Sta. 4 S

(21) JUN 24 2003

ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT 628470

2. To: (Receiving Organization) Distribution	3. From: (Originating Organization) DST Integrity Program	4. Related EDT No.: n/a
5. Proj./Prog./Dept./Div.: DSTIP & WFO Projects	6. Design Authority/Design Agent/Cog. Engr.: Gary P. Duncan	7. Purchase Order No.: n/a
8. Originator Remarks: This EDT transmits the Engineering Evaluation of Double-Shell Tank Vapor Space Condensation and Annulus Relative Humidity for review and approval.		9. Equip./Component No.: n/a
		10. System/Bldg./Facility: n/a
		12. Major Assm. Dwg. No.: n/a
11. Receiver Remarks: 11A. Design Baseline Document? ☐ Yes ☒ No		13. Permit/Permit Application No.: n/a
No USQ required AM 6/19/03		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	RPP-12422, Rev. 0	n/a	1	Engineering Evaluation of Double-Shell Tank Vapor Space Condensation and Annulus Relative Humidity	ESQ	1		

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) MSI
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DISTRIBUTION SHEET

To	From	Page 1 of 1
Distribution	DST Integrity Program	Date 1/16/03
Project Title/Work Order		EDT No. 628470
Engineering Evaluation of Double-Shell Tank Vapor Space Condensation and Annulus Relative Humidity		ECN No.

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
Aardal, P. K.	S5-12	x			
Adams, W. L.	S5-07	x			
Anantatmula, R. P.	R3-76	x			
Becker, D. L.	R3-76	x			
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Carothers, K. G.	R2-11	x			
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Schroeder, J. R.	R3-76	x			
Tardiff, G. R.	S5-05	x			
Tate, D. D.	L6-38	x			

ENGINEERING EVALUATION OF DOUBLE-SHELL TANK VAPOR SPACE CONDENSATION AND ANNULUS RELATIVE HUMIDITY

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U.S. Department of Energy Contract DE-AC27-99RL14047

EDT/ECN: 628470 UC: 2000
Cost Center: 7P100 Charge Code: 501120
B&R Code: Total Pages: 135

Key Words: double-shell tank, annulus ventilation, vapor space, relative humidity, condensation, dew point

Abstract: An engineering evaluation of psychrometric conditions within the primary tank vapor space and the wall annulus of the twenty-eight double-shell tanks was conducted by the Hanford double-shell tank integrity project. The purpose of the evaluation was to identify conditions which can promote condensation on the primary liner surface and identify tanks whose wall annulus region exceeds recommended relative humidity limits.

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6/23/03
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JUN 24 2003
DATE:
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Date Published
March 2003

CH2MHILL
Hanford Group, Inc.

Issued by

CH2M HILL Hanford Group, Inc.
Richland, Washington

For the

U.S. DEPARTMENT OF ENERGY
OFFICE OF RIVER PROTECTION
RICHLAND, WASHINGTON

ENGINEERING EVALUATION OF DOUBLE-SHELL TANK VAPOR SPACE CONDENSATION AND ANNULUS RELATIVE HUMIDITY

EXECUTIVE SUMMARY

The purpose of the Double-Shell Tank Integrity Project (DSTIP) is to ensure Double-Shell Tank (DST) system integrity throughout the Department of Energy (DOE) River Protection Project Mission which has an operational horizon of 2028. The elements of the DSTIP include:

- Assessment of DST system integrity.
- Restoration and maintenance of corrosion controls and compliance with chemical limits.
- Engineering studies and analyses supporting tank integrity and waste chemistry control.

An expert panel workshop held in May of 2001 (Bush 2001) made specific recommendations to extend the life of the DST's. The panel identified Pitting Corrosion on the primary liner surfaces, near the water line, as a potential failure mechanism. The expert panel also identified the need for proper control of Relative Humidity (RH) in the annulus space of DST's.

A workshop on Vapor Space Corrosion in nuclear waste storage tanks within the DOE complex (Lillard 2002) was conducted in March of 2002. A panel of experts reviewed vapor space corrosion issues for High Level Waste tanks. The panel recommended the evaluation of tank conditions which can promote condensation on the primary liner of the tank vapor space.

An engineering evaluation of Psychrometric conditions within the primary tank vapor space and the wall annulus of the twenty-eight DST's was conducted by the Hanford DSTIP. The purpose of the evaluation was to identify conditions which can promote condensation on the primary liner surface and identify tanks whose wall annulus region exceeds recommended relative humidity limits.

VAPOR SPACE ENGINEERING EVALUATION

The engineering evaluation of the vapor space of all twenty-eight DST's determined that condensation on the primary tank liner in the region of the dome and straight wall is expected for many of the tanks in the AN, AP and AW-Farms and a single Aging Waste Tank:

- Dome or wall condensation is expected on all the AN-Farm tanks.
- Dome condensation is expected for five AP-Farm tanks. Wall condensation is expected for only one.
- Dome condensation is expected for five AW-Farm tanks. Wall condensation expected for only one.
- No dome or wall condensation is expected for the SY-Farm.
- Wall condensation is expected for tank 241-AY-101.
- No dome or wall condensation is expected for tanks 241-AY-102 and the AZ-Farm tanks.

A preliminary mitigation evaluation was conducted for vapor space condensation. This evaluation determined that the increased flow capacity resulting from the Project W-314 (Lentsch 1999) planned upgrades to the primary ventilation systems for the AN, AP and AW-Farms will eliminate all wall or dome condensation in the vapor space. Wall condensation for tank 241-AY-101 can be eliminated by one of two methods:

- Eliminating the annulus wall bypass flow, or
- Reducing the annulus ventilation flow rate by 85%

ANNULUS RELATIVE HUMIDITY EVALUATION

The annulus relative humidity engineering evaluation was conducted for all twenty-eight DST's. The evaluation compared the predicted annulus relative humidity with the limits recommended by the expert panel workshop. The following is a summary of the results:

- Two tanks in the AN-Farm exceed the 60% relative humidity limit for short periods.
- All the tanks in the AP-Farm exceed the 60% relative humidity limit for short periods.
- Three tanks in the AW-Farm exceed the 60% relative humidity limit for short periods.
- No tanks in the SY-Farm exceed the recommended relative humidity limit.
- Tank 241-AY-101 exceeds the recommended annulus space relative humidity of 30%.
- An 85% reduction of annulus flow will reduce the relative humidity of tank 241-AY-101 below the recommended limit (minimum moisture removal must be addressed for reduced annulus flow).

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LIST OF TERMS

AWF	aging waste facility
cfm	cubic feet per minute
DST	double-shell tank
ESP	environmental simulation program
FCD	flow control device
ft	feet
GOTH-SNF	proprietary thermal-hydraulic software
gpm	gallons per minute
in.	inches
JMI	John Marvin, Inc.
OSD	operating safety document
P_{H20}	vapor pressure of water
TWINS	tank waste information retrieval system
°F	degrees Fahrenheit

1.0 INTRODUCTION

1.1 BACKGROUND

The purpose of the Double-Shell Tank Integrity Project (DSTIP) is to ensure Double-Shell Tank (DST) system integrity throughout the Department of Energy (DOE) River Protection Project Mission which has an operational horizon of 2028. The elements of the DSTIP include:

- Assessment of DST system integrity.
- Restoration and maintenance of corrosion controls and compliance with chemical limits.
- Engineering studies and analyses supporting tank integrity and waste chemistry control.

An expert panel workshop held in May of 2001 (Bush 2001) to review the Hanford DSTIP made specific recommendations to extend the life of the DST's. The panel identified Pitting Corrosion on the primary liner surfaces, near the water line, as a potential failure mechanism. The expert panel also identified the need for proper control of Relative Humidity (RH) in the annulus space of DST's. It recommended that the RH in the annulus space be maintained below 60% for tanks without significant existing corrosion and 30% for tanks with significant existing corrosion.

A workshop on Vapor Space Corrosion in nuclear waste storage tanks within the DOE complex (Lillard 2002) was conducted in March of 2002. A panel of experts reviewed vapor space corrosion issues for High Level Waste tanks. The focus of this workshop was potential corrosion above the water line of the tank vapor space. The panel recommended the evaluation of tank conditions which can promote condensation on the primary liner of the tank vapor space.

1.2 PURPOSE AND OVERVIEW

An engineering evaluation of Psychrometric conditions within the primary tank vapor space and the wall annulus of the twenty-eight DST's was conducted by the Hanford DSTIP. The purpose of the evaluation was to identify conditions which can promote condensation on the primary liner surface and identify tanks where the wall annulus region relative humidity exceeds recommended limits. The evaluations employed computer models of the twenty-eight DST's which modeled the heat and mass transfer mechanisms in the primary tank vapor space and annulus region. An evaluation of potential mitigation through ventilation system operations was also evaluated. The mitigation evaluation was intended to provide only preliminary evaluation of mitigation options. The Vapor Space Corrosion panel cautioned against implementation of quick fixes until the surface chemistry and corrosion mechanisms are better understood.

This report is intended to provide an interim status of the vapor space engineering and annulus region evaluations. Additional efforts are underway in Fiscal Year 2003 (FY03) to:

- Refine the vapor space analyses for selected tanks.

- Review available video record of the DST vapor space.
- Perform system evaluation of mitigation options, which will consider operational constraints.
- Further investigate surface chemistry and corrosion mechanisms on the primary tank liner.

The engineering evaluation methodology used for the study is described in Section 2.0, including all important tank input data and assumptions. The results of the engineering evaluation of vapor space condensation are presented in Section 3.0. Predicted vapor space dew point temperatures are compared with primary tank liner temperatures. The results of the annulus space relative humidity evaluation are presented in Section 4.0. The conclusions of the engineering study are provided in Section 5.0.

2.0 EVALUATION METHODOLOGY AND MODELS

The methodology and models used for the engineering evaluations are presented in this section. A discussion of the ventilation system information and specific tank data used for the evaluation model input are also provided.

2.1 ENGINEERING EVALUATION METHODOLOGY

There are twenty-eight Double-Shell Tanks (DSTs) at Hanford. These tanks are contained in five separate tank farms as follows:

- AN-Farm – 7 tanks
- AP-Farm – 8 tanks
- AW-Farm – 6 tanks
- SY-Farm – 3 tanks
- Aging Waste Facility (AWF)
  - 2 AY tanks
  - 2 AZ tanks

The purpose of the engineering evaluation is to investigate the Psychrometric conditions in the vapor space and wall annulus region of the twenty-eight DST's and to identify:

- Potential for condensation on the primary tank liner surface of vapor space.
- Wall annulus space relative humidity's which exceed recommended limits.

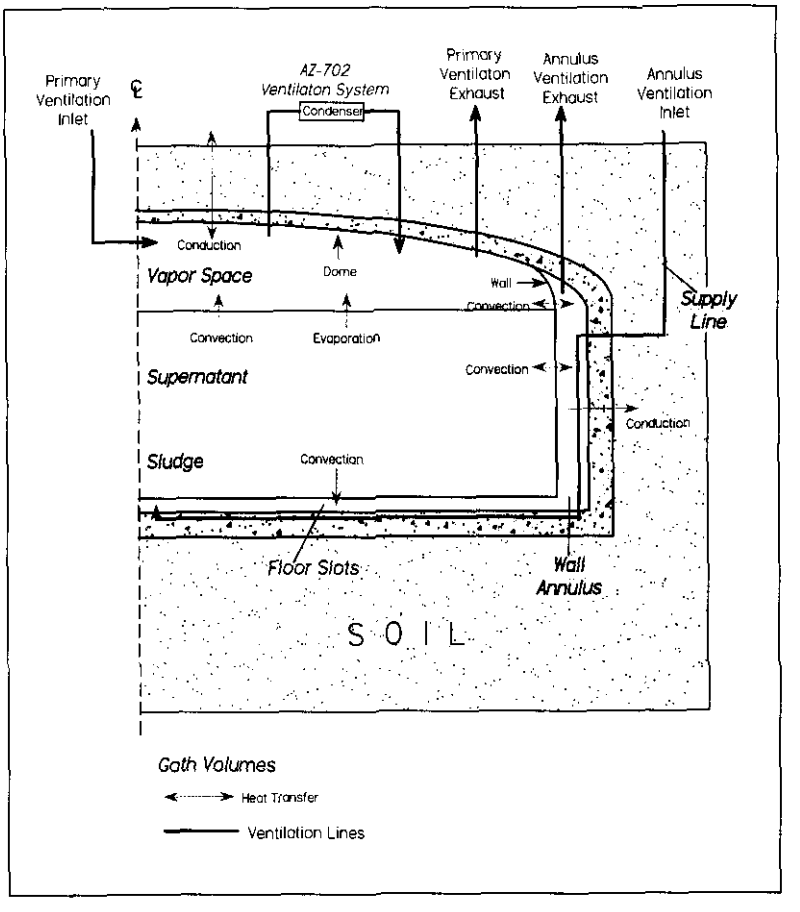
Figure 2-1 shows a schematic of a DST, related ventilation systems and important heat and mass transfer pathways. The DST is comprised of a primary tank containing both liquid and solid waste and a secondary tank surrounded by soil. The space between the primary tank wall and the secondary tank wall forms the wall annulus region. The portion of the primary tank liner surface which interfaces with both the vapor space and the wall annulus is labeled in Figure 2-1 as "wall". The portion of the primary tank liner which is surrounded by the dome soil is labeled "dome". The temperature of the wall surface is strongly affected by the annulus ventilation air stream. The temperature of the dome surface is primarily controlled by the concrete dome contacting the soil.

There are three types of ventilation system used for the twenty-eight DST's. Each DST has a primary and annulus ventilation system. The primary ventilation system removes both heat and moisture from the primary tank vapor space through the once-through flow of ambient air. The performance data for these systems is discussed in Section 2.3. The annulus ventilation system removes heat from the primary tank by heat transfer to the annulus system air stream. Heat transfer first occurs as ambient air is directed to flow slots under the primary tank liner in the floor of the tank. Heat transfer further occurs as the air stream passes through the wall annulus region in direct contact with the primary tank wall. Both the primary and annulus ventilation system can either remove or add heat to the primary tank waste dependent upon the tank waste temperatures and the ambient air temperatures. The performance data for the annulus ventilation system is discussed in Section 2.3. The four AWF have an additional ventilation system which interfaces directly with the vapor dome space. The AZ-702 ventilation system shown in Figure 2-1 removes air from the vapor space through a recirculation fan, cools the air stream and

removes moisture through the use of a condenser. Performance data for the AZ-702 system is presented in Section 2.3.

The vapor space Psychrometric conditions for the AN, AP, AW and SY tank farms can be determined by modeling the evaporation from the supernatant surface, flow of ambient air from the primary ventilation system and modeling the transfer of heat into or from the vapor space through conduction to the dome soil, heat transfer from the supernatant surface and heat transfer to or from the annulus ventilation system air stream through the primary tank wall. Evaluation of the vapor space Psychrometric conditions for the AWF must also include the condensation of vapor space moisture by the AZ-702 recirculation system.

Figure 2-1. Overview of Double-Shell Tank and Heat Transfer Pathways.



The engineering evaluations were performed through computer modeling of the dome vapor space, wall annulus region and associated heat and mass transfer. Ventilation system flow rates, ambient Psychrometric conditions and measured waste temperatures were provided as input to the computer model. The computer modeling then determined the vapor space and wall annulus Psychrometric conditions by modeling mass transfer to the vapor space from the supernatant and the transfer of heat through the heat transfer pathways shown in Figure 1-1. The evaluation model also predicted the structure surface temperatures. Vapor space condensation was evaluated by comparing the predicted dew point temperature in the vapor space to the structure

temperatures. The annulus space relative humidity was evaluated by comparing predicted annulus relative humidity to recommended relative humidity limits. A description of the engineering evaluation model is presented in Section 2.2.

2.2 ENGINEERING EVALUATION MODEL DESCRIPTION

GOTH-SNF computer program[1] was used to create a thermal-hydraulic model of the DST and associated heat and mass transfer. The computer code and evaluation model are described below.

2.2.1 *GOTH-SNF Computer Program*

GOTH-SNF is a general-purpose, thermal-hydraulics computer program developed by John Marvin, Inc. (JMI). GOTH-SNF is a multi-dimensional, multi-phase, finite-difference, thermal-hydraulic computer code, which has been applied extensively to the analyses of waste tanks. The current version and the predecessor program GOTH has been used extensively at Hanford and other U.S. Department of Energy sites and in the commercial nuclear industry for design, safety, and operations analyses (Thurgood 1999a and 1999b). GOTH-SNF has been verified and validated and is controlled through the JMI Quality Assurance Program (Thurgood and Ogden 1999).

2.2.2 *Evaluation Model Description*

A schematic of the GOTH-SNF thermal-hydraulic model used for the engineering evaluation is shown in Figure 2-2. The tank vapor space is modeled using GOTH-SNF thermal and fluid components. These are described below:

1. Control Volumes – these are shown in Figure 2-2 as rectangles with dashed lines and numbers at the top left corner. The variables including temperature, pressure, density and void faction are specified for each volume. The primary tank vapor space is modeled with control volume 4s. The annulus ventilation system is modeled with three control volumes. The air inlet supply line is modeled with volume 2, the floor slots in the primary tank floor are modeled with volume 1s and the wall annulus region is modeled with volume 3. The portion of the primary tank containing the waste is not modeled as a control volume since the waste temperatures are specified as boundary conditions.

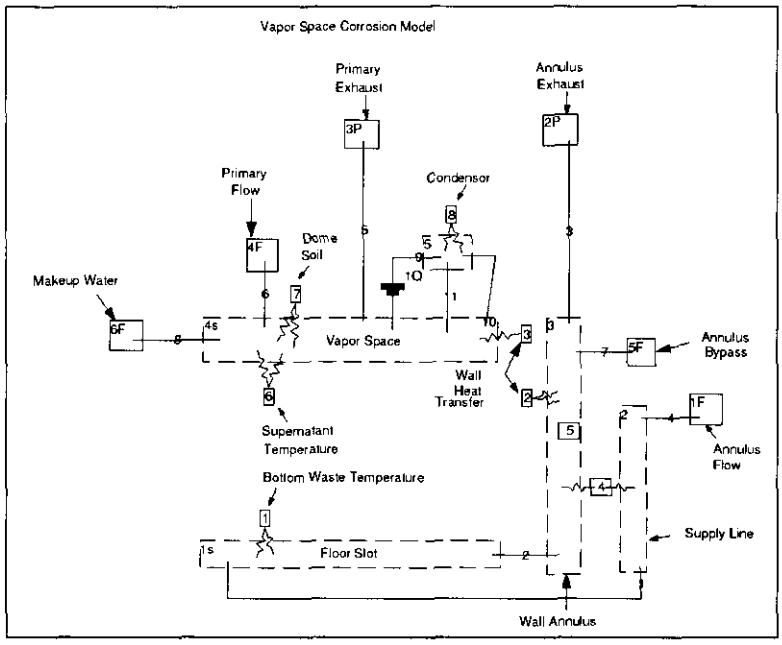
2. Flow Connectors – are shown in Figure 2-2 as lines with a number beside them. The flow connectors connect control volumes and boundary condition components. Flow variables such as velocity and momentum are specified at the flow connectors.

3. Thermal Conductors – Thermal conductors provide one-dimensional thermal conduction and are also used to specify waste temperatures. They are shown in the figure as small boxes with numbers. The temperature of the supernatant is specified by conductors 2 and 6. Conductor 2 models the heat transfer from the supernatant through the primary tank wall to the wall annulus region. The top two feet of the supernatant is included in Control Volume 4s. The measured temperature of the supernatant is specified with Conductor 6. The average waste temperature at the bottom is modeled with Conductor 6, which connects to the floor slot control volume. The heat transfer characteristics of the floor slots are modeled with this

[1] Proprietary software of John Marvin, Inc.

conductor. Conductor 3 connects to the vapor space volume and the wall annulus. The wall temperature is modeled with this conductor. Conductor 7 models the dome soil and dome concrete and liner surface.

Figure 2-2. GOTH-SNF Evaluation Model Nodal Diagram.



4. Boundary Conditions – shown in Figure 2-2 as squares with a number and the letter "P" or "F" inside. "P" refers to a pressure boundary condition while "F" refers to a flow boundary condition. The primary and annulus ventilation systems are modeled with these components as shown in Figure 2-2. Daily average ambient temperature and relative humidity are specified by the flow boundary conditions.

2.3 DST VENTILATION SYSTEMS

Operating data for the three DST ventilation systems are presented in the following sections.

2.3.1 *Primary Ventilation Systems*

Each tank farm shares a common primary ventilation system which ventilates all the tanks in the farm. Flow to individual tanks is controlled by valves or Flow Control Devices (FCD) on the tank inlets. Typical flow rates for the individual tanks are presented below.

<u>AN-Farm</u>

The AN-Farm tanks are equipped with FCD's. The flow rates are determined by an orifice plate and controlled to a constant value (Mintier 1995). The current filtered inlet flow rates for the AN-Farm are shown in Table 2-1 (Carothers 2002). There is an unfiltered inlet flow from in-leakage. The total stack flow is approximately 760 cfm (Nelson 2002a). The total filtered inlet flow shown in Table 2-1 is 375 cfm. This leaves an average of 55 cfm per tank in-leakage. The total inlet flow which includes in-leakage is shown in Table 2-1.

The primary ventilation system for the AN-Farm is planned to be upgraded in FY03 through Project W-314 (Lentsch 1999a). The new ventilation system has been designed for waste retrieval operations with a much greater flow capability. The upgraded exhaust fans will provide approximately 2000 cfm inlet air (Nelson 2002a).

Table 2-1. AN Farm Primary Ventilation Flow Rates.

Tank	Orifice Rating (cfm)	Total Inlet Flow (cfm)
AN-101	35	90
AN-102	35	90
AN-103	60	115
AN-104	60	115
AN-105	60	115
AN-106	35	90
AN-107	90	145

For the mitigation evaluation presented in Section 3.0, a flow rate of 250 cfm per tank will be assumed, consisting of 200 cfm filtered inlet flow and 50 cfm in-leakage.

AP-Farm

The AP-Farm tanks do not currently have inlet flow control stations. All inlet flow is through in-leakage. The stack flow rate for the primary ventilation system is approximately 1200 cfm. Thus the individual inlet flow rate on average is 150 cfm. The primary ventilation system will be upgraded by Project W-314. Inlet flow control stations will be added. The replacement exhaust fans are expected to be comparable to AN-Farm at 2000 cfm. Thus the upgraded inlet flow rate will be near 250 cfm.

AW-Farm

The AW-Farm tanks are also equipped with FCD's. The current filtered inlet flow rates for the AW-Farm are shown in Table 2-2 (Lohrasbi 2002). The total stack flow is approximately 960 cfm (Nelson 2002b). The total inlet flow which includes in-leakage is shown in Table 2-2.

Table 2-2. AW Farm Primary Ventilation Flow Rates.

Tank	Orifice Rating (cfm)	Total Inlet Flow (cfm)
AW-101	125	200
AW-102	70	140
AW-103	70	140
AW-104	125	200
AW-105	70	140
AW-106	70	140

The upgraded primary ventilation system (Project W-314) will have exhaust fans which can provide approximately 2000 cfm inlet air (Nelson 2002b). The mitigation evaluation presented in Section 3.0 will assume a flow rate of 330 cfm per tank, which includes both filtered and in-leakage flow.

SY-Farm

Table 2-3 shows the primary ventilation flow rates used for the SY-Farm tanks (Cash 2001). The flow can be split between the three tanks as desired. The engineering analyses assumed that the flow split was equal to all three tanks.

Table 2-3. SY Farm Primary Ventilation Flow Rates.

Tank	Orifice Rating (cfm)
SY-101	330
SY-102	330
SY-103	330

AWF

There are four tanks in the AWF. The measured primary ventilation system flow rates from August 1999 to July 2001 are shown in Figure 2-3. These data were obtained from the Tank Waste Information Retrieval System (TWINS) Data Base. The data were averaged to provide an average value for the engineering evaluation model. The average values are shown in Table 2-4.

Figure 2-3. Aging Waste Tanks Primary Ventilation Flow Rates.

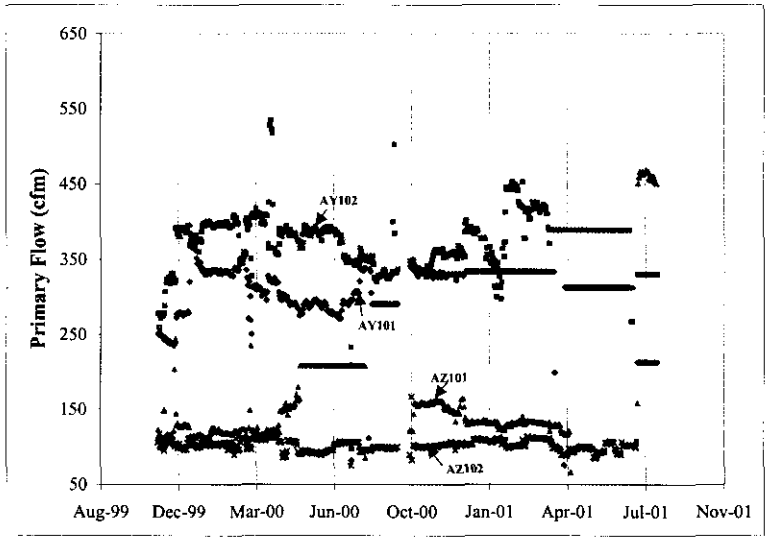


Table 2-4. AWF Primary Ventilation Flow Rates.

Tank	Orifice Rating (cfm)
AY-101	300
AY-102	360
AZ-101	120
AZ-102	100

2.3.2 *Annulus Ventilation Systems*

There are seven annulus ventilation systems for the twenty-eight DST's. Representative average

flow rates for individual tanks are summarized in Table 2-5 (Ogden 2001). The ambient air is supplied to the center of the tank floor and passes through the floor slots to the wall annulus as shown schematically in Figure 2-1. There are three exceptions as noted in Table 2.-5. For tank 241-AY-101, a portion of the inlet air bypasses the floor slots and goes directly to the wall annulus. This wall bypass flow accounts for about 80% of the total flow. The effect of the wall bypass flow on the primary tank wall condensation is discussed in Section 3.0. The two AZ tanks also have wall bypass flow. However, external valves allow this flow to be eliminated. Tank 241-AY-101 is unique in that the wall bypass flow exists and can not be eliminated without modifications to the ventilation system piping.

Table 2-5. Annulus Ventilation System Flow Rates.

Tank Farm	Tank Number	Exhaust System	Measured Flow Rate (cfm/tank)
AWF	AY-101	Dedicated	1500[2]
	AY-102	Dedicated	950
	AZ-101	Common	550[3,4]
	AZ-102		
AN	AN-101	Common	900
	AN-102		
	AN-103		
	AN-104		
	AN-105		
	AN-106		
	AN-107		
AP	AP-101	Common	1050
	AP-102		
	AP-103		
	AP-104		
	AP-105		
	AP-106		
	AP-107		
	AP-108		
AW	AW-101	Common	800
	AW-102		
	AW-103		
	AW-104		
	AW-105		
	AW-106		
SY	SY-101	Common	300
	SY-102		
	SY-103		

[2] This is the total flow, split between wall bypass flow and slot flow.
[3] The wall bypass flow for the AZ tanks can be controlled by external valves. The wall bypass flow can be eliminated through the operation of these valves.
[4] Annulus ventilation flows have been increased. Flow measurements on 11/14/02 (Work Package 2E-02-01375) of 1100 cfm. The higher flow rates will be addressed in Section 3.6 with parametric analyses.

2.3.3 *AZ-702 Ventilation System*

The AZ-702 ventilation system provides additional cooling for the AWF tanks. Flow is extracted from the vapor space by a recirculation fan and passed by a condenser unit which cools the air stream and condenses moisture from the nearly saturated air. This system is modeled with a recirculation fan and control volume 5. The condenser is modeled with heat conductor 8 (Figure 2-2). The sink temperature for the condenser is the ambient dew point. The recirculation flow rate for the four AWF tanks is determined from the recirculation fan curve and the measured fan differential pressure (Dp). The Dp data for each tank is shown in Figure 2-4. The corresponding flow rates are near 900 cfm.

The measured condenser inlet and outlet temperatures for tank 241-AZ-102 are shown in Figure 2-5. These data for the four AWF were used to determine area of conductor 8 (Figure 2-2) needed to reproduce the condenser characteristics.

Figure 2-4. Aging Waste Tanks Recirculation Fan Dp.

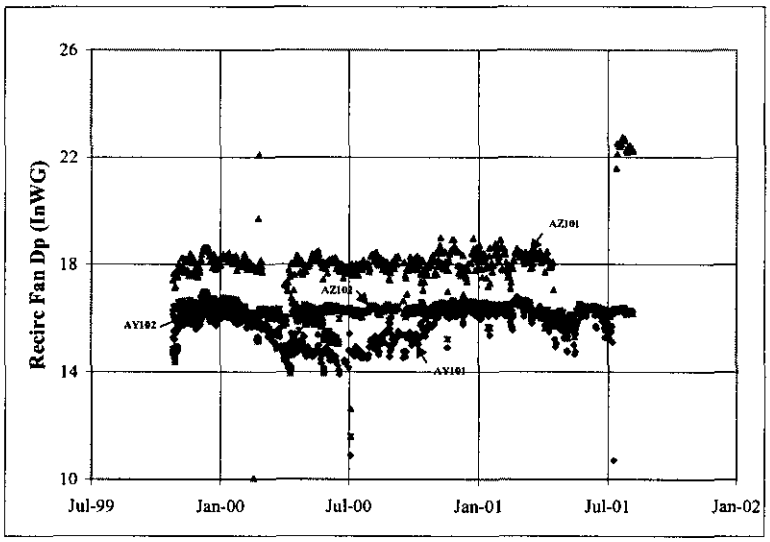
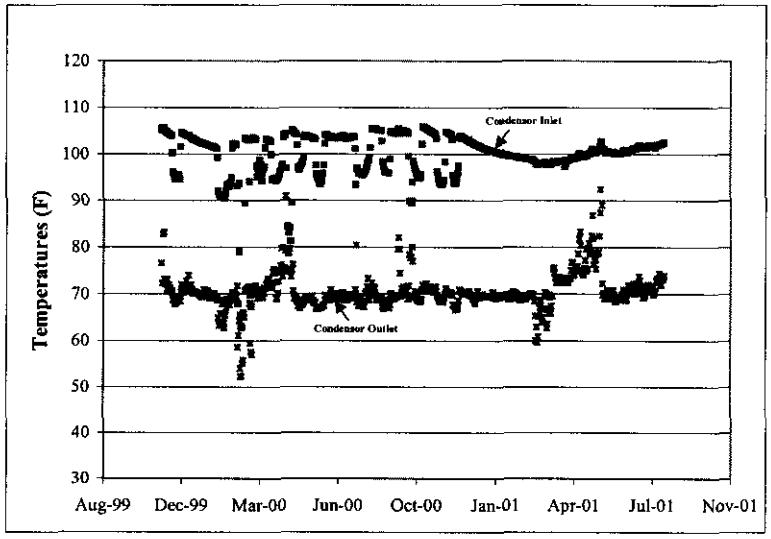


Figure 2-5. Tank 241-AZ-102 Condenser Inlet and Outlet Temperatures.

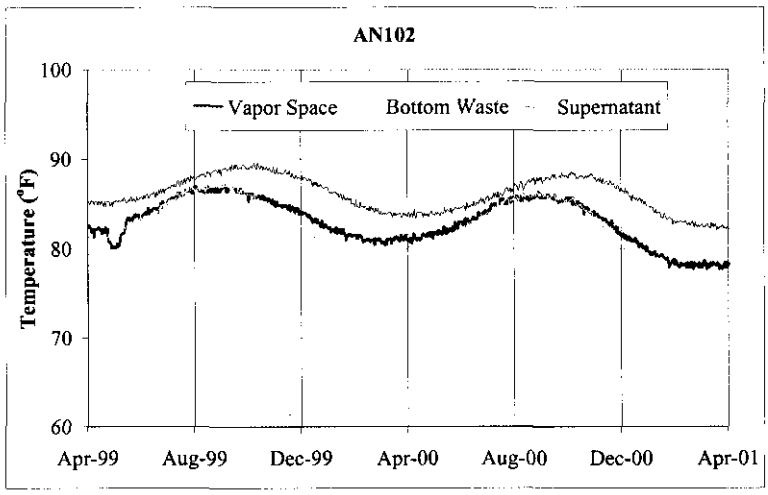


2.4 TANK DATA AND AMBIENT PYSCHROMETRICS

2.4.1 *Tank Temperatures*

The supernatant and bottom waste temperatures are not predicted by the evaluation model but rather specified by heat conductors 1, 2, and 6 (Section 2.2.2). Typical data is shown in Figure 2-6 and 2-7. All tank temperature data was obtained from the TWINS Data Base. Measured data for a two year period was used for the analyses. The

Figure 2-6. AN-102 Waste Temperatures.



analyses included the effects of the normal seasonal variation in ambient Psychrometric conditions. Daily averaged waste temperatures were used. Diurnal variations were not considered. Temperature data for all twenty-eight DST's is provided in Appendix A.

The goal of the study was not a precise quantification of condensation rates, but to identify conditions and periods when condensation on the primary tank liner may occur. A summary of the average temperature over the two year period is show in Table 2-5. While daily temperatures were used for the analyses, the average temperatures are useful for comparing different tanks and interpreting the results of the vapor space evaluation.

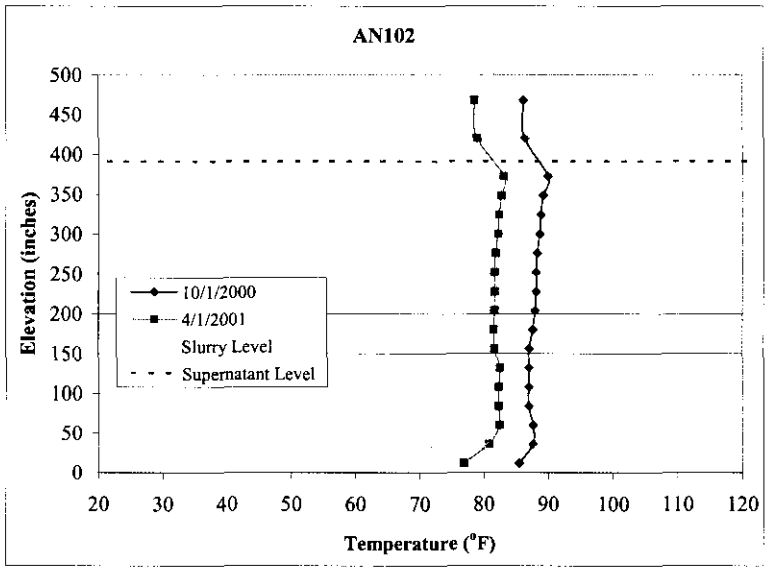
Figure 2-7 shows the temperature profile for a typical tank. The supernatant and slurry levels are also shown. These data are helpful in the interpretation of the results of the evaluation.

2.4.2 *Supernatant Vapor Suppression*

The evaporation rate of liquid from the surface of the supernatant is an important parameter for vapor space Psychrometric conditions. The salt content of the waste suppresses the vapor pressure which reduces the evaporation rate for a given temperature. Vapor suppression analyses were performed using the Environmental Simulation Program (ESP)[4]. The analyses used data

[4] ESP is proprietary software of OLI Systems.

Figure 2-7. AN-102 Waste Temperature Profiles.



from the Best Basis Inventory to determine the waste constituents and determine the vapor suppression of the supernatant. The results of the analyses are summarized in Table 2-5. Additional information is provided in Appendix B.

2.4.3 *Ambient Psychrometric Data*

Daily averaged ambient temperature and relative humidity were used as boundary conditions for the engineering evaluation model. These data were obtained for the Hanford Meteorological Station operated for the Department of Energy by Pacific Northwest National Laboratory. Figure 2-8 shows the temperature and relative humidity used for the analyses.

Figure 2-8. Ambient Temperatures.

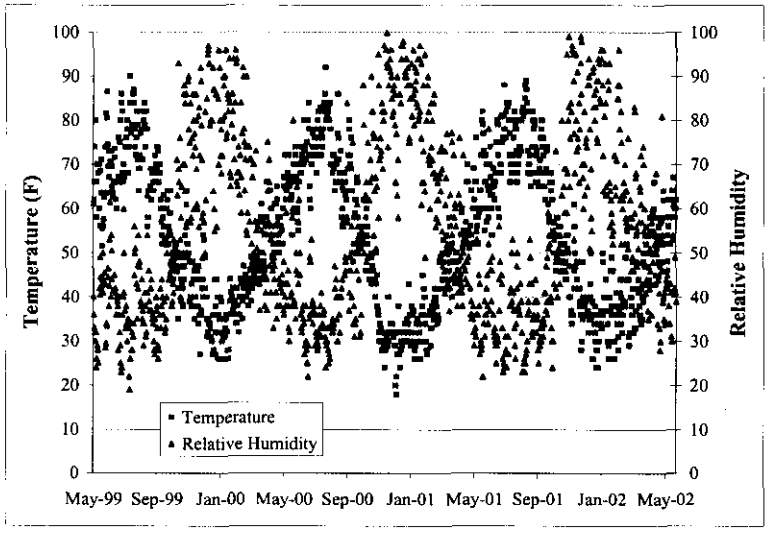


Table 2-6. Annulus Ventilation System Temperatures and Vapor Pressure Rates.

Tank ID	Average Temperature (°F)			Vapor Pressure Ratio $(P/P_{H2O})*100$
	Bottom Waste	Supernatant	Vapor Space	
AN101	66	65	65	69
AN102	82	86	83	70
AN103	85	100	82	68
AN104	87	92	83	72
AN105	85	91	81	53
AN106	63	63	61	90
AN107	81	84	79	74
AP101	66	68	64	74
AP102	68	68	66	82
AP103	63	63	64	100
AP104	68	70	68	82
AP105	68	68	66	75
AP106	67	67	67	95
AP107	63	64	62	99
AP108	61	61	61	93
AW101	81	94	90	47
AW102	67	66	66	89
AW103	65	64	64	90
AW104	73	66	66	90
AW105	62	60	61	94
AW106	92	83	80	75
SY101	103	102	81	97
SY102	85	88	85	96
SY103	85	84	82	87
AY101	97	--	80	94
AY102	132	107	102	72
AZ101	176	155	139	88
AZ102	139	113	112	54

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3.0 VAPOR SPACE ENGINEERING EVALUATION

An evaluation of the vapor space Psychrometric conditions and the potential for vapor space condensation was performed for each of the twenty-eight DST's. The engineering evaluation was conducted using the GOTH-SNF model described in Section 2.0. Engineering analyses determined the Psychometric conditions in the vapor space of individual tanks. The predicted dew point temperature of the vapor space was compared to the surface temperatures of the vapor space dome and tank wall to assess the potential for surface condensation. A limited evaluation of potential mitigation through ventilation system operation was performed for tank farms which were predicted to have a significant potential for primary tank surface condensation.

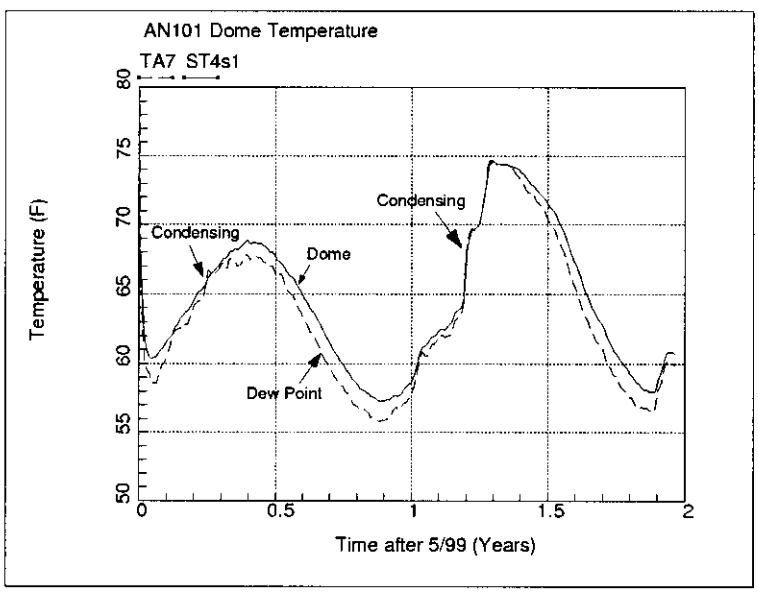
3.1 AN-FARM EVALUATION

The evaluation of the vapor space of each of the seven AN-Farm tanks was conducted for a period from May 1, 1999 to May 1, 2001. The results of the seven AN-Farm tanks are discussed below.

3.1.1 *241-AN-101*

Results of the engineering evaluation for tank 241-AN-101 are shown in Figures 3-1 and 3-2. The first figure shows the predicted surface temperature of the vapor space dome. This is the section of the primary tank liner which interfaces directly with the soil above the tank. The dome surface temperature is compared to the predicted dew point

Figure 3-1. Comparison of AN-101 Dome and Dew Point Temperatures.



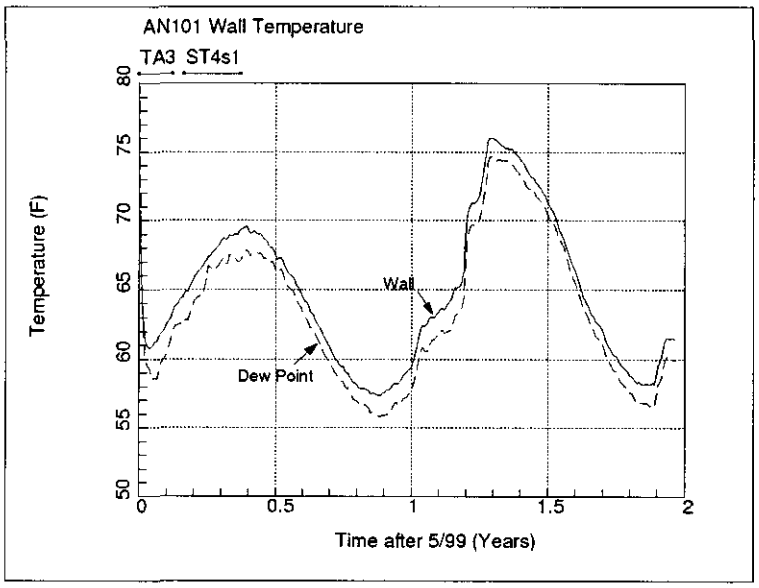
temperature of the vapor space in Figure 3-1. The time axis is shown in years from May 1, 1999. During the first 0.4 years the temperatures increase as a result of increasing summer temperatures. The waste temperatures in the DST's generally reach their maximum near October. During the summer period the vapor space temperature

increases due to an increase in ambient air temperature. The dome surface temperature increases more slowly because of the thermal inertia of the soil. As a result, the dew point temperature reaches the dome surface temperature, allowing condensation on this surface to occur. For the next six months the ambient temperatures decrease. The vapor space air cools the dome surface and the dew point temperature is below the dome surface temperature. Thus, condensation on the dome surface does not occur during the winter period from about November to April. This same behavior is seen in the period from May 2000 to May 2001. In general, dome condensation for the DST's will occur during the summer and fall.

The comparison of the vapor space dew point and the predicted wall temperatures are shown in Figure 3-2. The wall is that portion of the primary tank liner, which interfaces with both the vapor space and the annulus region. For 241-AN-101 the dew point temperature is always lower than the wall surface temperature. Thus condensation of the wall surface is not expected to occur. Figure 3-2 shows that the temperature difference between the surface temperature and the vapor space dew point is smallest during the period from November to April. During this winter and spring period, the vapor space is cooled by the annulus ventilation system by heat transfer through the vapor space wall. In general, conditions are most conducive to wall condensation during the winter and spring.

A summary of the results of engineering evaluation for the twenty-eight tanks is shown in Table 3-1 in Section 3-6. For 241-AN-102, conditions compatible with dome condensation exist during the summer and fall period. Wall condensation is not expected to occur.

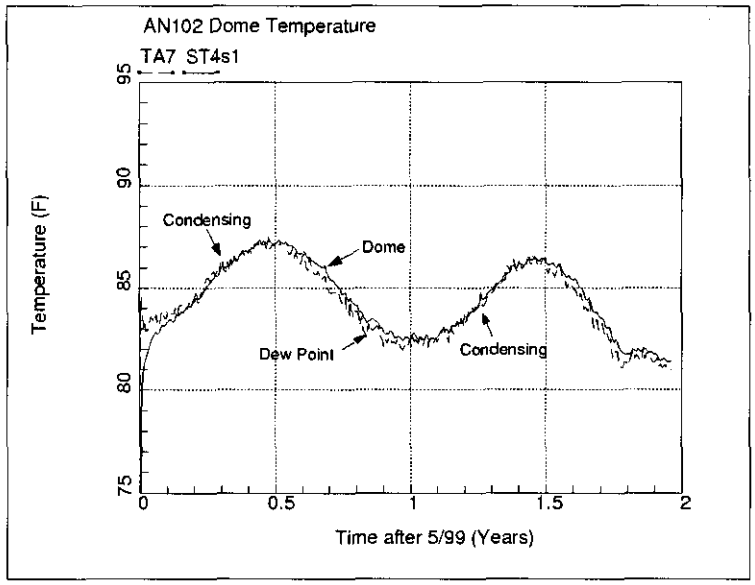
Figure 3-2. Comparison of AN-101 Wall and Dew Point Temperatures.



3.1.2 *241-AN-102*

Results of the engineering evaluation for tank 241-AN-102 are shown in Figures 3-3 and 3-4. The predicted vapor space dome temperatures are shown in Figure 3-3. The dome surface temperature is compared to the predicted dew point. Table 3-1 provides a summary of the average temperatures during the two year period of the engineering evaluation.

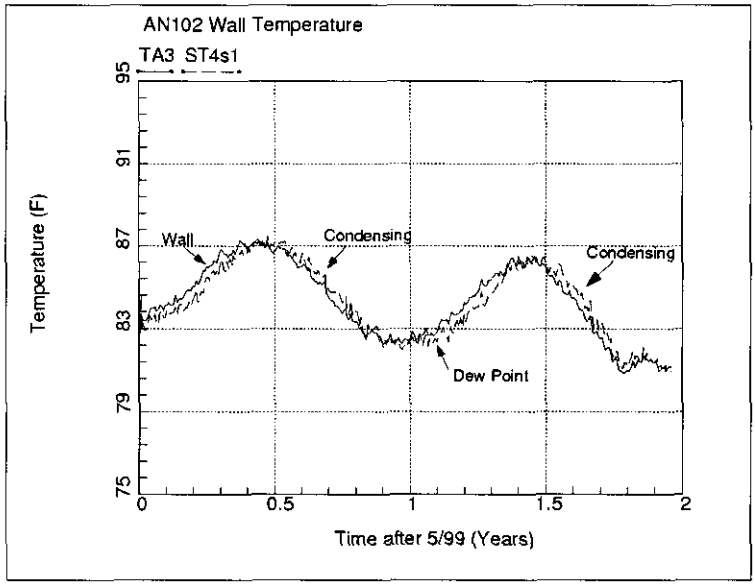
Figure 3-3. Comparison of AN-102 Dome and Dew Point Temperatures.



Tank 241-AN-102 supernatant temperatures are on average 20 °F higher than the tank 241-AN-101 temperatures. This increases the evaporation rate from the supernatant, increasing the condensation potential for the dome and wall surfaces. Figure 3-3 shows that condensation can occur on the dome for nearly six months of the year (summer and fall) The dome temperature is generally above the dew point temperature during the winter and spring months (0.5 to 1 years and 1.5 to 2 years). However the temperature difference is small and some condensation may occur during this period as well.

The predicted vapor space dew point and wall temperatures for tank 241-AN-102 are shown in Figure 3-4. During the summer and fall (0 to 0.5 years and 1 to 1.5 years), the wall temperatures are greater than the dew point temperature, though the temperature difference is small. Some wall condensation may occur during this period. However, during the winter and spring period (0.5 to 1 years and 1.5 to 2 years) the dew point temperatures exceed the wall surface temperature and wall condensation is expected to occur. The results are summarized in Table 3-1.

Figure 3-4. Comparison of AN-102 Wall and Dew Point Temperatures.



3.1.3 *241-AN-103*

Results of the engineering evaluation for tank 241-AN-103 are shown in Figures 3-5 and 3-6. Table 3-1 shows that the average supernate temperatures for tank 241-AN-103. The average supernatant temperature is the highest in the AN-Farm. This increases the condensation potential in the vapor space. Figure 3-5 compares the predicted dew point and dome surface temperatures. Condensation on the dome surface is expected to occur during the entire summer and fall period. The dome temperature is greater than the dew point temperature during the winter and spring, thus condensation is not expected to occur.

The predicted wall surface temperature and vapor space dew point temperatures are compared in Figure 3-6. The average supernatant temperatures for tank 241-AN-103 are nearly 20 °F higher than the dome temperatures (Table 3-1). This indicates the existence of a crust on the surface of the supernatant (liquid natural convection in the supernatant and vapor natural convection in the dome space can account for this large of a temperature difference). Bottom waste temperatures are also higher than the dome temperatures. As a result, the annulus ventilation air stream is heated above the dome temperatures from the bottom waste and supernatant. Thus the vapor space is heated by the annulus ventilation air. The result of this is seen in Figure 3-6. The wall temperature is always higher than the vapor space dew point temperature. Wall condensation is not expected for tank 241-AN-103.

Figure 3-5. Comparison of AN-103 Dome and Dew Point Temperatures.

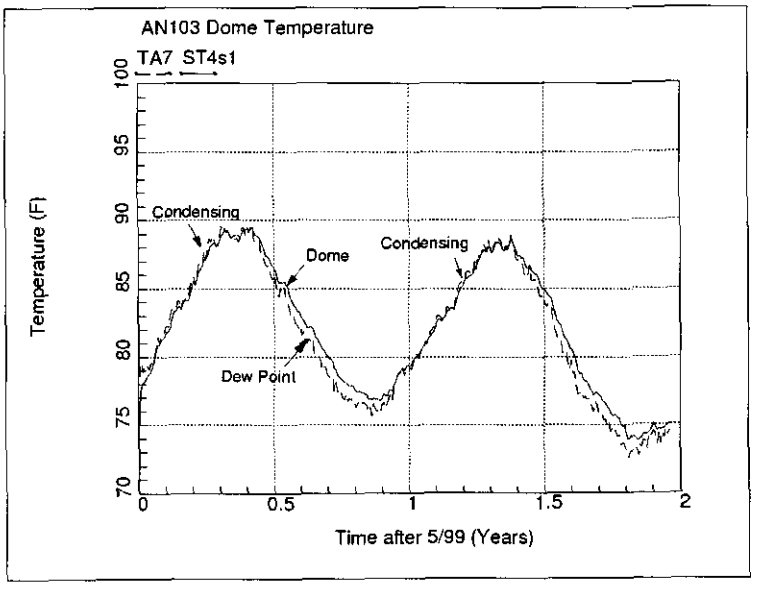
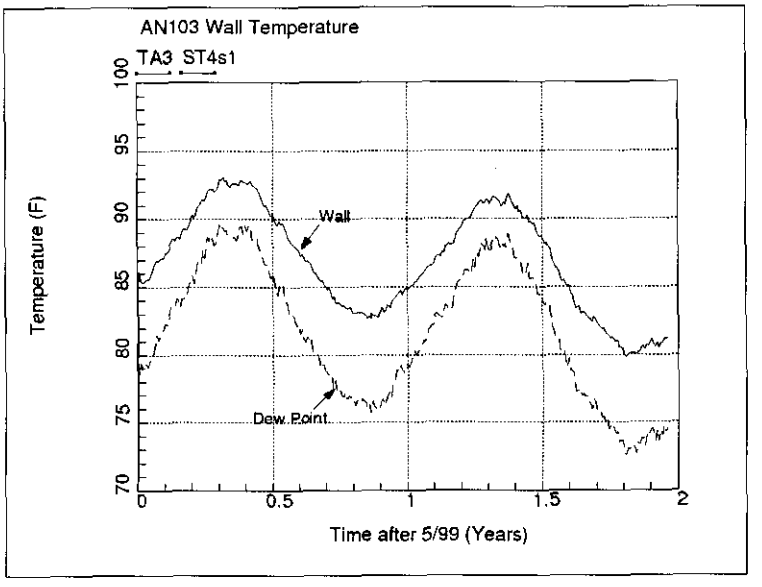


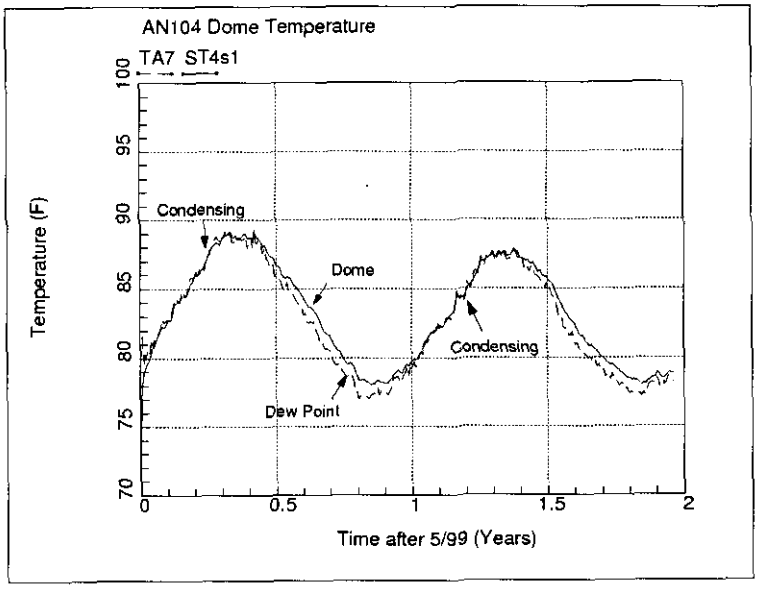
Figure 3-6. Comparison of AN-103 Vapor Wall and Dew Point Temperatures.



3.1.4 *241-AN-104*

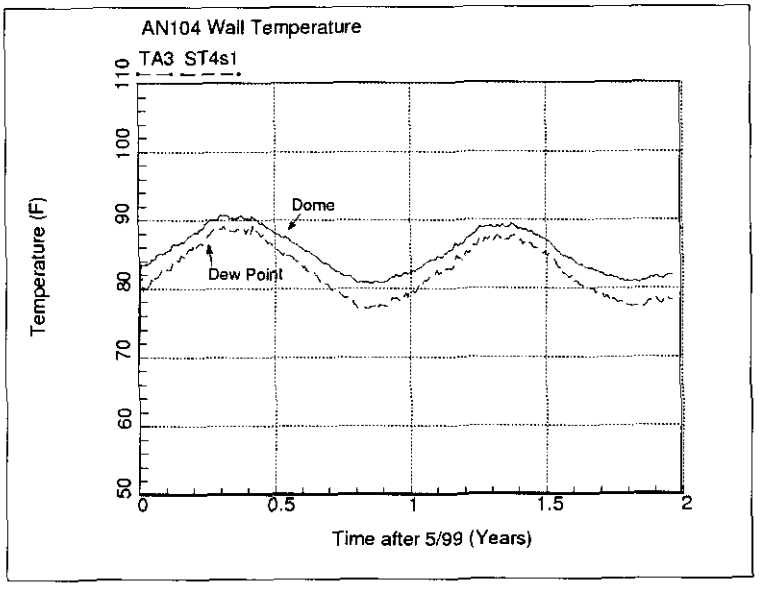
The results of the engineering evaluation for tank 241-AN-104 are shown in Figure 3-7 and 3-8. Supernatant temperatures for this tank are on average over 90 °F. Figure 3-7 shows that condensation is expected on the dome surface during the summer and fall months (0 to 0.5 years and 1.0 to 1.5 years). Dome surface temperatures remain above the dew point temperatures for most of the winter and spring months.

Figure 3-7. Comparison of AN-104 Dome and Dew Point Temperatures.



The predicted wall temperatures are compared with the predicted vapor space dew point temperatures in Figure 3-8. The figure indicates that wall condensation is not expected to occur at any time of year. Table 3-1 shows that the average temperatures of the supernatant and bottom waste temperatures are higher than the vapor space. The annulus ventilation air transfers heat through the wall to the vapor space. This keeps the wall temperature higher than the dew point temperature.

Figure 3-8. Comparison of AN-104 Wall and Dew Point Temperatures.



3.1.5 *241-AN-105*

The results of the engineering evaluation for tank 241-AN-105 are shown in Figures 3-9 and 3-10. Supernatant temperatures for this tank are also on average over 90 °F.

Figure 3-9. Comparison of AN-105 Dome and Dew Point Temperatures.

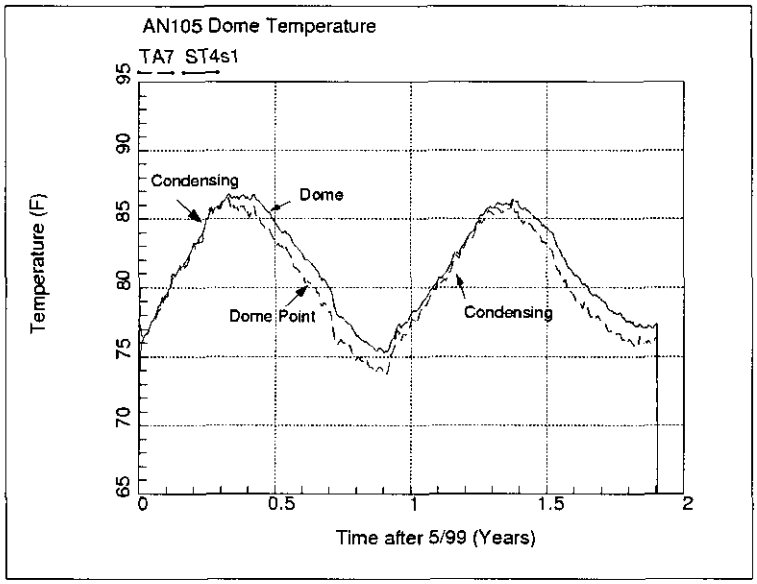
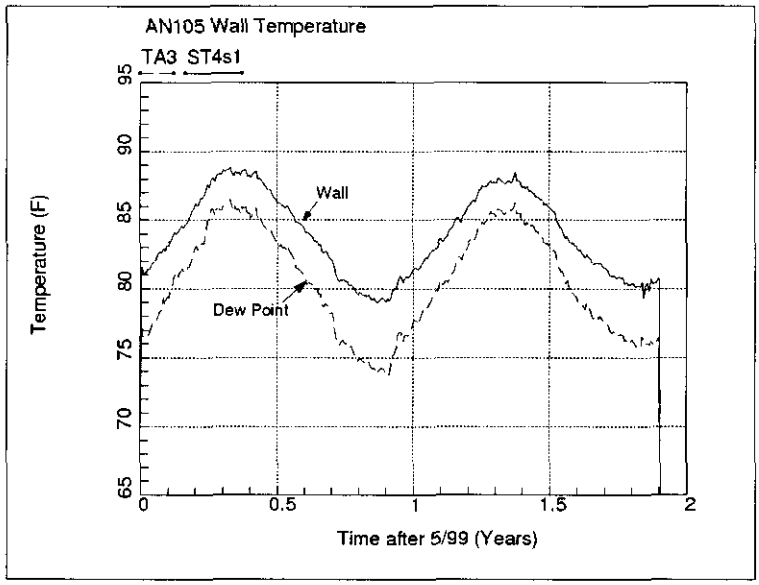


Figure 3-7 shows that condensation is expected on the dome surface during the summer and fall months (0 to 0.5 years and 1.0 to 1.5 years). Dome surface temperatures remain above the dew point temperatures for most of the winter and spring months.

The predicted wall temperatures are compared with the predicted vapor space dew point temperatures in Figure 3-10. The figure indicates that similar to tanks 241-AN-103 and 241-AN-104, wall condensation is not expected to occur.

Figure 3-10. Comparison of AN-105 Wall and Dew Point Temperatures.



3.1.6 *241-AN-106*

The results of the engineering evaluation for tank 241-AN-106 are shown in Figure 3-11 and 3-12. Supernatant temperatures for this tank are much lower than 241-AN-103 through 241-AN-105. They are the same as tank 241-AN-101. Supernatant evaporation is reduced, reducing the potential for condensation. Figure 3-11 shows that condensation is expected on the dome surface during the summer and fall months (0 to 0.5 years and 1.0 to 1.5 years). However, the time condensation can occur is less than the previous three tanks. No condensation is expected during the winter and spring period.

The predicted wall and dew point temperatures are compared in Figure 3-12. No condensation is predicted during the summer and fall. The predicted wall temperature is higher than the dew point temperature for the winter and spring for the first year of the evaluation (May 1999 to May 2000). However, during the second year, condensation is predicted to occur during portions of the winter and spring months. Thus, the lower supernatant temperature decreases the potential for both dome and wall condensation.

Figure 3-11. Comparison of AN-106 Dome and Dew Point Temperatures.

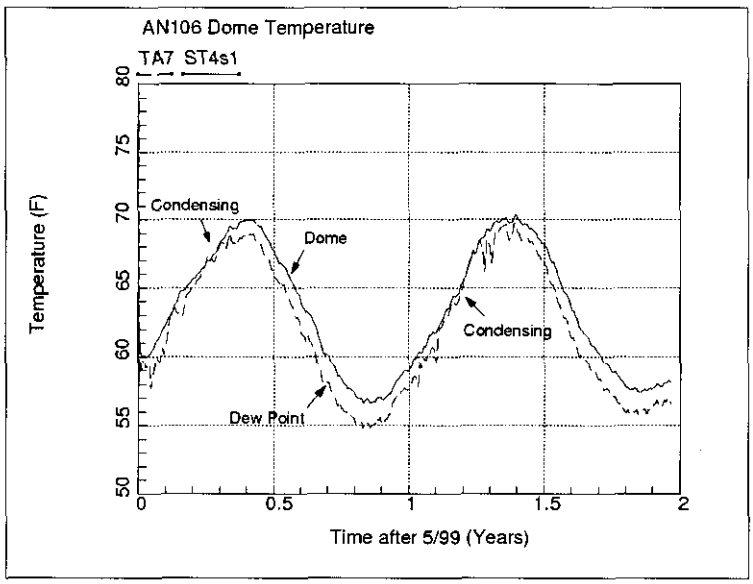
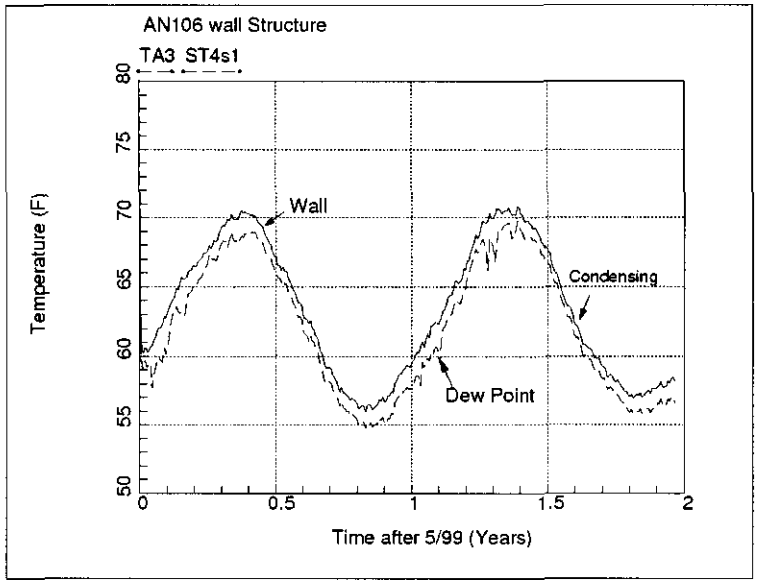


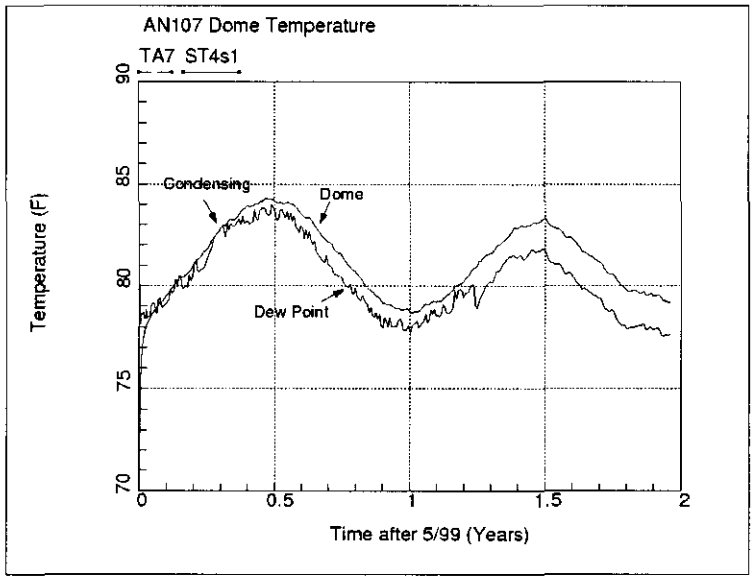
Figure 3-12. Comparison of AN-106 Wall and Dew Point Temperatures.



3.1.7 *241-AN-107*

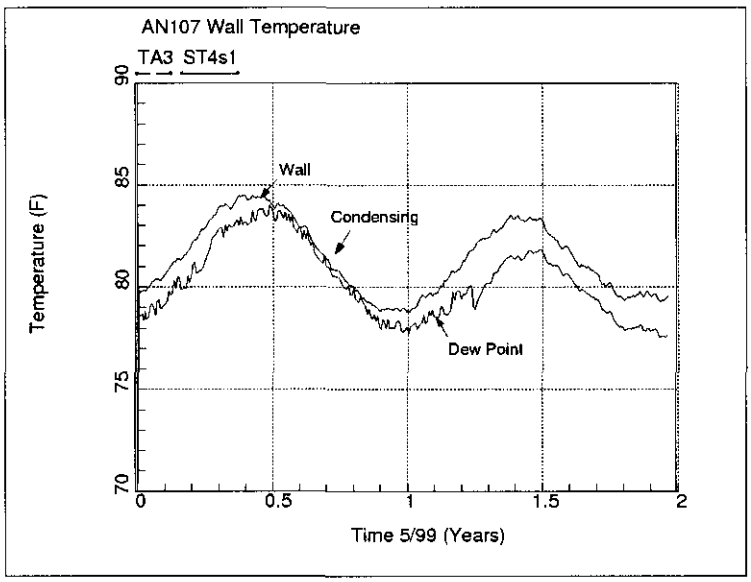
The results of the engineering evaluation for tank 241-AN-106 are shown in Figure 3-13 and 3-14. Supernatant temperatures for this tank are lower than 241-AN-103 through 241-AN-105, but greater than tanks 241-AN-101 and 241-AN-106. Figure 3-13 shows the predicted dome and vapor space dew point temperatures. Condensation is predicted to occur during portions of the summer and fall months. No condensation is expected during the winter and spring period.

Figure 3-13. Comparison of AN-107 Dome and Dew Point Temperatures.



The predicted wall and dew point temperatures are compared in Figure 3-14. No condensation is predicted during the summer and fall. The dew point temperature is equal to or greater however during the winter and spring months. Condensation is expected on wall portion of the primary tank liner during this portion of the year.

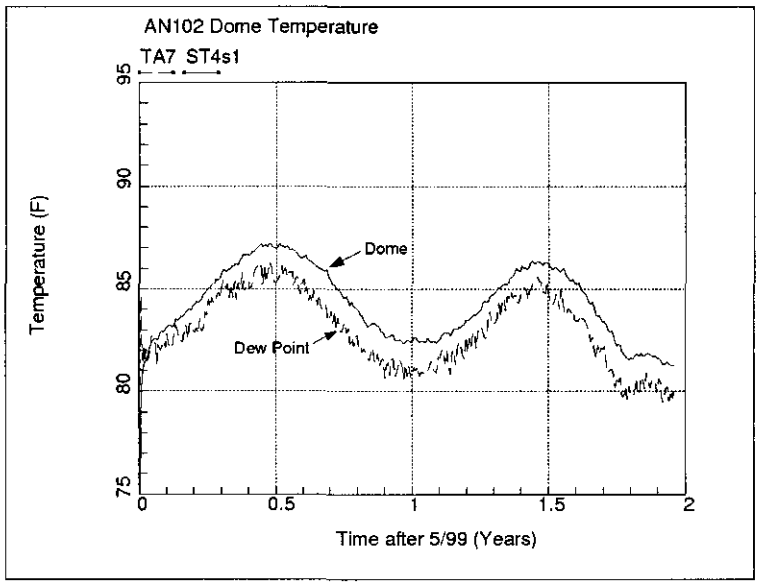
Figure 3-14. Comparison of AN-107 Wall and Dew Point Temperatures.



3.1.8 *AN-Farm Mitigation Evaluation*

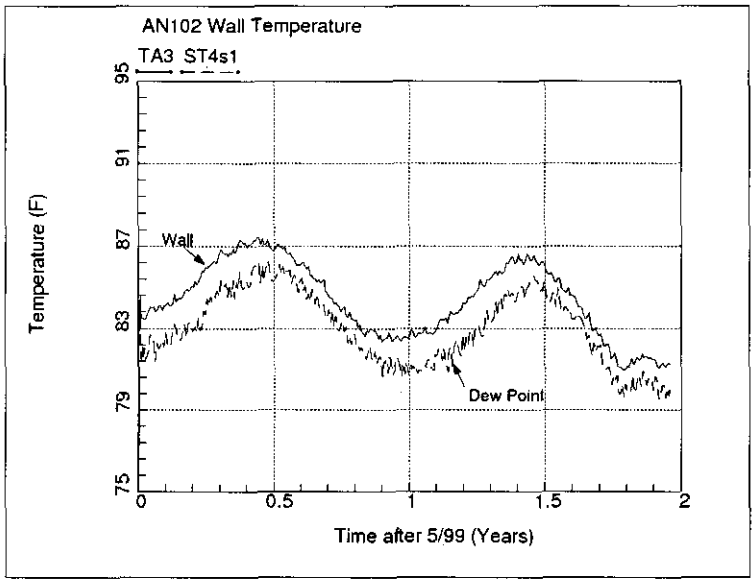
The evaluation of the condensation potential for the AN-Farm vapor space indicated that the potential for condensation of the dome surface or wall surface (or both) exists for all of the AN-Farm tanks. Additional analyses were conducted with the GOTH-SNF

Figure 3-15. Comparison of AN-102 Dome and Dew Point Temperatures with Increased Primary Flow.



evaluation model to evaluate mitigation options using the ventilation system operation. In general, the potential for dome and wall condensation can be reduced by lowering the dew point temperature of the vapor space. This can be accomplished by increasing the primary ventilation system flow rates. A greater flow capacity will be available for the AN-Farm primary ventilation system after the Project W-314 upgrade (Section 2.3).

Figure 3-16. Comparison of AN-102 Wall and Dew Point Temperatures with Increased Primary Flow.



Analyses were performed for tank 241-AN-102. The results summarized in Table 3-1, show that this is the tank with the greatest potential for both dome and wall condensation. The primary flow rate for each of the AN-Farm tanks was increased to 250 cfm. Increasing the heat removal from the tank will decrease the supernatant temperatures and further reduce the vapor space dew point. This effect was not included in this evaluation.

Results of the mitigation evaluation for the dome and wall temperatures are shown in Figures 3-15 and 3-16. The analyses show that increasing the primary ventilation system flow reduces the vapor space dew point temperature such that no condensation would be expected to occur for either the dome or wall surfaces of the primary tank liner.

3.2 AP-FARM EVALUATION

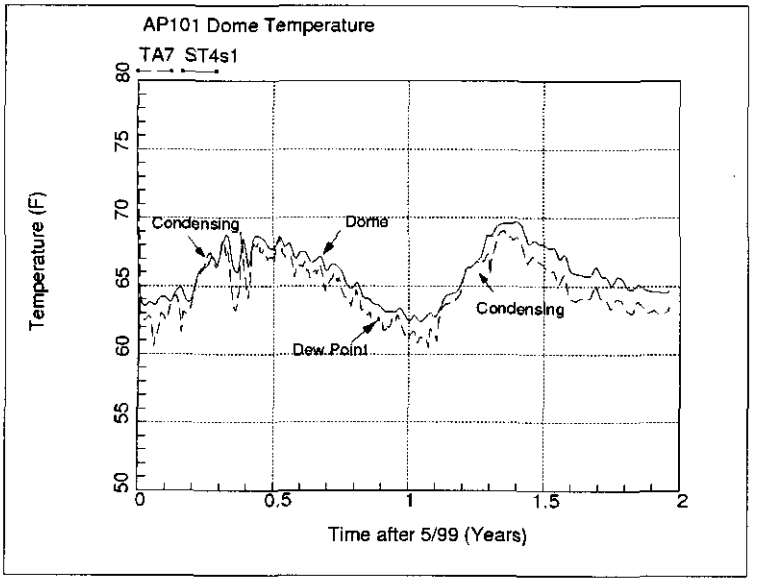
The evaluation of the vapor space of each of the eight AP-Farm tanks was conducted for a period from May 1, 1999 to May 1, 2001. The results are presented in the following sections.

A summary of the average temperatures for the two year evaluation period are shown in Table 3-1. The average supernatant temperature for the seven AN-Farm tanks is 83 °F. The average supernate temperature for the AP-Farm is 66 °F. The cooler supernatant temperatures will result in less supernatant evaporation. The potential for dome and wall condensation should be less for AP-Farm compared to AN-Farm.

3.2.1 *241-AP-101*

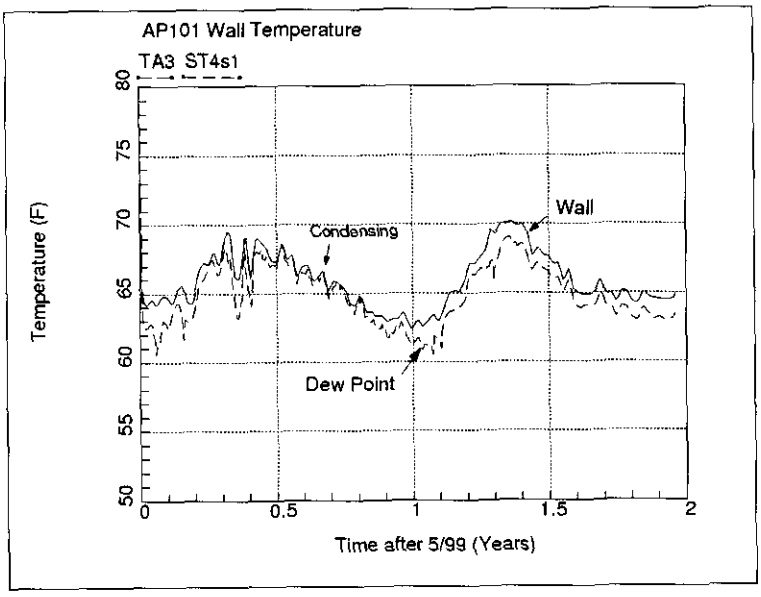
The results of the engineering evaluation for tank 241-AP-101 are shown in Figure 3-17 and 3-18. A comparison of the dome surface temperatures and vapor space dew point temperatures are shown in Figure 3-17. As seen for the AN-Farm tanks, condensation is predicted to occur during portions of the summer and fall months. However, no condensation is expected during the winter and spring period.

Figure 3-17. Comparison of AP-101 Dome and Dew Point Temperatures.



The predicted wall and dew point temperatures for 241-AP-101 are compared in Figure 3-18. No condensation is predicted during the summer and fall. The dew point temperature is equal to or greater however during the winter and spring months of the first year. During the period from May 2000 to May 2001, note the wall temperature is always higher than the dew point temperature. Thus, no condensation is expected on the wall portion of the primary tank liner.

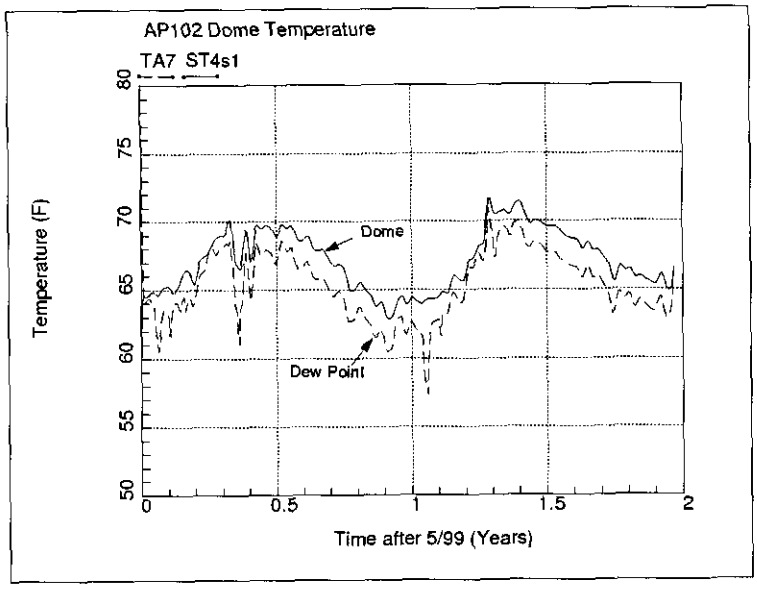
Figure 3-18. Comparison of AP-101 Wall and Dew Point Temperatures.



3.2.2 *241-AP-102*

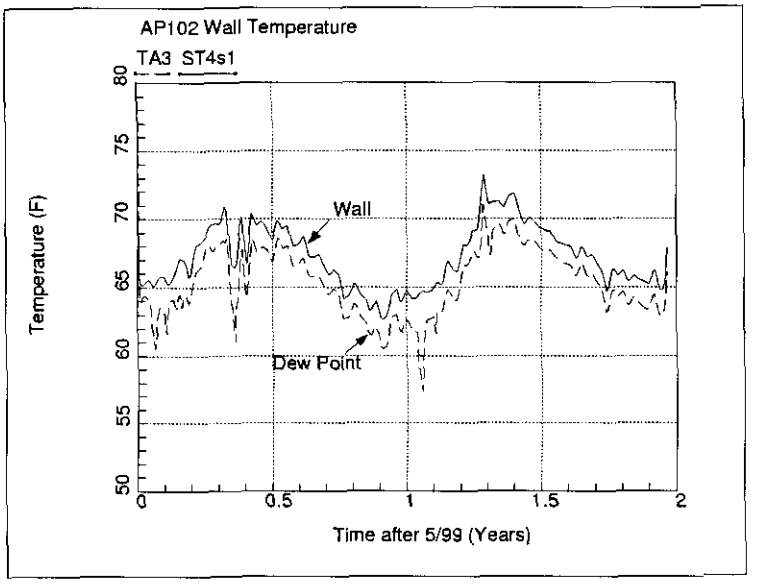
The results of the engineering evaluation for tank 241-AP-102 are shown in Figure 3-19 and 3-20. A comparison of the dome surface temperatures and vapor space dew point temperatures are shown in Figure 3-19. The predicted dome temperatures are higher than

Figure 3-19. Comparison of AP-102 Dome and Dew Point Temperatures.



predicted vapor space dew point temperatures for the two year period of the evaluation. Thus, no condensation is expected to occur on the surface of the dome for tank 241-AP-102.

Figure 3-20. Comparison of AP-102 Wall and Dew Point Temperatures.

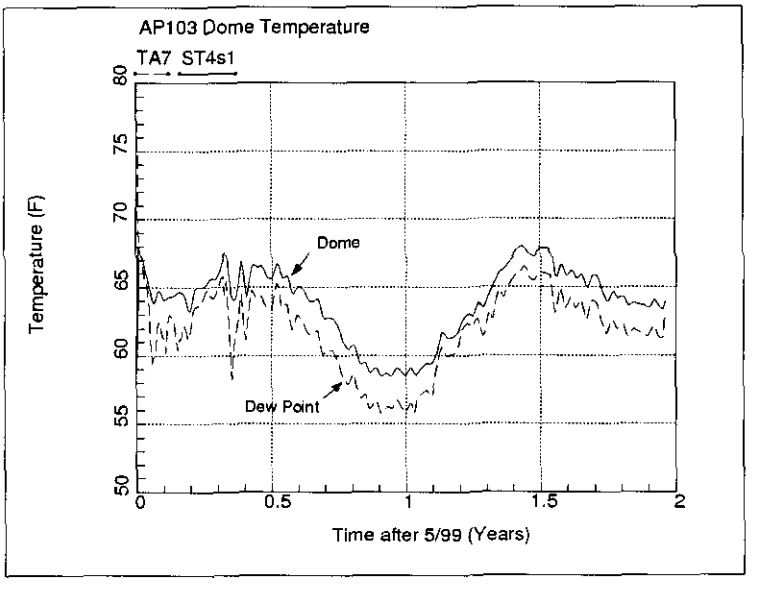


A comparison of the predicted wall and dew point temperatures for 241-AP-102 are shown in Figure 3-20. The predicted wall temperatures are always greater than the predicted vapor space dew point temperature. Thus, no condensation is expected to occur on the wall surface of tank 241-AP-102.

3.2.3 *241-AP-103*

The results of the engineering evaluation for tank 241-AP-103 are shown in Figure 3-21

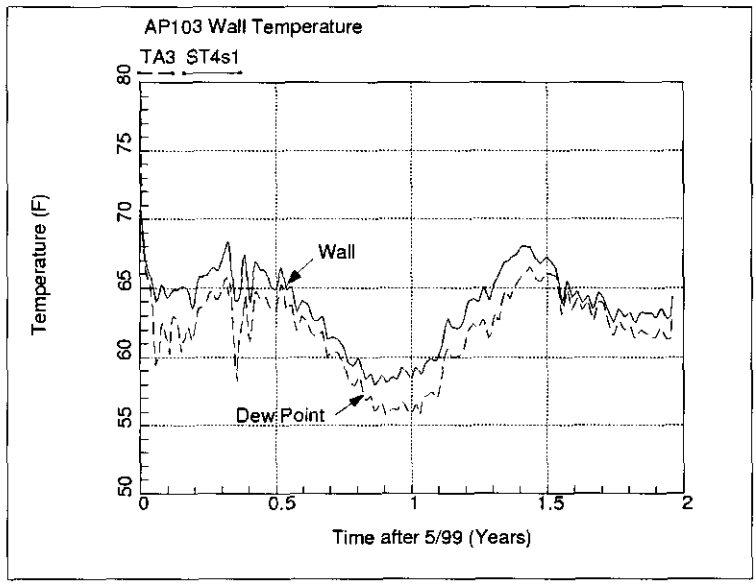
Figure 3-21. Comparison of AP-103 Dome and Dew Point Temperatures.



and 3-22. A comparison of the dome surface temperatures and vapor space dew point temperatures are shown in Figure 3-21. Similar to 241-AP-102, the predicted dome

temperatures are higher than predicted vapor space dew point temperatures for the two year period of the evaluation. Thus, no condensation is expected to occur on the surface of the dome for tank 241-AP-103.

Figure 3-22. Comparison of AP-103 Wall and Dew Point Temperatures.



A comparison of the predicted wall and dew point temperatures for 241-AP-103 are shown in Figure 3-22. The predicted wall temperatures are always greater than the predicted vapor space dew point temperature. Thus, no condensation is expected to occur on the wall surface of tank 241-AP-103.

3.2.4 *241-AP-104*

The results of the engineering evaluation for tank 241-AP-104 are shown in Figure 3-23 and 3-24. A comparison of the dome surface temperatures and vapor space dew point temperatures are shown in Figure 3-23. As seen for the AN-Farm tanks, condensation is predicted to occur during portions of the summer and fall months. However, no condensation is expected during the winter and spring period.

A comparison of the predicted wall and dew point temperatures for 241-AP-104 are shown in Figure 3-24. The predicted wall temperatures are always greater than the predicted vapor space dew point temperature. Thus, no condensation is expected to occur on the wall surface of tank 241-AP-104.

Figure 3-23. Comparison of AP-104 Dome and Dew Point Temperatures.

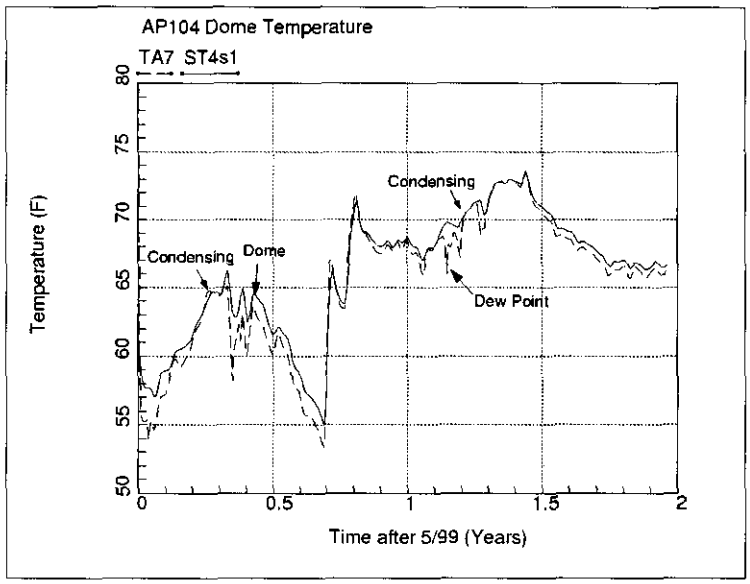
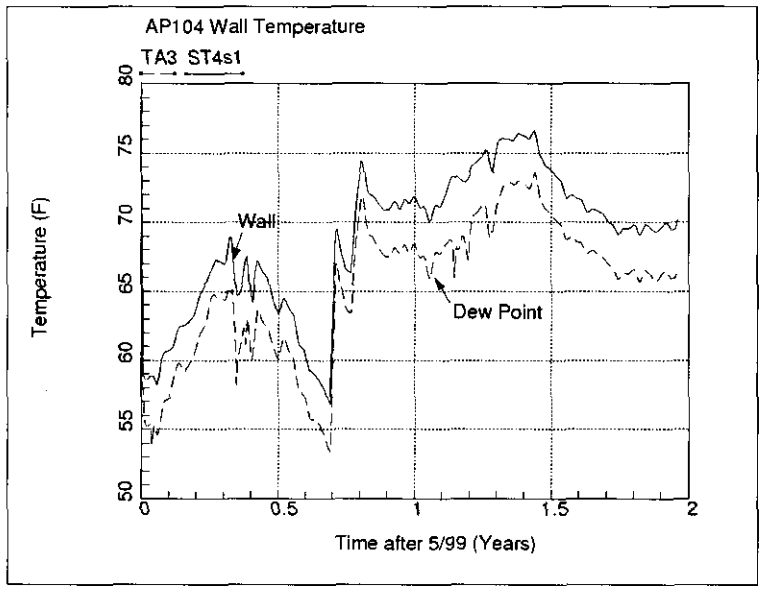


Figure 3-24. Comparison of AP-104 Wall and Dew Point Temperatures.



3.2.5 *241-AP-105*

The results of the engineering evaluation for tank 241-AP-105 are shown in Figure 3-25 and 3-26. A comparison of the dome surface temperatures and vapor space dew point temperatures are shown in Figure 3-25. Condensation is predicted to occur for only a short period during the summer of 1999. No condensation is predicted to occur during remainder of the evaluation period.

A comparison of the predicted wall and dew point temperatures for 241-AP-105 are shown in Figure 3-26. The predicted wall temperatures are always greater than the predicted vapor space dew point temperature. Thus, no condensation is expected to occur on the wall surface of tank 241-AP-105.

Figure 3-25. Comparison of AP-105 Dome Dew Point Temperatures.

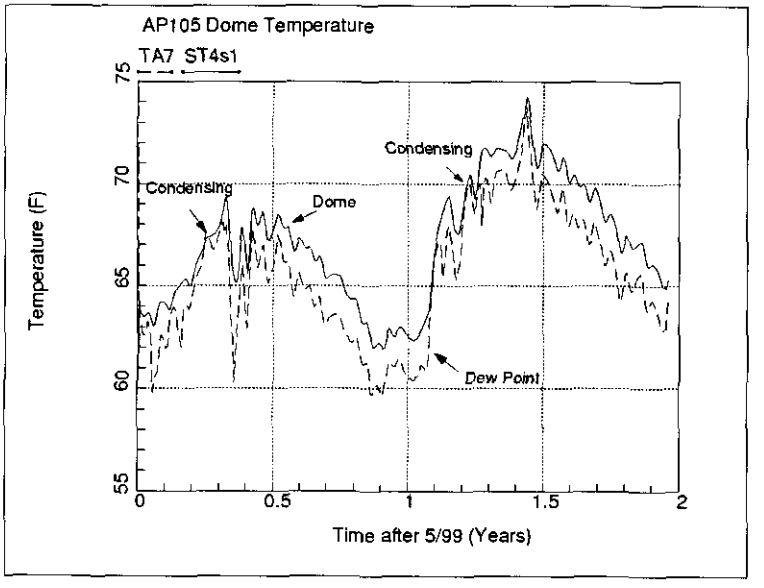
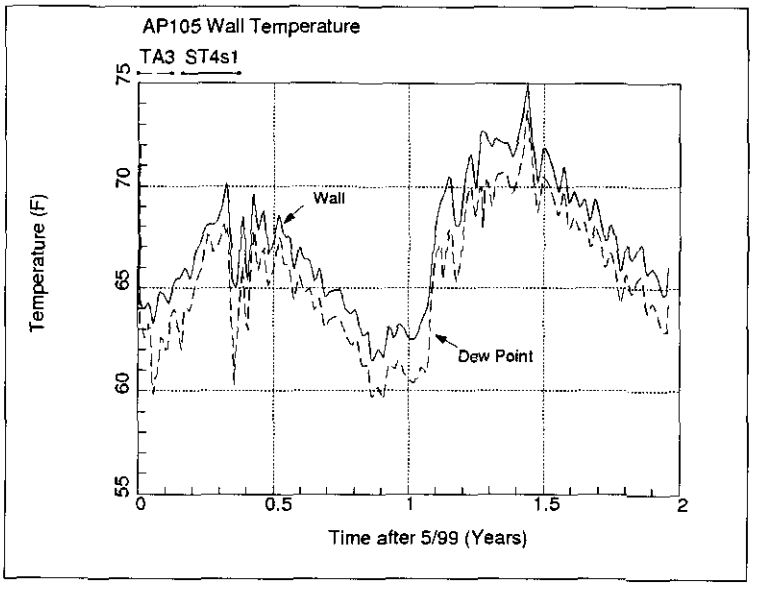


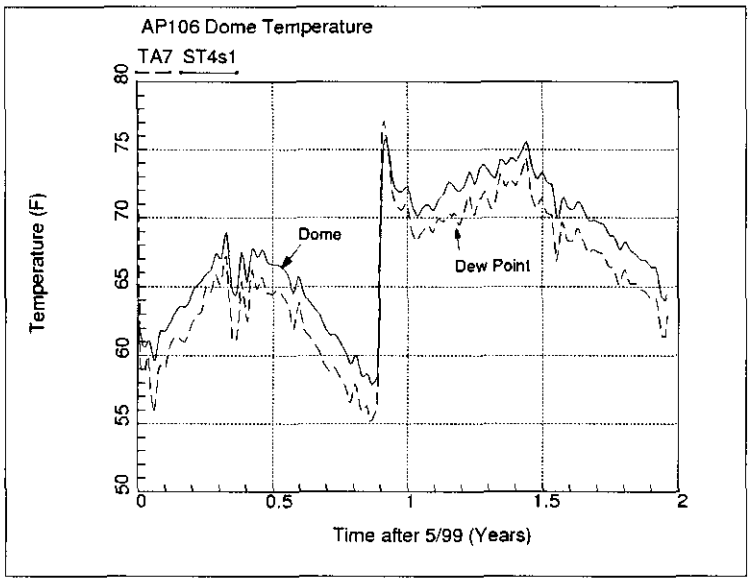
Figure 3-26. Comparison of AP-105 Wall Dew Point Temperatures.



3.2.6 *241-AP-106*

The results of the engineering evaluation for tank 241-AP-106 are shown in Figures 3-27 and 3-28. A comparison of the dome surface temperatures and vapor space dew point temperatures are shown in Figure 3-27. The predicted wall temperatures are always

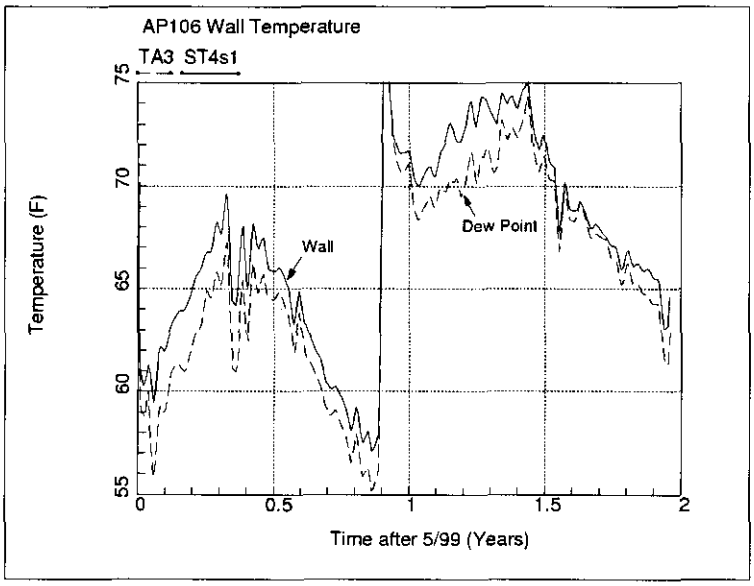
Figure 3-27. Comparison of AP-106 Dome and Dew Point Temperatures.



higher than the predicted vapor space dew point temperatures. No condensation is expected to occur on the dome of tank 241-AP-106.

A comparison of the predicted wall and dew point temperatures for 241-AP-106 are shown in Figure 3-28. The predicted wall temperatures are always greater than the predicted vapor space dew point temperature. Thus, no condensation is expected to occur on the wall surface of tank 241-AP-106.

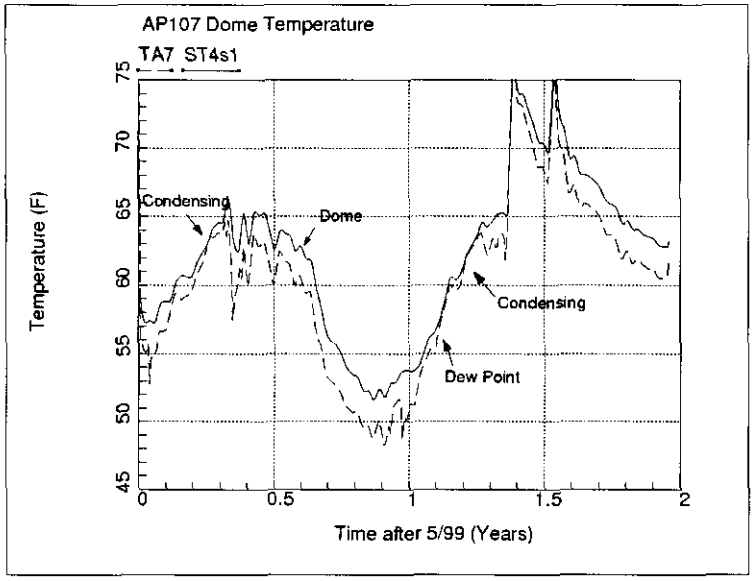
Figure 3-28. Comparison of AP-106 Wall and Dew Point Temperatures.



3.2.7 *241-AP-107*

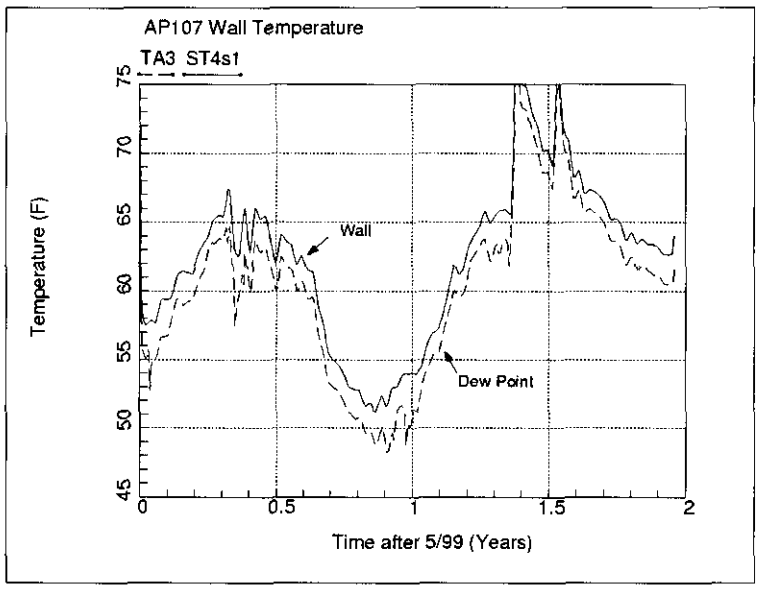
The results of the engineering evaluation for tank 241-AP-107 are shown in Figures 3-29 and 3-30. A comparison of the dome surface temperatures and vapor space dew point

Figure 3-29. Comparison of AP-107 Dome and Dew Point Temperatures.



temperatures are shown in Figure 3-29. Condensation is predicted to occur during portions of the summer and fall months. However, no condensation is expected during the winter and spring period.

Figure 3-30. Comparison of AP-107 Vapor Wall and Dew Point Temperatures.



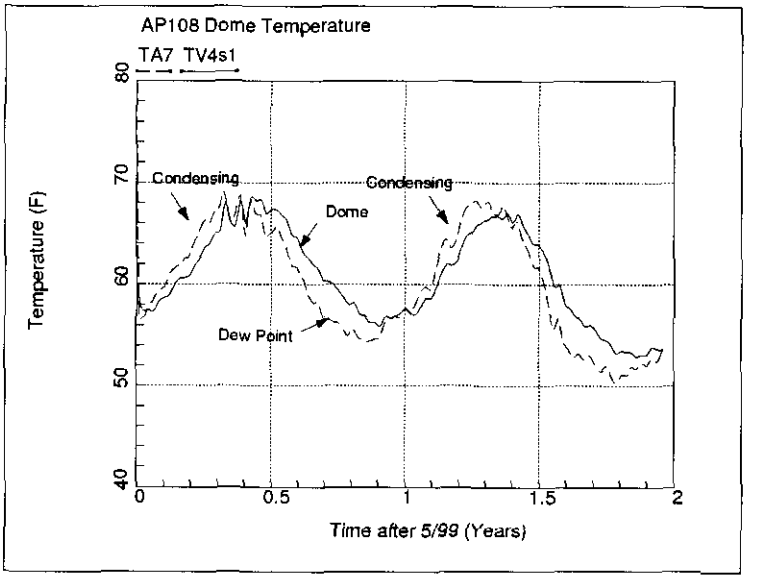
A comparison of the predicted wall and dew point temperatures for 241-AP-107 are shown in Figure 3-30. The predicted wall temperatures are always greater than the predicted vapor space dew point temperature except during short periods in 2001 when

the waste temperatures were higher than the expected seasonal temperatures. Thus, no condensation is expected to occur on the wall surface of tank 241-AP-107 during normal operation.

3.2.8 *241-AP-108*

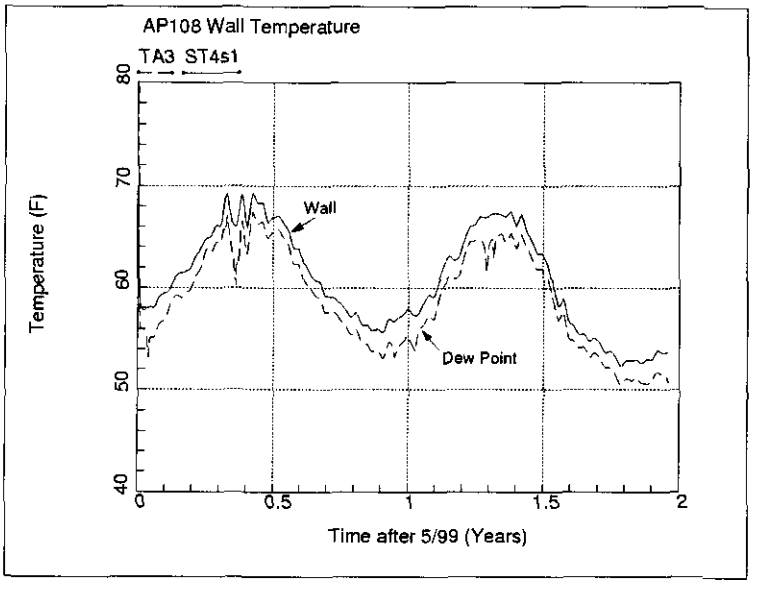
The results of the engineering evaluation for tank 241-AP-108 are shown in Figure 3-31 and 3-32. A comparison of the dome surface temperatures and vapor space dew point

Figure 3-31. Comparison of AP-108 Dome and Dew Point Temperatures.



temperatures are shown in Figure 3-31. As seen for the AN-Farm tanks, condensation is predicted to occur during portions of the summer and fall months. However, no condensation is expected during the winter and spring period.

Figure 3-32. Comparison of AP-108 Wall and Dew Point Temperatures.

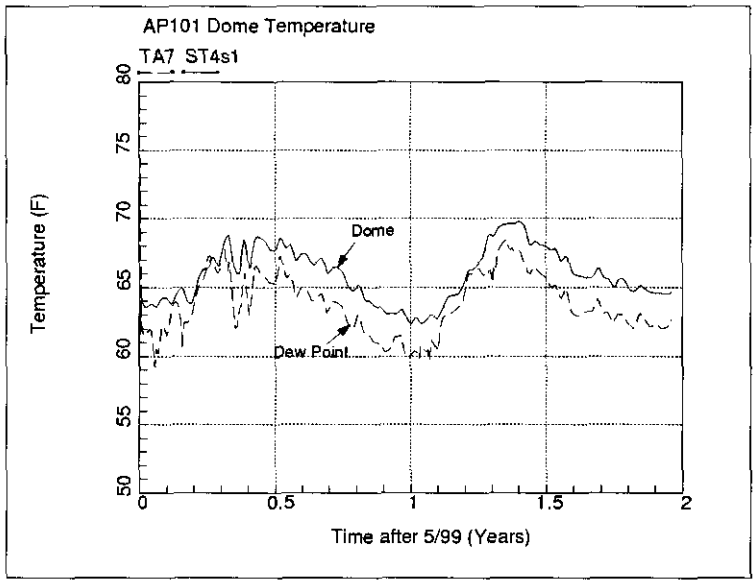


A comparison of the predicted wall and dew point temperatures for 241-AP-108 are shown in Figure 3-32. The predicted wall temperatures are always greater than the predicted vapor space dew point temperature. Thus, no condensation is expected to occur on the wall surface of tank 241-AP-108.

3.2.9 *AP-Farm Mitigation Evaluation*

The evaluation of the condensation potential for the AP-Farm vapor space indicated that there is a potential for condensation on the dome surface for many of the AP-Farm tanks. Condensation of the wall portion of the primary tank liner is expected to occur for only tank 241-AP-101. Analyses were conducted with the GOTH-SNF evaluation model to evaluate mitigation options using the ventilation system operation. A greater flow capacity will be available for the AP-Farm primary ventilation system after the Project W-314 upgrade discussed in Section 2.3.

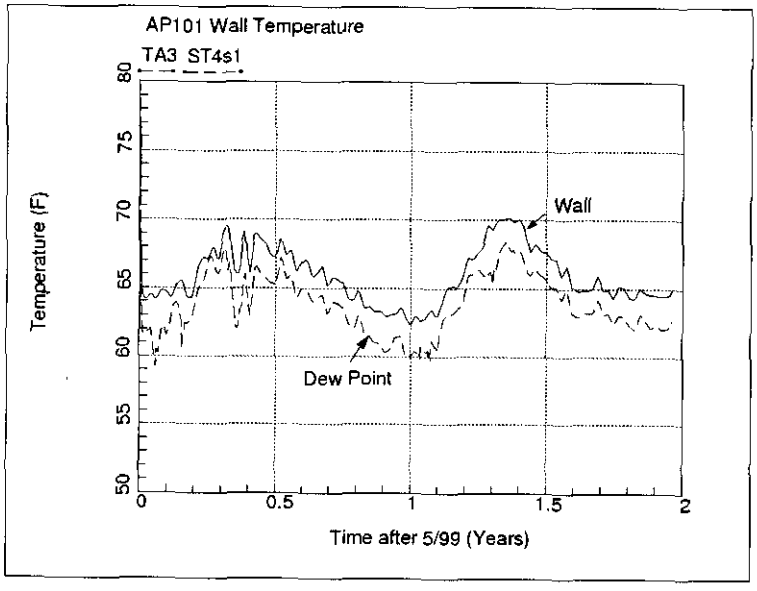
Figure 3-33. Comparison of AP-101 Dome and Dew Point Temperatures with Increased Primary Flow.



Analyses were performed for tank 241-AP-101 since both dome and wall condensation is predicted for this tank. The primary flow rate for each of the AN-Farm tanks was increased to 250 cfm. Increasing the heat removal from the tank will decrease the supernatant temperatures and further reduce the vapor space dew point. This effect was not included in this evaluation.

Results of the mitigation evaluation for the dome and wall temperatures are shown in Figures 3-33 and 3-34. The analyses show that increasing the primary ventilation system flow reduces the vapor space dew point temperature such that no condensation would be expected to occur for either the dome or wall surfaces of the primary tank.

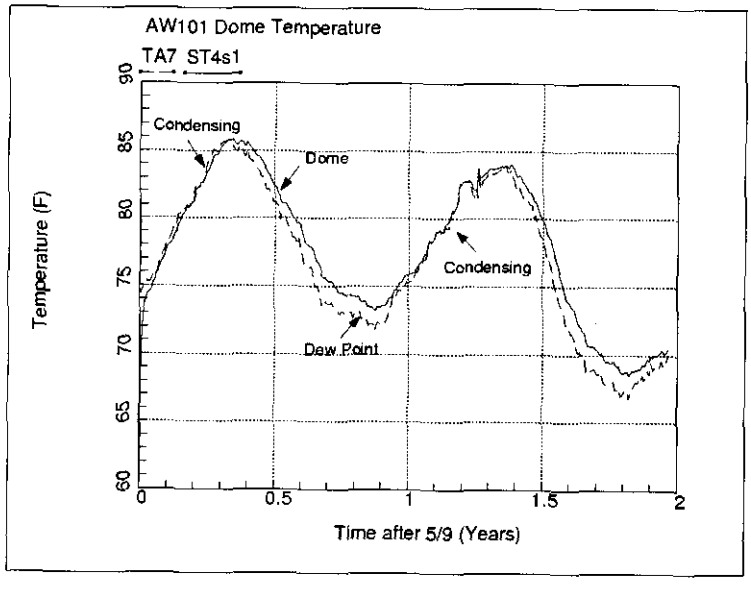
Figure 3-34. Comparison of AP-101 Wall and Dew Point Temperatures with Increased Primary Flow.



3.3 AW-FARM

The evaluation of the vapor space of each of the six AW-Farm tanks was conducted for a period from May 1, 1999 to May 1, 2001. The results are presented in the following sections.

Figure 3-35. Comparison of AW-101 Dome and Dew Point Temperatures.



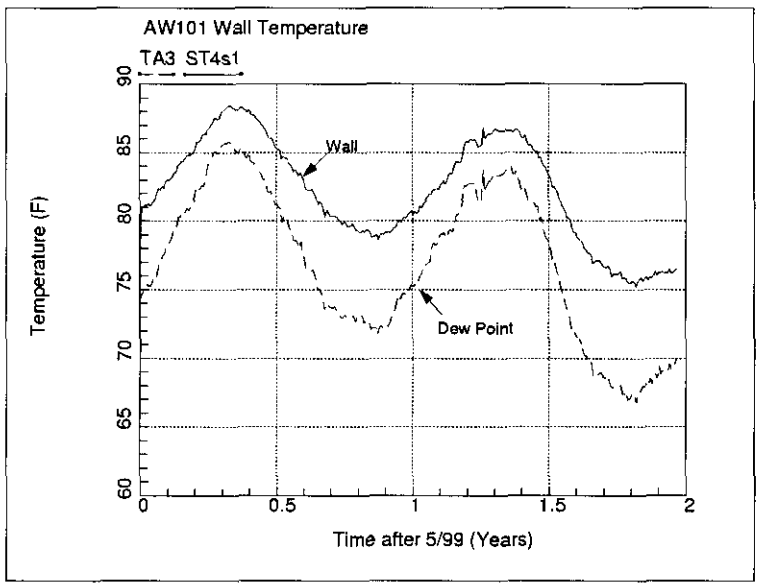
A summary of the average temperatures for the two year evaluation period are shown in Table 3-1. The average supernatant temperature for the seven AN-Farm tanks is 83 °F. The average supernatant temperature for the AP-Farm is 66 °F. The average supernatant temperature for the AW-Farm is 78 °F. On average the AW-Farm tanks are cooler than the AN-Farm tanks but hotter than the AP-Farm tanks. The potential for dome and wall condensation should be greater than the AP-Farm tanks but less than the AN-Farm tanks.

3.3.1 *241-AW-101*

The results of the engineering evaluation for tank 241-AW-101 are shown in Figures 3-35 and 3-36. A comparison of the dome surface temperatures and vapor space dew point temperatures are shown in Figure 3-35. As seen for the AN-Farm tanks, condensation is predicted to occur during portions of the summer and fall months. However, no condensation is expected during the winter and spring period.

A comparison of the predicted wall and dew point temperatures for 241-AW-101 are shown in Figure 3-36. The predicted wall temperatures are always greater than the predicted vapor space dew point temperature. Thus, no condensation is expected to occur on the wall surface of tank 241-AW-101. This result is similar to the tanks 241-AN-103 to 241-AN-105. A comparison of the average supernatant and dome for this tank (Table 3-1) indicates that a crust is limiting the flow of heat from the supernatant to the vapor space. Both the supernatant and bottom waste temperatures are greater than the

Figure 3-36. Comparison of AW-101 Wall and Dew Point Temperatures.

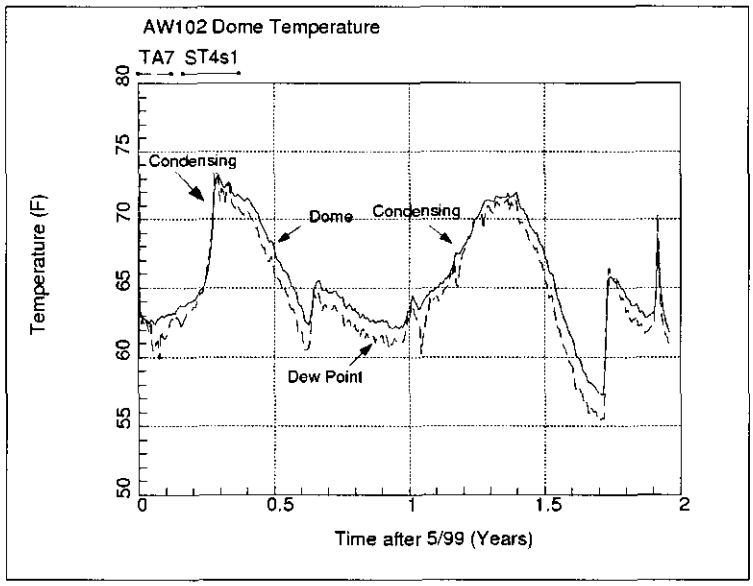


dome temperature. Thus the annulus air is heating the vapor space air through the primary tank wall which keeps the surface temperature of the wall greater than the predicted dew point temperature.

3.3.2 *241-AW-102*

The results of the engineering evaluation for tank 241-AW-102 are shown in Figures 3-37 and 3-38. A comparison of the dome surface temperatures and vapor space

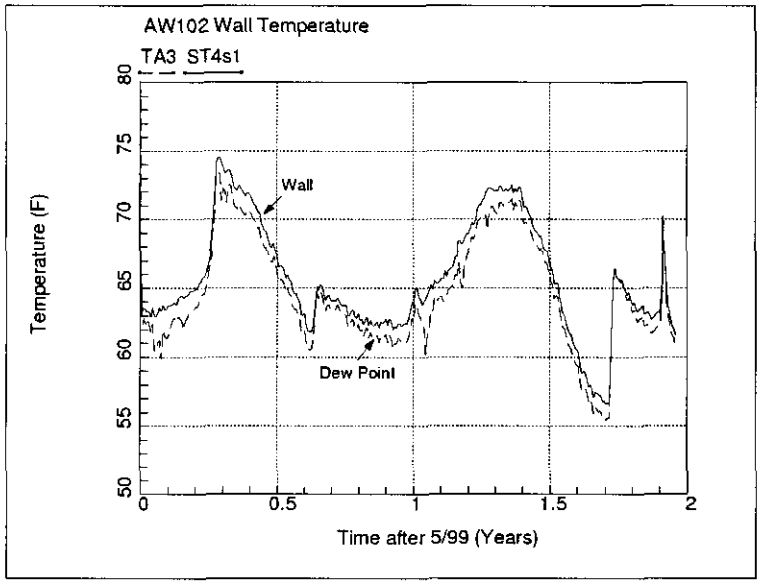
Figure 3-37. Comparison of AW-102 Dome and Dew Point Temperatures.



dew point temperatures are shown in Figure 3-37. As seen for the AN-Farm tanks, condensation is predicted to occur during portions of the summer and fall months. However, no condensation is expected during the winter and spring period.

A comparison of the predicted wall and dew point temperatures for 241-AW-102 are shown in Figure 3-38. The predicted wall temperatures are greater than the predicted vapor space dew point temperature during the summer and fall months (0 to0.5 years and 1.0 to 1.5 years). Thus, no condensation is expected to occur on the wall surface of tank 241-AW-102 during this period. However, dew point temperature approaches the wall temperature during the winter and spring months. Thus, wall condensation is expected to occur during this time.

Figure 3-38. Comparison of AW-102 Wall and Dew Point Temperatures.



3.3.3 *241-AW-103*

The results of the engineering evaluation for tank 241-AW-103 are shown in Figures 3-39 and 3-40. A comparison of the dome surface temperatures and vapor space dew point temperatures are shown in Figure 3-39. Dew point temperature is equal to or greater than the dome surface temperatures during portions of the summer and fall months. Dome surface condensation would be expected during the summer and fall months. No condensation is expected during the winter and spring months.

A comparison of the predicted wall and dew point temperatures for 241-AW-103 are shown in Figure 3-40. The predicted wall temperatures are always greater than the predicted vapor space dew point temperature. Thus, no condensation is expected to occur on the wall surface of tank 241-AW-103.

Figure 3-39. Comparison of AW-103 Dome and Dew Point Temperatures.

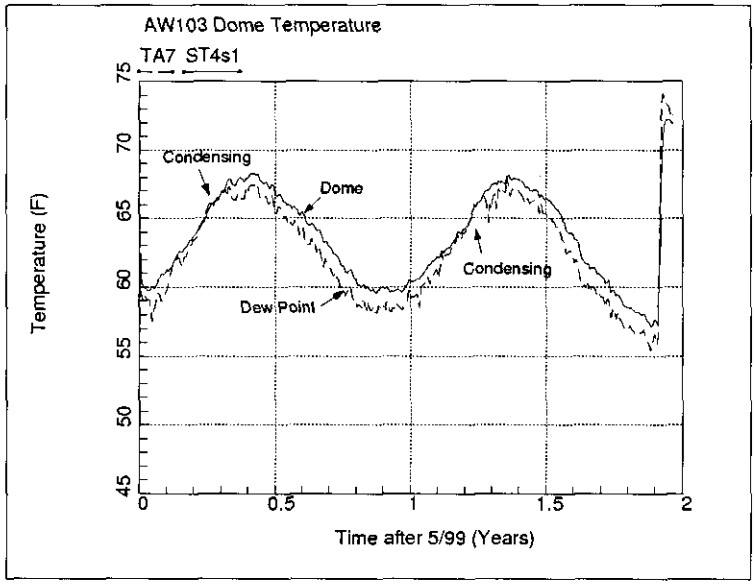
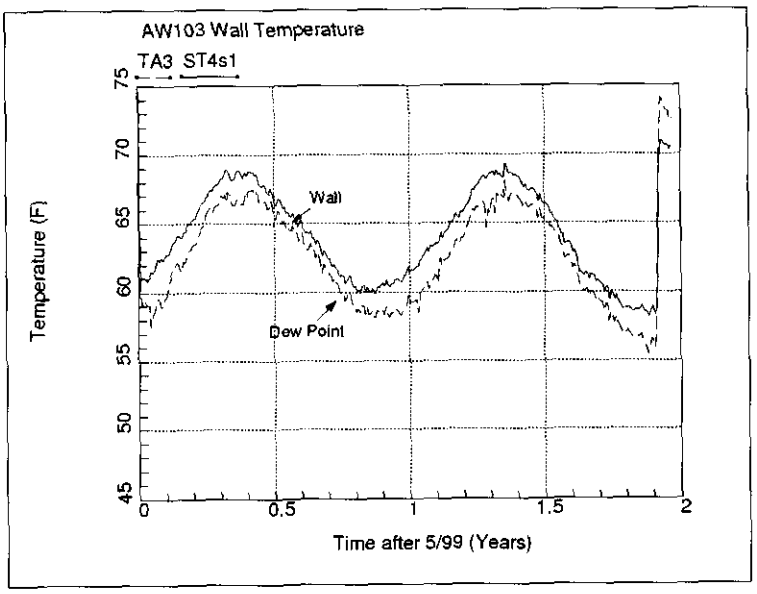


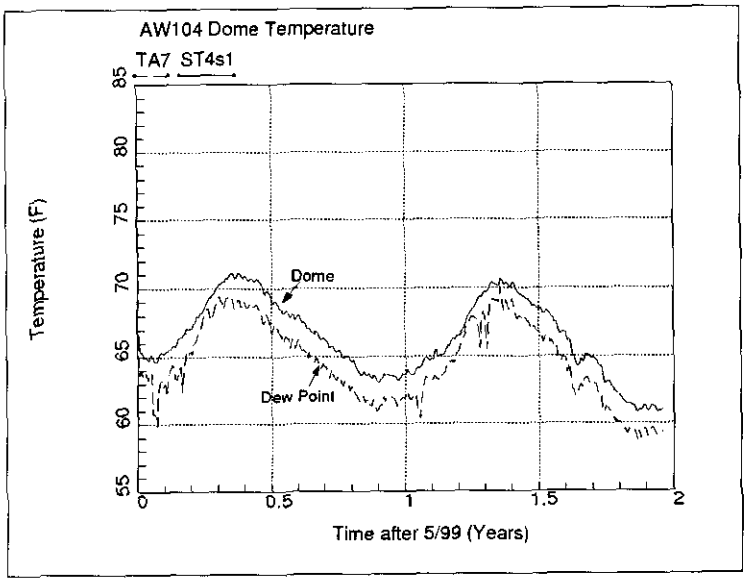
Figure 3-40. Comparison of AW-103 Wall and Dew Point Temperatures.



3.3.4 *241-AW-104*

The results of the engineering evaluation for tank 241-AW-104 are shown in Figures 3-41 and 3-42. A comparison of the dome surface temperatures and vapor space dew point temperatures are shown in Figure 3-41. Dew point temperature less than the dome surface temperatures during the entire period of the evaluation. Dome surface condensation is not expected to occur for tank 241-AW-104.

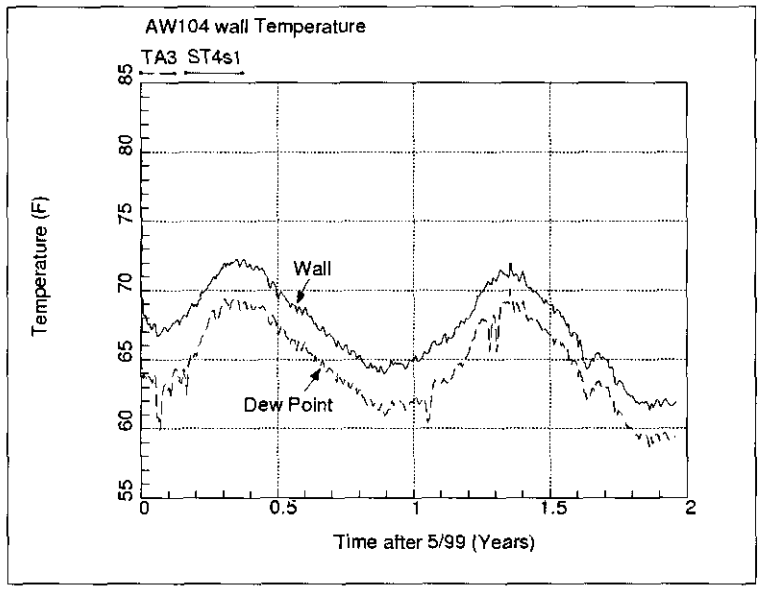
Figure 3-41. Comparison of AW-104 Dome and Dew Point Temperatures.



A comparison of the predicted wall and dew point temperatures for tank 241-AW-104 are shown in Figure 3-42. The predicted wall temperatures are always greater than the

predicted vapor space dew point temperature. Thus, no condensation is expected to occur on the wall surface of tank 241-AW-104.

Figure 3-42. Comparison of AW-104 Wall and Dew Point Temperatures.



3.3.5 *241-AW-105*

The results of the engineering evaluation for tank 241-AW-105 are shown in Figures 3-43 and 3-44. A comparison of the dome surface temperatures and vapor space dew point temperatures are shown in Figure 3-43. Dew point temperature is equal to or greater than the dome surface temperatures during portions of the summer and fall months. Dome surface condensation is expected to occur for tank 241-AW-105 during this period. The dome temperature is greater than the dew point temperatures during the winter and spring months. No condensation is expected to occur on the wall during this period.

Figure 3-43. Comparison of AW-105 Dome and Dew Point Temperatures.

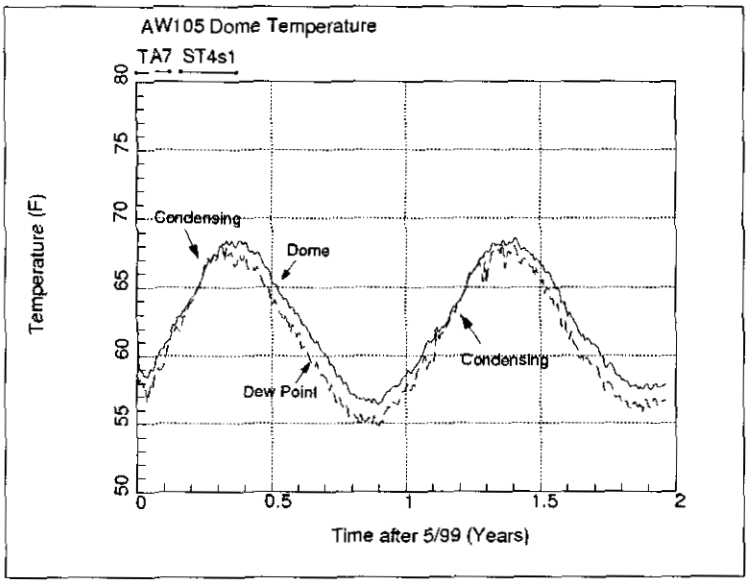
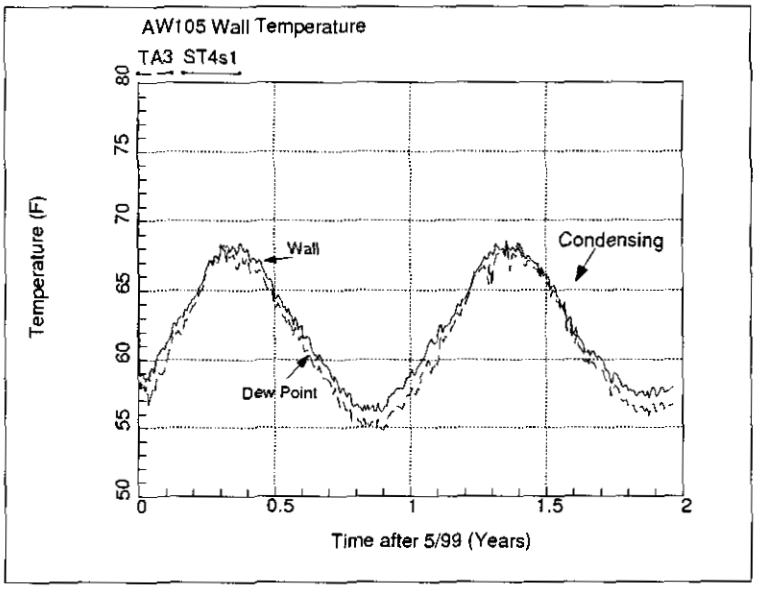


Figure 3-44. Comparison of AW-105 Wall and Dew Point Temperatures.

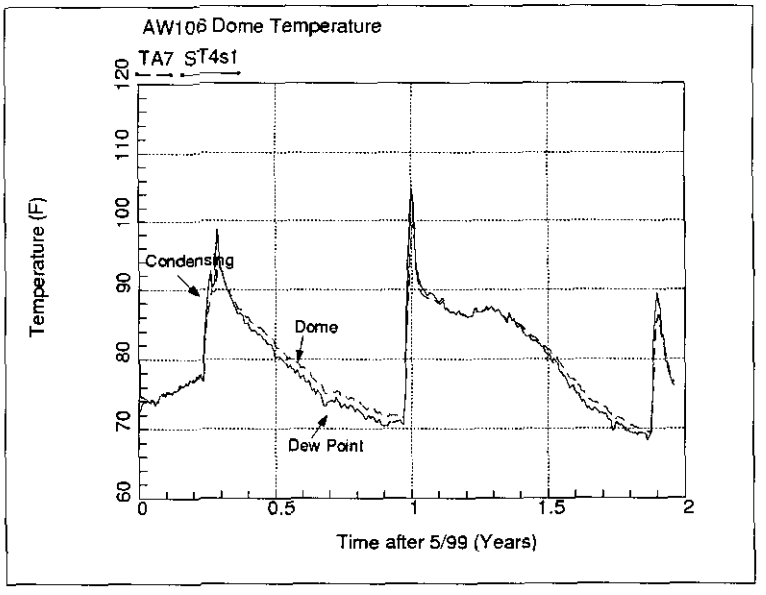


A comparison of the predicted wall and dew point temperatures for tank 241-AW-105 are shown in Figure 3-44. The predicted dew point temperature is equal to or greater than the wall surface temperatures during the winter and spring months (.5 to 1 years and 1.5 to 2.0 years). Condensation is expected to occur during this period. The dew point temperature is lower than the wall temperature during the remainder of the evaluation period

3.3.6 *241-AW-106*

The results of the engineering evaluation for tank 241-AW-106 are shown in Figures 3-45 and 3-46. A comparison of the dome surface temperatures and vapor space

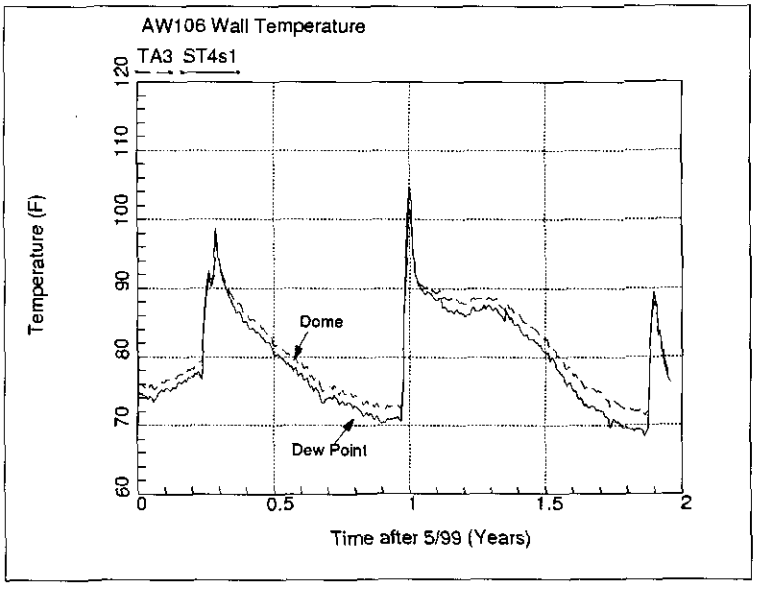
Figure 3-45. Comparison of AW-106 Dome and Dew Point Temperatures.



dew point temperatures are shown in Figure 3-45. Dew point temperature is equal to or greater than the dome surface temperatures during portions of the summer and fall months. Dome surface condensation is expected to occur for tank 241-AW-105 during this period. The dome temperature is greater than the dew point temperatures during the winter and spring months. No condensation is expected to occur on the dome during this period.

A comparison of the predicted wall and dew point temperatures for tank 241-AW-106 are shown in Figure 3-46. The predicted dew point temperature is less than the wall surface temperatures except during two periods of rapid temperature change not typical of the normal seasonal temperature variation. Condensation is not expected to occur on the wall surface during normal operation.

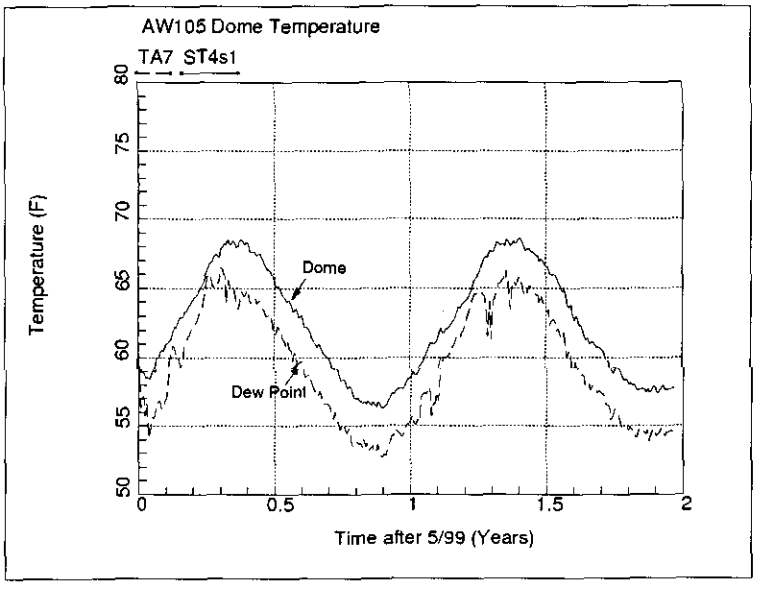
Figure 3-46. Comparison of AW-106 Wall and Dew Point Temperatures.



3.3.7 *AW-Farm Mitigation Evaluation*

The evaluation of the condensation potential for the AW-Farm vapor space indicated that there is a potential for condensation on the dome and wall surfaces for many of the AW-Farm tanks. Analyses were conducted with the GOTH-SNF evaluation model to

Figure 3-47. Comparison of AW-105 Dome and Dew Point Temperatures with Increased Primary Flow.

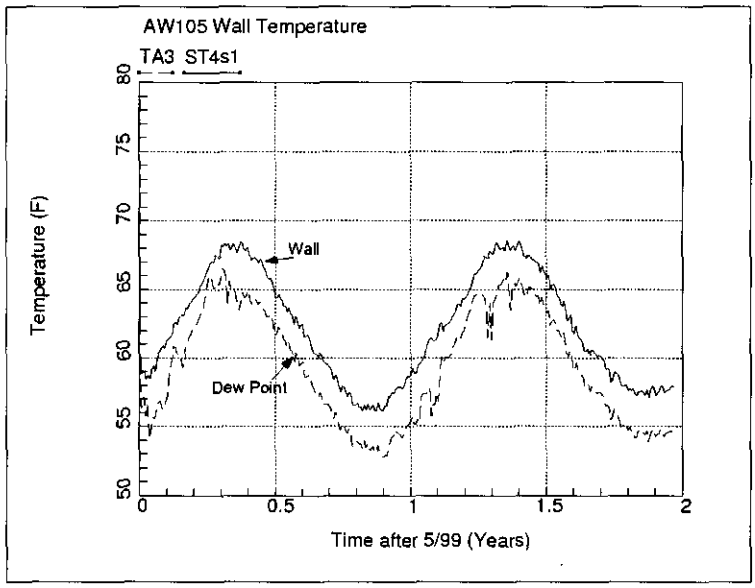


evaluate mitigation options using the ventilation system operation. A greater flow capacity will be available for the AW-Farm primary ventilation system after the Project W-314 upgrade discussed in Section 2.3.

Analyses were performed for tank 241-AW-105 since both dome and wall condensation is predicted for this tank. The primary flow rate for each of the AW-Farm tanks was increased to 330 cfm. Increasing the heat removal from the tank will decrease the supernatant temperatures and further reduce the vapor space dew point. This effect was not included in this evaluation.

Results of the mitigation evaluation for the dome and wall temperatures are shown in Figures 3-47 and 3-48. The analyses show that increasing the primary ventilation system flow reduces the vapor space dew point temperature such that no condensation would be expected to occur for either the dome or wall surfaces of the primary tank liner.

Figure 3-48. Comparison of AW-105 Wall and Dew Point Temperatures with Increased Primary Flow.



3.4 SY-FARM

The evaluation of the vapor space of each of the three SY-Farm tanks was conducted for a period from May 1, 1999 to May 1, 2001. The results are presented in the following sections.

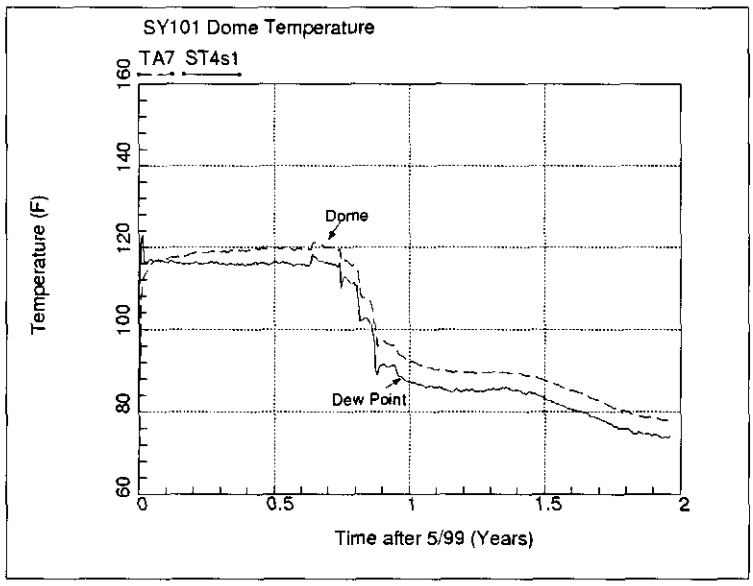
A summary of the average temperatures for the two-year evaluation period are shown in Table 3-1. The average supernatant temperature for the seven AN-Farm tanks is 83 °F. The average supernatant temperature for the AP-Farm is 66 °F. The average supernatant temperature for the AW-Farm is 78 °F. The average supernatant temperature for the SY-Farm is 91 °F. On average the SY-Farm tanks are warmer than the AN, AP and AW-Farms. The potential for dome and wall condensation would be greater if the ventilation flow rate were comparable. However, SY-Farm has over 300 cfm per tank

primary ventilation flow (Table 2-3). The annulus flow rate is the least of all the DST's at 300 cfm. The larger primary flow rate and smaller annulus flow rate will greatly reduce the condensation potential on the vapor space dome and wall.

3.4.1 *241-SY-101*

The results of the engineering evaluation for tank 241-SY-101 are shown in Figures 3-49

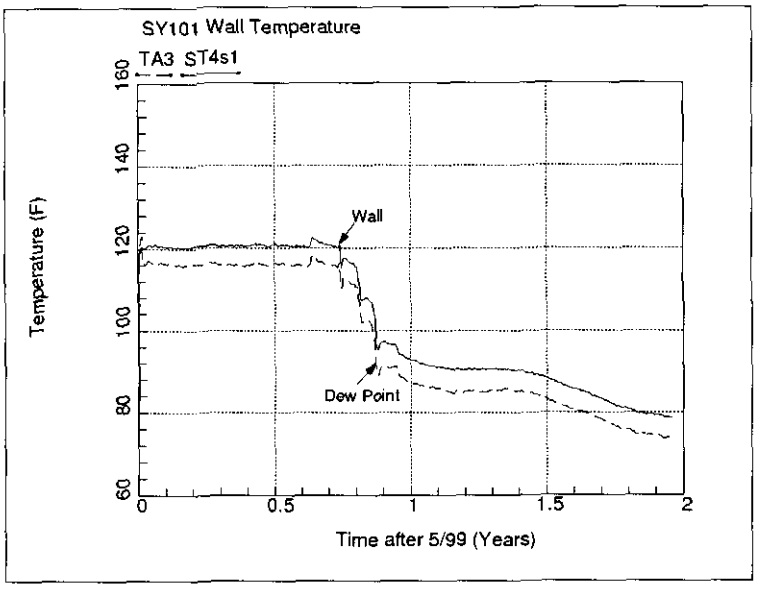
Figure 3-49. Comparison of SY-101 Dome and Dew Point Temperatures.



and 3-50. A comparison of the dome surface temperatures and vapor space dew point temperatures are shown in Figure 3-49. Dew point temperature is less than the dome surface temperature during the evaluation period. No condensation is expected during to occur on the dome surface of the vapor space.

A comparison of the predicted wall and dew point temperatures for 241-SY-101 are shown in Figure 3-50. The predicted wall temperatures are always greater than the predicted vapor space dew point temperature. Thus, no condensation is expected to occur on the wall surface of tank 241-SY-101.

Figure 3-50. Comparison of SY-101 Wall and Dew Point Temperatures.



3.4.2 *241-SY-102*

The results of the engineering evaluation for tank 241-SY-102 are shown in Figures 3-51 and 3-52. A comparison of the dome surface temperatures and vapor space dew point temperatures are shown in Figure 3-51. Dew point temperature is less than the dome surface temperature during the evaluation period. No condensation is expected during to occur on the dome surface of the vapor space.

A comparison of the predicted wall and dew point temperatures for 241-SY-102 are shown in Figure 3-52. The predicted wall temperatures are always greater than the predicted vapor space dew point temperature. Thus, no condensation is expected to occur on the wall surface of tank 241-SY-102.

3.4.3 *241-SY-103*

The results of the engineering evaluation for tank 241-SY-103 are shown in Figures 3-53 and 3-54. A comparison of the dome surface temperatures and vapor space dew point

Figure 3-51. Comparison of SY-102 Dome and Dew Point Temperatures.

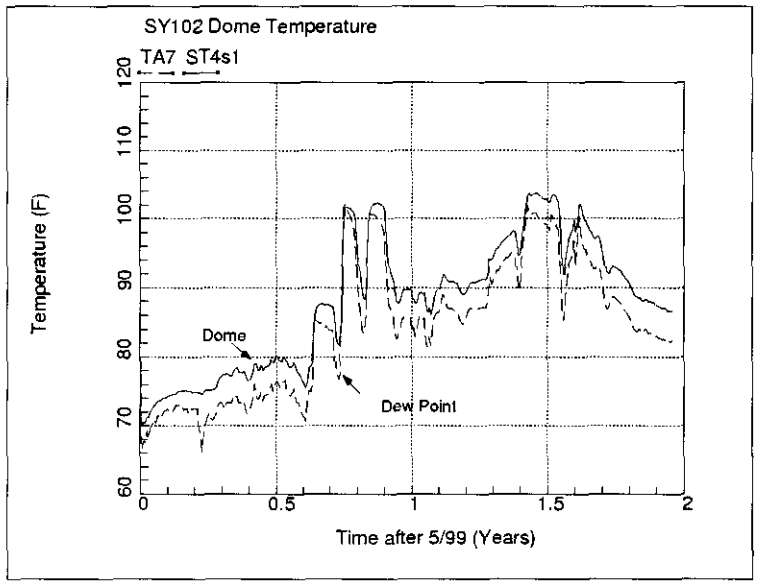
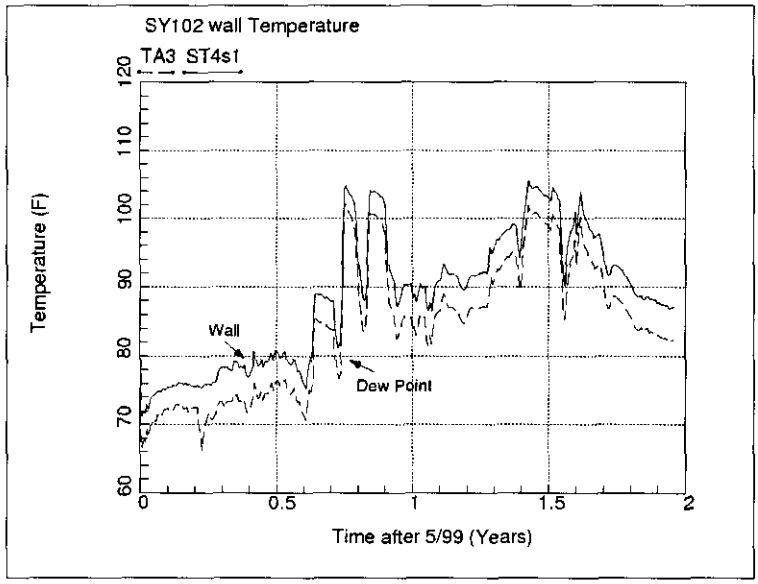


Figure 3-52. Comparison of SY-102 Wall and Dew Point Temperatures.



temperatures are shown in Figure 3-53. Dew point temperature is less than the dome surface temperature during the evaluation period. No condensation is expected during to occur on the dome surface of the vapor space.

A comparison of the predicted wall and dew point temperatures for 241-SY-103 are shown in Figure 3-54. The predicted wall temperatures are always greater than the predicted vapor space dew point temperature. Thus, no condensation is expected to occur on the wall surface of tank 241-SY-103.

Figure 3-53. Comparison of SY-103 Dome and Dew Point Temperatures.

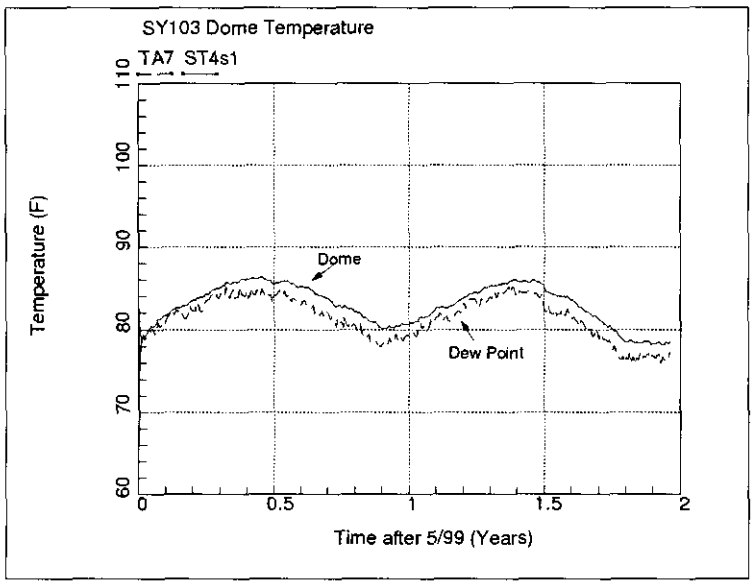
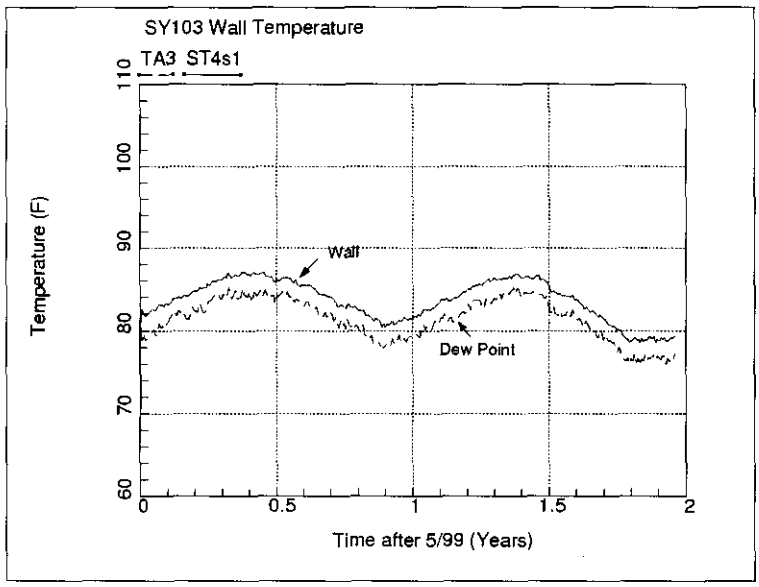


Figure 3-54. Comparison of AW-103 Wall and Dew Point Temperatures.



3.5 AY-FARM

The evaluation of the vapor space of both the AY-Farm tanks was conducted for a period from May 1, 2000 to May 1, 2002. The results are presented in the following sections.

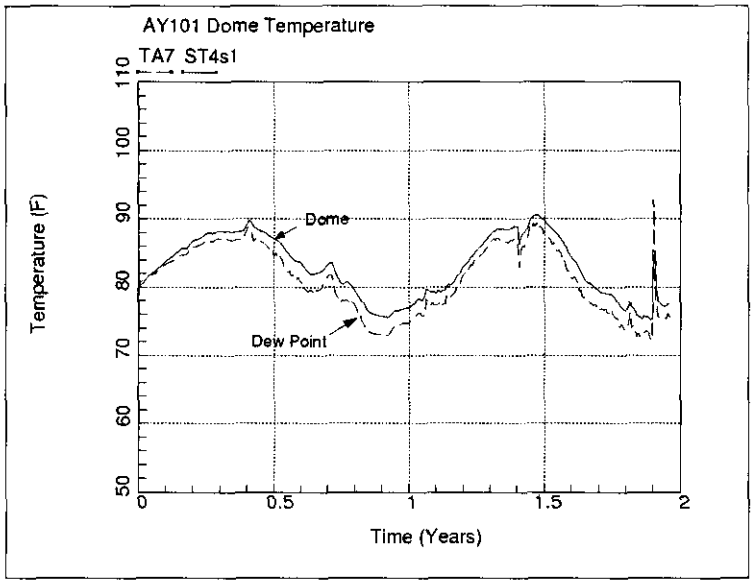
A summary of the average temperatures for the two-year evaluation period is shown in Table 3-1. The average supernatant temperature for the four AWF tanks are on average considerably higher than the AN, AP, AW and SY-Farm tanks. The primary ventilation flow rates for the AY tanks (Table 2-4) are both over 300 cfm. In addition, these tanks

are both cooled by the AZ-702 recirculation system in addition to the primary and annulus ventilation systems.

3.5.1 *241-AY-101*

The results of the engineering evaluation for tank 241-AY-101 are shown in Figures 3-55 and 3-56. A comparison of the dome surface temperatures and vapor space dew point

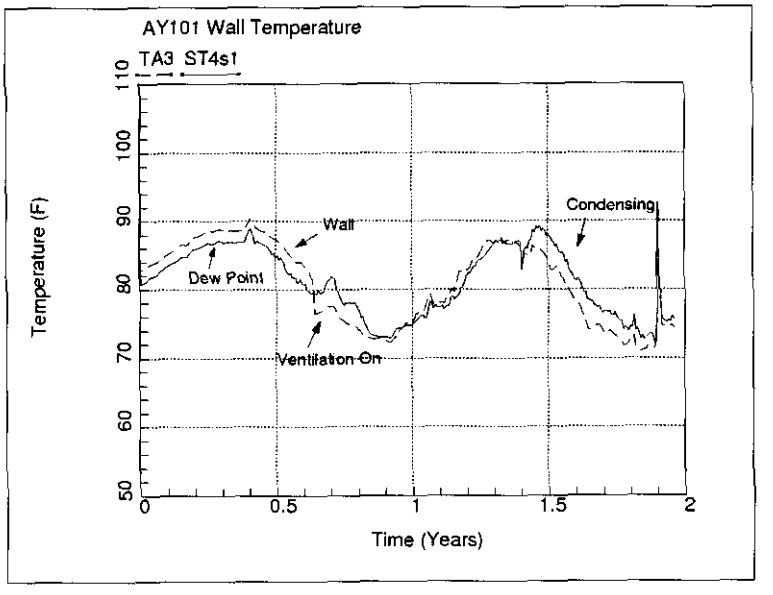
Figure 3-55. Comparison of AY-101 Dome and Dew Point Temperatures.



temperatures are shown in Figure 3-55. Dew point temperature is less than the dome surface temperature during the evaluation period. No condensation is expected to occur on the dome surface of the vapor space during this period.

A comparison of the predicted wall and dew point temperatures for 241-AY-101 are shown in Figure 3-56. The predicted wall temperatures are greater than the predicted vapor space dew point temperature for the first 0.7 years. The annulus ventilation system was not in operation during this period. After the annulus ventilation system operation was initiated, the dew point temperature exceeded the wall temperature. This condition occurred again during the winter and spring months of 2002. Thus the initiation of the annulus ventilation system operation created vapor space conditions which promote condensation of the vapor space wall. This is a direct result of the annulus wall bypass flow discussed in Section 2.3.2. Approximately 80% of the annulus system air goes directly to the annulus wall region. This air is not pre-heated by the bottom air, which occurs, as the annulus air passes through the floor slots. As a result, during the winter and spring months, the annulus air is cooled by the ambient temperature below the vapor space air temperature. The vapor space is cooled by the vapor space wall, which promotes wall condensation.

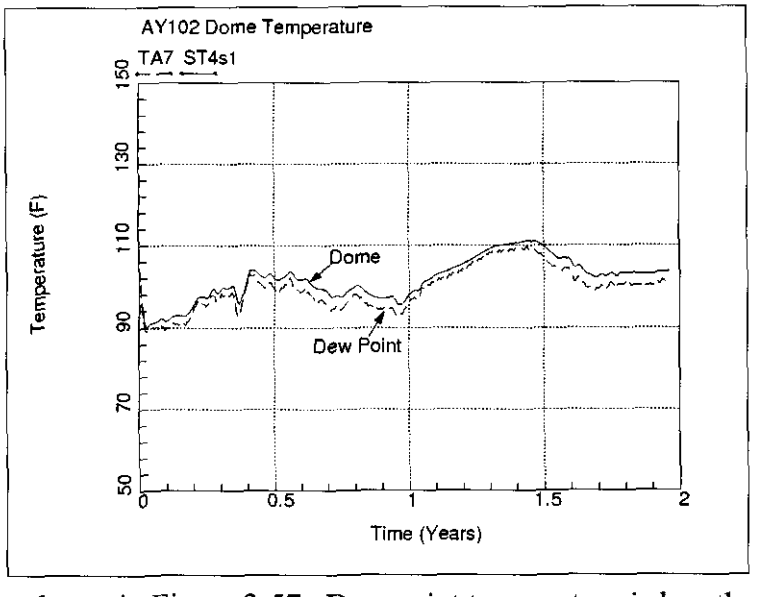
Figure 3-56. Comparison of AY-101 Wall and Dew Point Temperatures.



3.5.2 *241-AY-102*

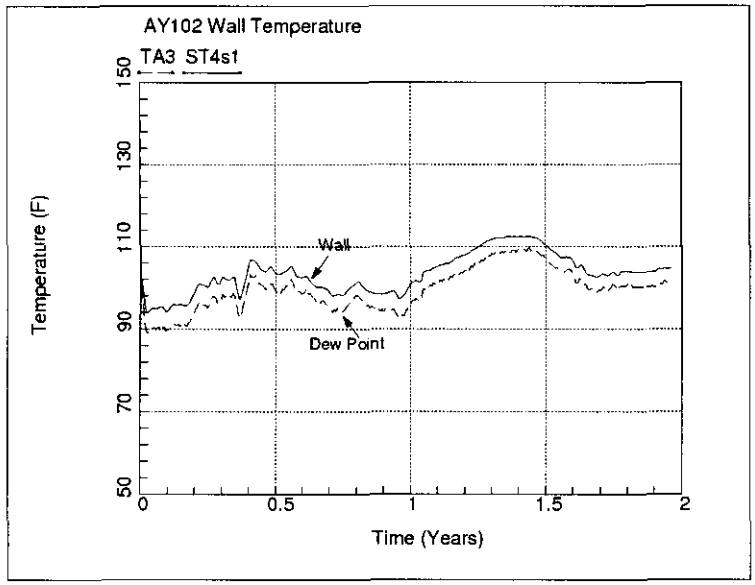
The results of the engineering evaluation for tank 241-AY-102 are shown in Figures 3-57 and 3-58. A comparison of the dome surface temperatures and vapor space dew point

Figure 3-57. Comparison of AY-102 Dome and Dew Point Temperatures.



temperatures are shown in Figure 3-57. Dew point temperature is less than the dome surface temperature during the evaluation period. No condensation is expected during to occur on the dome surface of the vapor space.

Figure 3-58. Comparison of AY-102 Wall and Dew Point Temperatures.

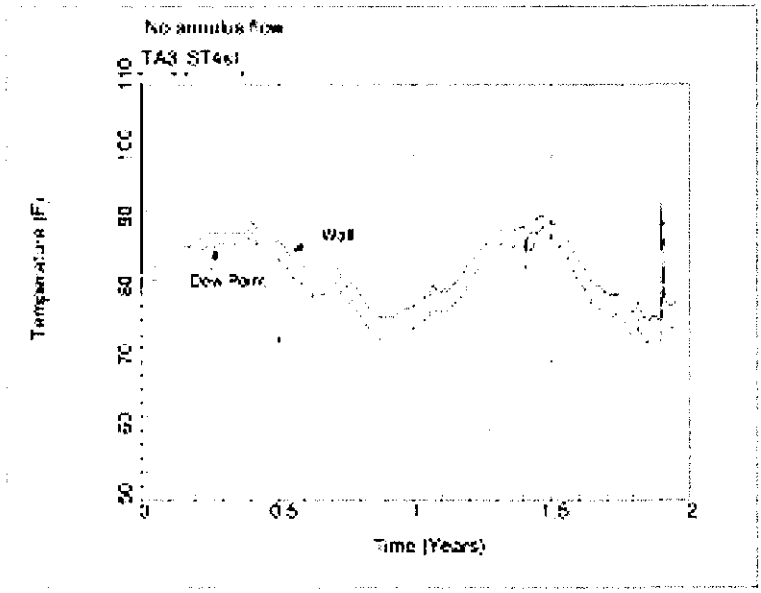


A comparison of the predicted wall and dew point temperatures for 241-AY-102 are shown in Figure 3-58. The predicted wall temperatures are always greater than the predicted vapor space dew point temperature. Thus, no condensation is expected to occur either on the dome or wall surfaces of tank 241-AY-102.

3.5.3 *AY-Farm Mitigation Evaluation*

Wall condensation will occur for tank 241-AY-101 because of the operation of the annulus ventilation system. Mitigation analyses were performed for tank to determine the annulus system flow rate that would not promote wall condensation. Analyses were performed with the GOTH-SNF evaluation model. The first analyses assumed no annulus ventilation flow. This analysis further demonstrated that the annulus ventilation flow was contributing to the wall condensation. The results are shown in Figures 3-59. The wall temperatures are always higher than the dew point temperature if the annulus ventilation system is not operating as shown in the figure. Thus, condensation of the wall of 241-AY-101 will not occur if there is no annulus ventilation flow.

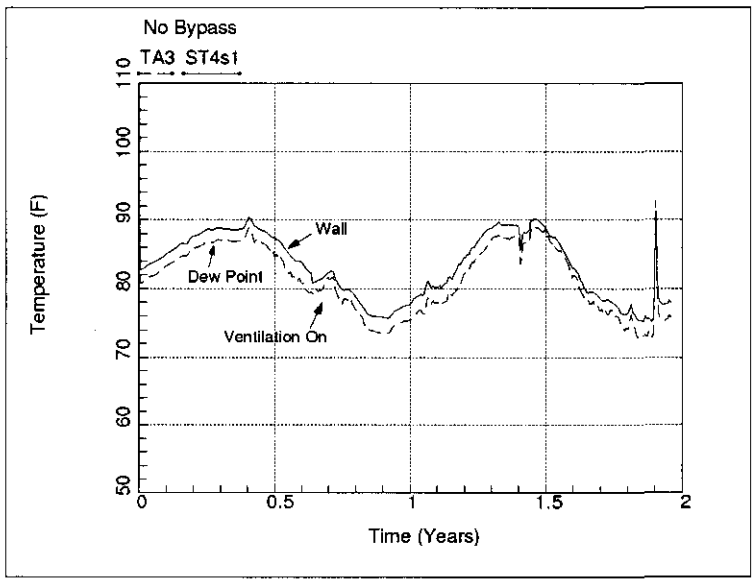
Figure 3-59. Comparison of AY-101 Wall and Dew Point Temperatures with No Annulus Flow.



The annulus ventilation system must operate to remove possible moisture ingress into the annulus region. Eliminating the annulus system flow is not an alternative for mitigating wall condensation. However, only a minimum flow on the order of 200 cfm (Ogden 2001) is required for moisture removal.

Two options for mitigation using the ventilation system exist. The first option is the elimination of the wall bypass flow for the annulus ventilation system. This was

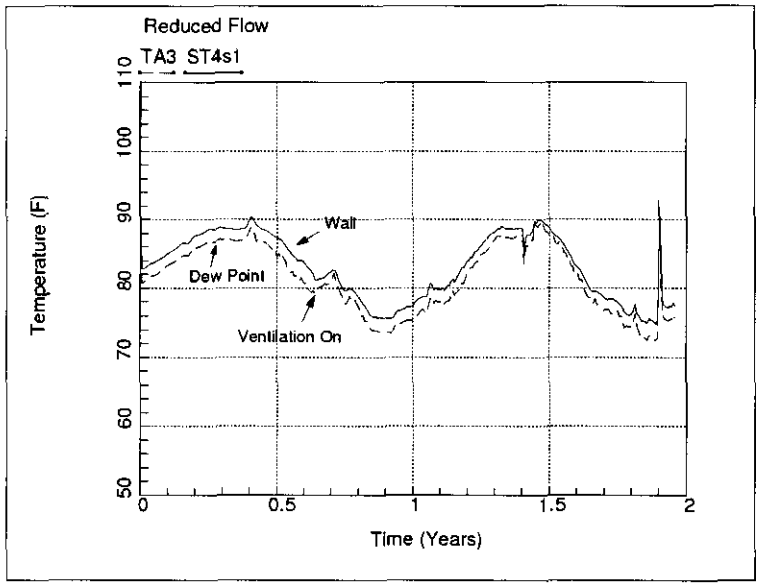
Figure 3-60. Comparison of AY-101 Wall and Dew Point Temperatures with No Bypass Flow.



accomplished for tank 241-AY-102 as part of Project W-320 (Lentsch 1999b). This would eliminate the wall condensation. The annulus air would be heated by the bottom waste. Table 3-1 shows that the bottom waste temperatures for 241-AY-101. It is over 30 °F higher than the vapor space temperature. The vapor space would be heated by the annulus air and water vapor could not condense on the wall. Figure 3-60 shows the results of analyses with no wall bypass flow. A total annulus flow of 900 cfm (based upon 241-AY-102 annulus flow without wall bypass) was used. All the flow is directed to the floor slots with no wall bypass. Figure 3-60 shows that the wall temperature is always above the dew point temperature. No wall condensation would occur if the bypass flow is eliminated. Eliminating the wall bypass would however be costly and may not be the best alternative.

A second alternative would be to simply reduce annulus ventilation system flow. This may be possible by closing damper valves. Analyses were performed for a reduced annulus system flow. The relative flow split between the slot and bypass flow was maintained. The total flow was reduced to 240 cfm or about 85%. The results of the analyses are shown in Figure 3-61. With this reduced annulus system flow, the wall condensation is eliminated.

Figure 3-61. Comparison of AY-101 Wall and Dew Point Temperatures with Reduced Annulus Flow.



Further evaluations will be required to determine if it is possible to reduce the annulus system flow by as much as 85%. Moisture removal capabilities of the annulus ventilation system with a significantly reduced flow must also be evaluated (Ogden 2001). However, these analyses suggest that either elimination of the wall bypass or a significant reduction in the annulus system flow is required to eliminate the potential for condensation of the wall of tank 241-AY-101.

3.6 AZ-FARM

The evaluation of the vapor space of both the AZ-Farm tanks was conducted for a period from May 1, 2000 to May 1, 2002. The results are presented in the following sections.

A summary of the average temperatures for the two year evaluation period are shown in Table 3-1. The average supernatant temperature for the AZ tanks is significantly higher than all other DST's. The primary ventilation flow rates for the AZ tanks (Table 2-4) are on the order of the AN, AP and AW-Farms. Both of the AZ tanks are cooled by AZ-702 recirculation system in addition to the primary and annulus ventilation systems. The annulus wall bypass valves were assumed to be closed, which would direct all the flow to the floor slots. This may not be the current operating mode, but it can be achieved through external valve settings.

3.6.1 *241-AZ-101*

The results of the engineering evaluation for tank 241-AZ-101 are shown in Figures 3-62 and 3-63. A comparison of the dome surface temperatures and vapor space dew point temperatures are shown in Figure 3-62. Dew point temperature is less than the dome surface temperature during the evaluation period. No condensation is expected during to occur on the dome surface of the vapor space.

A comparison of the predicted wall and dew point temperatures for 241-AZ-101 are shown in Figure 3-63. The predicted wall temperatures are always greater than the predicted vapor space dew point temperature. Thus, no condensation is expected to occur either on the dome or wall surfaces of tank 241-AZ-101.

Figure 3-62. Comparison of AZ-101 Dome and Dew Point Temperatures.

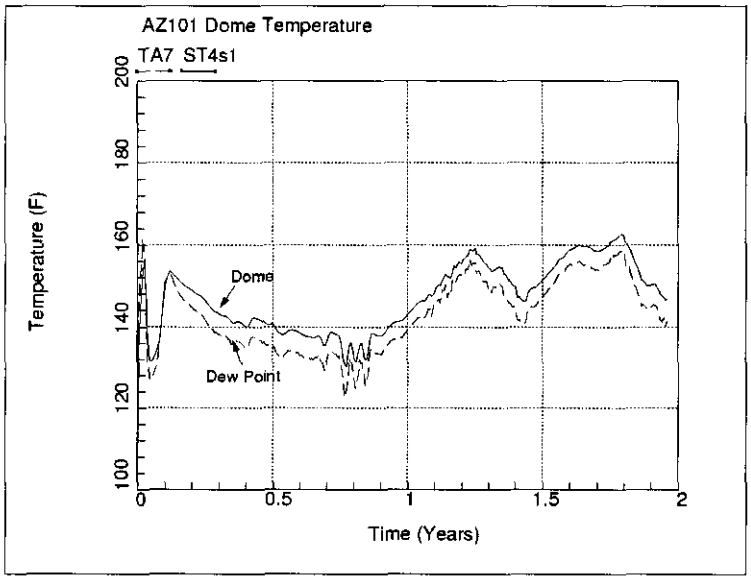
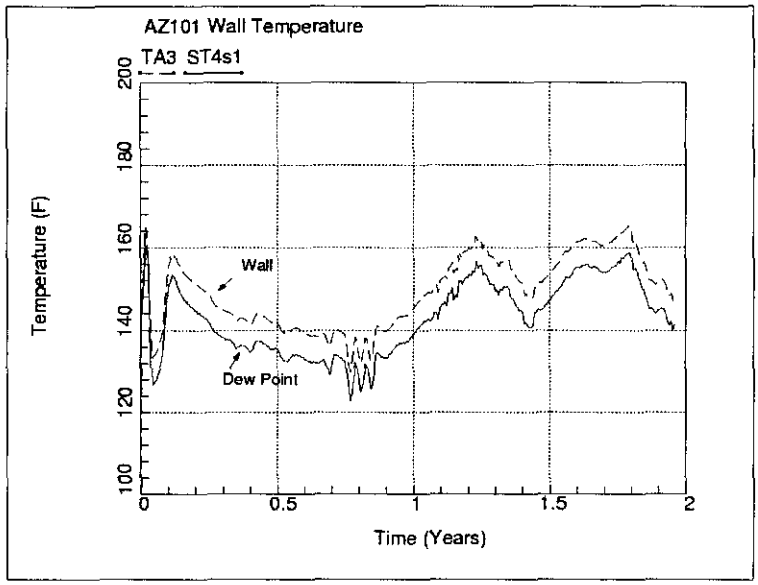


Figure 3-63. Comparison of AZ-101 Wall and Dew Point Temperatures.



Sensitivity analyses were performed for the wall bypass valves in an open position and a total flow of 1100 cfm, which is consistent with current ventilation system operations. The temperature difference between the dome/wall and the dew point temperature was reduced; however the structure temperatures remained higher than the dew point temperature. Thus, condensation would not be expected to occur on the dome or the tank wall with annulus wall bypass flow.

3.6.2 *241-AZ-102*

The results of the engineering evaluation for tank 241-AZ-102 are shown in Figures 3-64 and 3-65. A comparison of the dome surface temperatures and vapor space dew point temperatures are shown in Figure 3-64. Dew point temperature is less than the dome surface temperature during the evaluation period. No condensation is expected during to occur on the dome surface of the vapor space.

A comparison of the predicted wall and dew point temperatures for 241-AZ-102 are shown in Figure 3-65. The predicted wall temperatures are always greater than the predicted vapor space dew point temperature. Thus, no condensation is expected to occur either on the dome or wall surfaces of tank 241-AZ-102.

Sensitivity analyses were performed for the wall bypass valves in an open position and a total flow of 1100 cfm, which is consistent with current ventilation system operations. The temperature difference between the dome/wall and the dew point temperature was reduced; however the structure temperatures remained higher than the dew point temperature. Thus, condensation would not be expected to occur on the dome or the tank wall with annulus wall bypass flow.

Figure 3-64. Comparison of AZ-102 Dome and Dew Point Temperatures.

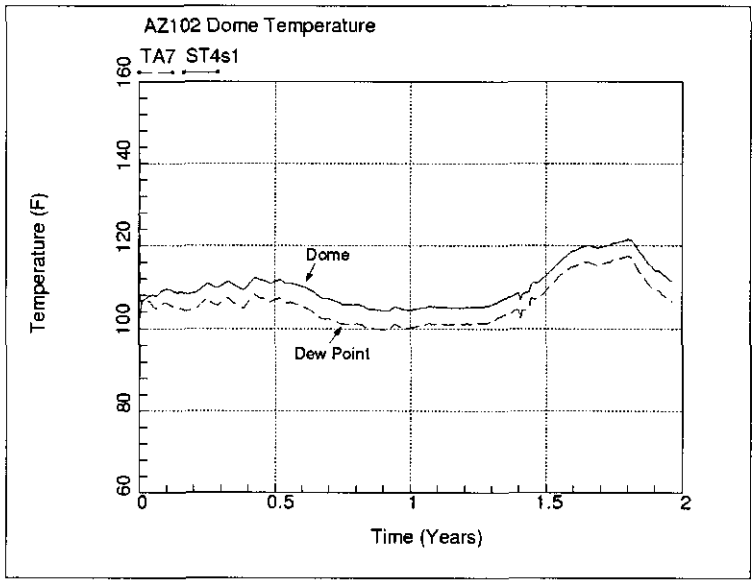
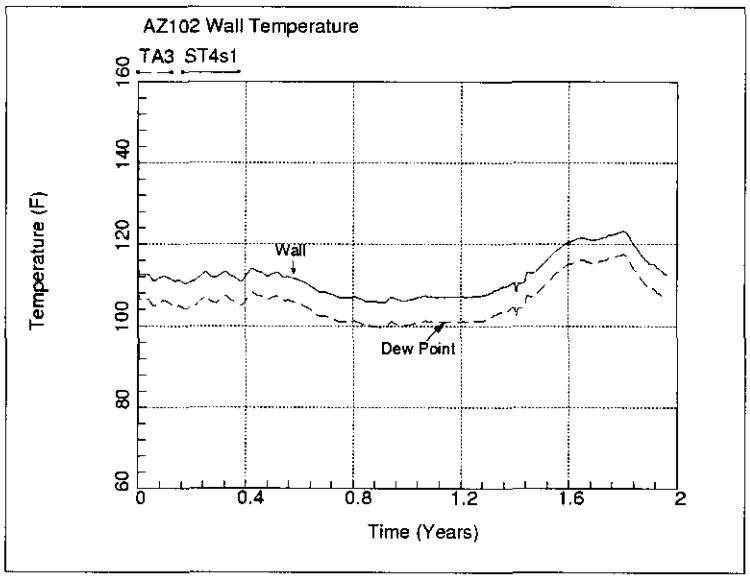


Figure 3-65. Comparison of AZ-102 Wall and Dew Point Temperatures.



3.7 SUMMARY OF VAPOR SPACE ENGINEERING EVALUATION

Results of the engineering evaluation of the vapor space Psychrometric conditions and surface condensation potential is provided in the following sections.

3.7.1 *Current Conditions*

Table 3-1 summarizes the results of the engineering evaluation of the twenty-eight DST's using the current ventilation system flows. Dome and wall surface condensation is expected for many of the tank in the AN, AP and AW-Farms. Dome condensation is expected on all the AN-Farm tanks and wall condensation is expected for 4 out of 7 tanks. The AP-Farm in general has the lowest temperature waste. As a result, the condensation potential is less than the AN-Farm. Wall condensation is expected on only one of the AP-Farm tanks and dome condensation on 5 out of the 8 tanks. The average supernatant temperatures of the AW-Farm are cooler than the AN-Farm but hotter than the AP-Farm. Table 3-1 shows the expected condensation for this farm is greater than AP-Farm, but less than AN-Farm.

The SY and AWF (AY and AZ tanks) waste temperatures are generally hotter than the AN, AP and AW farms and the primary ventilation flow rate higher. The AWF tanks also have an additional ventilation system. Figure 3-1 shows that surface condensation is expected on only 241-AY-101. The annulus ventilation system for this tank is unique in that 80% of the flow bypasses the floor slots and goes directly to the wall annulus region (wall bypass for the two AZ tanks can be controlled by external valves). This creates a cooling of the vapor space through the vapor space wall, which promotes wall condensation.

3.7.2 *Mitigation Evaluations*

Analyses were conducted to investigate mitigation options for tanks where dome for wall condensation is expected. Only ventilation system operation was considered for mitigation. Primary ventilation system flow was considered for the AN, AP and AW-Farms. The primary ventilation systems of these farms will be upgraded by Project W-314. The mitigation analyses showed that increased primary ventilation system flow resulting from the Project W-314 upgrades will eliminate Dome and Wall Condensation for the AN, AP and AW-Farms.

Tank 241-AY-101 is the only tank expected to have surface condensation outside of the AN, AP and AW-Farms. Wall condensation is expected because of the wall bypass flow of the annulus ventilation system. Mitigation analyses showed that elimination of the bypass flow (100% of flow directed through the floor slots) or reducing the total flow by about 85% (while maintaining wall bypass flow) will eliminate the condensation of the vapor space wall of tank 241-AY-101.

Table 3-1. Annulus Ventilation System Flow Rates.

		Average Temperature (°F)			Ventilation Flow Rates (cfm)		Dome Condensation		Wall Condensation	
Tank	Vapor Pressure Ratio $(P/P_{H2O})*100$	Bottom Waste	Super-nate	Dome	Primary Vent Flow	Annulus Vent Flow	May - Oct	Nov - Apr	May - Oct	Nov - Apr
AN-101	69	66	65	65	90	900	Yes	No	No	No
AN-102	70	82	86	83	90	900	Yes	Yes	No	Yes
AN-103	68	85	100	82	115	900	Yes	No	No	No
AN-104	72	87	92	83	115	900	Yes	No	No	Yes
AN-105	53	85	91	81	115	900	Yes	No	No	No
AN-106	90	63	63	61	90	900	Yes	No	No	Yes
AN-107	74	81	84	79	145	900	Yes	No	No	Yes
AP-101	74	66	68	64	150	1050	Yes	No	No	Yes
AP-102	82	68	68	66	150	1050	No	No	No	No
AP-103	100	63	63	64	150	1050	No	No	No	No
AP-104	82	68	70	68	150	1050	Yes	No	No	No
AP-105	75	68	68	66	150	1050	Yes	No	No	No
AP-106	95	67	67	67	150	1050	No	No	No	No
AP-107	99	63	64	62	150	1050	Yes	No	No	No
AP-108	93	61	61	61	150	1050	Yes	No	No	No
AW-101	47	81	94	90	200	800	Yes	No	No	No
AW-102	89	67	66	66	140	800	Yes	No	No	Yes
AW-103	90	65	64	64	140	800	Yes	No	No	No
AW-104	90	73	66	66	200	800	No	No	No	No
AW-105	94	62	60	61	140	800	Yes	No	No	Yes
AW-106	75	92	83	80	140	800	Yes	No	No	No
SY-101	97	103	102	81	330	300	No	No	No	No
SY-102	96	85	88	85	330	300	No	No	No	No
SY-103	87	85	84	82	330	300	No	No	No	No
AY-101	94	97	--	80	300	1500	No	No	No	Yes
AY-102	72	132	107	102	360	950	No	No	No	No
AZ-101	88	176	155	139	120	550	No	No	No	No
AZ-102	54	139	113	112	100	550	No	No	No	No

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4.0 ANNULUS RELATIVE HUMIDITY ENGINEERING EVALUATION

An expert panel workshop held in May of 2001 (Berman 2001) to review the Hanford DSTIP made specific recommendations to extend the life of the DST's. The panel identified Pitting Corrosion on the primary liner surfaces, near the water line, as a potential failure mechanism. The expert panel also identified the need for proper control of Relative Humidity (RH) in the annulus space of DST's. It recommended that the RH in the annulus space be maintained below 60% for tanks without significant existing corrosion and 30% for tanks with significant existing corrosion.

The vapor space condensation evaluation presented in Section 3.0 used the GOTH-SNF model described in Section 2.0. The analyses determined Psychrometric conditions for both the vapor space and the wall annulus region. The predicted annulus relative humidity for the twenty-eight DST's is presented in the following section.

The purpose of the annulus evaluation was to determine the relative humidity in the annulus region and compare the relative humidity to the recommended limit of 60% for non-corroded tanks and 30% for tanks with significant annulus wall corrosion. The 30% limit is applied only to tank 241-AY-101 at this time. The evaluation was performed for normal ventilation system operation with ambient air only in the annulus and no ingress of water into the annulus region.

4.1 AN-FARM EVALUATION

The evaluation of the AN-Farm tanks was conducted for the period from May 1, 1999 to May 1, 2001. The predicted annulus relative humidity is shown in Figures 4-1 through Figure 4-7 for the seven AN-Farm tanks. The predicted relative humidity exceeds the 60% limit for only two tanks, 241-AN-101 (Figure 4-1) and 241-AN-106 (Figure 4-6). The average supernatant temperatures for the twenty-eight DST's are shown in Table 2-6. The annulus region air temperature is strongly affected by the supernatant and bottom waste temperatures.

Figure 4-1. Annulus Relative Humidity for Tank 241-AN-101.

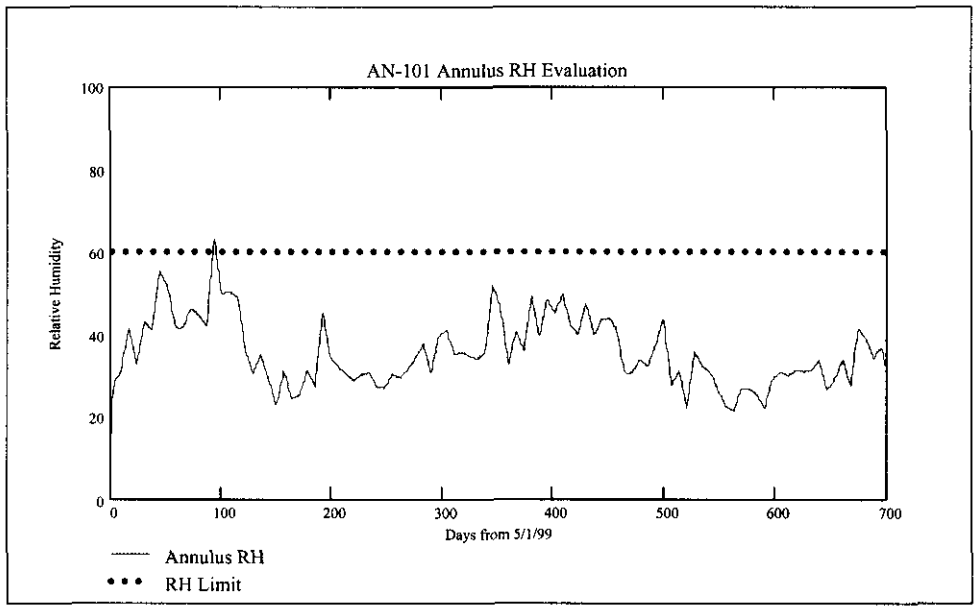


Table 2-6 shows that the supernatant temperatures for tanks AN-101 and AN-106 are 20 °F below the AN-Farm average supernatant temperature of 83 °F. The bottom waste temperatures are also lower than the other five tanks. The annulus relative humidity decreases as the annulus air is heated above the ambient temperature. The coolest tanks will then have the highest relative humidity. The relative humidity for tanks 241-AN-101 and 241-AN-106 exceed the 60% limit only briefly. However, the relative humidity for these tanks is on average higher than the other five AN-Farm tanks. If corrosion were observed in these tanks, the relative humidity would exceed the 30% limit.

Figure 4-2. Annulus Relative Humidity for Tank 241-AN-102.

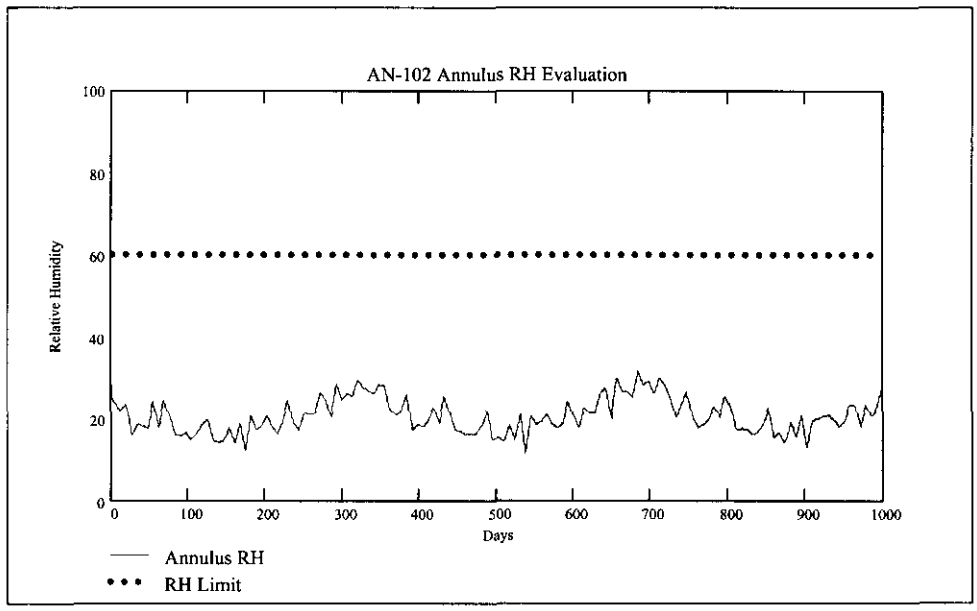


Figure 4-3. Annulus Relative Humidity for Tank 241-AN-103.

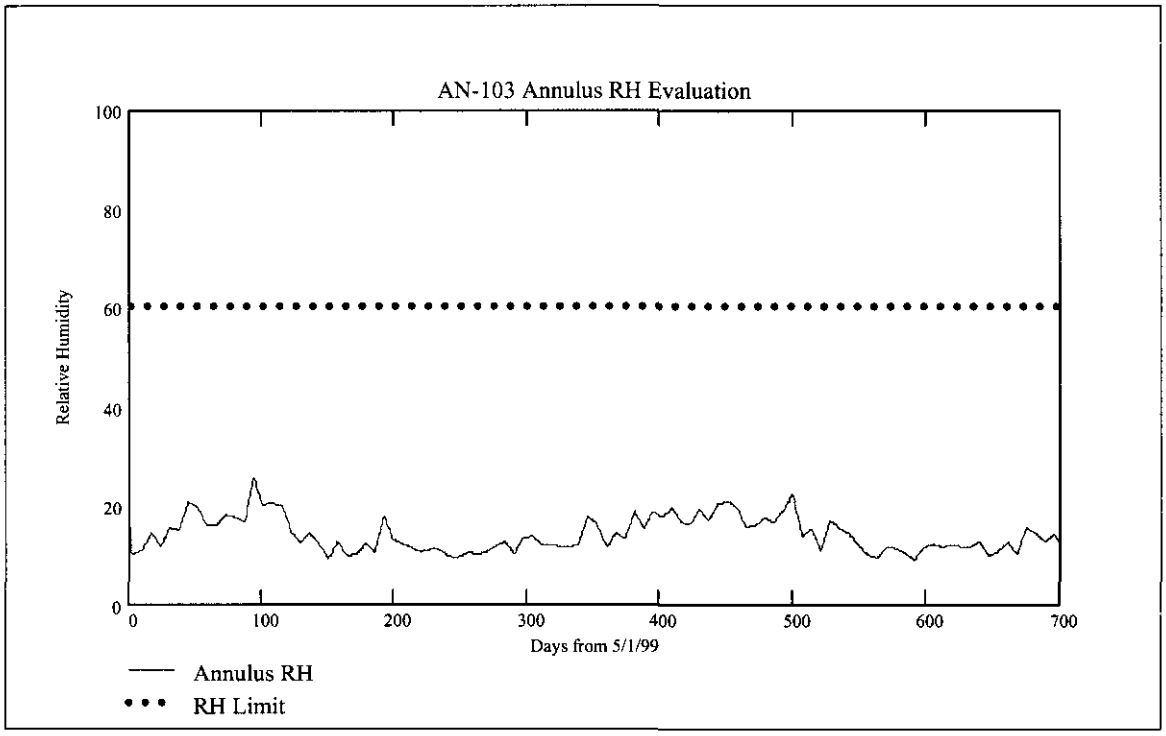


Figure 4-4. Annulus Relative Humidity for Tank 241-AN-104.

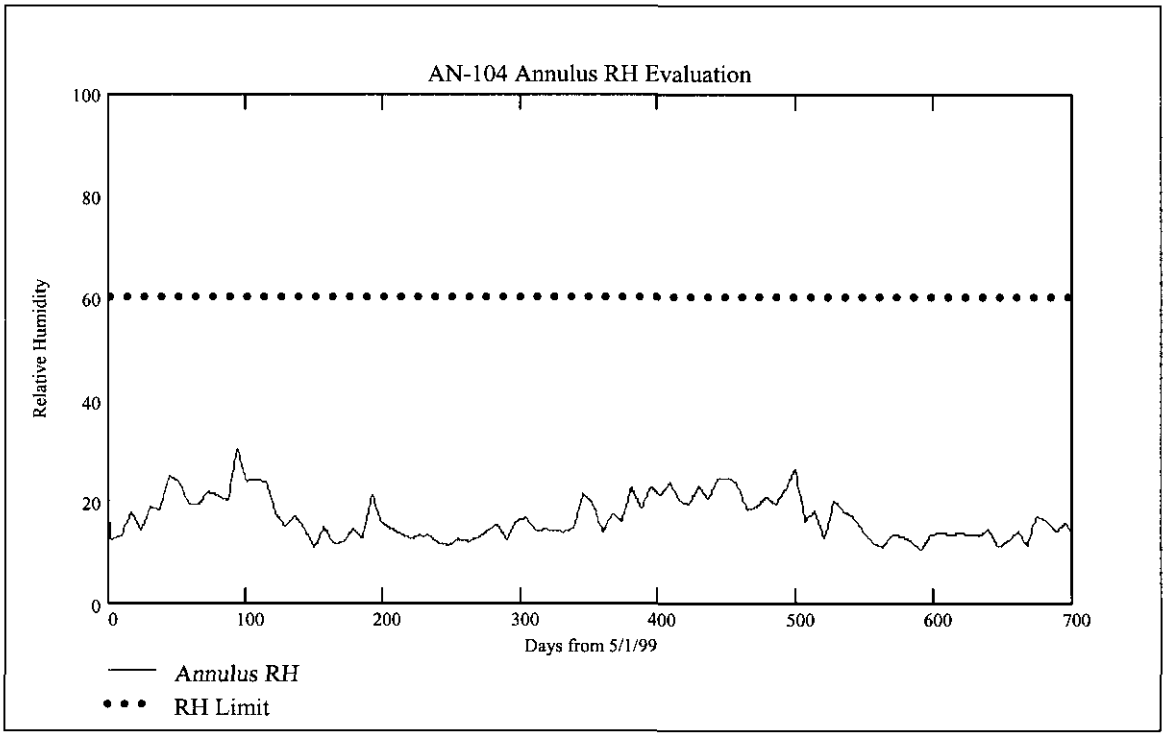


Figure 4-5. Annulus Relative Humidity for Tank 241-AN-105.

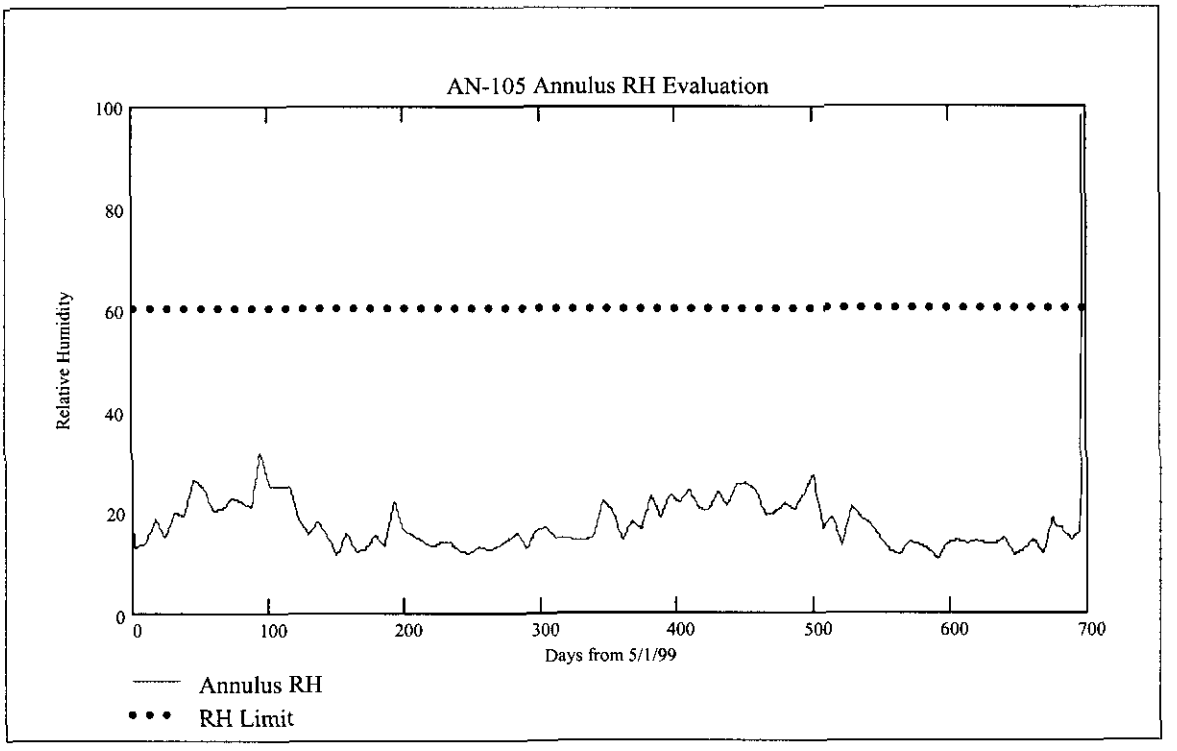


Figure 4-6. Annulus Relative Humidity for Tank 241-AN-106.

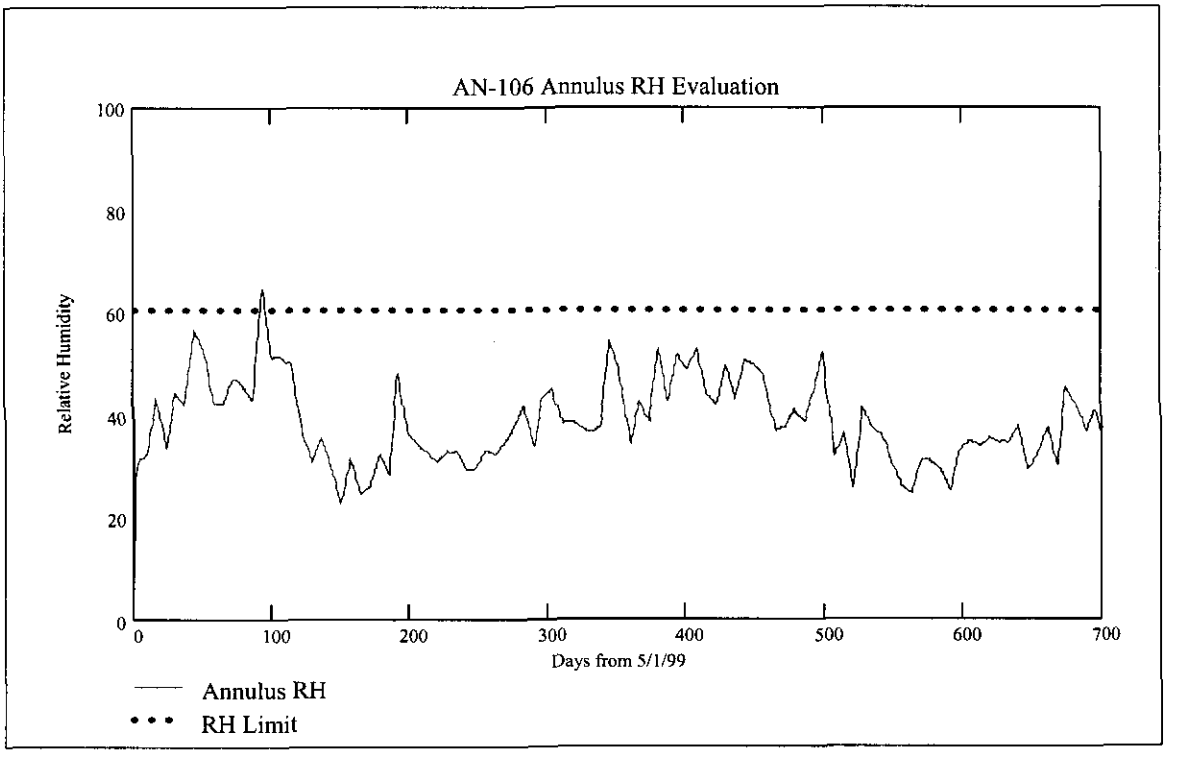
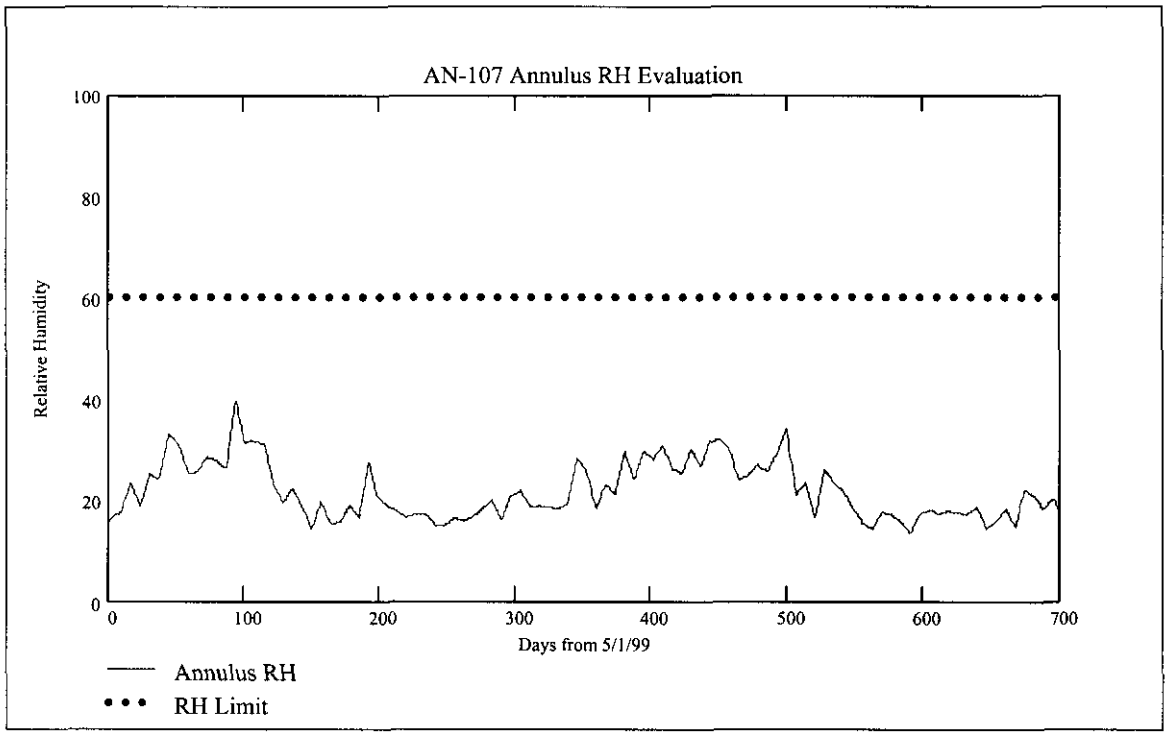


Figure 4-7. Annulus Relative Humidity for Tank 241-AN-107.



4.2 AP-FARM EVALUATION

The evaluation of the AP-Farm tanks was conducted for the period from May 1, 1999 to May 1, 2001. The predicted annulus relative humidity is shown in Figures 4-8 through Figure 4-15 for the eight AP-Farm tanks. The predicted relative humidity exceeds the 60% limit briefly for all the AP-Farm tanks. The average supernatant temperature for the AP-Farm is 66 °F compared to an average supernatant temperature of 83 °F for AN-Farm. Thus, the annulus air temperature for the AP-Farm will be cooler and the relative humidity higher. This is observed in the relative humidity of the AP-Farm shown in Figure 4-8 through 4-15. Tank 241-AP-108 has the lowest supernatant and bottom waste temperatures for the AP-Farm (Table 2-6). Figure 4-15 shows that the predicted relative humidity is highest for this tank. With the exception of brief excursions above the relative humidity limit, the annulus relative humidity for the AP-Farm tanks are below the recommended limit. If tank wall corrosion is discovered for any of the AP-Farm tanks, the annulus relative humidity would exceed the recommended limit of 30%.

Figure 4-8. Annulus Relative Humidity for Tank 241-AP-101.

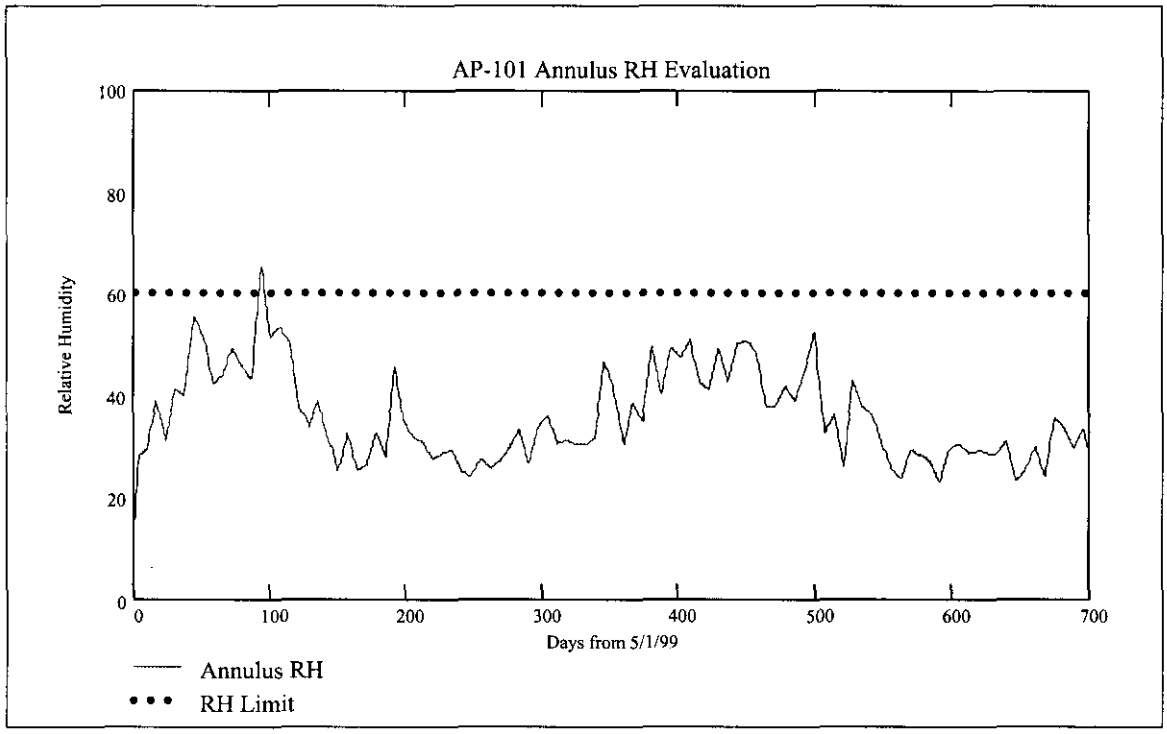


Figure 4-9. Annulus Relative Humidity for Tank 241-AP-102.

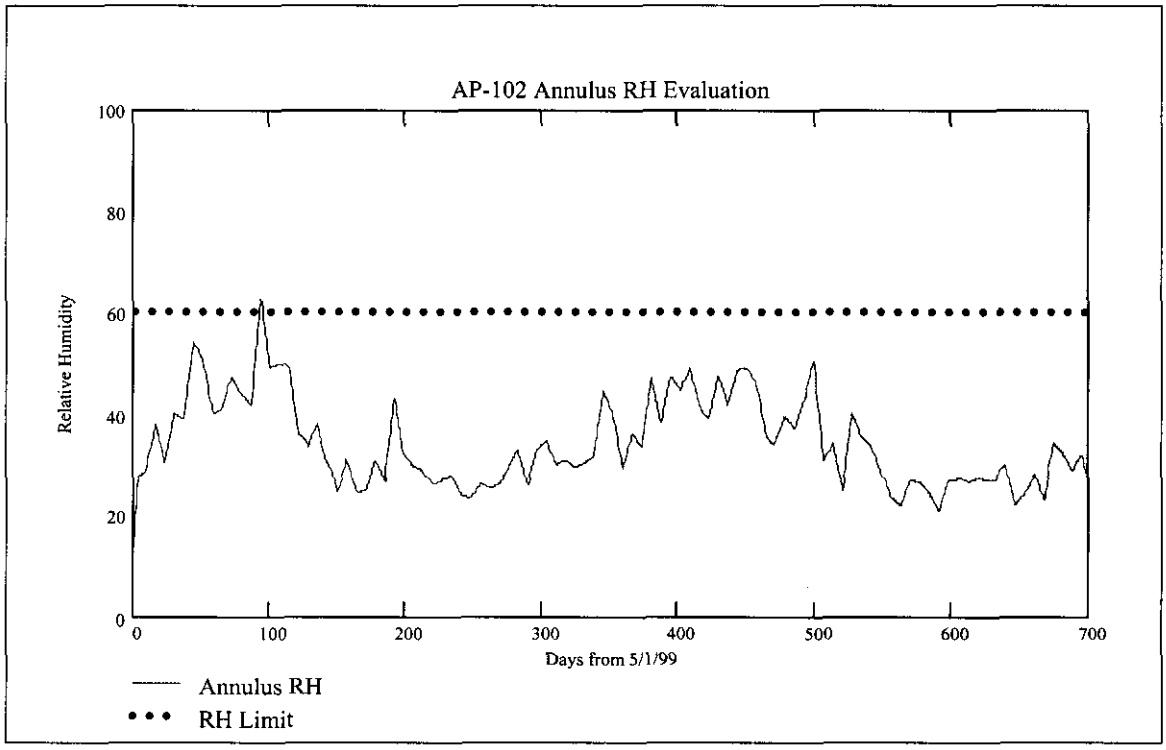


Figure 4-10. Annulus Relative Humidity for Tank 241-AP-103.

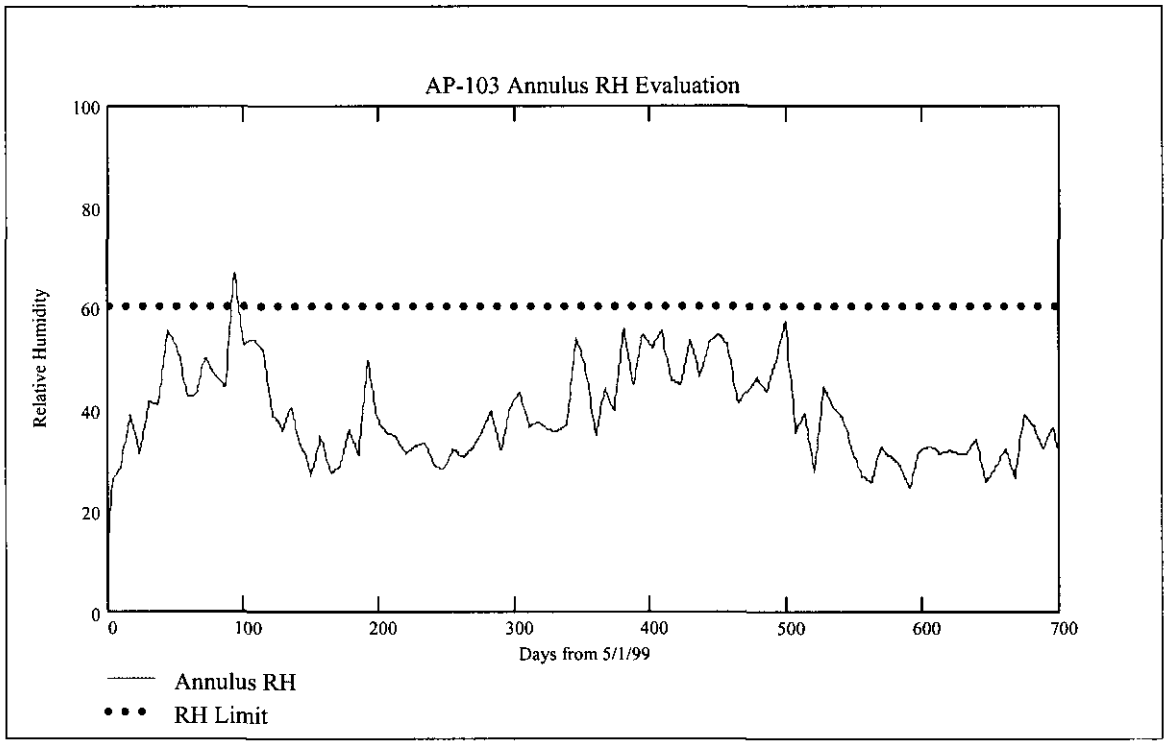


Figure 4-11. Annulus Relative Humidity for Tank 241-AP-104.

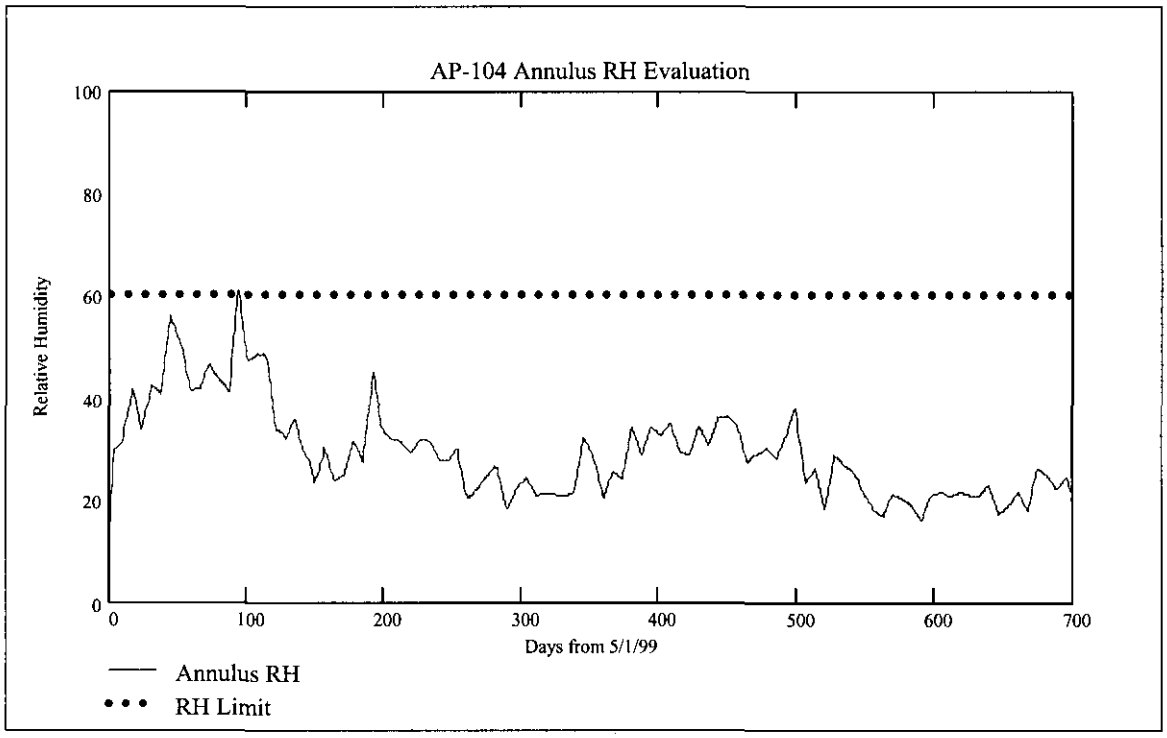


Figure 4-12. Annulus Relative Humidity for Tank 241-AP-105.

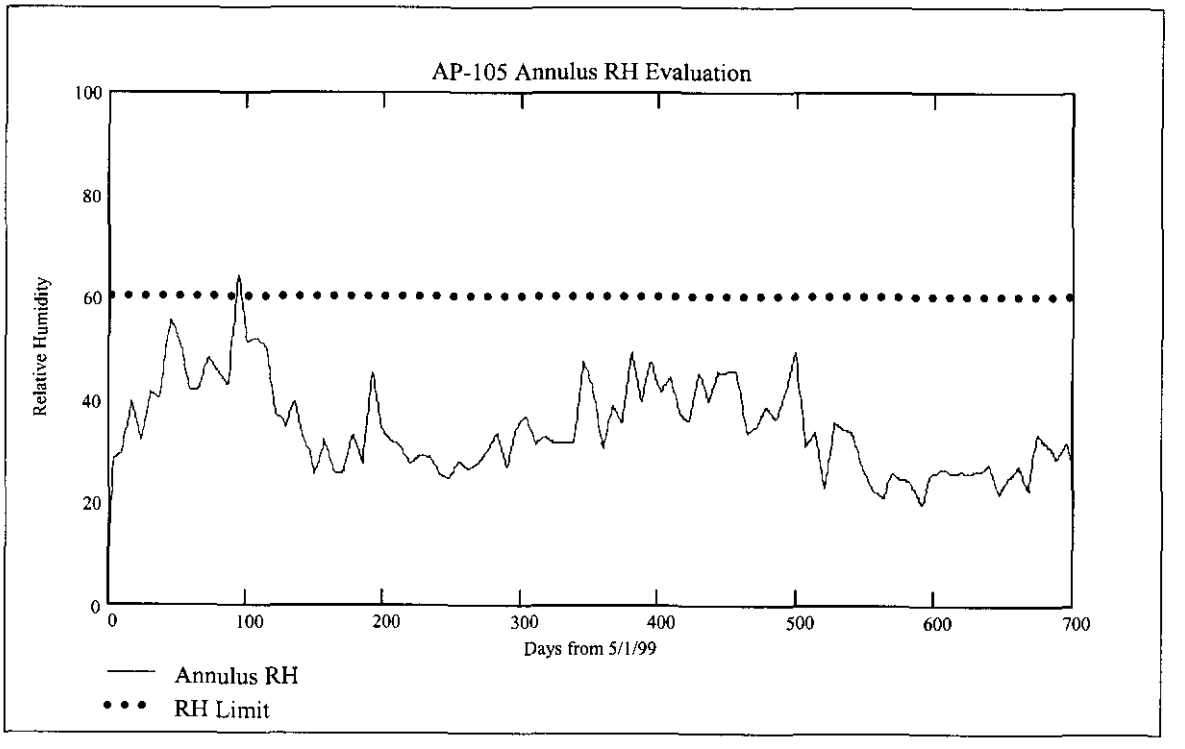


Figure 4-13. Annulus Relative Humidity for Tank 241-AP-106.

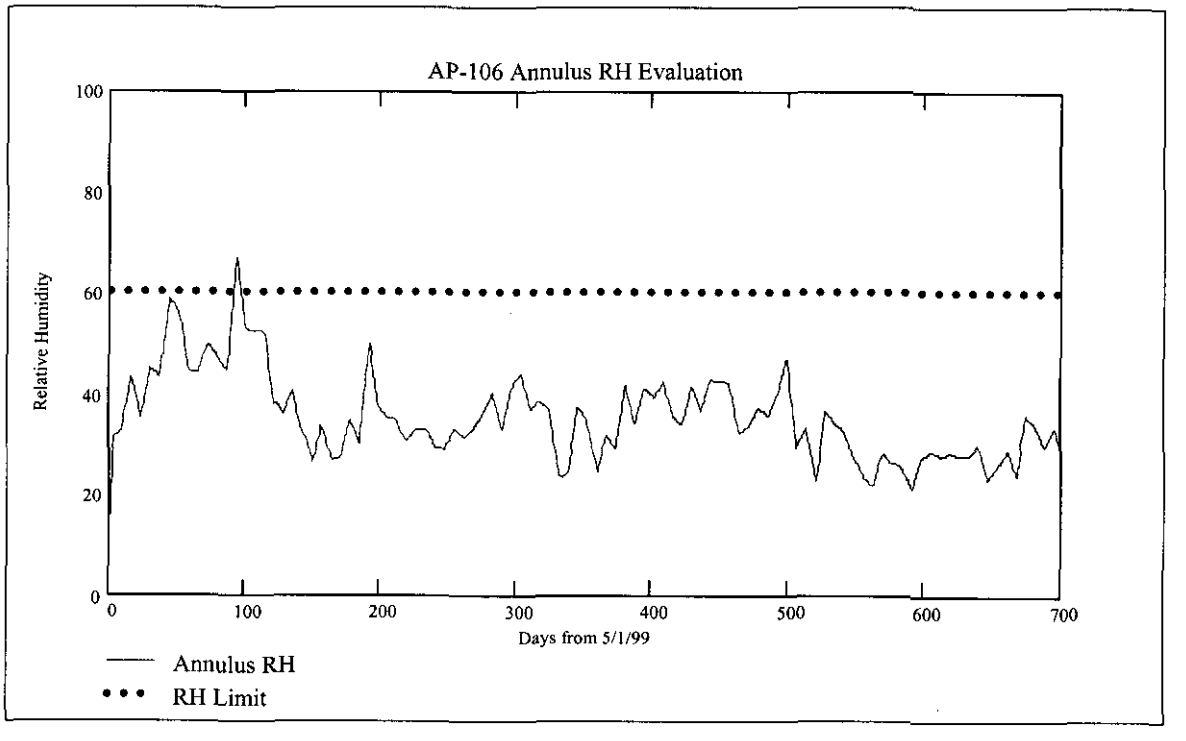


Figure 4-14. Annulus Relative Humidity for Tank 241-AP-107.

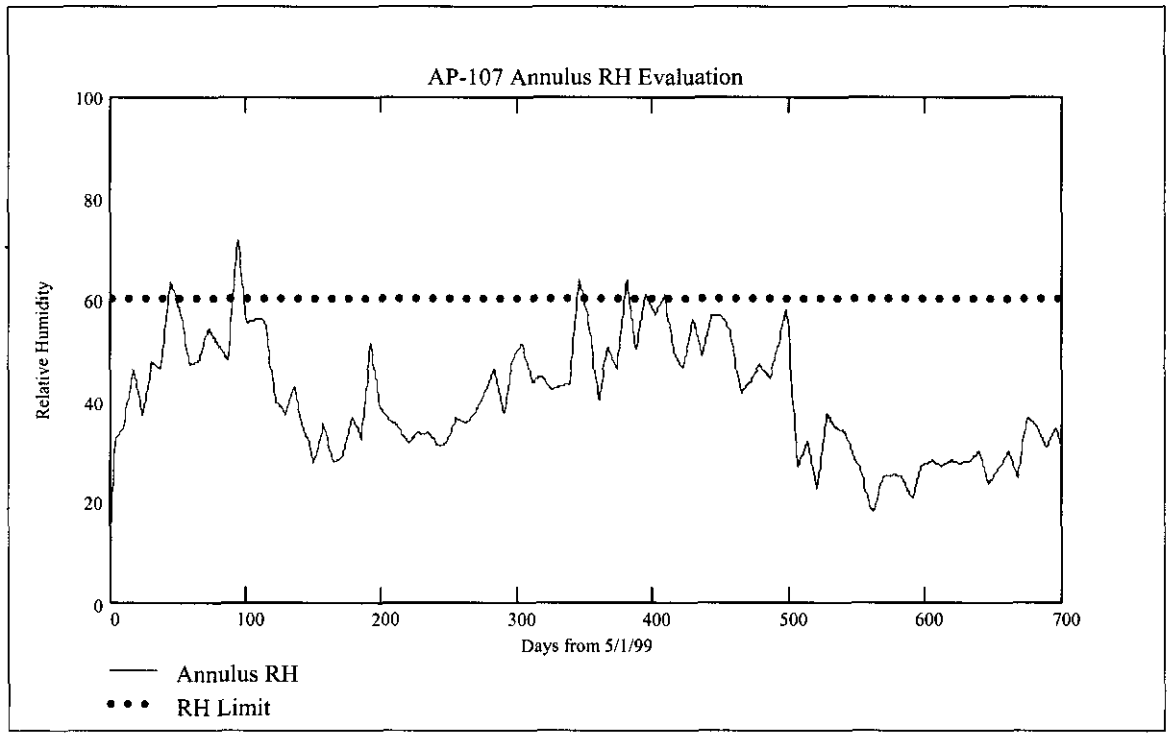
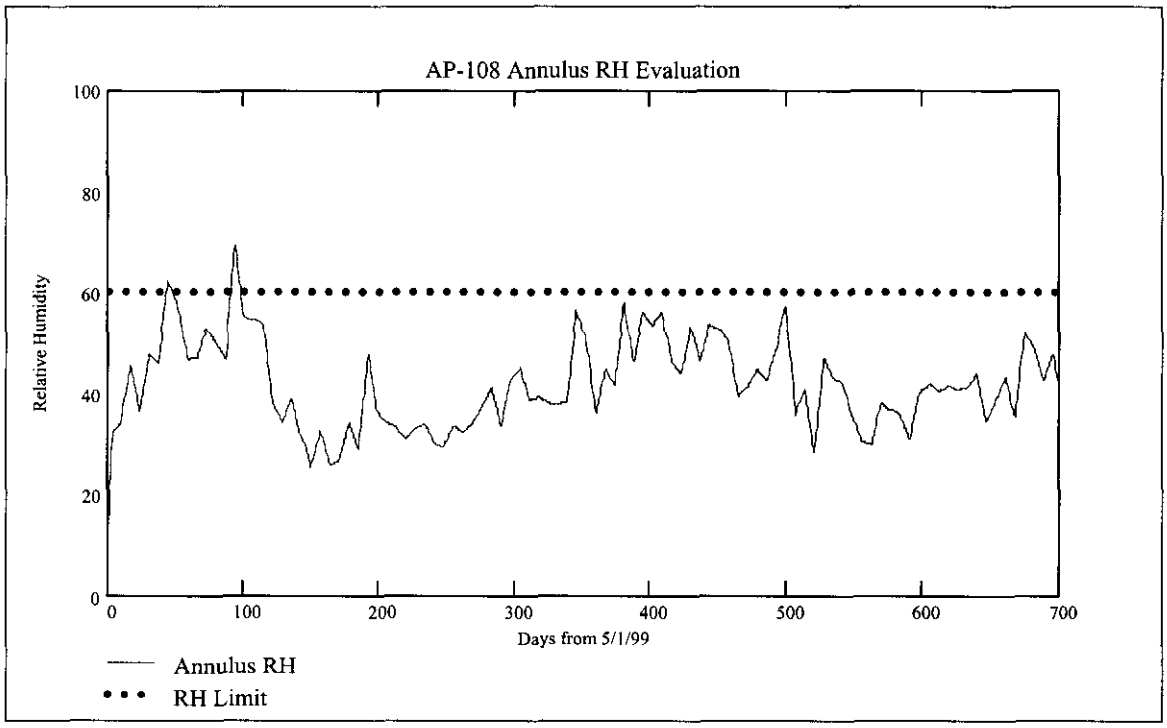


Figure 4-15. Annulus Relative Humidity for Tank 241-AP-108.



4.3 AW-FARM EVALUATION

The evaluation of the AW-Farm tanks was conducted for the period from May 1, 1999 to May 1, 2001. The predicted annulus relative humidity is shown in Figures 4-16 through Figure 4-21 for the six AW-Farm tanks. The predicted relative humidity exceeds the 60% limit briefly for tanks 241-AW-102, 241-AW-103 and 241-AW-105. A comparison of the tank average supernatant temperatures summarized in Table 2-6 shows that these tanks have the lowest supernatant temperatures for the AW-Farm. The remaining AW-Farm tanks have significantly higher temperatures and correspondingly lower annulus relative humidity. The annulus relative humidity for tanks 241-AW-102 through 241-AW-105 exceeds the lower 30% relative humidity limit. If corrosion is discovered on the annulus for these tanks, the relative humidity would exceed the 30% limit.

Figure 4-16. Annulus Relative Humidity for Tank 241-AW-101.

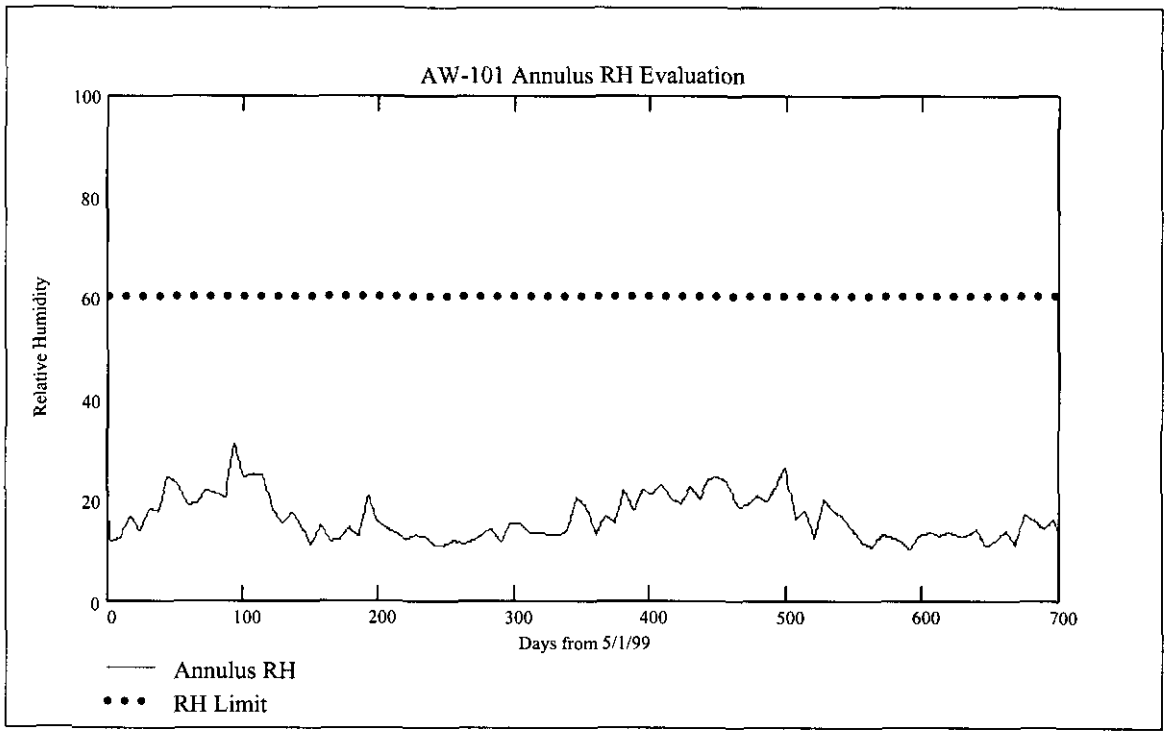


Figure 4-17. Annulus Relative Humidity for Tank 241-AW-102.

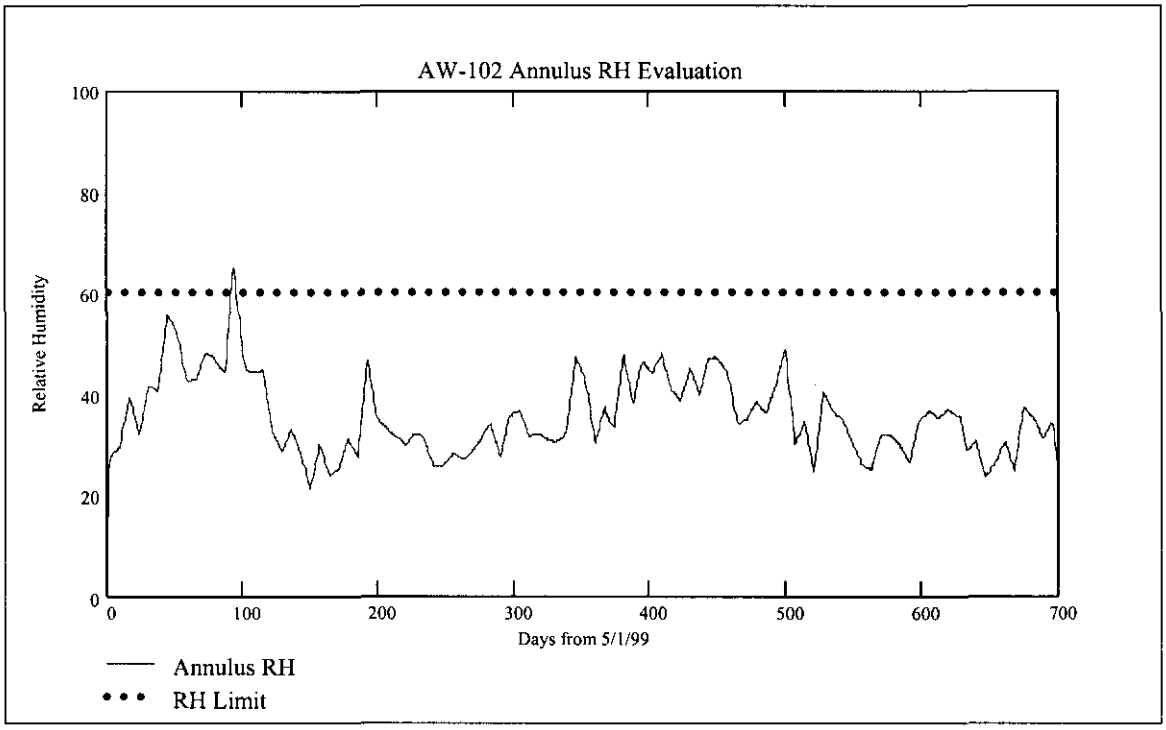


Figure 4-18. Annulus Relative Humidity for Tank 241-AW-103.

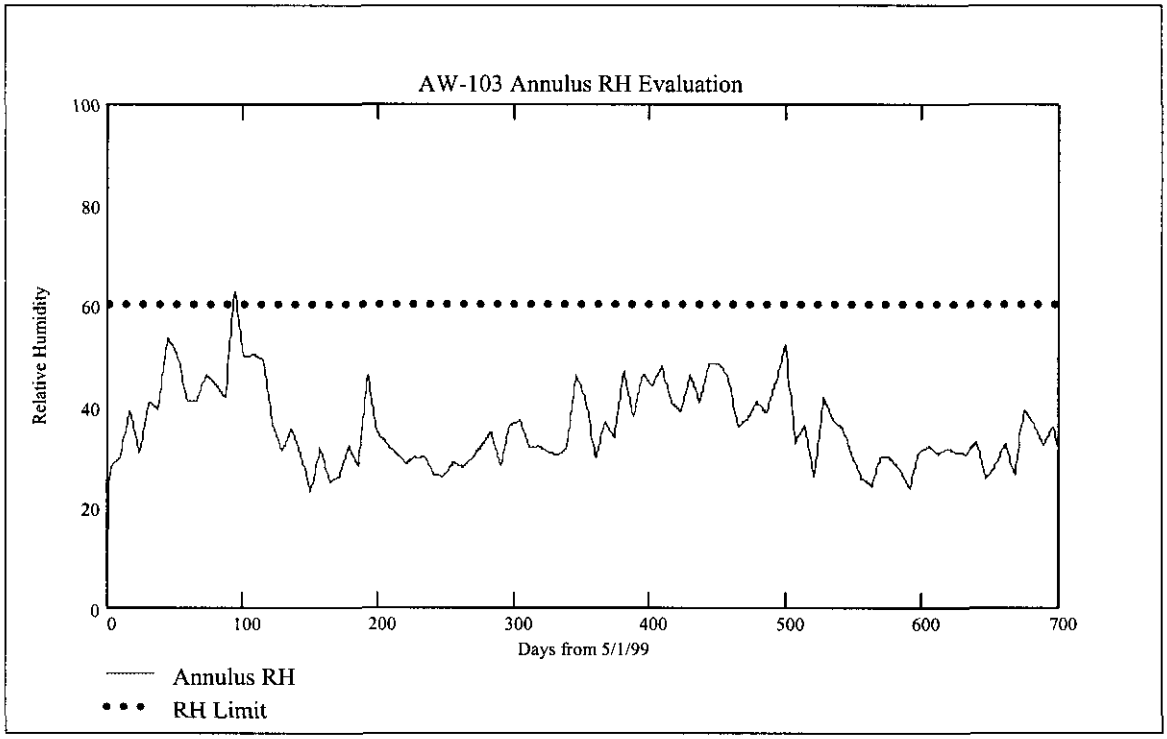


Figure 4-19. Annulus Relative Humidity for Tank 241-AW-104.

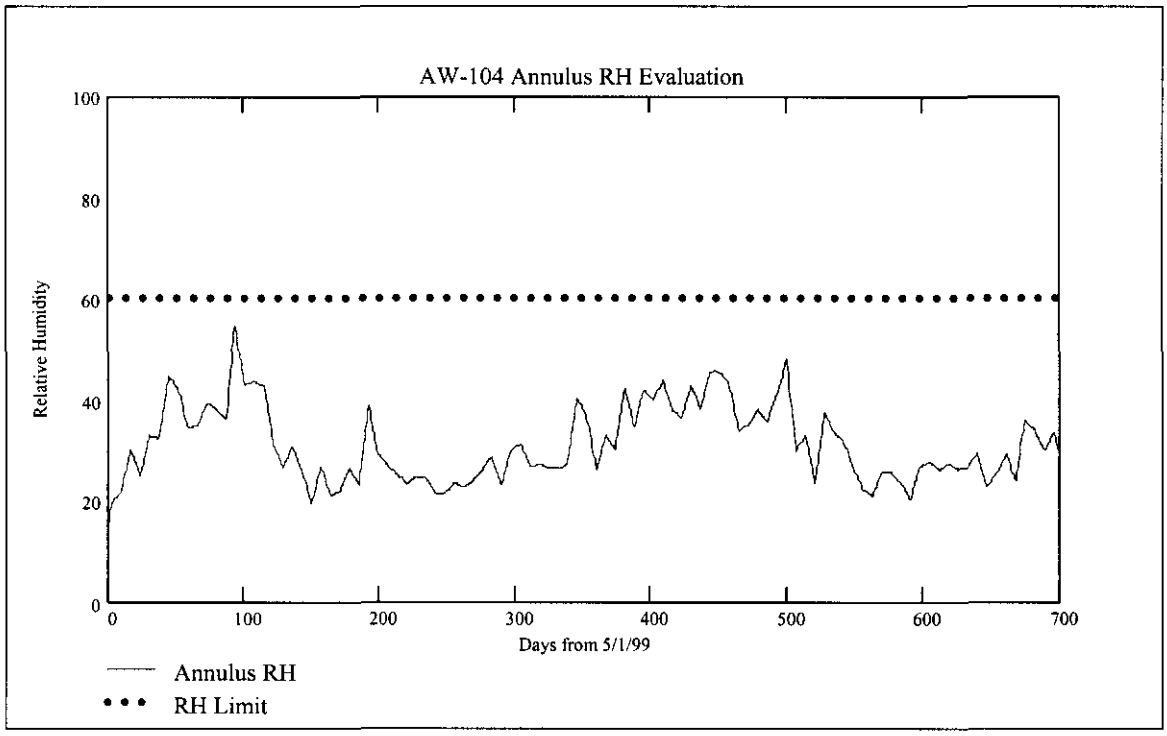


Figure 4-20. Annulus Relative Humidity for Tank 241-AW-105.

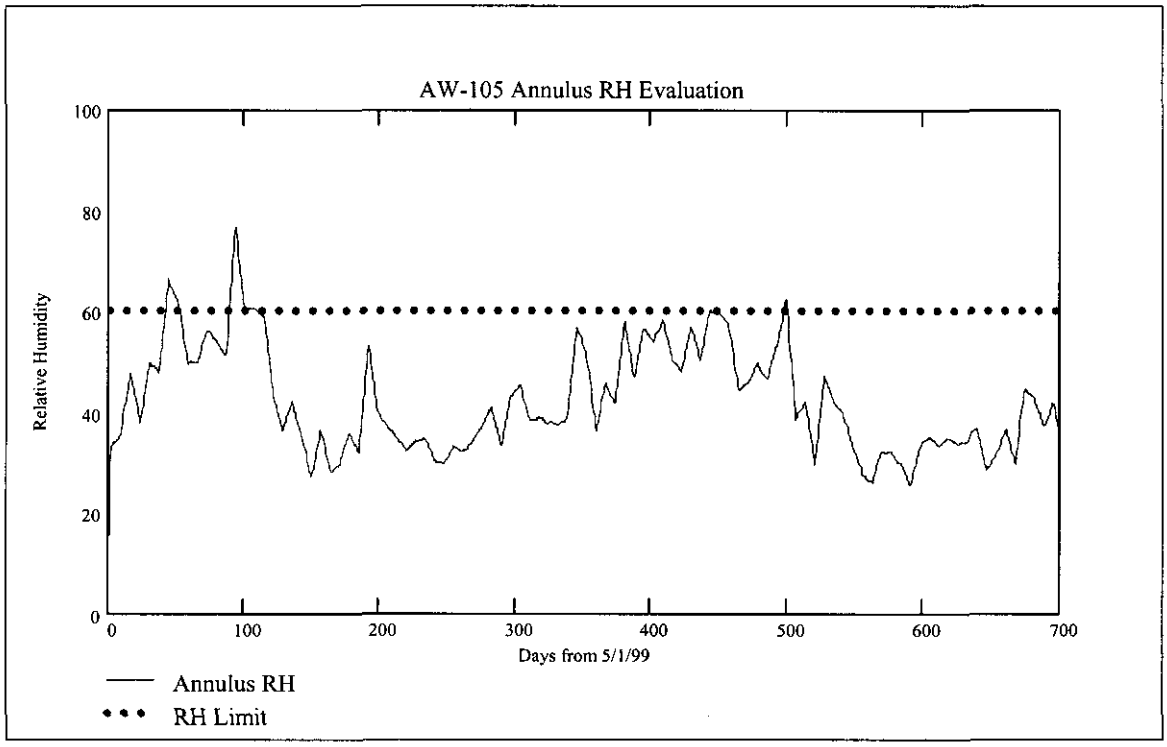
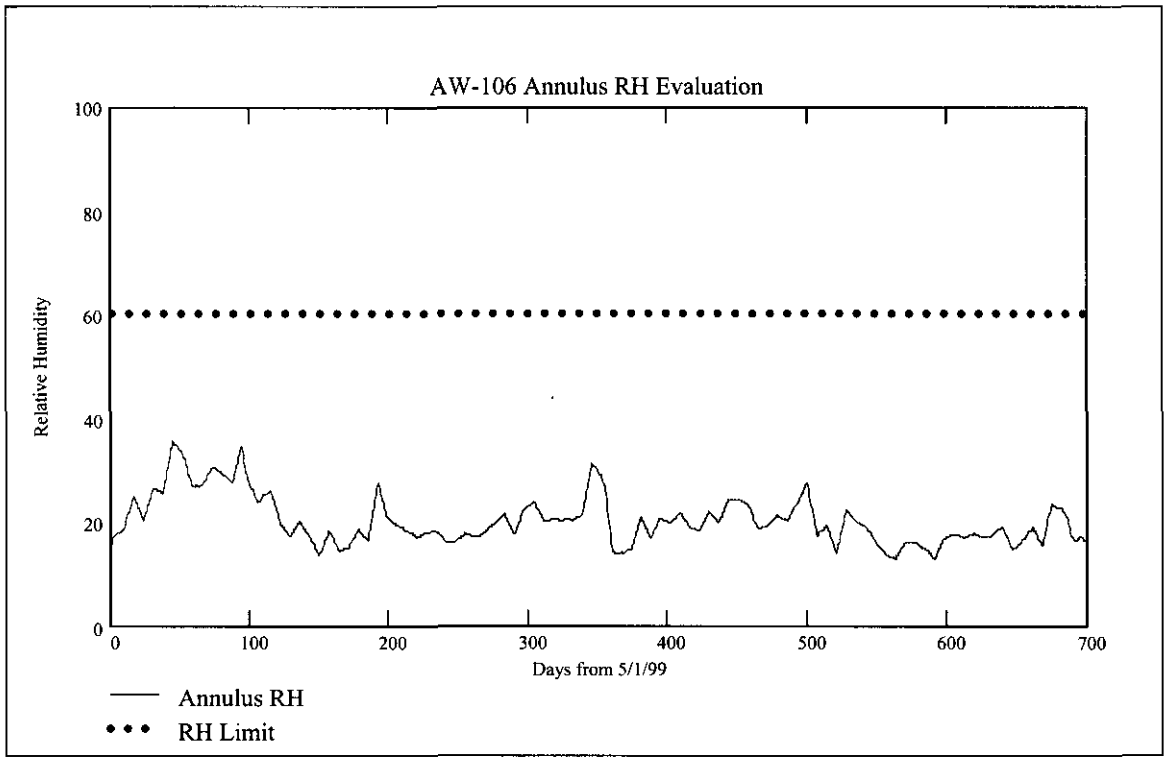


Figure 4-21. Annulus Relative Humidity for Tank 241-AW-106.



4.4 SY-FARM EVALUATION

The evaluation of the SY-Farm tanks was conducted for the period from May 1, 1999 to May 1, 2001. The predicted annulus relative humidity is shown in Figures 4-22 through Figure 4-24 for the three SY-Farm tanks. The predicted relative humidity is well below the 60% limit for all the SY-Farm tanks. The average supernatant temperature for the SY-Farm is 91 °F. This is much higher than AN, AP and AW-Farms which have average supernatant temperatures of 83 °F, 66 °F, and 78 °F. Thus, the annulus relative humidity should be lower on average than the AN, AP and AW-Farms. The relative humidity of the SY-Farm tanks is below the 30% relative humidity limit for corroded tanks with the exception of tank 241-SY-102 during calendar year 1999.

Figure 4-22. Annulus Relative Humidity for Tank 241-SY-101.

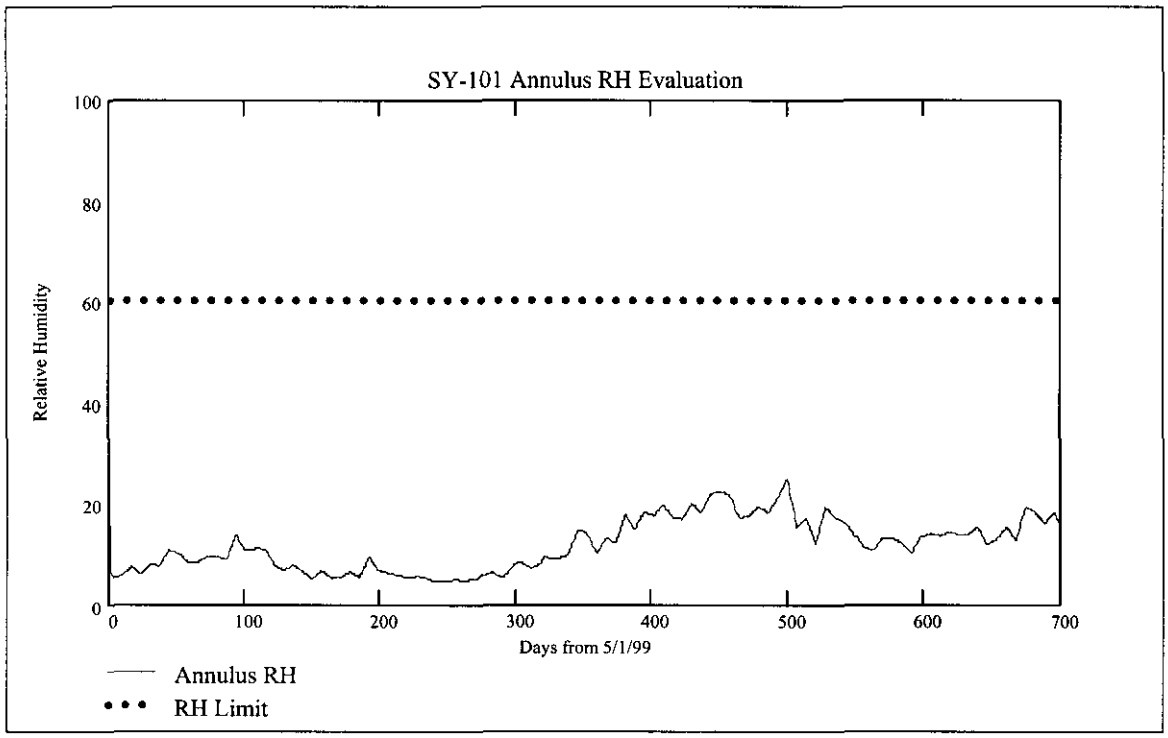


Figure 4-23. Annulus Relative Humidity for Tank 241-SY-102.

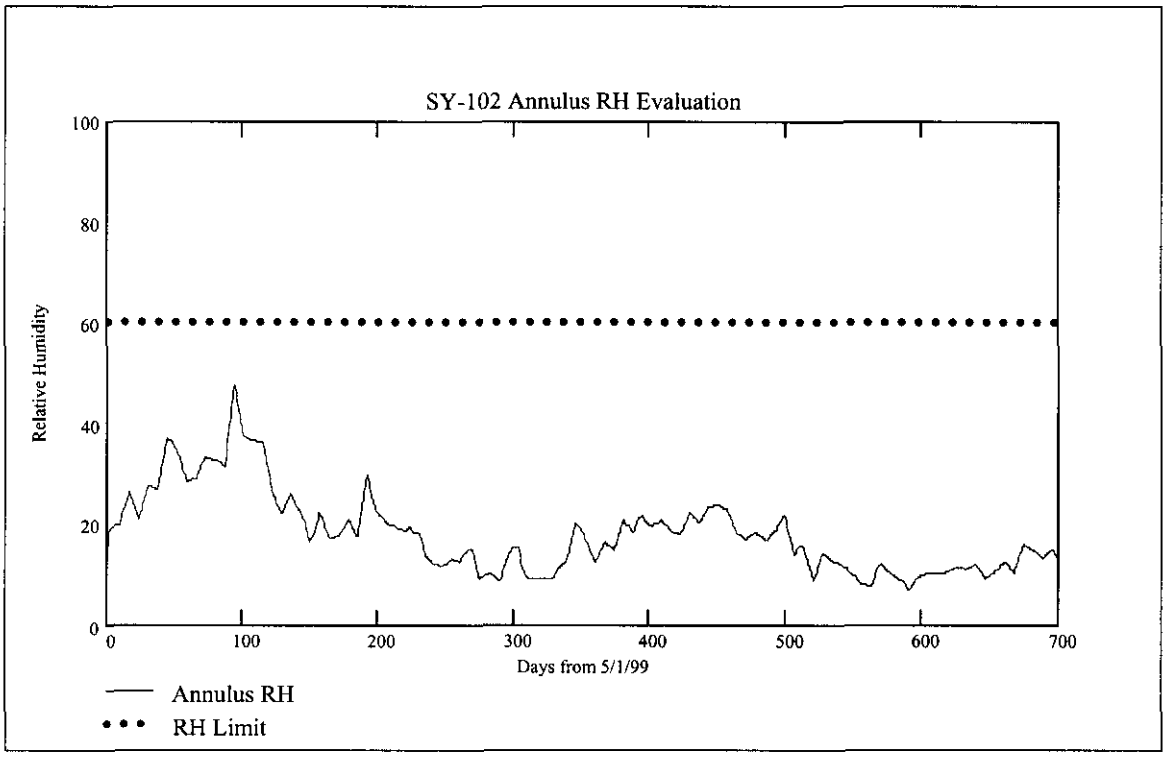
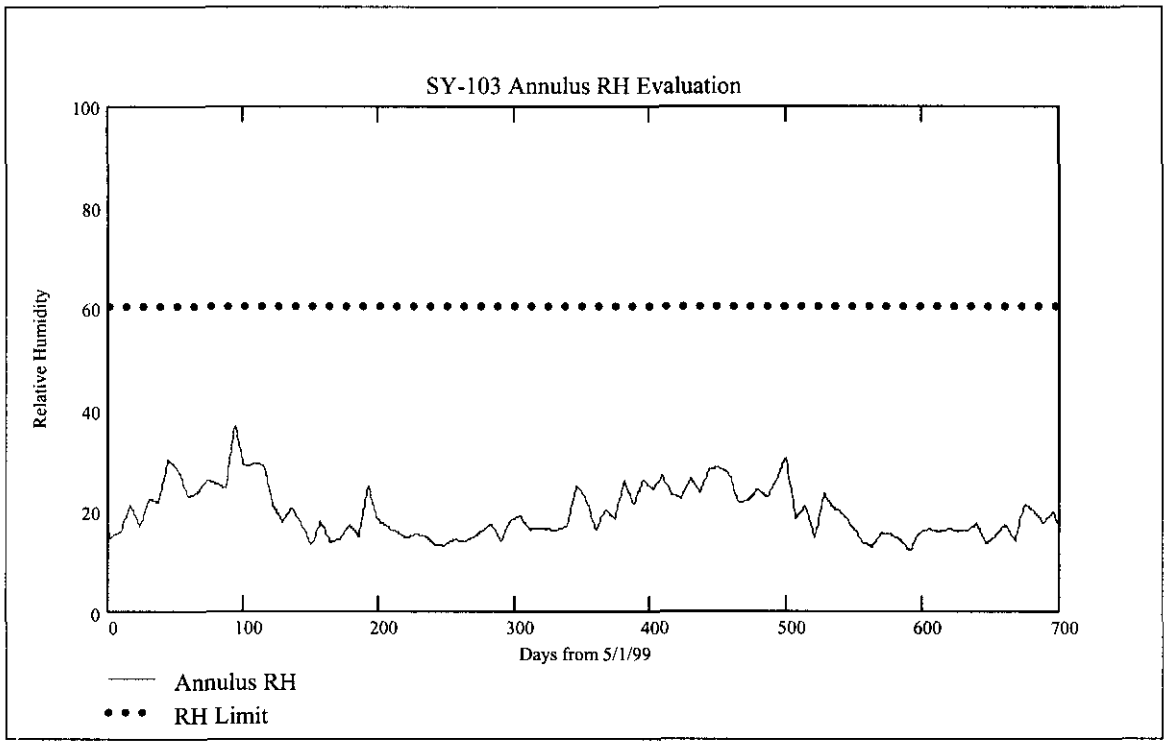


Figure 4-24. Annulus Relative Humidity for Tank 241-SY-103.



4.5 AY-FARM EVALUATION

Tanks 241-AY-101 and 241-AY-102 were part of an engineering evaluation of caustic mixing following recent caustic additions. Thermal-hydraulic analyses were performed with a GOTH-SNF mixing model which is described in Ogden 2002. These analyses also predict both the vapor space and annulus Psychrometric conditions and were used for the annulus relative humidity evaluation. The predicted annulus relative humidity for tank 241-AY-101 is shown in Figure 4-25. The annulus wall for this tank has been shown to be highly corroded. The 30% relative humidity limit applies to this tank.

Figure 4-25 shows that the annulus relative humidity is at or near the 30% limit. The bottom waste and dome temperature (supernatant temperatures are not available) are higher than all the previous tanks evaluated with the exception of the bottom waste temperature of SY-101 (Table 2-6). However, the predicted relative humidity exceeds many of the tanks. As discussed in Section 3.5.1, the annulus ventilation system for tank 241-AY-101 is unique in that 80% of the flow is directed directly to the annulus region rather than the floor slots. This keeps the annulus air temperature well below the supernatant or dome temperatures. As a result, the annulus relative humidity exceeds the 30% relative humidity limit.

Figure 4-25. Annulus Relative Humidity for Tank 241-AY-101.

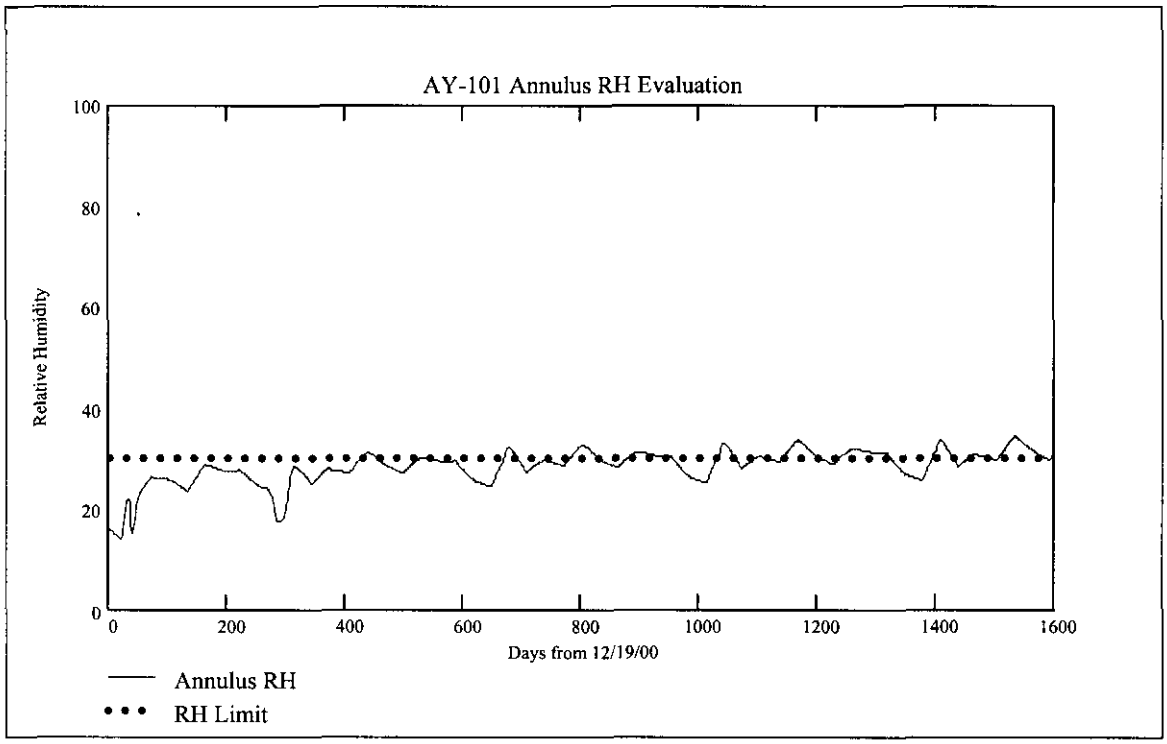
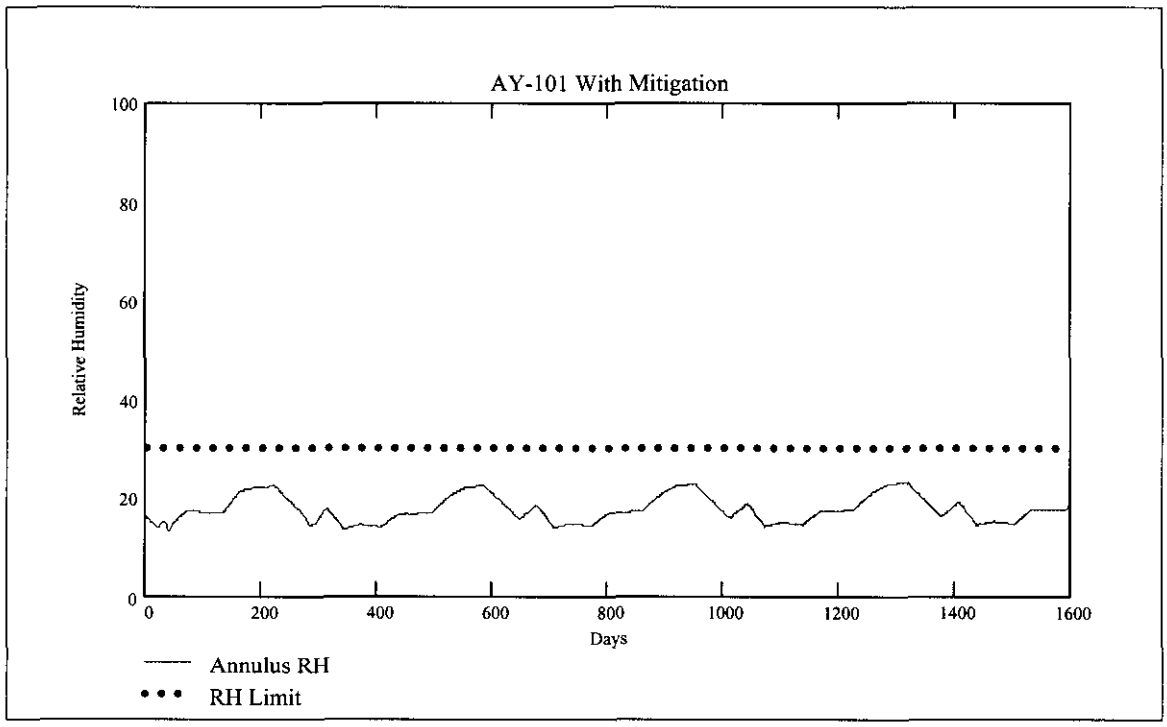


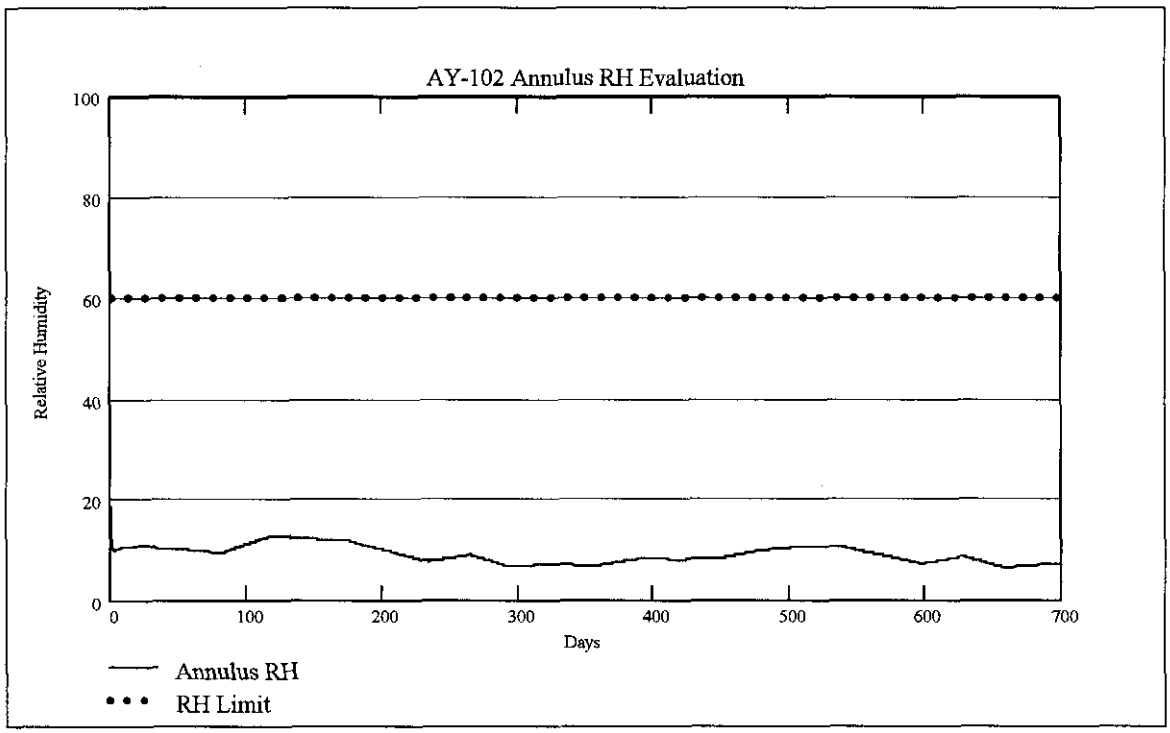
Figure 4-26. Annulus Relative Humidity for Tank 241-AY-101 with Mitigation.



Mitigation options for vapor space corrosion for tank 241-AY-101 were discussed in Section 3.5.3. The mitigation options included reducing the overall annulus ventilation system flow. This reduces annulus cooling by the ambient air. This reduced flow increases the annulus air temperature which will reduce the relative humidity. The annulus relative humidity for the reduced annulus flow case discussed in Section 3.5.3 is shown in Figure 4-26. The annulus relative humidity remains well below the 30% relative humidity limit.

The predicted annulus relative humidity for tank 241-AY-102 is shown in Figure 4-27. The waste temperatures for tank 241-AY-102 exceed the waste temperatures for all previous tanks discussed above (Table 2-6). The annulus flow is all directed through the floor slots similar to the AN, AP, AW and SY-Farms. The annulus relative humidity for tank 241-AY-102 is lower than all AN, AP, AW and SY-Farm tanks. It is well below even the 30% relative humidity limit.

Figure 4-27. Annulus Relative Humidity for Tank 241-AY-102.



4.6 AZ-FARM EVALUATION

The evaluation of the AZ-Farm tanks was conducted for the period from May 1, 1999 to May 1, 2001. The predicted annulus relative humidity is shown in Figures 4-28 and 29. The predicted relative humidity is well below both the 60% and 30% relative humidity limits. The average supernatant temperatures are higher than all the tanks in the AN, AP, AW, SY and AY-Farms. As a result, the annulus relative humidity for the AZ-Farm tanks is the lowest of all twenty-eight DST's and is well below even the 30% relative humidity limit.

Figure 4-28. Annulus Relative Humidity for Tank 241-AZ-101.

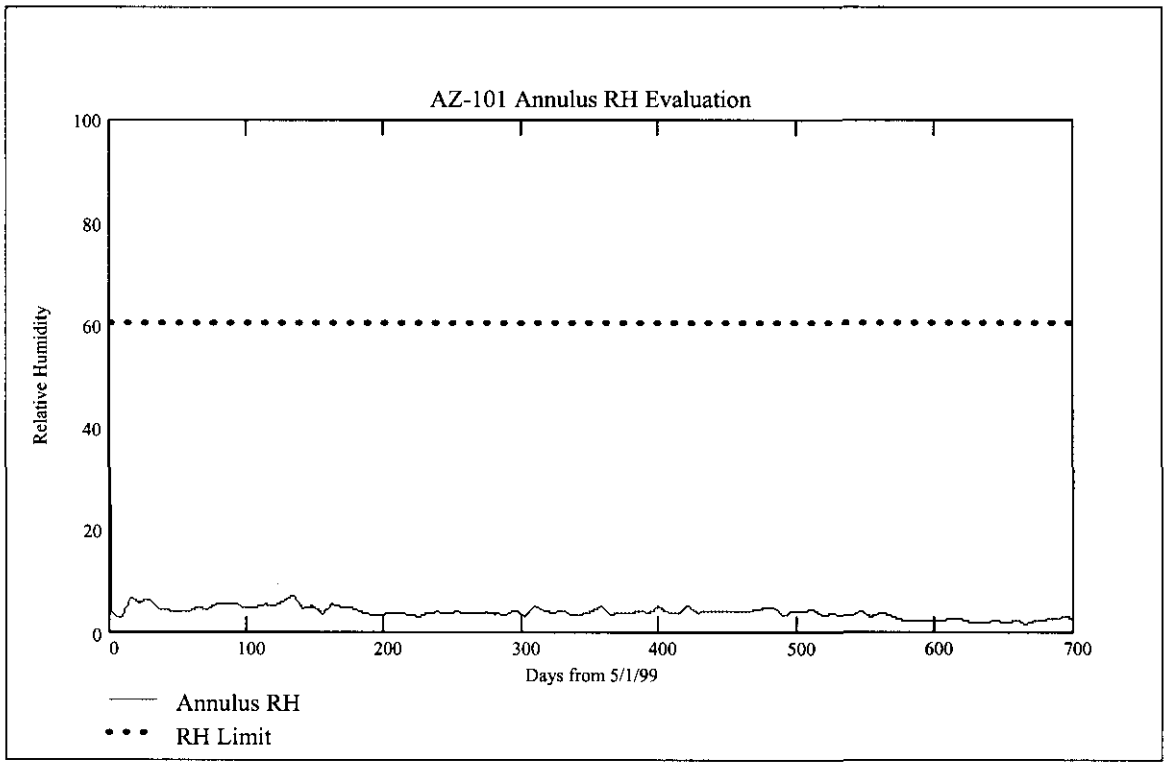
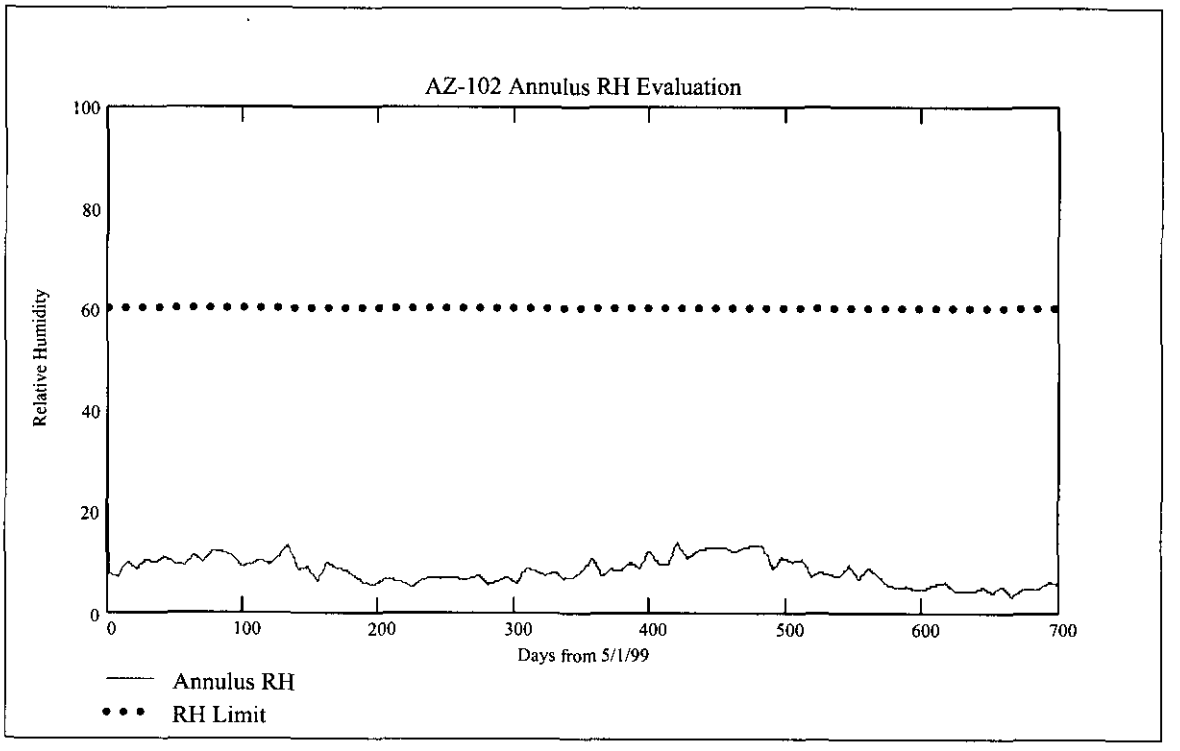


Figure 4-29. Annulus Relative Humidity for Tank 241-AZ-102.



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5.0 CONCLUSIONS

VAPOR SPACE ENGINEERING EVALUATION

The engineering evaluation of the vapor space determined that condensation on the primary tank liner in the region of the dome and straight wall is expected for many of the tanks in the AN, AP and AW-Farms and a single Aging Waste Tank:

- Dome or wall condensation is expected on all the AN-Farm tanks.
- Dome condensation is expected for five AP-Farm tanks. Wall condensation is expected for only one.
- Dome condensation is expected for five AW-Farm tanks. Wall condensation expected for only one.
- No dome or wall condensation is expected for the SY-Farm.
- Wall condensation is expected for tank 241-AY-101.
- No dome or wall condensation is expected for tanks 241-AY-102 and the AZ-Farm tanks.

A preliminary mitigation evaluation determined that the increased flow capacity resulting from the Project W-314 upgrades to the primary ventilation systems for the AN, AP and AW-Farms will eliminate all wall or dome condensation in the vapor space. Wall condensation for tank 241-AY-101 can be eliminated by one of two methods:

- Eliminating the annulus wall bypass flow, or
- Reducing the annulus ventilation flow rate by 85%

An evaluation of moisture removal capabilities is needed if the annulus flow is reduced.

ANNULUS RELATIVE HUMIDITY EVALUATION

The annulus relative humidity engineering evaluation resulted in the following conclusions:

- Two tanks in the AN-Farm exceed the 60% relative humidity limit for short periods.
- All the tanks in the AP-Farm exceed the 60% relative humidity limit for short periods.
- Three tanks in the AW-Farm exceed the 60% relative humidity limit for short periods.
- No tanks in the SY-Farm exceed the recommended relative humidity limit.
- Tank 241-AY-101 exceeds the recommended annulus space relative humidity of 30%.
- An 85% reduction of annulus flow will reduce the relative humidity of tank 241-AY-102 below the recommended limit.

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APPENDIX A - TANK TEMPERATURE DATA

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A-1.0 INTRODUCTION

Measured waste temperature data provided the basis for the engineering evaluation of the dome vapor space and annulus Psychrometrics. These data were obtained from the Tank Waste Information Retrieval System (TWINS) data base. The measured supernatant and bottom waste temperatures were used as temperature boundary conditions for the GOTH-SNF model described in Section 2.0. Waste level data determined the supernatant depth and heat transfer surface area for the GOTH-SNF conductor component representing the supernatant.

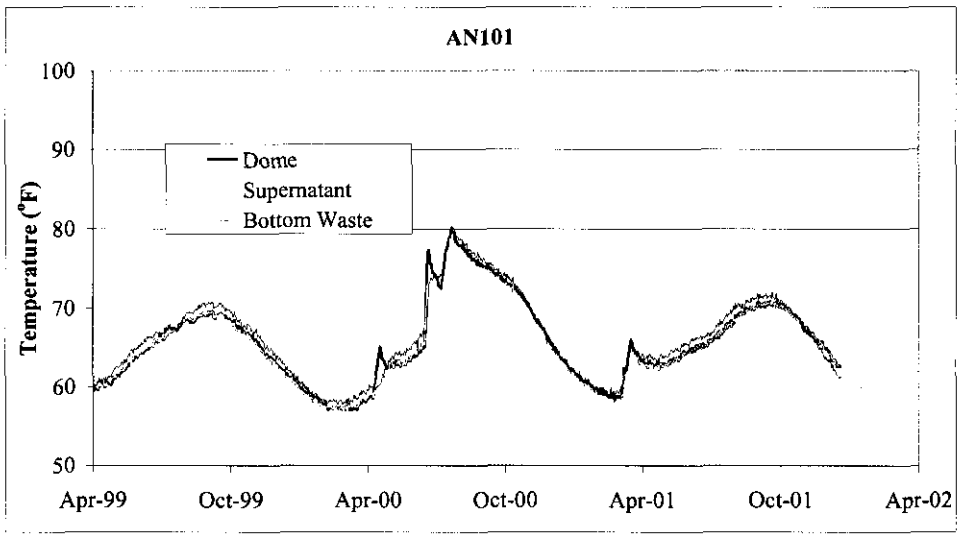
The measured tank data used for the engineering evaluations are presented in the following sections. This information is supplied to provide supporting and backup information related to the engineering evaluations. Two graphs are provided for each tank with a few exceptions which are discussed below. The first figure shows the measured dome, supernatant and bottom waste temperature. The bottom waste temperature is the temperature measured by the first thermal-couple of a thermal-couple tree. The location of the thermal-couple trees are between 20 ft and 30 ft from the tank centerline. Tank 241-AY-101 does not have thermal-couples in the supernatant. Figure 6-1 only shows the bottom waste and dome temperatures.

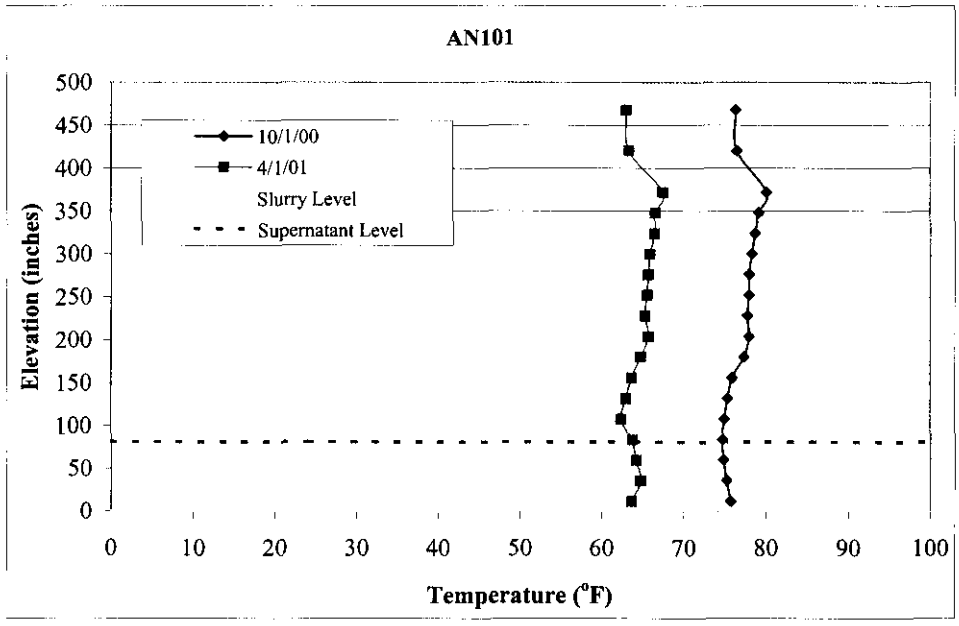
The second figure for each tank shows an axial temperature profile. The second figure also shows the approximate waste level during the period of the evaluation. The approximate slurry level is also provided. This is based upon tank inventory data. The waste level data is used to determine heat transfer surface areas. The slurry level and the temperature profiles are used to understand the thermal behavior of the tank waste to help interpret the results of the engineering evaluations. Sufficient axial temperature data to construct a temperature profile was not available for tanks 241-AY-101, 241-AZ-101 and 241-AZ-102.

A-2.0 AN-FARM

A-2.1 TANK 241-AN-101

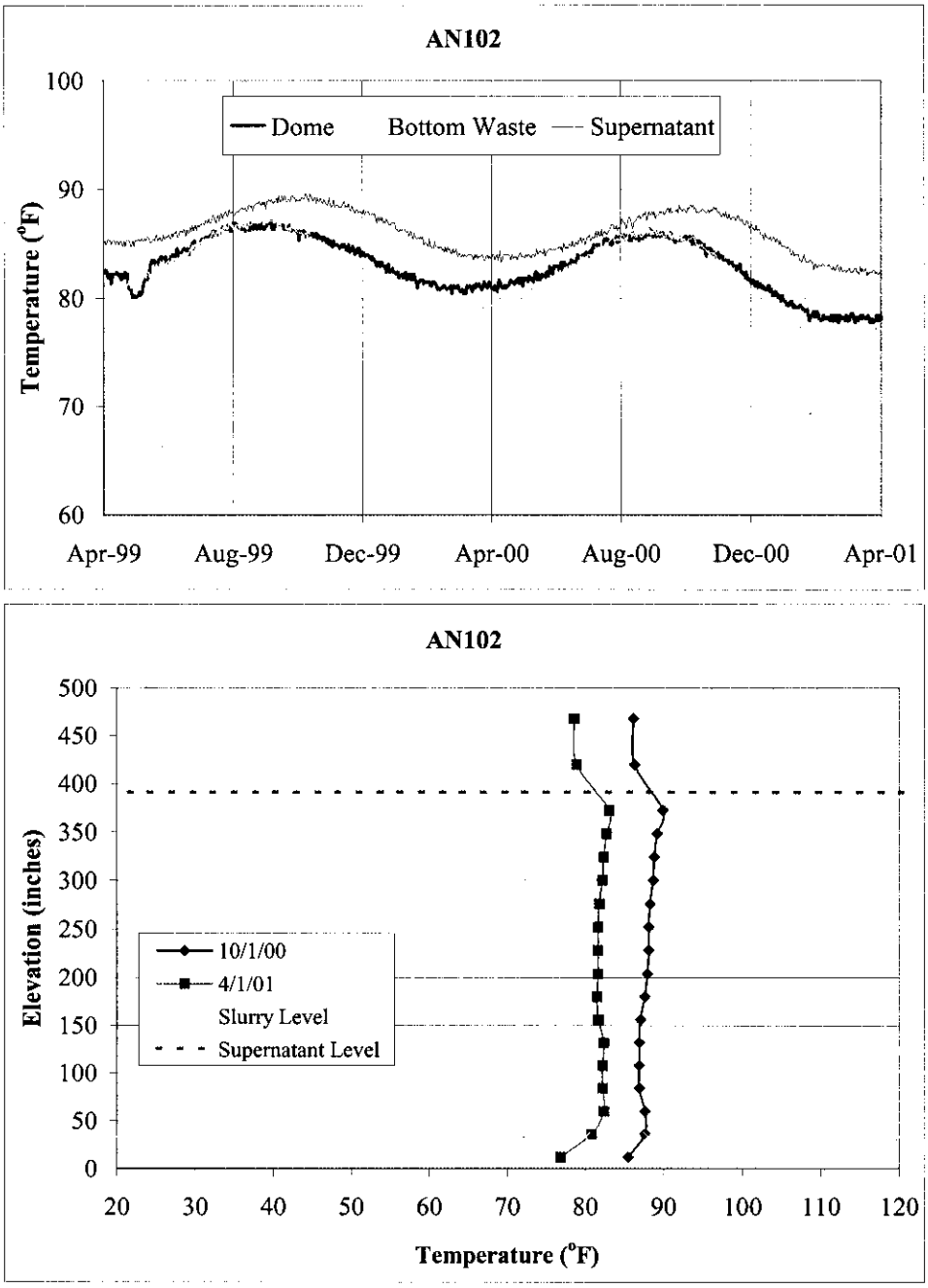
Figure 2-1. Tank 241-AN-101 Data.





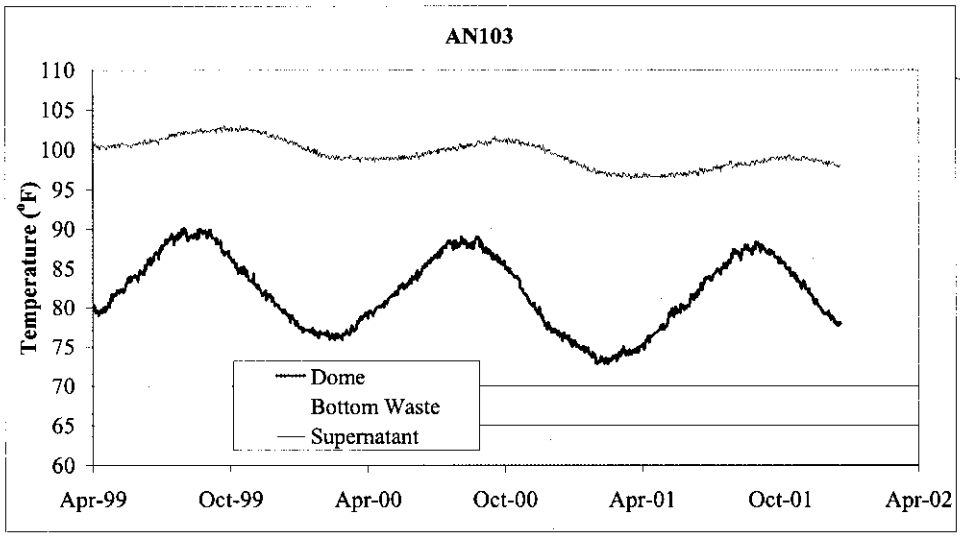
A-2.2 TANK 241-AN-102

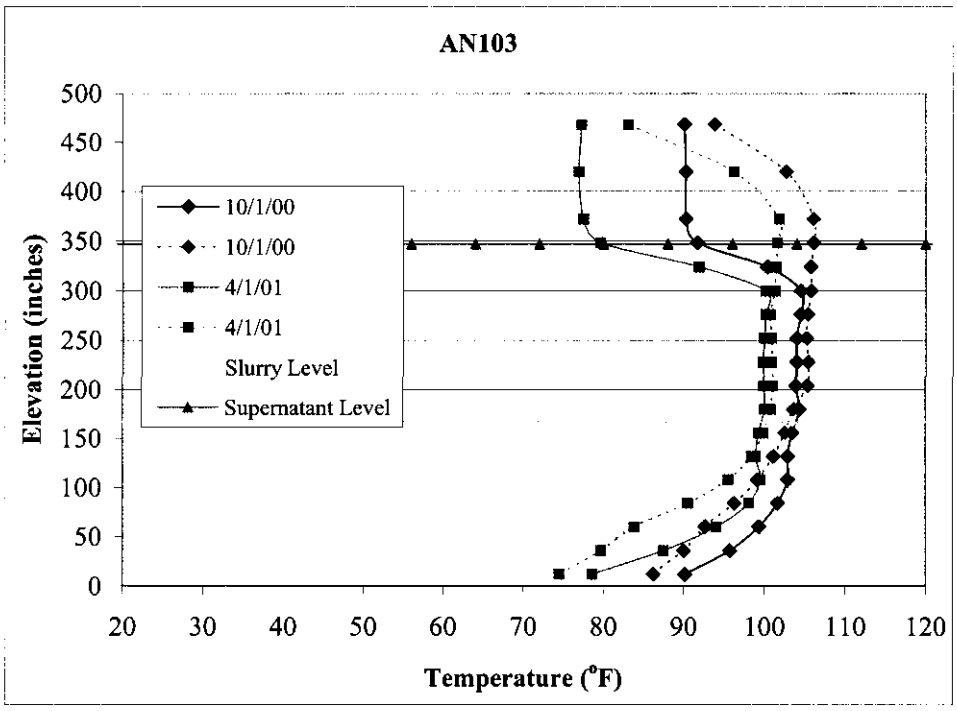
Figure 2-2. Tank 241-AN-102 Data.



A-2.3 TANK 241-AN-103

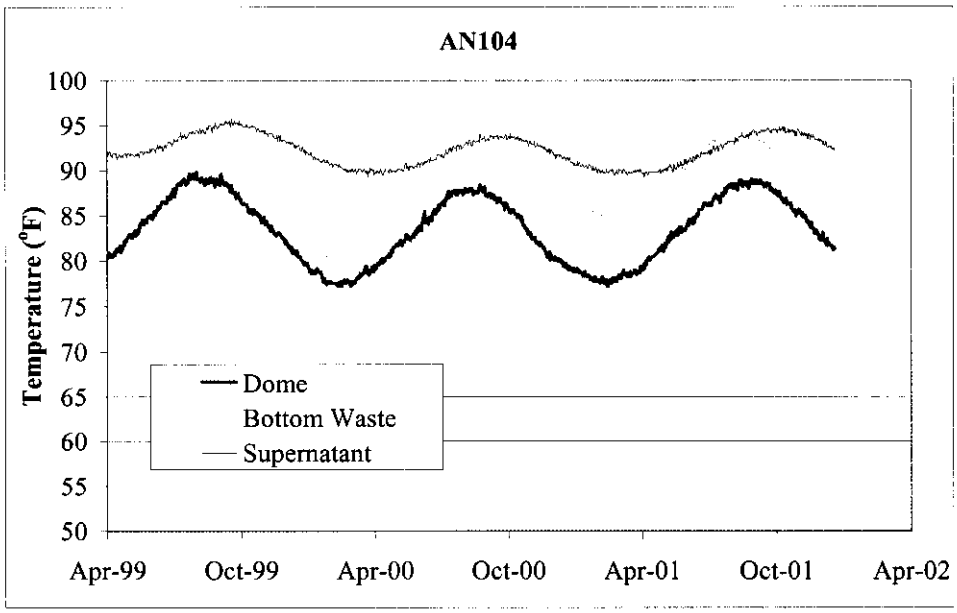
Figure 2-3. Tank 241-AN-103 Data.

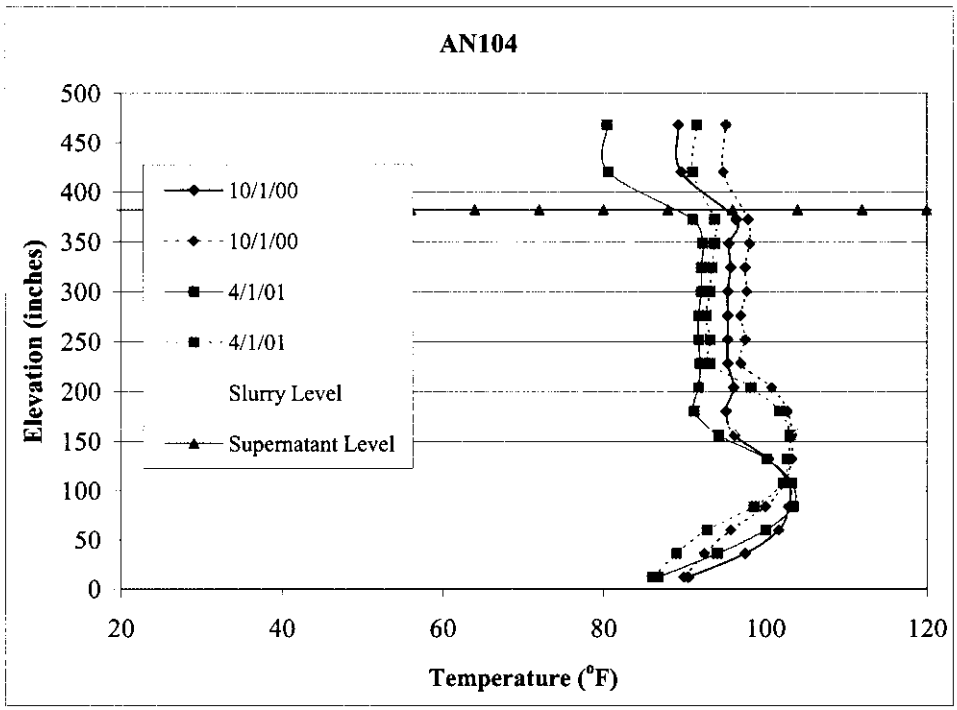




A-2.4 TANK 241-AN-104

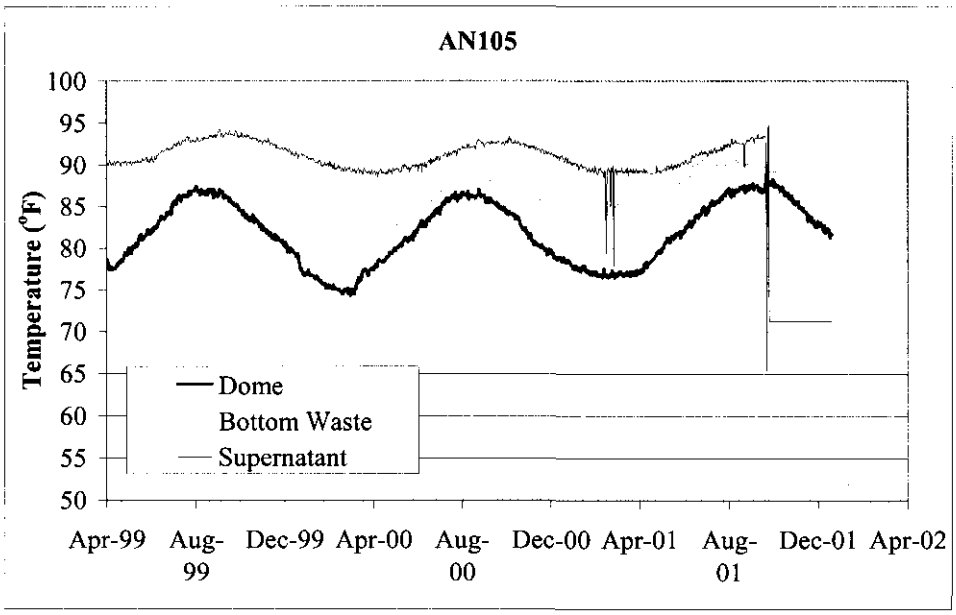
Figure 2-4. Tank 241-AN-104 Data.

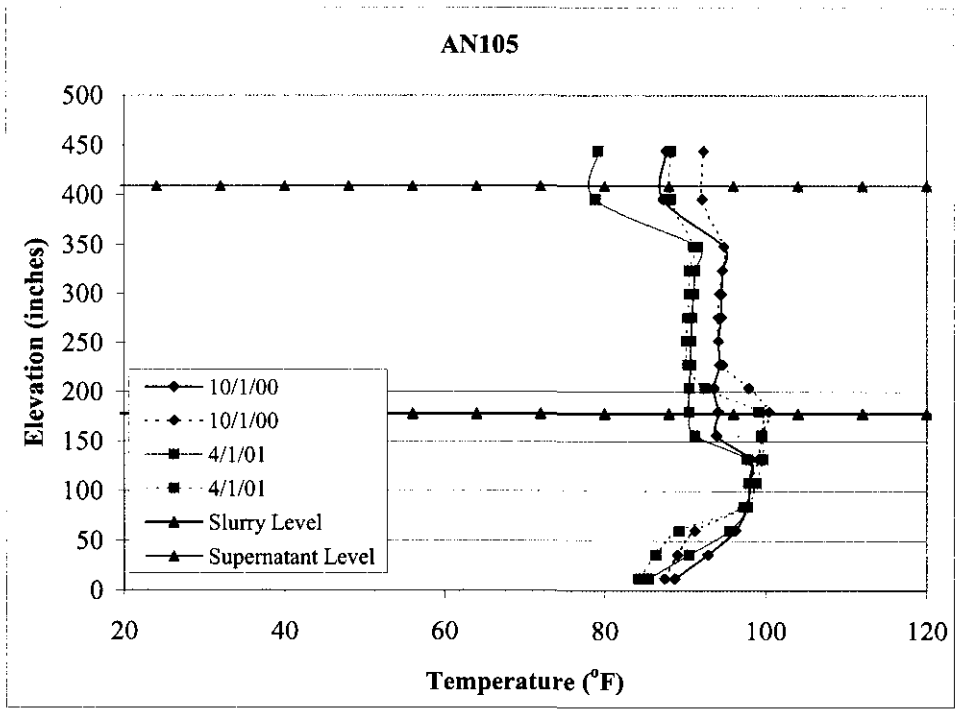




A-2.5 TANK 241-AN-105

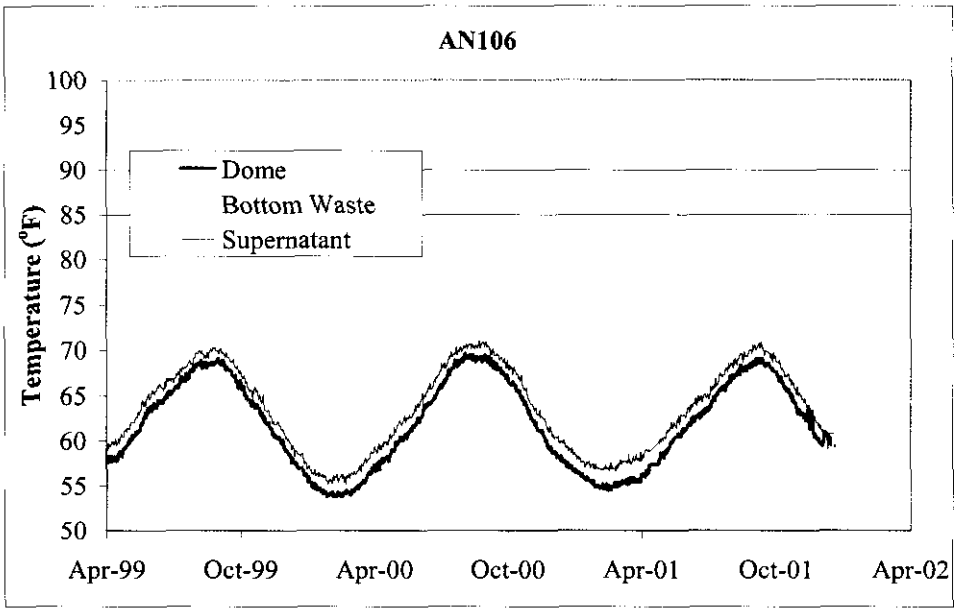
Figure 2-5. Tank 241-AN-105 Data.

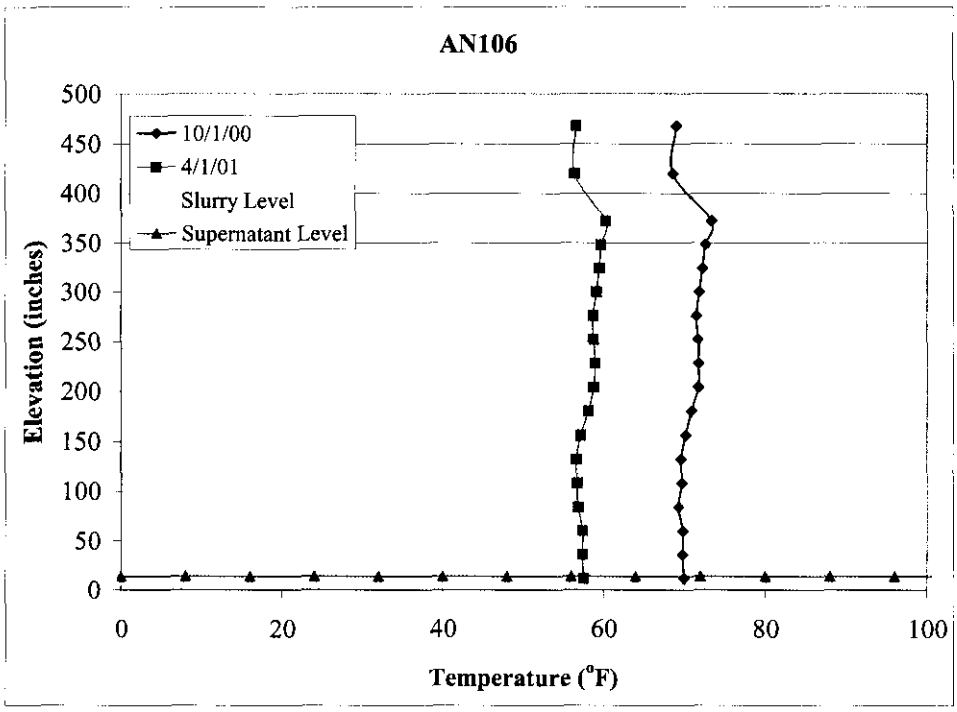




A-2.6 TANK 241-AN-106

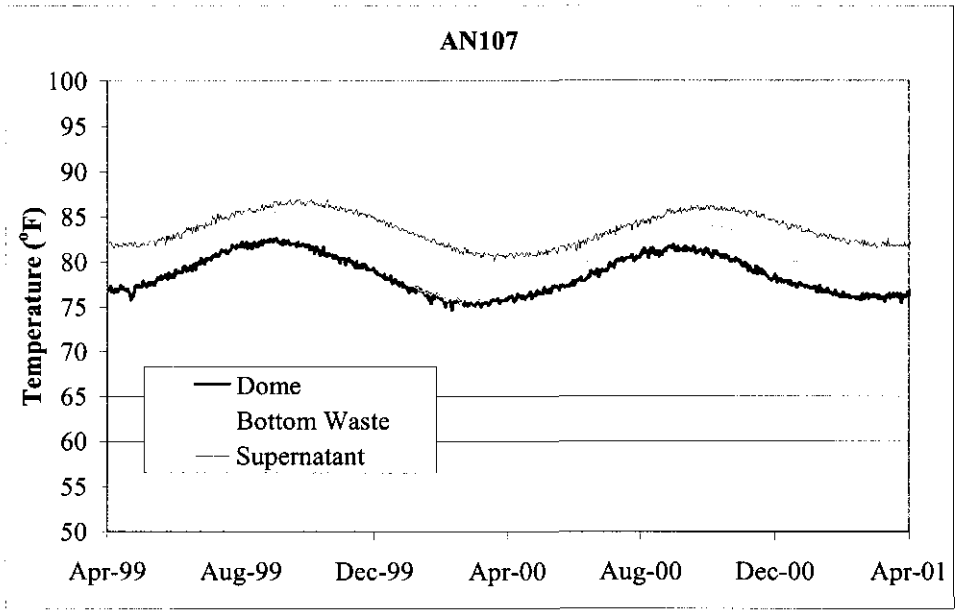
Figure 2-6. Tank 241-AN-106 Data.

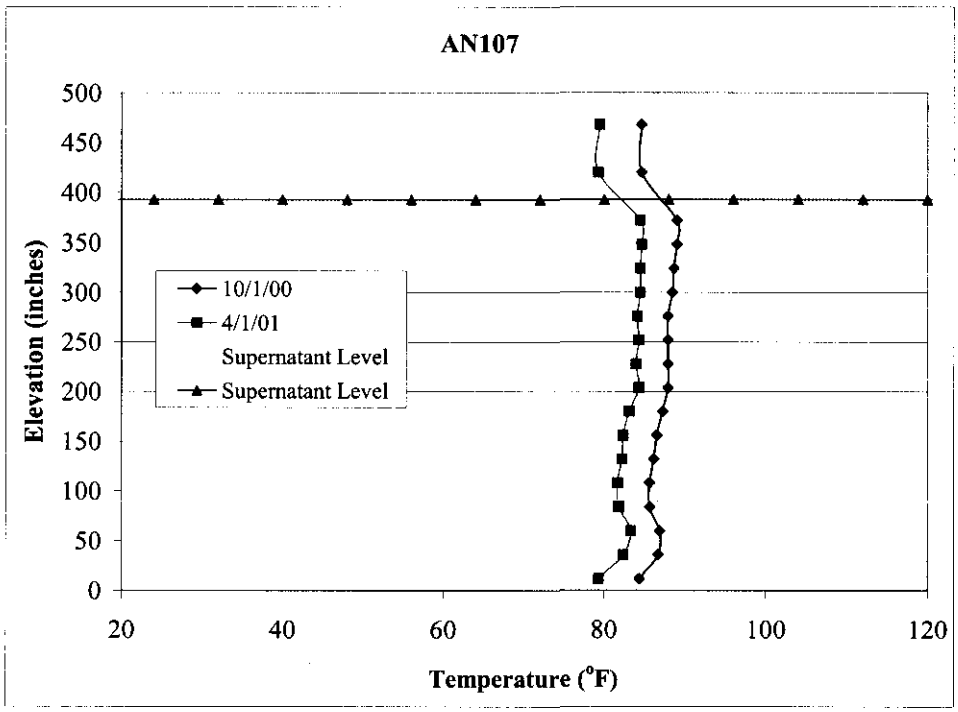




A-2.7 TANK 241-AN-107

Figure 2-7. Tank 241-AN-107 Data.

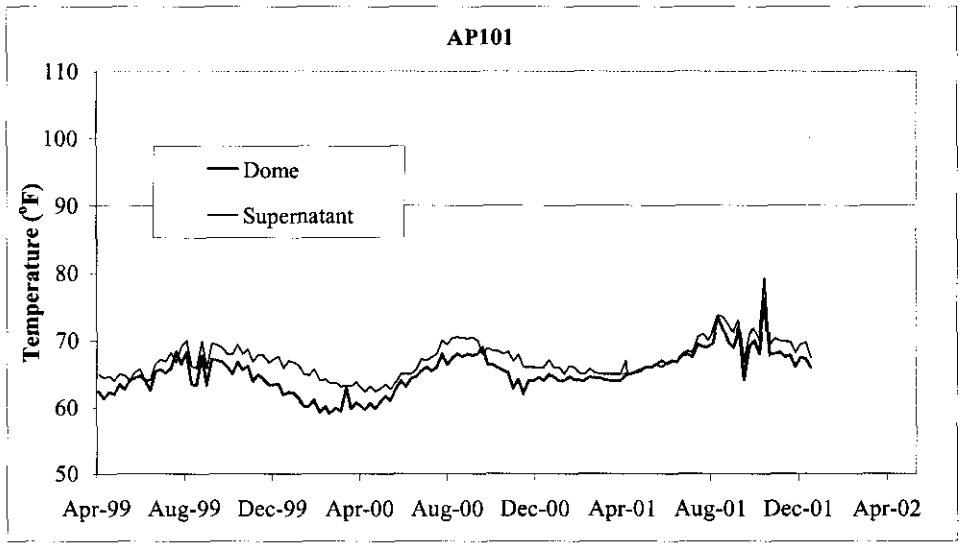


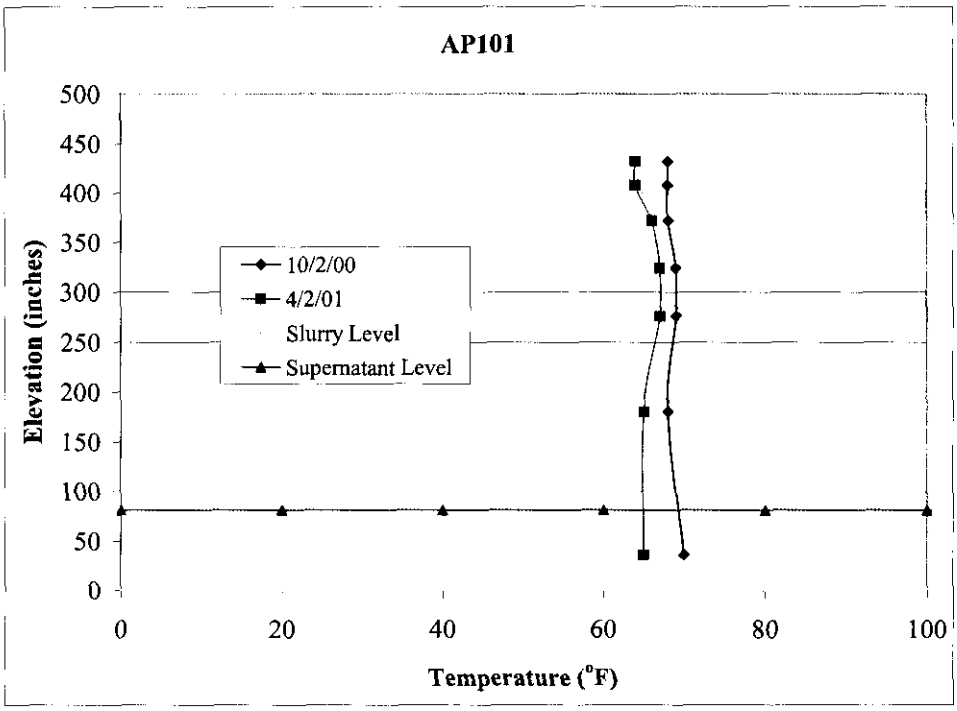


A-3.0 AP-FARM

A-3.1 TANK 241-AP-101

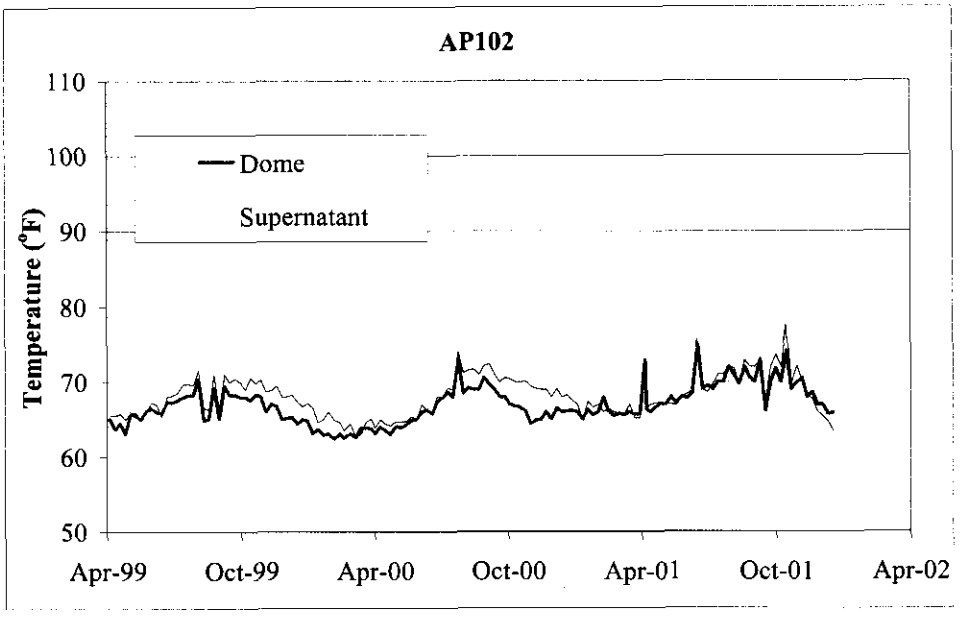
Figure 3-1. Tank 241-AP-101 Data.

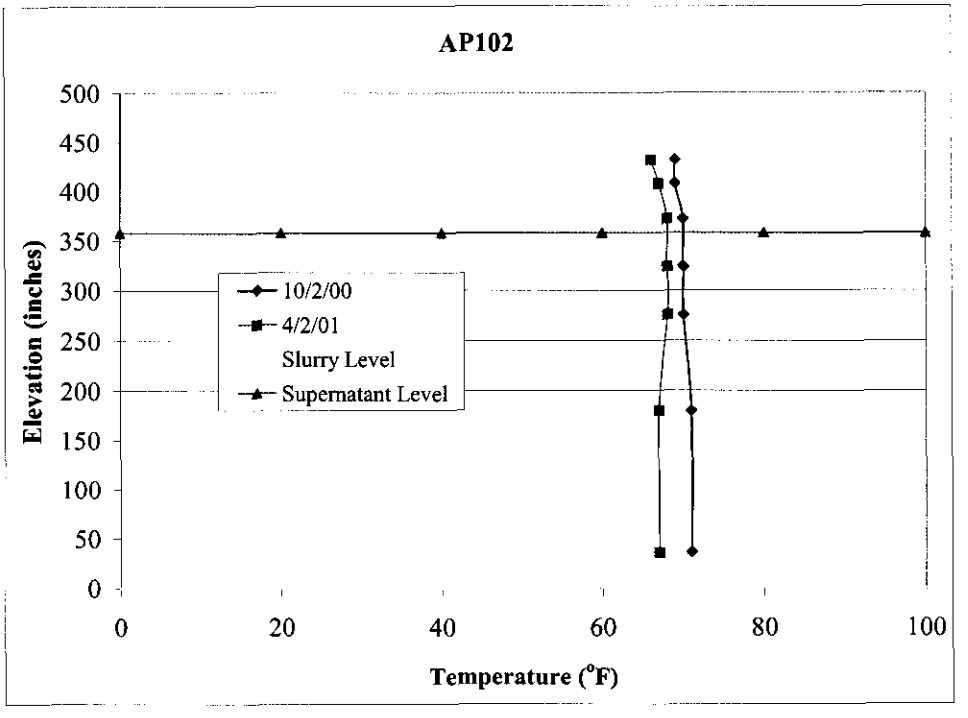




A-3.2 TANK 241-AP-102

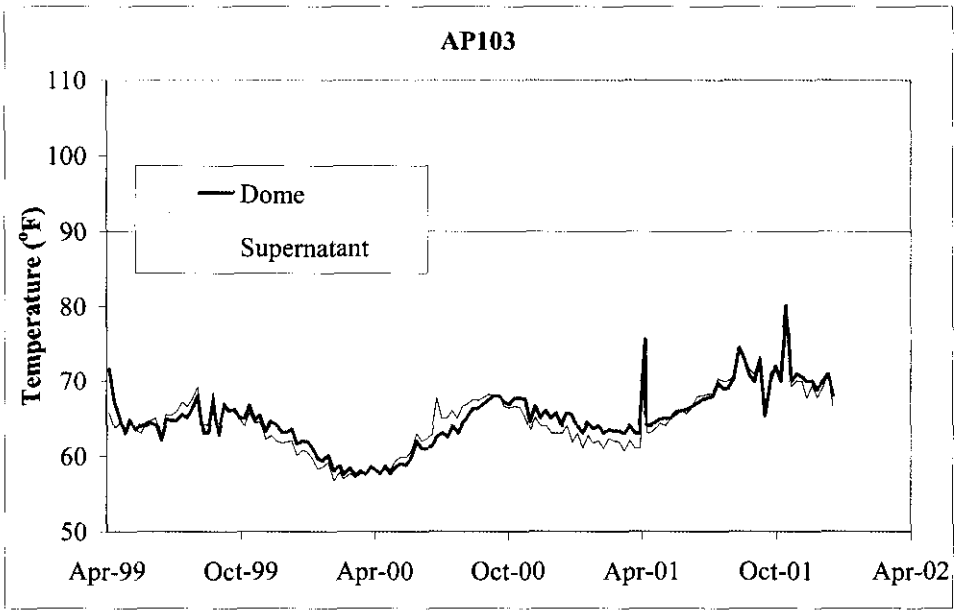
Figure 3-2. Tank 241-AP-102 Data.

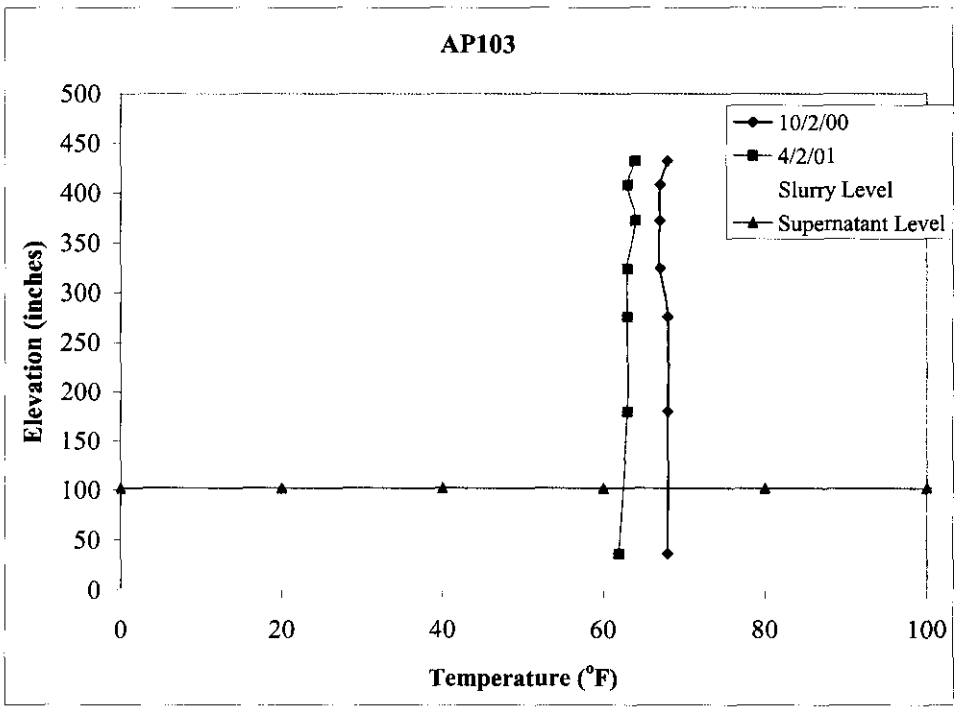




A-3.3 TANK 241-AP-103

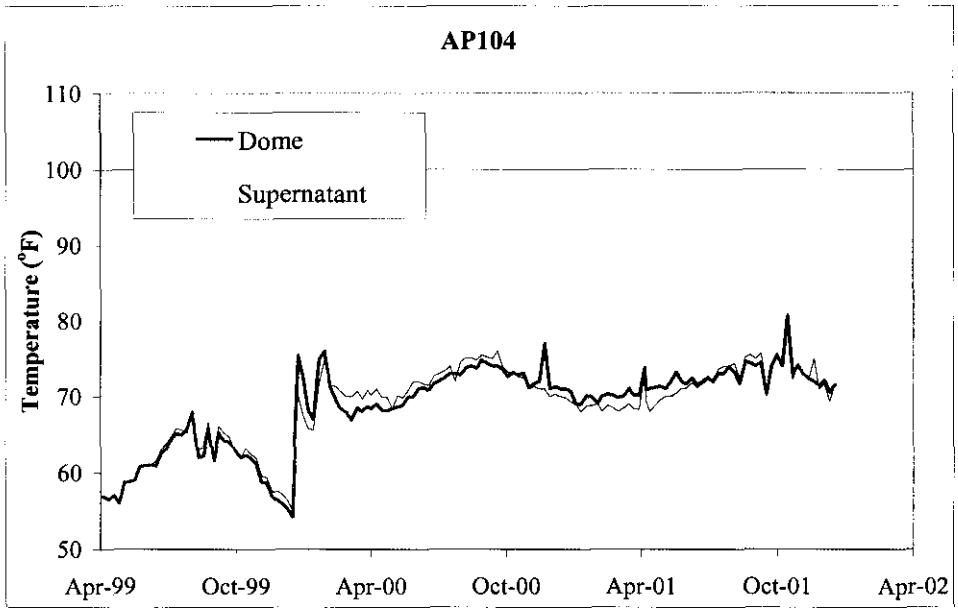
Figure 3-3. Tank 241-AP-103 Data.

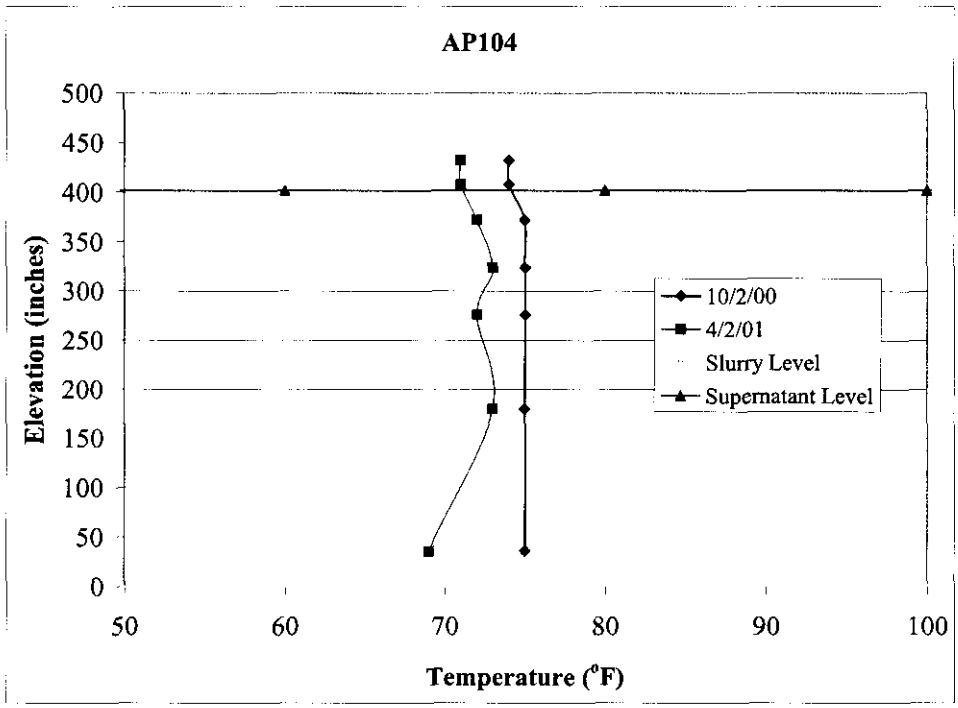




A-3.4 TANK 241-AP-104

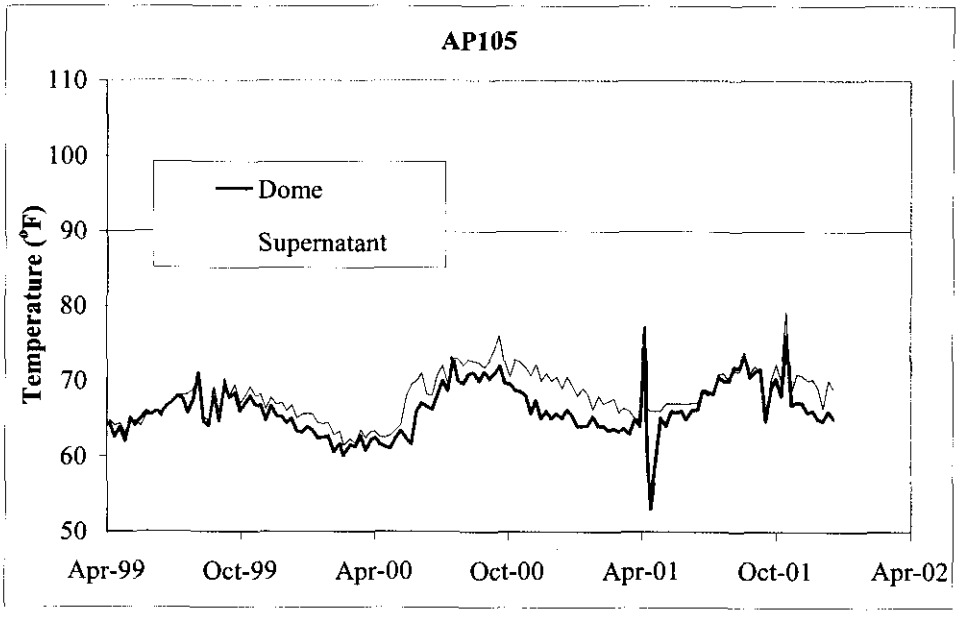
Figure 3-4. Tank 241-AP-104 Data.

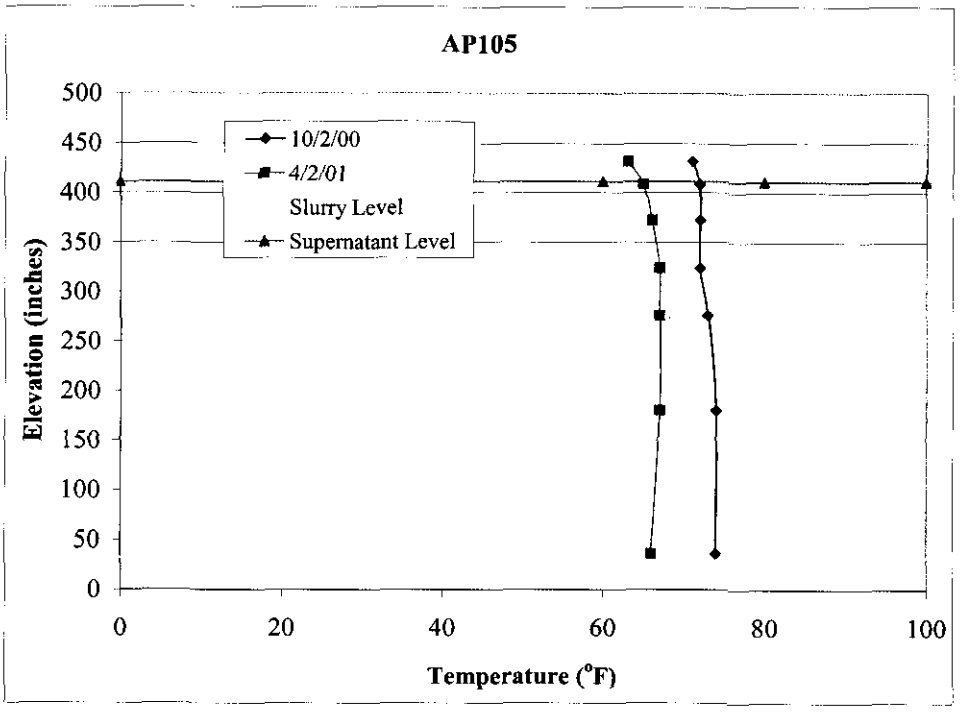




A-3.5 TANK 241-AP-105

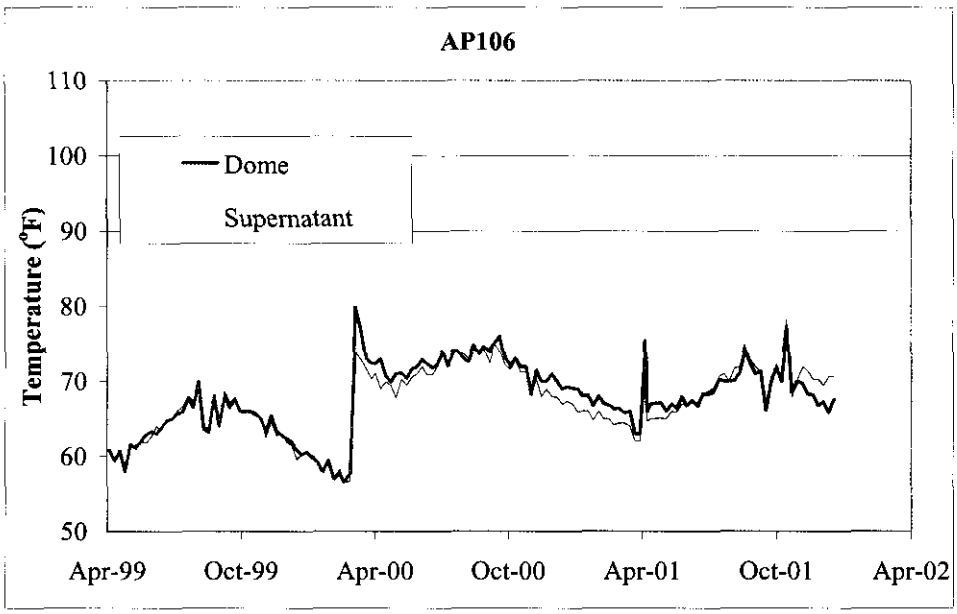
Figure 3-5. Tank 241-AP-105 Data.

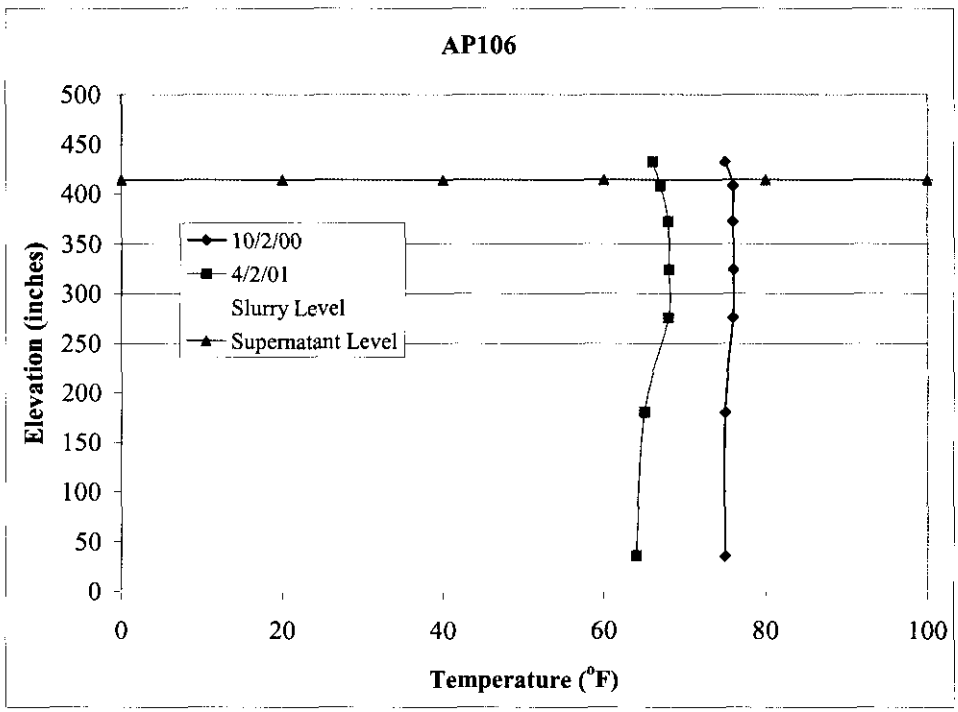




A-3.6 TANK 241-AP-106

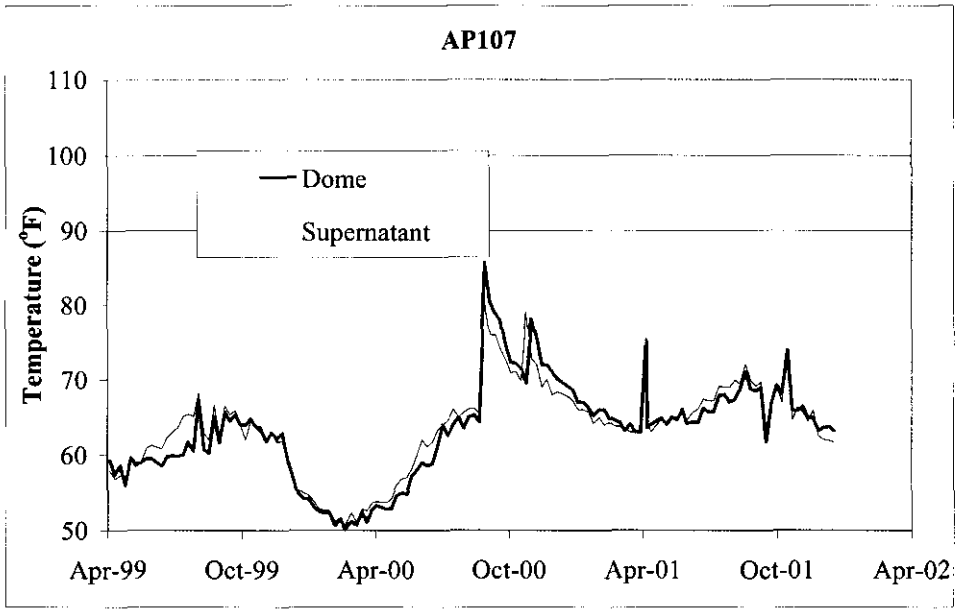
Figure 3-6. Tank 241-AP-106 Data.

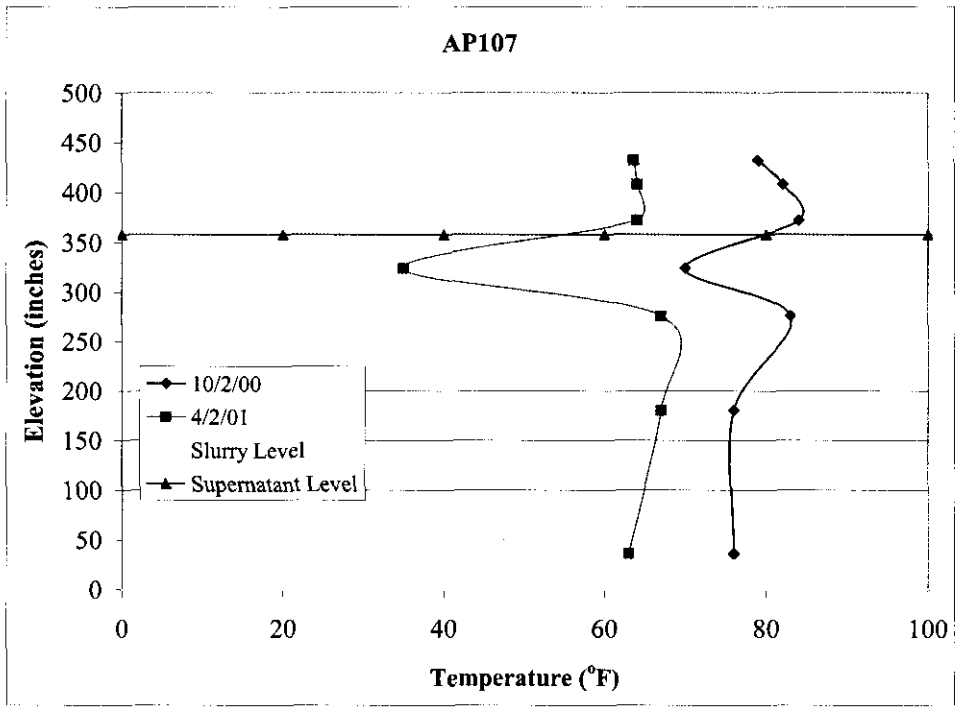




A-3.7 TANK 241-AP-107

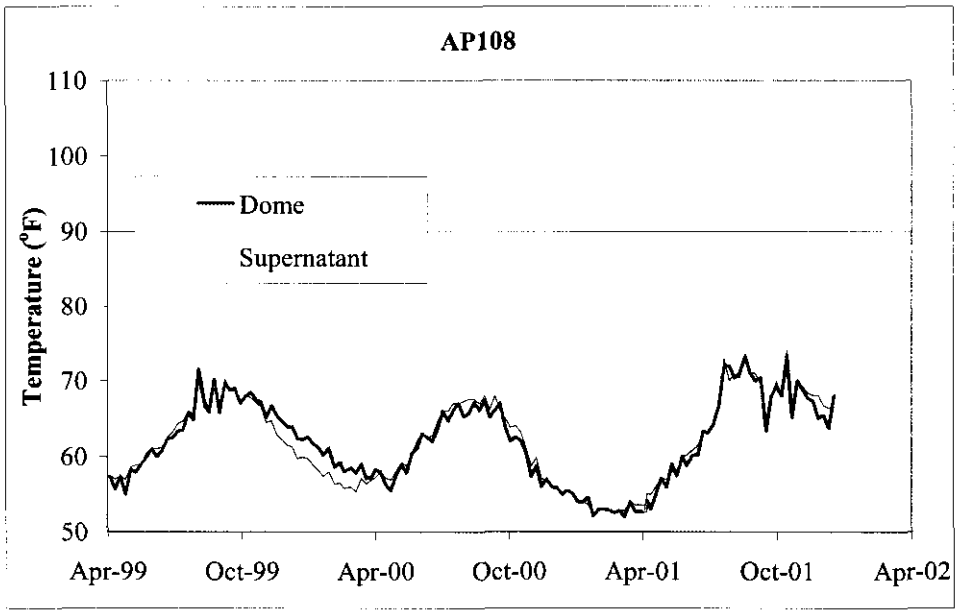
Figure 3-7. Tank 241-AN-107 Data.

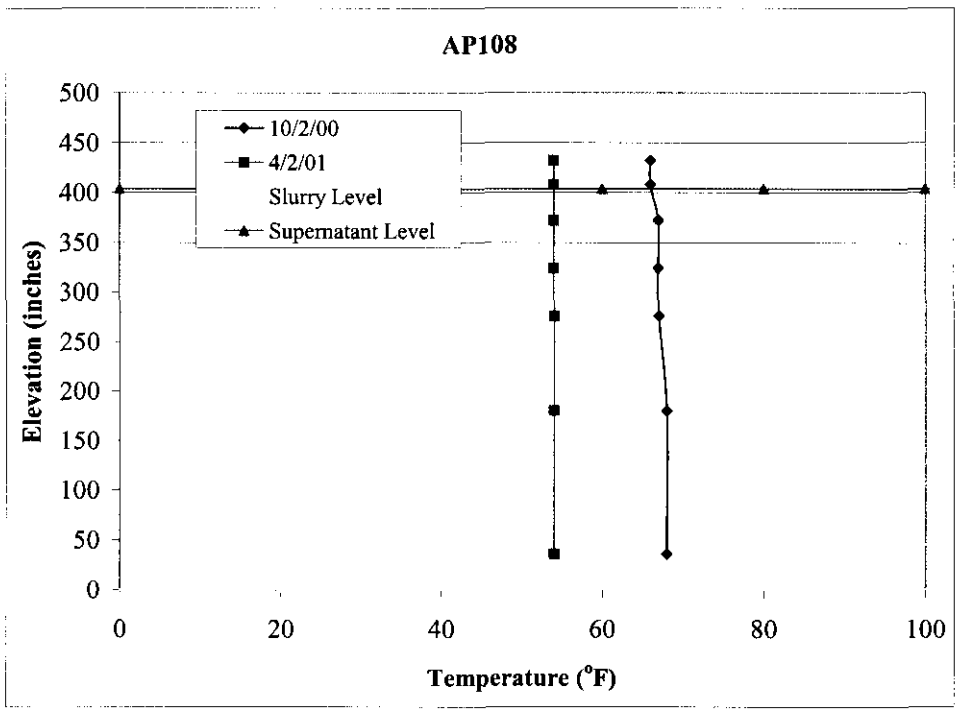




A-3.8 TANK 241-AP-108

Figure 3-8. Tank 241-AP-108 Data.

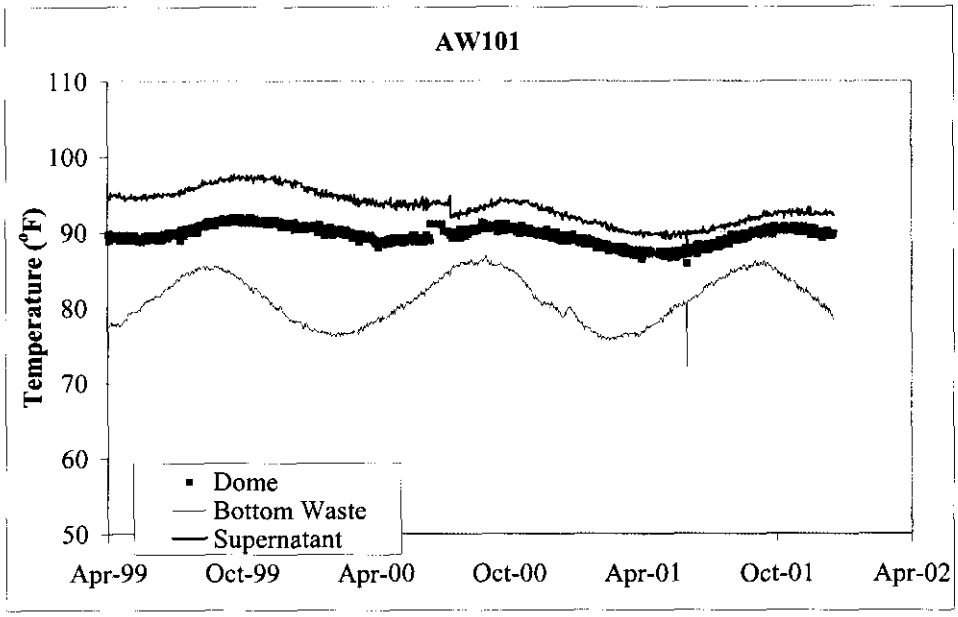


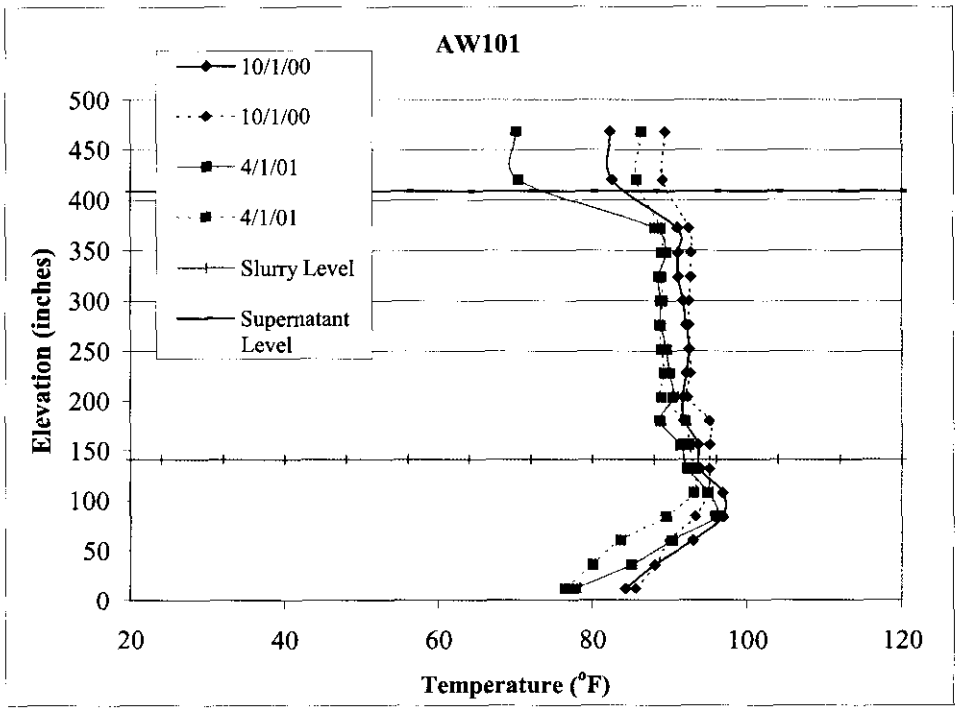


A-4.0 AW-FARM

A-4.1 TANK 241-AW-101

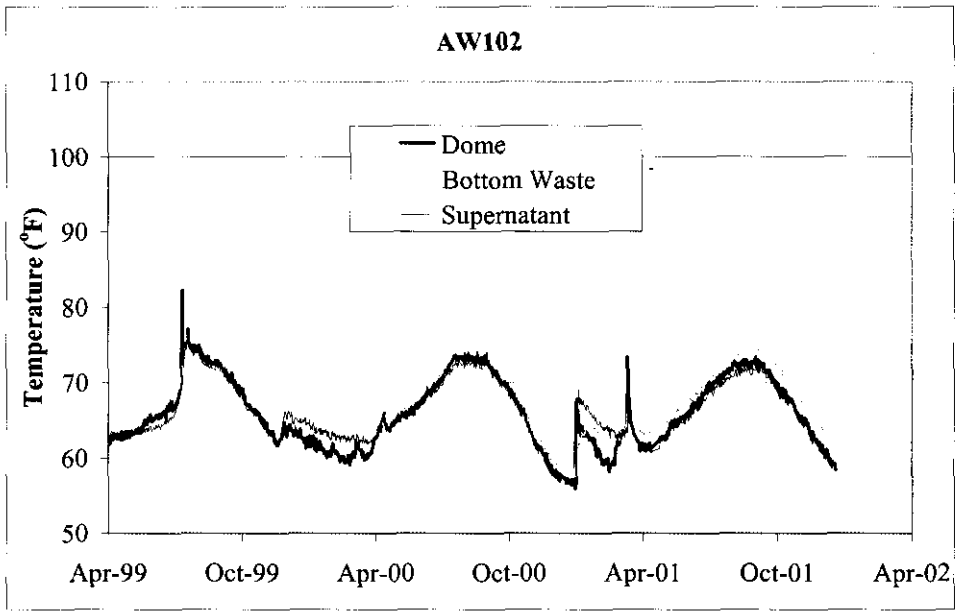
Figure 4-1. Tank 241-AW-101 Data.

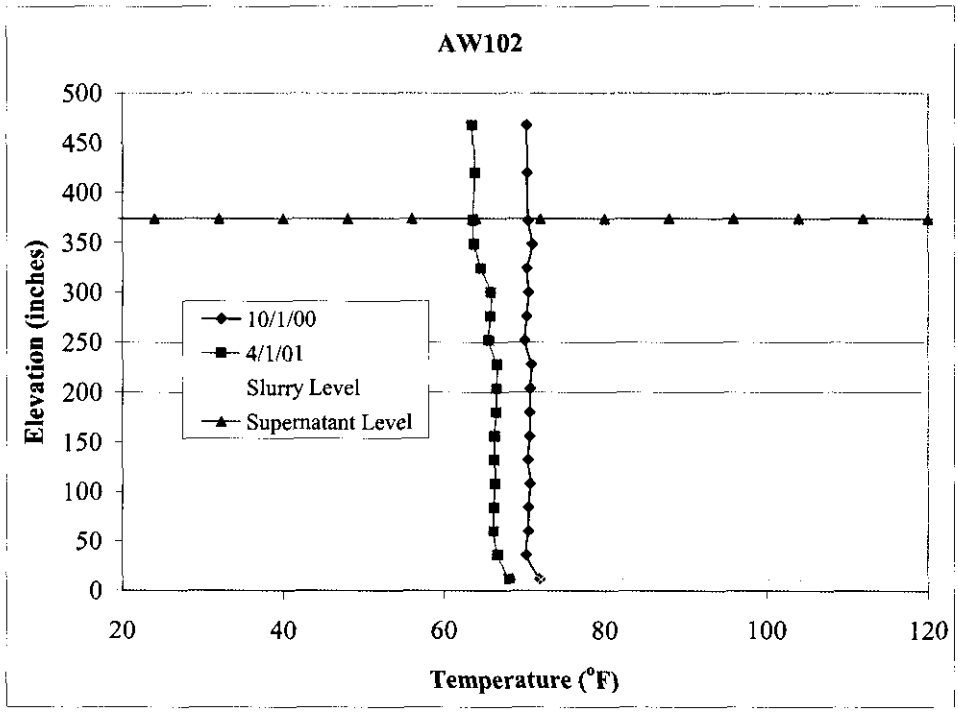




A-4.2 TANK 241-AW-102

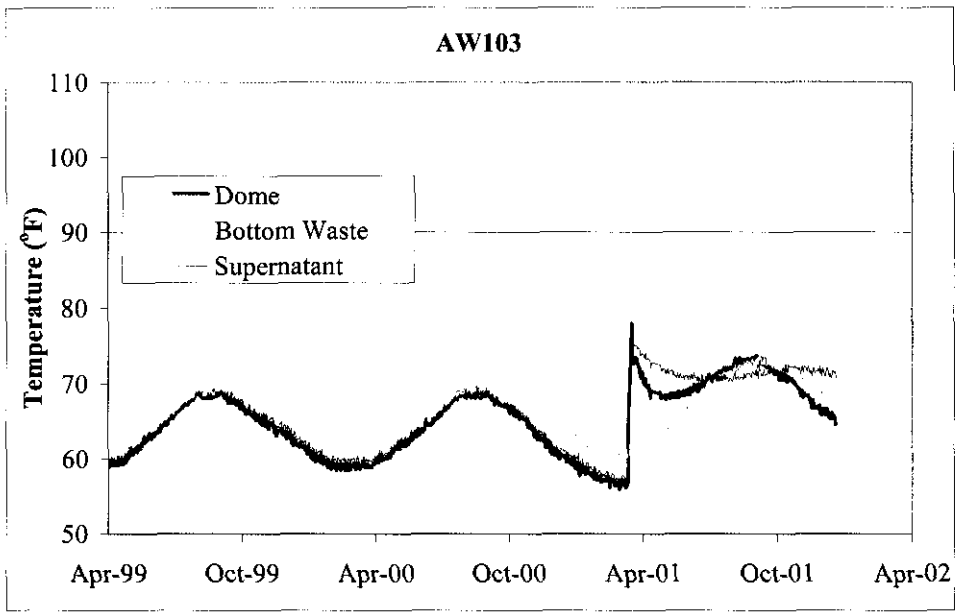
Figure 4-2. Tank 241-AW-102 Data.

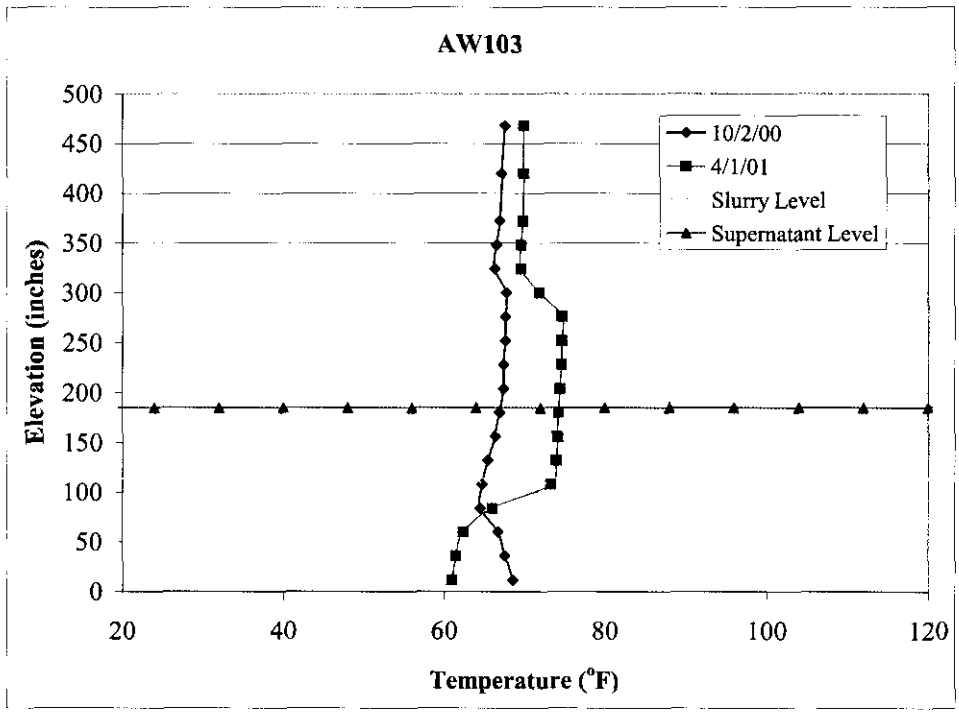




A-4.3 TANK 241-AW-103

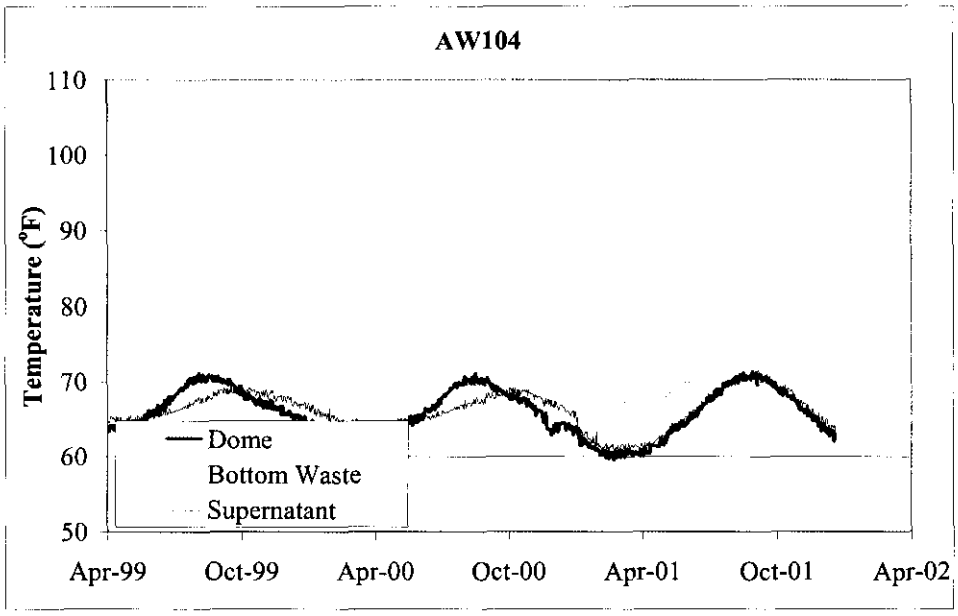
Figure 4-3. Tank 241-AW-103 Data.

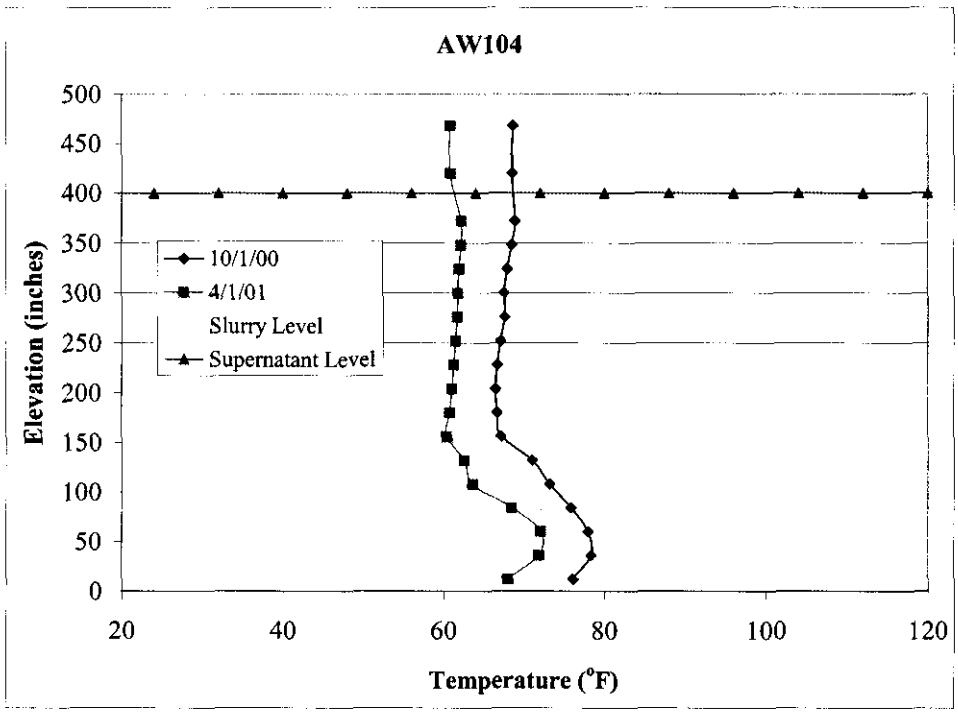




A-4.4 TANK 241-AW-104

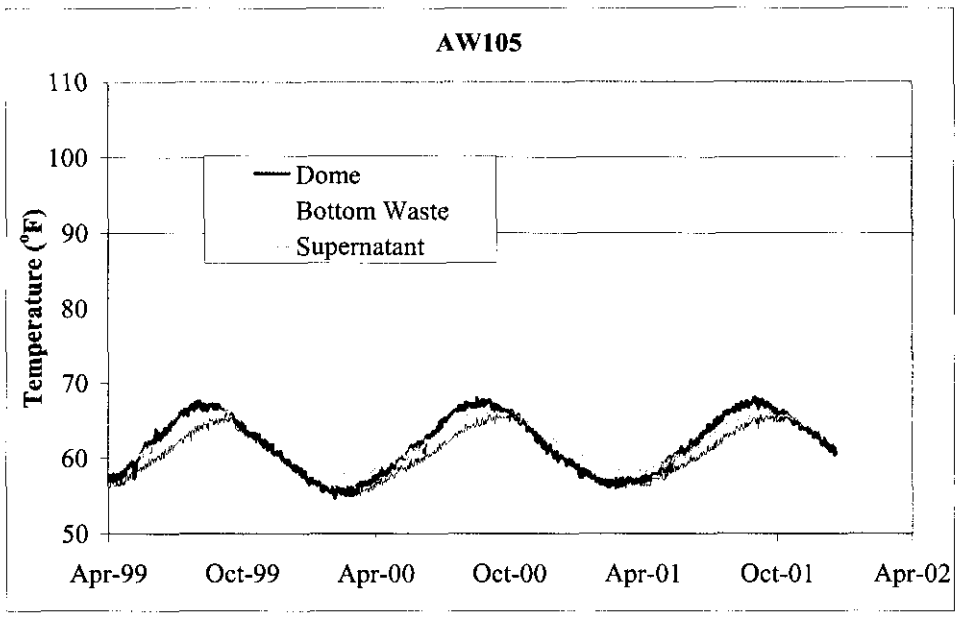
Figure 4-4. Tank 241-AW-104 Data.

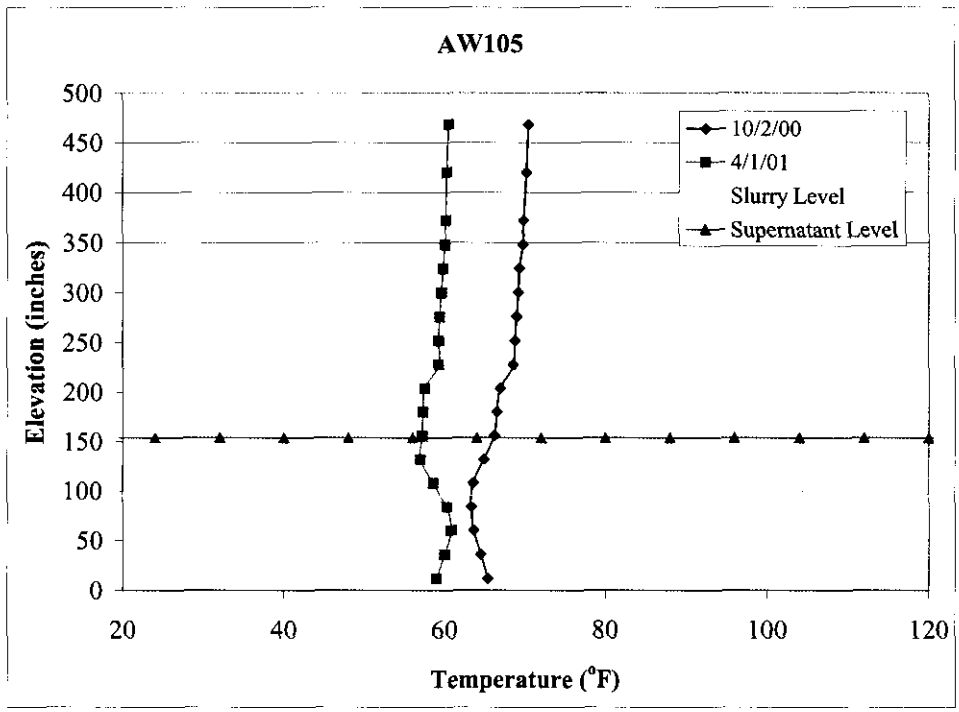




A-4.5 TANK 241-AW-105

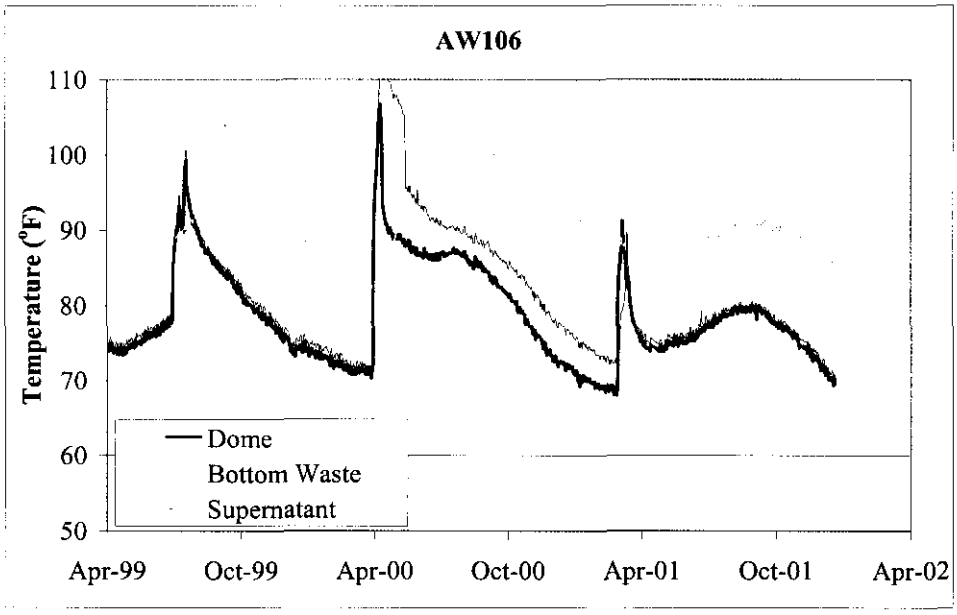
Figure 4-5. Tank 241-AW-105 Data.

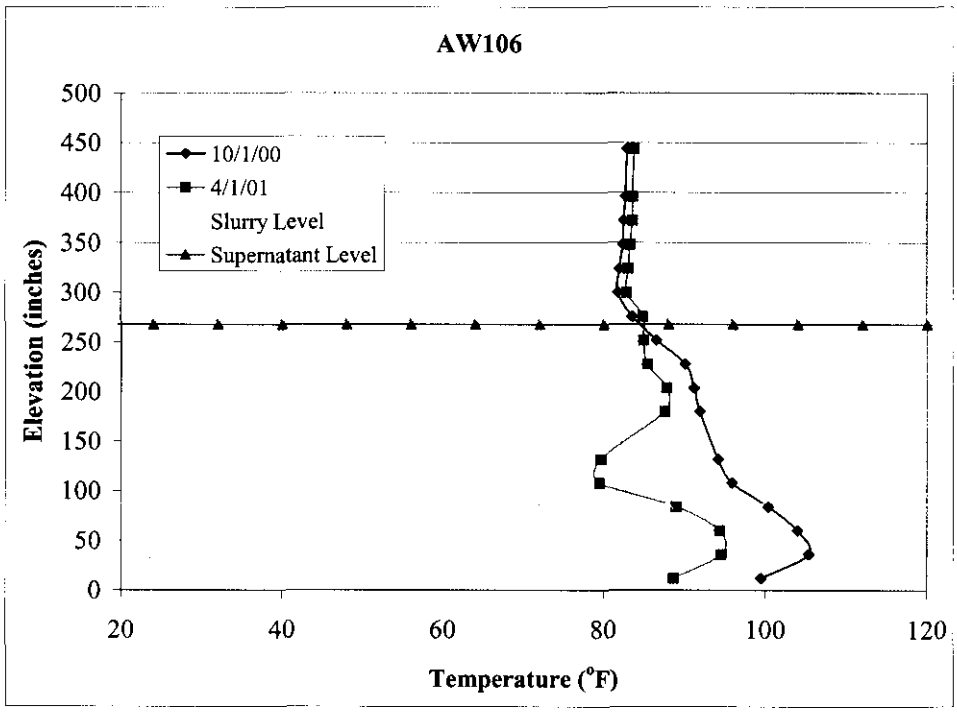




A-4.6 TANK 241-AW-106

Figure 4-6. Tank 241-AW-106 Data.

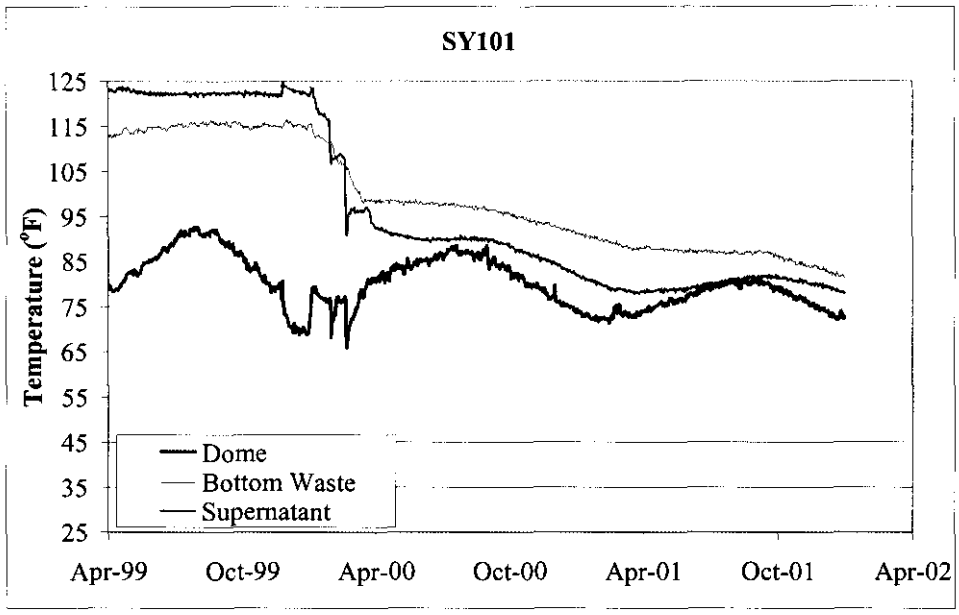


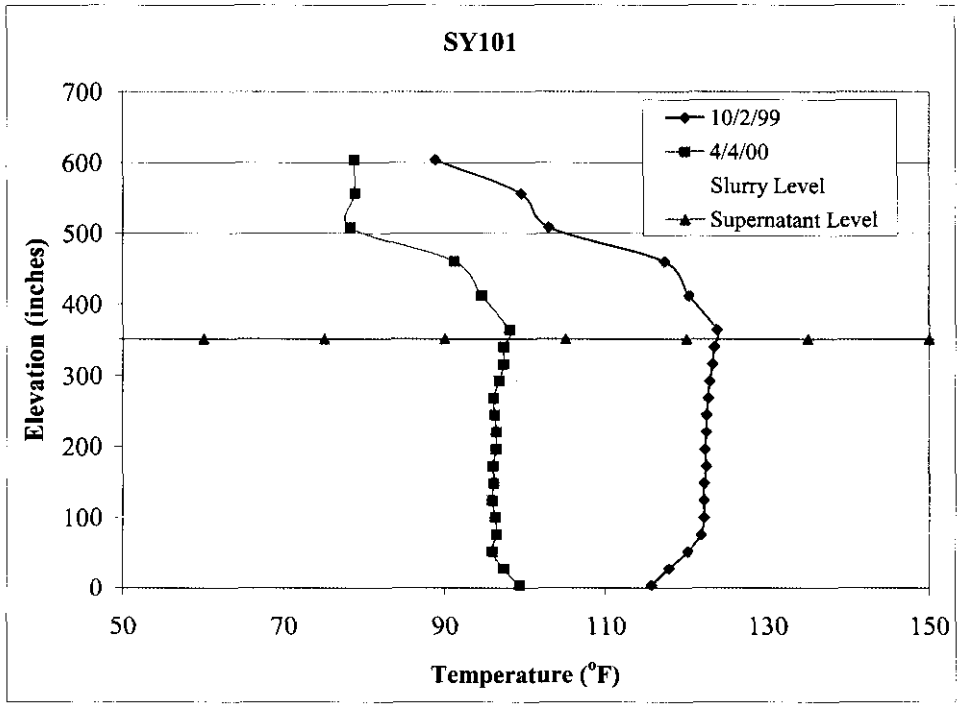


A-5.0 SY-FARM

A-5.1 TANK 241-SY-101

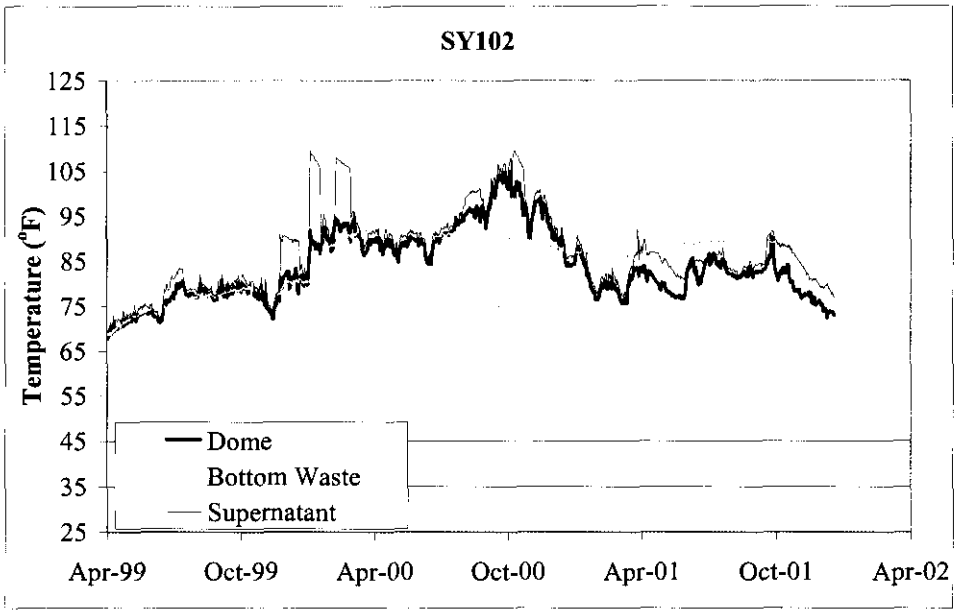
Figure 5-1. Tank 241-SY-101 Data.

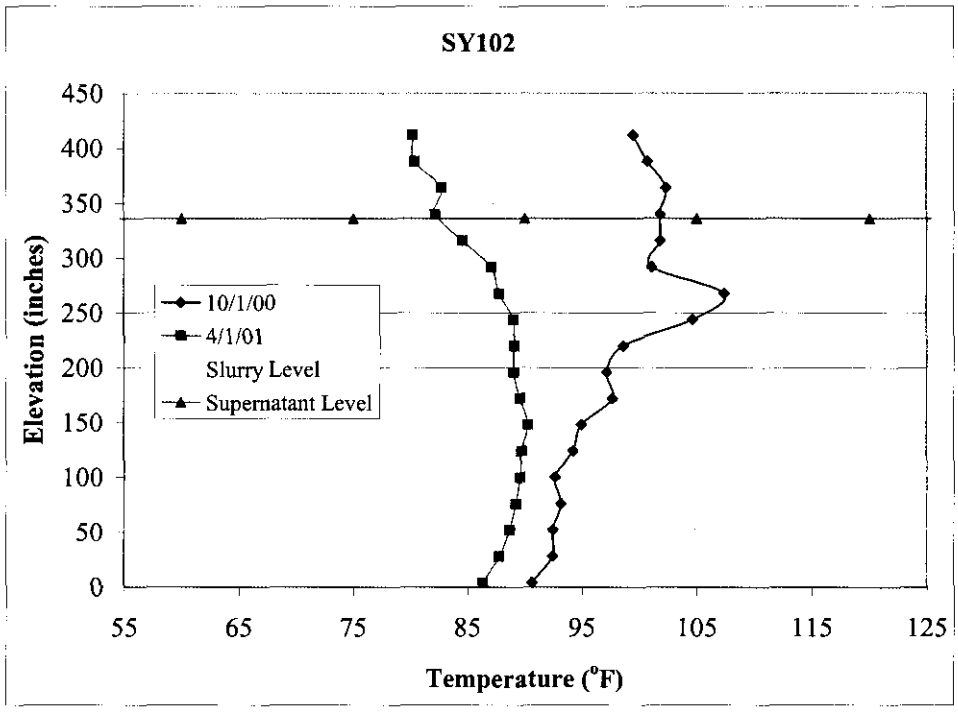




A-5.2 TANK 241-SY-102

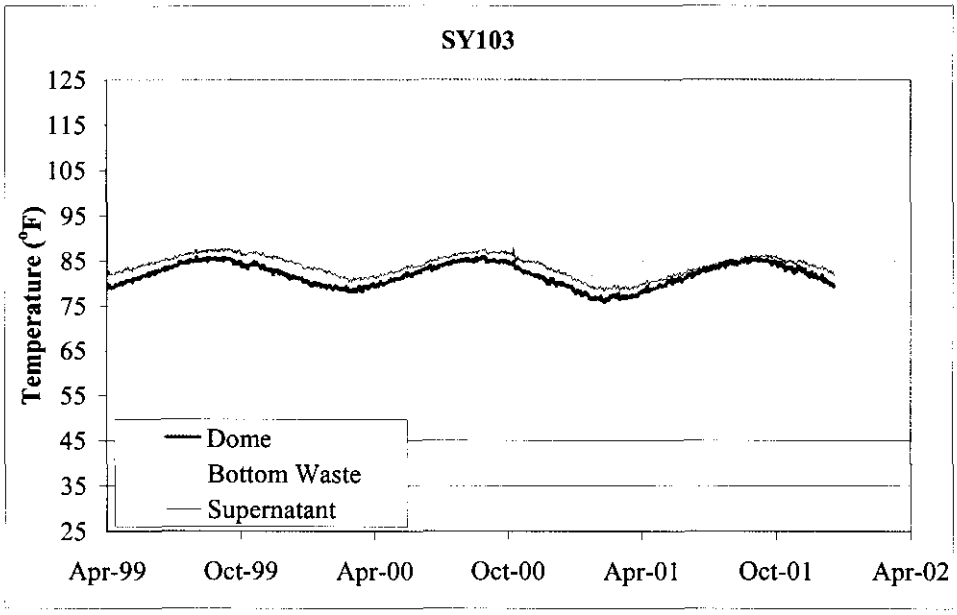
Figure 5-2. Tank 241-SY-102 Data.

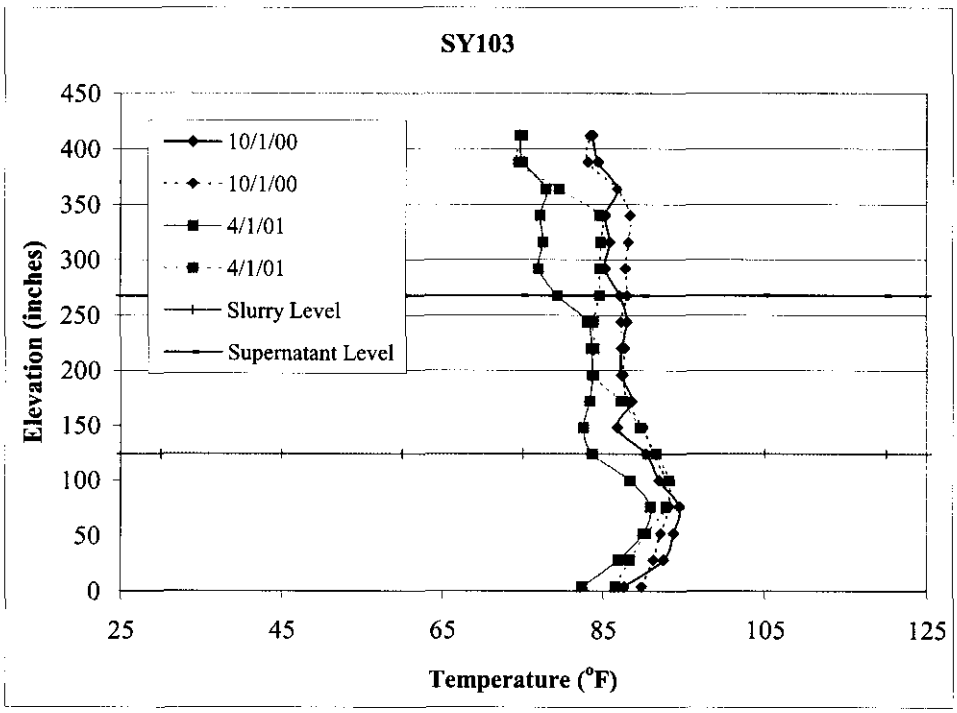




A-5.3 TANK 241-SY-103

Figure 5-3. Tank 241-SY-103 Data.

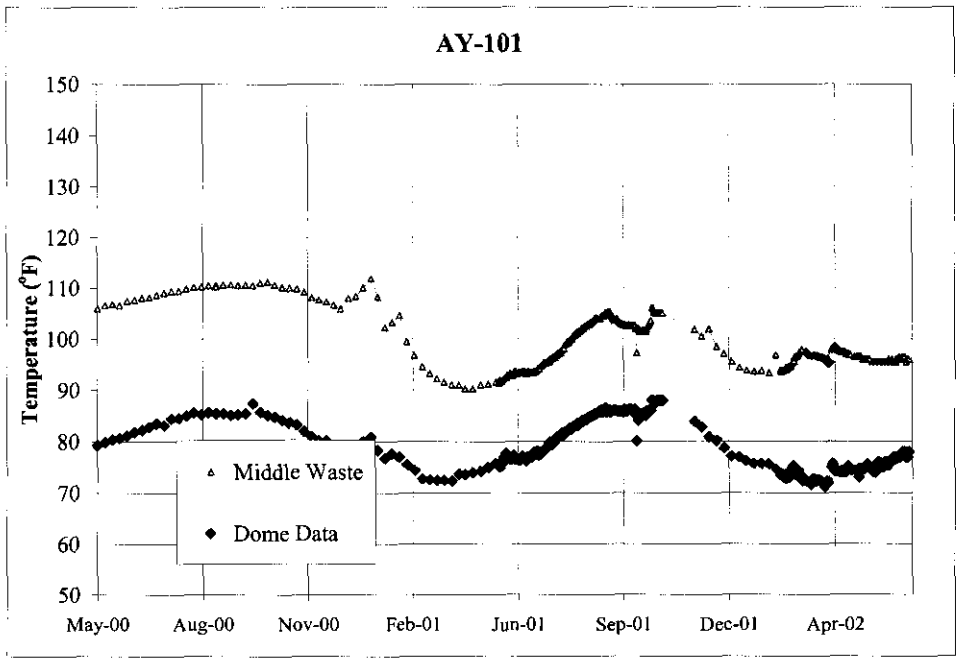




A-6.0 AY-FARM

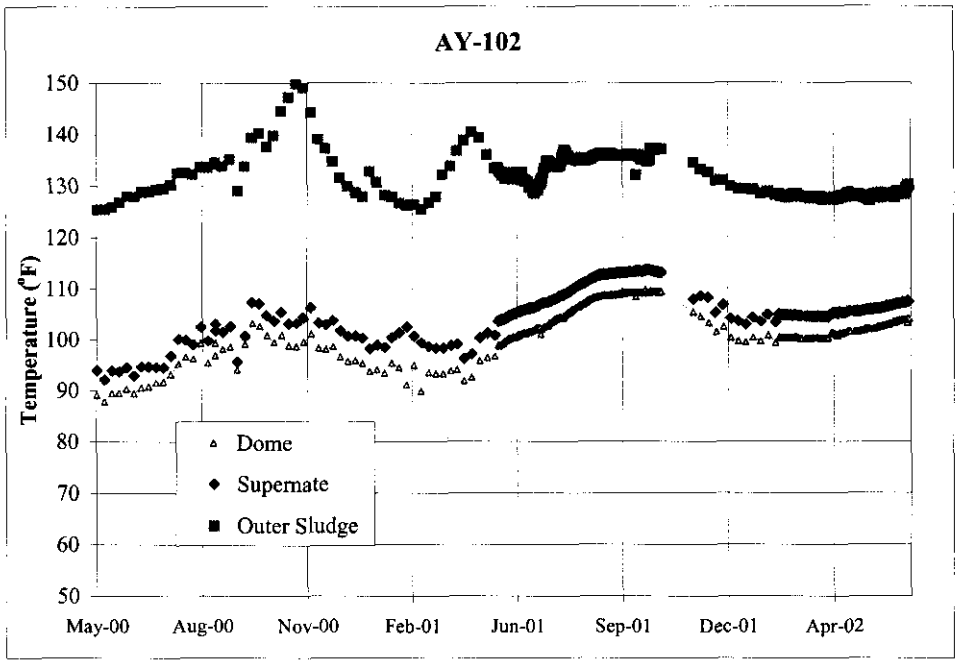
A-6.1 TANK 241-AY-101

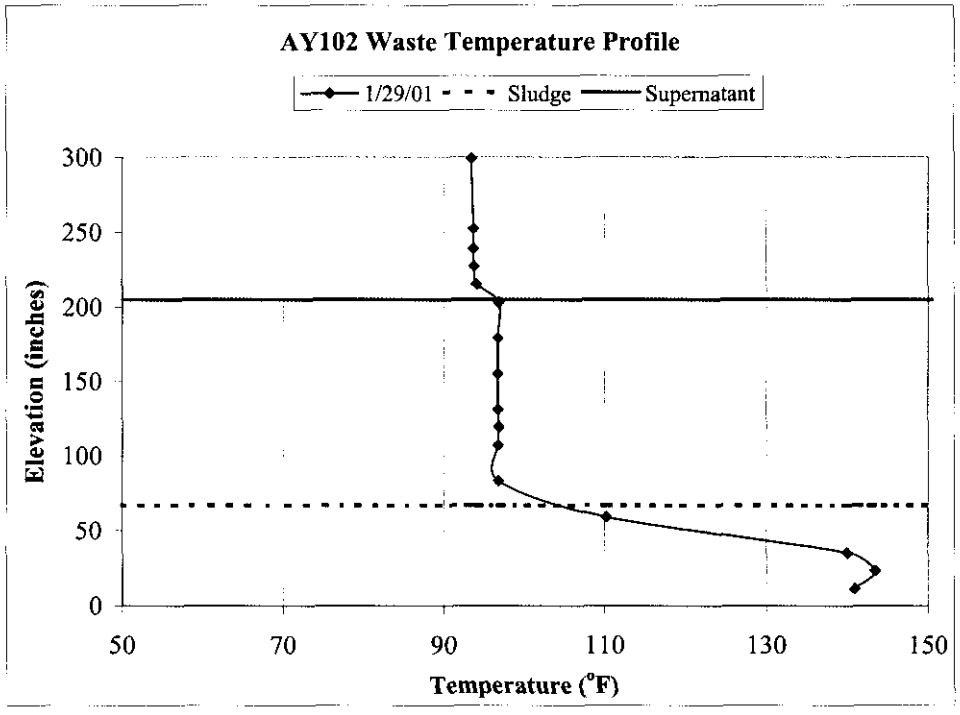
Figure 6-1. Tank 241-AY-101 Data.



A-6.2 TANK 241-AY-102

Figure 6-2. Tank 241-AY-102 Data.

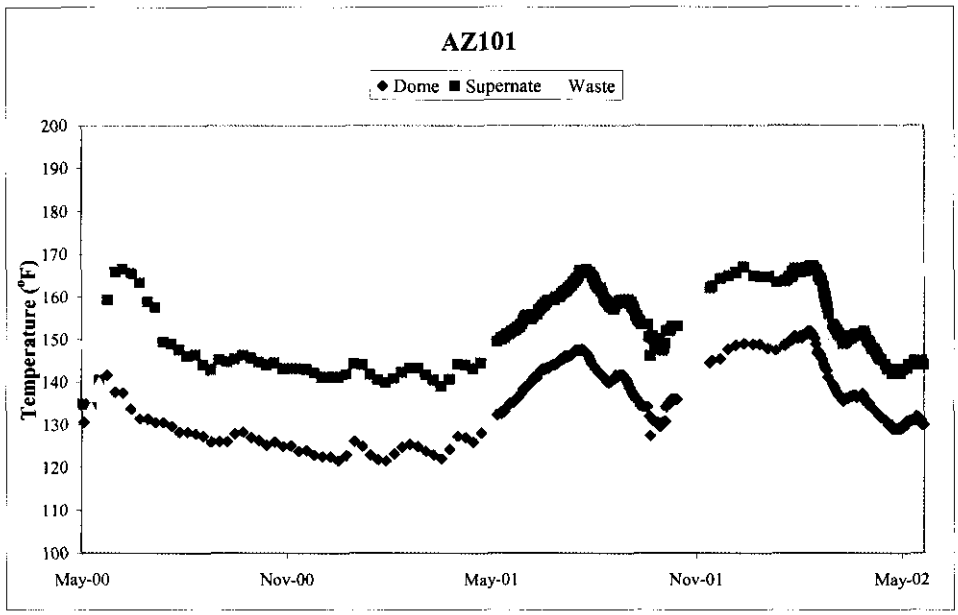




A-7.0 AZ-FARM

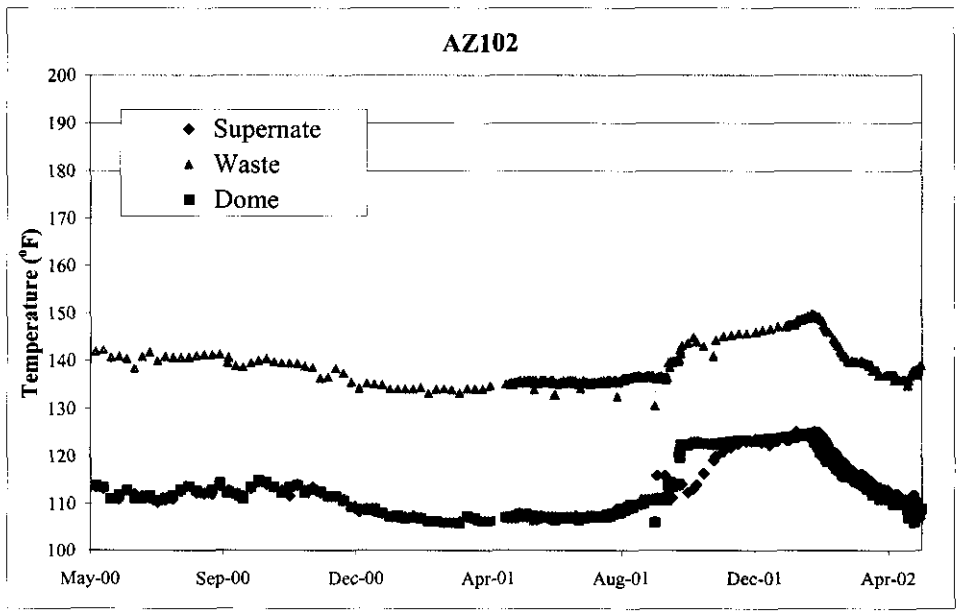
A-7.1 TANK 241-AZ-101

Figure 7-1. Tank 241-AZ-101 Data.



A-7.2 TANK 241-AZ-102

Figure 7-2. Tank 241-AZ-102 Data.



APPENDIX B - ESP CHEMICAL EQUILIBRIUM ANALYSES

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February 25, 2002

Mr. Edward A. Fredenburg
Maintenance/Reliability Engineering
CH2M Hill Hanford Group, Inc.
P.O. Box 1500
Richland, Washington 99352-1505

Dear Mr. Fredenburg:

SUPPORT TO ANALYSIS OF CONDENSATION POTENTIAL ON DST PRIMARY TANK INTERIORS

Attached are the results of the vapor pressure and other calculations for the 28 double-shell tank wastes. This work was performed under Contract No. 8249, Release No. 165, "Support to Analysis of Condensation Potential on DST Primary Tank Interiors." The calculations were made using version 6.4 of the Environmental Simulation Program (ESP). The sample files used for input were from the Best Basis Inventory ESP simulations made in 1997 and 1998, except for a few that were developed more recently as part of Waste Feed Delivery simulations for the CH2M Hill Group.

For a few wastes, the inventories were split between supernatant and sludge layers, so the supernatant compositions were used for calculating the vapor pressure. The solid phase compositions were taken from the already available ESP simulations of the sludge layer at the actual tank temperature. Therefore, for these cases, solid densities and compositions are shown on the attached chart at only the actual tank temperature.

If you have any questions regarding this work, please contact me at (509) 372-0405.

Sincerely,

Originally Signed

Graham T. MacLean
Principal Engineer
Fluor Federal Services

Enclosure

c: Donald M. Ogden
John Marvin, Inc.
12122 N Guinevere Drive
Spokane, WA 99218

AN-101

T oc	P atm	PH2O atm	P/PH2O	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0247	0.0313	0.6931	2.442	ALOH3 (.999)
40	0.0577	0.0729	0.6897	2.443	ALOH3 (.998)
55	0.1235	0.1555	0.6883	2.445	ALOH3 (.996)
70	0.2451	0.3078	0.6867	4.085	CA5OHPO43 (.334), PBOH2 (.305), FEOOH (.287)
85	0.4548	0.5707	0.6861	4.090	CA5OHPO43 (.334), PBOH2 (.310), FEOOH (.279)
100	0.7971	1.0002	0.6866	4.090	CA5OHPO43 (.336), PBOH2 (.314), FEOOH (.271)
		AVERAGE	0.6884	3.266	

AN-102

T oc	P atm	PH2O atm	P/PH2O	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0217	0.0313	0.6947	2.349	ALOH3 (.512), NA2C2O4 (.183), NA3FSO4 (.157), NA3PO4.8H2O (.106)
40	0.0507	0.0729	0.6962	2.506	ALOH3 (.470), NA6SO4CO3 (.277), NA2C2O4 (.172)
55	0.1079	0.1555	0.6940	2.516	ALOH3 (.441), NA6SO4CO3 (.350), NA2C2O4 (.166)
70	0.2120	0.3078	0.6887	2.505	ALOH3 (.472), NA6SO4CO3 (.293), NA2C2O4 (.186)
80	0.3229	0.5707	0.5658	2.521	ALOH3 (.339), NA2C2O4 (.162), NA6SO42CO3 (.379)
100	0.6894	1.0002	0.6893	2.509	NAALCO3OH2 (.444), NA6SO42CO3 (.338), NA2C2O4 (.171)
		AVERAGE	0.6715	2.484	

AN-103

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0210	0.0313	0.6722	2.264	ALOH3 (.264) NANO3 (.413), NA2CO3.1H2O (.182) at 30°C
40	0.0493	0.0729	0.6768		
55	0.1059	0.1555	0.6812		
70	0.2109	0.3078	0.6852		
85	0.3933	0.5707	0.6890		
100	0.6924	1.0002	0.6923		
		AVERAGE	0.6828	2.264	

AN-104

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0223	0.0313	0.7119	2.273	NANO3 (.118), NA2C2O4 (0.0916), NA2CO3.1H2O (.550), NA6SO42CO3 (.151) at 30°C
40	0.0522	0.0729	0.7159		
55	0.1120	0.1555	0.7199		
70	0.2227	0.3078	0.7236		
85	0.4149	0.5707	0.7270		
100	0.7301	1.0002	0.7300		
		AVERAGE	0.7214	2.273	

AN-105

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0161	0.0313	0.5148	2.201	NA2CO3.1H2O (.635), NA3PO4.8H2O (.116) at 30°C
40	0.0384	0.0729	0.5263		
55	0.0828	0.1555	0.5324		
70	0.1656	0.3078	0.5380		
85	0.3100	0.5707	0.5432		
100	0.5480	1.0002	0.5479		
		AVERAGE	0.5338	2.201	

AN-106

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0282	0.0313	0.9027	2.113	ALOH3 (.336), NAFPO4.19H2O (.313), NA2U2O7 (.133), KALSIO4 (.132)
40	0.0656	0.0729	0.9006	3.025	ALOH3 (.377), KALSIO4 (.283), NA2U2O7 (.207)
55	0.1399	0.1555	0.8993	3.141	ALOH3 (.251), KALSIO4 (.361), NA2U2O7 (.235)
70	0.2764	0.3078	0.8979	3.384	KALSIO4 (.415), NA2U2O7 (.293)
85	0.5115	0.5707	0.8962	3.477	NAALSIO4 (.475), NA2U2O7 (.320)
100	0.8942	1.0002	0.8940	3.472	NAALSIO4 (.477), NA2U2O7 (.318)
		AVERAGE	0.8985	3.102	

AN-107

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0234	0.0313	0.7473	2.523	NAALCO3OH2 (.769), NA3FSO4 (.148)
40	0.0539	0.0729	0.7399	2.526	NAALCO3OH2 (.755), NA3FSO4 (.163)
55	0.1142	0.1555	0.7345	2.525	NAALCO3OH2 (.754), NA3FSO4 (.165)
70	0.2250	0.3078	0.7311	2.530	NAALCO3OH2 (.727), NA6SO42CO3 (.202)
85	0.4159	0.5707	0.7286	2.544	NAALCO3OH2 (.694), NA3FSO4 (.232)
100	0.7267	1.0002	0.7265	2.550	NAALCO3OH2 (.677), NA3FSO4 (.248)
		AVERAGE	0.7347	2.533	

AP-101

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0232	0.0313	0.7421	2.360	NA2C2O4 (.948)
40	0.0541	0.0729	0.7422	2.366	NA2C2O4 (.976)
55	0.1155	0.1555	0.7427	2.373	NA2C2O4 (.937)
70	0.2287	0.3078	0.7430	2.383	NA2C2O4 (.930)
85	0.4243	0.5707	0.7434	2.394	NA2C2O4 (.920)
100	0.7437	1.0002	0.7435	2.409	NA2C2O4 (.908)
		AVERAGE	0.7428	2.381	

AP-102

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0257	0.0313	0.8212	2.460	ALOH3 (.982)
40	0.0598	0.0729	0.8202	2.463	ALOH3 (.979)
55	0.1277	0.1555	0.8211	2.470	ALOH3 (.972)
70	0.2530	0.3078	0.8219	2.491	ALOH3 (.948)
85	0.4697	0.5707	0.8229	2.631	ALOH3 (.777)
100	0.8227	1.0002	0.8225	3.544	NAALSIO4 (.335), FEOOH (.263), MNO2 (.150), CA5OHPO43 (.135)
		AVERAGE	0.8217	2.676	

AP-103

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0312	0.0313	0.9976	2.464	ALOH3 (.981)
40	0.0726	0.0729	0.9963	2.464	ALOH3 (.982)
55	0.1548	0.1555	0.9953	2.459	ALOH3 (.985)
70	0.3060	0.3078	0.9941	2.445	ALOH3 (.996)
85	0.5667	0.5707	0.9929	2.449	ALOH3 (.992)
100	0.9915	1.0002	0.9912	4.268	FEOOH (1.0)
		AVERAGE	0.9946	2.758	

AP-104

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0258	0.0313	0.8249	2.277	ALOH3 (.784), NA3PO4.8H2O (.146)
40	0.0600	0.0729	0.8238	2.433	ALOH3 (.913)
55	0.1280	0.1555	0.8231	2.432	ALOH3 (.903)
70	0.2533	0.3078	0.8227	2.434	ALOH3 (.876), NA2C2O4 (.112)
85	0.4695	0.5707	0.8226	2.436	ALOH3 (.802), NA2C2O4 (.168)
100	0.8227	1.0002	0.8224	2.451	ALOH3 (.121), NA2C2O4 (.683)
		AVERAGE	0.8233	2.411	

AP-105

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0234	0.0313	0.7489	2.405	ALOH3 (.707), NA2C2O4 (.287)
40	0.0547	0.0729	0.7506	2.369	ALOH3 (.404), NA2C2O4 (.585)
55	0.1168	0.1555	0.7513	2.323	NA2C2O4 (.981)
70	0.2312	0.3078	0.7512	2.323	NA2C2O4 (.980)
85	0.4289	0.5707	0.7515	2.324	NA2C2O4 (.980)
100	0.7518	1.0002	0.7516	2.325	NA2C2O4 (.980)
		AVERAGE	0.7508	2.345	

AP-106

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0297	0.0313	0.9510	2.445	ALOH3 (.855), NA2C2O4 (.124)
40	0.0692	0.0729	0.9491	2.475	ALOH3 (.970)
55	0.1474	0.1555	0.9477	2.499	ALOH3 (.949)
70	0.2913	0.3078	0.9463	4.449	NA2U2O7 (.496), CA5OHPO43 (.185)
85	0.5392	0.5707	0.9447	4.434	NA2U2O7 (.502), CA5OHPO43 (.188)
100	0.9431	1.0002	0.9429	4.429	NA2U2O7 (.505), CA5OHPO43 (.190)
		AVERAGE	0.9469	3.455	

AP-107

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0308	0.0313	0.9850	2.475	ALOH3 (.973)
40	0.0717	0.0729	0.9837	3.495	ALOH3 (.411), NA2U2O7 (.589)
55	0.1528	0.1555	0.9827	5.001	NA2U2O7 (.9998)
70	0.3021	0.3078	0.9815	5.001	NA2U2O7 (.9998)
85	0.5595	0.5707	0.9803	5.001	NA2U2O7 (.9999)
100	0.9790	1.0002	0.9787	5.000	NA2U2O7 (.9999)
		AVERAGE	0.9820	4.329	

AP-108

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0290	0.0313	0.9256	2.759	KALSIO4 (.675), ALOH3 (.139)
40	0.0673	0.0729	0.9233	2.829	KALSIO4 (.846), NIOH2 (.0981)
55	0.1433	0.1555	0.9214	2.825	KALSIO4 (.849), NIOH2 (.0965)
70	0.2830	0.3078	0.9195	2.823	KALSIO4 (.850), NIOH2 (.0962)
85	0.5239	0.5707	0.9179	2.824	KALSIO4 (.849), NIOH2 (.0968)
100	0.9163	1.0002	0.9160	2.822	NAALSIO4 (.567), KALSIO4 (.275), NIOH2 (.102)
		AVERAGE	0.9206	2.814	

AW-101

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0145	0.0313	0.4649	2.150	KNO3 (.260), NA2C2O4 (.158), NA2CO3.1H2O (.422) at 30°C
40	0.0341	0.0729	0.4685		
55	0.0737	0.1555	0.4739		
70	0.1470	0.3078	0.4775		
85	0.2770	0.5707	0.4853		
100	0.4905	1.0002	0.4904		
		AVERAGE	0.4768	2.150	

AW-102

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0278	0.0313	0.8889	2.923	NAALSIO4 (.472), NA2U2O7 (.205), NA2C2O4 (.212)
40	0.0646	0.0729	0.8864	2.918	NAALSIO4 (.493), NA2U2O7 (.200), NA2C2O4 (.199)
55	0.1375	0.1555	0.8844	2.917	NAALSIO4 (.507), NA2U2O7 (.197), NA2C2O4 (.190)
70	0.2717	0.3078	0.8825	2.919	NAALSIO4 (.518), NA2U2O7 (.196), NA2C2O4 (.181)
85	0.5028	0.5707	0.8810	2.923	NAALSIO4 (.527), NA2U2O7 (.197), NA2C2O4 (.172)
100	0.8796	1.0002	0.8794	2.929	NAALSIO4 (.535), NA2U2O7 (.197), NA2C2O4 (.163)
		AVERAGE	0.8838	2.922	

AW-103

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0280	0.0313	0.8968	3.547	NAF (.427), ZRO2 (.390), KALSIO4 (.122)
40	0.0652	0.0729	0.8947	3.550	NAF (.425), ZRO2 (.391), KALSIO4 (.122)
55	0.1390	0.1555	0.8938	3.553	NAF (.424), ZRO2 (.392), KALSIO4 (.122)
70	0.2740	0.3078	0.8901	3.556	NAF (.421), ZRO2 (.394), KALSIO4 (.123)
85	0.5054	0.5707	0.8855	3.560	NAF (.419), ZRO2 (.395), KALSIO4 (.123)
100	0.8824	1.0002	0.8822	3.568	NAF (.417), ZRO2 (.399), KALSIO4 (.0949)
		AVERAGE	0.8905	3.556	

AW-104

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0282	0.0313	0.9007	2.819	ALOH3 (.461), NAF (.242)
40	0.0655	0.0729	0.8983	2.834	ALOH3 (.447), NAF (.239)
55	0.1394	0.1555	0.8961	2.850	ALOH3 (.442), NAF (.237)
70	0.2752	0.3078	0.8939	2.861	ALOH3 (.447), NAF (.235), NA2U2O7 (.0919)
85	0.5090	0.5707	0.8918	2.881	ALOH3 (.437), NAF (.239), NA2U2O7 (.0976)
100	0.8895	1.0002	0.8893	2.910	ALOH3 (.422), NAF (.225), NA2U2O7 (.104)
		AVERAGE	0.8950	2.859	

AW-105

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0293	0.0313	0.9384	3.504	ZRO2 (.397), NAF (.358), NA2C2O4 (.115)
40	0.0681	0.0729	0.9350	3.522	ZRO2 (.404), NAF (.354), NA2C2O4 (.110)
55	0.1449	0.1555	0.9318	3.545	ZRO2 (.411), NAF (.350), NA2C2O4 (.105)
70	0.2858	0.3078	0.9284	3.571	ZRO2 (.419), NAF (.345), NA2C2O4 (.0990)
85	0.5279	0.5707	0.9250	3.605	ZRO2 (.429), NAF (.340), NA2C2O4 (.0921)
100	0.9213	1.0002	0.9211	3.647	ZRO2 (.441), NAF (.334)
		AVERAGE	0.9300	3.566	

AW-106

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0234	0.0313	0.7492	2.469	NA2C2O4 (.583), NAALSIO4 (.334)
40	0.0548	0.0729	0.7515	2.477	NA2C2O4 (.556), NAALSIO4 (.319)
55	0.1171	0.1555	0.7528	2.484	NA2C2O4 (.536), NAALSIO4 (.308), NA6SO42CO3 (.107)
70	0.2316	0.3078	0.7524	2.487	NA2C2O4 (.525), NAALSIO4 (.302), NA6SO42CO3 (.130)
85	0.4289	0.5707	0.7514	2.489	NA2C2O4 (.520), NAALSIO4 (.299), NA6SO42CO3 (.139)
100	0.7503	1.0002	0.7502	2.490	NA2C2O4 (.517), NAALSIO4 (.298), NA6SO42CO3 (.143)
		AVERAGE	0.7512	2.483	

AY-101

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0300	0.0313	0.9588	2.751	NALACO3OH2 (.592), FEOOH (.229), NA2C2O4 (.109)
40	0.0704	0.0729	0.9661	2.755	NALACO3OH2 (.580), FEOOH (.230), NA2C2O4 (.106)
55	0.1519	0.1555	0.9768	2.762	NALACO3OH2 (.557), FEOOH (.232), NA2C2O4 (.103)
70	0.3038	0.3078	0.9868	2.770	NALACO3OH2 (.527), FEOOH (.232), NA2C2O4 (.101)
85	0.5634	0.5707	0.9872	2.776	NALACO3OH2 (.502), FEOOH (.232), NAALSIO4 (.107), NA2C2O4 (.101)
100	0.9759	1.0002	0.9757	2.780	NALACO3OH2 (.489), FEOOH (.231), NAALSIO4 (.120), NA2C2O4 (.100)
		AVERAGE	0.9752	2.765	

AY-102

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0301	0.0313	0.9614	3.013	NAALCO3OH2 (.346), FEOOH (.339), ALOH3 (.171)
40	0.0699	0.0729	0.9593	3.011	NAALCO3OH2 (.350), FEOOH (.338), ALOH3 (.162)
55	0.1489	0.1555	0.9577	3.008	NAALCO3OH2 (.357), FEOOH (.337), ALOH3 (.153)
70	0.2943	0.3078	0.9560	3.004	NAALCO3OH2 (.366), FEOOH (.337), ALOH3 (.143)
85	0.5449	0.5707	0.9547	3.000	NAALCO3OH2 (.378), FEOOH (.339), ALOH3 (.131)
100	0.9535	1.0002	0.9532	3.001	NAALCO3OH2 (.397), FEOOH (.340), ALOH3 (.111)
		AVERAGE	0.9571	3.006	

AZ-101

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0269	0.0313	0.8604	2.882	ALOH3 (.641), FEOOH (.222)
40	0.0626	0.0729	0.8586	2.914	ALOH3 (.629), FEOOH (.240)
55	0.1333	0.1555	0.8572	2.976	ALOH3 (.597), FEOOH (.264)
70	0.2636	0.3078	0.8562	3.066	ALOH3 (.531), FEOOH (.299)
85	0.4882	0.5707	0.8554	3.214	ALOH3 (.442), FEOOH (.352)
100	0.8547	1.0002	0.8545	3.472	ALOH3 (.308), FEOOH (.434), ZRO2 (.121)
		AVERAGE	0.8571	3.088	

AZ-102

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0294	0.0313	0.9385	3.097	ALOH3 (.499), FEOOH (.331)
40	0.0683	0.0729	0.9366	3.110	ALOH3 (.491), FEOOH (.333)
55	0.1455	0.1555	0.9353	3.114	ALOH3 (.481), FEOOH (.335)
70	0.2874	0.3078	0.9337	3.113	ALOH3 (.473), FEOOH (.339)
85	0.5322	0.5707	0.9324	3.098	ALOH3 (.447), FEOOH (.348)
100	0.9313	1.0002	0.9310	3.071	FEOOH (.349), ALOH3 (.348), NAALCO3OH2 (.136)
		AVERAGE	0.9346	3.100	

SY-101

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0225	0.0313	0.7209	2.291	ALOH3 (.623), NA2C2O4 (.214) at 30°C
40	0.0526	0.0729	0.7222		
55	0.1123	0.1555	0.7222		
70	0.2222	0.3078	0.7220		
85	0.4121	0.5707	0.7221		
100	0.7224	1.0002	0.7222		
		AVERAGE	0.7219	2.291	

SY-102

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0277	0.0313	0.8866	2.259	ALOH3 (.523), NAFPO4.19H2O (.211), CR2O3 (.0896)
40	0.0642	0.0729	0.8814	2.483	ALOH3 (.575), NAFPO4.19H2O (.117), CR2O3 (.100)
55	0.1363	0.1555	0.8765	2.828	ALOH3 (.646), CR2O3 (.114), FEOOH (.0908)
70	0.2685	0.3078	0.8722	2.830	ALOH3 (.646), CR2O3 (.111), FEOOH (.0926)
85	0.4956	0.5707	0.8683	2.804	ALOH3 (.620), CR2O3 (.0939), FEOOH (.0947)
100	0.8660	1.0002	0.8658	2.691	ALOH3 (.498), NAALCO3OH2 (.238), FEOOH (.0954)
		AVERAGE	0.8751	2.649	

SY-103

T °C	P atm	P_{H2O} atm	P/P_{H2O}	Solid Dens. kg/L	Major Solids (weight fraction)
25	0.0164	0.0313	0.5250	2.079	ALOH3 (.653), NAFPO4.19H2O (.216)
40	0.0391	0.0729	0.5368	2.071	ALOH3 (.614), NAFPO4.19H2O (.239), NA6SO42CO3 (.0985)
55	0.0861	0.1555	0.5539	2.562	ALOH3 (.649), NA2CO3 (.133), NA6SO42CO3 (.145)
70	0.1745	0.3078	0.5669	2.598	ALOH3 (.470), NA2CO3 (.296), NA6SO42CO3 (.158)
85	0.3287	0.5707	0.5759	2.639	ALOH3 (.286), NA2CO3 (.433), NA6SO42CO3 (.189)
100	0.5821	1.0002	0.5819	2.702	NA2CO3 (.588), NA6SO42CO3 (.245)
		AVERAGE	0.5568	2.442	