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An Analysis of Tank and Pump Pit Flammable Gas Data in Support of Saltwell Pumping Safety Basis Simplification

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An Analysis of Tank and Pump Pit Flammable Gas Data in Support of Saltwell Pumping Safety Basis Simplifications

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LIST OF TERMS

cfm	cubic feet per meter
CGM	combustible gas monitor
DST	double-shell tank
FSAR	Final Safety Analysis Report
kgal	kilogallon
kL	kiloliter
LFL	lower flammability limit
LIQ	liquid waste tanks
m^3/min	cubic meters per minute
MIX	mixed waste tanks
NL	less than a meter of free-standing liquid present
% H_2	percent hydrogen
%	percent
ppm	parts per million
SC/SS	saltcake/salt slurry waste tanks
SL	sludge waste tanks
SHMS	Standard Hydrogen Monitoring System
SWP	saltwell pump
vol %	volume percent

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1.0 INTRODUCTION

Hanford Site high-level waste tanks are interim stabilized by pumping supernatant and interstitial waste liquids to double-shell tanks (DSTs) through a saltwell pump (SWP). The motor to this SWP is located atop the tank, inside a pump pit. A pumping line extends down from the pump motor into the well area, located in the salt/sludge solids in the tank below. Pumping of these wastes is complicated by the fact that some of the wastes generate and retain potentially hazardous amounts of hydrogen, nitrous oxide, and ammonia. Monitoring of flammable gas concentrations during saltwell pumping activities has shown that one effect of pumping is acceleration in the release of accumulated hydrogen. A second effect is that of a temporarily increased hydrogen concentration in both the dome space and pump pit. There is a safety concern that the hydrogen concentration during saltwell pumping activities might approach the lower flammability limit (LFL) in either the tank dome space or the pump pit. The current Final Safety Analysis Report (FSAR) (CHG 2000) for saltwell pumping requires continuous flammable gas monitoring in both the pump pit and the tank vapor space during saltwell pumping. The FSAR also requires that portable exhauster fans be available by most of the passively ventilated tanks to be saltwell pumped in the event that additional air flow is required to dilute the headspace concentration of flammable gases to acceptable levels.

1.1 OBJECTIVE

The first objective of this analysis is to review the need for an auxiliary exhauster. Since the purpose of the exhauster is to diffuse unacceptably high flammable gas concentrations, discovery of an alternate method of accomplishing the same task may provide cost savings. The method reviewed is that of temporarily stopping the saltwell pumps. This analysis also examines the typical hydrogen concentration peaks and the rates of increase in hydrogen levels already witnessed in tanks during saltwell pumping activities. The historical data show that these rates and maximum concentrations are so low as to make it unlikely that the LFL concentration would ever be approached.

The second objective of this analysis is to review the data provided by two separate flammable gas measurement systems on each tank being saltwell pumped to see if there is an unnecessary redundancy. Eliminating redundant measurement systems would provide cost savings if the quality of data and resultant margin of safety during saltwell pumping activity are not compromised.

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2.0 EFFECT OF PUMPING ON DOME SPACE HYDROGEN CONCENTRATIONS

This analysis provides examination of hydrogen concentrations in tank headspaces of thirteen tanks that have recently been involved in saltwell pumping campaigns. For those tanks equipped with multiple component monitors, ammonia concentrations were also studied. Gas concentration data have been compared on a timeline to daily pumping activity with the objective of determining a statistical base from which maximum concentrations may be estimated for other tanks. This timeline comparison between pumping activity and hydrogen concentration increases provides direct evidence that pumping-induced concentration increases can be controlled or "turned around" by merely stopping the pumping activity.

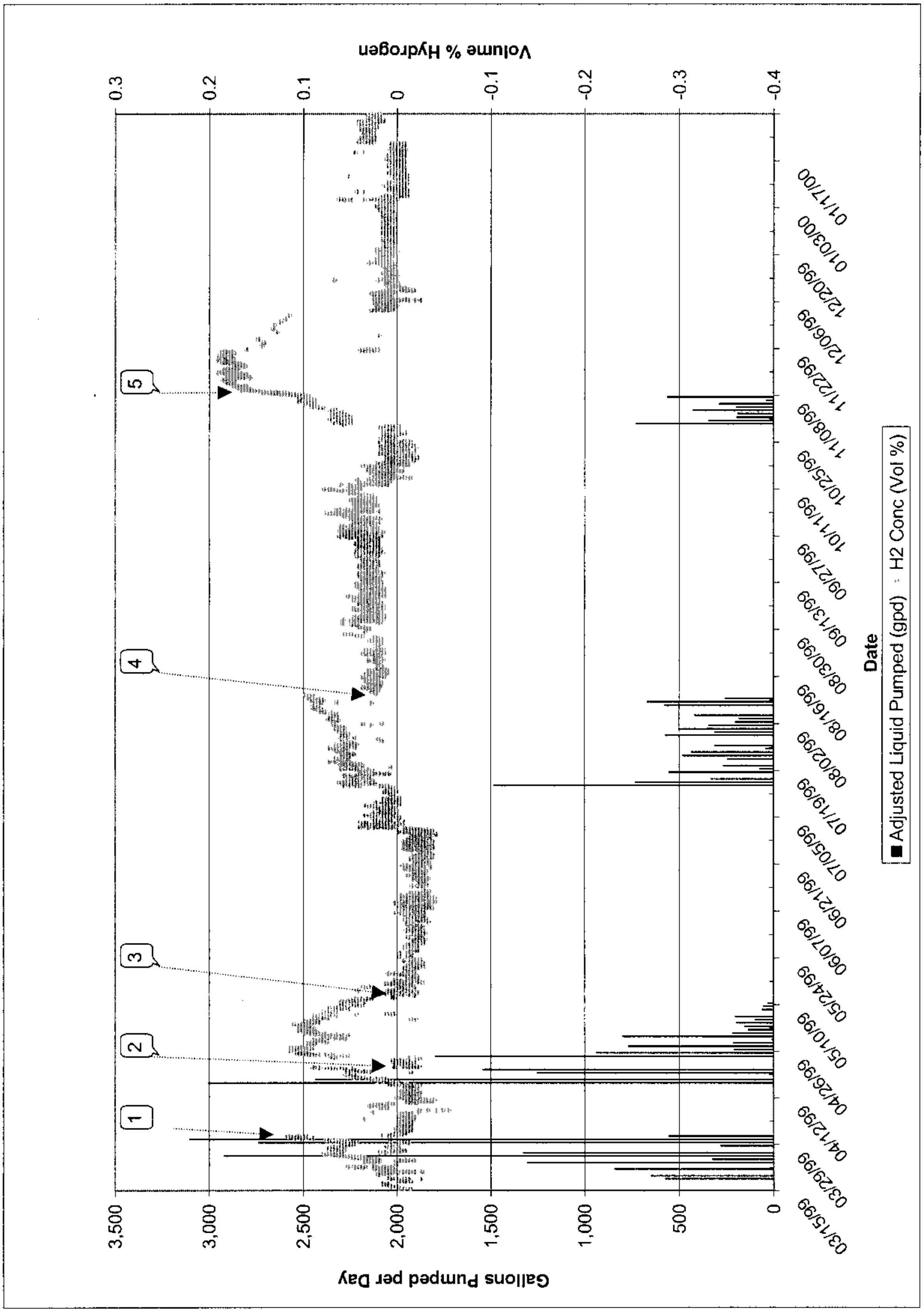
2.1 METHOD OF ANALYSIS

Single-shell tanks 241-S-102, 241-S-106, 241-SX-104, 241-SX-106, 241-T-110, 241-U-103, and 241-U-105 were saltwell pumped within the last year. All of these tanks were equipped with Whittaker™[1] Cell instrumentation to measure hydrogen concentration in the tank headspace. Two of these tanks (241-S-106 and 241-U-105) were equipped with a gas chromatograph and photoacoustic monitors that also measured ammonia and other gases.

Ventilation flow rate through a tank's dome space is an important factor affecting measured gas concentrations. Of the seven tanks above, five (241-S-102, 241-S-106, 241-T-110, 241-U-103, and 241-U-105) were "static" – ventilated only by atmospheric breathing. Because of their low ventilation flow, four of these tanks showed significant changes in dome space gas concentrations in response to saltwell pumping activities. Tank 241-T-110 showed essentially a zero hydrogen concentration with only noise type variation throughout the pumping activity. Tanks 241-SX-104 and 241-SX-106 are equipped with active (or forced) ventilation and, consequently, their gas concentrations did not vary as dramatically. Figures 2-1 through 2-5 show the correlation of hydrogen concentration versus pumping activity for five tanks where hydrogen concentration changes can be seen. Numbered tags represent identifiable events for each tank, detailed in Table 2-2. Percent Lower Flammability Limit (LFL) data were also electronically logged from six tanks (241-T-104, 241-S-108, 241-S-110, 241-BY-103, 241-BY-106, and 241-BY-109) that were being saltwell pumped in 1996. These data were obtained from Caley et al. (1996).

[1] Whittaker is a trademark of Whittaker Corporation, Garden Grove, California.

Figure 2-1. Tank 241-S-102 Hydrogen Released Versus SWP Gallons Pumped



Figures 2-2. Tank 241-S-106 Hydrogen Released Versus SWP Gallons Pumped

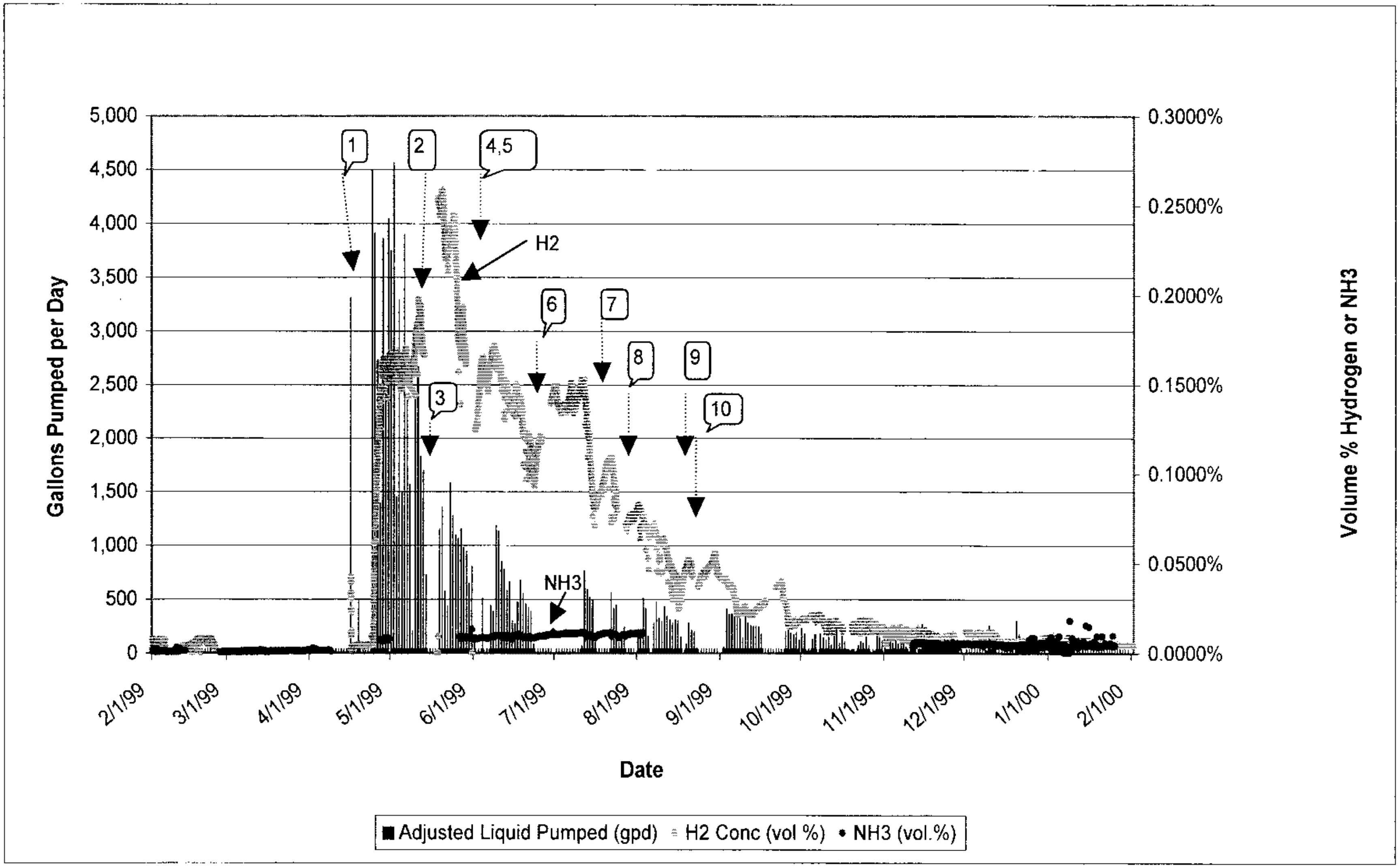


Figure 2-3. Tank 241-SX-104 Hydrogen Released Versus SWP Gallons Pumped

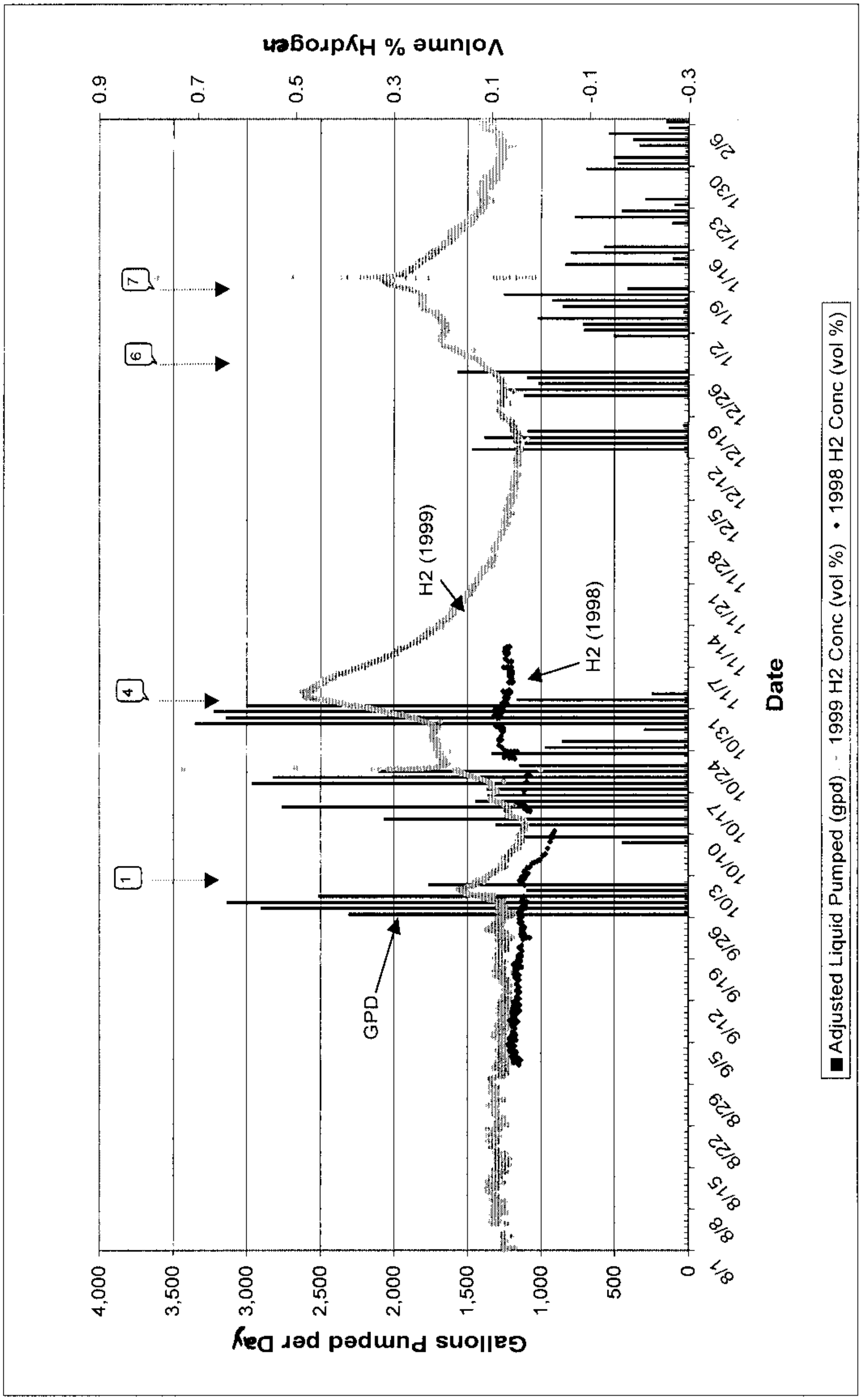


Figure 2-4. Tank 241- U-103 Hydrogen Released Versus SWP Gallons Pumped

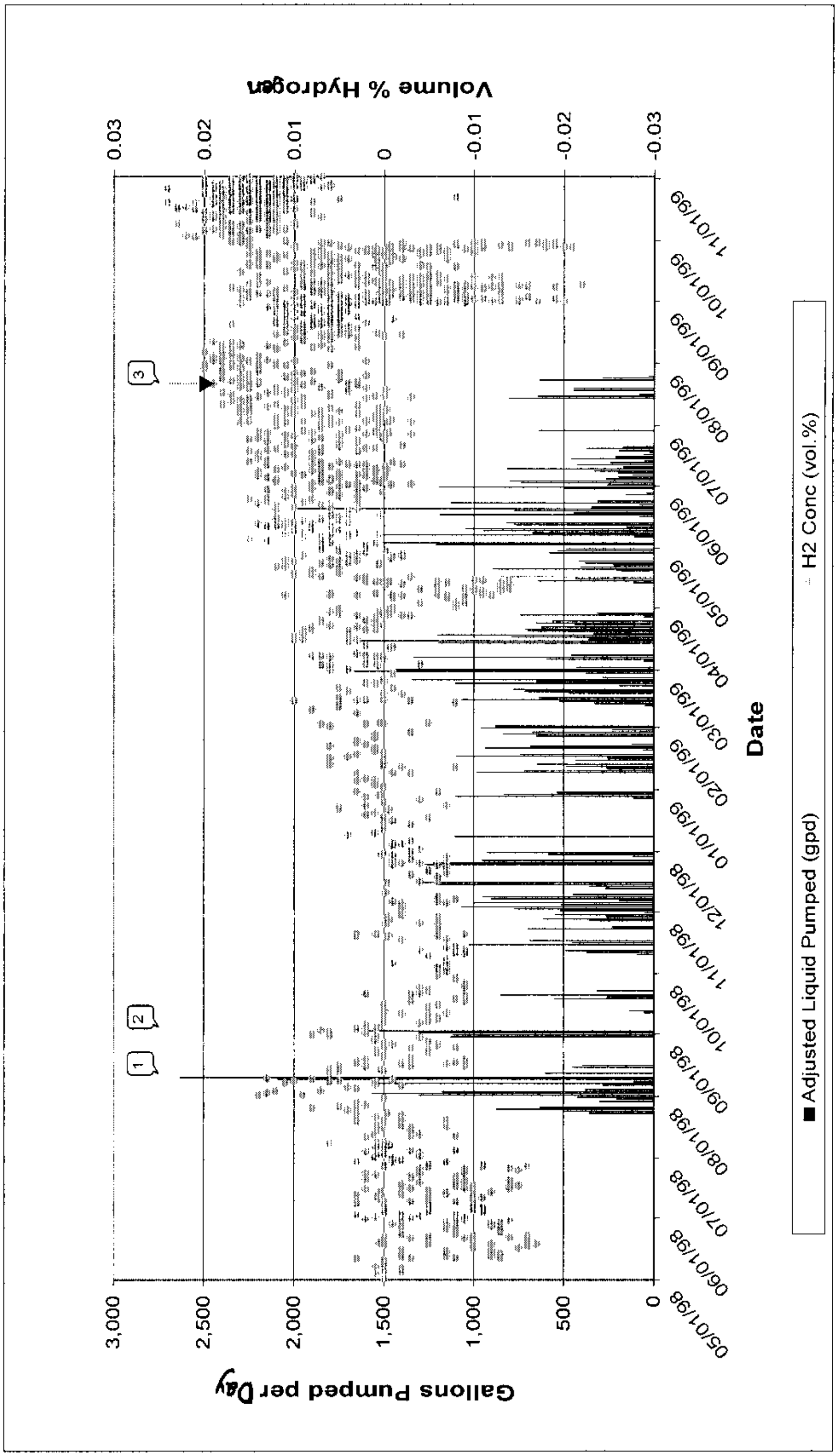


Figure 2-5. Tank 241-U-105 Hydrogen Released Versus SWP Gallons Pumped

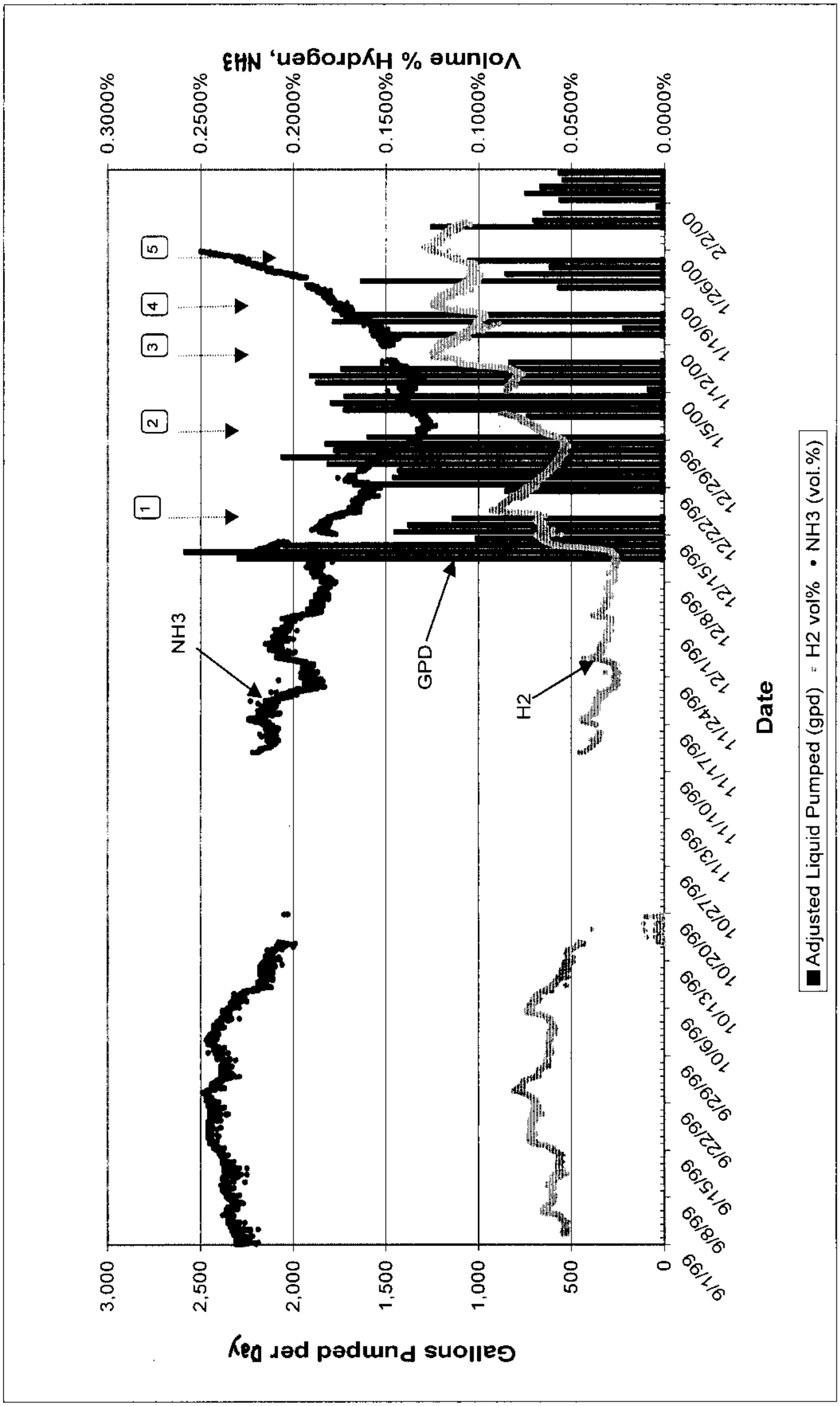


Table 2-1 shows two hydrogen concentration values for those tanks that showed perceptible responses to pumping: baseline hydrogen concentration prior to pumping and maximum concentration during pumping activities.

Table 2-1. Flammable Gas Concentrations Observed During Saltwell Pumping.

Tank	Period of Observation		Baseline Concentration	Maximum Concentration	Units
	Start	End			
S-102	3/15/99	1/31/00	Approx. 0	0.19	Vol. % H_2
S-106	2/1/99	2/1/00	<0.01	0.27	Vol. % H_2
SX-104	5/1/98	11/1/99	<0.006	0.025	Vol. % H_2
U-103	8/1/99	2/6/00	<0.1	0.5	Vol. % H_2
U-105	9/1/99	1/30/00	<0.08	0.13	Vol. % H_2
T-104	3/24/96	8/31/96	NA	2.0	% LFL
S-110	3/24/96	8/7/96	0.2	1.8	% LFL
S-108	3/31/96	8/31/96	NA	1.6	% LFL
BY-106	9/1/95	10/10/95	NA	18.	% LFL
BY-103	9/6/95	10/16/95	NA	3	% LFL
BY-109	9/6/95	10/9/95	NA	3	% LFL
SX-106	10/7/98	11/3/99	Approx. 0	0.02	Vol. % H_2
T-110	1/1/98	12/31/99	Approx. 0	0.06	Vol. % H_2

Notes:

Approx. = approximately
NA = not available in Caley et al. (1996)--just maximum concentrations
Vol. % = volume percent
% LFL = Lower Flammability Limit

Table 2-2 shows hydrogen concentration responses to pumping activity as depicted in Figures 2-1 through 2-5 and as described in Caley et al. (1996). The data were examined to determine how the hydrogen concentration responded after a saltwell pump was stopped. Each response (either decreasing or increasing) was also evaluated for the delay between pump start or stoppage and the corresponding response. For three events where the hydrogen concentration increased most dramatically, a maximum rate of hydrogen increase was calculated as a percent of the LFL rise per day.

Table 2-2. Hydrogen Response Correlation to Saltwell Pumping Activity. (2 Sheets)

		Ongoing Event (Pumping Starts)			Pumping Termination Event (Pumping Stops)	
Tank	Event #	H_2 Response +/-	Delay (Days)	Rate of Rise (% Units/d)	H_2 Response +/-	Delay (Days)
S-102	1	+	1		-	1
S-102	2	+	0		-	0

Table 2-2. Hydrogen Response Correlation to Saltwell Pumping Activity. (2 Sheets)

		Ongoing Event (Pumping Starts)			Pumping Termination Event (Pumping Stops)	
Tank	Event #	H_2 Response +/-	Delay (Days)	Rate of Rise (% Units/d)	H_2 Response +/-	Delay (Days)
S-102	3	+	0		-	0
S-102	4	+	0		-	0
S-102	5	+	0	0.06	-?	13
S-106	1	+	0		-	0
S-106	2	+	1		-	1
S-106	3	None	NA		-	1-4?
S-106	4	+	0		+	0
S-106	5	+	1		-	0
S-106	6	+	0		+	0
S-106	7	-	0		+	0
S-106	8	-	0		+	0
S-106	9	?	?		?	?
S-106	10	+	0		-	6
SX-104	1	+	0		-	0
SX-104	2	?	?		?	?
SX-104	3	+	0?		-	0?
U-103	1	+	3		-	1
U-103	2	NA				
U-103	3	+	5		None	
U-103	4	+	0	0.07	-	0
U-103	5	+	3		None	
U-103	6	+	4		-	4
U-103	7	+	2		-	0
U-105	1	+	1	0.04	-	1
U-105	2	+	8		-	4
U-105	3	+	7		-	0
U-105	4	+	4		-	2
U-105	5	+	5		-	2
T-104	1	+	3		-	5
T-104	2	+	1		?	-
T-104	3	+	0		+	1
S-110	1	+	5		-	0
S-110	2	+	1		-	1
S-108	1	+	?		-	2
S-108	2	+	2		-	1
S-108	3	+	2		-	0

Notes:

/d = per day

? =Saltwell pumps start/end without recoverable/decipherable monitoring data.

2.2 ANALYSIS RESULTS

The data from Table 2-1 show that saltwell pumping has induced hydrogen concentration peaks, but none have exceeded a value of 0.5 volume percent (vol. %) hydrogen or 12.5 percent of the LFL for hydrogen.

The general observation obtained from Table 2-2 is that hydrogen concentrations increased for eight tanks after pumping was started (or restarted after one or more days of no pumping). The "+" values in Table 2-2, column three reflect this trend. The more important observation is that hydrogen concentrations generally decreased after pumping was terminated. The "-" values in Table 2-2, column 6 show this response, generally between 0 and 6 days. Exceptions to this trend have been highlighted in Table 2-2. The first exception occurs in tank 241-S-102, event #5, where hydrogen concentrations began rising almost immediately after pumping began on October 29,1999. When pumping was terminated on November 8, 1999, the percent H_2 continued to rise for four days and then leveled out for another nine days (at 0.19 % H_2) before beginning to decrease to a baseline reading of 0.02 % or less. In tank 241-S-106, events #4, #6, #7, and #8, the termination of pumping appears to have caused immediate increases in hydrogen concentrations. In tank 241-T-104, event #3, termination of pumping resulted in a significant increase in hydrogen concentration, lasting about six days.

The behavior of hydrogen releases in response to terminations in pumping can be summarized as follows:

- Out of 32 "off-going" events, the hydrogen concentration decreased 27 times and increased 5 times.

- Of the 27 decreasing responses, most decreases occurred within six days or less after pumping was terminated. However, in two events it took 13 and 15 days before concentrations began to drop.

These observations of 32 responses support the proposal that rising hydrogen concentrations can be controlled (turned around) by merely stopping pumping operations. However, in 16 percent of the total responses or in 25 percent of the tanks observed, hydrogen concentrations increased after pumping was terminated and remained at an increased level for periods of 2 to 17 days. How long these increased release rates would have lasted is uncertain since in four of these five anomalous events, pumping was always restarted before the point of natural concentration downturn occurred. In no event was 25% of the LFL exceeded.

The combination of a maximum observed rate of concentration increase (0.07 vol. % per day) and a maximum observed duration of release after termination (17 days) conservatively suggests that a tank's hydrogen concentration might climb by 1.2 vol. % even after pumping is terminated. However, Table 2-3 summarizes the anomalous responses to pumping terminations and indicates that a 1.2 vol. % rise in hydrogen concentration is not likely, since the maximum rise during an extended "pumping termination" event is less than 0.06 vol. % hydrogen. The results in Table 2-3 show that the largest observed increase in flammable gas concentration following pumping termination was 1.4 % of the LFL (0.056 vol. % hydrogen). This rise in flammable gas concentration following pumping termination should be easily handled given the margin of safety that the control point of 25 % of the LFL provides.

Table 2-3. Anomalous Responses to Pumping Terminations.

Tank	Event #	Vol. % H_2 at time of termination	Vol. % H_2 at peak after termination	Days delay until peak	Pumping termination H_2 rise. Vol. % (% LFL)
241-S-102	5	0.147	0.189	7	0.042 (1.05)
241-S-106	4	0.1276	0.162	2	0.0344 (0.86)
241-S-106	6	0.0959	0.1511	17	0.0552 (1.38)
241-S-106	7	0.0836	0.1086	5	0.025 (0.625)
241-S-106	8	0.0702	0.08	4	0.0098 (0.245)
241-T-104	3	0.016	0.072	2	0.056 (1.4)

3.0 EVALUATION OF DATA FROM PUMP PIT MONITORS

Section 2.5.2.1.5.6 of the FSAR requires tanks being saltwell pumped to be equipped with a flammable gas monitor that monitors the area where the pump operates and is interlocked with the pump. If readings from the monitor show flammable gas concentrations greater than 25% of the LFL, pumping is discontinued until the monitor reads less than or equal to 25 % of the LFL.

Two manufacturers have provided monitors for use in the pump pits. They employ a catalytic bead converter that is calibrated with methane and measures percent of the LFL. The output of the monitors represents all of the flammable gases in the vapor. Most of the tanks being saltwell pumped also have a Standard Hydrogen Monitoring System (SHMS) connected to the dome space of the tank. These units have a sensor made by the Whittaker™ Corporation that directly detects hydrogen.

Evaluations have been made for six tanks during periods of pumping so that comparisons can be made between the two monitors. The LFL for hydrogen in air is 4%, or 40,000 parts per million (ppm) hydrogen; thus 25 % of the LFL would be 1%, or 10,000 ppm.

Figures 3-1 and 3-2 show monitoring data from tank 241-S-102 for June through January 2000. The maximum reading in the pit was about 17% of the LFL while the corresponding peak value in the dome space was about 1,800 ppm hydrogen.

Data from tank 241-S-106 for the period of April to December 1999 are shown in Figures 3-3 and 3-4. The peak value in the pump pit was about 12% of the LFL and the peak dome value was 2,500 ppm.

Readings for tank 241-U-102 are presented in Figures 3-5 and 3-6 for the period of January to March 2000. A peak value of about 12% of the LFL occurred in the pump pit while the maximum hydrogen concentration in the dome was 3,000 ppm.

Data for the period of December 1999 to March 2000 are shown for tank 241-U-103 in Figures 3-7 and 3-8. This tank had the highest LFL readings of the tanks discussed in this report. Values of up to 20 % of the LFL were recorded. However, the corresponding dome space concentration was only 3,300 ppm.

Data for 241-U-105 in Figures 3-9 and 3-10 show the pump pit reached 15% of the LFL while the dome was about 6 % of the LFL. LFL was calculated for 241-U-105 dome space (instead of ppm values) because of the availability of gas chromatography and photoacoustic measurement systems on that tank. Finally, Figures 3-11 and 3-12 for tank 241-U-109 for the period of March to April 2000 show that the pump pit maximum was 9 % of the LFL and the dome peaked at 5,000 ppm.

Figure 3-1. Tank 241-S-102 Pump Pit Flammable Gas Monitoring.

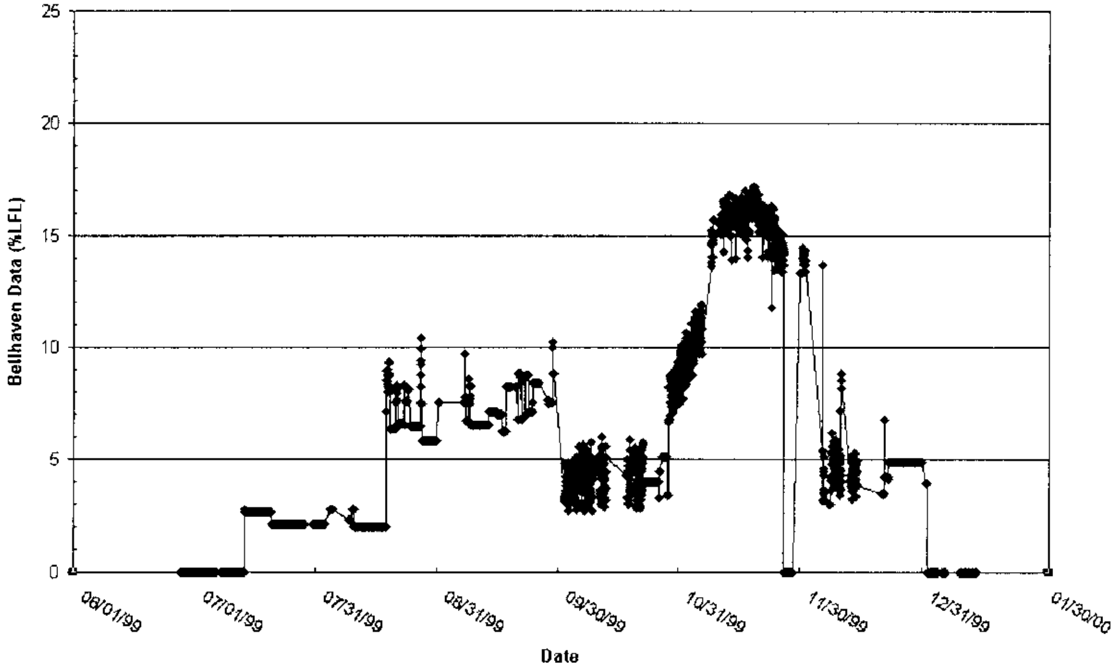
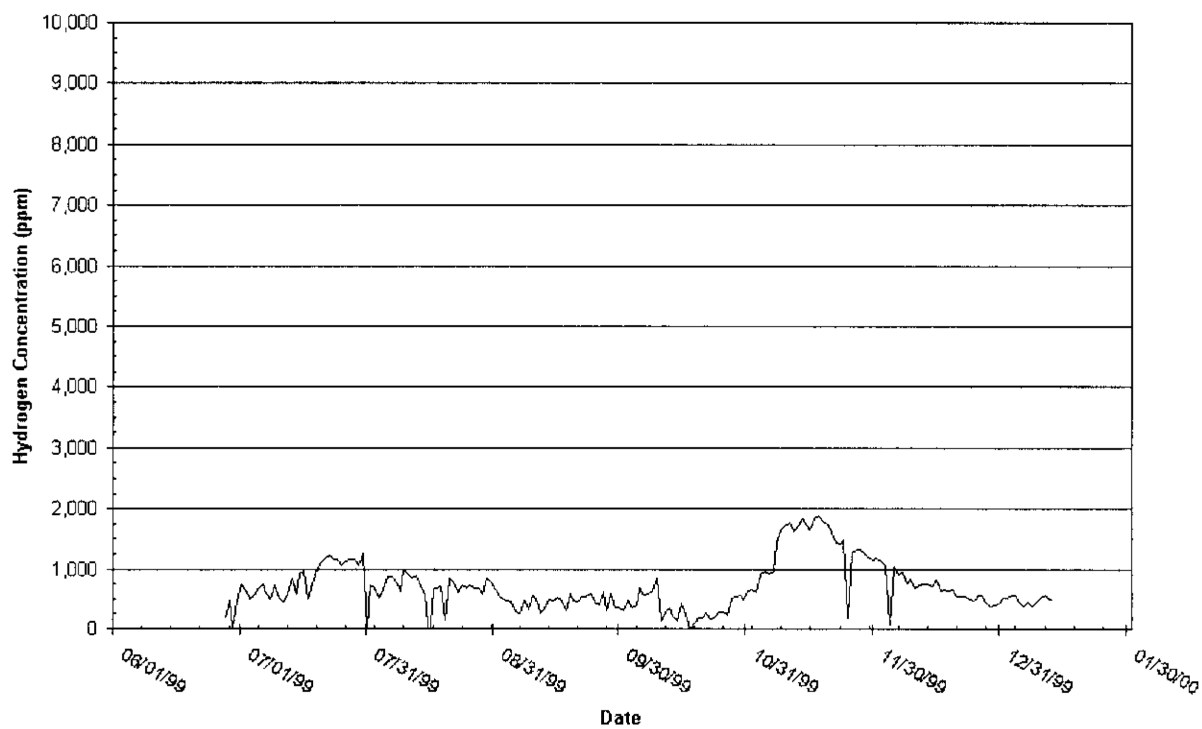


Figure 3-2. Tank 241-S-102 Dome Space Hydrogen Monitoring.



7Figure 3-3. Tank 241-S-106 Pump Pit Flammable Gas Monitoring.

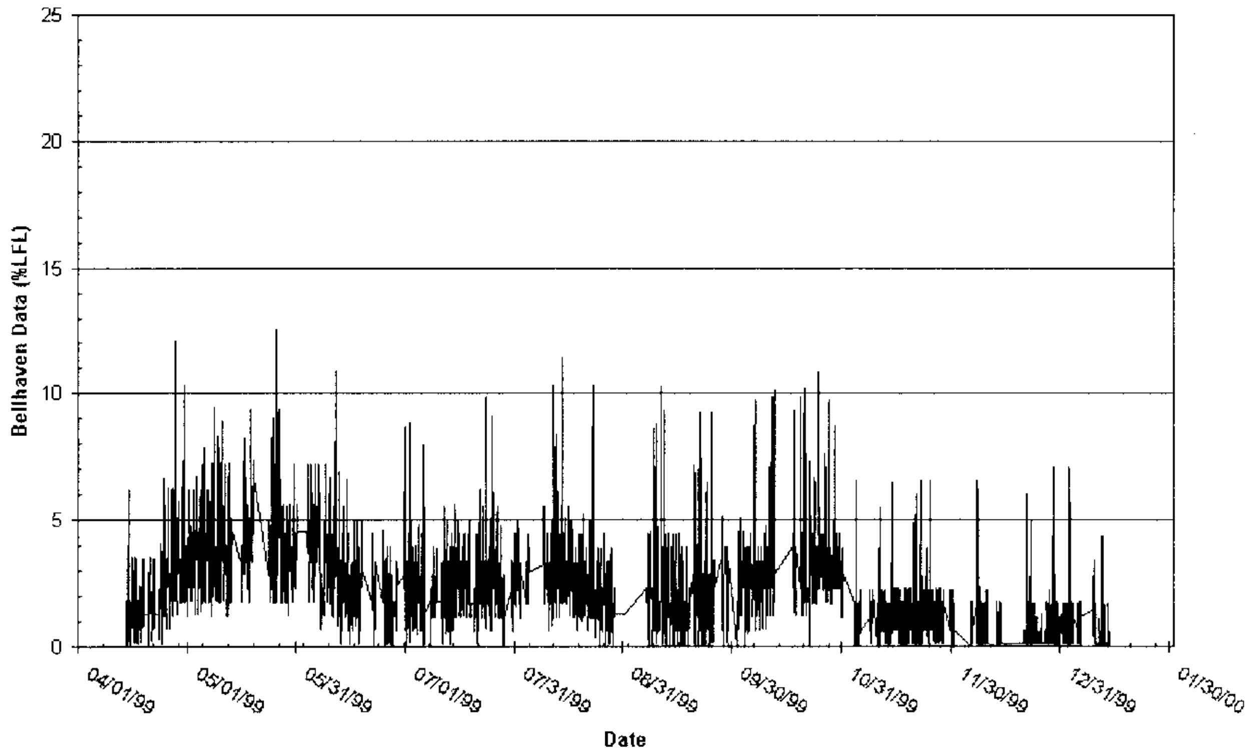


Figure 3-4. Tank 241-S-106 Dome Space Hydrogen Monitoring.

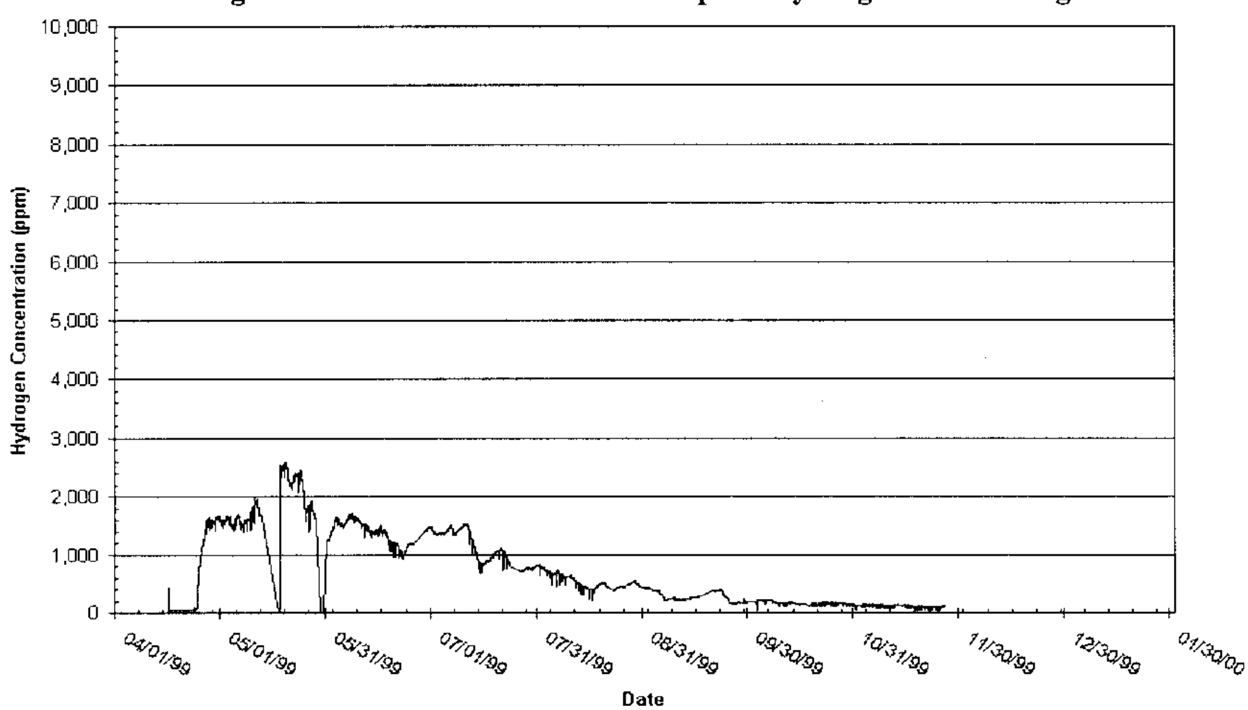


Figure 3-5. Tank 241-U-102 Pump Pit Flammable Gas Monitoring.

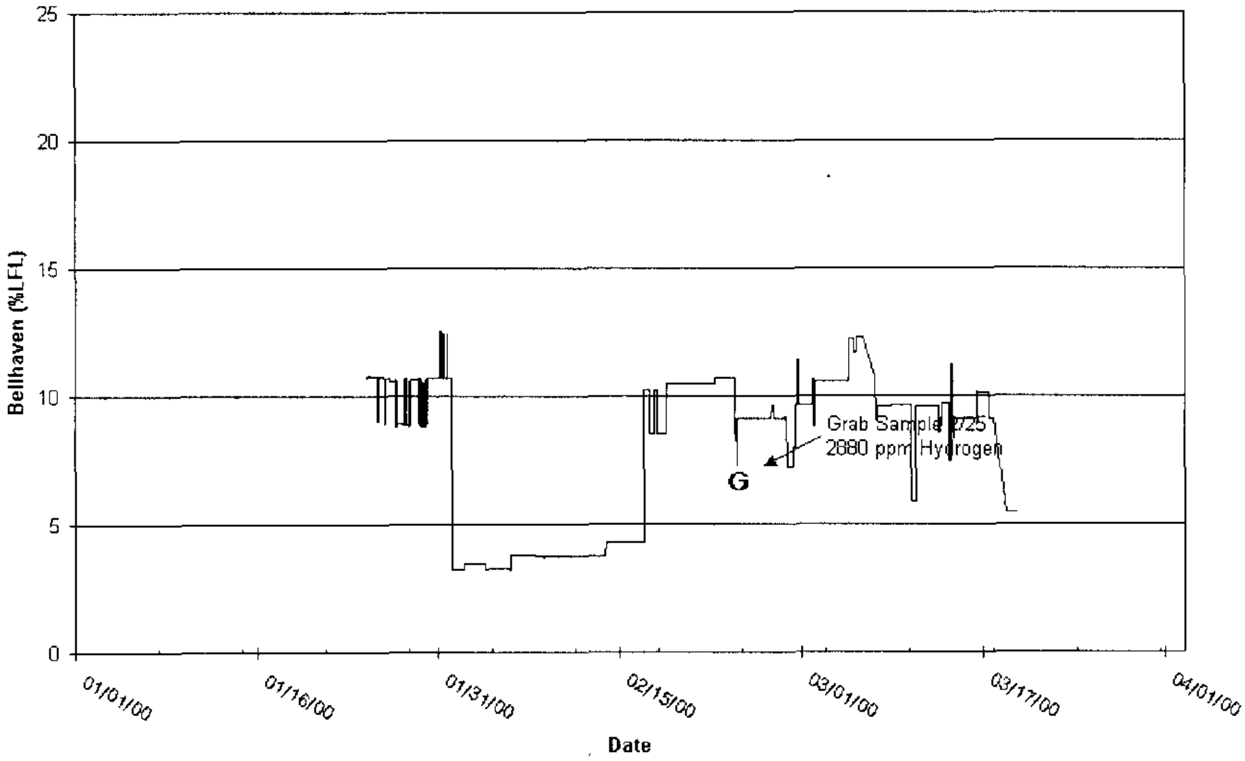


Figure 3-6. Tank 241-U-102 Dome Space Hydrogen Monitoring.

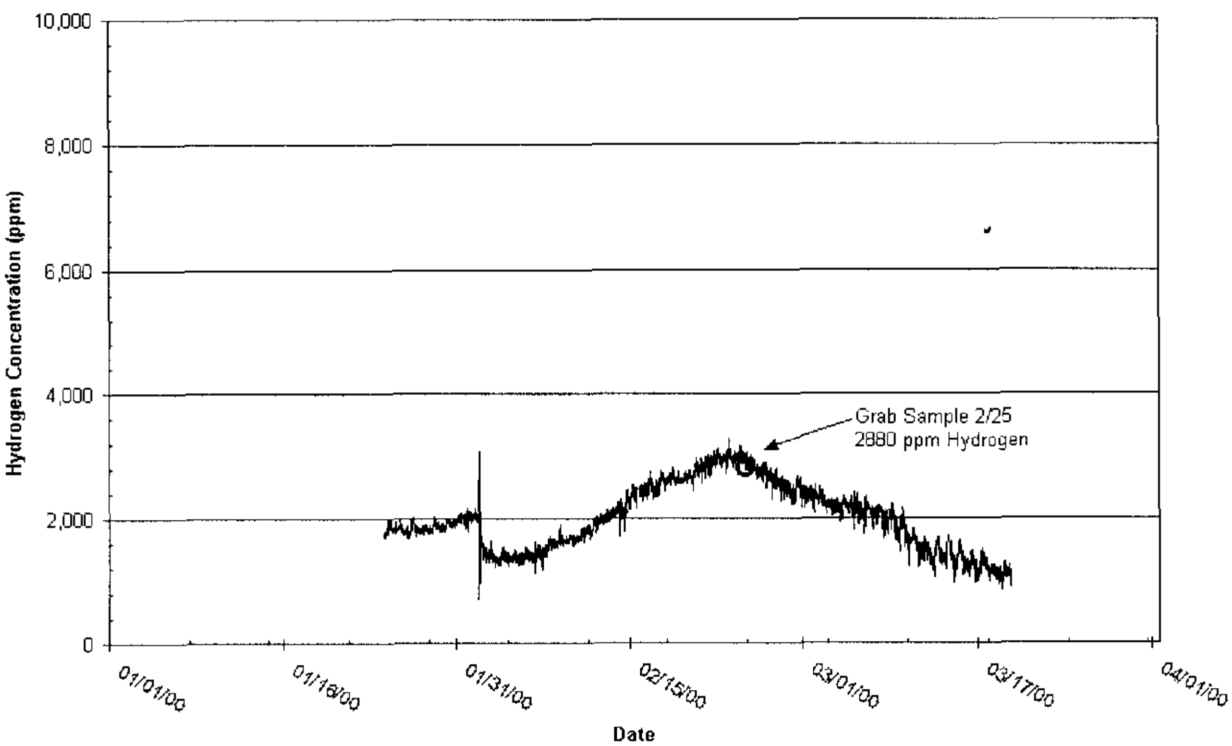


Figure 3-7. Tank 241-U-103 Pump Pit Flammable Gas Monitoring.

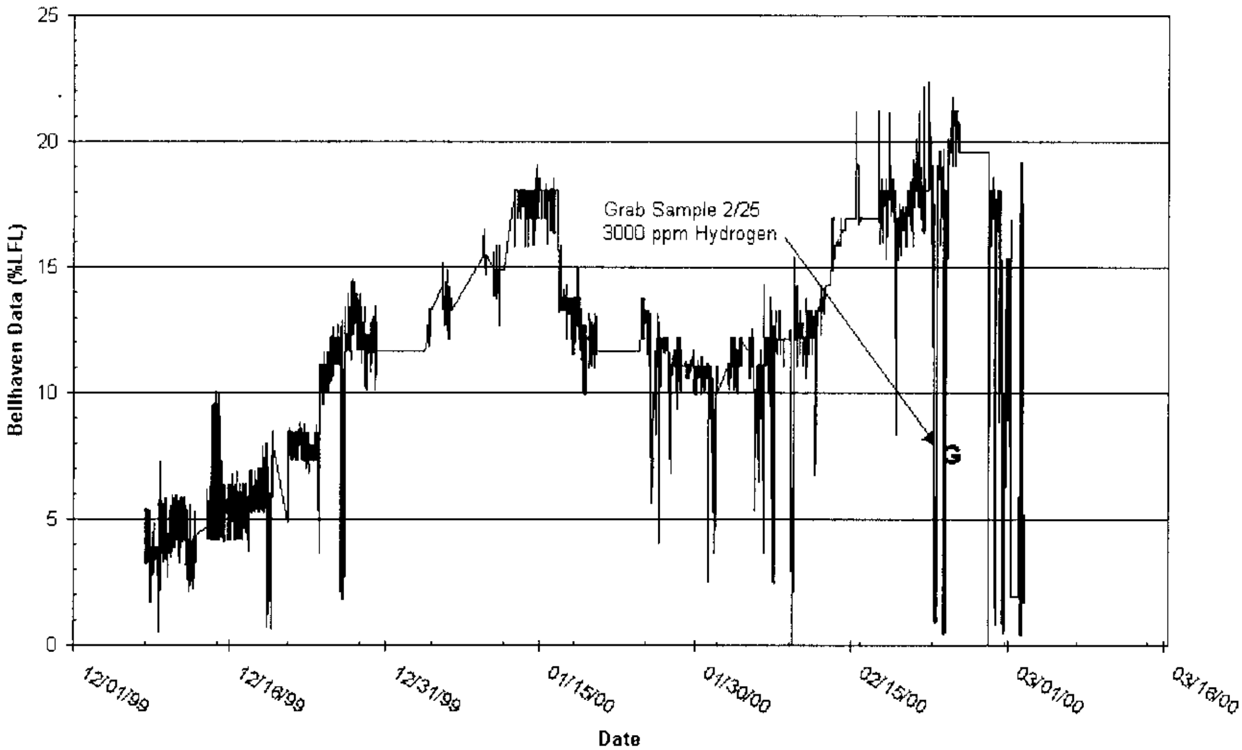


Figure 3-8. Tank 241-U-103 Dome Space Hydrogen Monitoring.

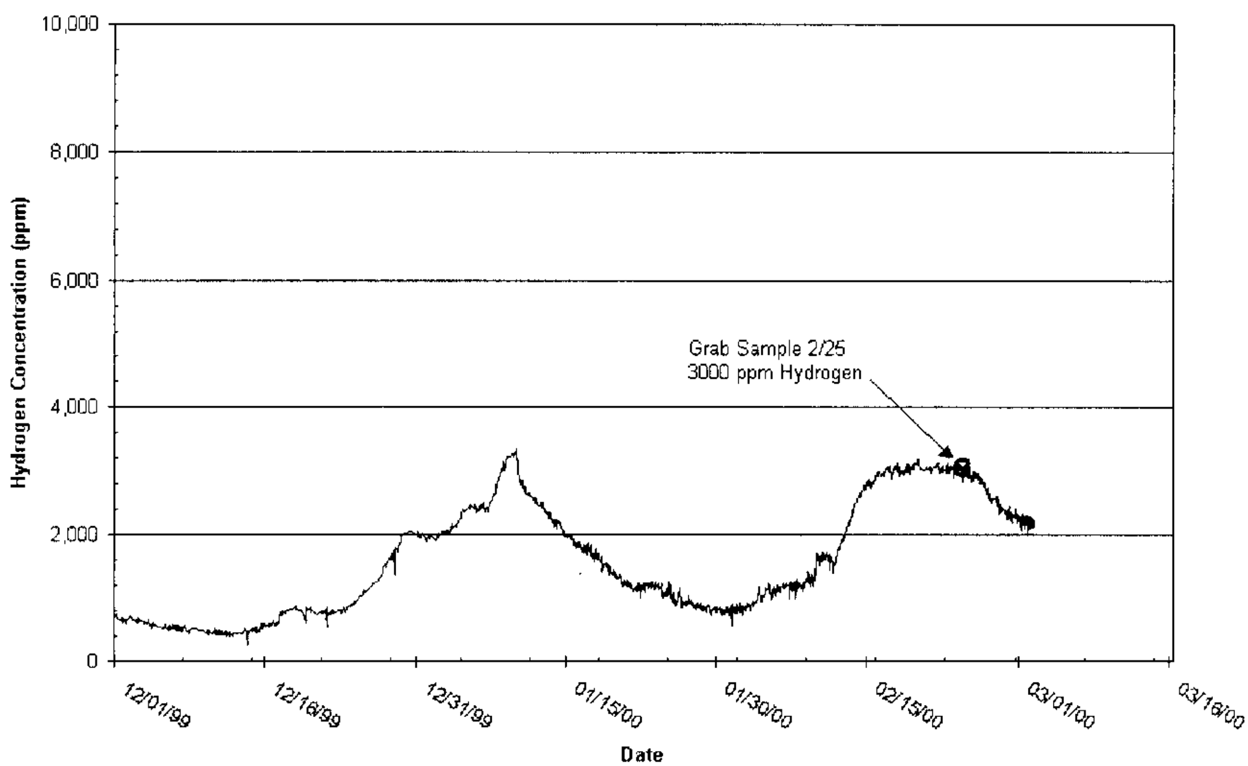


Figure 3-9. Tank 241-U-105 Pump Pit Flammable Gas Monitoring.

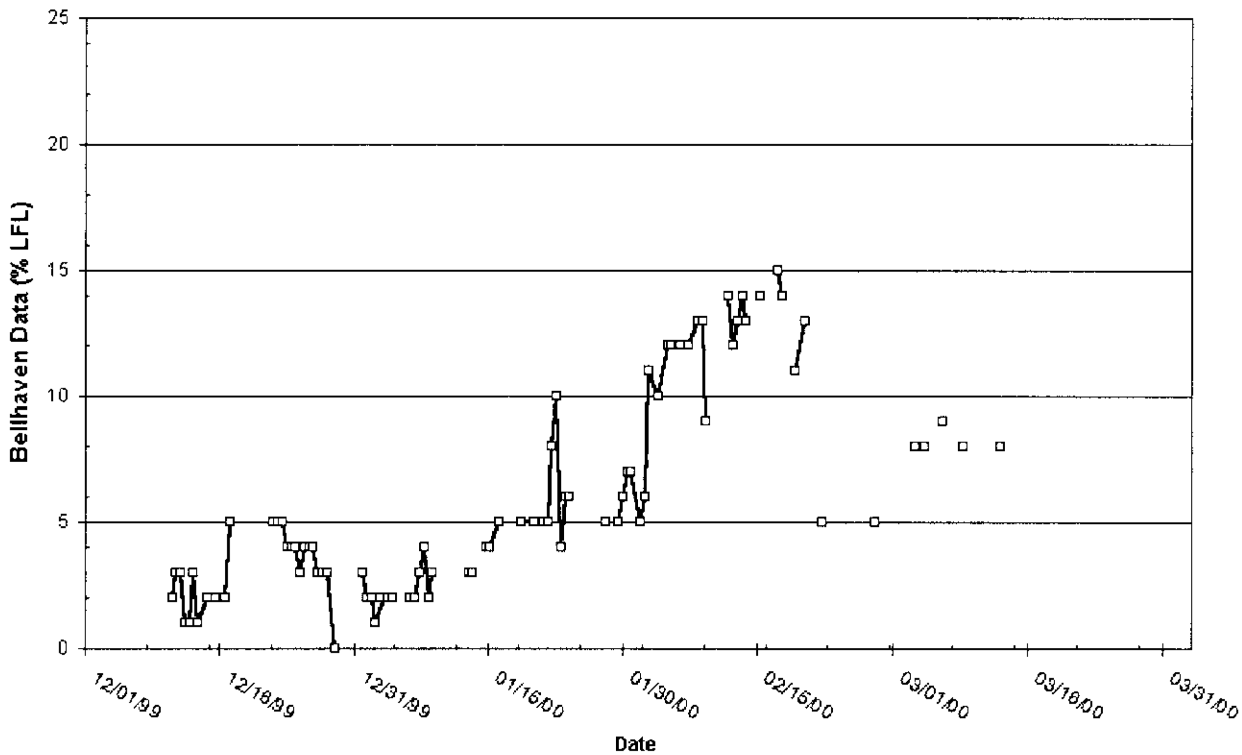


Figure 3-10. Tank 241-U-105 Dome Space Hydrogen Monitoring.

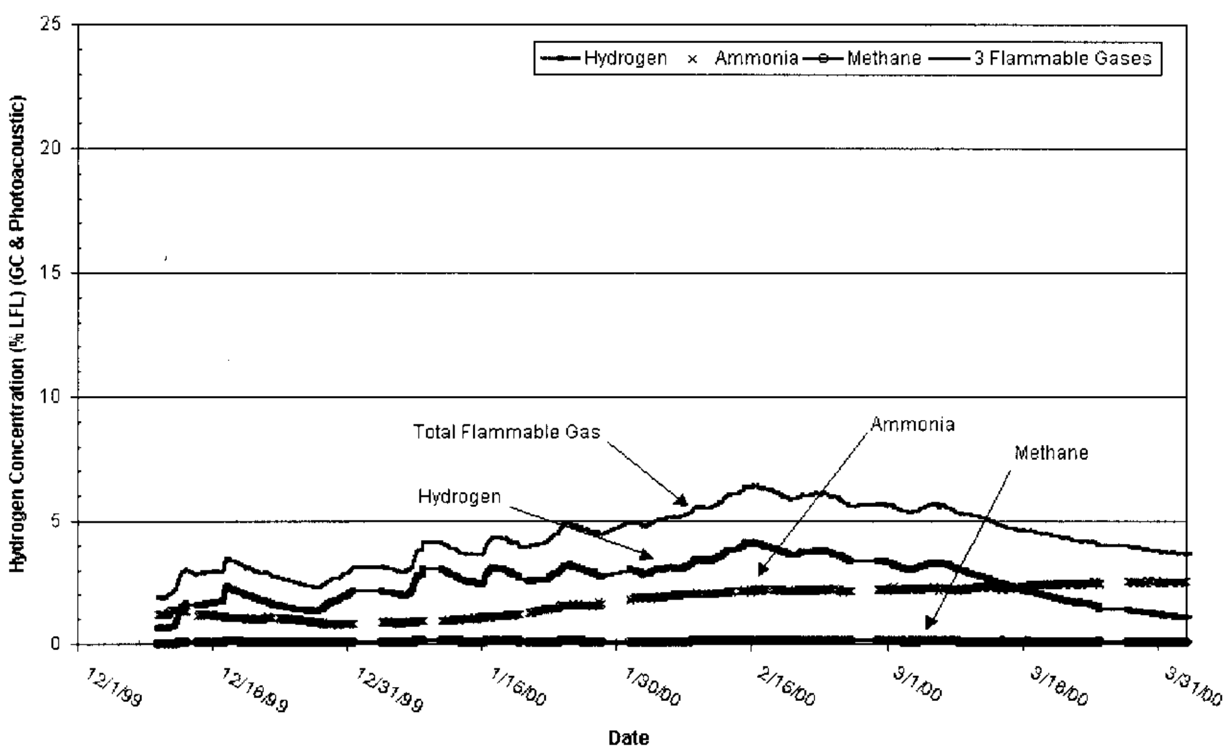


Figure 3-11. Tank 241-U-109 Pump Pit Flammable Gas Monitoring.

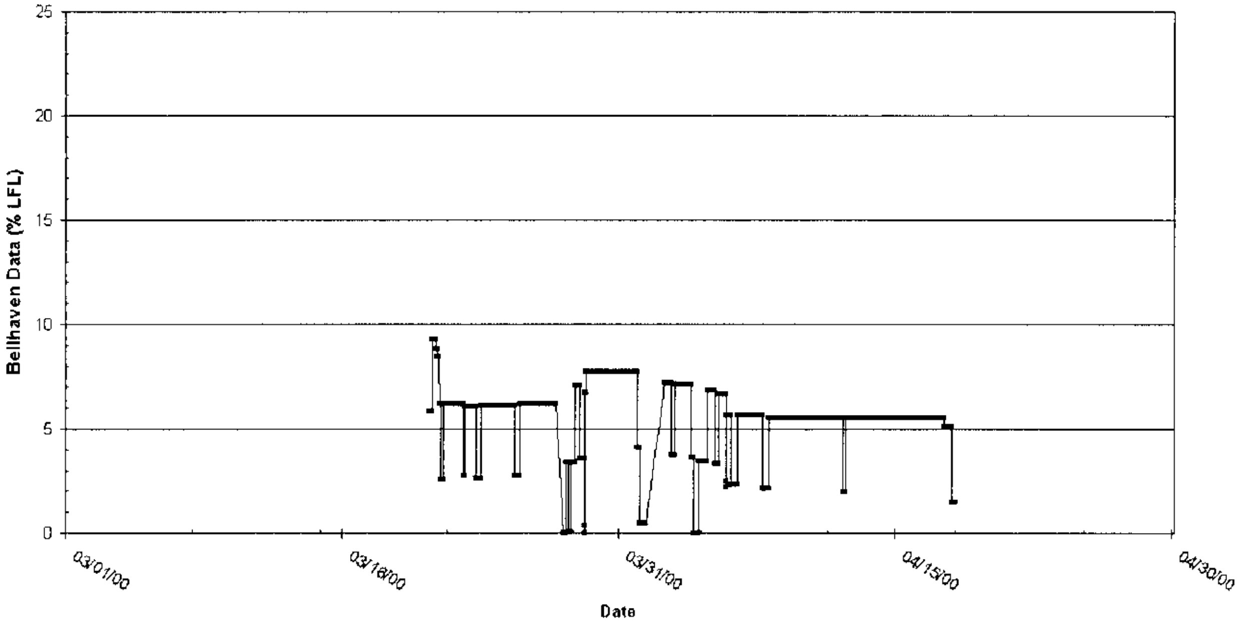
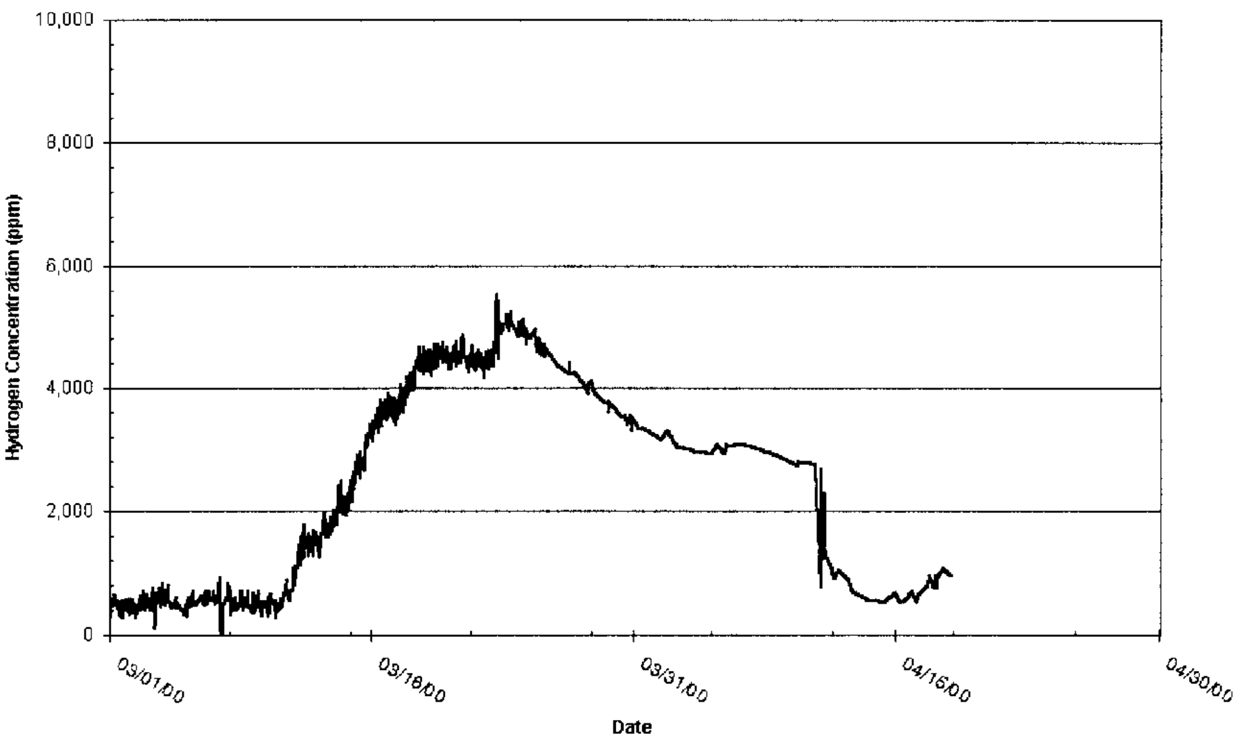


Figure 3-12. Tank 241-U-109 Dome Space Hydrogen Monitoring.



3.1 RESULTS

It is difficult to make a direct comparison of the readings from the two monitoring systems. The instrument for the pump pit is a "flammable gas meter," while the dome space monitor is more specific to hydrogen. However, in no case did the readings exceed 25% of the LFL, whether measuring flammable gas or hydrogen or three gases measurable by gas chromatograph and photoacoustic cells. Three grab samples were taken from the pump pits recently during saltwell pumping operations. The grab samples were analyzed by mass spectrometry, an even more precise measurement system. The results are found in Table 3-1.

Table 3-1. Comparison of Monitoring Results with Pump Pit Vapor Samples

TANK	Pump Pit Hydrogen from Grab Sample, ppm	Dome Space Hydrogen from SHMS, ppm
241-U-102	2880	3060
241-U-103	3000	2940
241-U-105	1600	1411

The data are key to establishing which of the two monitoring methods is most accurate. A quick review of Figures 3-5 through 3-8 shows that the mass spectroscopy values coincide most with those from the dome space rather than from the pump pit flammable gas meter. Since the accuracy of the data from the grab samples is about 1 ppm, it can be concluded that the monitors in the pump pits may be giving a reading somewhat higher than the actual concentration.

A similar observation has been documented (Wilkins 1996) for the hand held combustible gas monitors commonly used for "sniff" analysis at the tank risers. These units, which are calibrated with pentane, were found to give an LFL reading that was 5 to 40% higher than the actual LFL for hydrogen concentrations above 1,220 ppm. If ammonia and/or nitrous oxide were added to the hydrogen-air mixture the unit also indicated a higher LFL than was actually present.

Another important observation is that the charts for the pump pit readings tend to be congruent with the dome space readings over the same time period. This demonstrates that the pits are in communication with the dome spaces. It is highly unlikely that there could be an accumulation of gases in the pits above that measured in the dome space. If the pump pit were accumulating hydrogen (a light gas), it would have to be sealed very tightly, and a congruent decrease in flammable gas concentration with the dome space would not have been observed.

It was shown in the first section of this report that the rate of increase of the concentration upon termination of pumping is fairly slow (maximum 0.07 vol. % per day). The data also support the fact that the pit and dome space are in good communication and that the changes in hydrogen concentration occur slowly. It should be noted that the use of 25% of the LFL is a conservative approach; this gives a factor of 4 reduction from the point of potential ignition capability.

4.0 ANALYSIS OF WASTE TYPES

In order to predict flammable gas behavior in the tanks yet to be pumped, an analysis was performed on tanks previously pumped and on tanks that are currently being pumped. Fifteen tanks that have been pumped or are currently being saltwell pumped and nineteen tanks that are scheduled to be pumped in the next several years were reviewed. The groupings of tanks are saltcake/salt slurry waste tanks (SC/SS), sludge waste tanks (SL), mixed wasted tanks (MIX), and liquid waste tanks (LIQ). A suffix is added to indicate whether or not at least a meter of liquid is present over the solids layer (LIQ indicates at least a meter of free-standing liquids is present, NL indicates that less than a meter of free-standing liquids is present).

Barker et al. (1999) previously presented the results of a data review workshop, where criteria were developed to group the tanks to predict missing properties, especially with respect to flammable gas behavior. Barker and Lechelt (2000) then took the latest process control information and classified the tanks using the methodology proposed by the workshop. Table 4-1 presents the 34 tanks investigated, along with the assigned waste grouping, pumping status, waste volume, and normal ventilation rates for each tank. The analysis methodology presented by Barker et al. (1999) indicates that tanks classified as SC/SS-NL or SC/SS-LIQ are more likely to retain gas than tanks classified as MIX or SL. If insufficient information is available for a specific waste grouping, then defaulting to data from a more conservative set of data is justified. The ranking of the waste groups from less likely to retain large amounts of gas (less conservative) to waste groups that are more likely to retain gas (more conservative) is: SL, MIX, SC/SS. In summary, when insufficient information is available for SL or MIX waste groupings, SC/SS waste group information will be conservative and appropriate for analysis of the SL or MIX waste group tanks.

Table 4-1. Saltwell Pumping Tanks Waste Grouping and Pumping Status. (2 Sheets)

Tank	Waste Group	Pump Status	Pump Start Date	Pump End Date	Waste Solids Volume kL (kgal)	Nominal Vent. Rate m^3/min(cfm)
241-A-101	SC/SS-NL	pumping	5/6/00		1685 (445)	0.283 (10)
241-BY-106	SC/SS-NL	pumping			2127 (562)	0.167 (5.9)
241-S-102	SC/SS-NL	pumping	3/18/99		1946 (514)	0.062 (2.2)
241-S-106	SC/SS-NL	pumping	4/16/99		1613 (426)	0.261 (9.2)
241-SX-104	SC/SS-NL	pumping	3/1/98		1768 (467)	0.85 (30)
241-SX-106	SC/SS-NL	pumping	10/7/98		1223 (323)	0.85 (30)
241-T-104	SL-NL	pumping	3/1/96		1234 (326)	0.198 (7)
241-T-110	SL-NL	pumping	5/1/97		1465 (387)	0.198 (7)
241-U-102	SC/SS-NL	pumping	1/20/00		1351 (357)	0.059 (2.1)
241-U-103	SC/SS-NL	pumping	9/26/99		1722 (455)	0.068 (2.4)
241-U-105	SC/SS-NL	pumping	12/11/99		1442 (381)	0.142 (5)
241-U-109	SC/SS-NL	pumping	2/11/00		1688 (446)	0.122 (4.3)
241-BY-103	SC/SS-NL	pumping ended		11/30/97	1514 (400)	0.408 (14.4)

Table 4-1. Saltwell Pumping Tanks Waste Grouping and Pumping Status. (2 Sheets)

Tank	Waste Group	Pump Status	Pump Start Date	Pump End Date	Waste Solids Volume kL (kgal)	Nominal Vent. Rate m^3/min(cfm)
241-BY-109	SC/SS-NL	pumping ended		5/31/97	1098 (290)	0.416 (14.7)
241-S-103	SC/SS-NL	pumping	6/4/99		874 (231)	0.433 (15.3)
241-S-108	SC/SS-NL	pumping ended		9/30/96	1703 (450)	0.198 (7)
241-S-110	MIX-NL	pumping ended		7/31/96	1476 (390)	0.294 (10.4)
241-T-107	SL-NL	pumping ended		4/30/96	655 (173)	0.181 (6.4)
241-AX-101	SC/SS-NL	to be pumped			1370 (362)	0.801 (28.3)
241-BY-105	SC/SS-NL	to be pumped			1904 (503)	0.45 (15.9)
241-C-103	SL-NL	to be pumped			450 (119)	0.283 (10)
241-S-101	MIX-NL	to be pumped			1571 (415)	0.176 (6.2)
241-S-107	SL-NL	to be pumped			1370 (362)	0.125 (4.4)
241-S-109	SC/SS-NL	to be pumped			1919 (507)	0.198 (7)
241-S-111	SC/SS-LIQ	to be pumped			1624 (429)	0.153 (5.4)
241-S-112	SC/SS-NL	to be pumped			1980 (523)	0.113 (4)
241-SX-101	SC/SS-NL	to be pumped			1696 (448)	1.133 (40)
241-SX-102	SC/SS-LIQ	to be pumped			1438 (380)	1.133 (40)
241-SX-103	SC/SS-NL	to be pumped			2400 (634)	1.487 (52.5)
241-SX-105	SC/SS-NL	to be pumped			2411 (637)	2.832 (100)
241-U-106	SC/SS-NL	to be pumped			799 (211)	0.037 (1.3)
241-U-107	SC/SS-NL	to be pumped			1420 (375)	0.334 (11.8)
241-U-108	SC/SS-NL	to be pumped			1681 (444)	0.102 (3.6)
241-U-111	SC/SS-NL	to be pumped			1245 (329)	0.054 (1.9)

When the tanks are ordered based on volume and ventilation rate, Table 4-2, it can be seen that for actively ventilated tanks, only two of the six tanks listed have been or are undergoing saltwell pumping. The maximum hydrogen concentration reached during pumping operations was 0.625 % of the LFL. If it is expected that actively ventilated tanks would not be ventilated during saltwell pumping, the remaining four scheduled tanks would have to be grouped with the passively ventilated tanks.

The remaining 28 tanks are passively ventilated. Since the ability of a tank to retain flammable gases is proportional to the waste volume, the tanks are also sorted by waste volume in Table 4-2. The passively ventilated tanks exhibited peak hydrogen concentrations in the range from two to 18 % of the LFL (high range of data was measured by the combustible gas monitor, so this data point is considered very conservative).

Table 4-2. Tanks Sorted by Ventilation Type and Waste Volume.

Tank	Waste Group	Pump Status	Waste Solids Volume kL	Nominal Vent. Rate cfm	Ventilation Type	H_2 Gen Rate cfm	Steady-State H_2 Conc. In Headspace Vol. % (% LFL)	Max H_2 Conc. During Pumping Vol. % (% LFL)
241-SX-105	SC/SS-NL	to be pumped	2,411	100	Active	1.22E-02	0.012 (0.305)	
241-SX-103	SC/SS-NL	to be pumped	2,400	52.5	Active	7.25E-03	0.014 (0.345)	
241-SX-104	SC/SS-NL	pumping	1,768	30	Active	4.55E-03	0.015 (0.379)	0.025 (0.625)
241-SX-101	SC/SS-NL	to be pumped	1,696	40	Active	1.32E-03	0.003 (0.083)	
241-SX-102	SC/SS-LIQ	to be pumped	1,438	40	Active	2.56E-03	0.006 (0.16)	
241-SX-106	SC/SS-NL	pumping	1,223	30	Active	1.35E-03	0.005 (0.113)	0.02 (0.500)
241-BY-106	SC/SS-NL	pumping	2,127	5.9	Passive	2.61E-03	0.044 (1.106)	0.72 (18)
241-S-112	SC/SS-NL	to be pumped	1,980	4	Passive	1.59E-03	0.04 (0.994)	
241-S-102	SC/SS-NL	pumping	1,946	2.2	Passive	2.60E-03	0.118 (2.955)	0.19 (4.75)
241-S-109	SC/SS-NL	to be pumped	1,919	7	Passive	1.16E-03	0.017 (0.414)	
241-BY-105	SC/SS-NL	to be pumped	1,904	15.9	Passive	1.21E-03	0.008 (0.19)	
241-U-103	SC/SS-NL	pumping	1,722	2.4	Passive	1.87E-03	0.078 (1.948)	0.5 (12.5)
241-S-108	SC/SS-NL	Pumping ended	1,703	7	Passive	9.85E-04	0.014 (0.352)	0.064 (1.6)
241-U-109	SC/SS-NL	pumping	1,688	4.3	Passive	1.15E-03	0.027 (0.669)	
241-A-101	SC/SS-NL	pumping	1,685	10	Passive	5.62E-03	0.056 (1.405)	
241-U-108	SC/SS-NL	to be pumped	1,681	3.6	Passive	1.51E-03	0.042 (1.049)	
241-S-111	SC/SS-LIQ	to be pumped	1,624	5.4	Passive	1.17E-03	0.022 (0.542)	
241-S-106	SC/SS-NL	pumping	1,613	9.2	Passive	1.19E-03	0.013 (0.323)	0.27 (6.75)
241-S-101	MIX-NL	to be pumped	1,571	6.2	Passive	3.31E-03	0.053 (1.335)	
241-BY-103	SC/SS-NL	Pumping ended	1,514	14.4	Passive	1.05E-03	0.007 (0.183)	0.12 (3)
241-S-110	MIX-NL	Pumping ended	1,476	10.4	Passive	1.59E-03	0.015 (0.382)	0.072 (1.8)
241-T-110	SL-NL	pumping	1,465	7	Passive	8.83E-04	0.013 (0.315)	
241-U-105	SC/SS-NL	pumping	1,442	5	Passive	1.67E-03	0.033 (0.835)	0.13 (3.25)
241-U-107	SC/SS-NL	to be pumped	1,420	11.8	Passive	9.58E-04	0.008 (0.203)	
241-AX-101	SC/SS-NL	to be pumped	1,370	28.3	Passive	2.95E-03	0.01 (0.261)	
241-S-107	SL-NL	to be pumped	1,370	4.4	Passive	1.13E-03	0.026 (0.642)	
241-U-102	SC/SS-NL	pumping	1,351	2.1	Passive	1.58E-03	0.075 (1.881)	
241-U-111	SC/SS-NL	to be pumped	1,245	1.9	Passive	1.17E-03	0.062 (1.539)	
241-T-104	SL-NL	pumping	1,234	7	Passive	8.00E-04	0.011 (0.286)	0.08 (2)
241-BY-109	SC/SS-NL	Pumping ended	1,098	14.7	Passive	8.47E-04	0.006 (0.144)	0.12 (3)
241-S-103	SC/SS-NL	Pumping ended	874	15.3	Passive	9.87E-04	0.006 (0.161)	
241-U-106	SC/SS-NL	to be pumped	799	1.3	Passive	1.77E-03	0.136 (3.404)	
241-T-107	SL-NL	Pumping ended	655	6.4	Passive	6.91E-04	0.011 (0.27)	
241-C-103	SL-NL	to be pumped	450	10	Passive	2.55E-03	0.026 (0.638)	

Note: Columns 7 and 8 were derived from Hu et al. (2000)

Of the ten tanks with the highest hydrogen generation rates (Table 4-3), three have been pumped and five also appear in the listing of the ten saltwell pumping tanks with the greatest volume (Table 4-4). The five tanks on both lists are 241-BY-106 (pumping), 241-S-102 (pumping), 241-SX103, 241-SX-104 (pumping), and 241-SX-105.

Table 4-3. Saltwell Pumping Tanks with Greatest Hydrogen Generation Rates.

Tank	Waste Group	Pump Status	Waste Solids Volume (kL)	Nominal Vent. Rate (cfm)	Ventilation Type	H_2 Gen Rate (cfm)	Steady-State H_2 Conc. In Headspace Vol. % (% LFL)	Max H_2 Conc. During Pumping Vol. % (% LFL)
241-SX-105	SC/SS-NL	to be pumped	2,411	100	Active	1.22E-02	0.012 (0.305)	
241-SX-103	SC/SS-NL	to be pumped	2,400	52.5	Active	7.25E-03	0.014 (0.345)	
241-A-101	SC/SS-NL	pumping	1,685	10	Passive	5.62E-03	0.056 (1.405)	
241-SX-104	SC/SS-NL	pumping	1,768	30	Active	4.55E-03	0.015 (0.379)	0.025 (0.625)
241-S-101	MIX-NL	to be pumped	1,571	6.2	Passive	3.31E-03	0.053 (1.335)	
241-AX-101	SC/SS-NL	to be pumped	1,370	28.3	Passive	2.95E-03	0.01 (0.261)	
241-BY-106	SC/SS-NL	pumping	2,127	5.9	Passive	2.61E-03	0.044 (1.106)	0.72 (18)
241-S-102	SC/SS-NL	pumping	1,946	2.2	Passive	2.60E-03	0.118 (2.955)	0.19 (4.75)
241-SX-102	SC/SS-LIQ	to be pumped	1,438	40	Active	2.56E-03	0.006 (0.16)	
241-C-103	SL-NL	to be pumped	450	10	Passive	2.55E-03	0.026 (0.638)	

Table 4-4. Saltwell Pumping Tanks with Largest Waste Solids Volumes.

Tank	Waste Group	Pump Status	Waste Solids Volume (kL)	Nominal Vent. Rate (cfm)	Ventilation Type	H2 Gen Rate (cfm)	Steady State H2 Conc. In Headspace Vol. % (% LFL)	Max H2 Conc. During Pumping Vol. % (% LFL)
241-SX-105	SC/SS-NL	to be pumped	2,411	100	Active	1.22E-02	0.012 (0.305)	
241-SX-103	SC/SS-NL	to be pumped	2,400	52.5	Active	7.25E-03	0.014 (0.345)	
241-BY-106	SC/SS-NL	pumping	2,127	5.9	Passive	2.61E-03	0.044 (1.106)	0.72 (18)
241-S-112	SC/SS-NL	to be pumped	1,980	4	Passive	1.59E-03	0.04 (0.994)	
241-S-102	SC/SS-NL	pumping	1,946	2.2	Passive	2.60E-03	0.118 (2.955)	0.19 (4.75)
241-S-109	SC/SS-NL	to be pumped	1,919	7	Passive	1.16E-03	0.017 (0.414)	
241-BY-105	SC/SS-NL	to be pumped	1,904	15.9	Passive	1.21E-03	0.008 (0.19)	
241-SX-104	SC/SS-NL	pumping	1,768	30	Active	4.55E-03	0.015 (0.379)	0.025 (0.625)
241-U-103	SC/SS-NL	pumping	1,722	2.4	Passive	1.87E-03	0.078 (1.948)	0.5 (12.5)
241-S-108	SC/SS-NL	pumping ended	1,703	7	Passive	9.85E-04	0.014 (0.352)	0.064 (1.6)

Flammable gas behavior is a function of waste volume, waste type and configuration, and hydrogen generation rate. The waste volume determines the amount of gas retained, and the characteristics of gas releases. The waste type is a key factor in the ability of the waste to retain gas and how it is retained and released. The waste configuration (how the solids are distributed with respect to the supernatant layer and the thickness of the supernatant layer) determines the retaining capacity of the waste (a function of pressure of the waste on the gas) and size and frequency of the gas releases. The hydrogen generation rate determines how quickly the waste matrix can be refilled with generated gases if pumping operations are stopped for long periods of time.

A review of Tables 4-1, 4-2, 4-3, and 4-4 finds that tank 241-BY-106 is the bounding tank with respect to the highest flammable gas concentration observed during saltwell pumping (18 % of the LFL by combustible gas monitor [CGM]). As expressed earlier in this document, the CGM readings are suspect because they have proven to read high in comparison to other measurement devices. However, using CGM data will only add to the conservatism of this review. Tank 241-U-103 reached the highest hydrogen concentration, 12.5 % of the LFL, for all tanks with continuous SHMS monitoring. Unpumped tanks 241-SX-103 and 241-SX-105 have the largest waste volumes and hydrogen generation rates of all tanks investigated, and exceed tank 241-BY-106 in both hydrogen generation rate and in waste volume. However, both of these SX farm tanks are currently actively ventilated and should not pose a flammable gas problem in their current configuration. The impact of this greater volume is that more gas may be retained and as a result, gases may be released at a rate faster than currently observed. Also, gas releases following cessation of pumping may be greater than those experienced to-date. However, the evidence indicates that gas releases in tanks of this waste type can be controlled by limiting pumping rate or by occasionally stopping pumping operations. The presence or absence of active ventilation should not be a factor in the saltwell pumping activities in these tanks.

Tank 241-A-101 exceeds tank 241-BY-106 in hydrogen generation rate, but has 20% less waste than 241-BY-106 and, therefore, should not be a problem. Tanks 241-A-101 and 241-AX-101 have a unique waste configuration in that the solid layer is floating above the liquid layer and may be hindered in movement by the many riser penetrations into the solid waste layer. Because of the uncertainty of waste behavior in these tanks, tank 241-A-101 is initially being pumped more conservatively than other tanks. Gas releases and dome stresses are monitored closely to verify waste level movement responsive to saltwell pumping progress.

A review of the tanks listed in Table 2-1 shows that the wastes may be discussed as if they were SC/SS tanks - a conservative assumption. Observations of tanks belonging to the SC/SS waste-type find that gas releases are expected. The maximum daily release rate expected during saltwell pumping should not greatly exceed 3 % of the LFL per day (Figure 2-2). The maximum flammable gas concentration increase following cessation of pumping was 1.5 % of the LFL (Table 2-3); this occurred in both a SC/SS and a SL tank Flammable gas release experience for all tanks reported in this document shows that they behave very similarly. In all cases, flammable gas concentration can be controlled by controlling pumping rates or by stopping pumping. There is no reason to expect that any of the tanks currently being pumped or yet to be pumped will behave significantly different that those reported in this document. Finally, as saltwell pumping progresses, hydrogen generation rates will decrease as the wetted waste volume is decreased and as soluble radionuclides are removed. This also reduces the volume of waste able to retain gas.

5.0 SUMMARY

This document presents data concerning flammable gas concentrations associated with tanks in different phases of saltwell pumping activities. Comparative data for two separate measurement systems of flammable gas concentrations in the tank headspace and pump pits are reported. Finally, waste materials in tanks already pumped are compared with tanks yet to be pumped. This comparison established that the tanks to be saltwell pumped are bounded by the tanks previous pumped or that are currently being pumped.

Tank dome space flammable gas concentrations are comparable to pump pit gas concentrations indicating that the pump pits and the tank headspace are in good communication with respect to gas compositions. The pump pit concentration increases and decreases when the dome space increases and decreases. Flammable gas monitors in the pump pit generally read higher concentrations of gases than the SHMS monitors in the dome space (attributed mostly to more conservative calibration procedures on the former). Vapor grab samples (from three different tanks) taken in the pump pits agree very well with tank headspace concentrations and confirm that the pump pit flammable gas concentration readings as measured by the flammable gas instruments are high.

Flammable gas behavior is a function of waste volume, waste type and configuration, and hydrogen generation rate. The waste volume determines the amount of gas retained and the characteristics of gas releases. The waste type indicates the ability of the waste to retain gas and how it is retained and released. The waste configuration (how the solids are distributed with respect to the supernatant layer and the thickness of the supernatant layer) determines the retaining capacity of the waste (a function of pressure of the waste on the gas) and the size and frequency of gas releases. The hydrogen generation rate determines how quickly the waste matrix can be refilled with generated gases if pumping operations are stopped for long periods of time

In conclusion, saltwell pumping does release flammable gases into the tank dome space and pump pit. Both regions have good vapor communication and mirror each other's rises and falls in flammable gas concentrations. For saltwell pumping experience observed to date, the maximum dome space flammable gas concentration ranged from 2 to 18% of the LFL. The maximum daily release rate expected during saltwell pumping should not greatly exceed 3% of the LFL per day (Table 2-2). Upon termination of saltwell pumping, the release of retained gases usually stops, but it may continue for 17 days or more. The maximum rise in hydrogen concentration following termination of pumping was less than 2% of the LFL and should allow operations to stay within the control bounds of 25% of the LFL. Flammable gas release experience for all tanks reported in this document has shown that they behave very similarly.

In all cases, flammable gas concentration can be controlled by limiting pumping rates or by stopping pumping. There is no reason to expect that any of the tanks currently being pumped or yet to be pumped will behave significantly different that those reported in this document. Finally, as saltwell pumping progresses, hydrogen generation rates will decrease as the wetted waste volume is decreased and as soluble radionuclides are removed. This also reduces the volume of waste able to retain gas.

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D. J. McCain	R2-11	5			
D. J. Saueressig	S7-20	X			
R. L. Schlosser	R3-47	X			
R. D. Smith	R1-49	X			
D. T. Vladimiroff	S7-20	3			
R. A. Watrous	R3-75	X			
T.C.S.R.C.	R1-10	X			
CHEW & Associates, Inc.					
C. Carro	R1-44	X			
G & P Consulting, Inc.					
J. M. Grigsby	R1-44	X			
H & R Technical Associates					
L. J. Kripps	R1-44	X			
Lockheed Martin Services, Inc.					
Central Files	B1-07	X			
Office of River Protection					
W. Abdul	H6-60	X			
C. A. Groendyke	H6-60	X			
Y. G. Noorani	H6-60	X			
J. Shuen	H6-60	X			
DOE Reading Room	H2-53	X			