053
C_2H_x	-	1[3]	<0.001	-	-	-	-	-	0.042	-	-	-	-	-
Other Hydrocarbons	-	0.6[3]	<0.001	>0.16	>0.31	>0.45	>0.53	-	0.025	-	0.031	0.043	0.018	0.027
Nitrous Oxide	0.09[1]	15	0.423	>0.59	>2.6	>3.5	>5.3	0.13	0.63	0.65	0.11	0.21	0.14	0.27
Nitrogen	-	57[5]	94.87[5]	>24.1	>32.7	>32.5	>40.0	-	2.38[5]	-	4.70	2.71	1.27	2.05
Oxygen	-	1[5]	3.86[5]	>3.1	>2.2	>1.2	>0.97	-	0.042[5]	-	0.59	0.18	0.046	0.049
Argon[6]	-	-	0.18	>2.4	>0.6	>0.4	>0.4	-	-	-	-	-	-	-

[1] Remaining gas concentrations not readily available for S-107 drill string grab sample.

[2] A drager tube sample of the drill string taken about the time of the gas sample indicated about 1000 ppm ammonia (0.1 %).

[3] OVM reading of the drill string taken about the time of the gas sample indicated an organic level of 234 ppm (0.02 %).

[4] Ammonia concentrations in RGS samples shown in table were calculated based upon the total ammonia removed from the waste sample as described in A.2.2. The actual equilibrium ammonia concentrations in RGS samples will be less than the calculated values shown. Therefore the ammonia concentrations are shown as less than values in the table, and the concentrations of other constituents are shown as greater than values.

[5] Nitrogen ratio not meaningful as majority of nitrogen believed from drill string purge gas. Oxygen present believed from air inleakage.

[6] Argon believed present in RGS samplers because of cross contamination from argon used to purge drill string of flammable gases.

Table A-5. Summary of Lower Flammability Limit Values for Selected Waste Slurry Flammable Gas Constituents in Air and Nitrous Oxide Used in Lower Flammability Limit Calculations.

Gas	LA-UR-92-3196 App B Rev 14	WHC-SD-WM-ES-346 Rev 0		WHC-SD-WM-SARR-004 Rev 1		CRC Handbook 68th Edition
	Air	Air/O_2	N_2O	Air	N_2O	Air
Hydrogen	4%	3.5[1]	1.8	3.5[1]	1.8	4.00
Ammonia	15%	8.0	2.0	8.0[2]	2.0	15.50
Methane	5.5%	5.0	0.8	5.0	0.8	5.00
Carbon Monoxide	12.5%	12.5	--	12.5	--	12.50

[1] LFL @ 400°K (127°C). Other LFLs given at 20-25°C.

[2] Based upon an LFL for upward propagation. Per footnote in References 3 and 4 further investigation does not show support for using this value.

Table A-6. "Best" Estimates of Waste Gas Composition.

Gas	LA-UR-92-3196 App B Rev 14 and WHC-SD-WM-SARR-002/ 004 Rev 1, Appendix B	WHC-SD-WM-ES-346 Rev 0
Hydrogen	28.77 vol %	26.66 vol %
Ammonia	10.95 %	16.53 %
Methane	0.35 %	0.33 %
Others	0.25 %	0.25 %
Nitrous Oxide	24.45 %	22.66 %
Nitrogen	32.82 %	30.40 %
Water	2.4 %	3.07 %

DISTRIBUTION COVERSHEET

Author	Addressee
Mr. J. J. Klos, WHC 376-3792	Mr. J. E. Kinzer, RL

Subject: JUSTIFICATION FOR CONTINUED OPERATION FOR FLAMMABLE GAS UNREVIEWED SAFETY QUESTION

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