NOV 10 1998 Sta. 4 58

ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT 625701

2. To: (Receiving Organization) Distribution	3. From: (Originating Organization) Mechanical Systems Design	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: Waste Management	6. Design Authority/ Design Agent/Cog. Engr.: JS Hertzel	7. Purchase Order No.: N/A
8. Originator Remarks: This document is being processed for release.		9. Equip./Component No.: N/A
		10. System/Bldg./Facility: N/A
11. Receiver Remarks: 11A. Design Baseline Document? [] Yes [X] No		12. Major Assm. Dwg. No.: N/A
		13. Permit/Permit Application No.: N/A
		14. Required Response Date: N/A

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	HNF-3018		0	Single Shell Tank Sluicing History and Failure Frequency	N/A	2		

16. KEY

Approval Designator (F)	Reason for Transmittal (G)		Disposition (H) & (I)	
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)	1. Approval 2. Release 3. Information	4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)	1. Approved 2. Approved w/comment 3. Disapproved w/comment	4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION
(See Approval Designator for required signatures)

(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
		Design Authority						GREG BOGEN			R3-74
		Design Agent									
1	1	Cog.Eng. JS Hertzel	JS Hertzel	9/30/98	R3-74						
1	1	Cog. Mgr.PJ Certa	PJ Certa	10/5/98							
		QA									
		Safety									
		Env.									

18. JS Hertzel Signature of EDT Originator — Date 9/30/98	19. Authorized Representative for Receiving Organization — Date	20. PJ Certa 10/5/98 Design Authority/ Cognizant Manager — Date	21. DOE APPROVAL (if required) Ctrl. No. [] Approved [] Approved w/comments [] Disapproved w/comments

BD-7400-172-2 (05/96) GEF097

BD-7400-172-1

Single Shell Tank Sluicing History and Failure Frequency

Jeffory S. Hertzel
Numatec Hanford Corporation, Richland, WA 99352
U.S. Department of Energy Contract DE-AC06-96RL13200

EDT/ECN: 625701 UC: 2030
Org Code: 81200 Charge Code: 1D2631
B&R Code: EW3130010 Total Pages: ~~53~~ 150

Key Words: Leak Detection, Leak Monitoring, Sluicing, SST

Abstract: This document assesses the potential for failure of the single-shell tanks (SSTs) that are presumably sound and helps to establish the retrieval priorities for these and the assumed leakers. Furthermore, this report examines probabilities of SST failure as a function of age and operational history, and provides a simple statistical summary of historical leak volumes, leak rates, and corrosion factor.

ENRAF is a trademark of ENRAF Corporation, Houston, Texas.

TRADEMARK DISCLAIMER. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

Printed in the United States of America. To obtain copies of this document, contact: Document Control Services, P.O. Box 950, Mailstop H6-08, Richland WA 99352, Phone (509) 372-2420; Fax (509) 376-4989.

11/10/98

Release Approval Date

DATE STA: 4 HANFORD RELEASE ID: 58 NOV 10 1998

Release Stamp

Approved for Public Release

ERRATA:

Immediately after this report was submitted for duplication and distribution, it was learned that at least some, if not all, of the interstitial liquid level (ILL) measurements were suspect. It is possible, but undetermined at this time, that some of the ILL sensor data are measurements of the waste surface rather than an interstitial liquid interface. To the extent the ILL data is not measuring the interstitial liquid level, the ILL-measured tank data and subsequent analysis shown in Appendix E will be in error. The conclusions and recommendations described in this report are supported by the ENRAF and FIC data and remain valid.

Single-Shell Tank Sluicing History and Failure Frequency

COGEMA Engineering Corporation Purchase Agreement C-98-P-PO1-0007
Vista Research Project No. F007

Prepared by:

Phillip C. Ohl
Dennis G. Douglas
Joseph W. Maresca, Jr.

Prepared for:

U.S. Department of Energy – Office of Environmental Restoration and Waste Management (EM-30)
c/o Lockheed Martin Hanford Corporation
P.O. Box 1500
Richland, Washington 99352-1505

3 September 1998

Executive Summary

Single-shell tanks (SSTs) were initially constructed at Hanford in 1944 to store radioactive wastes resulting from plutonium/uranium separations processes necessary for plutonium production. The first SSTs to leak were TY-106 and U-101, in 1959. To date, 67 of the total of 149 single-shell tanks have been declared "confirmed or assumed leakers"; the other 82 tanks are deemed "presumably sound." While some of the SSTs have had the supernatant pumped off (or *stabilized*) many of the tanks contain significant volumes of supernatant, interstitial liquids, or both. These tanks represent a potential insult to the environment should a failure occur prior to or during the retrieval of their contents.

To assess the potential for failure of the SSTs that are *presumably sound* (at present) and to help establish retrieval priorities for these and the *assumed leakers*, this report examines several factors that can facilitate retrieval planning. First, this report reviews the probability of single-shell tank failure as a function of tank age and operational history. Second, it provides a simple statistical summary of historical leak volumes, leak rates, and corrosion factors.

A preliminary integrity assessment of the remaining useful life of the tanks is included. This assessment, which is based upon factors such as corrosiveness of the waste, maximum waste temperature, and lower-knuckle construction, is then used in conjunction with predicted failure frequencies to make an initial estimate of the remaining useful life of the SSTs. The end result is a preliminary screening of the single-shell tanks that may be candidates for initial hydraulic retrieval based on tank integrity. Accordingly, 12 presumably sound tanks are proposed as candidates for immediate detailed integrity assessment, 20 presumably sound tanks are proposed as contingency candidates for immediate detailed integrity assessment, and 52 presumably sound tanks and 62 assumed leakers are proposed for subsequent detailed integrity assessment.

For those SSTs with a reportable liquid level—supernatant measured with a level gauge or interstitial liquids measured by a gamma/neutron probe in the liquid observation wells—this report also provides a preliminary assessment of the significance of volume changes over month-long periods, and it provides a preliminary estimate of the minimum leak rates that could be detected in these tanks. Together with available data based on expected retrieval times, this estimate of minimum detectable leak rates was used to calculate a maximum undetected leak volume for each SST.

This preliminary screening of SST failure frequencies and sluicing histories concludes that for many SSTs, tank integrity indicators such as corrosiveness of the waste and maximum waste temperature are favorable. Furthermore, level data show that many tanks with a recordable liquid level are leak-tight today—within quantified criteria and probability of detection and probability of false alarm. Finally, methodologies are suggested for confirmatory tank integrity analysis and failure frequency predictions prior to the initiation of full-scale retrieval operations on the SSTs.

Table of Contents

Executive Summary iii
List of Figures vi
List of Tables vii
List of Acronyms viii
Acknowledgements ix

1 Introduction 1

2 Background 2
2.1 Operating History 2
2.2 Failure Mechanisms 2
2.3 Sluicing History 6
2.4 Failure Frequencies 8

3 Preliminary Integrity Assessment 11
3.1 Structural Integrity 11
3.2 Liquid Integrity 12
3.2.1 Selection of Level Data 13
3.2.2 Statistical Analysis of Level Data 14
3.2.2.1 Significance of the Average Volume Rate 19
3.2.2.2 Minimum Detectable Leak 19

4 Assessment of Remaining Useful Life 23
4.1 Catastrophic Failure 23
4.2 Loss of Containment 24
4.3 Tank-by-Tank Ranking 26

5 Impact of Hydraulic Retrieval on Liquid Integrity 28
5.1 Calculated Flow Constant for Laminar Flow 28
5.2 Maximum Undetected Leak Volume 30

6. Conclusions and Recommendations 33
6.1 Conclusions 33
6.2 Recommendations 33

References 35

Appendix A: Single-Shell Tank Quick Reference Facts A-1
Appendix B: SST Failure Frequencies B-1
Appendix C: SST Waste Tank Volumes and Available Liquid Level Data C-1
Appendix D: Tank Level Data Obtained From TWINS D-1
Appendix E: Statistical Analyses of Level Data E-1
Appendix F: Calculation of Potential Leaks F-1

Figures

Figure 1. Savannah River Site, Tank 14 (Photograph # 4080-13)..... 3

Figure 2. Histogram of SST failure frequency based on the date at which the tank was declared an "assumed leaker"..... 9

Figure 3. Histogram of SST failure frequency based on the date of level decrease 9

Figure 4. Plots from Tank A-103..... 15-16

Figure 5. Plot used in the analysis of Tank A-103..... 17

Figure 6. Impact of hydraulic retrieval..... 29

Figure 7. Fluid dynamics data for seven SSTs with "confirmed" leak rates... 30

Figure 8. Fluid dynamics data for "confirmed" and "postulated" leak rates of 10 leaking SSTs..... 30

Figure 9. Baseline retrieval time history for Tank C-102, using Kirkbride's formula..... 31

Tables

Table 1. Waste Grouping vs. Leak Status and Corrosivity Factor..... 4

Table 2. Corrosivity Factors for Primary Waste Types 5

Table 3. Sluicing Campaigns for Strontium and Cesium Recovery 6

Table 4. Sluicing Campaigns for Uranium Recovery 7

Table 5. A Comparison of Reported Tank Integrity with Analysis-Inferred Integrity..... 21

Table 6. Length of Service of SSTs according to Tank Farm Grouping 23

Table 7. Catastrophic Leaks in SSTs..... 24

Table 8. Tank Groupings according to Category 26

Table 9. Relative Rankings of the Remaining Useful Lives of SSTs..... 29

Table 10. Critical Flow Constant (k) Calculations for Known and Postulated Leak Rates..... 29

Table 11. Average Retrieval Times and Potenital Undetected Leak Volumes for Tanks of Various Capacities..... 32

Acronyms

CF	Corrosivity factor (i.e., ratio of nitrate to nitrite-plus-hydroxide)
ILL	Interstitial liquid level
LOW	Liquid observation well
L_{MD}	Minimum detectable leak
P_D	Probability of detection
P_F	Probability of failure
P_{FA}	Probability of false alarm
RCRA	Resource Conservation Recovery Act
SCC	Stress corrosion cracking
SST(s)	Single-shell tank(s)
SRS	Savannah River Site

Acknowledgments

The program sponsors for this report were Rob Marshall and Jeff Hertzel of Numatec Hanford Corporation and Jim Andersen of COGEMA Engineering Corporation. Additional technical contributors to this report through analysis, review and reference material include Steve Barcellos of Vista Research, George Crawford of Numatec Hanford Corporation, Mo Anantatmula and Dave Barnes of the Lockheed Martin Hanford Corporation, and Larry Julyk and Jim Truitt of Fluor Daniel Northwest. Technical editing was provided by Monique Seibel of Vista Research.

1 Introduction

Under the Single-Shell Tank (SST) Retrieval Program Plan, the contents of the Hanford SSTs are scheduled for "retrieval" with various hydraulic (sluicing-based) technologies. A primary input to this plan is the characterization of the current condition of the SSTs.

Since the SSTs were taken out of service, a number of circumstances regarding SST retrieval have changed. First, some of the SSTs have been "stabilized"; that is, pumpable liquids have been removed, leaving sludge and salt cake in a stable condition while they await retrieval. Second, there has been some degradation of tank liners. Third, the "leak designation" of some SSTs has changed (i.e., whether they are considered leaking or not). And fourth, there have been changes in retrieval technology. All of these circumstances must be considered in context in order to devise a viable retrieval strategy—one that allows efficient waste retrieval and at the same time minimizes the risk of leaks into the vadose zone. As the condition of the tanks continues to degrade, retrieval options may become limited to technologies that would not cause further degradation (at least not to the point of creating new leaks).

Appendix A shows quick reference facts for SSTs. This appendix summarizes the SSTs in terms of the age of the tanks, the number of tanks assumed to be leaking, the number of sound tanks, and other pertinent information. A tank-by-tank ranking of integrity is shown in Appendix B.

2 Background

2.1 Operating History

Single-shell tanks were initially constructed at Hanford in 1944 to store radioactive wastes resulting from plutonium/uranium separation processes necessary for plutonium production. The first SSTs known to leak were TY-106 and U-101, in 1959. To date, 67 out of a total of 149 SSTs have been declared "known leakers" or "assumed leakers." The approach used to determine what constitutes a "leaker" has not been consistent. Anecdotal information indicates that, in some circumstances, a leak was merely inferred—on the basis of partial or inconclusive data. Accordingly, not all "assumed leakers" may have actually leaked. The SSTs were formally removed from active service in 1981, but they still contain over 35 million gallons of radioactive waste that has not yet been retrieved [Hanlon, 1998].

During the 37 years that the SSTs were in active service, 13 different types of waste were generated [Hill, 1994]—the result of various processes for plutonium/uranium separation, uranium recovery, and cesium/strontium removal. These 13 distinct wastes have been mixed together as a result of consolidation efforts and the cascading of wastes to form 30 discrete tank groupings by specific waste chemistry [Anantatmula, 1994].

Since 1978, 119 SSTs have been "interim-stabilized." Interim stabilization is the process of removing pumpable liquids from the tanks, leaving the sludge and salt cake in a stable condition while they await retrieval. Even after the supernatant liquids have been pumped off, SSTs may contain significant volumes of interstitial liquids—liquids contained in the void space between the grains and particles that comprise the sludge and the wetted portions of the salt cake.

2.2 Failure Mechanisms

Aside from process upsets and structural/mechanical failures, the most likely failure mechanisms for SSTs are corrosion-related. It is important to note that any discussion of SST corrosion issues should be prefaced by the fact that nearly everything we know about SST corrosion is inferred from laboratory simulants or Savannah River data. There exist only limited data on the exposure of in-tank coupons to PUREX, Redox and $BiPO_4$ wastes at Hanford.

The failure mechanisms applicable to the Hanford SSTs are ranked as follows, in decreasing order of importance [Edgemon, 1996]:

(1) stress-corrosion cracking (SCC)
(2) pitting/crevice corrosion
(3) uniform corrosion

The most common, and most plausible, leakage mechanism for the Hanford SSTs is stress-corrosion cracking. SCC can occur when the tank's carbon-steel liner is exposed to aqueous solutions containing sodium hydroxide and sodium nitrate. Cracks form in and near the welds in the tank's sidewall, in the weld "heat-affected zones"—a region whose width is typically two to three times the thickness of the base material and where there is an accumulation of residual stresses from the welding that occurred during the tank's construction. (The Hanford SSTs were not treated for stress relief during construction.) The strongest evidence of stress-corrosion cracking comes from the failure of Tanks #9, #10, #14 and #16 at the Savannah River Site [Girdler, 1965; Poe, 1974]. Figure 1 shows a photograph of the exterior of Tank #14 at the SRS—a tank that leaked as a result of SCC. The effects of the leaks are clearly evident in the photo. These leaks occurred along numerous cracks that appeared in the lower horizontal weld of the tank.

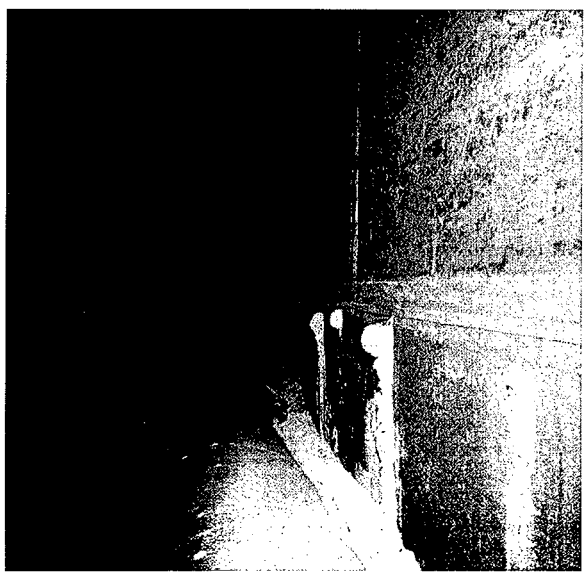


Figure 1. Savannah River Site, Tank #14 (Photograph #4080-13). In this non-stress-relieved tank, leaks due to nitrate-assisted, stress-corrosion cracking can be seen in the heat-affected zone near the weld. Note that the leaks appear to have self-sealed.

The time it takes for cracking to occur cannot be predicted; it may be anywhere from a few months to several years. A common tool for assessing SCC in the waste tanks at Hanford and Savannah River is the corrosivity factor (CF), which is the ratio of the molar concentrations of nitrate to nitrite-plus-hydroxide. In the present corrosion specifications for double-shell tanks, the CF is maintanied below 2.5. The calculation of the CFs is based on a rough approximation of the chemistry of the primary and secondary wastes (70% and 30%, respectively) [Anantatmula, 1994]. The CFs calculated for the SSTs are shown in Tables 1 and 2.

Table 1. Waste Grouping vs. Leak Status and Corrosivity Factor (Reprinted from Anantatmula, 1994)

Waste Group/ Waste Type	Tanks	Percent Leaked**	CF
TBP, EB-ITS	BY-109, BY-102	0	67.67
CW, TBP	C-102, C-105	0	24.54
SS, TBP	C-103, C-106	0	24.53
EB, CW	U-105, U-107, U-108, U-109	0	21.21
CW	U-201, U-202, U-203	0	0.05
EB, TBP	TX-108, TX-118	0	45.70
REDOX, EB	S-102, S-111, S-106, S-105, S-109, S-108, S-110, S-112, S-103, S-101, S-107, SX-105, SX-106, SX-104, SX-102, SX-101, TX-102, TX-104, TX-105, TX-106, TX-107	14	13.66
EB, REDOX	U-103, U-102, U-111, U-106, TX-115	20	23.16
1C, EB	B-107, B-108, B-109, BX-112	25	11.01
DSSF, NCPLX	A-101, A-102, A-103, AX-101	25	0.77
2C, 224	T-110, T-111, T-112	33	4.04
224	B-201, B-202, B-203, B-204, T-201, T-202, T-203, T-204	37.5	1.80
Ungrouped	A-104, A-105, A-106, AX-104, B-104, BX-109, C-104, C-107, SX-103, T-109, T-104, TX-101, TX-103, TX-112, TY-101, U-110, U-112, U-204	39	0.85 for C-107; 4.87 for SX-103; 2.75 for T-104
TBP-F, 1C	C-108, C-109, C-111, C-112, T-107	40	35.83
TBP, CW	BX-101, BX-102, BX-103, BX-104, BX-105, BX-106, C-101	43	57.18
TBP-F, EB-ITS	BY-101, BY-103, BY-104, BY-105, BY-106, BY-107, BY-108, BY-110, BY-111, BY-112	50	45.5
CCPLX, DSSF	AX-102, AX-103	50	1.10
1C, CW	T-105, T-106	50	1.94
1C, TBP	B-106, BX-107, BX-108, C-110, T-108	60	26.43
CW, EB	B-101, B-102, B-103	67	9.12
CW, MIX	T-101, T-102, T-103	67	0.10
EB, 1C	B-105, TX-109, TX-110, TX-111, TX-113, TX-114, TX-116, TX-117, TY-102	75	22.02
REDOX	S-104, SX-107, SX-108, SX-109, SX-112, SX-115, U-101	100	6.53

continued

Waste Group/ Waste Type	Tanks	Percent Leaked**	CF
HS	C-201, C-202, C-203, C-204	100	1.59
2C, 5-6	B-110, B-111, B-112	100	5.00
REDOX, REDOX-IX	SX-110, SX-111, SX-114	100	6.07
1C, EB-ITS	BX-110, BX-111	100	12.43
TBP	TY-105, TY-106	100	81.67
TBP, 1C-F	TY-103, TY-104	100	57.99
REDOX, DIA	SX-113, U-104	100	4.57

* Underline indicates tanks that were sound and not stabilized (as of 1994).
** Percentage of tanks, by waste group, that have leaked.

Table 2. Corrosivity Factors for Primary Waste Types [Anantatmula, 1994]

Waste Type	$OH + NO_2$ moles/liter	NO_3 moles/liter	Corrosivity Factor $NO_3/(OH + NO_2)$
REDOX	0.74	4.83	6.53
HS	1.32	2.1	1.59
2C	NR	1.27	5*
OWW	NR	0.06	1*
1C	0.56	1.54	2.75
EB**	0.57	17.26	30.28
TBP	0.09	7.35	81.67
CW	0.37	0.02	0.05
CCPLX	0.52	0.72	1.38
DSSF	6.05	2.72	0.45
224	0.59	1.06	1.8
NCPLX	2.2	3.3	1.5
SS	5.74	NR	0.04*

* = assumed value
** = assumed a density of 1.45 g/cc for molarity calculation
NR = none reported

Temperature also plays an important role in initiating SCC. A critical temperature of 122° F was discovered to be the threshold below which nitrate-assisted SCC would occur only at very low rates [Ondrejcian, 1978].

While stress-corrosion cracking is expected to be the dominant failure mechanism for the Hanford SSTs, pitting/crevice corrosion cannot be discounted. Pits often begin at the site of manganese sulfide (MnS) precipitates prevalent in carbon steels. They result from a highly localized corrosion process that produces small-diameter holes in a solid metal structure. Once a pit begins, the local chemistry in the tank will cause it to grow. Typically, the growth rate accelerates as the pit grows deeper. Once initiated, the pitting can rapidly produce a hole in plate steels.

While uniform corrosion does occur in the SSTs, the corrosion rates are generally less than 1 mil (0.001 in.) per year. Thinning to point of failure is highly unlikely. Accordingly, SST failures due to uniform corrosion are discounted in this report.

2.3 Sluicing History

Between 1952 and 1957, 43 SSTs in the B, BX, BY, C, T, TX, and U tank farms were sluiced to recover uranium and then returned to service. Between 1962 and 1978, an additional 10 tanks in the A and AX tank farms were sluiced to recover strontium and cesium. Of these, eight were returned to service; during the sluicing operations Tanks A-104 and A-105 were found to be leaking and were therefore removed from service at the completion of those operations [Rodenhizer, 1987]. (Tank A-105 was sluiced after the leak was discovered, so that high-heat-producing sludge could be removed. Tank A-104 started to leak during the sluicing operations, but no definitive relationship between the leak and these operations was established [Rasmussen, 1980].) Tables 3 and 4 list tanks and sludge volume retrieved during both the strontium and cesium and the uranium recovery campaigns.

With respect to leaks and sluicing, 53 tanks in total have been sluiced to empty or nearly empty levels. The bulk of sluicing operations took place in tanks that held the relatively benign bismuth-phosphate wastes as part of uranium recovery operations. The one tank that was identified as a leaker during sluicing operations (A-104) contained a mixture of wastes from the PUREX process and organic wash wastes [Brevick, 1994; Rodenhizer, 1987]. For this analysis, Tank A-105 was removed from the population of sluiced tanks because it had been identified as a leaker prior to sluicing; thus, 51 out of the 52 tanks that were sluiced (98.1%) remained sound and were returned to service. Of the 51 tanks returned to service, 21 (41.2%) were subsequently declared "assumed leakers." The remaining 30 tanks that have been sluiced and that have not produced indications of leaks may be candidates for early hydraulic retrieval.

Table 3. Sluicing Campaigns for Strontium and Cesium Recovery

Tank	Sluicing Period	Sludge Volume Retrieved (Kgal)
A-101	1968 – 1976	107
A-102	1964 – 1976	170
A-103	1962 – 1976	116

continued

A-104	1969 – 1975	223
A-105	1968 – 1970	147
A-106	1969 – 1977	237
AX-101	1975 – 1976	66
AX-102	1976	66
AX-103	1976 – 1977	82
AX-104	1977	52

Table 4. Sluicing Campaigns for Uranium Recovery

Tank	Sluicing Period	Sludge Volume Retrieved (Kgal)
U-101	1952 – 1956	132.5
U-102	1953 – 1957	59.6
U-103	1952 – 1956	0+132.5 (from U-101)
U-104	1953 – 1956	132.5
U-105	1953 – 1957	59.6
U-106	1956	0
U-107	1953 – 1957	132.5
U-108	1953 – 1956	59.6
U-109	1953 – 1956	0
C-101	1952 – 1953	132.5
C-102	1953	59.6
C-103	1953	0
C-104	1953 – 1955	132.5
C-105	1953	59.6
C-106	n/a	0
C-201	1954	16
C-202	1954	8
C-203	1954	0
C-204	1954 – 1955	0
B-101	1953	132.5
B-102	1953	59.6
B-103	n/a	0
BX-101	1953 – 1954	280
BX-102	1954	134
BX-103	1954	33
BX-104	1954 – 1955	181.5
BX-105	1955	89
BX-106	1955	12.5
BY-101	1954	0
BY-102	1954	0

continued

BY-103	1954	0
BY-104	n/a	0
BY-105	1954	--
BY-106	n/a	--
BY-111	1955	--
BY-112	1955	--
T-101	1954 – 1956	132.5
T-102	1953 – 1956	59.6
T-103	1953 – 1957	0
TX-101	1954 – 1956	259
TX-102	1954 – 1956	121
TX-103	1954	0
TX-104	1954 – 1956	0
TX-105	1954 – 1957	91
TX-106	1955	--
TX-107	1954 – 1957	--
TX-108	1954 – 1957	--

2.4 Failure Frequencies

There are many methods of quantifying failure frequencies for a population of failed components. Three such methods are presented in this report:

- deterministic failure frequencies based on declaration date
- deterministic failure frequencies based on indications from liquid level data
- probabilistic failure frequencies based on corrosivity

In the case of the SSTs, it is possible to determine the age of the tank at the time it was declared leaking by subtracting its installation date from the raw "declared leaker date" published in the monthly Waste Tank Summary Report [Hanlon, 1998]. A histogram of tank age at (declared) failure is presented in Figure 2. The column plot in this figure shows the number of tanks that were declared "leakers" or presumed to be "leakers" as a function of their age at the declaration date. (The plot is "binned" at two-year intervals.) The line plot in Figure 2 shows the cumulative distribution of the failures. The cumulative distribution describes—for tanks that have actually leaked or that are presumed to have leaked (relative to the total number of tanks that were declared leaking)—the percentage of failures as a function of age. The average age-to-failure for the 67 SSTs that have leaked or are presumed to have leaked is about 24 years.

This simple estimation of failure frequency assumes that the tanks have common operational histories and are subjected to the same criteria when the "presumed leaker" designation is applied. There is a firmer criterion on which to base the decision that a leak has occurred or is occurring—a definite decrease in level that is not plausibly attributable to other sources. A histogram of tank age at failure for 24 such SSTs is shown in Figure 3. For these data, the

average age-to-failure is about 28 years. When one compares these data to the ages of the tanks that exhibited unambiguous decreases in level, the implication is that the assignment of a "declared leaker" status to an SST may have been conservative.

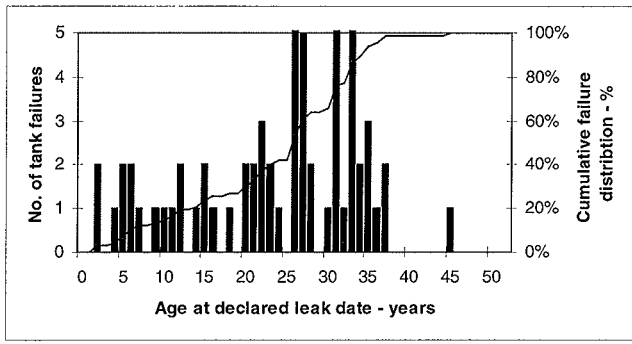


Figure 2. Histogram of SST failure frequency based on the date at which the tank was declared an "assumed leaker." Mean time to declaration is 24 years.

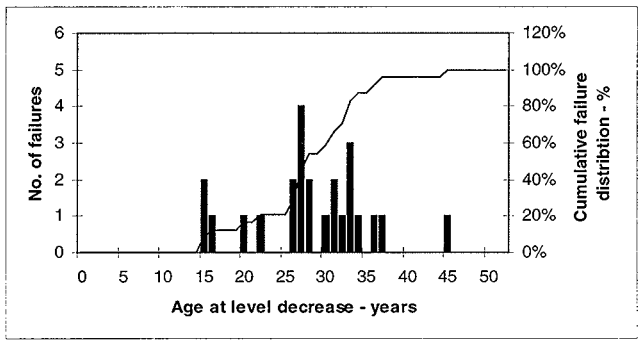


Figure 3. Histogram of SST failure frequency based on the date of level decrease. Mean time to level decrease is 28 years.

The final failure frequency method presented here is a probabilistic method based on expected corrosion-related failures for large, carbon-steel tanks. Information from both Hanford and the Savannah River Site suggests that the primary failure mode for SSTs is nitrate-assisted SCC [Edgemon, 1994; Girdler, 1965]. SCC is insidious and is difficult to predict because of the wide variability in the time it takes for a crack to appear. SCC requires an aggressive environment (enhanced by elevated temperatures), a high-stress state

due either to residual fabrication stresses or applied loads, and a crack initiation site such as an impurity, a scratch, or a void in a weld.

The probability, P_{SCC}, that SCC will occur in a waste storage tank can be qualitatively defined as

$$P_{SCC} = P_{env} \times P_{\sigma}$$

where P_{env} is the probability that the contents of the tank constitute an aggressive environment and P_{σ} is the probability that the tank is subject to stresses above the k_{ISCC} (the threshold stress for SCC) required to initiate cracking [Anantatmula in Abatt, 1996]. A third term (not shown in the equation) represents the probability that the tank has numerous crack initiation sites. Because of the way the tanks are constructed, this third term can be taken to be 1.0. In the case of the SSTs, P_{σ} can also be taken to be 1.0, because the SSTs were put into service without the benefit of a stress-relief annealing process.

This leaves P_{env} as the controlling factor in the probability of the occurrence of SCC. In the case of the SSTs, environmental aggressiveness can be divided into two sub-parameters: (1) the corrosivity factor of the waste, and (2) temperature. Tanks with maximum temperatures less than 122° F would not be expected to experience significant SCC damage regardless of waste type. Tanks that have maximum temperatures above 122° F *and* CFs greater than 2.5 would be expected to suffer severe SCC-related damage. Based upon these values, a relative failure frequency can be assigned to each individual tank. Using these parameters for CF and temperature, relative failure frequencies were assigned quantitatively. This is described in Section 4.0 (Assessment of Remaining Useful Life).

3 Preliminary Integrity Assessment

Tank integrity can be discussed on two levels: structural integrity and liquid integrity. Structural integrity addresses whether the tank is likely to collapse or rupture, whereas liquid integrity addresses whether it can maintain the confinement of liquids. The SSTs derive their structural integrity from their concrete encasements. They derive their liquid integrity from the carbon-steel liner that defines the confinement boundary. Although the SSTs are believed to be structurally sound, many of them are suspect in terms of liquid integrity.

The Tank Farms Surveillance Group at Hanford has established administrative controls on the allowable changes in liquid level in the SSTs; when levels go beyond these limits, some investigation is required. There are, however, no leak detection or reporting methods in place whose performance—in terms of probability of false alarm and probability of detection as measured against some specified criterion—has been evaluated and demonstrated. In this section of the report, we examine the SST level data in an attempt to (1) provide a statistical assessment of the significance of changes in tank volume over time; (2) assess the minimum leak rate that could be detected in these tanks using the existing level-sensing instruments and data systems; and (3) estimate the performance of an integrity monitoring system that is based upon the extant level sensors and data systems.

3.1 Structural Integrity

The structural integrity of the SSTs must be inferred from non-empirical data. There are no in-service inspection records for the SSTs. Thus, the structural integrity of the tank is established on the basis of its concrete encasement. In calculations performed for the Final Safety Analysis Report (FSAR)," the design of the SSTs showed an ample margin for tolerating operational loads and withstanding credible accident scenarios [Han, 1996a, 1996b]. Concentrated loads ranging from 100 tons over a 30-ft radius to 200 tons over a 10-ft radius were considered. The most critical factor in assessing the structural integrity of the SSTs is dome loading. Based on a safety factor between 2 and 3, according to ACI code, the "100 series" of SSTs examined here are expected to withstand a concentrated load of 300 to 600 tons over an area with a 10-ft radius. Under these conditions, the predicted failure mode is a flattening of the tank dome and eventual shearing through the 10-ft-radius area centered at the crown of the dome.

Dome loads for SSTs are rigorously enforced through OSD-T-151-00013 D-15, which limits static dome loads to 5 tons over a 12-ft radius for "200 series" tanks, and 5 tons over a 10-ft radius for "100 series" tanks. Live loads are limited to 50 tons for "200 series" tanks and 100 tons for "100 series" tanks. Based on Han's analyses [Han, 1996a, 1996b], it is not expected that the SSTs will collapse during interim storage, stabilization or retrieval operations as long as the dome loading limits are observed.

3.2 Liquid Integrity

The liquid integrity assessment for each SST requires a measure of the liquid volume over time. Some tanks contain measurable amounts of supernatant, while others have had (most of) the supernatant liquids removed. These latter tanks can, however, contain a significant volume of interstitial liquid that is trapped in the sludge and that is not readily pumpable in large volumes. Since nearly all of the tanks can be considered as having some volume of liquid in them, any loss of liquid integrity poses a clear and present danger of insult to the environment, including the likelihood of groundwater contamination. This is an important issue now, and will be even more so during retrieval operations.

The single-shell tanks can be subdivided into two categories: interim-stabilized and non-stabilized. There are 119 tanks that have been *interim-stabilized*—that is, tanks whose supernatant liquid has been pumped off, leaving only sludge, interstitial liquids, and salt cake [Hanlon, 1998]. The level (volume) of the interstitial liquid in the stabilized tanks is measured with a gamma/neutron probe (or Interstitial Liquid Level [ILL]) that is raised and lowered into a liquid observation well (LOW) located in the center of each tank. The liquid-air interface is detected as a sudden and significant change in the activity monitored by the probe.[1] There are also 30 tanks that are *non-stabilized*—meaning that they contain sludge, interstitial liquid, and supernatant liquids. The liquid level in these tanks is measured (typically) with a level gauge such as the ENRAF or FIC. (Note that the ILL probe will also provide a measure of the air/liquid interface in these tanks.) A number of the interim-stabilized tanks are *effectively empty;* that is, most of the liquid and sludge has been removed during an earlier campaign. These tanks are nominally free of both liquids and sludge, except, perhaps, for a thin layer at the bottom, or scattered areas of dried or drying sludge.

A table of SST waste volumes as of 31 December 1997 is shown in Appendix C, a portion of which was abstracted from one of the monthly Hanlon reports. Included is the total volume in each tank, subdivided according to the volume of supernatant liquid, interstitial liquid, sludge and salt cake. The second-to-last column in this table indicates whether there is a sufficient volume of liquid to warrant a liquid integrity analysis of the tank, and the last column indicates whether that tank incorporates the instrumentation needed to obtain the measurements for such an analysis. Since the height-to-volume ratio of most of the SSTs is about 2,750 gal/in., a cutoff point of about 5,000 gal was established; tanks with volumes less than this amount were not analyzed. For tanks containing a significant volume of supernatant, level-measurement data from an ENRAF, FIC or equivalent sensor were used if such data were available and if these data were both recent and continuous. For tanks with significant volumes of interstitial liquid but little or no supernatant, data from the gamma/neutron probe, if available, were used.

[1] The inferred volume of liquid will depend on both the depth of the liquid and the void fraction. The void fraction will vary depending upon the makeup of the sludge, and thus will be tank-specific. Values for the void fraction for each tank can be found, for example, in WHC-SD-WM-ER-349, "Historical Tank Content Estimates for the Northeast Quadrant of the Hanford 200 Area" [Brevick, 1994].

The tank documents reviewed in this work show that there were a total of 102 SSTs that contain sufficient quantities of liquid (as defined above), either supernatant or interstitial, to warrant further analysis. Of these, 70 have data that are suitable for preliminary integrity assessment analysis.[2] An important point is that this liquid can leak, regardless of which type it is. A statistical analysis of the data from a tank that presently contains liquid can be used to infer—in a very general sense—the liquid integrity of that tank, and to assess the leak detection performance of its extant level gauges.

The SST liquid level data are measured by any of several different methods. Early in the Hanford program, the method was a "stick" (or manual tape) inserted into the tank, and data were taken infrequently, several times per year or perhaps quarterly. These data are not very useful in a leak detection analysis because the sample frequency is too low to be of value on a reasonable time scale—say, a week to a month. Later, the stick method was replaced with automatic tank gauges such as the FIC and the ENRAF. Typically, these sensors measure and record the air/liquid interface once every 10 min, with averages computed on an hourly and a daily basis[3] [Barnes, 1998]. The daily averages were used in the analysis described below for the ENRAF and FIC data. In the case of the ILL probe, data are collected manually, using an instrumented van that is driven from tank to tank, approximately once per week. The ILL data were obtained from TWINS and were used in the same manner as the data from the ENRAF and FIC gauges.

3.2.1 Selection of Level Data

The data gathered in this report were obtained from TWINS—an interface to Hanford-related databases that is accessible from the Internet.[4] Subsets of these data were used in the analysis. Appendix D includes a listing of the data that were obtained from TWINS, and those data selected for analysis. The entries in this appendix show the range, in terms of date, of the various sensor data that were available. As can be seen from the entries, some tanks have had several sensors installed, but some of the sensor data may be many years old. For the purposes of the analysis described below, we selected data that represented the most reliable, recent, and continuous set available. When more than one set met the selection criteria, the Auto ENRAF data, when available, were chosen over other data. If the Auto ENRAF data were not available (or were discontinuous), we selected the Manual ENRAF, then the Auto or Manual FIC data, and finally the Manual Tape data. In cases where there was interstitial liquid only, and the LOW data were available, the ILL probe data were selected.

[2] Thirty-two of the 102 tanks either exhibited liquid-level data that were erratic or otherwise not sufficiently continuous for use in the analysis, or were not equipped with a LOW sensor. Accordingly, the data from a total of 70 tanks have been analyzed for this report.

[3] To minimize the data storage requirements, a data compression technique is used whereby only level values that have changed more than 0.01 in. are actually recorded. There is no critical information lost when this technique is used.

[4] See http://twins.pnl.gov:8001/TCD/main.html, for example.

To be useful for the analysis, the level data needed to be sampled over a long duration, at a more or less uniform frequency. Since hourly samples were not readily available for this analysis, we used daily samples, seeking block-lengths of at least two years. (This usually led to the selection of either the Auto ENRAF or Auto FIC data.) A second requirement for the analysis was that the level data needed to be more or less internally consistent with the other level measurements made on the tank. That is, if a tank had liquid level measurements made by several sensors, then a measure of the quality or reliability of the data would be how well the several independent data compared. For example, if two sensors measured (about) 118 in. of liquid, and the data from a third sensor was to be used in the analysis, it was expected that the value measured by the third sensor would be (about) 118 in. also.

To compare the similarity and potential temporal overlap of the various sensor sets, a plot of measured level as a function of time was made for each available sensor, for each of the tanks shown in the table in Appendix D. Figure 4 shows a series of plots from Tank A-103. As shown in Appendix D, the TWINS-accessible databases contain level data on Tank A-103 from six level sensing systems during various past years: Auto ENRAF, Auto FIC, Intrusion FIC, Manual ENRAF, Manual FIC, and Manual Tape. For this tank, the best and most reliable data appeared to be the Manual ENRAF data. These choices are illustrated in Appendix D, and the data used in the analysis are denoted by boldface type. Note that for some of the tanks, no usable data were obtained. This was either because the data quality was too poor, or because there was no sensor installed on that tank to provide relevant data.

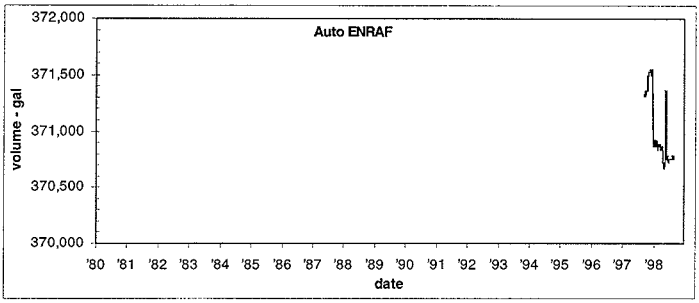
3.2.2 Statistical Analysis of Level Data

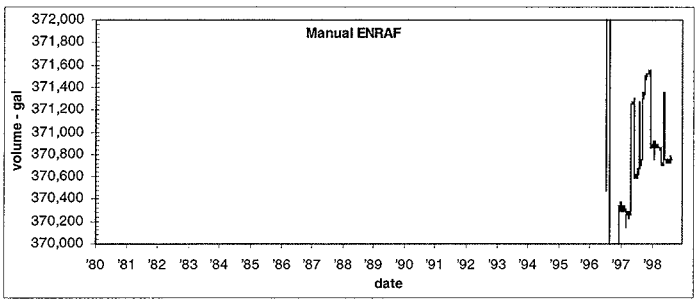
After the required data had been downloaded, it was analyzed with an Excel™ spreadsheet prepared for processing large quantities of data. The output is presented in Appendix E. The analysis technique is explained below, using the Auto ENRAF data from Tank A-103 as an example.[5] The data plots shown in Figure 4 illustrate a data sample taken from Appendix E.

The first step in the data analysis was to convert level to volume, using the appropriate height-to-volume conversion factor,[6] and then make a plot of the volume data. The plot used in the analysis of A-103 is shown at the top of Figure 5. In a few cases (including A-103), the data obtained through TWINS contained spurious points that could be edited without compromising the integrity of the data set. The spurious points edited out of the A-103 data set, although not plotted, are indicated at the lower right of the plot. A comparison of the Manual ENRAF plot in Figure 4 with the volume plot in Figure 5 reveals the three spurious points that were edited from the data: one point at the beginning of the record, one early in January 1997, and another early in 1998.

[5] Although Tank A-103 was declared an assumed leaker in 1987, and was administratively stabilized, it reportedly contains an estimated 4,000 gal of supernatant [Brevick, 1994]. Accordingly, changes in the level of the liquid surface can be analyzed. Because of the sludge and salt cake present in the tank, the absolute volume estimates will be in error, but the rate of change of volume will be correct.

[6] For the 100-series tanks, the height-to-volume conversion is 2,753.8 gal/in; for the 200-series tanks, the height-to-volume conversion ratio is 195.7 gal/in.





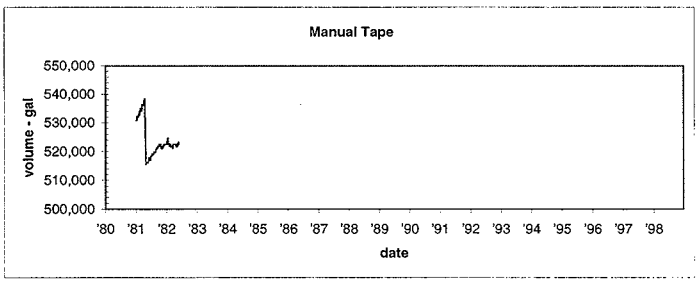
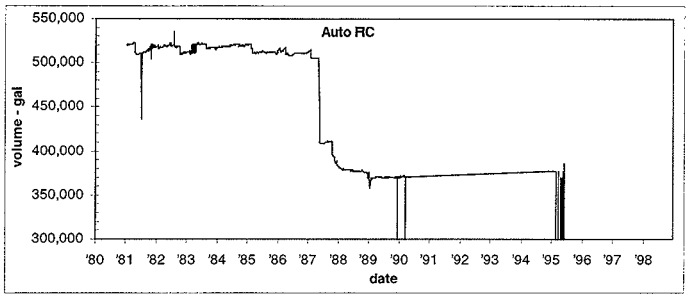
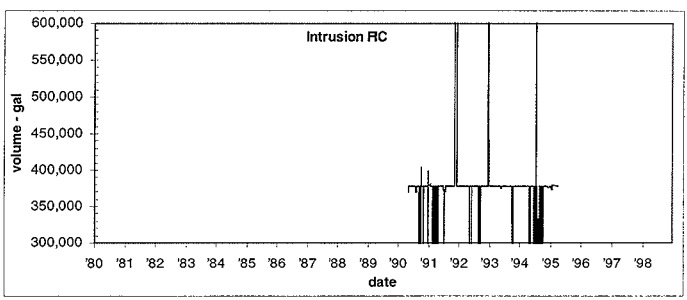


Figure 4. Plots from Tank A-103.





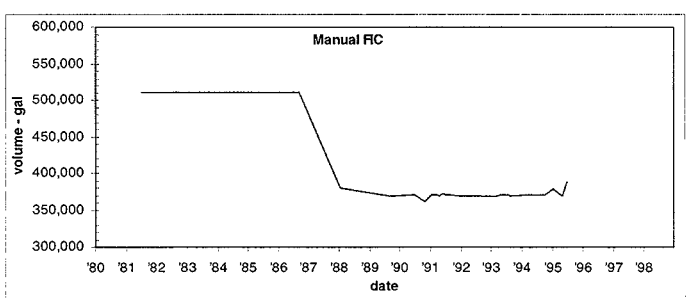
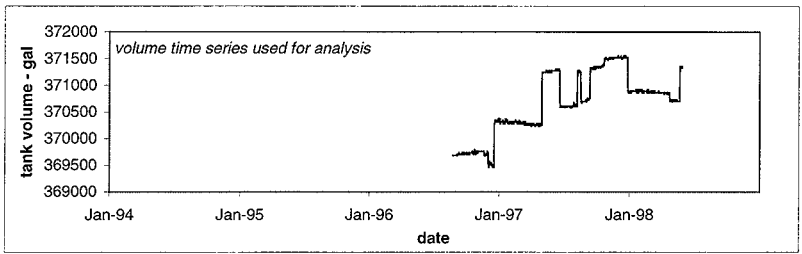
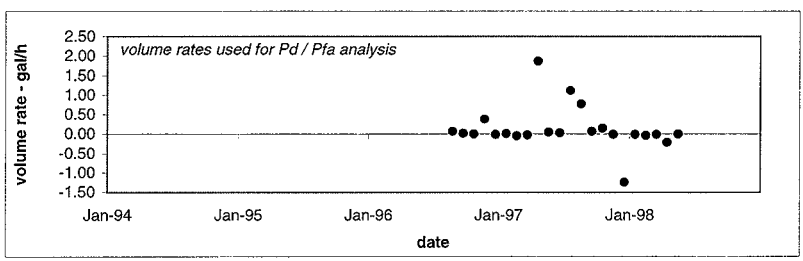


Figure 4 (concluded). Plots from Tank A-103.

Data File: **A-103** Data is from sensor type: **Manual ENRAF**



No. points edited from time series = 3

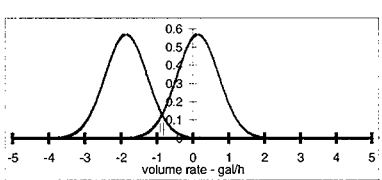


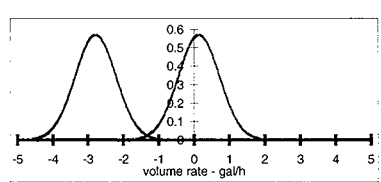
No. avg. vol rate estimates removed = 1
N = 21

During the analysis period, the average volume rate = 0.14 gal/h
The standard deviation of the volume rate estimates = 0.58 gal/h

For Pd / Pfa = 95% / 5%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -1.00 gal/h
Min. Detectable Leak: -2.00 gal/h

For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -1.46 gal/h
Min. Detectable Leak: -2.92 gal/h





For this data, a threshold= -1.84 gal/h will detect a tank release of 2.92 gal/h at a Pd = 95%
The corresponding Pfa is 0.16%

Figure 5. Plots used in the analysis of Tank A-103.

The volume plot in Figure 5 shows that Tank A-103 had seven or eight periods, lasting two to three months each, during which volume was more or less constant. Between these periods, there are also eight or nine places in the data where the volume changes abruptly—either up or down. Since the character of the *indicated* positive and negative volume changes is suggestive of sensor adjustments, calibrations, or other non-actual volumetric changes, these data are retained in the analysis.

After generating the plot, the spreadsheet parsed the data into 30-day sets.[7] As many of these (nominally) month-long data sets were parsed as could be obtained from the data. For example, in a case where 2½ years of sensor data were available, 30 (thirty) 30-day data sets could be obtained. After the data had been parsed, a least-squares linear regression fit was made to each of the 30-day data sets. The slope of the regression line, expressed in terms of gallons per hour, was saved as an estimate of the *volume rate* during the month-long period. The standard deviation of the y-estimate, which describes the fluctuations during the month-long period (i.e., how well the data "behave"), was also saved. In the case of A-103, it was expected that the abrupt volume changes observed in the data set would cause unusually large and entirely spurious estimates of volume rate, standard deviation, or both. To provide a data quality filter, we rejected from the ensemble any data set having a standard deviation of more than 1,000 gal/h (2,000 gal/h for the ILL data). The final volume rate data set used in the analysis is plotted in Figure 5. It forms the basis for the performance and leak detection estimates. The number of volume rate estimates removed from the data set because of poor quality (i.e., high standard deviation) is shown at the lower right of the volume rate plot of Figure 5. Immediately below this is the number, N, of data sets that were available for analysis for the tank in question. For A-103, for example, N was equal to 21.

The EPA provides a concise approach for evaluating the performance of leak detection methods using a gaussian analysis ["Standard Test Procedures for Evaluating Leak Detection Methods: Automatic Tank Gauging Systems," 1990]. This evaluation procedure, applied to the Hanford tank data, allows an estimate to be made of the minimum leak that can be detected in each tank, assuming that the data sets used are representative of the liquid level data from that tank. Using the final analysis set, the EPA's gaussian analysis first calculates a test statistic, t_s, given as

$$t_s = N^{1/2} \times (m / \sigma_m),$$

where N is the number of data sets that are usable after the data have been culled and anomalous data points removed, m is the average volume rate over the entire analysis period (the average of the N volume rate estimates), and σ_m is the standard deviation of the set of volume rate estimates. As described above, for the A-103 data, there were 21 data sets of volume rate data after culling. For a mean volume rate of 0.14 gal/h and a standard deviation of m of 0.58 gal/h, the resulting test statistic is calculated to be 1.10.

[7] Since the ILL data were recorded weekly, there are far fewer samples available, compared to the ENRAF or equivalent sensor. When the ILL data were used, 30 samples were taken; this typically corresponds to a record length of about seven months.

3.2.2.1 Significance of the Average Volume Rate

To determine the statistical significance of the average volume rate, m, *a null hypothesis test* can be used. The null hypothesis states—in this case—that m is zero gallons per hour. The test compares the test statistic to a *critical statistic*, t_c, determined from a table of Student's t-values, for specified one-sided confidence intervals. Given the month-to-month fluctuations in the values of volume rate, the test determines whether the measured value of m is statistically different from 0 gal, or whether the observed value can be attributed to random occurrence. In the case of the analysis of the SST data, we test at two confidence intervals, 5% and 1%. In the hypothesis test, these values are the probability of rejecting the null hypothesis when it is true—in other words, at 5% and 1% probabilities of false alarm. A Student's t-table gives a t_c value of 1.729 at a 5% error, and a value of 2.539 for a 1% error. Since t_s is less than t_c in both cases, we conclude that, with only a 5% chance of error (or 1%, depending upon the value used), the measured average volume rate, m = 0.14 gal/h, is due to pure chance and cannot be distinguished from 0 gal/h. Had t_s been greater than t_c (as it is for some of the SST data analyzed below), we would conclude that, with only a 5% (or 1%) chance of error, the mean volume rate could not be explained by random error. This *does not* mean the tank is leaking; it simply describes that the average volume rate is not likely attributable to random error. In the language of statistics, when t_s is less than t_c, we say we "fail to reject the null hypothesis." While this statement is technically correct, it is obtuse; accordingly, we have shown the result in Figure 5 in terms of the statement "the mean volume rate is equivalent to 0 gal/h."

3.2.2.2 Minimum Detectable Leak

Using the volume rate data for each tank, a threshold, T, can be determined that will specify the maximum likelihood of incorrectly detecting a leak, if a leak test were conducted on this tank; this is the probability of false alarm, P_{FA}. The threshold will also allow us to estimate the minimum leak that would be correctly detected; this is the probability of detection, P_D. The relationship is

$$T_{PFA} = - t_c \times \sigma_m ,$$

where t_c is selected from a table of Student's t-values to match the desired P_{FA} for the number of degrees of freedom available (N-1). Using these data, the minimum detectable leak, L_{MD}, at a probability of detection of 1-P_{FA}, can be calculated simply as 2xT. Figure 5 shows these calculations for P_D/P_{FA}s of 95%/5% and 99%/1%.

In the case of Tank A-103, for example, these calculations indicate that if we implement a leak detection threshold, T, of -1.00 gal/h on the Manual ENRAF data stream we can, by using a single month-long data period, detect a leak as small as -2.00 gal/h with a P_D of 95%. Because the P_{FA} is 5%, we would also expect five false alarms for every 100 tests attempted. Since responding to false alarms is both expensive and time-consuming, it is of interest to lower the value of the P_{FA}. If we implement a leak detection threshold, T, of -1.46 gal/h instead, we obtain a lowered P_{FA} of 1% and can detect a leak of -2.92 gal/h with a P_D of

99%.[8] These performance data are illustrated in Figure 5. The plots near the bottom of the figure show how the noise and signal-plus-noise data (assuming that these data were normally distributed) would be related to the m, σ_m, and T values in each case (P_D and P_{FA} of 95% and 5%, respectively, and P_D and P_{FA} of 99% and 1%, respectively).

The selection of a threshold to match various P_D and P_{FA} requirements invariably entails compromise: any attempt to reduce P_{FA} also reduces P_D. Within the leak detection community,[9] however, a P_D of 95% is the commonly accepted standard. In order to improve the performance of the leak detection method, we can extend the statistical analysis used to make the performance estimates by finding a threshold that minimizes P_{FA} yet is consistent with a P_D of 95%. When this tactic is applied to the data from Tank A-103, for example, we find that if we implement a leak detection threshold of -1.84 gal/h we can detect a release of -2.92 gal/h with a P_D of 95% and a P_{FA} of only 0.16%. This represents approximately a six-fold increase in the leak detection capability for Tank A-103, with no concurrent loss of P_D. The results of the calculation for minimizing P_{FA} are shown at the bottom of Figure 5.

As noted at the beginning of Section 3.2.2, an analysis similar to that described above has been conducted for each of the SSTs that exhibited data of sufficient quality and duration to warrant such an analysis. The results are presented in Appendix E. Assuming that the data measured for each tank faithfully represents the liquid level in that tank, the essential conclusions from the work described above are several. First, the TWINS data show that 70 of the 149 SSTs have a sufficient volume of supernatant or interstitial liquids, and have liquid level data of sufficient quality, to be useful for a volumetric-based liquid integrity assessment method. Second, the analysis showed that the liquid integrity of those tanks could successfully be assessed. Third, the performance of a volumetric-based integrity assessment method is expected to be reasonably good (i.e., minimum detectable leaks of a few gallons per hour at a P_D of 95%, with a P_{FA} typically much less than 1%). This is an especially useful result when one considers integrity assessments for assigning retrieval priorities, considering that the installed level instruments were never designed for a "leak test" purpose.

Furthermore, the successful use of liquid-level data to assess tank integrity demonstrates the potential usefulness of this approach for periodic monitoring (for example, during waste retrieval operations). To achieve the degree of performance described above would require 30 daily measurements (or, for ILL measurements, weekly samples). Thus, a single test would last one month (seven months in the case of ILL measurements)—too long a duration for most applications. A shorter test duration would be possible if the level data were based on hourly measurements; for example, a two-day test could be conducted using 48 hourly measurements. Such a test would require a separate performance assessment (since its performance would not necessarily be the same as that of the 30-day test). Given the

[8] Existing procedures at TMACS examine the liquid-level data stream for changes in volume of 3 standard deviations. This is *roughly* comparable to a P_{FA} of 1%. While the P_{FA} of the existing procedures is comparable to the 1% described for the volume rate estimates, the P_D inherent in the existing TMACS procedures has not been established, nor has the minimum detectable leak been established.

[9] and many other detection-oriented communities as well, such as those using radar and sonar

availability of hourly liquid-level data, this assessment could be accomplished through analysis of these data.

A final conclusion resulting from the statistical analysis of the level data was that, with only a few exceptions, this work confirms the DOE-published assumptions regarding tank integrity. In 40 of the cases where DOE determined that a particular tank is likely to be sound, this analysis confirmed that determination. The results of the analysis are tabulated in Table 5. It is important to note that the analysis described in this section did not attempt to identify phenomena that might affect the volume data or to correlate these phenomena with the data. For example, it is known that the measured volume in some tanks is strongly anti-correlated with barometric pressure. The identification of such influences, and compensation for their effects on the measured volume data, was beyond the scope of this work.

Table 5. A Comparison of Reported Tank Integrity with Analysis-Inferred Integrity

DOE-Reported Integrity	Analysis-Inferred Integrity	Number of Tanks	Tank IDs
Presumed sound	Volume rate = 0 gal/h	40	A-101, B-102, B-104, BX-104, BX-105, BY-101, BY-102, BY-104, BY-109, BY-110, BY-112, C-103, C-106, S-101, S-103, S-105, S-108,S-109, S-110, S-111, SX-101, SX-102, SX-103, SX-105, SX-106, T-102, T-104, T-110, T-112, TX-101, TX-102, TX-106, TX-109,TX-118, U-102, U-103, U-107, U-108, U-109
Presumed sound	Statistically significant negative volume rate	0	—
Presumed sound	Statistically significant positive volume rate	9	BX-103, S-102, S-106, S-107, S-112, TX-111, TX-112, U-105, U-106
Assumed leaker	Volume rate = 0 gal/h	17	A-103, B-105, B-111, B-112, BX-110, BY-103, BY-105, BY-106, BY-107, S-104, SX-104, T-111 (>1995), TX-114, TX-115, TY-103, TY-104, U-101
Assumed leaker	Statistically significant negative volume rate	1	B-110
Assumed leaker	Statistically significant positive volume rate	3	TX-110, TX-113, TX-117

***Total** of 70 tanks containing sufficient liquid and possessing functional instrumentation*

4 Assessment of Remaining Useful Life

All of the SSTs have been removed from active service. They are currently used to store waste that is awaiting retrieval under a RCRA Part A, interim-status permit. In other words, the SSTs have already reached the end of their useful lives in active service. The term "remaining useful life," as used in this report, refers to the SSTs' viability as interim storage receptacles for solid and liquid wastes awaiting retrieval. In the context of "remaining useful life," the definition of "failure" is the loss of liquid containment during the interim storage period or during subsequent retrieval operations. A corollary to this definition is that any tank that has been declared an "assumed leaker" is considered to have undergone failure.

The service life of all SSTs (grouped according to tank farm) is shown in Table 6. This table covers the period from 1998 to 2018, the target date for SST closure.

Table 6. Length of Service of SSTs according to Tank Farm Grouping

Tank Farm	In Service From/To	Service Life in 1998 (in Years)	Service Life in 2018 (in Years)
A	1956-57	42	62
AX	1965-66	33	53
B	1945-47	53	73
BX	1948-50	50	70
BY	1950-51	48	68
C	1946-53	52	72
S	1952-53	46	66
SX	1954-60	44	64
T	1944-47	54	74
TX	1949-51	49	69
TY	1953	45	65
U	1946-49	52	72

4.1 Catastrophic Failure

Catastrophic failure, defined in this analysis as either structural collapse or the loss of 50,000 gal or more, has a relatively low probability of occurrence. Table 7 presents information on the five tanks known to have leaked catastrophically.

Table 7. Catastrophic Leaks in SSTs

Tank	Date	Age of Tank (Years)	Leak Volume (gal)	Postulated Failure Mechanism
A-105	1963	6	10,000 to 277,000	Steam rupture
BX-102	1971	21	70,000	Unknown
SX-115	1965	5	50,000	Thermal cycling
T-106	1973	26	115,000	Unknown
U-104	1961	12	55,000	Unknown

Minimizing catastrophic failures during retrieval operations will depend largely on the response time necessary to declare a leak and the ability of in-tank equipment to remove free liquids.

Based on the preliminary integrity assessment presented in Section 3, the SSTs can be qualified for interim storage of solids for the duration of the expected SST retrieval program, i.e., through the year 2028.

4.2 Loss of Containment

An initial approach to estimating an SST's remaining useful life is to simply bound the expected time-to-failure and assign a probabilistic distribution within those bounds. As the carbon-steel liners of these tanks degrade over time, breaches are likely to occur. Time-to-failure can reasonably be bounded by the following:

- ***Minimum*** time-to-failure: 0 years (assuming some SSTs leak when placed into service)
- ***Maximum*** time-to-failure: 90 years (two times the longest known time-to-failure)
- ***Mean*** time-to-failure: (90 – 0)/2 = 45 years

Once the minimum, maximum, and mean time-to-failures are defined, various probability distribution functions can be examined for utility as a reasonable remaining useful life estimator. A bounding estimator may be useful for the total population, but its utility for making remaining-useful-life estimates for individual tanks is limited.

A slightly more sophisticated approach to estimating a tank's remaining useful life is through the use of a simple linear likelihood estimator. Linear likelihood estimators are a common tool for predicting future component failures based on component failure histories. Sixty-seven SSTs have been declared "assumed leakers." Using the formula

$$\text{Linear Likelihood Estimator (Tank Age)} * \frac{\text{\# Failed}}{\text{Total Population}} = \text{Probability of Failure}$$

we can develop a linear likelihood estimator based on the declaration date of the leak (as shown in Figures 2 and 3).

Tank AX-102, for example, went into service between 1965 and 1966. The linear estimator in Figure 2 shows that 70% of the 67 tanks that have been declared "leakers" had been in service between 30 and 35 years when that designation was applied. The estimated probability that Tank AX-102 would be declared an assumed leaker today is

$$70\% * 67/149 = 31\%$$

The probability of a level decrease can be estimated similarly, using the simple linear estimator in Figure 3. The probability of a level decrease for Tank AX-102 today is:

$$60\% * 24/149 = 10\%$$

These simple linear estimators have been applied to the remaining 82 SSTs—those that are considered sound. The results are shown in Table B-1 in Appendix B. Since the oldest SST to have been declared a leaker was Tank T-101, in 1992 (when it had been in service for 45 years), the linear estimators predict a "declared leaker" probability of 45% (100% * 67/149 = 45%) and a probability of level decrease of 16% (100%*24/149 = 16%) once a sound tank reaches a service life of 45 years.

Linear likelihood estimators are only as useful as the data used to develop them. Unfortunately, the protocols used to declare an SST an "assumed leaker" have not been consistent through the years, and tank-to-tank operations vary significantly. Linear estimator predictions should therefore be taken within the context of other predictors.

Any discussion of SSTs as a group is difficult because of the number of independent variables associated with each individual tank. The major variables affecting corrosion-related failures include waste type, waste temperature, tank construction, and the percent of wetted surface time (i.e., how much time the interior surface of the liner has spent in contact with the contained liquids). All four of these four variables were qualitatively determined for the remaining 82 sound SSTs, according to the following protocols (and sorted in Appendix B):

Waste Type	• 0% leakers	Good
	• 0-25% leakers	Moderate
	• Over 25% leakers	Bad
	• 100% leakers	Very bad
Corrosivity Factor	• Below 25	Good
	• 25 to 50	Moderate
	• Above 50	Bad

continued

Maximum Waste Temperature	• Below 120°F	Good
	• 120°F to 170°F	Moderate
	• Over 170°F	Bad
Tank Construction	• Radius knuckle	Good
	• Butt-weld knuckle	Bad

A common tool for screening the aggressiveness of a particular waste type is the corrosivity factor discussed in Section 2.2. It is important to note that the CF is most valid for nitric-acid-based waste streams. There are many constituents comprising the 30 waste groupings used in this analysis [Anantatmula, 1994]. Appendix B shows the results of an initial screening of corrosive conditions based on waste type, maximum temperature, and tank construction.

4.3 Tank-by-Tank Ranking

Table 8 shows tank groupings according to five categories. It describes the characteristics of tanks in each category and gives the number of tanks in that category. Table 9 provides a relative ranking of the remaining useful lives of all the SSTs.

Table 8. Tank Groupings according to Category

Category	Characteristics	Number of Tanks
I.	Benign waste type, low temperature, good to moderate corrosivity factor, constant service history, consistent surface level	12
II.	Inconsistent liquid level, benign waste type, elevated temperature, good to moderate corrosivity factor, consistent service history, listed as sound, may or may not have been stabilized	20
III.	Inconsistent liquid level or aggressive waste type, elevated temperature, good to moderate corrosivity factor, inconsistent service history, listed as sound, may or may not have been stabilized	50
IV.	Listed as "assumed leaker," leaked less than 50,000 gal, may or may not have been stabilized	62
V.	Listed as "assumed leaker," leaked more than 50,000 gal	5

The relative rankings provided here should be used for preliminary screening of SST candidates for early retrieval demonstrations. While qualitative rankings are indicative of trends, definitive conclusions regarding the structural and liquid integrity of individual tanks cannot be drawn from these limited data.

Table 9. Relative Rankings of the Remaining Useful Lives of SSTs

Category	Tank Name	Number of Tanks
I.	C-102, C-103, C-105, TX-108, TX-118, U-105, U-107, U-108, U-109, U-201, U-202, U-203	12
II.	BY-102, BY-109, C-106, S-112, S-111, S-102, SX-106, SX-101, SX-102, SX-105, S-101, S-103, S-105, S-106, S-107, S-108, S-109, S-110, TX-102, TX-104	20
III.	TX-106, U-106, U-111, U-103, U-102, AX-101, A-101, A-102, B-108, B-109, BX-112, T-110, T-112, B-202, T-201, T-202, T-203, T-204, U-204, SX-103, A-106, B-104, BX-109, C-104, C-107, T-104, TX-101, TX-103, TX-112, C-108, C-109, C-112, BX-103, BX-104, BX-105, BX-106, BY-111, BY-112, AX-103, BY-110, BY-104, BY-101, T-105, B-106, BX-107, B-102, T-102, TX-109, TX-111, TY-102	50
IV.	A-103, A-104, AX-102, AX-104, B-101, B-103, B-105, B-107, B-110, B-111, B-112, B-201, B-203, B-204, BX-101, BX-108, BX-110, BX-111, BY-103, BY-105, BY-106, BY-107, BY-108, C-101, C-110, C-111, C-201, C-202, C-203, C-204, S-104, SX-104, SX-107, SX-108, SX-109, SX-110, SX-111, SX-112, SX-113, SX-114, T-101, T-103, T-107, T-108, T-109, T-111, TX-105, TX-107, TX-110, TX-113, TX-114, TX-115, TX-116, TX-117, TY-101, TY-103, TY-104, TY-105, TY-106, U-101, U-110, U-112	62
V.	A-105, BX-102, SX-115, T-106, U-104	5

5 Impact of Hydraulic Retrieval on Liquid Integrity

During SST retrieval operations, the rate which liquid could potentially be released to the surrounding soils depends primarily on two parameters: (1) total hydraulic head and (2) leak path. The *total volume* of liquid that could be released to the soil depends on three additional parameters: (1) retrieval time, (2) detection time, and (3) response time. The impact of hydraulic retrieval is illustrated in Figure 6.

There are many theories regarding leak mechanisms for SSTs. One such theory says that leaking SSTs all have essentially the same flow area resulting from a similar distribution of stress corrosion cracks. A confident understanding of a leak's expected behavior will allow appropriate application of leak detection and leak response measures during retrieval operations in the SSTs.

5.1 Calculated Flow Constant for Laminar Flow

A detailed engineering study was conducted in 1993 to estimate leak rates associated with hydraulic retrieval of sludge from Tank C-106 [Lowe, 1993]. This study estimated leak rates from a distribution of 20 stress corrosion cracks to be as high as 40,000 gal over a 500-h retrieval campaign, for an overall leak rate of 80 gal/h. An earlier study [Isaacson, 1984] identified 13 SSTs with known or postulated leak rates. After declaring three of these tanks catastrophic leakers and removing them from the population, this study found (with 95% confidence) that 95% of the SSTs would leak at a rate less than 1.8 gal/h. In an effort to reduce this 40-fold difference between calculated and measured leak rates, a simple first-order calculation was performed to quantify the relationship between leak rate and hydraulic head. For a specific fluid system, hydraulic head (H) and volumetric flow (Q) can be measured such that standard fluid dynamics equations reduce to

$$Q_{turbulent} = k_{turbulent} (H)^{1/2}$$

and

$$Q_{laminar} = k_{laminar} (H)$$

where $k_{turbulent}$ and $k_{laminar}$ account for all constants like effective flow area, flow length, surface roughness, and fluid viscosity.

Laminar flow constants for seven tanks known to be leaking and six that were postulated leaking [Isaacson, 1981] were calculated; the results are shown in Table 10. Hydraulic head and leak rate data used for the calculations are plotted in Figures 7 and 8. As is evident in both the table and the figures, it is not possible to postulate conclusively a relationship between leak rate and hydraulic head that would be common to all the tanks. Additional data and analyses are necessary before potential leak rates for SSTs undergoing retrieval operations can be estimated. Specifically, leak rate and hydraulic head data should be validated prior to further investigation.

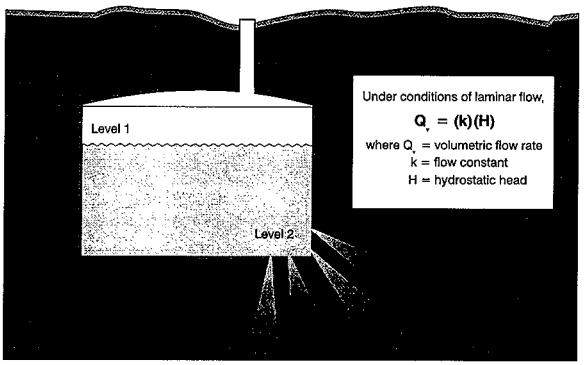


Figure 6. Impact of hydraulic retrieval.

Table 10. Laminar Flow Constant ($k_{laminar}$) Calculations for Known and Postulated Leak Rates

Tank	Leak Rate (gal/h)	Head (ft)	$k_{laminar}$	Leak Rate Confidence
SX-115*	306	22.0	13.91	Confirmed
T-106*	102	15.3	6.69	Confirmed
B-201	0.30	12.5	0.02	Confirmed
B-107	0.66	4.5	0.15	Confirmed
C-101	1.14	2.0	0.57	Confirmed
U-112	1.20	2.0	0.60	Confirmed
U-110	1.38	11.0	0.13	Confirmed
T-108	0.09	16.0	0.01	Postulated
T-111	0.12	14.5	0.01	Postulated
TX-107	0.36	2.0	0.18	Postulated
TY-101	0.78	23.2	0.03	Postulated
B-110	1.20	8.3	0.14	Postulated
SX-110*	12.00	13.0	0.92	Postulated
Average	*0.72*	*9.6*	*0.18*	
Std. Dev.	*0.46*	*6.8*	*0.21*	

* Denotes a tank having a catastrophic leak rate. These tanks are not included in the average or in the standard deviation.

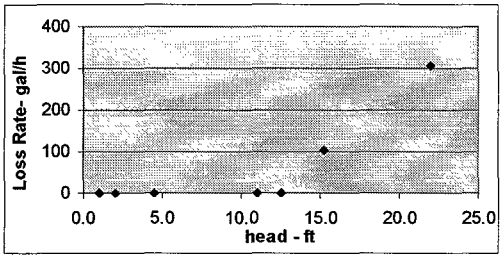


Figure 7. Fluid dynamics data for seven SSTs with "confirmed" leak rates.

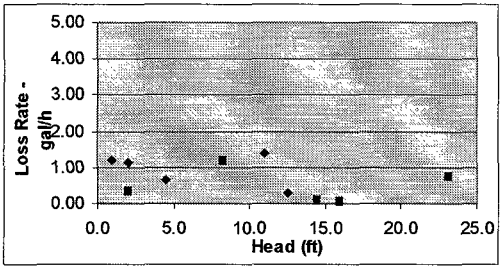


Figure 8. Fluid Dynamics data for "confirmed" and "postulated" leak rates of ten leaking SSTs. Squares indicate "confirmed" leak rates and diamonds indicate "postulated" leak rates. Three catastrophic leak rates are removed for scaling.

5.2 Maximum Undetected Leak Volume

Section 6.5 of the Tank Waste Remediation System Operation and Utilization Plan [Kirkbride, 1997] provides a formula that describes an estimated baseline retrieval time, T_r, as

T_r	=	$0.72\ m^3 / d$	[190.2 gal/d]	for	$0.01 >$	V_w/V_t		
T_r	=	$72*(V_w/V_t)\ m^3 / d$	[$19.02*(V_w/V_t)$ gal/d]	for	$0.1 \geq$	V_w/V_t	$\geq$	0.01
T_r	=	$7.2\ m^3 / d$	[1902 gal/d]	for		V_w/V_t	$>$	0.1

where V_t is the total volume capacity of the tank, and V_w is the residual waste in the tank. Using this formula, we can estimate a time history for retrieval, and from this history we can estimate how much time will be required to retrieve any specified quantity of waste. This process is illustrated in Figure 9, an estimated retrieval time history for Tank C-102. Figure 9 shows that, beginning with the current volume of waste in C-102, 316,000 gal (see Appendix F), the waste removal operations proceed rapidly at a rate of about 1,900 gal/day

until about Day 150—at which time the retrieval rate begins to slow down. The calculations show that according to the baseline retrieval formula, it will take approximately 208 days to retrieve 99% of the wastes in C-102 and about 225 days to retrieve 100% of the wastes. The amount of time necessary to retrieve 99% of the wastes is tabulated, tank by tank, in Appendix B. (Based on the sum of the estimated retrieval times for all the SSTs, it is noted that if the retrieval program operated on each tank serially it would take 74.6 years to remove 99% of the wastes in the SSTs.)

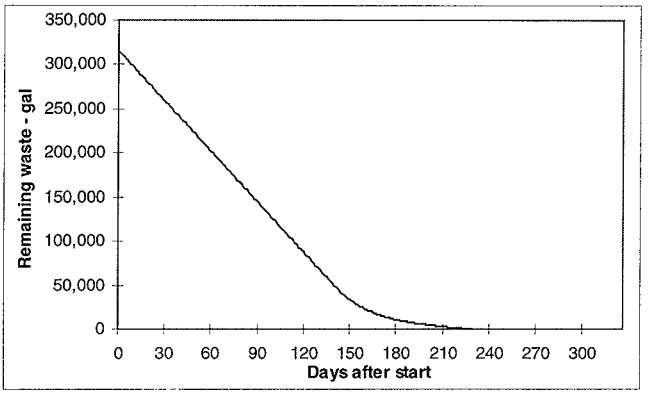


Figure 9. Baseline retrieval time history for Tank C-102, using Kirkbride's formula.

If, for a given tank, the onset of a leak occurs at the beginning of the retrieval campaign, and if the rate of that leak is just slightly less than the minimum detectable leak rate, the total volume of the undetected release will be no greater than the leak rate multiplied by the retrieval time. Thus, using the tank information, the known waste volumes, the minimum detectable leak rates calculated above (and listed for each tank in Appendix E), and the formula for estimating retrieval time, we can estimate the maximum volume of a potentially undetected leak from each tank as

Retrieval Time * Leak Rate = Maximum Undetected Leak Volume

The "maximum undetected leak volume" was calculated for each tank. (It is reported in the last column of the table in Appendix F.) Table 11 shows the average time necessary to retrieve 99% of the wastes and the average volume of a potentially undetected leak under three different conditions based on the volume of liquid in the tank (1,000,000 gal, 750,000 gal, and 500,000 gal). The table shows an average retrieval time of 14 days for tanks containing 55,000 gal, but since there were no level data available for these tanks that could be used to calculate a minimum detectable leak rate, it was not possible to determine a maximum undetected leak volume in this analysis.

Table 11. Average Retrieval Times and Potential Undetected Leak Volumes for Tanks of Various Capacities

Tank Volume (gal)	Average Retrieval Time (days)	Average Potentially Undetected Leak Volume (Kgal)
1,000,000	238	40
750.000	261	20
500,000	143	10
55,000	14	N/A

6 Conclusions and Recommendations

6.1 Conclusions

This work demonstrates that there are several techniques possible for screening the Hanford SSTs for liquid integrity. Much of the data employed by these techniques, however, are not readily available and are in many cases suspect. The use of multiple techniques in a way that exploits all of the available SST data, on the other hand, can facilitate a tank-by-tank understanding of liquid integrity and can foster a relative confidence in predictions of remaining useful life. Specifically, the following conclusions are presented.

- A qualitative tank integrity screening (based on engineering judgment using indicators such as corrosiveness of waste, maximum temperature, and lower-knuckle design) was prepared. SSTs can be grouped into relative rankings as candidates for early retrieval demonstrations.

- The analysis showed that volumetric methods can be applied to many of the SSTs as part of a regular test program to detect leaks in the range of regulatory interest (i.e., less than 5 gal/h), using existing sensors. Performance specifications that include a probability of detection of 95% and a probability of false alarm of 1% or less can be developed for those tanks with measurable liquid levels. Test times of 24- to 48-hours are likely for many of the SSTs.

- For many SSTs, tank liquid integrity indicators such as corrosiveness of the waste and maximum waste temperature are favorable.

- A maximum leak rate for "known leakers" was calculated as 1.8 gal/h [Isaacson, 1981]. A common relationship between fluid level and leak rate (critical flow constant) in SSTs could not be established with the data reviewed. Additional data and further analysis are necessary for such correlations to be established and justified.

6.2 Recommendations

The following recommendations are submitted for consideration in future SST tank integrity reviews.

(1) Perform detailed tank integrity assessments on the following candidate SSTs:

C-102	TX-118	U-107	U-201
C-103	TX-108	U-108	U-202
C-105	U-105	U-109	U-203

Detailed integrity assessments should include a critical review of waste chemistry and a calculation of the corrosivity factor throughout the life of the tank, a critical

review of all tank temperature and level data from tank-farm operations logs, and a review of tank construction reports.

(2) Establish leak test protocols for SSTs for each retrieval methodology based on a statistically significant sample period and frequency.

(3) Review archived tank-farm operations logs for leak dates and level recordings to establish expected leak rates from SSTs.

References

Abatt, F. G., 1996, "Double-Shell Tank Useful Life Analysis," WHC-SD-WM-ER-556, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Anantatmula, R. P., 1994, "Characterization of the Corrosion Behavior of the Carbon Steel Liner in Hanford Site Single-Shell Tanks," WHC-EP-0772, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

Barnes, David, Lockheed Martin Hanford Corporation, conversation with authors, 3 June 1998.

Brevick, C. H., 1994, "Historical Tank Content Estimate for the Northeast Quadrant of the Hanford 200 East Area," WHC-SD-WM-ER-349, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Edgemon, G. L., 1995, "Hanford Waste Tank System Degradation Mechanisms," WHC-SD-WM-ER-414, Rev. 1, Westinghouse Hanford Company, Richland, Washington.

Girdler, R. M., 1965, "Leaks in Radioactive Waste Tanks," DP-990, E. I. Du Pont De Nemours & Company, Aiken, South Carolina.

Han, F. C., 1996a, "Structural Integrity and Potential Failure Modes of the Hanford High-Level Waste Tanks," WHC-SD-TWR-RPT-002, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Han, F. C., 1996b, "DELPHI Expert Panel Evaluation of Hanford High-Level Waste Tank Failure Modes and Release Quantities," WHC-SD-TWR-RPT-003, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Hanlon, B. M., 1998, "Waste Tank Summary Report for Month Ending March 31, 1998," HNF-EP-0182-120, Rev. 0, Fluor Daniel Hanford, Inc., Richland, Washington.

Hill, J. G., 1994, "SORT on Radioactive Waste Tanks at Hanford," WHC-PNL-90814, Rev. 2, Westinghouse Hanford Company, Richland, Washington.

Isaacson, R. E., 1981, "A Scientific Basis for Establishing Dry Well-Monitoring Frequencies," RHO-ST-34-201, Rockwell Hanford Operations, Richland, Washington.

Kirkbride, R. A., 1997, "Tank Waste Remediation System Operation and Utilization Plan," HNF-SD-WM-SP-012, Rev. 0, Numatec Hanford Corporation, Richland, Washington.

Lowe, S. S., 1993, "Engineering Study of Tank Leaks Related to Retrieval of Sludge from Tank 241-C-106," WHC-SD-WM-ES-218, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Ondrejcin, R. S., 1978, "Prediction of Stress Corrosion of Carbon Steel by Nuclear Process Liquid Wastes," DP-1478, E. I. Du Pont de Nemours & Co., Aiken, South Carolina.

Poe, W. L., 1974, "Leakage from Waste Tank 16, Amount, Fate, and Impact," DP-1358, E. I. Du Pont de Nemours & Co., Aiken, South Carolina.

Rasmussen, O. R., 1980, "Hanford Radioactive Tank Cleanout and Sludge Processing," RHO-ST-30, Rev. 0, Rockwell Hanford Operations, Richland, Washington.

Rodenhizer, D. G., 1987, "Hanford Waste Tank Sluicing History," WHC-TI-302, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

"Standard Test Procedures for Evaluating Leak Detection Methods: Automatic Tank Gauging Systems," 1990, EPA Report No. EPA/530/UST-90/006, US Environmental Protection Agency, Washington, D.C.

"Tank Waste Support Table," Tank Waste Information Network System 2 (TWINS), cited 31 December 1997, available from http://twins.pnl.gov:8001.

Appendix A

Single-Shell Tank Quick Reference Facts

Single-Shell Tank Quick Reference Facts

- The first single-shell tanks were constructed in 1943-1944
- The last SST was placed in service in 1964
- In 1959, the first single-shell tank was confirmed to have leaked
- 32 of the 66 SSTs located in the East area are assumed leakers [Hanlon]
- 35 of the 83 SSTs located in the West area are assumed leakers [Hanlon]
- The SSTs contain ~550,000 gal of supernate [Hanlon]
- The SSTs contain ~5,700,000 gal of pumpable liquid [Hanlon]
- The SSTs contain ~5,800,000 gal of drainable interstitial liquid [Hanlon]
- There is a total of 149 SSTs (67 of which, or 45%, have been declared leakers)
- There is a total of 25 1,000,000-gal tanks (15 of which, or 60%, have been declared leakers)
- There is a total of 48 758,000 gal tanks (19 of which, or 39%, have been declared leakers)
- There is a total of 64 530,000 gal tanks (26 of which, or 41%, have been declared leakers)
- There is a total of 12 55,000 gal tanks (7 of which, or 58%, have been declared leakers)
- Only 24 of the declared "leakers" have shown a detectable decrease in surface level
- The total leakage from SSTs to date is ~ 750,000 gallons
- 9 out of 10 high-heat tanks have leaked (C-106 is the only non-leaker) [Hanlon]
- 3 out of 19 H_2 tanks have leaked [Hanlon]
- 5 out of 20 organic tanks have leaked [Hanlon]
- 2 out of 11 tanks with DSSF waste have leaked (A-103, SX-104) [Hanlon]
- 27 sound SSTs have not be stabilized; 55 sound tanks have been stabilized [Hanlon]

Appendix B

SST Failure Frequencies

Tank	Tank Integrity	Stabilization Status	Total Waste (Kgal)	In-Service Date	Time to Failure (yrs)	Max. Temp. (°F)	Corrosion Factor	Waste Type (% Leaked)	Lower Knuckle	Linear Estimator (1 - σ P(fail))	Linear Estimator (2 - σ P(fail))	Corrosivity P(fail)	Category
A-101 (T, H, O)	SOUND	/PI	953	1957	n/a	153	0.77	25%	Radius	43%	15%	Low	3
A-102 (T)	SOUND	IS/PI	41	1957	n/a		0.77	25%	Radius	43%	15%	Low	3
A-103 (T)	ASMD LKR	IS/II	371	1957	30		0.77	25%	Radius	43%	15%	Low	4
A-104 (T)	ASMD LKR	IS/II	28	1957	18	187	0	39%	Radius	43%	15%	Low	4
A-105	ASMD LKR	IS/II	19	1957	6	141	0	39%	Radius	43%	15%	Low	5
A-106 (T)	SOUND	IS/II	125	1957	n/a		0	39%	Radius	43%	15%	Low	3
AX-101 (T, H)	SOUND	/PI	748	1966	n/a	134	0.77	25%	Butt-weld	31%	10%	Low	3
AX-102 (T, H)	ASMD LKR	IS/II	39	1966	22	78	1.1	50%	Butt-weld	31%	10%	Low	4
AX-103 (H)	SOUND	IS/II	112	1966	n/a	115	1.1	50%	Butt-weld	31%	10%	Low	3
AX-104 (T)	ASMD LKR	IS/II	7	1966	11		0	39%	Butt-weld	31%	10%	Low	4
B-101 (T)	ASMD LKR	IS/II	113	1947	27		9.12	67%	Radius	45%	16%	Low	4
B-102 (T)	SOUND	IS/II	32	1947	n/a		9.12	67%	Radius	45%	16%	Low	3
B-103 (T)	ASMD LKR	IS/II	59	1947	31	66	9.12	67%	Radius	45%	16%	Low	4
B-104	SOUND	IS/II	371	1947	n/a		0	39%	Radius	45%	16%	Low	3
B-105	ASMD LKR	IS/II	306	1947	31		22	75%	Radius	45%	16%	Low	4
B-106	SOUND	IS/II	117	1947	n/a		26.4	60%	Radius	45%	16%	Med	3
B-107	ASMD LKR	IS/II	165	1947	33		11	25%	Radius	45%	16%	Low	4
B-108	SOUND	IS/II	94	1947	n/a		11	25%	Radius	45%	16%	Low	3
B-109	SOUND	IS/II	127	1947	n/a		11	25%	Radius	45%	16%	Low	3
B-110 (T)	ASMD LKR	IS/II	246	1947	34		5	100%	Radius	45%	16%	Low	4
B-111	ASMD LKR	IS/II	237	1947	31		5	100%	Radius	45%	16%	Low	4
B-112 (T)	ASMD LKR	IS/II	33	1947	31		5	100%	Radius	45%	16%	Low	4
B-201	ASMD LKR	IS/II	29	1947	33		1.8	37%	Radius	45%	16%	Low	4
B-202 (T)	SOUND	IS/II	27	1947	n/a		1.8	37%	Radius	45%	16%	Low	3
B-203	ASMD LKR	IS/II	51	1947	36		1.8	37%	Radius	45%	16%	Low	4
B-204	ASMD LKR	IS/II	50	1947	37		1.8	37%	Radius	45%	16%	Low	4
BX-101 (T)	ASMD LKR	IS/II	43	1950	22		57.2	43%	Radius	45%	16%	High	4
BX-102 (T)	ASMD LKR	IS/II	96	1950	21		57.2	43%	Radius	45%	16%	High	5
BX-103	SOUND	IS/II	66	1950	n/a		57.2	43%	Radius	45%	16%	High	3
BX-104 (T)	SOUND	IS/II	99	1950	n/a		57.2	43%	Radius	45%	16%	High	3
BX-105 (T)	SOUND	IS/II	51	1950	n/a		57.2	43%	Radius	45%	16%	High	3
BX-106 (T)	SOUND	/PI	46	1950	n/a		57.2	43%	Radius	45%	16%	High	3
BX-107	SOUND	IS/PI	345	1950	n/a		26.4	60%	Radius	45%	16%	Med	3
BX-108	ASMD LKR	IS/II	26	1950	24		26.4	60%	Radius	45%	16%	Med	4
BX-109	SOUND	IS/PI	193	1950	n/a		0	39%	Radius	45%	16%	Low	3
BX-110	ASMD LKR	IS/PI	207	1950	26		12.4	100%	Radius	45%	16%	Low	4
BX-111	ASMD LKR	/PI	162	1950	34		12.4	100%	Radius	45%	16%	Low	4
BX-112	SOUND	IS/PI	165	1950	n/a		11	25%	Radius	45%	16%	Low	3

Tank	Tank Integrity	Stabilization Status	Total Waste (Kgal)	In-Service Date	Time to Failure (yrs)	Max. Temp. (°F)	Corrosion Factor	Waste Type (% Leaked)	Lower Knuckle	Linear Estimator (1 - σ P(fail))	Linear Estimator (2 - σ P(fail))	Corrosivity P(fail)	Category
BY-101	SOUND	IS/II	387	1951	n/a		45.5	50%	Radius	45%	16%	Med	3
BY-102	SOUND	/PI	341	1951	n/a		67.7	0%	Radius	45%	16%	High	2
BY-103 (T, Fe)	ASMD LKR	/PI	400	1951	22	81	45.5	50%	Radius	45%	16%	Med	4
BY-104 (T, Fe)	SOUND	IS/II	406	1951	n/a	125	45.5	50%	Radius	45%	16%	Med	3
BY-105 (T, Fe)	ASMD LKR	/PI	503	1951	33	118	45.5	50%	Radius	45%	16%	Med	4
BY-106	ASMD LKR	/PI	642	1951	33	122	45.5	50%	Radius	45%	16%	Med	4
BY-107 (Fe)	ASMD LKR	IS/II	266	1951	33	95	45.5	50%	Radius	45%	16%	Med	4
BY-108 (Fe)	ASMD LKR	IS/II	228	1951	21	108	45.5	50%	Radius	45%	16%	Med	4
BY-109	SOUND	/PI	423	1951	n/a		67.7	0%	Radius	45%	16%	High	2
BY-110 (Fe)	SOUND	IS/II	398	1951	n/a	116	45.5	50%	Radius	45%	16%	Med	3
BY-111 (Fe)	SOUND	IS/II	459	1951	n/a	87	45.5	50%	Radius	45%	16%	Med	3
BY-112 (Fe)	SOUND	IS/II	291	1951	n/a	90	45.5	50%	Radius	45%	16%	Med	3
C-101 (T)	ASMD LKR	IS/II	88	1953	27		57.2	43%	Radius	45%	16%	High	4
C-102 (T, O)	SOUND	/PI	423	1953	n/a	86	24.5	0%	Radius	45%	16%	Low	1
C-103 (T, O)	SOUND	/PI	195	1953	n/a	120	24.5	0%	Radius	45%	16%	Low	1
C-104 (T)	SOUND	IS/II	295	1953	n/a		0	39%	Radius	45%	16%	Low	3
C-105 (Sn, T)	SOUND	/PI	135	1953	n/a		24.5	0%	Radius	45%	16%	Low	1
C-106 (T, HL)	SOUND	/PI	229	1953	n/a	154	24.5	0%	Radius	45%	16%	Low	2
C-107 (T)	SOUND	/PI	275	1953	n/a		0.85	39%	Radius	45%	16%	Low	3
C-108 (T, Fe)	SOUND	IS/II	66	1953	n/a	78	35.8	40%	Radius	45%	16%	Med	3
C-109 (Fe)	SOUND	IS/II	66	1953	n/a	81	35.8	40%	Radius	45%	16%	Med	3
C-110 (T)	ASMD LKR	/PI	187	1953	31		26.4	60%	Radius	45%	16%	Med	4
C-111(T)	ASMD LKR	IS/II	57	1953	15	77	35.8	40%	Radius	45%	16%	Med	4
C-112 (T)	SOUND	IS/PI	104	1953	n/a	84	35.8	40%	Radius	45%	16%	Med	3
C-201	ASMD LKR	IS/II	2	1953	35		1.59	100%	Radius	45%	16%	Low	4
C-202	ASMD LKR	IS/II	1	1953	35		1.59	100%	Radius	45%	16%	Low	4
C-203	ASMD LKR	IS/II	5	1953	31		1.59	100%	Radius	45%	16%	Low	4
C-204	ASMD LKR	IS/II	3	1953	35		1.59	100%	Radius	45%	16%	Low	4
S-101 (T)	SOUND	/PI	427	1953	n/a		13.7	14%	Radius	45%	16%	Low	2
S-102 (H,O)	SOUND	/PI	549	1953	n/a	110	13.7	14%	Radius	45%	16%	Low	2
S-103	SOUND	/PI	248	1953	n/a		13.7	14%	Radius	45%	16%	Low	2
S-104 (T)	ASMD LKR	IS/II	294	1953	15		6.53	100%	Radius	45%	16%	Low	4
S-105	SOUND	IS/II	456	1953	n/a		13.7	14%	Radius	45%	16%	Low	2
S-106	SOUND	/PI	479	1953	n/a		13.7	14%	Radius	45%	16%	Low	2
S-107 (T)	SOUND	/PI	376	1953	n/a		13.7	14%	Radius	45%	16%	Low	2
S-108	SOUND	/PI	604	1953	n/a		13.7	14%	Radius	45%	16%	Low	2
S-109	SOUND	/PI	568	1953	n/a		13.7	14%	Radius	45%	16%	Low	2

Tank	Tank Integrity	Stabilization Status	Total Waste (Kgal)	In-Service Date	Time to Failure (yrs)	Max. Temp. (°F)	Corrosion Factor	Waste Type (% Leaked)	Lower Knuckle	Linear Estimator (1 - σ P(fail))	Linear Estimator (2 - σ P(fail))	Corrosivity P(fail)	Category
S-110	SOUND	/PI	390	1953	n/a		13.7	14%	Radius	45%	16%	Low	2
S-111 (H,O)	SOUND	/PI	596	1953	n/a	94	13.7	14%	Radius	45%	16%	Low	2
S-112 (T, H)	SOUND	/PI	523	1953	n/a	87	13.7	14%	Radius	45%	16%	Low	2
SX-101 (T)	SOUND	/PI	456	1960	n/a	137	13.7	14%	Butt-weld	43%	15%	Low	2
SX-102 (H)	SOUND	/PI	543	1960	n/a	150	13.7	14%	Butt-weld	43%	15%	Low	2
SX-103 (T, H, O)	SOUND	/PI	652	1960	n/a	172	4.87	39%	Butt-weld	43%	15%	Low	3
SX-104 (T)	ASMD LKR	/PI	614	1960	28	166	13.7	14%	Butt-weld	43%	15%	Low	4
SX-105 (T, H)	SOUND	/PI	683	1960	n/a	181	13.7	14%	Butt-weld	43%	15%	Low	2
SX-106 (T, H)	SOUND	/PI	538	1960	n/a	112	13.7	14%	Butt-weld	43%	15%	Low	2
SX-107 (T)	ASMD LKR	IS/II	104	1960	4	170	6.53	100%	Butt-weld	43%	15%	Low	4
SX-108 (T)	ASMD LKR	IS/II	87	1960	2	197	6.53	100%	Butt-weld	43%	15%	Low	4
SX-109 (T)	ASMD LKR	IS/II	250	1960	5	151	6.53	100%	Butt-weld	43%	15%	Low	4
SX-110 (T)	ASMD LKR	IS/II	62	1960	16	170	6.07	100%	Butt-weld	43%	15%	Low	4
SX-111 (T)	ASMD LKR	IS/II	125	1960	14	194	6.07	100%	Butt-weld	43%	15%	Low	4
SX-112 (T)	ASMD LKR	IS/II	92	1960	9	155	6.53	100%	Butt-weld	43%	15%	Low	4
SX-113 (T)	ASMD LKR	IS/II	26	1960	2		4.57	100%	Butt-weld	43%	15%	Low	4
SX-114 (T)	ASMD LKR	IS/II	181	1960	12	188	6.07	100%	Butt-weld	43%	15%	Low	4
SX-115 (T)	ASMD LKR	IS/II	12	1960	5		6.53	100%	Butt-weld	43%	15%	Low	5
T-101 (T)	ASMD LKR	IS/PI	102	1947	45		0.1	67%	Radius	45%	16%	Low	4
T-102	SOUND	IS/II	32	1947	n/a		0.1	67%	Radius	45%	16%	Low	3
T-103	ASMD LKR	IS/II	27	1947	27		0.1	67%	Radius	45%	16%	Low	4
T-104	SOUND	/PI	445	1947	n/a		2.75	39%	Radius	45%	16%	Low	3
T-105 (T)	SOUND	IS/II	98	1947	n/a		1.94	50%	Radius	45%	16%	Low	3
T-106 (T)	ASMD LKR	IS/II	21	1947	26		1.94	50%	Radius	45%	16%	Low	5
T-107	ASMD LKR	/PI	180	1947	37	70	35.8	40%	Radius	45%	16%	Med	4
T-108	ASMD LKR	IS/II	44	1947	27		26.4	60%	Radius	45%	16%	Med	4
T-109	ASMD LKR	IS/II	58	1947	27		0	39%	Radius	45%	16%	Low	4
T-110 (T, H)	SOUND	/PI	379	1947	n/a	66	4.04	33%	Radius	45%	16%	Low	3
T-111	ASMD LKR	/PI	446	1947	32	67	4.04	33%	Radius	45%	16%	Low	4
T-112 (T)	SOUND	IS/II	67	1947	n/a		4.04	33%	Radius	45%	16%	Low	3
T-201	SOUND	IS/II	29	1947	n/a		1.8	37%	Radius	45%	16%	Low	3
T-202	SOUND	IS/II	21	1947	n/a		1.8	37%	Radius	45%	16%	Low	3
T-203	SOUND	IS/II	35	1947	n/a		1.8	37%	Radius	45%	16%	Low	3
T-204	SOUND	IS/II	38	1947	n/a		1.8	37%	Radius	45%	16%	Low	3
TX-101	SOUND	IS/II	87	1951	n/a		0	39%	Radius	45%	16%	Low	3
TX-102	SOUND	IS/II	217	1951	n/a		13.7	14%	Radius	45%	16%	Low	2
TX-103	SOUND	IS/II	157	1951	n/a		0	39%	Radius	45%	16%	Low	3
TX-104	SOUND	IS/II	65	1951	n/a		13.7	14%	Radius	45%	16%	Low	2

Tank	Tank Integrity	Stabilization Status	Total Waste (Kgal)	In-Service Date	Time to Failure (yrs)	Max. Temp. (°F)	Corrosion Factor	Waste Type (% Leaked)	Lower Knuckle	Linear Estimator (1 - σ P(fail))	Linear Estimator (2 - σ P(fail))	Corrosivity P(fail)	Category
TX-105 (O)	ASMD LKR	IS/II	609	1951	26	99	13.7	14%	Radius	45%	16%	Low	4
TX-106	SOUND	IS/II	453	1951	n/a		13.7	14%	Radius	45%	16%	Low	3
TX-107	ASMD LKR	IS/II	36	1951	33		13.7	14%	Radius	45%	16%	Low	4
TX-108	SOUND	IS/II	134	1951	n/a		45.7	0%	Radius	45%	16%	Med	1
TX-109 (T)	SOUND	IS/II	384	1951	n/a		22	75%	Radius	45%	16%	Low	3
TX-110	ASMD LKR	IS/II	462	1951	26		22	75%	Radius	45%	16%	Low	4
TX-111	SOUND	IS/II	370	1951	n/a		22	75%	Radius	45%	16%	Low	3
TX-112	SOUND	IS/II	649	1951	n/a		0	39%	Radius	45%	16%	Low	3
TX-113	ASMD LKR	IS/II	607	1951	23		22	75%	Radius	45%	16%	Low	4
TX-114	ASMD LKR	IS/II	535	1951	23		22	75%	Radius	45%	16%	Low	4
TX-115	ASMD LKR	IS/II	640	1951	26		23.2	20%	Radius	45%	16%	Low	4
TX-116	ASMD LKR	IS/II	631	1951	26		22	75%	Radius	45%	16%	Low	4
TX-117	ASMD LKR	IS/II	626	1951	26		22	75%	Radius	45%	16%	Low	4
TX-118 (T)	SOUND	IS/II	347	1951	n/a	77	45.7	0%	Radius	45%	16%	Med	1
TY-101 (T)	ASMD LKR	IS/II	118	1953	20	65	0	39%	Radius	45%	16%	Low	4
TY-102	SOUND	IS/II	64	1953	n/a		22	75%	Radius	45%	16%	Low	3
TY-103 (T)	ASMD LKR	IS/II	162	1953	20	70	58	100%	Radius	45%	16%	High	4
TY-104 (O)	ASMD LKR	IS/II	46	1953	28	71	58	100%	Radius	45%	16%	High	4
TY-105	ASMD LKR	IS/II	231	1953	7		81.7	100%	Radius	45%	16%	High	4
TY-106	ASMD LKR	IS/II	17	1953	6		81.7	100%	Radius	45%	16%	High	4
U-101	ASMD LKR	IS/II	25	1949	10		6.53	100%	Radius	45%	16%	Low	4
U-102	SOUND	/PI	374	1949	n/a		23.2	20%	Radius	45%	16%	Low	3
U-103 (H,O)	SOUND	/PI	468	1949	n/a	89	23.2	20%	Radius	45%	16%	Low	3
U-104	ASMD LKR	IS/II	122	1949	12		4.57	100%	Radius	45%	16%	Low	5
U-105 (H,O)	SOUND	/PI	418	1949	n/a	92	21.2	0%	Radius	45%	16%	Low	1
U-106 (O)	SOUND	/PI	226	1949	n/a	82	23.2	20%	Radius	45%	16%	Low	3
U-107 (T, O)	SOUND	/PI	406	1949	n/a	83	21.2	0%	Radius	45%	16%	Low	1
U-108 (H)	SOUND	/PI	468	1949	n/a	89	21.2	0%	Radius	45%	16%	Low	1
U-109 (H)	SOUND	/PI	463	1949	n/a	87	21.2	0%	Radius	45%	16%	Low	1
U-110 (T)	ASMD LKR	IS/PI	186	1949	26		0	39%	Radius	45%	16%	Low	4
U-111 (O)	SOUND	/PI	329	1949	n/a	82	23.2	20%	Radius	45%	16%	Low	3
U-112	ASMD LKR	IS/II	49	1949	31		0	39%	Radius	45%	16%	Low	4
U-201	SOUND	IS/II	5	1949	n/a		0.05	0%	Radius	45%	16%	Low	1
U-202 (O)	SOUND	IS/II	5	1949	n/a		0.05	0%	Radius	45%	16%	Low	1
U-203 (O)	SOUND	IS/II	3	1949	n/a	66	0.05	0%	Radius	45%	16%	Low	1
U-204 (O)	SOUND	IS/II	3	1949	n/a	63	0	39%	Radius	45%	16%	Low	3

Appendix C

SST Waste Tank Volumes and Available Liquid Level Data

Tank	Tank Integrity	Stabilization Status	Total Waste (Kgal)	Supernatant Volume (Kgal)	Drainable Interstitial Volume (Kgal)	Drainable Liquid Remaining (Kgal)	Pumpable Liquid Remaining (Kgal)	Sludge Volume (Kgal)	Salt Cake Volume (Kgal)	Usable Liquid Level	Analyzable Level Sensor(s) Data Available
241-A-101	SOUND	/PI	953	0	**464**	464	441	3	950	**YES**	**ILL**
241-A-102	SOUND	IS/PI	41	4	2	6	0	15	22	NO	NONE[2]
241-A-103	ASMD LKR	IS/II	371	**5**	15	20	0	366	0	**YES**	**ENRAF**
241-A-104	ASMD LKR	IS/II	28	0	0	0	0	28	0	NO	NONE[3,4]
241-A-105	ASMD LKR	IS/II	19	0	4	4	0	19	0	NO	NONE[3]
241-A-106	SOUND	IS/II	125	0	7	7	0	125	0	YES	NONE[2]
241-AX-101	SOUND	/PI	748	0	359	359	338	3	745	YES	NONE[2]
241-AX-102	ASMD LKR	IS/II	39	3	14	17	3	7	29	YES	MT[7]
241-AX-103	SOUND	IS/II	112	0	36	36	3	2	110	YES	NONE[5]
241-AX-104	ASMD LKR	IS/II	7	0	0	0	0	7	0	NO	ENRAF
241-B-101	ASMD LKR	IS/II	113	0	6	6	0	113	0	YES	NONE[8]
241-B-102	SOUND	IS/II	32	**4**	0	4	0	18	10	**YES**	**ENRAF**
241-B-103	ASMD LKR	IS/II	59	0	0	0	0	59	0	NO	NONE
241-B-104	SOUND	IS/II	371	1	**46**	47	40	301	69	YES	**ILL**
241-B-105	ASMD LKR	IS/II	306	0	**23**	23	0	40	266	**YES**	**ILL**, MT
241-B-106	SOUND	IS/II	117	1	6	7	0	116	0	YES	NONE[8]
241-B-107	ASMD LKR	IS/II	165	1	12	13	7	164	0	YES	NONE[8]
241-B-108	SOUND	IS/II	94	0	4	4	0	94	0	NO	NONE
241-B-109	SOUND	IS/II	127	0	8	8	0	127	0	YES	NONE[8]
241-B-110	ASMD LKR	IS/II	246	1	**22**	23	17	245	0	**YES**	**ILL**, MT
241-B-111	ASMD LKR	IS/II	237	1	**21**	22	16	236	0	**YES**	**ILL**, FIC
241-B-112	ASMD LKR	IS/II	33	**3**	0	3	0	30	0	**YES**	**ENRAF**
241-B-201	ASMD LKR	IS/II	29	1	3	4	0	28	0	NO	NONE
241-B-202	SOUND	IS/II	27	0	3	3	0	27	0	NO	NONE
241-B-203	ASMD LKR	IS/II	51	1	5	6	0	50	0	YES	NONE[8]
241-B-204	ASMD LKR	IS/II	50	1	5	6	0	49	0	YES	NONE[8]
241-BX-101	ASMD LKR	IS/II	43	1	0	1	0	42	0	NO	NONE
241-BX-102	ASMD LKR	IS/II	96	0	4	4	0	96	0	NO	NONE
241-BX-103	SOUND	IS/II	68	**6**	0	6	0	62	0	**YES**	**ENRAF**
241-BX-104	SOUND	IS/II	99	**3**	30	33	27	96	0	**YES**	**ENRAF**
241-BX-105	SOUND	IS/II	51	**5**	6	11	4	43	3	**YES**	**ENRAF**
241-BX-106	SOUND	/PI	38	0	0	0	0	38	0	NO	NONE

Tank	Tank Integrity	Stabilization Status	Total Waste (Kgal)	Supernatant Volume (Kgal)	Drainable Interstitial Volume (Kgal)	Drainable Liquid Remaining (Kgal)	Pumpable Liquid Remaining (Kgal)	Sludge Volume (Kgal)	Salt Cake Volume (Kgal)	Usable Liquid Level	Analyzable Level Sensor(s) Data Available
241-BX-107	SOUND	IS/PI	345	1	29	30	23	344	0	YES	NONE[8]
241-BX-108	ASMD LKR	IS/II	26	0	1	1	0	26	0	NO	NONE
241-BX-109	SOUND	IS/PI	193	0	13	13	8	193	0	YES	NONE[8]
241-BX-110	ASMD LKR	IS/PI	207	**3**	16	19	13	195	9	**YES**	**ENRAF**
241-BX-111	ASMD LKR	/PI	162	1	1	3	1	52	109	NO	NONE
241-BX-112	SOUND	IS/PI	165	1	7	8	2	164	0	YES	NONE[8]
241-BY-101	SOUND	IS/II	387	0	**5**	5	0	109	278	**YES**	**ILL**
241-BY-102	SOUND	/PI	277	0	**11**	11	0	0	277	**YES**	**ILL**
241-BY-103	ASMD LKR	/PI	414	0	**38**	38	32	5	409	**YES**	**ILL**
241-BY-104	SOUND	IS/II	406	0	**18**	18	0	40	366	**YES**	**ILL**
241-BY-105	ASMD LKR	/PI	503	0	**228**	228	216	44	459	**YES**	**ILL**
241-BY-106	ASMD LKR	/PI	642	0	**200**	200	163	95	547	**YES**	**ILL**
241-BY-107	ASMD LKR	IS/II	266	0	**25**	25	0	60	206	**YES**	**ILL**
241-BY-108	ASMD LKR	IS/II	228	0	9	9	0	154	74	YES	NONE[8]
241-BY-109	SOUND	/PI	290	0	**37**	37	20	57	233	**YES**	**ILL**
241-BY-110	SOUND	IS/II	398	0	**9**	9	0	103	295	**YES**	**ILL**
241-BY-111	SOUND	IS/II	459	0	0	0	0	21	438	NO	NONE
241-BY-112	SOUND	IS/II	291	0	**8**	8	0	5	286	**YES**	**ILL**
241-C-101	ASMD LKR	IS/II	88	0	3	3	0	88	0	NO	NONE
241-C-102	SOUND	/PI	316	0	46.7	30	17	316	0	YES	NONE[8]
241-C-103	SOUND	/PI	195	**133**	0	135	133	62	0	**YES**	**ENRAF**
241-C-104	SOUND	IS/II	295	0	0	11	5	295	0	NO	NONE
241-C-105	SOUND	/PI	134	2	0	32	9	132	0	NO	NONE
241-C-106	SOUND	/PI	229	**32**	0	62	52	197	0	**YES**	**ENRAF**
241-C-107	SOUND	/PI	237	0	40.8	24	15	237	0	YES	NONE[8]
241-C-108	SOUND	IS/II	66	0	0	0	0	66	0	NO	NONE
241-C-109	SOUND	IS/II	66	4	0	4	0	62	0	NO	NONE
241-C-110	ASMD LKR	/PI	178	1	28	29	15	177	0	YES	NONE[8]
241-C-111	ASMD LKR	IS/II	57	0	0	0	0	57	0	NO	NONE
241-C-112	SOUND	IS/PI	104	0	0	32	26	104	0	NO	NONE
241-C-201	ASMD LKR	IS/II	2	0	0	0	0	2	0	NO	NONE
241-C-202	ASMD LKR	IS/II	1	0	0	0	0	1	0	NO	NONE
241-C-203	ASMD LKR	IS/II	5	0	0	0	0	5	0	NO	NONE

Tank	Tank Integrity	Stabilization Status	Total Waste (Kgal)	Supernatant Volume (Kgal)	Drainable Interstitial Volume (Kgal)	Drainable Liquid Remaining (Kgal)	Pumpable Liquid Remaining (Kgal)	Sludge Volume (Kgal)	Salt Cake Volume (Kgal)	Usable Liquid Level	Analyzable Level Sensor(s) Data Available
241-C-204	ASMD LKR	IS/II	3	0	0	0	0	3	0	NO	NONE
241-S-101	SOUND	/PI	427	**12**	126	138	127	244	171	**YES**	**ENRAF**
241-S-102	SOUND	/PI	549	0	**262**	262	239	4	545	**YES**	**ILL**
241-S-103	SOUND	/PI	248	**17**	101	118	97	10	221	**YES**	**ENRAF**
241-S-104	ASMD LKR	IS/II	294	1	**28**	29	23	293	0	**YES**	**ILL**
241-S-105	SOUND	IS/II	456	0	**35**	35	13	2	454	**YES**	**ILL**
241-S-106	SOUND	/PI	479	**4**	186	190	168	28	447	**YES**	**ENRAF**
241-S-107	SOUND	/PI	376	**14**	85	99	88	293	69	**YES**	**ENRAF**
241-S-108	SOUND	/PI	450	0	**4**	4	0	4	446	**YES**	**ILL**
241-S-109	SOUND	/PI	568	0	**141**	141	119	13	555	**YES**	**ILL**
241-S-110	SOUND	/PI	390	0	**30**	30	23	131	259	**YES**	**ILL**
241-S-111	SOUND	/PI	540	**23**	195	205	134	139	378	**YES**	**ENRAF**
241-S-112	SOUND	/PI	523	0	**110**	110	107	5	517.7	**YES**	**ILL**
241-SX-101	SOUND	/PI	456	1	**184**	185	174	112	343	**YES**	**ILL**
241-SX-102	SOUND	/PI	543	0	**226**	226	216	117	426	**YES**	**ILL**
241-SX-103	SOUND	/PI	652	1	**281**	282	272	115	536	**YES**	**ILL**
241-SX-104	ASMD LKR	/PI	614	0	**201**	201	195	136	477.9	**YES**	**ILL**
241-SX-105	SOUND	/PI	683	0	**309**	309	299	73	610	**YES**	**ILL**
241-SX-106	SOUND	/PI	538	**61**	224	285	264	12	465	**YES**	**ENRAF**
241-SX-107	ASMD LKR	IS/II	104	0	5	5	0	104	0	YES	NONE[8]
241-SX-108	ASMD LKR	IS/II	87	0	5	5	0	87	0	YES	NONE[8]
241-SX-109	ASMD LKR	IS/II	244	0	48	48	25	0	244	YES	NONE[8]
241-SX-110	ASMD LKR	IS/II	62	0	0	0	0	62	0	NO	NONE
241-SX-111	ASMD LKR	IS/II	125	0	7	7	0	125	0	YES	NONE[8]
241-SX-112	ASMD LKR	IS/II	92	0	3	3	0	92	0	NO	NONE
241-SX-113	ASMD LKR	IS/II	26	0	0	0	0	26	0	NO	NONE
241-SX-114	ASMD LKR	IS/II	181	0	14	14	0	181	0	YES	NONE[8]
241-SX-115	ASMD LKR	IS/II	12	0	0	0	0	12	0	NO	NONE
241-T-101	ASMD LKR	IS/PI	102	1	16	17	0	101	0	YES	NONE[8]
241-T-102	SOUND	IS/II	32	**13**	0	13	13	19	0	**YES**	**ENRAF**
241-T-103	ASMD LKR	IS/II	27	4	0	4	0	23	0	NO	NONE[6]
241-T-104	SOUND	/PI	343	0	**67**	67	64	343	0	**YES**	**ILL**

Tank	Tank Integrity	Stabilization Status	Total Waste (Kgal)	Supernatant Volume (Kgal)	Drainable Interstitial Volume (Kgal)	Drainable Liquid Remaining (Kgal)	Pumpable Liquid Remaining (Kgal)	Sludge Volume (Kgal)	Salt Cake Volume (Kgal)	Usable Liquid Level	Analyzable Level Sensor(s) Data Available
241-T-105	SOUND	IS/II	98	0	23	23	17	98	0	YES	NONE[8]
241-T-106	ASMD LKR	IS/II	21	2	0	2	0	19	0	NO	NONE
241-T-107	ASMD LKR	/PI	173	0	22	22	12	173	0	YES	NONE[8]
241-T-108	ASMD LKR	IS/II	44	0	0	0	0	44	0	NO	NONE
241-T-109	ASMD LKR	IS/II	58	0	0	0	0	58	0	NO	NONE
241-T-110	SOUND	/PI	369	0	**26**	26	23	369	0	**YES**	**ILL**
241-T-111	ASMD LKR	/PI	446	0	**34**	34	29	446	0	**YES**	**ILL**
241-T-112	SOUND	IS/II	67	**7**	0	7	7	60	0	**YES**	**ENRAF**
241-T-201	SOUND	IS/II	29	1	3	4	0	28	0	NO	NONE
241-T-202	SOUND	IS/II	21	0	2	2	0	21	0	NO	NONE
241-T-203	SOUND	IS/II	35	0	4	4	0	35	0	NO	NONE
241-T-204	SOUND	IS/II	38	0	4	4	0	38	0	NO	NONE
241-TX-101	SOUND	IS/II	87	**3**	2	5	0	84	0	**YES**	**ENRAF**
241-TX-102	SOUND	IS/II	217	0	**22**	22	0	0	217	**YES**	**ILL**
241-TX-103	SOUND	IS/II	157	0	15	15	0	157	0	YES	NONE[8]
241-TX-104	SOUND	IS/II	65	1	14	15	0	0	64	YES	NONE[8]
241-TX-105	ASMD LKR	IS/II	609	0	20	20	0	0	609	YES	NONE[8]
241-TX-106	SOUND	IS/II	453	0	**10**	10	0	0	453	**YES**	**ILL**
241-TX-107	ASMD LKR	IS/II	36	1	1	2	0	0	35	NO	NONE
241-TX-108	SOUND	IS/II	134	0	0	0	0	0	134	NO	NONE
241-TX-109	SOUND	IS/II	384	0	**10**	10	0	0	384	**YES**	**ILL**
241-TX-110	ASMD LKR	IS/II	462	0	**15**	15	0	0	462	**YES**	**ILL**
241-TX-111	SOUND	IS/II	370	0	**9**	9	0	0	370	**YES**	**ILL**
241-TX-112	SOUND	IS/II	649	0	**24**	24	0	0	649	**YES**	**ILL**
241-TX-113	ASMD LKR	IS/II	607	0	**16**	16	0	0	607	**YES**	**ILL**
241-TX-114	ASMD LKR	IS/II	535	0	**15**	15	0	0	535	**YES**	**ILL**
241-TX-115	ASMD LKR	IS/II	640	0	**19**	19	0	0	640	**YES**	**ILL**
241-TX-116	ASMD LKR	IS/II	631	0	23	23	0	0	631	YES	NONE[8]
241-TX-117	ASMD LKR	IS/II	626	0	**8**	8	0	0	626	**YES**	**ILL**
241-TX-118	SOUND	IS/II	347	0	**27**	27	0	0	347	**YES**	**ILL**
241-TY-101	ASMD LKR	IS/II	118	0	0	0	0	118	0	NO	NONE
241-TY-102	SOUND	IS/II	64	0	14	14	0	0	64	YES	NONE[8]
241-TY-103	ASMD LKR	IS/II	162	0	**5**	5	0	162	0	**YES**	**ILL**

Tank	Tank Integrity	Stabilization Status	Total Waste (Kgal)	Supernatant Volume (Kgal)	Drainable Interstitial Volume (Kgal)	Drainable Liquid Remaining (Kgal)	Pumpable Liquid Remaining (Kgal)	Sludge Volume (Kgal)	Salt Cake Volume (Kgal)	Usable Liquid Level	Analyzable Level Sensor(s) Data Available
241-TY-104	ASMD LKR	IS/II	46	**3**	12	15	0	43	0	**YES**	**ENRAF**
241-TY-105	ASMD LKR	IS/II	231	0	0	0	0	231	0	NO	NONE
241-TY-106	ASMD LKR	IS/II	17	0	0	0	0	17	0	NO	NONE
241-U-101	ASMD LKR	IS/II	25	**3**	0	3	0	22	0	**YES**	**MT**
241-U-102	SOUND	/PI	374	18	**154**	172	160	43	313	**YES**	**ILL**
241-U-103	SOUND	/PI	468	**13**	207	220	205	32	423	**YES**	**ENRAF**
241-U-104	ASMD LKR	IS/II	122	0	7	7	0	122	0	YES	NONE[8]
241-U-105	SOUND	/PI	418	**37**	170	207	192	32	349	**YES**	**ENRAF**
241-U-106	SOUND	/PI	226	**15**	87	102	85	26	185	**YES**	**ENRAF**
241-U-107	SOUND	/PI	406	**31**	172	203	183	15	360	**YES**	**ENRAF**
241-U-108	SOUND	/PI	468	24	**202**	226	209	29	415	**YES**	**ILL**
241-U-109	SOUND	/PI	463	**19**	197	216	205	48	396	**YES**	**ENRAF**
241-U-110	ASMD LKR	IS/PI	186	0	15	15	9	186	0	YES	NONE[8]
241-U-111	SOUND	/PI	329	0	**146**	146	129	26	303	**YES**	**ILL**
241-U-112	ASMD LKR	IS/II	49	4	0	4	0	45	0	NO	NONE
241-U-201	SOUND	IS/II	5	1	0	1	0	4	0	NO	NONE
241-U-202	SOUND	IS/II	5	1	0	1	0	4	0	NO	NONE
241-U-203	SOUND	IS/II	3	1	0	1	0	2	0	NO	NONE
241-U-204	SOUND	IS/II	3	1	0	1	0	2	0	NO	NONE

Notes:

1: Stabilization Status: "IS" = interim stabilized; "II" = interim isolated; "PI" = partially interim isolated
2: Liquid volumes determined from photos.
3: Manual Tape data.
4: Monthly ENRAF data.
5: Monthly FIC data.
6: Discontinuous data
7: Only old data available ('81 - '89)
8: No Neutron ILL data

Appendix D

Tank Level Data Obtained from TWINS

Tank	Auto ENRAF	Auto FIC	Intrusion FIC	Manual ENRAF	Manual FIC	Manual Tape	ILL
241-A-101	9/97-5/98	1/81-5-82		9/95-5/98		1/81-7/95	**3/86-2/98**
241-A-102		1/81-10/89	**5/90-5/98**		8/83-5/98		
241-A-103	9/97-5/98	1/81-5/96	5/90-4/95	**7/96-5/98**	7/81-7/95	1/81-5/82	
241-A-104				6/96-4/98		5/78-4/96	
241-A-105						1/80-4/98	
241-A-106	9/97-5/98	1/81-4/84	4/84-1/96	1/96-4/98	1/87-7/95		
241-AX-101	9/97-5/98	1/81-4/84	4/84-9/95	9/95-5/98	7/84-9/95		
241-AX-102	12/97-5/98					1/81-4/98	
241-AX-103	9/97-5/98	1/81-1/92	1/92-9/95	9/95-5/98	8/98-9/95	11/90-9/94	
241-AX-104	9/97-5/98			10/86-4/98		1/81-10/96	
241-B-101		1/81-1/84	2/84-6/98		11/81-4-98		
241-B-102		1/81-3/95		**3/95-5/98**	9/83-12/94	1/81-1/83	
241-B-103		1/81-5/90	5/90-6/98		12/81-4/96		
241-B-104						1/79-4/98	**3/86-2/98**
241-B-105						1/81-4/98	
241-B-106		1/79-10/96			10/90-5/98		
241-B-107		1/84-1/84				1/81-4/98	
241-B-108		1/81-5/90	5/90-6/98		10/84-4/98		
241-B-109						1/81-4/98	
241-B-110						1/81-4/98	**11/94-2/98**
241-B-111		1/81-5/90	5/90-6/98		8/82-4/98		**11/94-2/98**
241-B-112		1/81-3/95		**3/95-5/98**	9/84-11/94	1/81-2/83	
241-B-201						5/78-5/98	
241-B-202						1/79-5/98	
241-B-203						1/81-5/98	
241-B-204						1/81-5/98	
241-BX-101	5/96-5/98			12/95-5/98		1/81-4/96	
241-BX-102	5/96-5/98			7/96-4/98		1/81-4/96	
241-BX-103	5/96-5/98	1/81-4/96		**12/95-5/98**	4/84-4/96		
241-BX-104	5/96-5/98	1/81-4/96		**12/95-5/98**	1/82-12/95	1/81-2/84	
241-BX-105	5/96-5/98	1/82-12/88	5/90-3/96	**3/96-4/98**	1/81-1/96	1/81-1/83	
241-BX-106	10/94-5/98	1/79-12/83		7/94-4/98	1/84-7/94	1/81-1/83	
241-BX-107	5/96-5/98	1/81-6/96		12/95-5/98	4/83-5/96		
241-BX-108	5/96-5/98			6/96-4/98		1/81-4/96	
241-BX-109	5/96-5/98	1/81-5/95	5/90-8/95	8/95-4/98	3/81-8/95		
241-BX-110	**5/96-4/98**					1/81-12/96	
241-BX-111		1/81-5/90	5/90-6/98		8/82-4/98		
241-BX-112	5/96-5/98	1/81-3/96		12/95-5/98	6/88-2/96	1/81-5/83	

Tank	Auto ENRAF	Auto FIC	Intrusion FIC	Manual ENRAF	Manual FIC	Manual Tape	ILL
241-BY-101						1/81-4/98	**3/86-2/98**
241-BY-102						7/79-3/98	**3/86-2/98**
241-BY-103	12/96-5/98						**3/86-2/98**
241-BY-104						1/81-4/98	**3/86-2/98**
241-BY-105						1/81-5/98	**3/86-2/98**
241-BY-106						1/81-5/98	**3/86-2/98**
241-BY-107						1/81-4/98	**3/86-2/98**
241-BY-108						1/81-4/98	
241-BY-109		2/79-3/96			1/83-2/98		**3/86-2/98**
241-BY-110				7/97-4/98		1/81-4/97	**3/86-2/98**
241-BY-111				4/97-5/98		1/81-11/96	
241-BY-112						1/81-4/98	**3/86-2/98**
241-C-101						1/81-4/98	
241-C-102						1/81-4/98	
241-C-103	10/94-5/98	8/79-8/94		**8/94-6/98**	7/79-7/94		
241-C-104		1/81-3/96			7/89-6/98	1/81-4/81	
241-C-105		1/81-3/96		7/96-6/98	1/83-7/96	1/81-7/82	
241-C-106	**10/94-5/98**	1/81-9/96		9/94-6/98	5/84-11/95		
241-C-107	6/95-5/98	1/81-4/95		4/95-6/98	7/85-4/95	1/81-1/81	
241-C-108						1/81-4/98	
241-C-109						1/81-4/98	
241-C-110						1/81-6/98	
241-C-111						1/81-4/98	
241-C-112				3/96-4/98		1/81-2/96	
241-C-201						1/81-4/98	
241-C-202						1/81-4/98	
241-C-203						1/81-4/98	
241-C-204						1/81-4/98	
241-S-101		1/81-4/93	8/84-2/95	**2/95-6/98**	1/81-1/95	1/81-12/84	
241-S-102		1/81-5/95		5/95-6/98	1/81-1/95	1/81-6/81	**3/86-2/98**
241-S-103	12/95-5/98	1/81-7/94		**5/94-6/98**	1/81-3/94	1/81-6/81	
241-S-104						1/81-4/98	**10/94-2/98**
241-S-105		1/81-10/90	6/89-7/95	7/95-4/98	4/81-4/95	1/81-6/81	**3/86-2/98**
241-S-106	12/95-5/98	1/81-7/94		**6/94-6/98**	6/83-7/94	1/81-3/85	
241-S-107	**12/95-5/98**	1/81-7/94		6/94-6/98	12/90-6/94	1/81-6/81	
241-S-108		1/81-6/90	6/90-7/95	7/95-5/98	10/86-4/95	1/81-7/95	**3/86-2/98**
241-S-109		1/81-6/90	1/90-8/95	8/95-5/98	9/82-7/95	1/81-6/81	**3/86-2/98**

Tank	Auto ENRAF	Auto FIC	Intrusion FIC	Manual ENRAF	Manual FIC	Manual Tape	ILL
241-S-110		1/81-6/90	1/90-9/95	8/95-5/98	3/81-7/95	1/81-6/81	**3/86-2/98**
241-S-111	12/95-5/98	1/81-8/94		**8/94-6/98**	5/84-8/94	1/81-6/81	
241-S-112		1/81-6/90	6/90-5/95	5/95-5/98	3/81-4/95	1/81-12/81	**3/86-2/98**
241-SX-101		1/81-5/84	5/84-5/95	5/95-5/98	4/82-4/95	1/81-1/85	**3/86-2/98**
241-SX-102		1/80-5/95	5/84-11/94	5/95-5/98	10/83-4/95	1/81-8/83	**3/86-2/98**
241-SX-103		1/80-4/93	4/93-5/95	5/95-5/98	7/87-4/95	1/81-1/85	**3/86-2/98**
241-SX-104		1/80-5/95	6/90-12/94	5/95-5/98	1/85-4/95	1/81-5/82	**3/86-2/98**
241-SX-105		1/80-6/89	5/84-5/95	5/95-5/98	7/84-4/95	1/81-5/84	**3/86-2/98**
241-SX-106	**12/95-5/98**	1/81-8/94	5/84-4/86	8/94-6/98	6/84-8/94	1/81-7/95	
241-SX-107						1/81-4/98	
241-SX-108						1/81-4/98	
241-SX-109						1/81-4/98	
241-SX-110						1/81-4/98	
241-SX-111						1/81-4/98	
241-SX-112						1/81-4/98	
241-SX-113						1/81-4/98	
241-SX-114						1/81-4/98	
241-SX-115						1/81-4/98	
241-T-101		1/81-12/93	7/93-5/95	6/95-5/98	6/97-6/95	1/81-4/95	
241-T-102	**10/94-5/98**	1/81-7/94		6/94-6/98	7/89-6/94		
241-T-103		1/81-11/93	7/93-7/95	7/95-4/98	3/82-7/95		
241-T-104				1/96-5/98		1/80-12/96	**3/86-2/98**
241-T-105		1/81-12/84	1/81-8/95	8/95-4/98	7/84-7/95	1/81-2/82	
241-T-106		1/81-2/84	7/84-8/95	8/95-4/98	6/83-7/95		
241-T-107	10/94-5/98	1/84-7/94		6/94-5/98	1/81-7/94		
241-T-108				10/95-6/98		1/81-9/95	
241-T-109	10/94-8/95	1/81-9/94	6/84-8/94	9/94-5/98	9/81-4/94		
241-T-110	5/97-5/98	1/81-5/95	6/90-9/94	6/95-5/98	1/89-4/95		**3/86-2/98**
241-T-111		1/84-7/95		7/95-5/98	1/81-7/95		**3/86-2/98**
241-T-112		1/81-10/95		**9/95-6/98**	5/82-9/95		
241-T-201						1/86-12/96	
241-T-202						1/81-6/98	
241-T-203						1/81-4/98	
241-T-204						1/81-6/98	
241-TX-101	**7/96-6/98**	1/81-10/95		10/95-6/98	4/89-8/95		
241-TX-102	5/96-4/98					1/81-4/96	**3/86-2/98**
241-TX-103	5/96-6/98	1/84-9/88	7/84-3/96	1/96-4/98	1/81-10/95		
241-TX-104	5/96-6/98	1/84-7/93	7/93-3/96	4/96-4/98	1/81-1/96		

Tank	Auto ENRAF	Auto FIC	Intrusion FIC	Manual ENRAF	Manual FIC	Manual Tape	ILL
241-TX-105	5/96-6/98			6/96-4/98		1/81-10/96	
241-TX-106	5/96-6/98			6/96-4/98		1/81-10/96	**3/86-2/98**
241-TX-107	5/96-6/98	1/79-3/96		5/96-4/98	4/84-4/96		
241-TX-108	5/96-6/98	1/81-7/90	7/84-4/96	5/96-4/98	3/81-4/96		
241-TX-109	5/96-6/98	1/84-6/84	9/84-1/96	1/96-4/98	1/81-10/95		**3/86-2/98**
241-TX-110	5/96-6/98			6/96-4/98		1/81-10/96	**3/86-2/98**
241-TX-111	5/96-6/98			7/96-4/98		1/81-4/96	**3/86-2/98**
241-TX-112	5/96-6/98			7/96-4/98		1/81-10/96	**3/86-2/98**
241-TX-113	5/96-6/98			6/96-4/98		1/81-10/96	**3/86-2/98**
241-TX-114	5/96-6/98			6/96-4/98		1/81-10/96	**3/86-2/98**
241-TX-115	5/96-6/98			4/96-4/98			**3/86-2/98**
241-TX-116	5/96-6/98			6/96-4/98		1/81-10/96	3/86-2/98
241-TX-117	5/96-6/98			6/96-4/98		1/81-10/96	**3/86-2/98**
241-TX-118	5/96-6/98			2/96-4/98			**3/86-2/98**
241-TY-101	12/95-6/98	1/81-2/85	7/84-7/95	7/95-4/98	8/81-7/95		
241-TY-102	12/95-6/98	1/81-10/95		9/95-6/98	9/81-9/95		
241-TY-103	12/95-6/98	1/81-6/84	7/84-10/95	10/95-4/98	8/84-8/95		**3/86-2/98**
241-TY-104	**12/95-6/98**	1/81-6/95		7/95-6/98	1/81-7/95		
241-TY-105	12/95-6/98			4/96-4/98			
241-TY-106	12/95-6/98			11/96-4/98			
241-U-101						**1/81-6/98**	
241-U-102		1/81-6/84	6/84-3/96	1/96-6/98	6/83-10/95		**3/86-2/98**
241-U-103	8/95-9/98	1/81-7/94		**7/94-6/98**	12/84-7/94		
241-U-104						1/81-4/98	
241-U-105	**12/95-6/98**	1/81-7/94		7/94-6/98	9/83-7/94	1/81-9/85	
241-U-106	**8/95-6/98**	1/79-8/94		8/94-6/98	9/89-8/94		
241-U-107	8/95-6/98	1/81-7/94		**7/94-6/98**	1/90-7/94		
241-U-108		1/81-1/93	6/84-5/95	5/95-6/98	1/90-1/95		**3/86-2/98**
241-U-109	**8/95-6/98**	5/78-5/94		7/94-6/98	10/85-7/94		
241-U-110		1/81-6/84	6/84-1/96	1/96-6/98	4/84-10/95		
241-U-111		1/84-7/84	7/89-1/96	1/96-6/98	1/81-10/95		**3/86-2/98**
241-U-112						1/81-4/98	
241-U-201						1/81-6/98	
241-U-202						1/81-6/98	
241-U-203						1/81-4/98	
241-U-204						1/81-6/98	

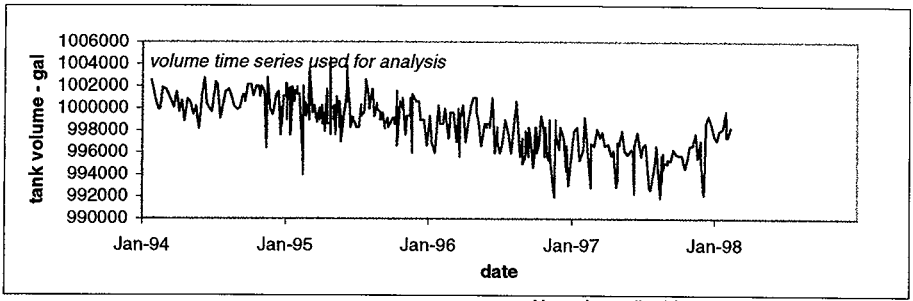
Appendix E

Statistical Analyses of Level Data

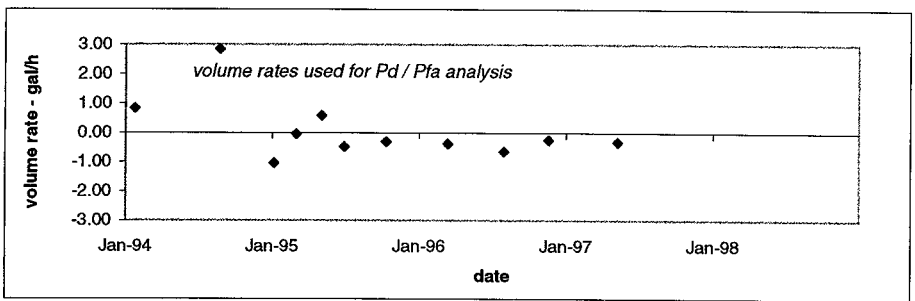
This appendix presents a statistical analysis of 70 SSTs that supports the preliminary integrity assessment. In these analyses, a result that "the mean volume rate is NOT equivalent to 0 gal/h" does not imply that the tank is leaking. Rather, it indicates that, in applying a null hypothesis test to the ensemble of volume rate data, the mean value cannot be explained simply by random occurrence. Similarly, a result that "the mean volume rate is equivalent to 0 gal/h" does not necessarily imply that the tank is leak-tight; it just describes that, as a result of the variability of the data, the mean volume rate cannot be distinguished from 0 gal/h.

The minimum detectable leak values reported in this appendix describe the smallest leak that could be reliably detected (at a P_D of 95% and 99%), if a leak test were conducted on that tank using the level sensor described and the 30-day test periods. These data demonstrate the performance potential for a possible future leak test program, and provide a preliminary liquid integrity assessment "baseline" for such a program.

Data File: **A-101** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 16



No. avg. vol rate estimates removed = 1

N = 11

During the analysis period, the average volume rate = 0.07 gal/h

The standard deviation of the volume rate estimates = 1.06 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -1.92 gal/h

Min. Detectable Leak: -3.83 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

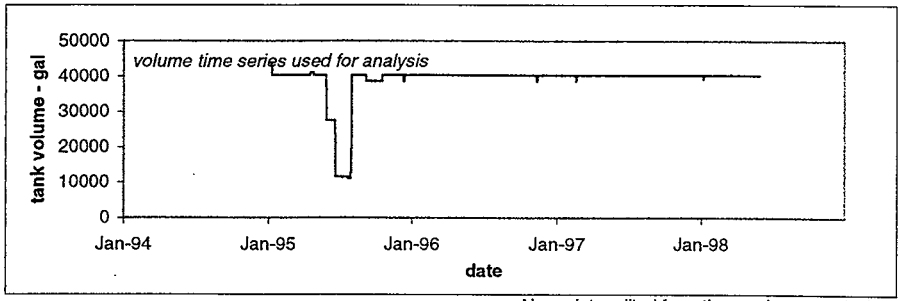
Threshold, T: -2.92 gal/h

Min. Detectable Leak: -5.85 gal/h

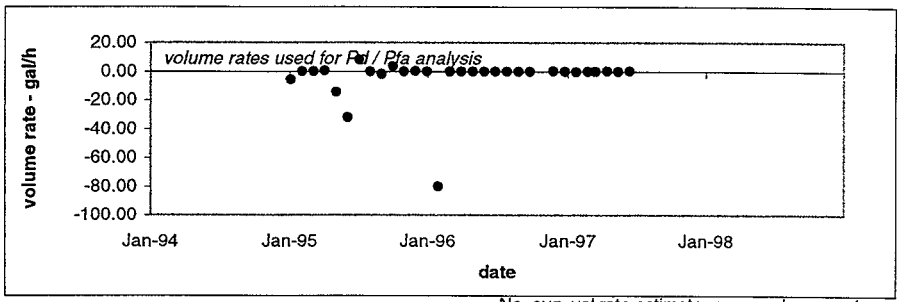
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **A102** Data is from sensor type: **Intrusion FIC**



No. points edited from time series = 305



No. avg. vol rate estimates removed = 4

N = 26

During the analysis period, the average volume rate = -4.73 gal/h

The standard deviation of the volume rate estimates = 17.00 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -29.03 gal/h

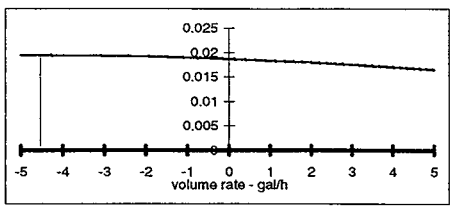
Min. Detectable Leak: -58.06 gal/h

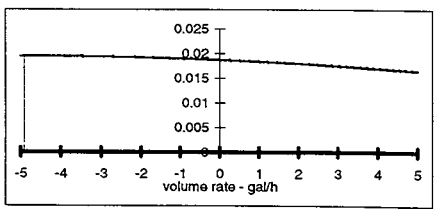
For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -42.24 gal/h

Min. Detectable Leak: -84.48 gal/h

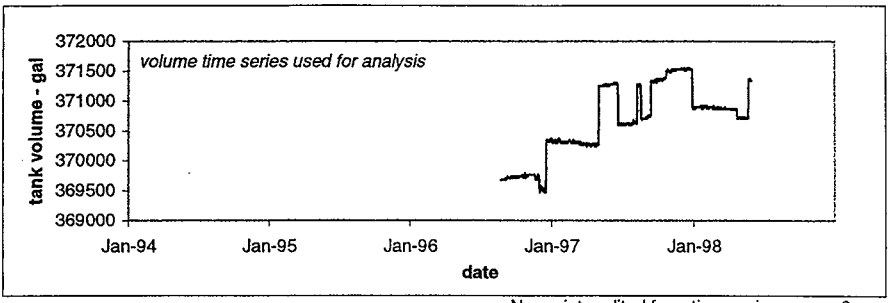




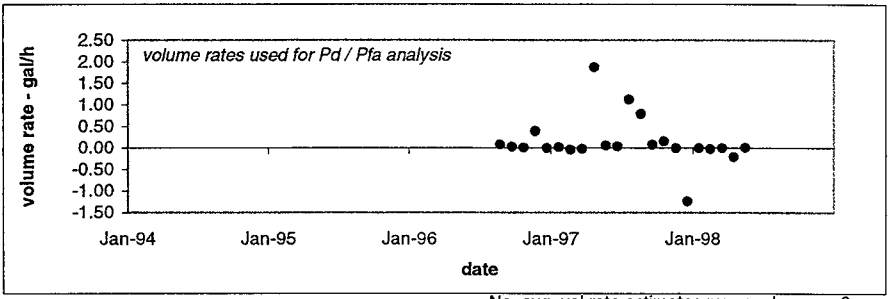
For this data, a threshold= 5.00 gal/h will detect a tank release of 84.48 gal/h at a Pd = 95%

The corresponding Pfa is 1.64%

Data File: **A-103** Data is from sensor type: **Manual ENRAF**



No. points edited from time series = 3



No. avg. vol rate estimates removed = 9

N = 21

During the analysis period, the average volume rate = 0.14 gal/h

The standard deviation of the volume rate estimates = 0.58 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -1.00 gal/h

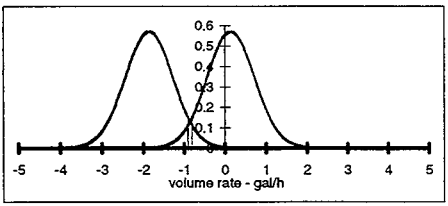
Min. Detectable Leak: -2.00 gal/h

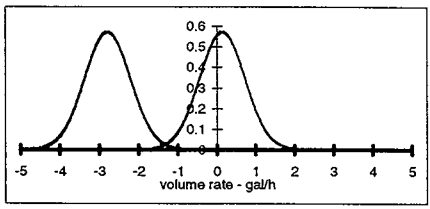
For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -1.46 gal/h

Min. Detectable Leak: -2.92 gal/h

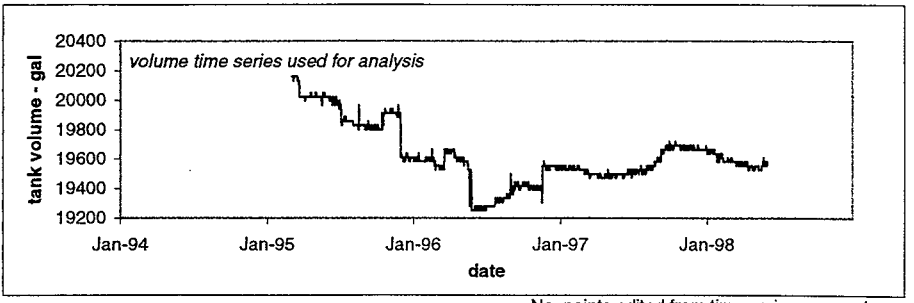




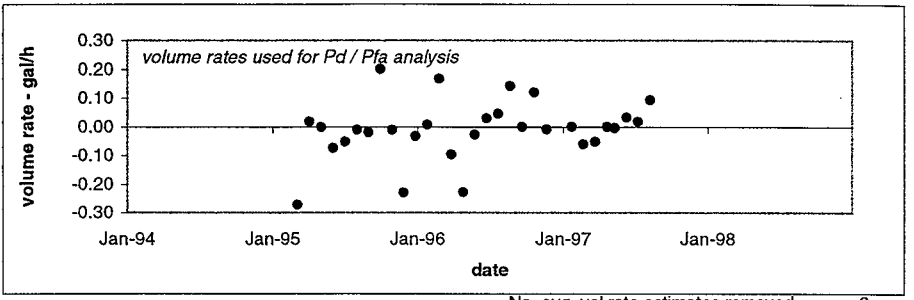
For this data, a threshold= -1.84 gal/h will detect a tank release of 2.92 gal/h at a Pd = 95%

The corresponding Pfa is 0.16%

Data File: **B-102** Data is from sensor type: **Manual ENRAF**



No. points edited from time series = 4



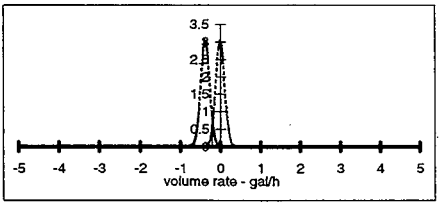
No. avg. vol rate estimates removed = 2

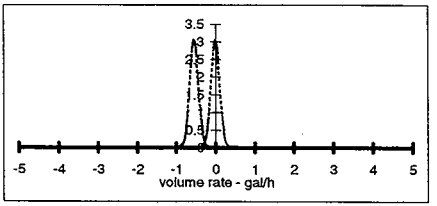
N = 28

During the analysis period, the average volume rate = -0.01 gal/h
The standard deviation of the volume rate estimates = 0.11 gal/h

For Pd / Pfa = 95% / 5%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -0.18 gal/h
Min. Detectable Leak: -0.37 gal/h

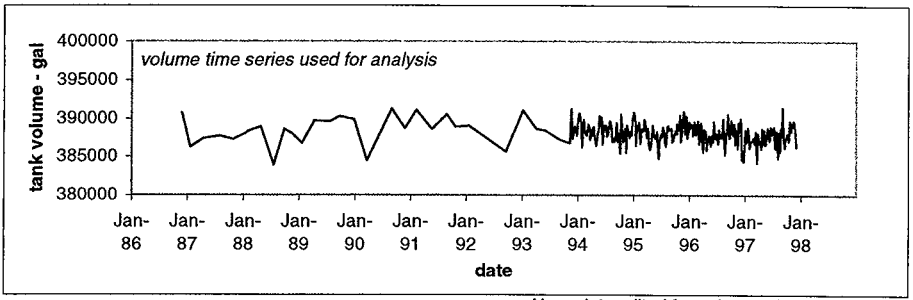
For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -0.27 gal/h
Min. Detectable Leak: -0.54 gal/h



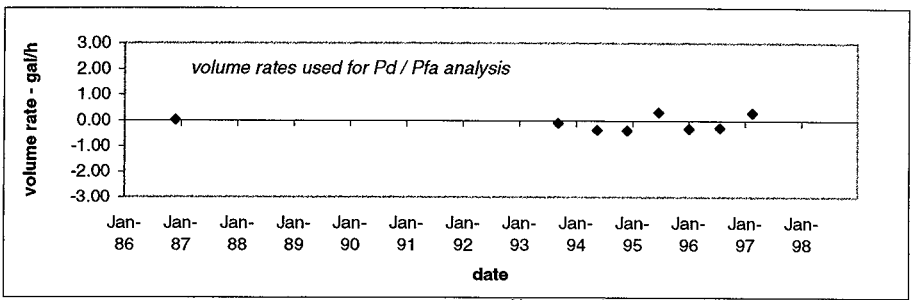


For this data, a threshold= -0.38 gal/h will detect a tank release of 0.54 gal/h at a Pd = 95%
The corresponding Pfa is 0.95%

Data File: **B-104** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 0



No. avg. vol rate estimates removed = 1

N = 8

During the analysis period, the average volume rate = -0.11 gal/h

The standard deviation of the volume rate estimates = 0.29 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.55 gal/h

Min. Detectable Leak: -1.11 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

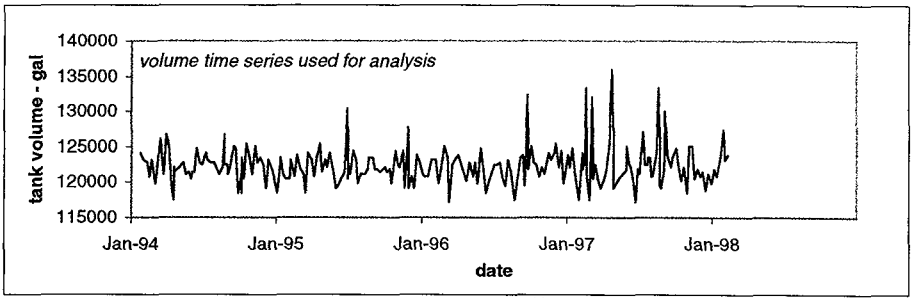
Threshold, T: -0.88 gal/h

Min. Detectable Leak: -1.76 gal/h

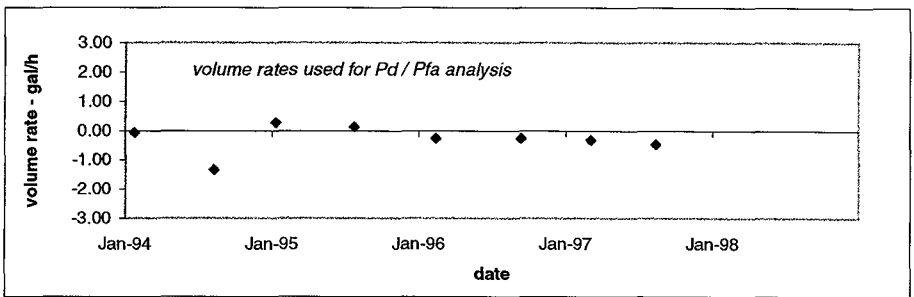
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **B-105** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 5



No. avg. vol rate estimates removed = 0

N = 8

During the analysis period, the average volume rate = -0.29 gal/h

The standard deviation of the volume rate estimates = 0.49 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.93 gal/h

Min. Detectable Leak: -1.85 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

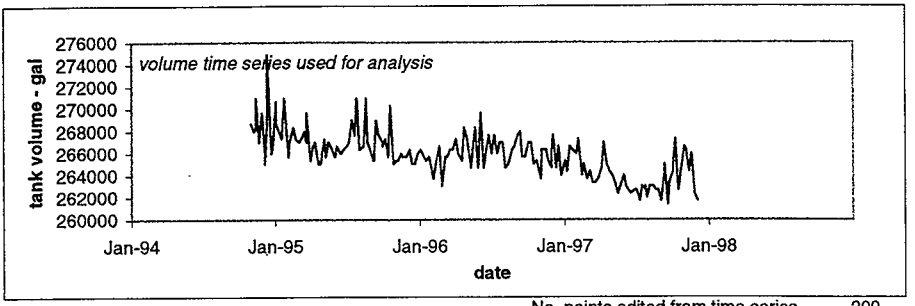
Threshold, T: -1.47 gal/h

Min. Detectable Leak: -2.93 gal/h

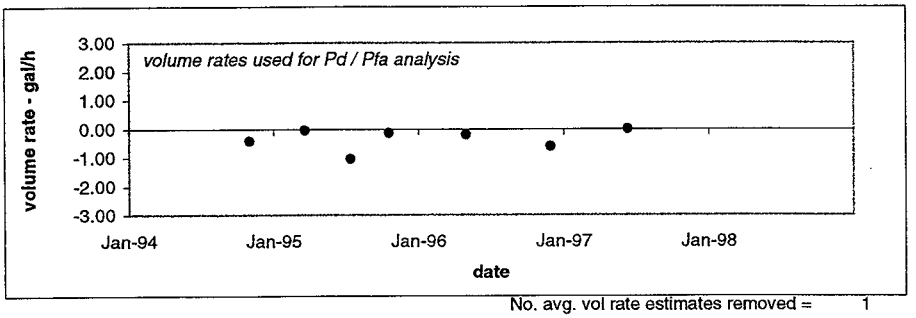
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **B-110** Data is from sensor type: **LOW**



No. points edited from time series = 209



No. avg. vol rate estimates removed = 1
N = 6

During the analysis period, the average volume rate = -0.41 gal/h
The standard deviation of the volume rate estimates = 0.37 gal/h

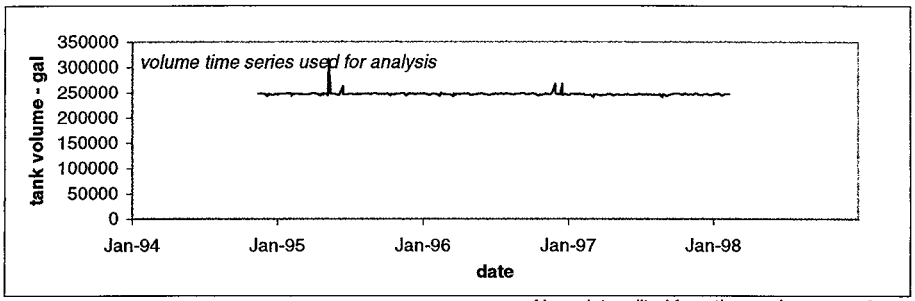
For Pd / Pfa = 95% / 5%:
The mean volume rate is NOT equivalent to 0 gal/h
Threshold, T: -0.75 gal/h
Min. Detectable Leak: -1.49 gal/h

For Pd / Pfa = 99% / 1%:
The mean volume rate is NOT equivalent to 0 gal/h
Threshold, T: -0.86 gal/h
Min. Detectable Leak: -1.73 gal/h

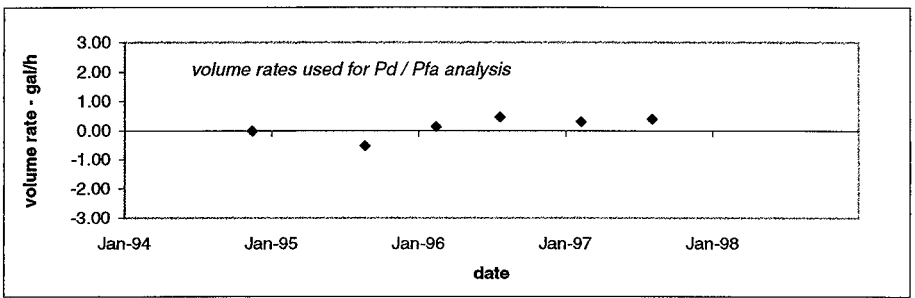
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **B-111** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 3



No. avg. vol rate estimates removed = 1

N = 6

During the analysis period, the average volume rate = 0.12 gal/h

The standard deviation of the volume rate estimates = 0.36 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.73 gal/h

Min. Detectable Leak: -1.45 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

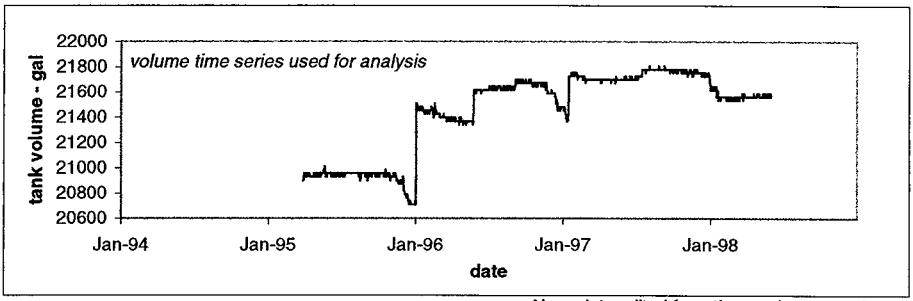
Threshold, T: -1.21 gal/h

Min. Detectable Leak: -2.43 gal/h

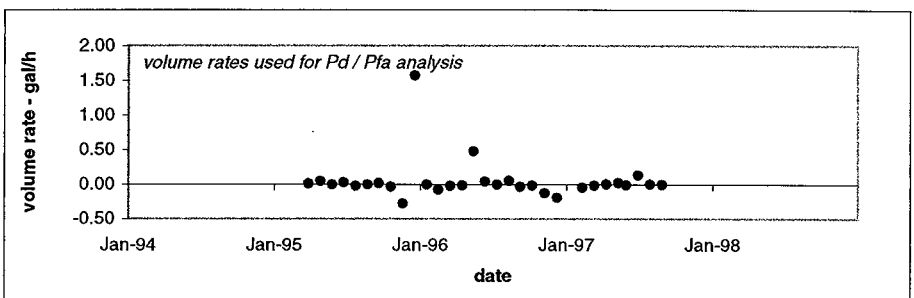
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **B-112** Data is from sensor type: **Manual ENRAF**



No. points edited from time series = 15



No. avg. vol rate estimates removed = 0

N = 30

During the analysis period, the average volume rate = 0.05 gal/h

The standard deviation of the volume rate estimates = 0.31 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.53 gal/h

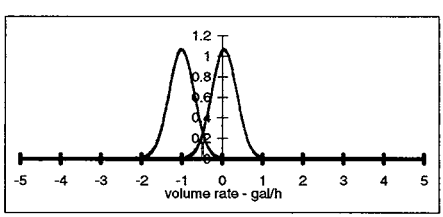
Min. Detectable Leak: -1.05 gal/h

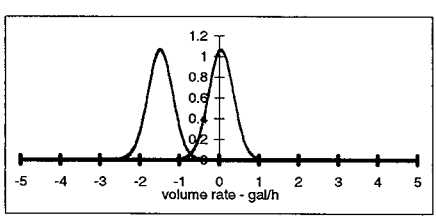
For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.76 gal/h

Min. Detectable Leak: -1.53 gal/h

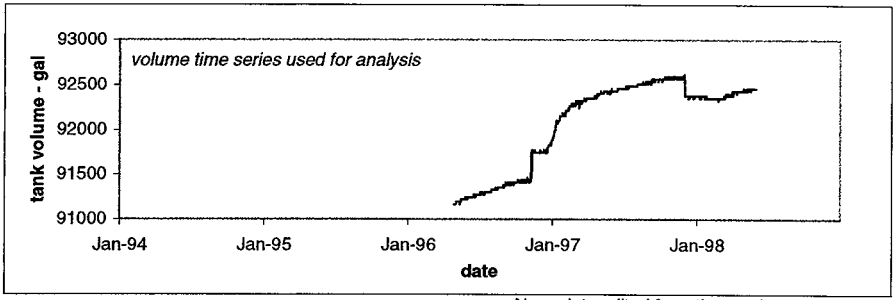




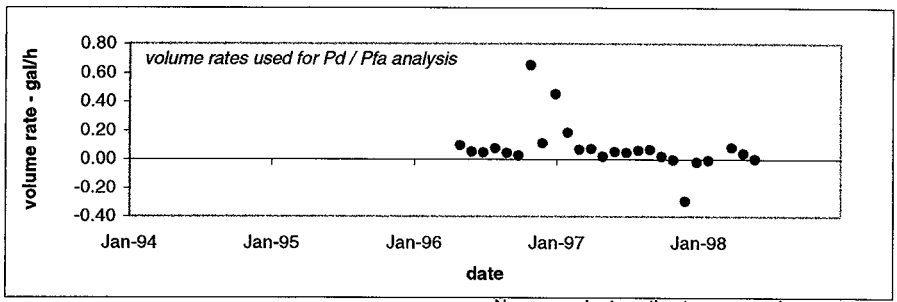
For this data, a threshold= -0.98 gal/h will detect a tank release of 1.53 gal/h at a Pd = 95%

The corresponding Pfa is 0.45%

Data File: **BX-103** Data is from sensor type: **Manual ENRAF**



No. points edited from time series = 4



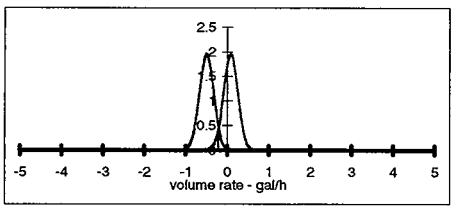
No. avg. vol rate estimates removed = 6

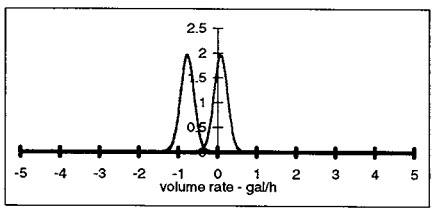
N = 24

During the analysis period, the average volume rate = 0.08 gal/h
The standard deviation of the volume rate estimates = 0.17 gal/h

For Pd / Pfa = 95% / 5%:
The mean volume rate is NOT equivalent to 0 gal/h
Threshold, T: -0.29 gal/h
Min. Detectable Leak: -0.58 gal/h

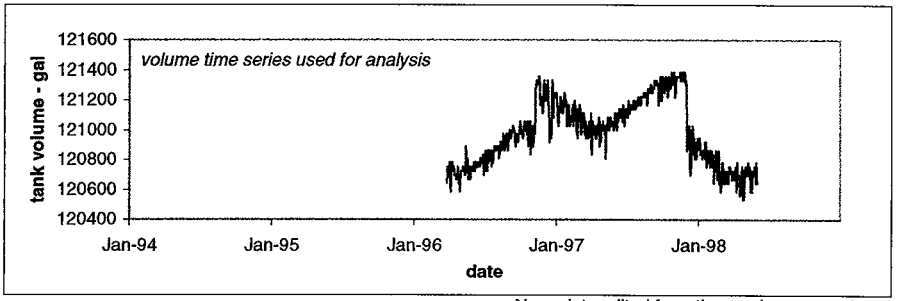
For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -0.42 gal/h
Min. Detectable Leak: -0.85 gal/h



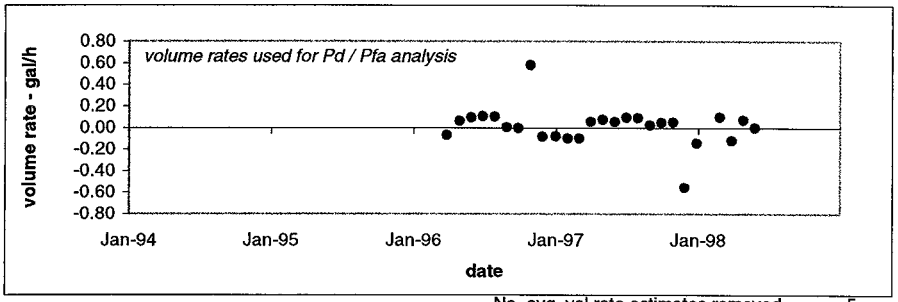


For this data, a threshold= -0.50 gal/h will detect a tank release of 0.85 gal/h at a Pd = 95%
The corresponding Pfa is 0.56%

Data File: **BX-104** Data is from sensor type: **Manual ENRAF**



No. points edited from time series = 4



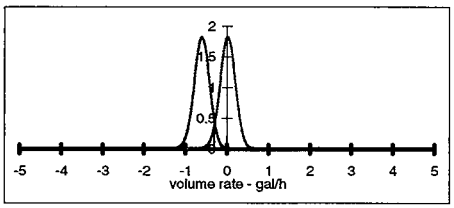
No. avg. vol rate estimates removed = 5

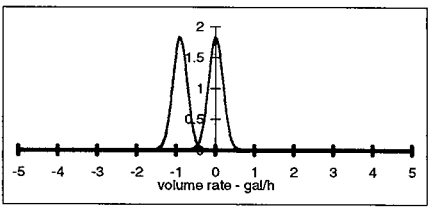
N = 25

During the analysis period, the average volume rate = 0.01 gal/h
The standard deviation of the volume rate estimates = 0.18 gal/h

For Pd / Pfa = 95% / 5%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -0.31 gal/h
Min. Detectable Leak: -0.62 gal/h

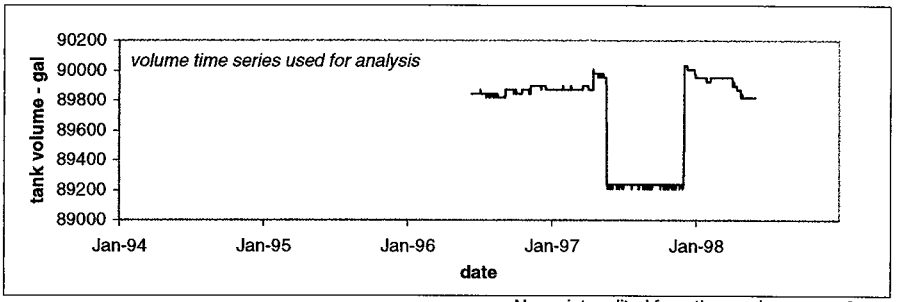
For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -0.45 gal/h
Min. Detectable Leak: -0.91 gal/h



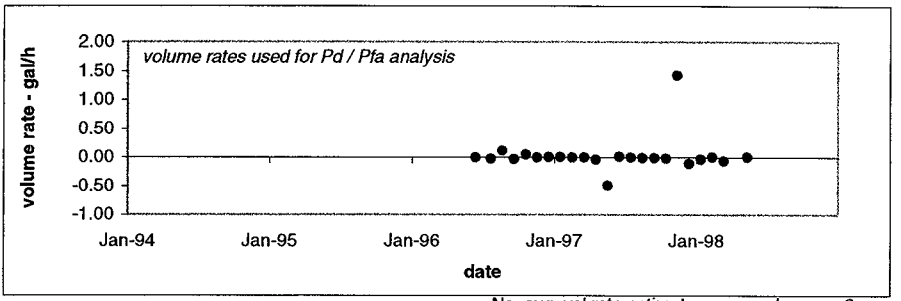


For this data, a threshold= -0.60 gal/h will detect a tank release of 0.91 gal/h at a Pd = 95%
The corresponding Pfa is 0.62%

Data File: **BX-105** Data is from sensor type: **Manual ENRAF**



No. points edited from time series = 0



No. avg. vol rate estimates removed = 8

N = 22

During the analysis period, the average volume rate = 0.03 gal/h

The standard deviation of the volume rate estimates = 0.33 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.57 gal/h

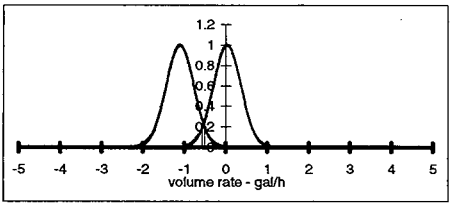
Min. Detectable Leak: -1.14 gal/h

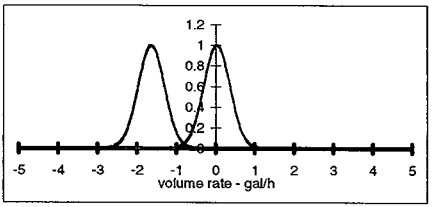
For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.83 gal/h

Min. Detectable Leak: -1.67 gal/h

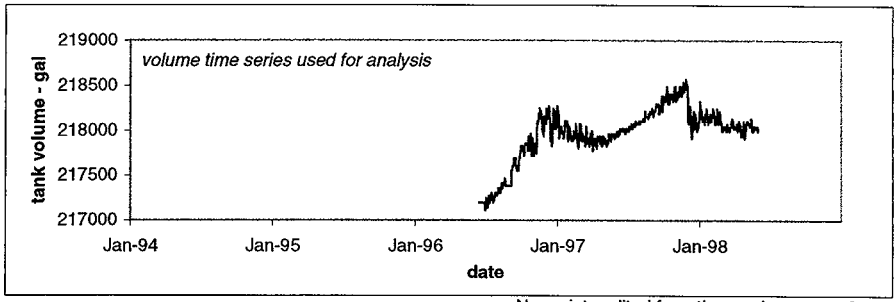




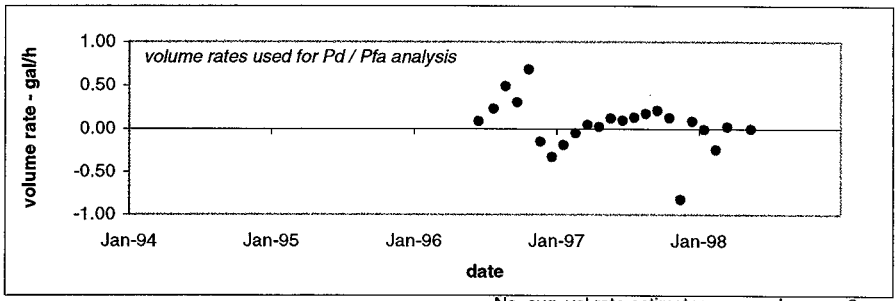
For this data, a threshold= -1.10 gal/h will detect a tank release of 1.67 gal/h at a Pd = 95%

The corresponding Pfa is 0.28%

Data File: **BX-110** Data is from sensor type: **Auto ENRAF**



No. points edited from time series = 3



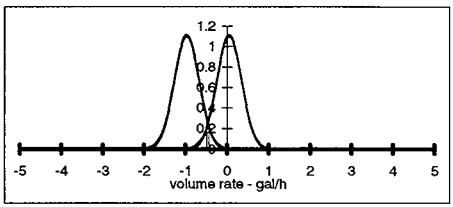
No. avg. vol rate estimates removed = 8

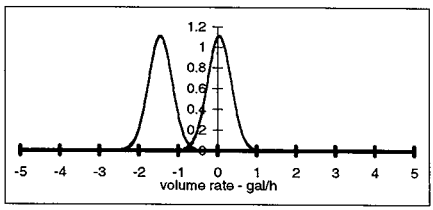
N = 22

During the analysis period, the average volume rate = 0.05 gal/h
The standard deviation of the volume rate estimates = 0.30 gal/h

For Pd / Pfa = 95% / 5%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -0.51 gal/h
Min. Detectable Leak: -1.02 gal/h

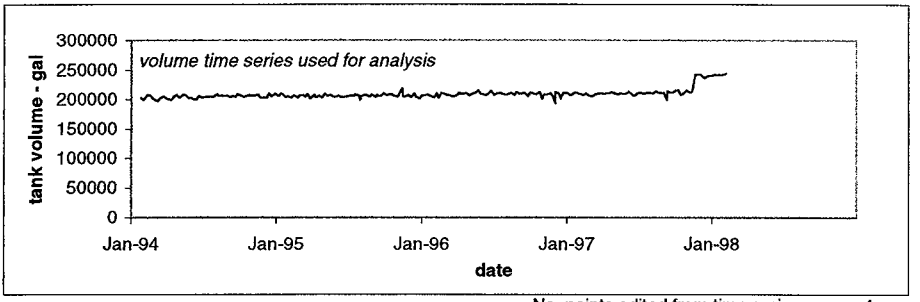
For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -0.75 gal/h
Min. Detectable Leak: -1.50 gal/h



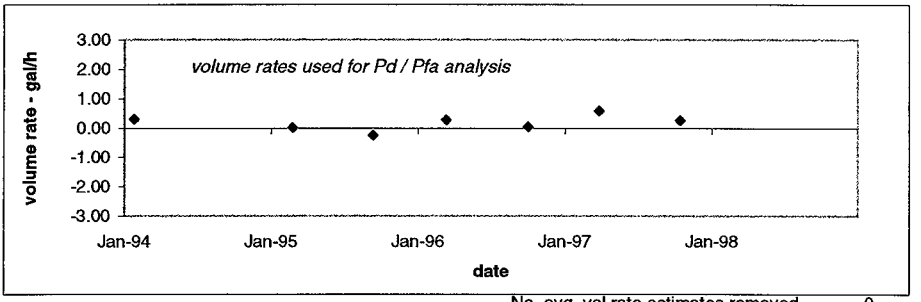


For this data, a threshold= -0.97 gal/h will detect a tank release of 1.50 gal/h at a Pd = 95%
The corresponding Pfa is 0.32%

Data File: **BY-101** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 4



No. avg. vol rate estimates removed = 0

N = 8

During the analysis period, the average volume rate = 0.98 gal/h

The standard deviation of the volume rate estimates = 2.31 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -4.37 gal/h

Min. Detectable Leak: -8.74 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

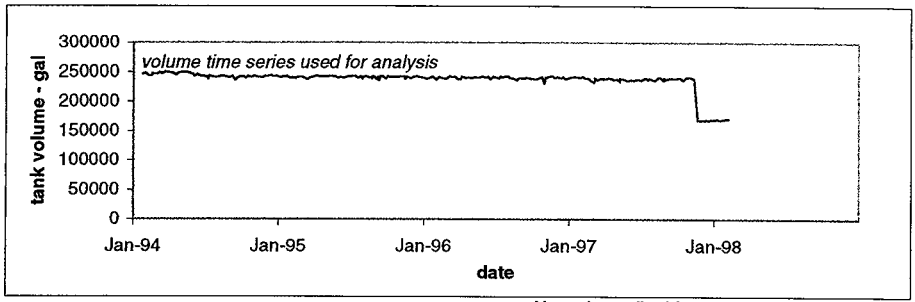
Threshold, T: -6.91 gal/h

Min. Detectable Leak: -13.82 gal/h

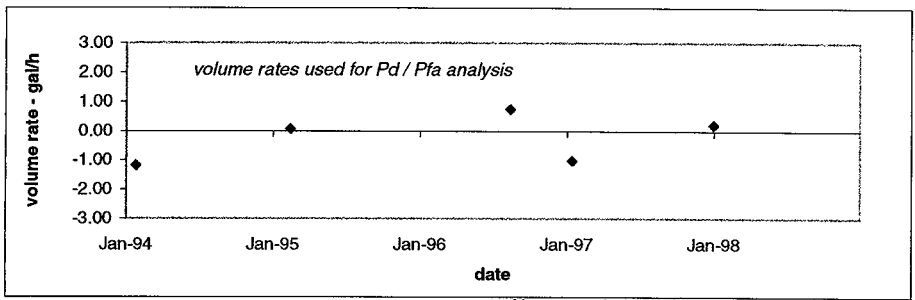
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **BY-102** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 6



No. avg. vol rate estimates removed = 1

N = 8

During the analysis period, the average volume rate = 1.42 gal/h

The standard deviation of the volume rate estimates = 4.17 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -7.90 gal/h

Min. Detectable Leak: -15.80 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

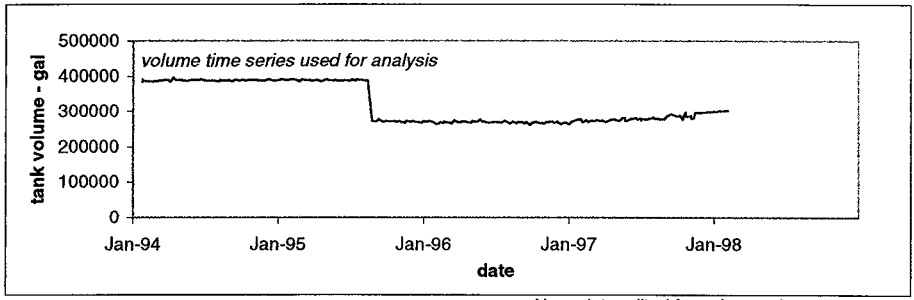
Threshold, T: -12.50 gal/h

Min. Detectable Leak: -25.00 gal/h

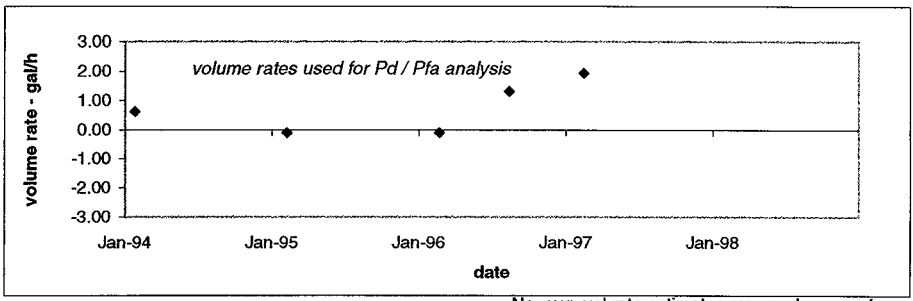
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **BY-103** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 16



No. avg. vol rate estimates removed = 4

N = 5

During the analysis period, the average volume rate = 0.72 gal/h

The standard deviation of the volume rate estimates = 0.89 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -1.90 gal/h

Min. Detectable Leak: -3.81 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

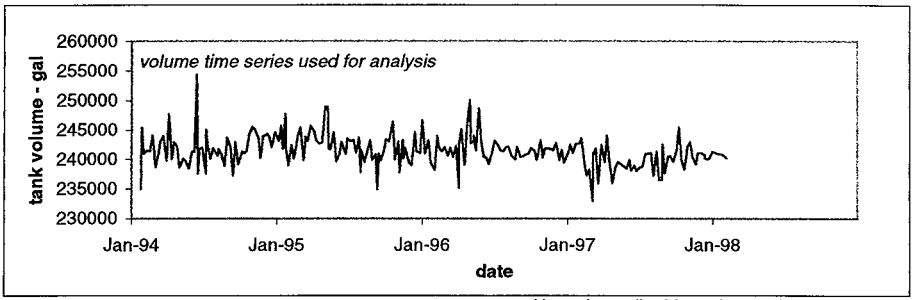
Threshold, T: -3.35 gal/h

Min. Detectable Leak: -6.69 gal/h

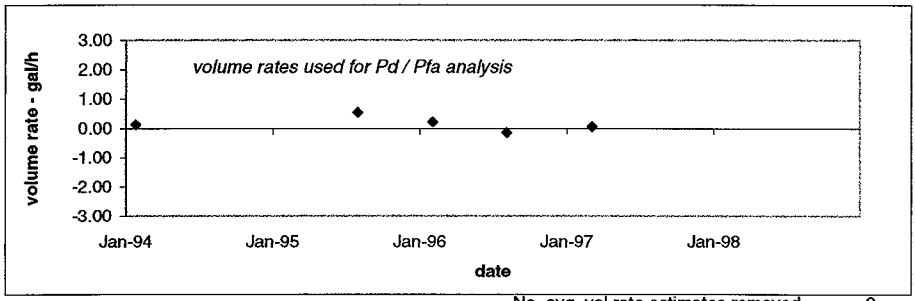
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **BY-104** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 5



No. avg. vol rate estimates removed = 3

N = 5

During the analysis period, the average volume rate = 0.15 gal/h

The standard deviation of the volume rate estimates = 0.25 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.53 gal/h

Min. Detectable Leak: -1.07 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

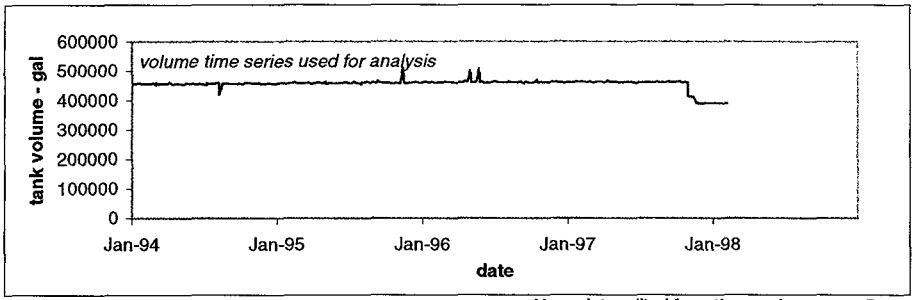
Threshold, T: -0.94 gal/h

Min. Detectable Leak: -1.88 gal/h

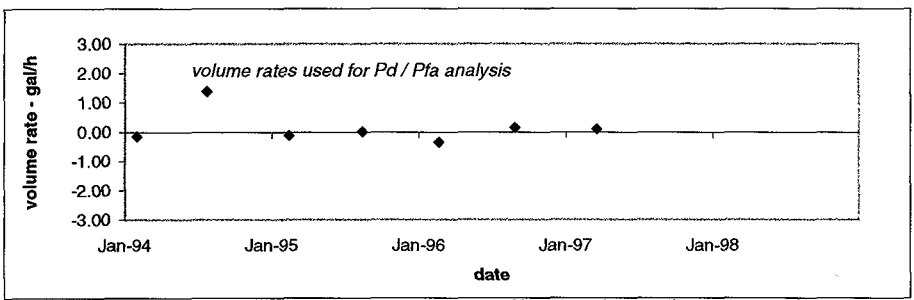
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **BY-105** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 5



No. avg. vol rate estimates removed = 2

N = 8

During the analysis period, the average volume rate = 0.15 gal/h

The standard deviation of the volume rate estimates = 0.53 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -1.00 gal/h

Min. Detectable Leak: -2.00 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

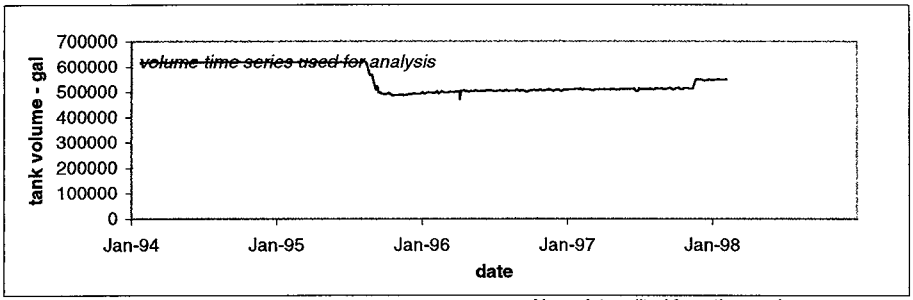
Threshold, T: -1.58 gal/h

Min. Detectable Leak: -3.16 gal/h

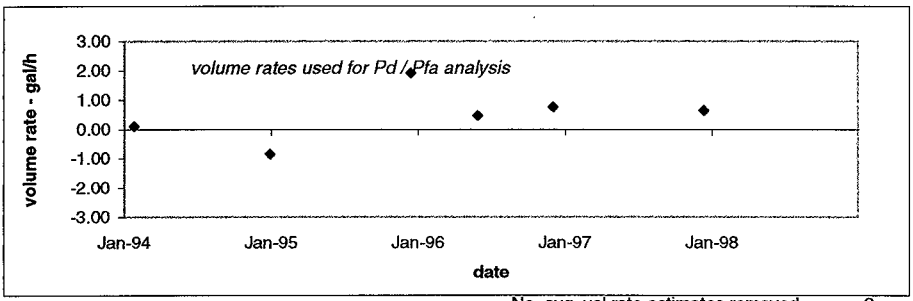
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **BY-106** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 8



No. avg. vol rate estimates removed = 3

N = 6

During the analysis period, the average volume rate = 0.50 gal/h

The standard deviation of the volume rate estimates = 0.90 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -1.82 gal/h

Min. Detectable Leak: -3.63 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

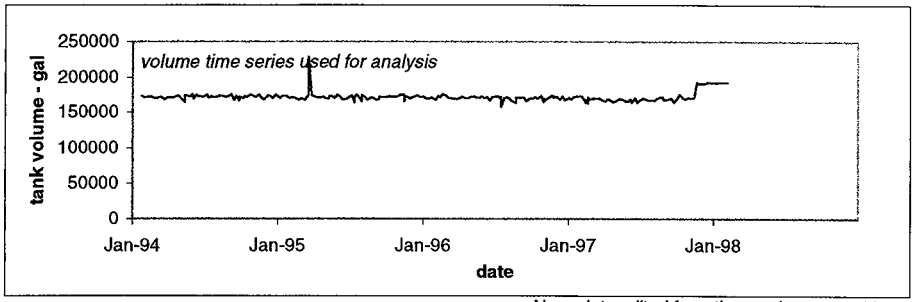
Threshold, T: -3.03 gal/h

Min. Detectable Leak: -6.07 gal/h

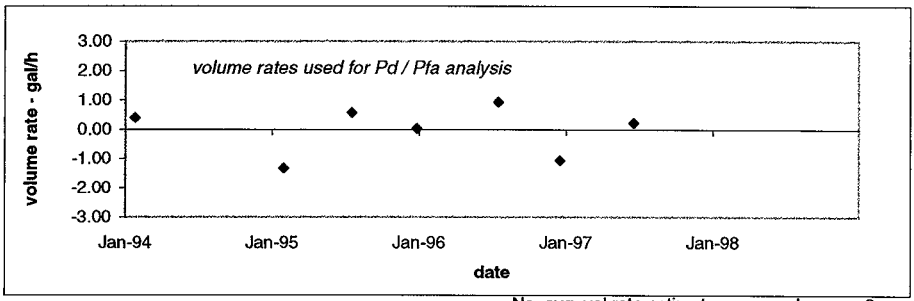
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **BY-107** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 11



No. avg. vol rate estimates removed = 2
N = 7

During the analysis period, the average volume rate = -0.04 gal/h
The standard deviation of the volume rate estimates = 0.84 gal/h

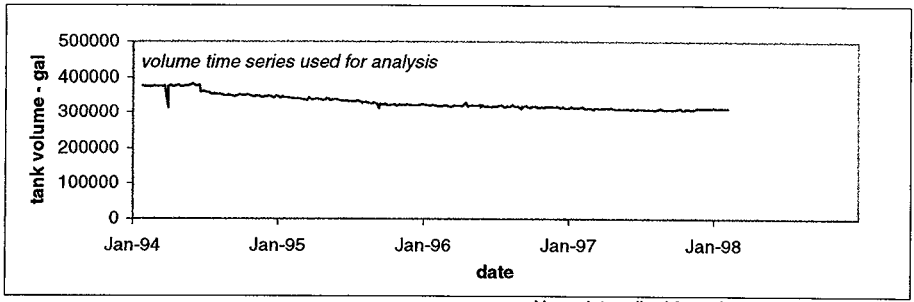
For Pd / Pfa = 95% / 5%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -1.64 gal/h
Min. Detectable Leak: -3.28 gal/h

For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -2.65 gal/h
Min. Detectable Leak: -5.31 gal/h

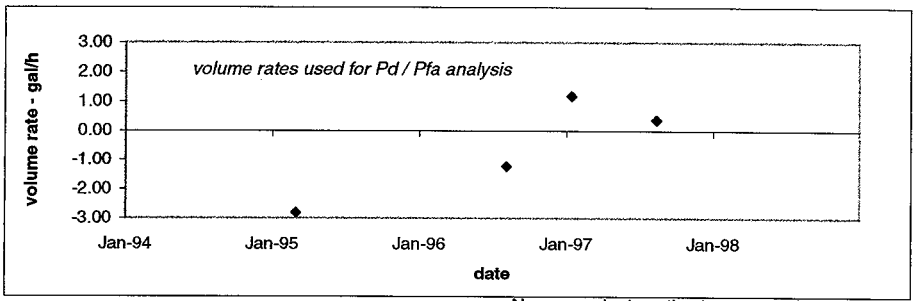
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **BY-109** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 4



No. avg. vol rate estimates removed = 4

N = 4

During the analysis period, the average volume rate = -0.62 gal/h

The standard deviation of the volume rate estimates = 1.76 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -4.14 gal/h

Min. Detectable Leak: -8.28 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

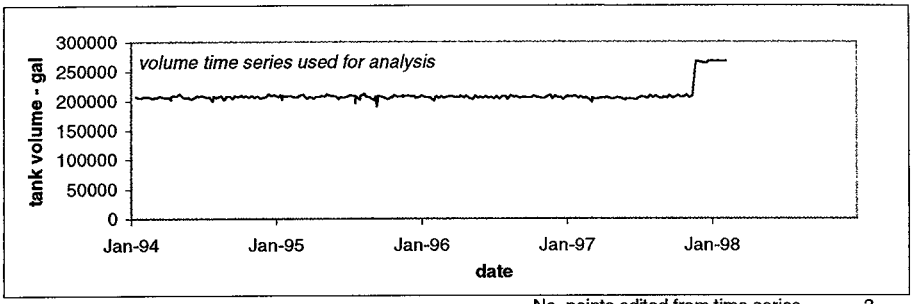
Threshold, T: -7.99 gal/h

Min. Detectable Leak: -15.97 gal/h

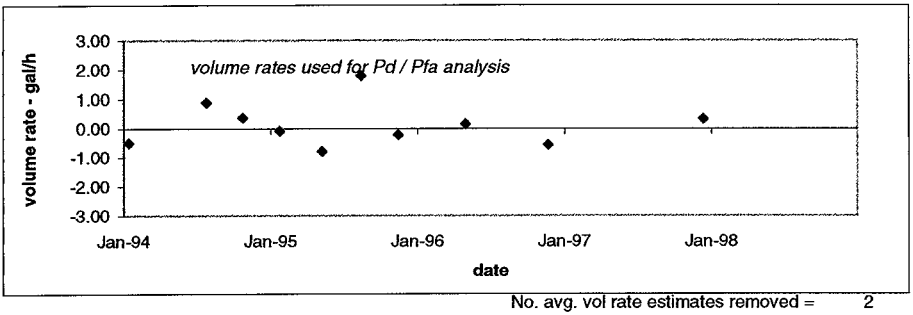
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **BY-110** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 3



No. avg. vol rate estimates removed = 2

N = 10

During the analysis period, the average volume rate = 0.13 gal/h

The standard deviation of the volume rate estimates = 0.77 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -1.41 gal/h

Min. Detectable Leak: -2.82 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

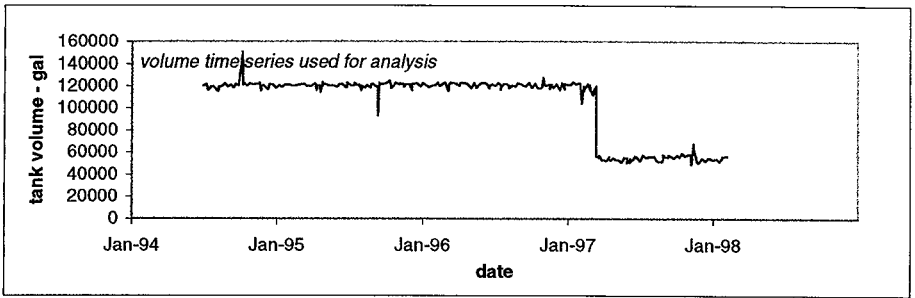
Threshold, T: -2.17 gal/h

Min. Detectable Leak: -4.33 gal/h

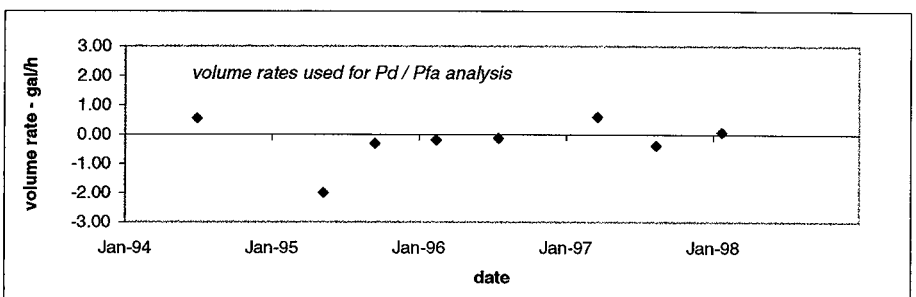
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **BY-112** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 10



No. avg. vol rate estimates removed = 2

N = 8

During the analysis period, the average volume rate = -0.23 gal/h

The standard deviation of the volume rate estimates = 0.80 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -1.53 gal/h

Min. Detectable Leak: -3.05 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

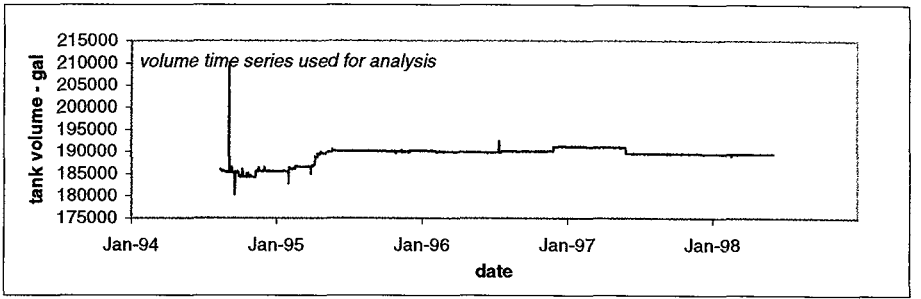
Threshold, T: -2.41 gal/h

Min. Detectable Leak: -4.83 gal/h

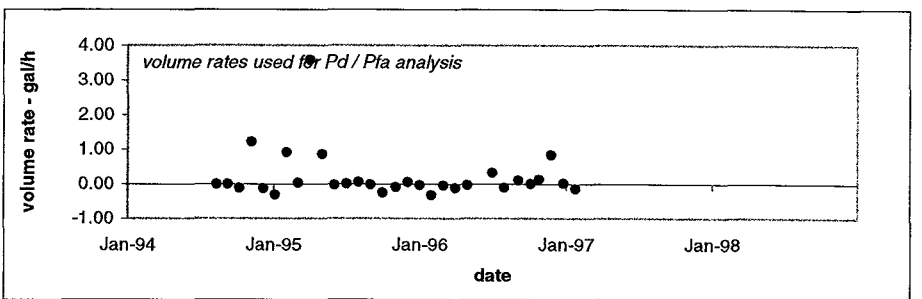
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **C-103** Data is from sensor type: **Manual ENRAF**



No. points edited from time series = 3

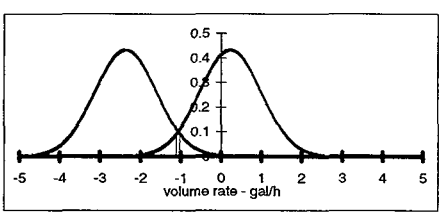


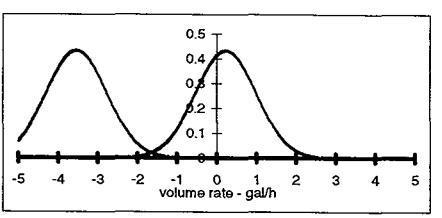
No. avg. vol rate estimates removed = 2
N = 28

During the analysis period, the average volume rate = 0.23 gal/h
The standard deviation of the volume rate estimates = 0.76 gal/h

For Pd / Pfa = 95% / 5%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -1.30 gal/h
Min. Detectable Leak: -2.59 gal/h

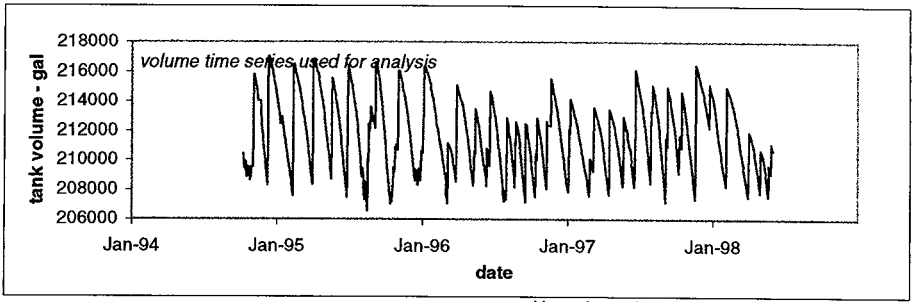
For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -1.88 gal/h
Min. Detectable Leak: -3.77 gal/h



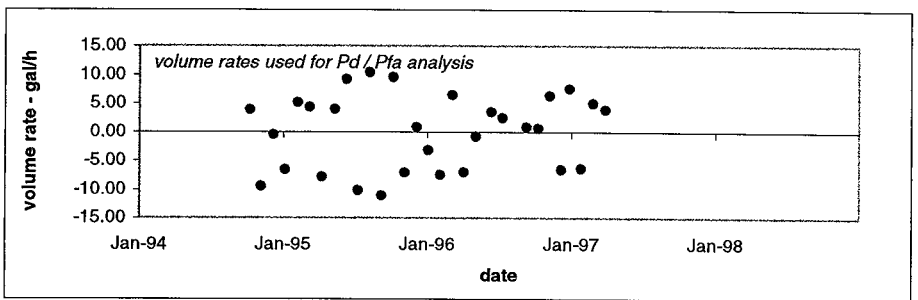


For this data, a threshold= -2.03 gal/h will detect a tank release of 3.77 gal/h at a Pd = 95%
The corresponding Pfa is 0.52%

Data File: **C-106** Data is from sensor type: **Auto ENRAF**



No. points edited from time series = 16



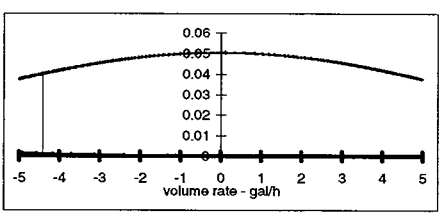
No. avg. vol rate estimates removed = 0

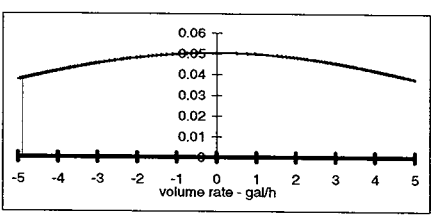
N = 30

During the analysis period, the average volume rate = 0.01 gal/h
The standard deviation of the volume rate estimates = 6.51 gal/h

For Pd / Pfa = 95% / 5%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -11.06 gal/h
Min. Detectable Leak: -22.12 gal/h

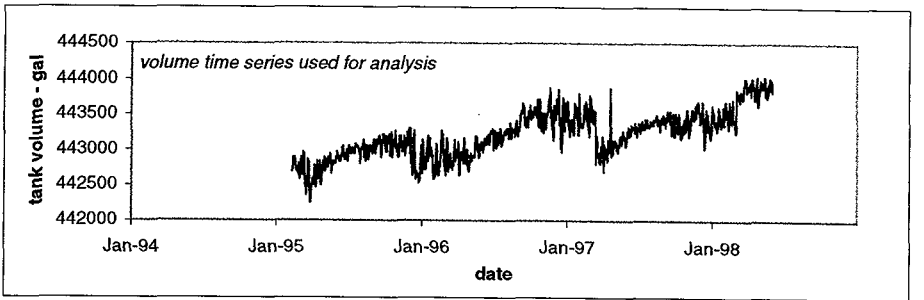
For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -16.03 gal/h
Min. Detectable Leak: -32.05 gal/h



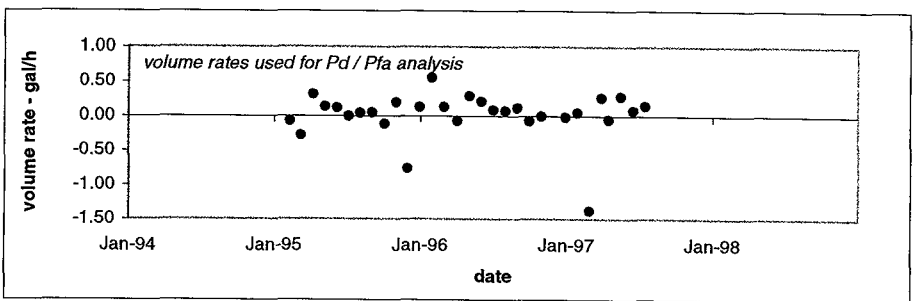


For this data, a threshold= 5.00 gal/h will detect a tank release of 32.05 gal/h at a Pd = 95%
The corresponding Pfa is 3.76%

Data File: **S-101** Data is from sensor type: **Manual ENRAF**



No. points edited from time series = 12



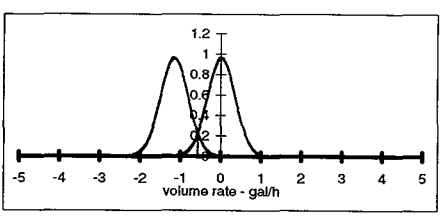
No. avg. vol rate estimates removed = 0

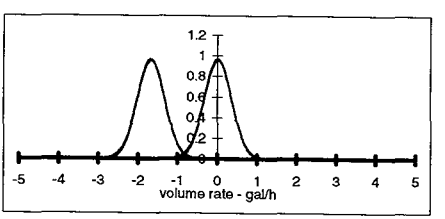
N = 30

During the analysis period, the average volume rate = 0.02 gal/h
The standard deviation of the volume rate estimates = 0.34 gal/h

For Pd / Pfa = 95% / 5%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -0.58 gal/h
Min. Detectable Leak: -1.17 gal/h

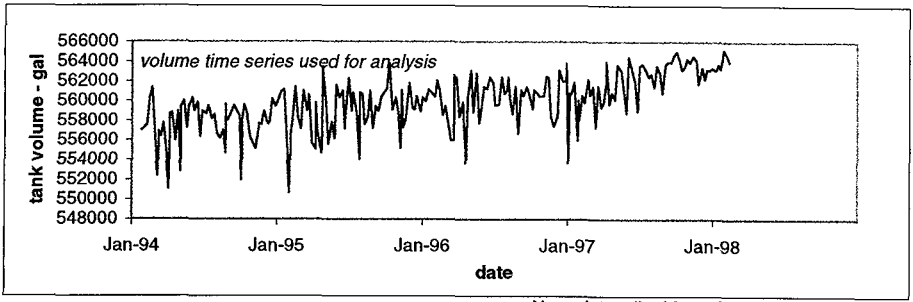
For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -0.84 gal/h
Min. Detectable Leak: -1.69 gal/h



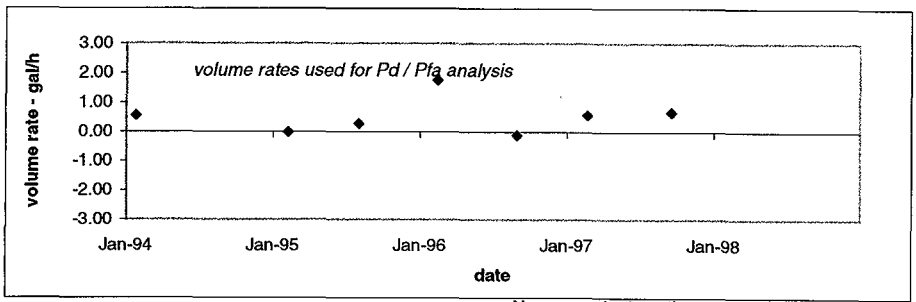


For this data, a threshold= -1.12 gal/h will detect a tank release of 1.69 gal/h at a Pd = 95%
The corresponding Pfa is 0.40%

Data File: **S-102** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 3



No. avg. vol rate estimates removed = 1

N = 7

During the analysis period, the average volume rate = 0.52 gal/h

The standard deviation of the volume rate estimates = 0.62 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is NOT equivalent to 0 gal/h

Threshold, T: -1.21 gal/h

Min. Detectable Leak: -2.41 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

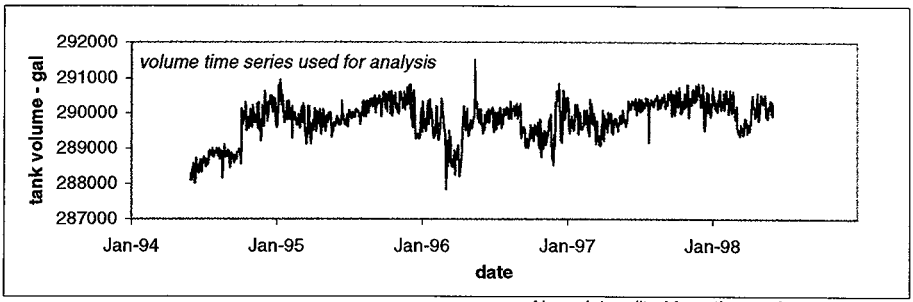
Threshold, T: -1.95 gal/h

Min. Detectable Leak: -3.91 gal/h

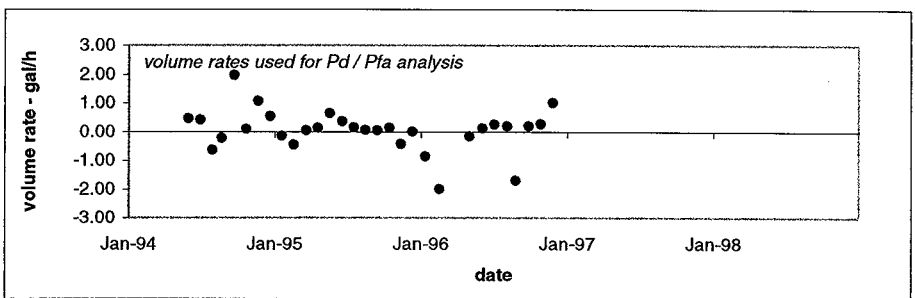
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **S-103** Data is from sensor type: **Manual ENRAF**



No. points edited from time series = 15



No. avg. vol rate estimates removed = 0

N = 30

During the analysis period, the average volume rate = 0.06 gal/h

The standard deviation of the volume rate estimates = 0.74 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -1.26 gal/h

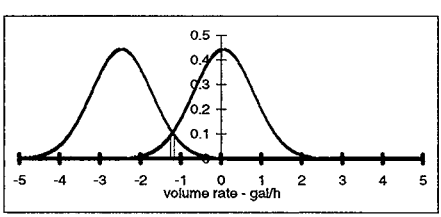
Min. Detectable Leak: -2.52 gal/h

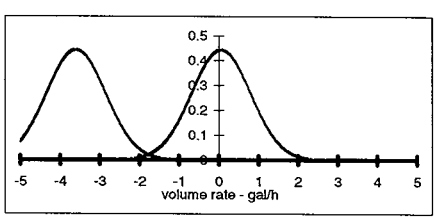
For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -1.83 gal/h

Min. Detectable Leak: -3.66 gal/h

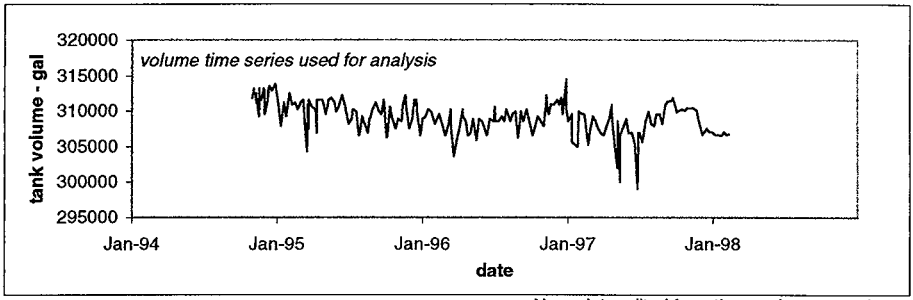




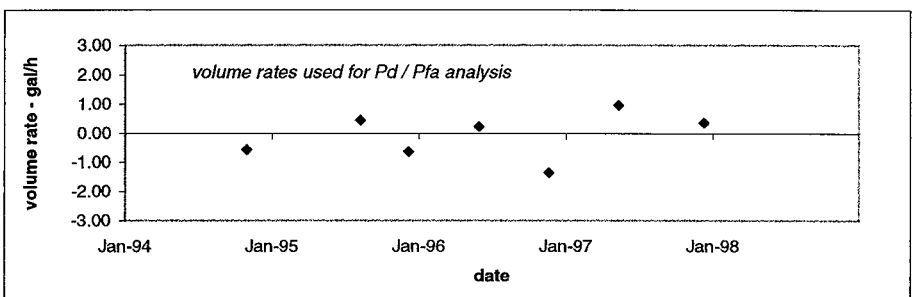
For this data, a threshold= -2.10 gal/h will detect a tank release of 3.66 gal/h at a Pd = 95%

The corresponding Pfa is 0.65%

Data File: **S-104** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 0



No. avg. vol rate estimates removed = 1

N = 7

During the analysis period, the average volume rate = -0.09 gal/h

The standard deviation of the volume rate estimates = 0.80 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -1.55 gal/h

Min. Detectable Leak: -3.10 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

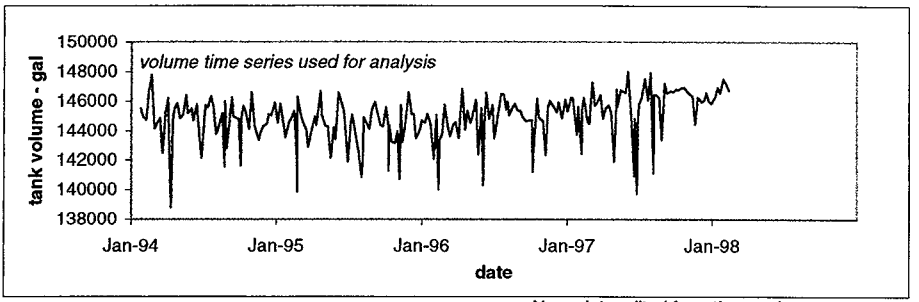
Threshold, T: -2.50 gal/h

Min. Detectable Leak: -5.01 gal/h

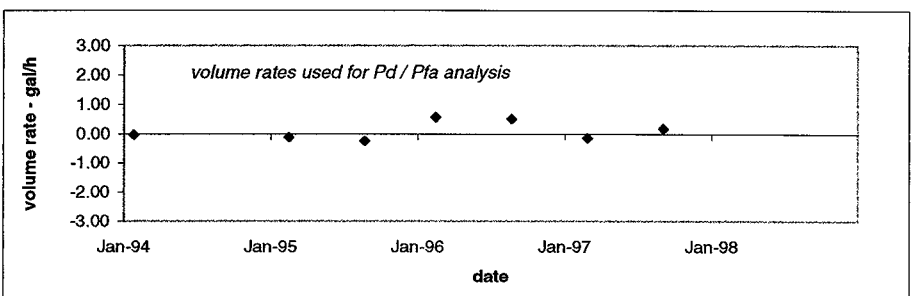
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **S-105** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 3



No. avg. vol rate estimates removed = 1

N = 7

During the analysis period, the average volume rate = 0.09 gal/h

The standard deviation of the volume rate estimates = 0.32 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.63 gal/h

Min. Detectable Leak: -1.25 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

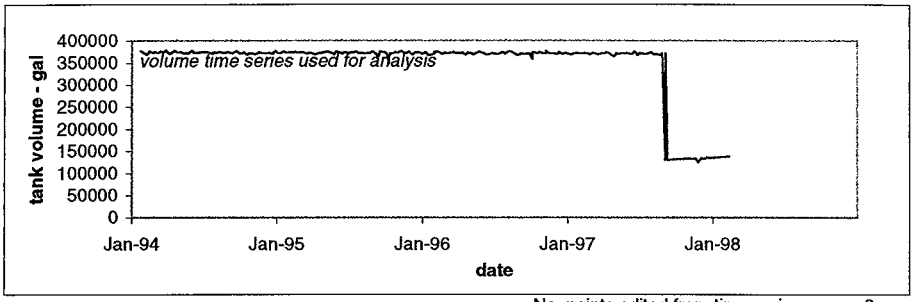
Threshold, T: -1.01 gal/h

Min. Detectable Leak: -2.03 gal/h

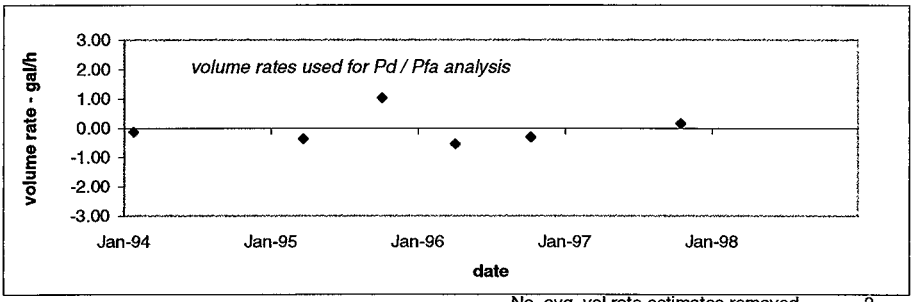
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **S-108** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 2



No. avg. vol rate estimates removed = 2

N = 6

During the analysis period, the average volume rate = -0.03 gal/h

The standard deviation of the volume rate estimates = 0.57 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -1.15 gal/h

Min. Detectable Leak: -2.29 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

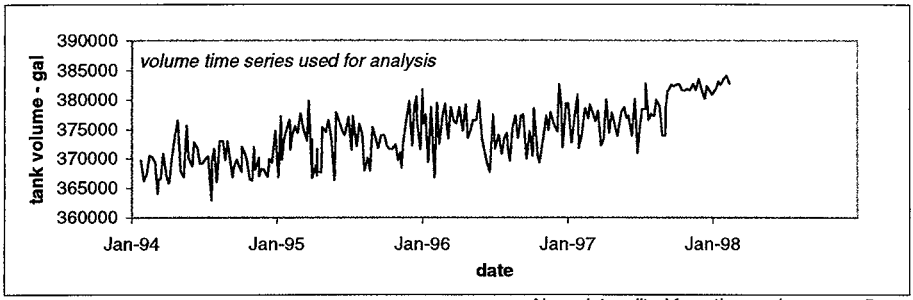
Threshold, T: -1.91 gal/h

Min. Detectable Leak: -3.83 gal/h

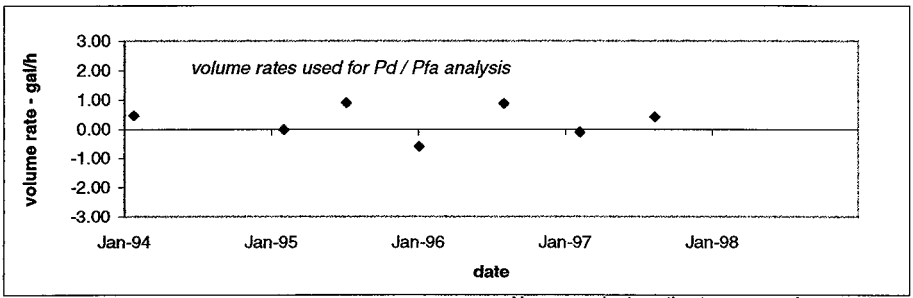
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **S-109** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 5



No. avg. vol rate estimates removed = 1
N = 7

During the analysis period, the average volume rate = 0.27 gal/h
The standard deviation of the volume rate estimates = 0.55 gal/h

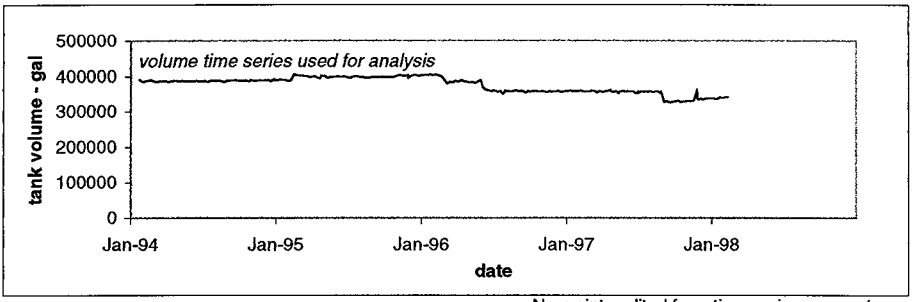
For Pd / Pfa = 95% / 5%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -1.07 gal/h
Min. Detectable Leak: -2.13 gal/h

For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -1.73 gal/h
Min. Detectable Leak: -3.45 gal/h

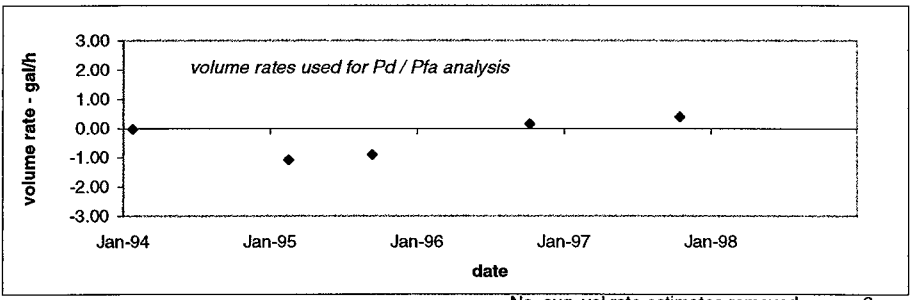
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **S-110** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 1



No. avg. vol rate estimates removed = 3

N = 5

During the analysis period, the average volume rate = -0.30 gal/h

The standard deviation of the volume rate estimates = 0.66 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -1.41 gal/h

Min. Detectable Leak: -2.81 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

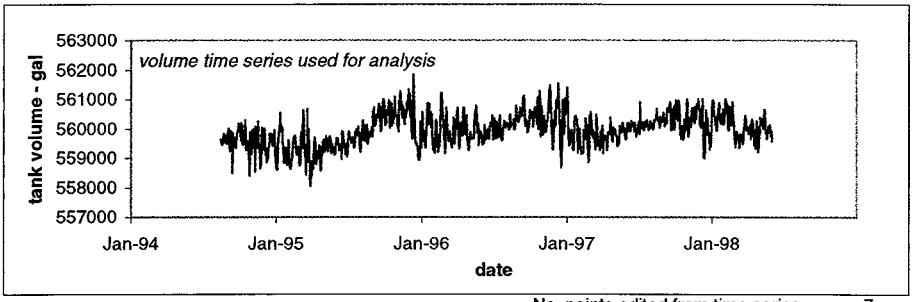
Threshold, T: -2.47 gal/h

Min. Detectable Leak: -4.94 gal/h

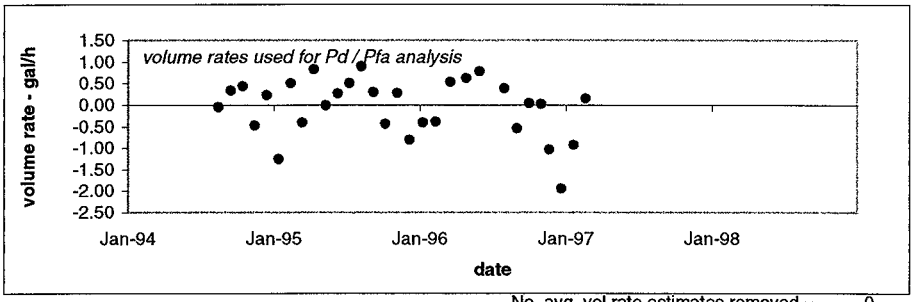
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **S-111** Data is from sensor type: **Manual ENRAF**



No. points edited from time series = 7

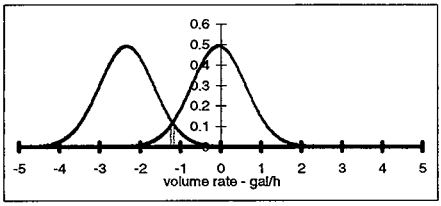


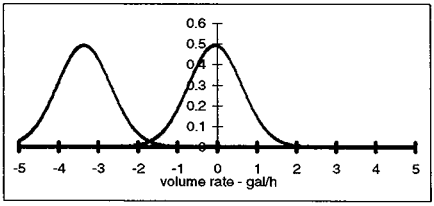
No. avg. vol rate estimates removed = 0
N = 30

During the analysis period, the average volume rate = -0.05 gal/h
The standard deviation of the volume rate estimates = 0.67 gal/h

For Pd / Pfa = 95% / 5%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -1.14 gal/h
Min. Detectable Leak: -2.28 gal/h

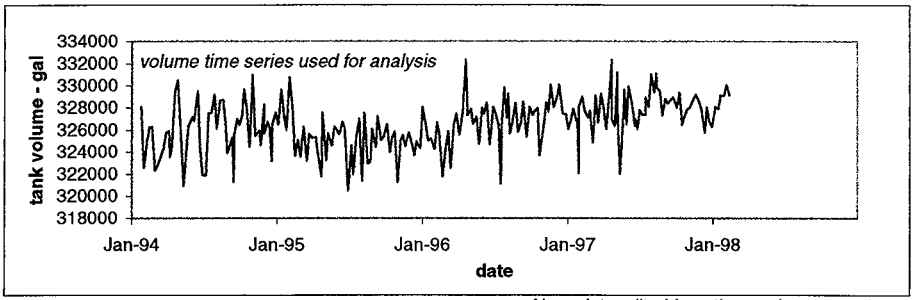
For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -1.65 gal/h
Min. Detectable Leak: -3.31 gal/h



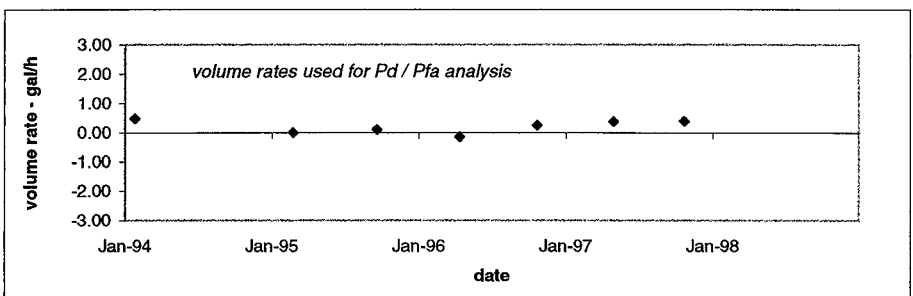


For this data, a threshold= -2.22 gal/h will detect a tank release of 3.31 gal/h at a Pd = 95%
The corresponding Pfa is 0.27%

Data File: **S-112** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 1



No. avg. vol rate estimates removed = 1

N = 7

During the analysis period, the average volume rate = 0.20 gal/h

The standard deviation of the volume rate estimates = 0.23 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is NOT equivalent to 0 gal/h

Threshold, T: -0.44 gal/h

Min. Detectable Leak: -0.89 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

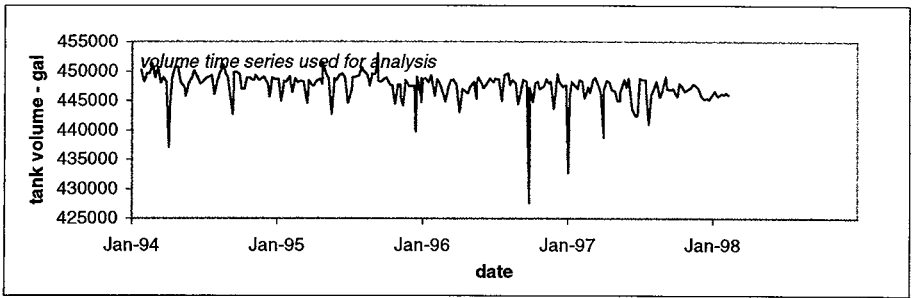
Threshold, T: -0.72 gal/h

Min. Detectable Leak: -1.43 gal/h

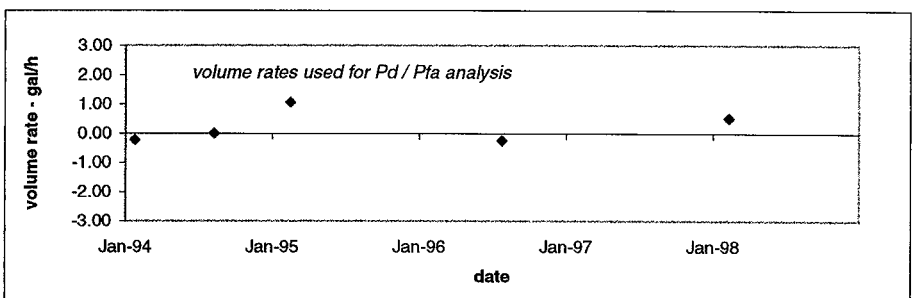
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **SX-101** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 15



No. avg. vol rate estimates removed = 3

N = 5

During the analysis period, the average volume rate = 1.49 gal/h
The standard deviation of the volume rate estimates = 2.79 gal/h

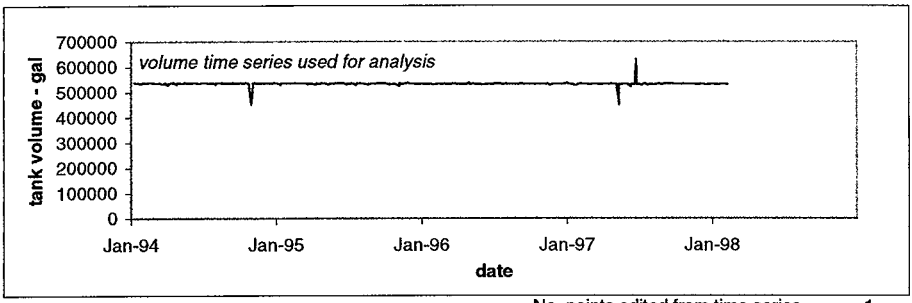
For Pd / Pfa = 95% / 5%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -5.94 gal/h
Min. Detectable Leak: -11.88 gal/h

For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -10.44 gal/h
Min. Detectable Leak: -20.88 gal/h

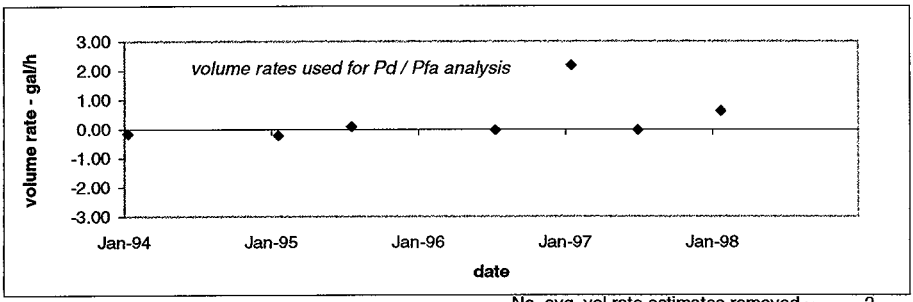
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **SX-102** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 1



No. avg. vol rate estimates removed = 2
N = 7

During the analysis period, the average volume rate = 0.35 gal/h
The standard deviation of the volume rate estimates = 0.86 gal/h

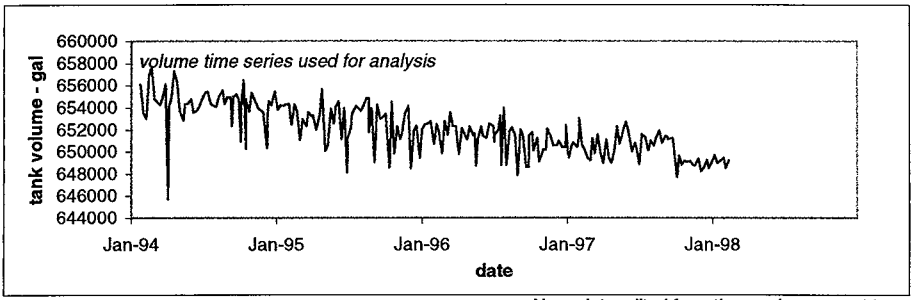
For Pd / Pfa = 95% / 5%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -1.67 gal/h
Min. Detectable Leak: -3.34 gal/h

For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -2.70 gal/h
Min. Detectable Leak: -5.40 gal/h

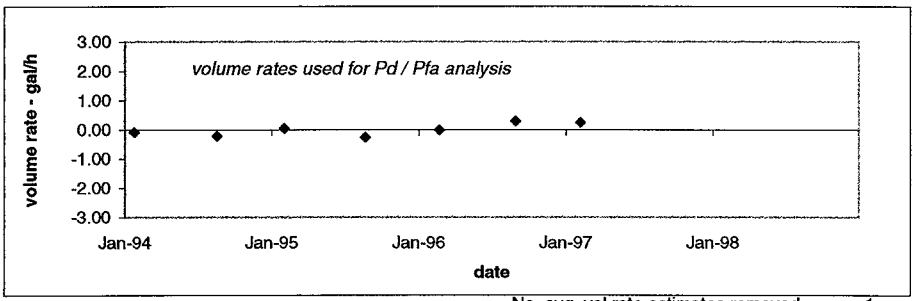
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **SX-103** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 11



No. avg. vol rate estimates removed = 1

N = 7

During the analysis period, the average volume rate = -0.01 gal/h

The standard deviation of the volume rate estimates = 0.21 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.41 gal/h

Min. Detectable Leak: -0.82 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

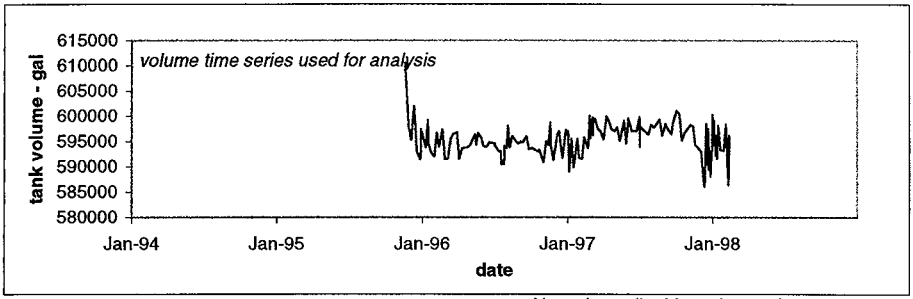
Threshold, T: -0.66 gal/h

Min. Detectable Leak: -1.33 gal/h

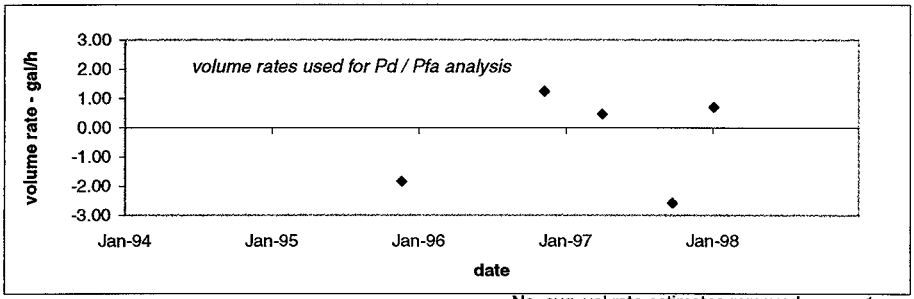
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **SX-104** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 6



No. avg. vol rate estimates removed = 1
N = 5

During the analysis period, the average volume rate = -0.41 gal/h
The standard deviation of the volume rate estimates = 1.69 gal/h

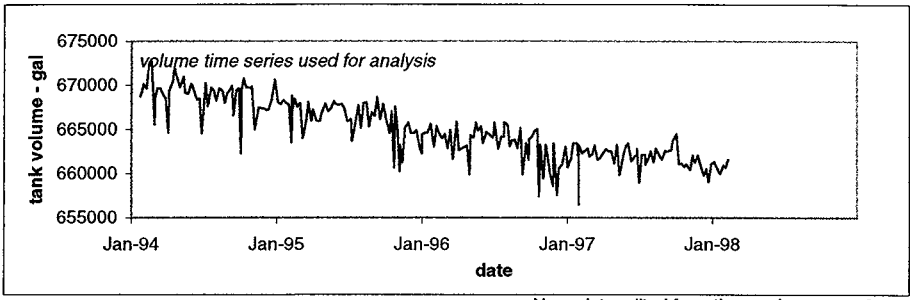
For Pd / Pfa = 95% / 5%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -3.60 gal/h
Min. Detectable Leak: -7.20 gal/h

For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -6.32 gal/h
Min. Detectable Leak: -12.65 gal/h

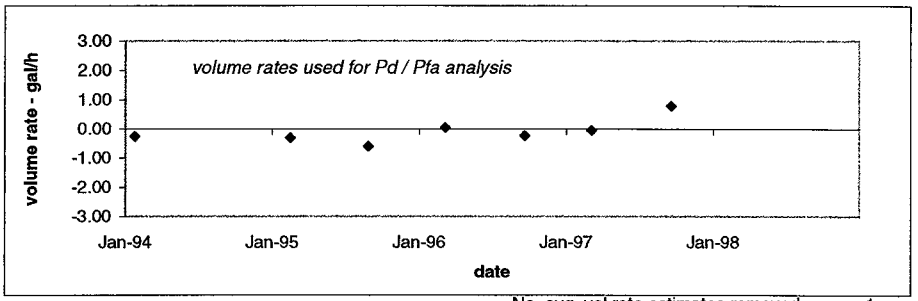
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **SX-105** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 8



No. avg. vol rate estimates removed = 1
N = 7

During the analysis period, the average volume rate = -0.10 gal/h
The standard deviation of the volume rate estimates = 0.43 gal/h

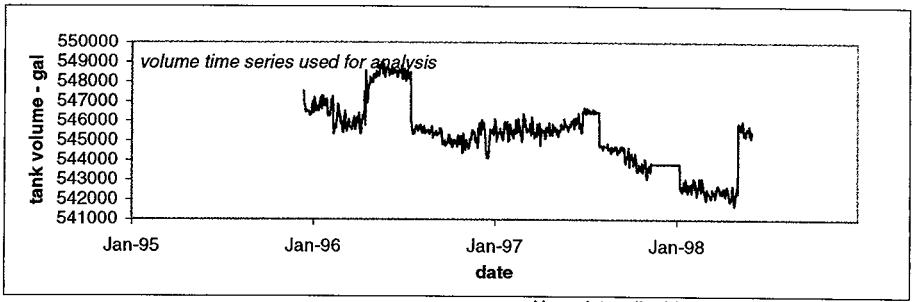
For Pd / Pfa = 95% / 5%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -0.84 gal/h
Min. Detectable Leak: -1.68 gal/h

For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -1.36 gal/h
Min. Detectable Leak: -2.72 gal/h

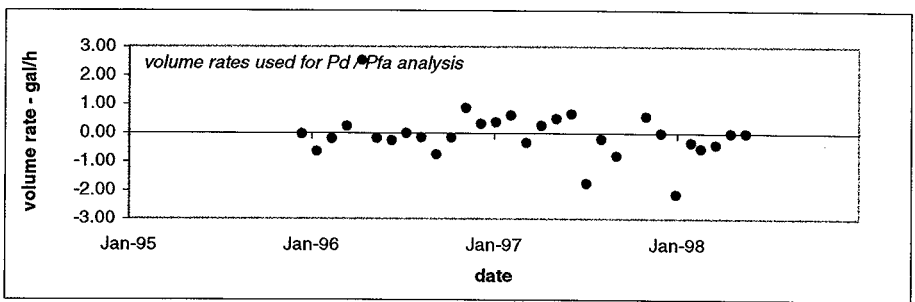
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **SX-106** Data is from sensor type: **Auto ENRAF**



No. points edited from time series = 1



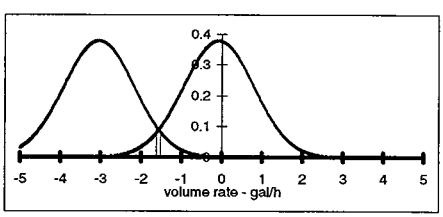
No. avg. vol rate estimates removed = 4

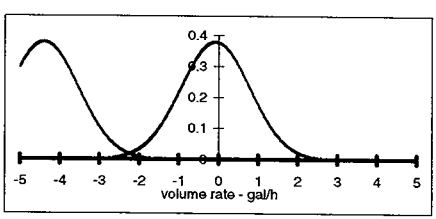
N = 26

During the analysis period, the average volume rate = -0.08 gal/h
The standard deviation of the volume rate estimates = 0.87 gal/h

For Pd / Pfa = 95% / 5%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -1.49 gal/h
Min. Detectable Leak: -2.97 gal/h

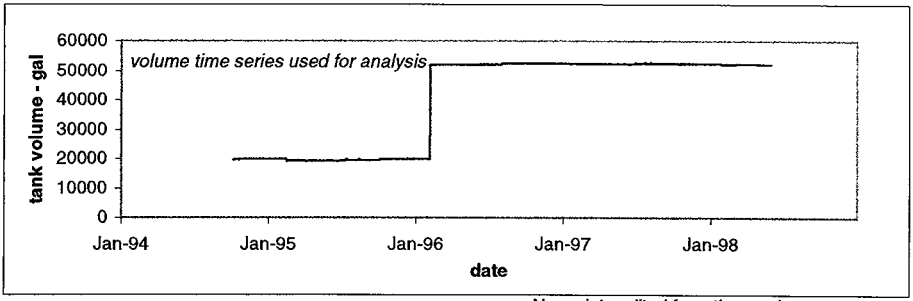
For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -2.16 gal/h
Min. Detectable Leak: -4.32 gal/h



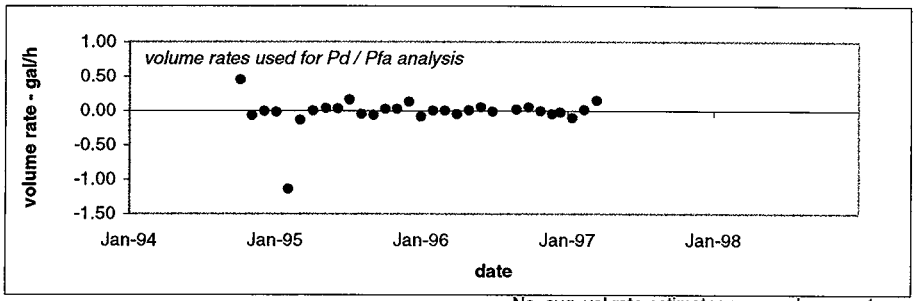


For this data, a threshold= 5.00 gal/h will detect a tank release of 4.32 gal/h at a Pd = 95%
The corresponding Pfa is 0.00%

Data File: **T-102** Data is from sensor type: **Auto ENRAF**



No. points edited from time series = 1



No. avg. vol rate estimates removed = 1

N = 29

During the analysis period, the average volume rate = -0.02 gal/h

The standard deviation of the volume rate estimates = 0.24 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.41 gal/h

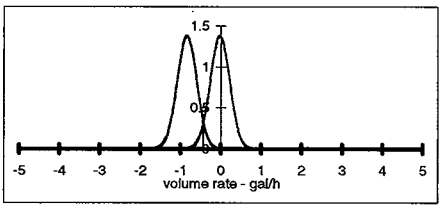
Min. Detectable Leak: -0.81 gal/h

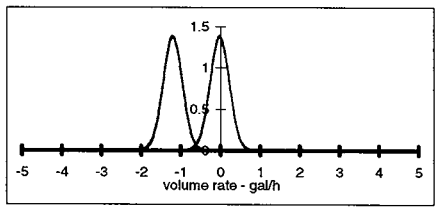
For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.59 gal/h

Min. Detectable Leak: -1.18 gal/h

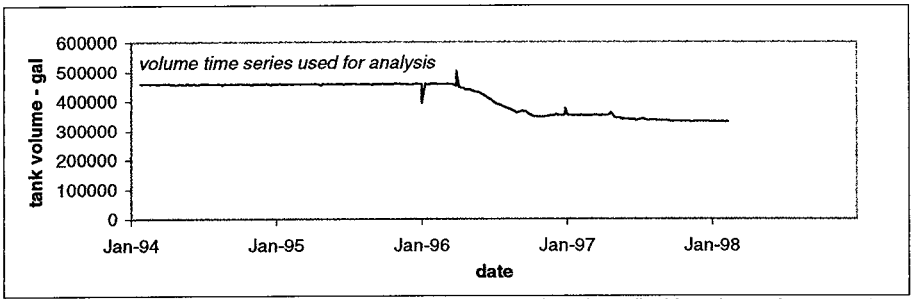




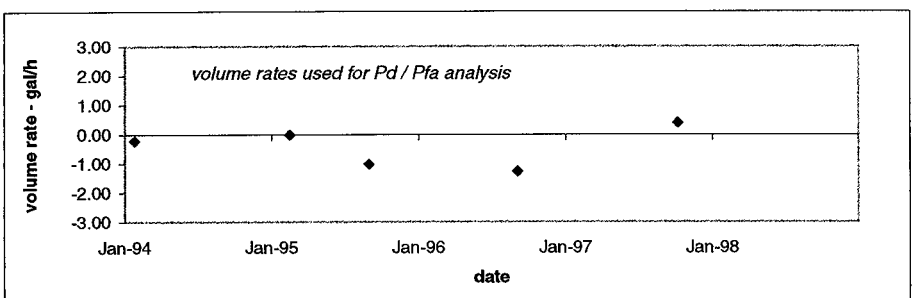
For this data, a threshold= -0.82 gal/h will detect a tank release of 1.18 gal/h at a Pd = 95%

The corresponding Pfa is 0.53%

Data File: **T-104** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 4



No. avg. vol rate estimates removed = 3

N = 5

During the analysis period, the average volume rate = -0.43 gal/h

The standard deviation of the volume rate estimates = 0.69 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -1.48 gal/h

Min. Detectable Leak: -2.96 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

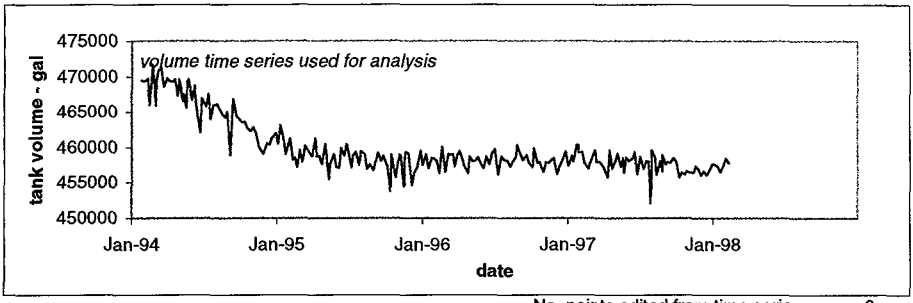
Threshold, T: -2.60 gal/h

Min. Detectable Leak: -5.20 gal/h

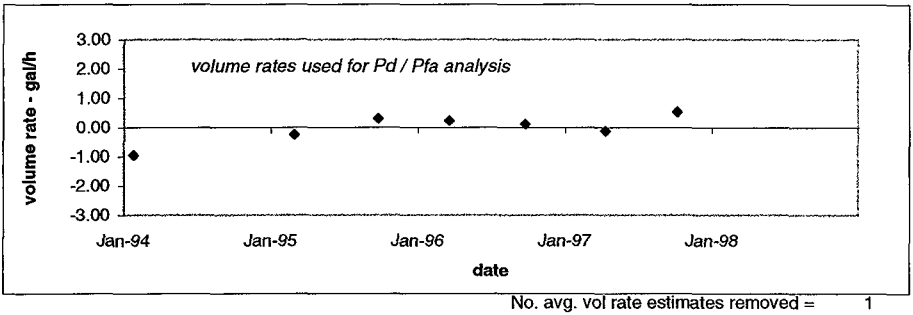
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **T-111** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 6



No. avg. vol rate estimates removed = 1

N = 7

During the analysis period, the average volume rate = -0.02 gal/h

The standard deviation of the volume rate estimates = 0.49 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is *equivalent to 0 gal/h*

Threshold, T: -0.95 gal/h

Min. Detectable Leak: -1.90 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

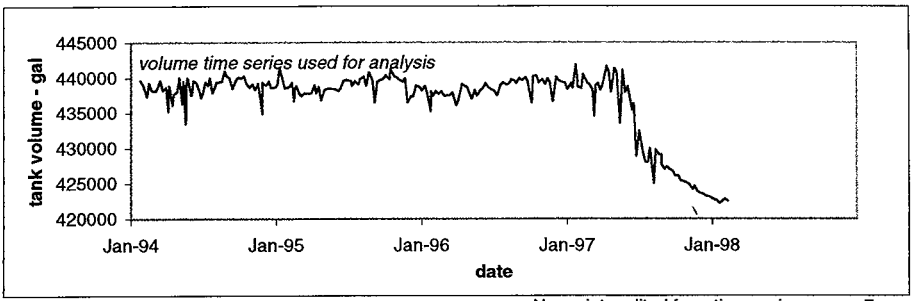
Threshold, T: -1.53 gal/h

Min. Detectable Leak: -3.07 gal/h

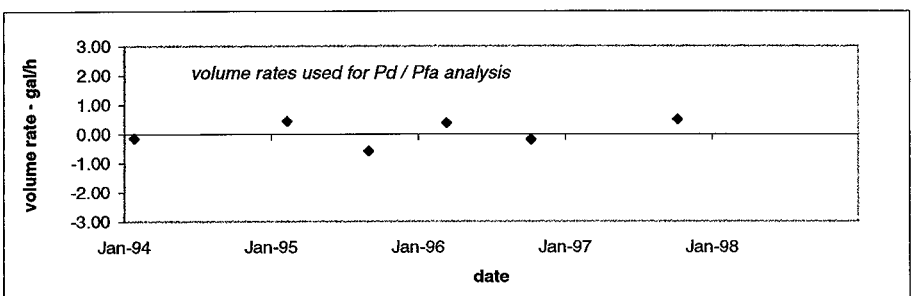
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **T-110** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 7



No. avg. vol rate estimates removed = 2
N = 6

During the analysis period, the average volume rate = 0.06 gal/h
The standard deviation of the volume rate estimates = 0.44 gal/h

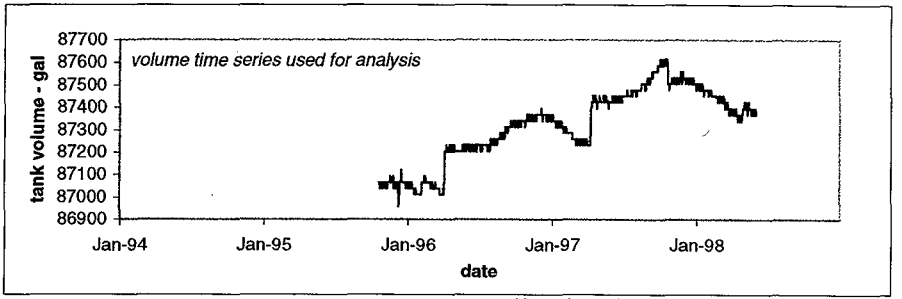
For Pd / Pfa = 95% / 5%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -0.88 gal/h
Min. Detectable Leak: -1.76 gal/h

For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -1.47 gal/h
Min. Detectable Leak: -2.94 gal/h

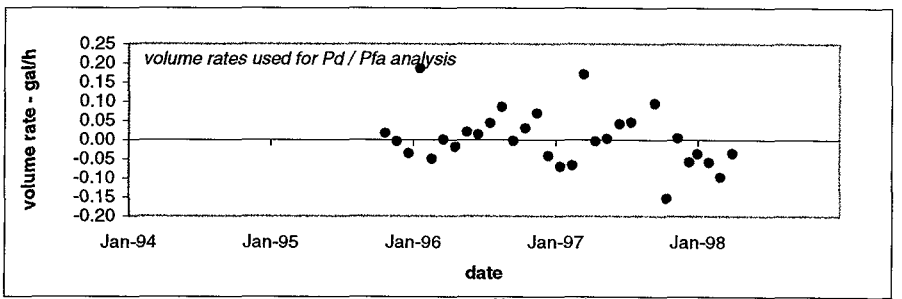
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **T-112** Data is from sensor type: **Manual ENRAF**



No. points edited from time series = 15



No. avg. vol rate estimates removed = 1

N = 29

During the analysis period, the average volume rate = 0.00 gal/h

The standard deviation of the volume rate estimates = 0.07 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.12 gal/h

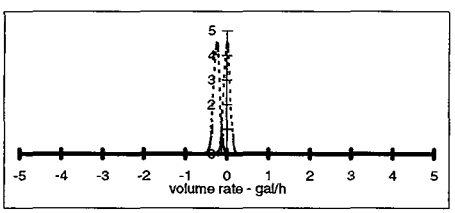
Min. Detectable Leak: -0.25 gal/h

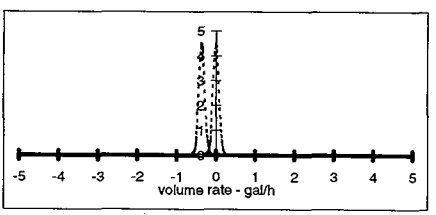
For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.18 gal/h

Min. Detectable Leak: -0.36 gal/h

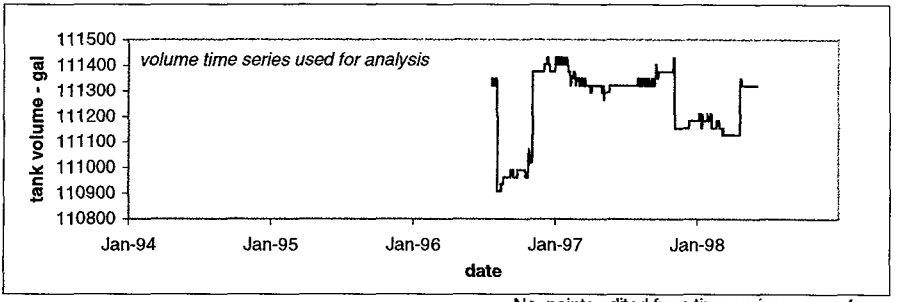




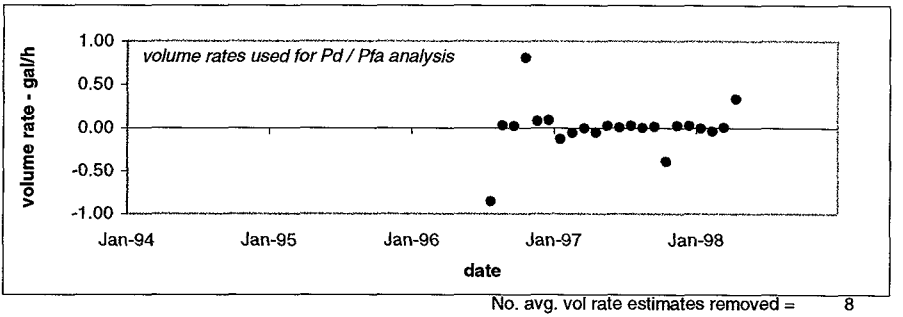
For this data, a threshold= -0.25 gal/h will detect a tank release of 0.36 gal/h at a Pd = 95%

The corresponding Pfa is 1.11%

Data File: **TX-101** Data is from sensor type: **Auto ENRAF**



No. points edited from time series = 4



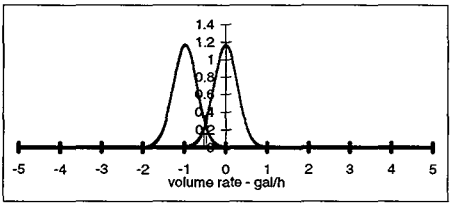
No. avg. vol rate estimates removed = 8

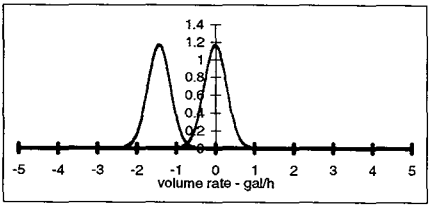
N = 22

During the analysis period, the average volume rate = -0.01 gal/h
The standard deviation of the volume rate estimates = 0.28 gal/h

For Pd / Pfa = 95% / 5%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -0.49 gal/h
Min. Detectable Leak: -0.98 gal/h

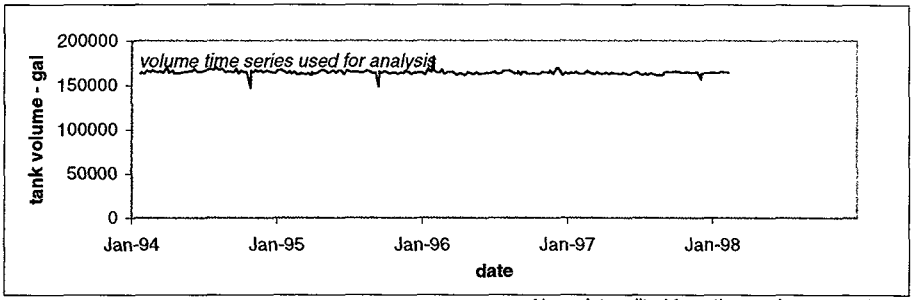
For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -0.71 gal/h
Min. Detectable Leak: -1.43 gal/h



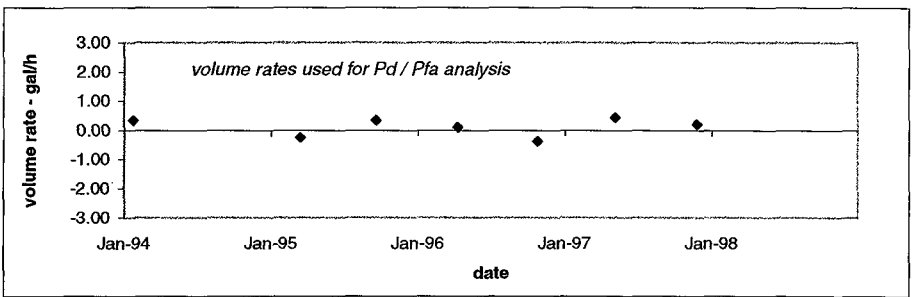


For this data, a threshold= -0.98 gal/h will detect a tank release of 1.43 gal/h at a Pd = 95%
The corresponding Pfa is 0.32%

Data File: **TX-102** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 6



No. avg. vol rate estimates removed = 1

N = 7

During the analysis period, the average volume rate = 0.10 gal/h

The standard deviation of the volume rate estimates = 0.31 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.60 gal/h

Min. Detectable Leak: -1.20 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

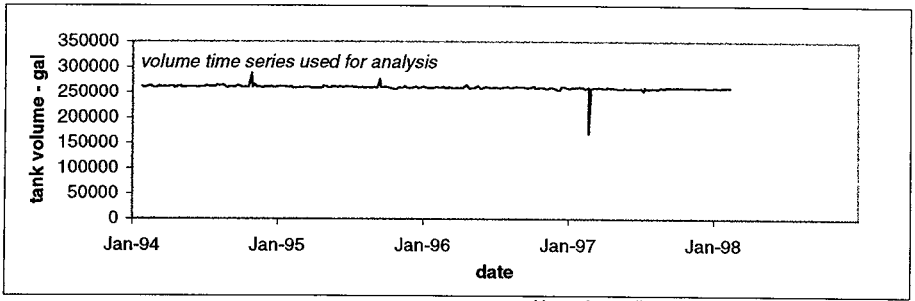
Threshold, T: -0.97 gal/h

Min. Detectable Leak: -1.94 gal/h

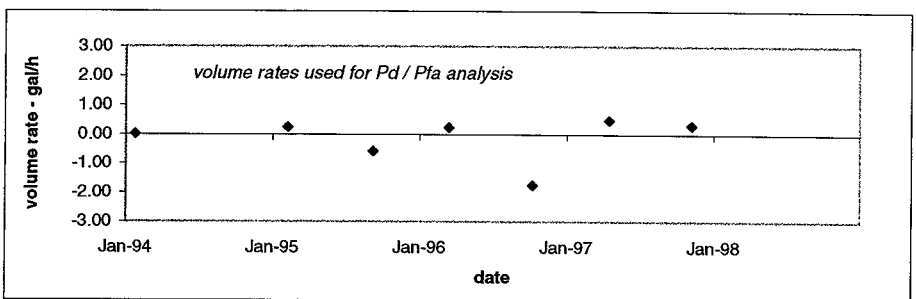
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **TX-106** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 4



No. avg. vol rate estimates removed = 1

N = 7

During the analysis period, the average volume rate = -0.16 gal/h

The standard deviation of the volume rate estimates = 0.78 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -1.52 gal/h

Min. Detectable Leak: -3.04 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

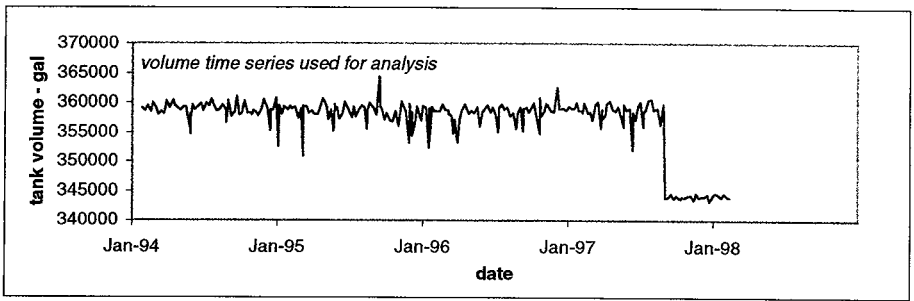
Threshold, T: -2.46 gal/h

Min. Detectable Leak: -4.92 gal/h

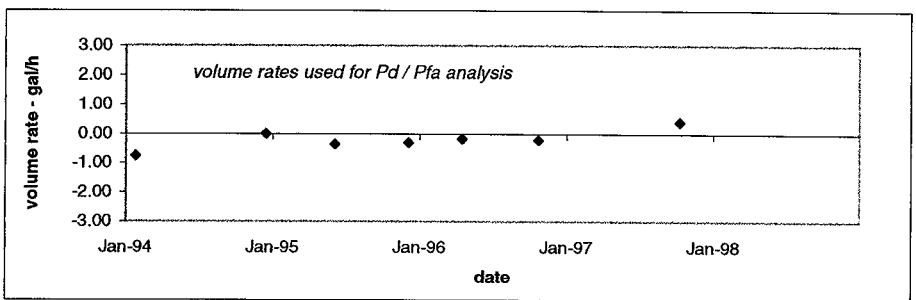
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **TX-109** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 8



No. avg. vol rate estimates removed = 2

N = 7

During the analysis period, the average volume rate = -0.21 gal/h

The standard deviation of the volume rate estimates = 0.36 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.69 gal/h

Min. Detectable Leak: -1.38 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

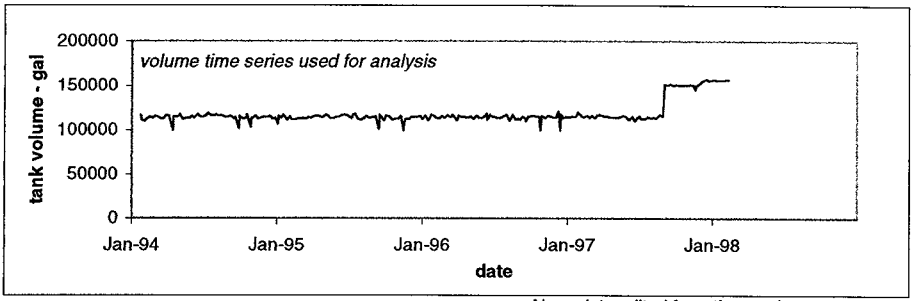
Threshold, T: -1.12 gal/h

Min. Detectable Leak: -2.23 gal/h

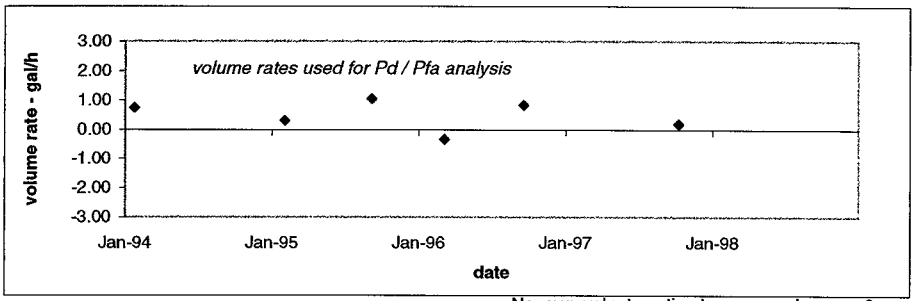
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **TX-110** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 2



No. avg. vol rate estimates removed = 2
N = 6

During the analysis period, the average volume rate = 0.46 gal/h
The standard deviation of the volume rate estimates = 0.51 gal/h

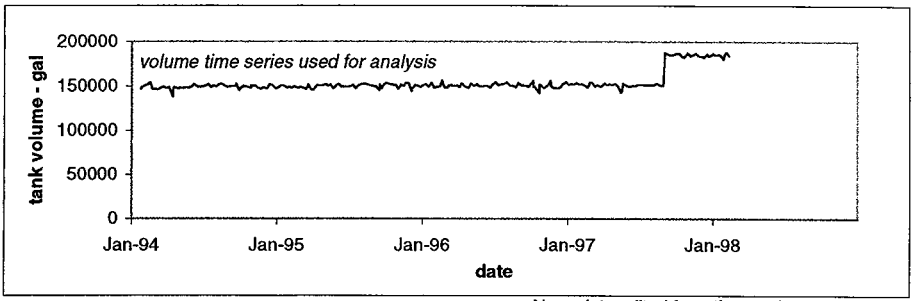
For Pd / Pfa = 95% / 5%:
The mean volume rate is NOT equivalent to 0 gal/h
Threshold, T: -1.02 gal/h
Min. Detectable Leak: -2.04 gal/h

For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -1.71 gal/h
Min. Detectable Leak: -3.41 gal/h

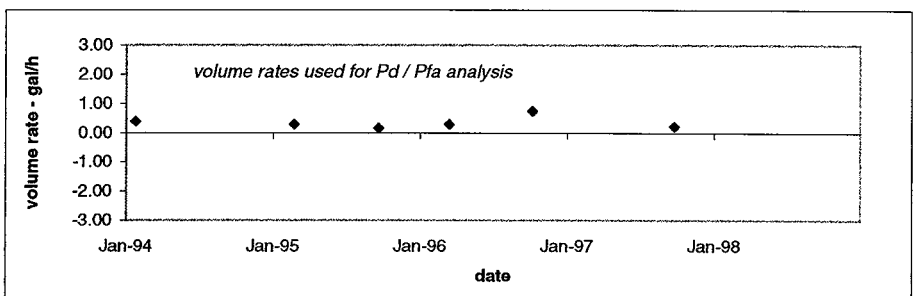
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **TX-111** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 6



No. avg. vol rate estimates removed = 2

N = 6

During the analysis period, the average volume rate = 0.34 gal/h

The standard deviation of the volume rate estimates = 0.21 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is NOT equivalent to 0 gal/h

Threshold, T: -0.42 gal/h

Min. Detectable Leak: -0.83 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is NOT equivalent to 0 gal/h

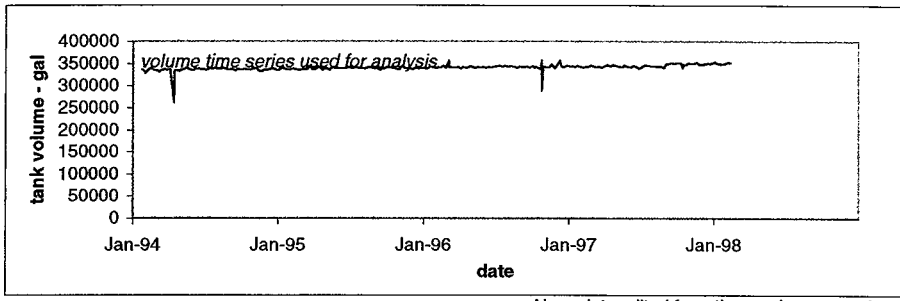
Threshold, T: -0.69 gal/h

Min. Detectable Leak: -1.39 gal/h

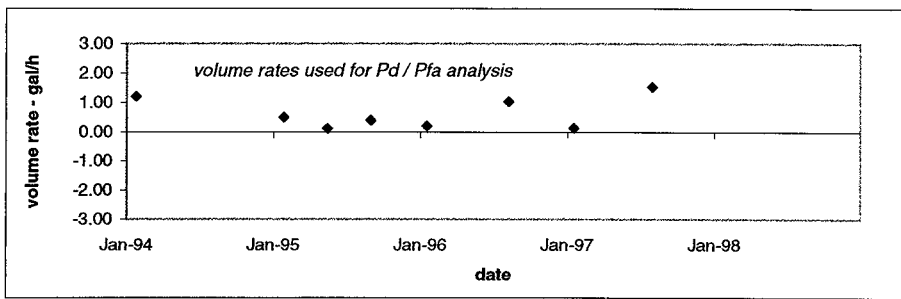
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **TX-112** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 0



No. avg. vol rate estimates removed = 1

N = 8

During the analysis period, the average volume rate = 0.63 gal/h

The standard deviation of the volume rate estimates = 0.55 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is NOT equivalent to 0 gal/h

Threshold, T: -1.04 gal/h

Min. Detectable Leak: -2.08 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is NOT equivalent to 0 gal/h

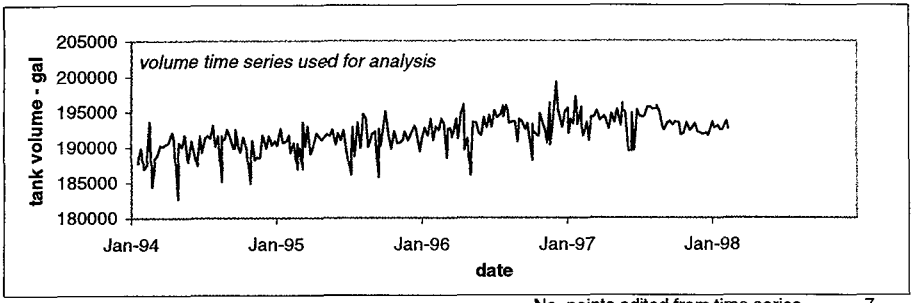
Threshold, T: -1.64 gal/h

Min. Detectable Leak: -3.29 gal/h

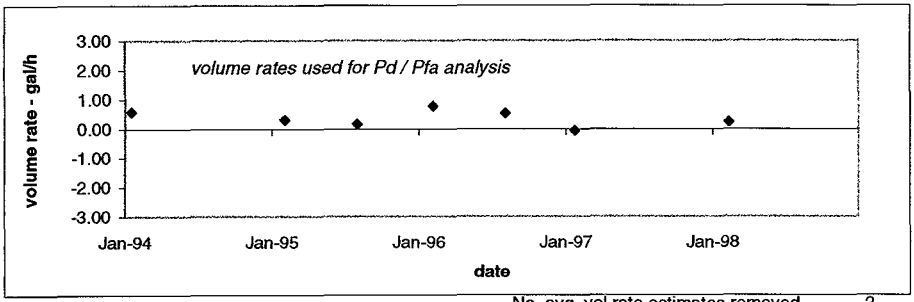
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **TX-113** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 7



No. avg. vol rate estimates removed = 2
N = 7

During the analysis period, the average volume rate = 0.35 gal/h
The standard deviation of the volume rate estimates = 0.28 gal/h

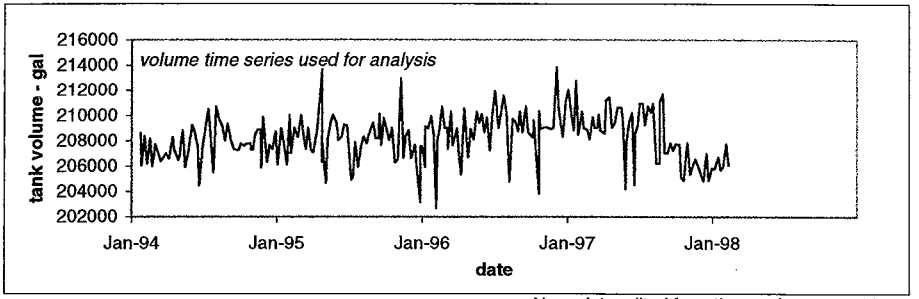
For Pd / Pfa = 95% / 5%:
The mean volume rate is NOT equivalent to 0 gal/h
Threshold, T: -0.55 gal/h
Min. Detectable Leak: -1.11 gal/h

For Pd / Pfa = 99% / 1%:
The mean volume rate is NOT equivalent to 0 gal/h
Threshold, T: -0.89 gal/h
Min. Detectable Leak: -1.79 gal/h

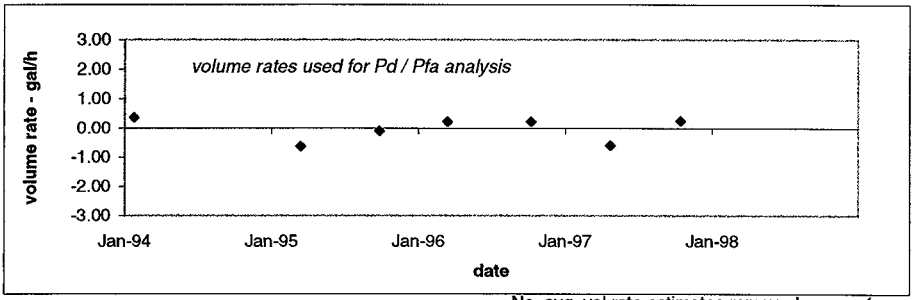
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **TX-114** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 11



No. avg. vol rate estimates removed = 1

N = 7

During the analysis period, the average volume rate = -0.05 gal/h

The standard deviation of the volume rate estimates = 0.41 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.81 gal/h

Min. Detectable Leak: -1.61 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

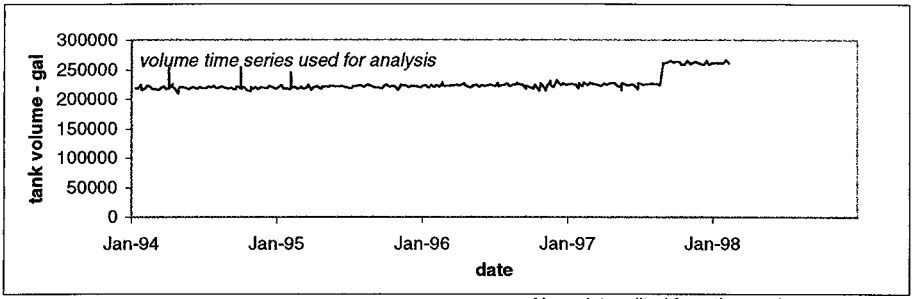
Threshold, T: -1.30 gal/h

Min. Detectable Leak: -2.61 gal/h

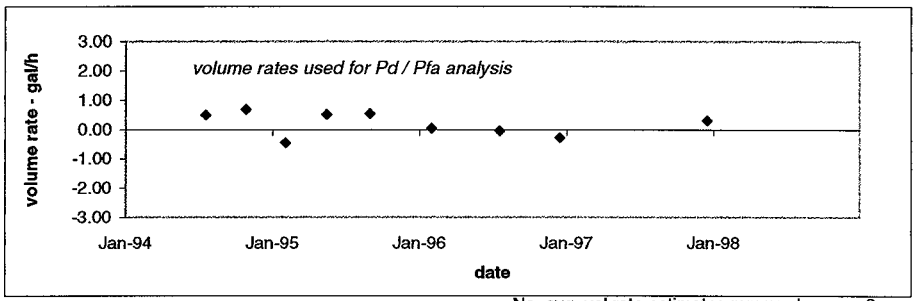
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **TX-115** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 8



No. avg. vol rate estimates removed = 3

N = 9

During the analysis period, the average volume rate = 0.19 gal/h

The standard deviation of the volume rate estimates = 0.40 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.74 gal/h

Min. Detectable Leak: -1.48 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

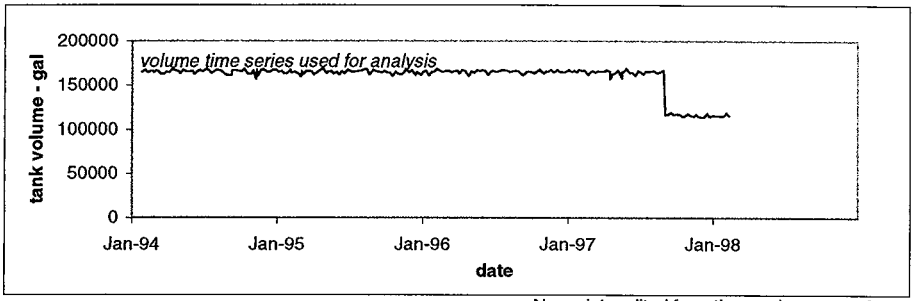
Threshold, T: -1.15 gal/h

Min. Detectable Leak: -2.31 gal/h

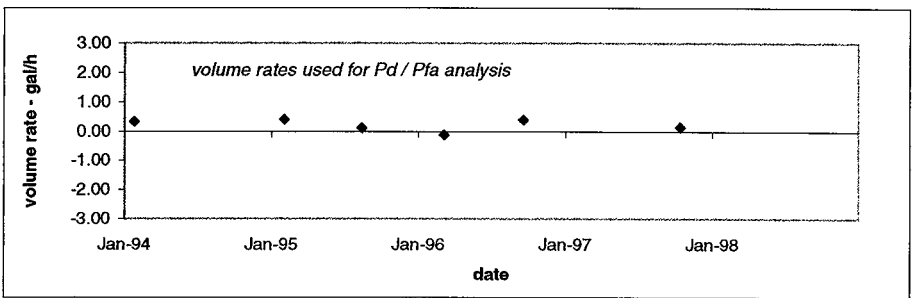
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **TX-117** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 8



No. avg. vol rate estimates removed = 2

N = 6

During the analysis period, the average volume rate = 0.20 gal/h

The standard deviation of the volume rate estimates = 0.20 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is NOT equivalent to 0 gal/h

Threshold, T: -0.40 gal/h

Min. Detectable Leak: -0.81 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

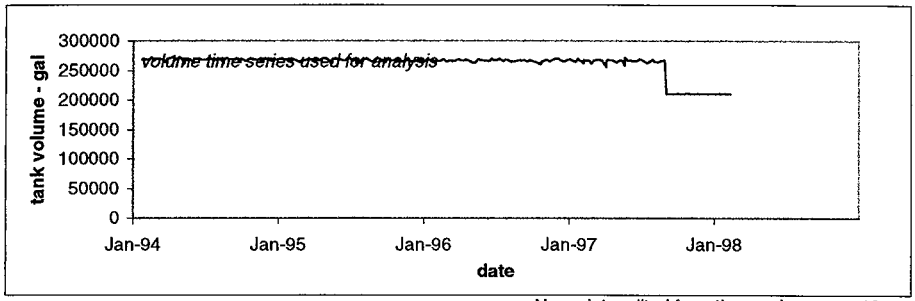
Threshold, T: -0.67 gal/h

Min. Detectable Leak: -1.35 gal/h

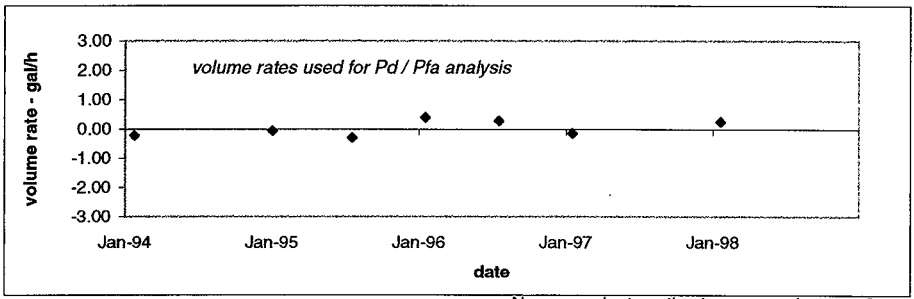
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **TX-118** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 10



No. avg. vol rate estimates removed = 2

N = 7

During the analysis period, the average volume rate = 0.03 gal/h

The standard deviation of the volume rate estimates = 0.27 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.52 gal/h

Min. Detectable Leak: -1.05 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

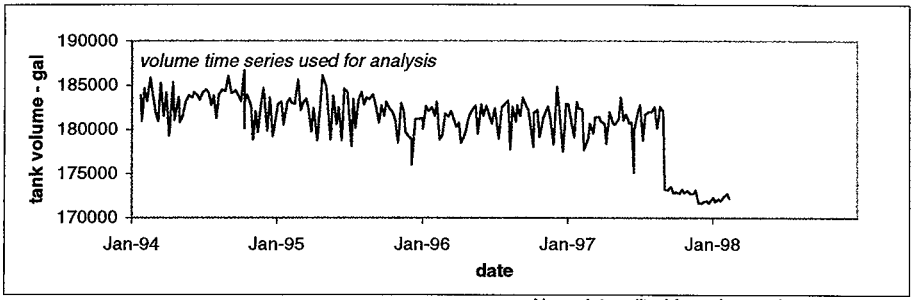
Threshold, T: -0.85 gal/h

Min. Detectable Leak: -1.69 gal/h

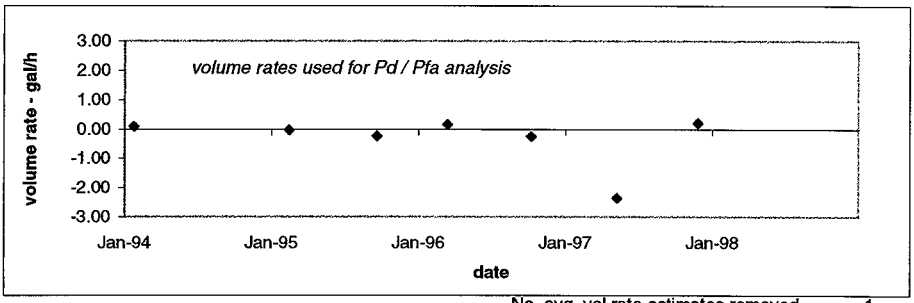
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **TY-103** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 5



No. avg. vol rate estimates removed = 1

N = 7

During the analysis period, the average volume rate = -0.35 gal/h

The standard deviation of the volume rate estimates = 0.91 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -1.76 gal/h

Min. Detectable Leak: -3.52 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

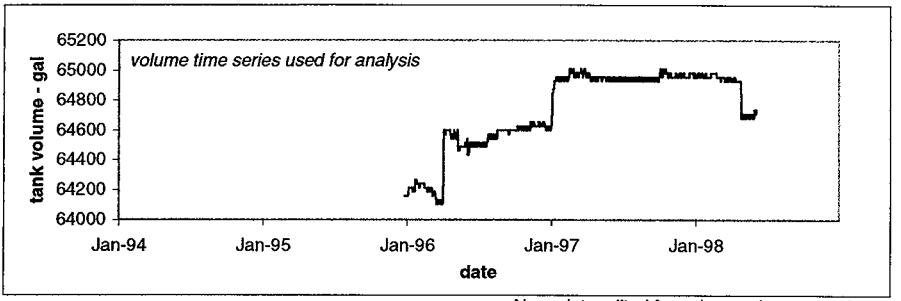
Threshold, T: -2.85 gal/h

Min. Detectable Leak: -5.69 gal/h

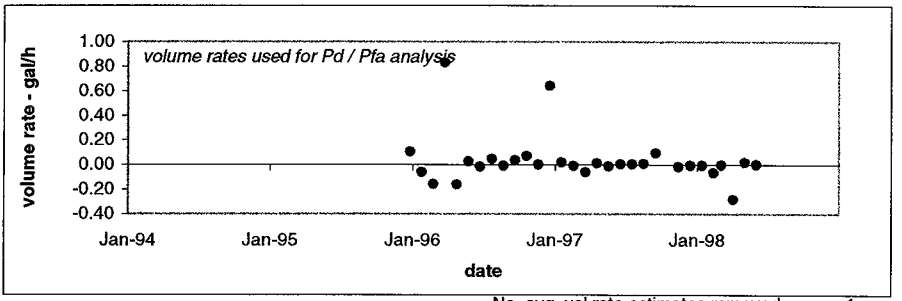
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **TY-104** Data is from sensor type: **Auto ENRAF**



No. points edited from time series = 2



No. avg. vol rate estimates removed = 1

N = 29

During the analysis period, the average volume rate = 0.04 gal/h

The standard deviation of the volume rate estimates = 0.21 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.36 gal/h

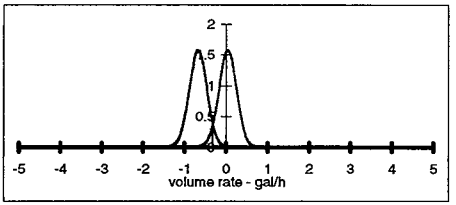
Min. Detectable Leak: -0.71 gal/h

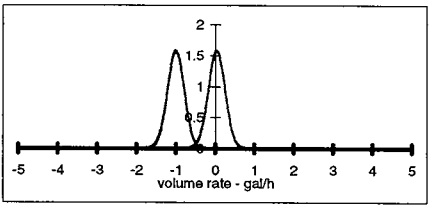
For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.52 gal/h

Min. Detectable Leak: -1.04 gal/h

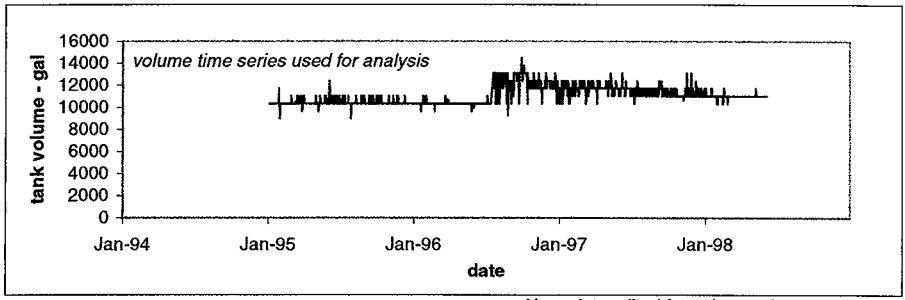




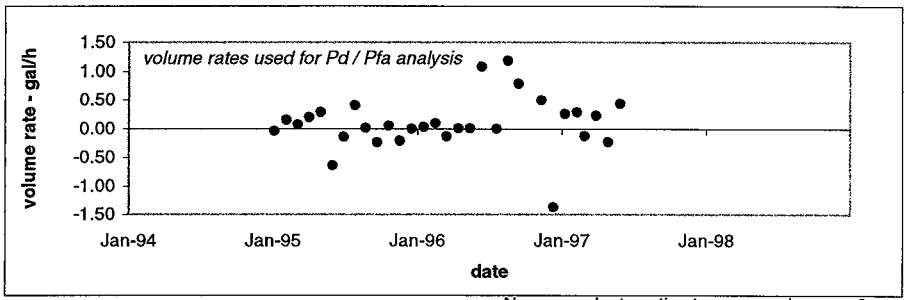
For this data, a threshold= -0.66 gal/h will detect a tank release of 1.04 gal/h at a Pd = 95%

The corresponding Pfa is 0.64%

Data File: **U-101** Data is from sensor type: **Manual Tape**



No. points edited from time series = 35



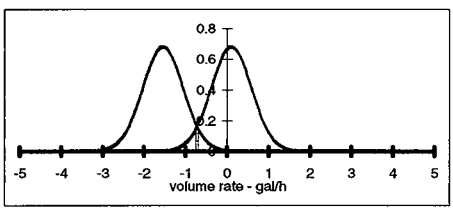
No. avg. vol rate estimates removed = 2

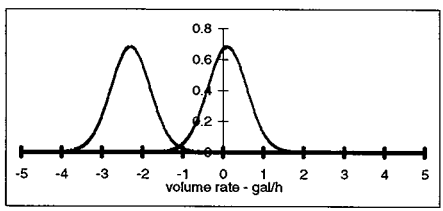
N = 28

During the analysis period, the average volume rate = 0.10 gal/h
The standard deviation of the volume rate estimates = 0.48 gal/h

For Pd / Pfa = 95% / 5%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -0.82 gal/h
Min. Detectable Leak: -1.65 gal/h

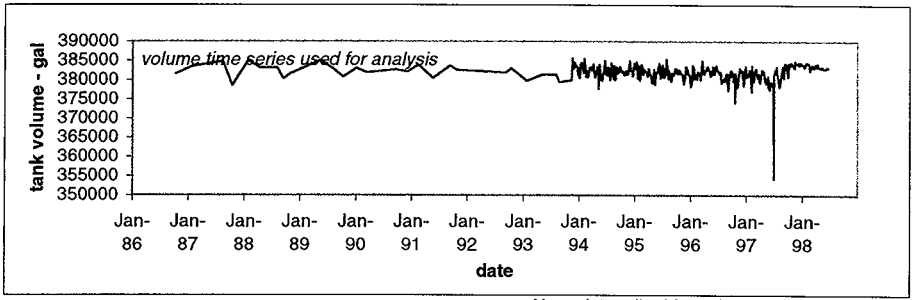
For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -1.20 gal/h
Min. Detectable Leak: -2.40 gal/h



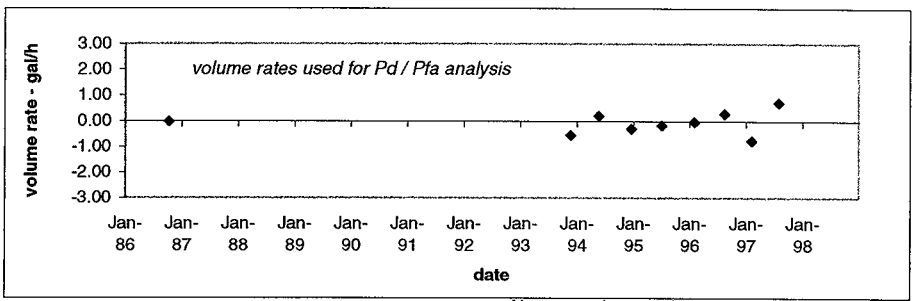


For this data, a threshold= -1.51 gal/h will detect a tank release of 2.40 gal/h at a Pd = 95%
The corresponding Pfa is 0.27%

Data File: **U-102** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 7



No. avg. vol rate estimates removed = 1
N = 9

During the analysis period, the average volume rate = -0.08 gal/h
The standard deviation of the volume rate estimates = 0.45 gal/h

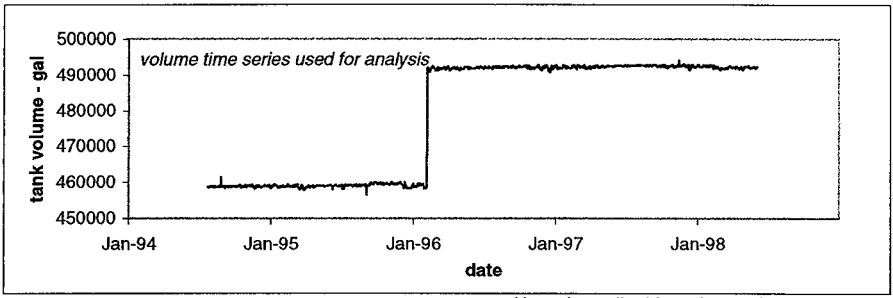
For Pd / Pfa = 95% / 5%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -0.83 gal/h
Min. Detectable Leak: -1.66 gal/h

For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -1.29 gal/h
Min. Detectable Leak: -2.59 gal/h

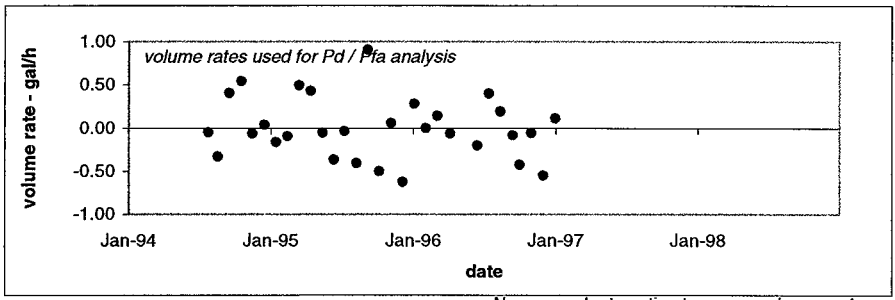
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **U-103** Data is from sensor type: **Manual ENRAF**



No. points edited from time series = 10



No. avg. vol rate estimates removed = 1

N = 29

During the analysis period, the average volume rate = 0.00 gal/h

The standard deviation of the volume rate estimates = 0.36 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.61 gal/h

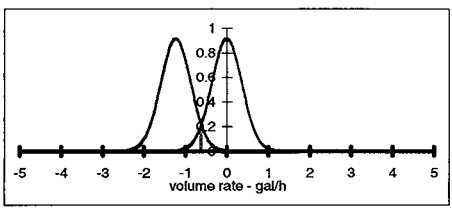
Min. Detectable Leak: -1.23 gal/h

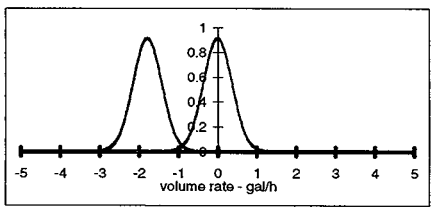
For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.89 gal/h

Min. Detectable Leak: -1.78 gal/h

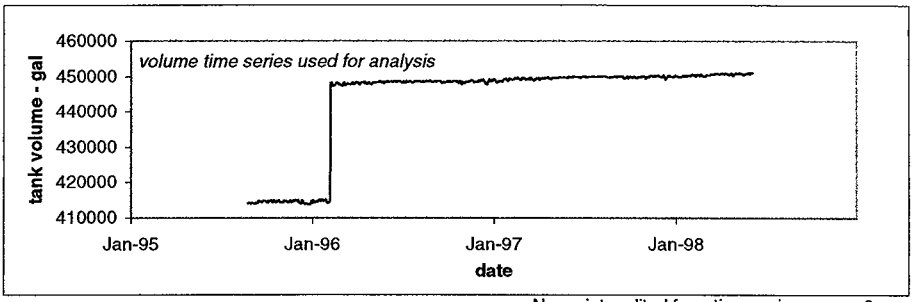




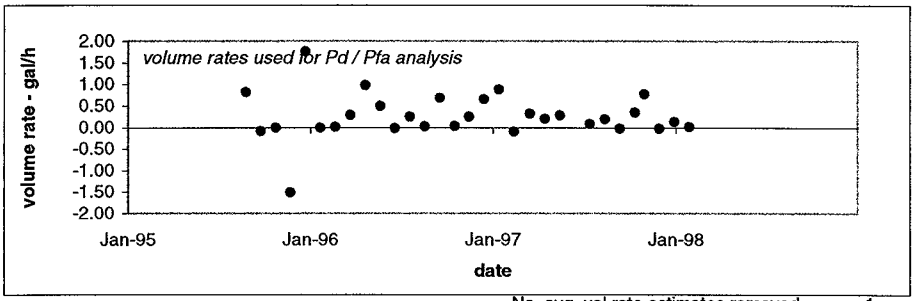
For this data, a threshold= -1.20 gal/h will detect a tank release of 1.78 gal/h at a Pd = 95%

The corresponding Pfa is 0.38%

Data File: **U-105** Data is from sensor type: **Auto ENRAF**



No. points edited from time series = 0

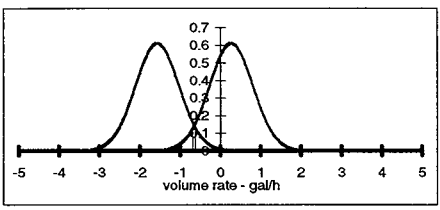


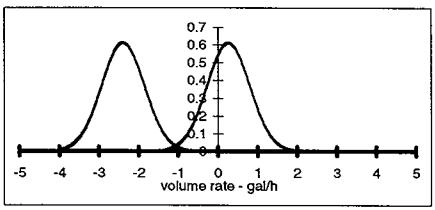
No. avg. vol rate estimates removed = 1
N = 29

During the analysis period, the average volume rate = 0.27 gal/h
The standard deviation of the volume rate estimates = 0.54 gal/h

For Pd / Pfa = 95% / 5%:
The mean volume rate is NOT equivalent to 0 gal/h
Threshold, T: -0.92 gal/h
Min. Detectable Leak: -1.83 gal/h

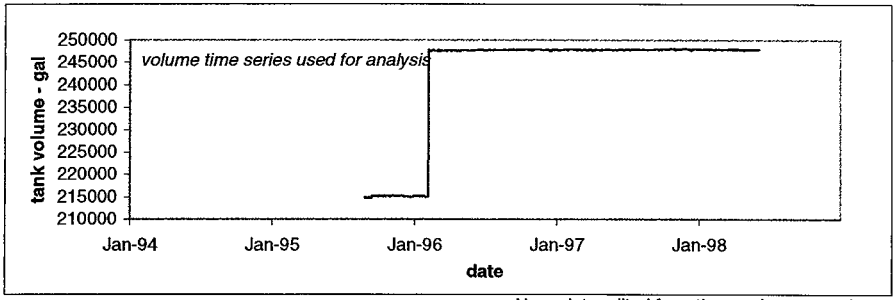
For Pd / Pfa = 99% / 1%:
The mean volume rate is NOT equivalent to 0 gal/h
Threshold, T: -1.33 gal/h
Min. Detectable Leak: -2.66 gal/h



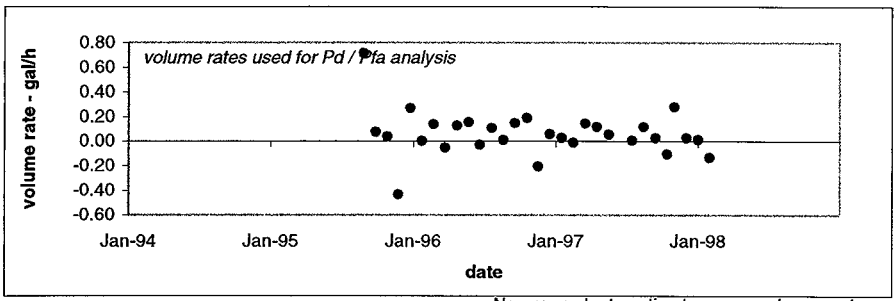


For this data, a threshold= -1.52 gal/h will detect a tank release of 2.66 gal/h at a Pd = 95%
The corresponding Pfa is 0.25%

Data File: **U-106** Data is from sensor type: **Auto ENRAF**



No. points edited from time series = 0



No. avg. vol rate estimates removed = 1

N = 29

During the analysis period, the average volume rate = 0.06 gal/h

The standard deviation of the volume rate estimates = 0.19 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is NOT equivalent to 0 gal/h

Threshold, T: -0.32 gal/h

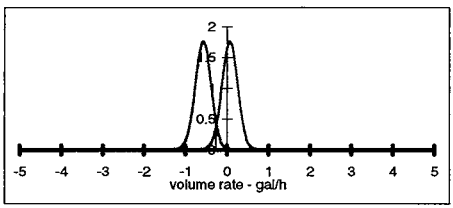
Min. Detectable Leak: -0.64 gal/h

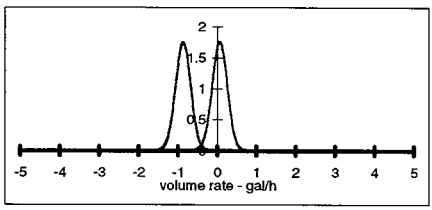
For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.46 gal/h

Min. Detectable Leak: -0.93 gal/h

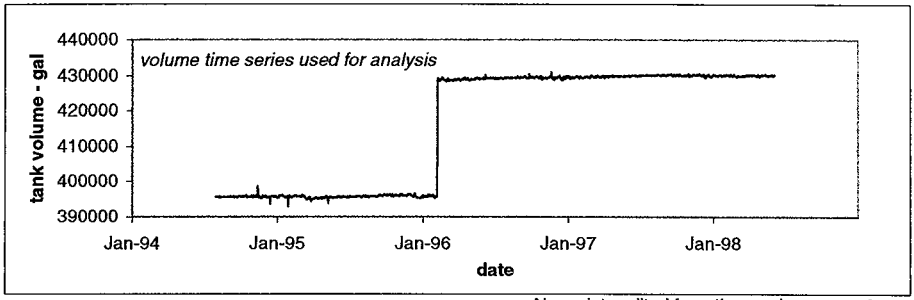




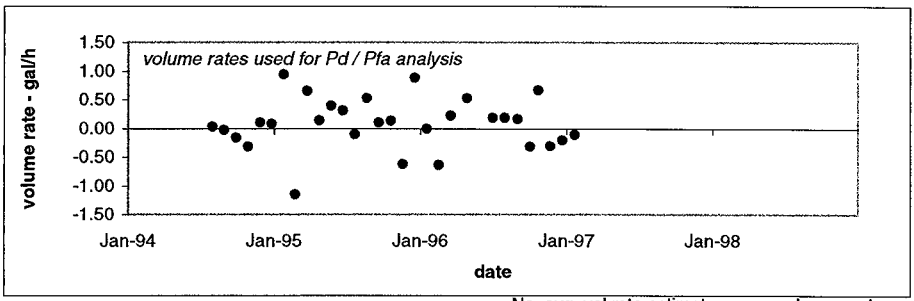
For this data, a threshold= -0.57 gal/h will detect a tank release of 0.93 gal/h at a Pd = 95%

The corresponding Pfa is 0.61%

Data File: **U-107** Data is from sensor type: **Manual ENRAF**



No. points edited from time series = 8



No. avg. vol rate estimates removed = 1

N = 29

During the analysis period, the average volume rate = 0.08 gal/h

The standard deviation of the volume rate estimates = 0.46 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.78 gal/h

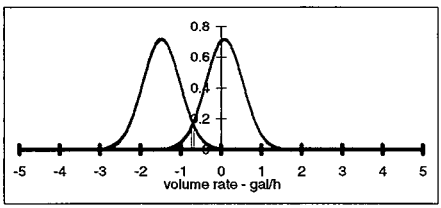
Min. Detectable Leak: -1.56 gal/h

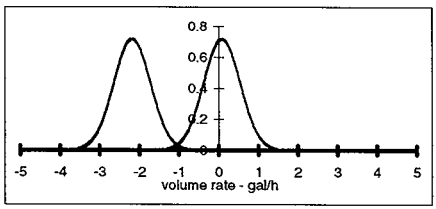
For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -1.13 gal/h

Min. Detectable Leak: -2.26 gal/h

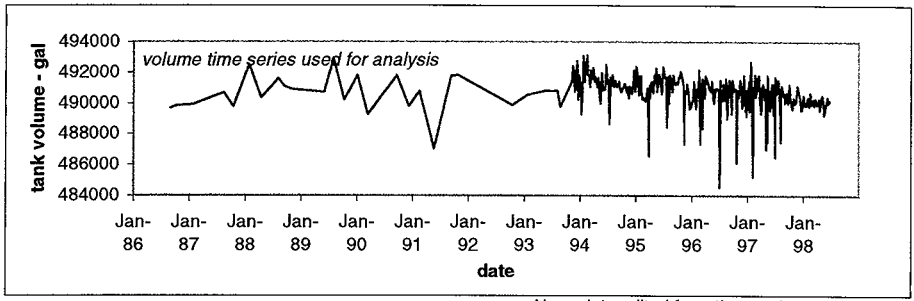




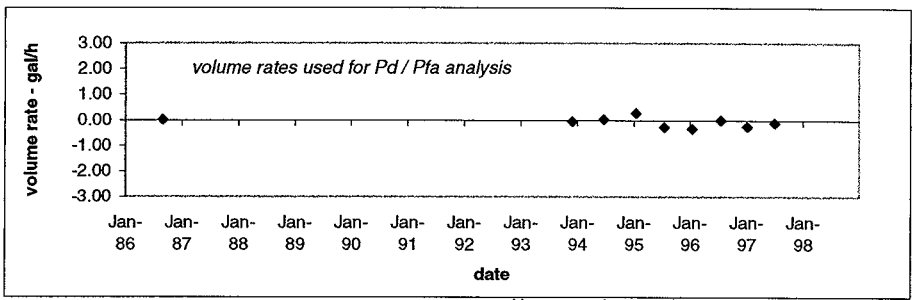
For this data, a threshold= -1.44 gal/h will detect a tank release of 2.26 gal/h at a Pd = 95%

The corresponding Pfa is 0.29%

Data File: **U-108** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 5



No. avg. vol rate estimates removed = 1

N = 9

During the analysis period, the average volume rate = -0.08 gal/h

The standard deviation of the volume rate estimates = 0.19 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.35 gal/h

Min. Detectable Leak: -0.71 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

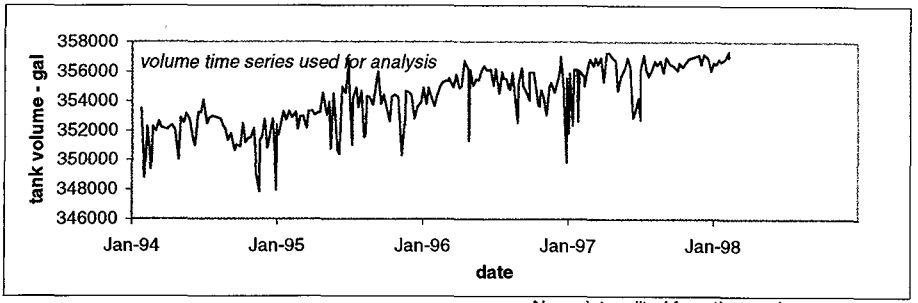
Threshold, T: -0.55 gal/h

Min. Detectable Leak: -1.10 gal/h

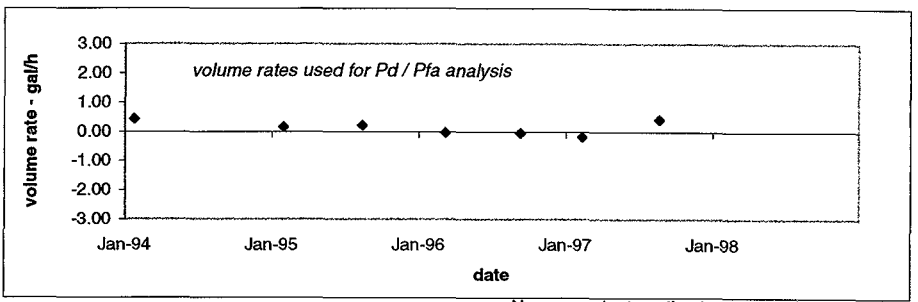
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **U-111** Data is from sensor type: **NEUTRON ILL**



No. points edited from time series = 8



No. avg. vol rate estimates removed = 1

N = 7

During the analysis period, the average volume rate = 0.13 gal/h

The standard deviation of the volume rate estimates = 0.24 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.46 gal/h

Min. Detectable Leak: -0.92 gal/h

For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

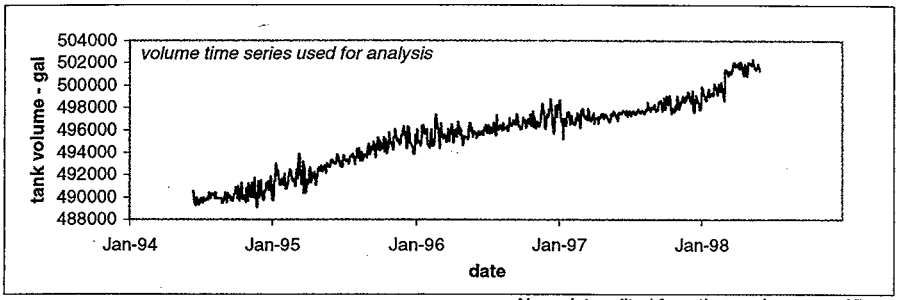
Threshold, T: -0.74 gal/h

Min. Detectable Leak: -1.49 gal/h

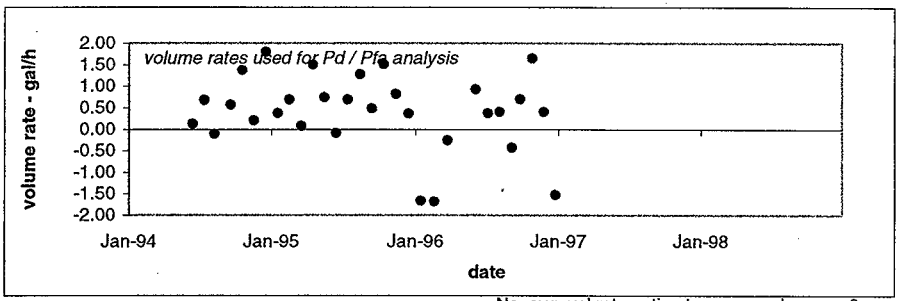
Gaussian Plots Not Representative
Due to small N....

Gaussian Plots Not Representative
Due to small N....

Data File: **S-106** Data is from sensor type: **Manual ENRAF**



No. points edited from time series = 25

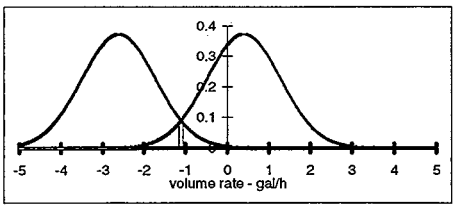


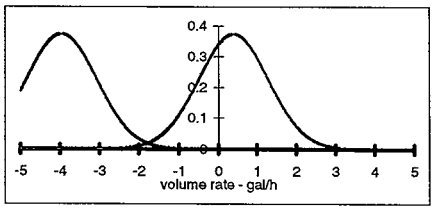
No. avg. vol rate estimates removed = 0
N = 30

During the analysis period, the average volume rate = 0.40 gal/h
The standard deviation of the volume rate estimates = 0.88 gal/h

For Pd / Pfa = 95% / 5%:
The mean volume rate is NOT equivalent to 0 gal/h
Threshold, T: -1.50 gal/h
Min. Detectable Leak: -3.00 gal/h

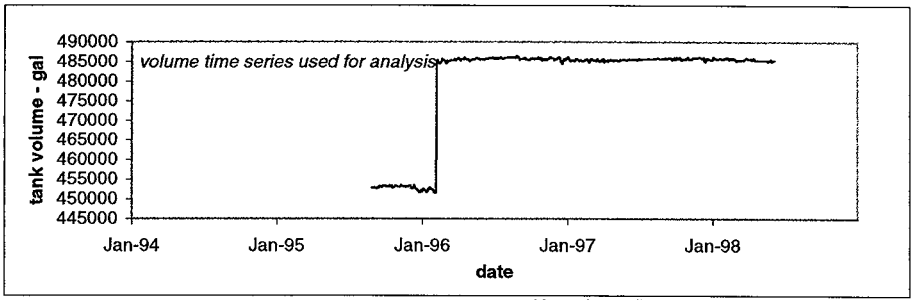
For Pd / Pfa = 99% / 1%:
The mean volume rate is equivalent to 0 gal/h
Threshold, T: -2.18 gal/h
Min. Detectable Leak: -4.35 gal/h



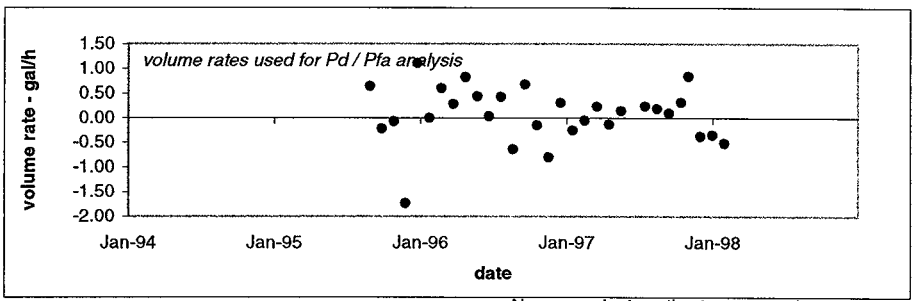


For this data, a threshold= 5.00 gal/h will detect a tank release of 4.35 gal/h at a Pd = 95%
The corresponding Pfa is 0.00%

Data File: **U-109** Data is from sensor type: **Auto ENRAF**



No. points edited from time series = 2



No. avg. vol rate estimates removed = 1

N = 29

During the analysis period, the average volume rate = 0.07 gal/h

The standard deviation of the volume rate estimates = 0.58 gal/h

For Pd / Pfa = 95% / 5%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -0.98 gal/h

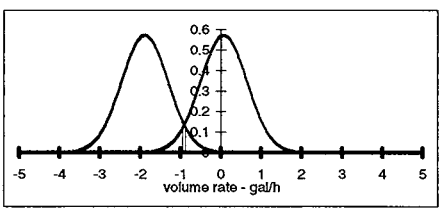
Min. Detectable Leak: -1.96 gal/h

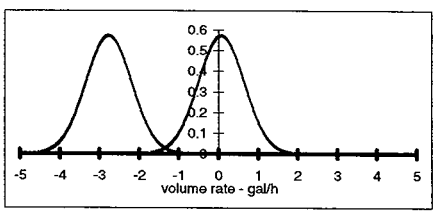
For Pd / Pfa = 99% / 1%:

The mean volume rate is equivalent to 0 gal/h

Threshold, T: -1.42 gal/h

Min. Detectable Leak: -2.84 gal/h

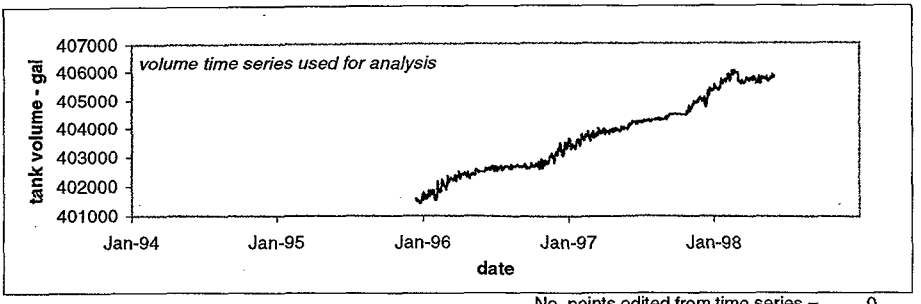




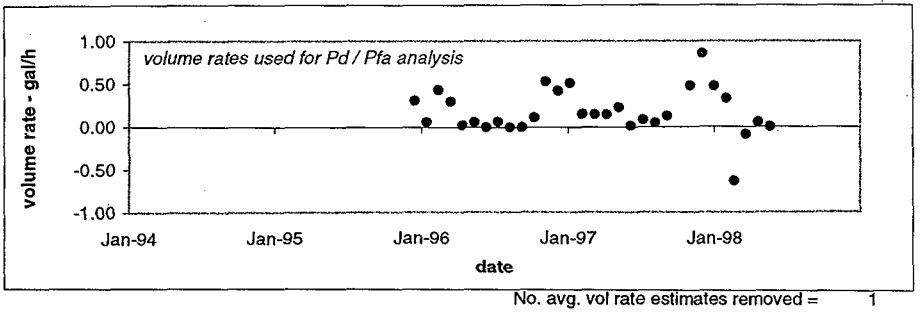
For this data, a threshold= -1.83 gal/h will detect a tank release of 2.84 gal/h at a Pd = 95%

The corresponding Pfa is 0.24%

Data File: **S-107** Data is from sensor type: **Auto ENRAF**



No. points edited from time series = 0

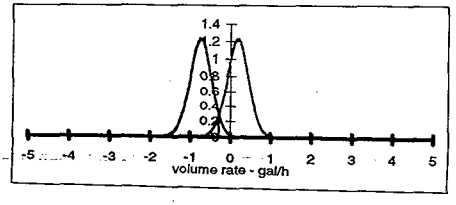


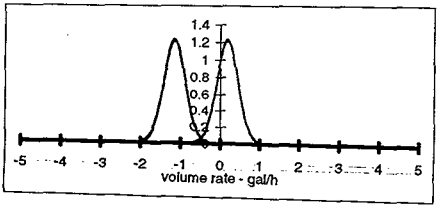
No. avg. vol rate estimates removed = 1
N = 29

During the analysis period, the average volume rate = 0.18 gal/h
The standard deviation of the volume rate estimates = 0.27 gal/h

For Pd / Pfa = 95% / 5%:
The mean volume rate is NOT equivalent to 0 gal/h
Threshold, T: -0.46 gal/h
Min. Detectable Leak: -0.92 gal/h

For Pd / Pfa = 99% / 1%:
The mean volume rate is NOT equivalent to 0 gal/h
Threshold, T: -0.67 gal/h
Min. Detectable Leak: -1.33 gal/h





For this data, a threshold= -0.72 gal/h will detect a tank release of 1.33 gal/h at a Pd = 95%
The corresponding Pfa is 0.46%

Appendix F

Calculation of Potential Leaks

Tank	Tank Integrity	Stabilization Status	Tank volume (Kgal)	Total waste (Kgal)	Current leak volume estimate (Kgal)	Baseline retrieval time (days)	Primary level instrument	Mimimum detectable leak* (gal/h)	Maximum potential leak volume (Kgal)
A-101 (T, H, O)	SOUND	/PI	1000	953	0	570	LOW	3.83	52
A-102 (T)	SOUND	IS/PI	1000	41	0	123	ENRAF	No Data	No Data
A-103 (T)	ASMD LKR	IS/II	1000	371	5.5	295	ENRAF	2.00	14
A-104 (T)	ASMD LKR	IS/II	1000	28	2.5	104	No Data	No Data	No Data
A-105	ASMD LKR	IS/II	1000	19	277	84	No Data	No Data	No Data
A-106 (T)	SOUND	IS/II	1000	125	0	179	LOW	No Data	No Data
AX-101 (T, H)	SOUND	/PI	1000	748	0	473	LOW	No Data	No Data
AX-102 (T, H)	ASMD LKR	IS/II	1000	39	3	121	No Data	No Data	No Data
AX-103 (H)	SOUND	IS/II	1000	112	0	172	LOW	No Data	No Data
AX-104 (T)	ASMD LKR	IS/II	1000	7	0	36	No Data	No Data	No Data
B-101 (T)	ASMD LKR	IS/II	500	113	0	112	No Data	No Data	No Data
B-102 (T)	SOUND	IS/II	500	32	0	72	ENRAF	0.37	1
B-103 (T)	ASMD LKR	IS/II	500	59	0	87	No Data	No Data	No Data
B-104	SOUND	IS/II	500	371	0	234	ENRAF	No Data	No Data
B-105	ASMD LKR	IS/II	500	306	0	204	LOW	1.85	9
B-106	SOUND	IS/II	500	117	0	114	ENRAF	No Data	No Data
B-107	ASMD LKR	IS/II	500	165	8	137	No Data	No Data	No Data
B-108	SOUND	IS/II	500	94	0	103	LOW	No Data	No Data
B-109	SOUND	IS/II	500	127	0	119	No Data	No Data	No Data
B-110 (T)	ASMD LKR	IS/II	500	246	10	175	LOW	1.49	6
B-111	ASMD LKR	IS/II	500	237	0	171	LOW	1.45	6
B-112 (T)	ASMD LKR	IS/II	500	33	2	73	ENRAF	1.05	2
B-201	ASMD LKR	IS/II	55	29	1.2	19	No Data	No Data	No Data
B-202 (T)	SOUND	IS/II	55	27	0	18	No Data	No Data	No Data
B-203	ASMD LKR	IS/II	55	51	0.3	29	No Data	No Data	No Data
B-204	ASMD LKR	IS/II	55	50	0.4	29	No Data	No Data	No Data
BX-101 (T)	ASMD LKR	IS/II	500	43	0	79	No Data	No Data	No Data
BX-102 (T)	ASMD LKR	IS/II	500	96	70	104	No Data	No Data	No Data
BX-103	SOUND	IS/II	500	68	0	91	ENRAF	0.58	1
BX-104 (T)	SOUND	IS/II	500	99	0	106	ENRAF	0.62	2
BX-105 (T)	SOUND	IS/II	500	51	0	83	ENRAF	1.14	2
BX-106 (T)	SOUND	/PI	500	38	0	76	No Data	No Data	No Data
BX-107	SOUND	IS/PI	500	345	0	222	No Data	No Data	No Data
BX-108	ASMD LKR	IS/II	500	26	2.5	67	No Data	No Data	No Data
BX-109	SOUND	IS/PI	500	193	0	150	No Data	No Data	No Data
BX-110	ASMD LKR	IS/PI	500	207	0	157	ENRAF	1.02	4
BX-111	ASMD LKR	/PI	500	162	0	136	No Data	No Data	No Data
BX-112	SOUND	IS/PI	500	165	0	137	No Data	No Data	No Data

Tank	Tank Integrity	Stabilization Status	Tank volume (Kgal)	Total waste (Kgal)	Current leak volume estimate (Kgal)	Baseline retrieval time (days)	Primary level instrument	Mimimum detectable leak* (gal/h)	Maximum potential leak volume (Kgal)
BY-101	SOUND	IS/II	750	387	0	272	LOW	8.74	57
BY-102	SOUND	/PI	750	277	0	220	LOW	15.80	83
BY-103 (T, Fe)	ASMD LKR	/PI	750	414	5	285	LOW	3.81	26
BY-104 (T, Fe)	SOUND	IS/II	750	406	0	281	LOW	1.07	7
BY-105 (T, Fe)	ASMD LKR	/PI	750	503	0	327	LOW	2.00	16
BY-106	ASMD LKR	/PI	750	642	0	393	LOW	9.37	88
BY-107 (Fe)	ASMD LKR	IS/II	750	266	15.1	215	LOW	3.28	17
BY-108 (Fe)	ASMD LKR	IS/II	750	228	5	197	No Data	No Data	No Data
BY-109	SOUND	/PI	750	290	0	226	LOW	8.28	45
BY-110 (Fe)	SOUND	IS/II	750	398	0	277	LOW	2.82	19
BY-111 (Fe)	SOUND	IS/II	750	459	0	306	No Data	No Data	No Data
BY-112 (Fe)	SOUND	IS/II	750	291	0	227	LOW	3.05	17
C-101 (T)	ASMD LKR	IS/II	500	88	20	101	No Data	No Data	No Data
C-102 (T, O)	SOUND	IS/IP	500	316	0	208	No Data	No Data	No Data
C-103 (T, O)	SOUND	/PI	500	195	0	151	ENRAF	2.59	9
C-104 (T)	SOUND	IS/II	500	295	0	198	No Data	No Data	No Data
C-105 (Sn, T)	SOUND	/PI	500	134	0	122	No Data	No Data	No Data
C-106 (T, HL)	SOUND	/PI	500	229	0	167	ENRAF	22.10	89
C-107 (T)	SOUND	/PI	500	237	0	171	No Data	No Data	No Data
C-108 (T, Fe)	SOUND	IS/II	500	66	0	90	No Data	No Data	No Data
C-109 (Fe)	SOUND	IS/II	500	66	0	90	No Data	No Data	No Data
C-110 (T)	ASMD LKR	/PI	500	178	2	143	No Data	No Data	No Data
C-111(T)	ASMD LKR	IS/II	500	57	5.5	86	No Data	No Data	No Data
C-112 (T)	SOUND	IS/PI	500	104	0	108	No Data	No Data	No Data
C-201	ASMD LKR	IS/II	55	2	0.55	5	No Data	No Data	No Data
C-202	ASMD LKR	IS/II	55	1	0.45	4	No Data	No Data	No Data
C-203	ASMD LKR	IS/II	55	5	0.4	7	No Data	No Data	No Data
C-204	ASMD LKR	IS/II	55	3	0.35	6	No Data	No Data	No Data
S-101 (T)	SOUND	/PI	750	427	0	291	ENRAF	1.17	8
S-102 (H,O)	SOUND	/PI	750	549	0	349	LOW	2.41	20
S-103	SOUND	/PI	750	248	0	206	ENRAF	2.52	12
S-104 (T)	ASMD LKR	IS/II	750	294	24	228	LOW	3.10	17
S-105	SOUND	IS/II	750	456	0	305	LOW	1.25	9
S-106	SOUND	/PI	750	479	0	316	ENRAF	3.00	23
S-107 (T)	SOUND	/PI	750	376	0	267	ENRAF	0.92	6
S-108	SOUND	/PI	750	450	0	302	LOW	2.29	17
S-109	SOUND	/PI	750	568	0	358	LOW	2.13	18

Tank	Tank Integrity	Stabilization Status	Tank volume (Kgal)	Total waste (Kgal)	Current leak volume estimate (Kgal)	Baseline retrieval time (days)	Primary level instrument	Mimimum detectable leak* (gal/h)	Maximum potential leak volume (Kgal)
S-110	SOUND	/PI	750	390	0	274	LOW	2.81	18
S-111 (H,O)	SOUND	/PI	750	540	0	345	ENRAF	2.28	19
S-112 (T, H)	SOUND	/PI	750	523	0	337	LOW	0.89	7
SX-101 (T)	SOUND	/PI	1000	456	0	335	LOW	11.88	96
SX-102 (H)	SOUND	/PI	1000	543	0	376	LOW	3.34	30
SX-103 (T, H, O)	SOUND	/PI	1000	652	0	428	LOW	0.82	8
SX-104 (T)	ASMD LKR	/PI	1000	614	6	410	LOW	7.20	71
SX-105 (T, H)	SOUND	/PI	1000	683	0	443	LOW	1.68	18
SX-106 (T, H)	SOUND	/PI	1000	538	0	374	ENRAF	2.97	27
SX-107 (T)	ASMD LKR	IS/II	1000	104	5	169	No Data	No Data	No Data
SX-108 (T)	ASMD LKR	IS/II	1000	87	35	160	No Data	No Data	No Data
SX-109 (T)	ASMD LKR	IS/II	1000	244	10	235	No Data	No Data	No Data
SX-110 (T)	ASMD LKR	IS/II	1000	62	5.5	144	No Data	No Data	No Data
SX-111 (T)	ASMD LKR	IS/II	1000	125	2	179	No Data	No Data	No Data
SX-112 (T)	ASMD LKR	IS/II	1000	92	30	163	No Data	No Data	No Data
SX-113 (T)	ASMD LKR	IS/II	1000	26	15	100	No Data	No Data	No Data
SX-114 (T)	ASMD LKR	IS/II	1000	181	0	205	No Data	No Data	No Data
SX-115 (T)	ASMD LKR	IS/II	1000	12	50	61	No Data	No Data	No Data
T-101 (T)	ASMD LKR	IS/PI	500	102	7.5	107	No Data	No Data	No Data
T-102	SOUND	IS/II	500	32	0	72	ENRAF	0.81	1
T-103	ASMD LKR	IS/II	500	27	1	68	No Data	No Data	No Data
T-104	SOUND	/PI	500	343	0	221	LOW	2.96	16
T-105 (T)	SOUND	IS/II	500	98	0	105	No Data	No Data	No Data
T-106 (T)	ASMD LKR	IS/II	500	21	115	62	No Data	No Data	No Data
T-107	ASMD LKR	/PI	500	173	0	141	No Data	No Data	No Data
T-108	ASMD LKR	IS/II	500	44	1	80	No Data	No Data	No Data
T-109	ASMD LKR	IS/II	500	58	1	86	No Data	No Data	No Data
T-110 (T, H)	SOUND	/PI	500	369	0	233	LOW	1.76	10
T-111	ASMD LKR	/PI	500	446	1	270	LOW	0.83	5
T-112 (T)	SOUND	IS/II	500	67	0	91	No Data	No Data	No Data
T-201	SOUND	IS/II	55	29	0	19	No Data	No Data	No Data
T-202	SOUND	IS/II	55	21	0	15	No Data	No Data	No Data
T-203	SOUND	IS/II	55	35	0	22	No Data	No Data	No Data
T-204	SOUND	IS/II	55	38	0	23	No Data	No Data	No Data
TX-101	SOUND	IS/II	750	87	0	130	ENRAF	0.98	3
TX-102	SOUND	IS/II	750	217	0	192	LOW	1.20	6
TX-103	SOUND	IS/II	750	157	0	163	No Data	No Data	No Data
TX-104	SOUND	IS/II	750	65	0	120	No Data	No Data	No Data

Tank	Tank Integrity	Stabilization Status	Tank volume (Kgal)	Total waste (Kgal)	Current leak volume estimate (Kgal)	Baseline retrieval time (days)	Primary level instrument	Mimimum detectable leak* (gal/h)	Maximum potential leak volume (Kgal)
TX-105 (O)	ASMD LKR	IS/II	750	609	0	377	No Data	No Data	No Data
TX-106	SOUND	IS/II	750	453	0	303	LOW	3.04	22
TX-107	ASMD LKR	IS/II	750	36	2.5	98	No Data	No Data	No Data
TX-108	SOUND	IS/II	750	134	0	153	No Data	No Data	No Data
TX-109 (T)	SOUND	IS/II	750	384	0	271	LOW	1.38	9
TX-110	ASMD LKR	IS/II	750	462	0	308	LOW	2.04	15
TX-111	SOUND	IS/II	750	370	0	264	No Data	No Data	No Data
TX-112	SOUND	IS/II	750	649	0	396	LOW	2.08	20
TX-113	ASMD LKR	IS/II	750	607	0	376	LOW	1.11	10
TX-114	ASMD LKR	IS/II	750	535	0	342	LOW	1.61	13
TX-115	ASMD LKR	IS/II	750	640	0	392	LOW	1.48	14
TX-116	ASMD LKR	IS/II	750	631	0	388	No Data	No Data	No Data
TX-117	ASMD LKR	IS/II	750	626	0	385	LOW	0.81	7
TX-118 (T)	SOUND	IS/II	750	347	0	253	LOW	1.05	6
TY-101 (T)	ASMD LKR	IS/II	750	118	1	145	No Data	No Data	No Data
TY-102	SOUND	IS/II	750	64	0	119	No Data	No Data	No Data
TY-103 (T)	ASMD LKR	IS/II	750	162	3	166	LOW	3.52	14
TY-104 (O)	ASMD LKR	IS/II	750	46	1.4	107	ENRAF	0.71	2
TY-105	ASMD LKR	IS/II	750	231	35	198	No Data	No Data	No Data
TY-106	ASMD LKR	IS/II	750	17	20	70	No Data	No Data	No Data
U-101	ASMD LKR	IS/II	500	25	30	66	ENRAF	1.65	3
U-102	SOUND	/PI	500	374	0	236	No Data	No Data	No Data
U-103 (H,O)	SOUND	/PI	500	468	0	280	ENRAF	1.23	8
U-104	ASMD LKR	IS/II	500	122	55	117	No Data	No Data	No Data
U-105 (H,O)	SOUND	/PI	500	418	0	257	ENRAF	1.83	11
U-106 (O)	SOUND	/PI	500	226	0	166	ENRAF	0.64	3
U-107 (T, O)	SOUND	/PI	500	406	0	251	ENRAF	1.56	9
U-108 (H)	SOUND	/PI	500	468	0	280	No Data	No Data	No Data
U-109 (H)	SOUND	/PI	500	463	0	278	ENRAF	1.96	13
U-110 (T)	ASMD LKR	IS/PI	500	186	8.1	147	No Data	No Data	No Data
U-111 (O)	SOUND	/PI	500	329	0	215	LOW	0.92	5
U-112	ASMD LKR	IS/II	500	49	8.5	82	No Data	No Data	No Data
U-201	SOUND	IS/II	55	5	0	7	No Data	No Data	No Data
U-202 (O)	SOUND	IS/II	55	5	0	7	No Data	No Data	No Data
U-203 (O)	SOUND	IS/II	55	3	0	6	No Data	No Data	No Data
U-204 (O)	SOUND	IS/II	55	3	0	6	No Data	No Data	No Data

* at P_D = 95%