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ACCEPTANCE CRITERIA FOR NONDESTRUCTIVE EXAMINATION OF DST

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1	1	Cog./Proj.Eng C. E. Jensen	[signature]	26 Jul 95	R1-30						
1	1	Cog./Proj.Eng.Mgr. K. V. Scott	[signature]		H5-52						
1	1	Mgr., R. D Gustavson	[signature]	9/22/95	R1-51						

18.	19.	20.	21. DOE APPROVAL (if required)
C. E. Jensen [signature] 26 Jul 95 Signature of EDT Originator / Date	C. A. Geier [signature] 9/26/95 Authorized Representative for Receiving Organization / Date	K. V. Scott [signature] 7-26-95 Cognizant/Project Engineer's Manager / Date	Ltr. No. [] Approved [] Approved w/comments [] Disapproved w/comments

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RELEASE AUTHORIZATION

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WHC Information Release Administration Specialist:

Kara Broz 9/27/95

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SUPPORTING DOCUMENT

1. Total Pages 40

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5. Key Words

Acceptance, NDE, Examination, Flaws, DST

6. Authors

Name: C. E. Jensen

[signature] 26 Aug 95

Signature

Organization/Charge Code: 74400/N131A

7. Abstract

This supporting document provides requirements for acceptance of relevant indications found during non-destructive examination of double-shell tanks (DSTs) at Hanford 200 areas. Requirements for evaluation of relevant indications are provided to determine acceptability of continued safe operation of the DSTs. Areas of the DSTs considered include the tank wall vapor space, liquid-vapor interface, wetted tank wall, sludge-liquid interface, and the knuckle region.

8. RELEASE STAMP

OFFICIAL RELEASE BY WHC (3)

DATE SEP 27 1995

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CONTENTS

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ACCEPTANCE CRITERIA FOR NON-DESTRUCTIVE EXAMINATION OF DOUBLE-SHELL TANKS

1.0 PURPOSE

The purpose of this document is to establish an acceptance criteria for non-destructive examination (NDE) of the double-shell waste storage tanks (DSTs). This acceptance criteria may be used to determine when actions are required to estimate remaining life and the operability of the DSTs.

2.0 INTRODUCTION

NDE of the DSTs is to be performed to meet the requirements of the *Washington Administrative Code* (WAC) (Reference 6.1) for dangerous waste tanks, in accordance with the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement or TPA) (Reference 6.2). The NDE will provide information on the structural integrity of the DSTs. The method of NDE to be used will be ultrasonic examination.

The examination of the DSTs will determine if there is any generic corrosion or material conditions affecting the DSTs. However, indications found may only be related to the tank being examined. In either case, the findings will be reported to a panel of experts for evaluation.

3.0 DEVELOPMENT

Flaws that are discovered during NDE need to be compared with an acceptance criteria. This initial acceptance criteria provides a "go no-go" assessment, requiring action only when an indication exceeds the tabulated acceptance criteria in Table 1. This table was generated using the following documents.

Guidelines for Development of Structural Integrity Programs for DOE High-Level Waste Storage Tanks (Reference 6.3). The guidelines were developed by the Tank Structural Integrity Panel for the Savannah River, Hanford, Idaho Falls, and West Valley sites. The sites contain a variety of tank designs and have different waste types. The panel developed general guidelines that are applicable at all the sites but also developed some specific guidance on acceptance criteria for flaws found in steel tanks and steel liners. The technical bases for the criteria are simply the judgement of the expert panel whose experience with materials aging and nuclear reactor flaw acceptance criteria make them qualified to make such judgements. These criteria address pitting, wall thinning, cracks, and inter-granular stress corrosion cracking. The panel's criteria were used as guidance in the development of criteria specifically for Hanford waste tanks.

TABLE 1

ITEM	EXAMINATION REQUIREMENTS	EXAMINATION METHODS	ACCEPTANCE CRITERIA
PRIMARY TANK[1]			
SHELL WELDS			
Longitudinal Welds	Wetted Area Welds	Volumetric	Thinning $a < 0.2t$ Pitting $a < 0.5t$ $\ell \leq 12"$, and $a \leq 3/16"$
Circumferential Welds	Wetted Area Welds	Volumetric	Thinning $a < 0.2t$ Pitting $a < 0.5t$ $\ell \leq 12"$, and $a \leq 3/16"$
Weld Intersections	Wetted Area Welds	Volumetric	Thinning $a < 0.2t$ Pitting $a < 0.5t$ $\ell \leq 12"$, and $a \leq 3/16"$
Liquid-Vapor Interface	Wetted Areas, +/- 30 cm nominal interface	Volumetric	Pitting $a < 0.5t$ Thinning $a < 0.2t$ $\ell \leq 12"$, and $a \leq 3/16"$
Liquid-Sludge Interface	Wetted Areas, +/- 30 cm of nominal interface	Volumetric	Thinning $a < 0.2t$ Pitting $a < 0.5t$ $\ell \leq 12"$ and $a \leq 3/16"$
Vapor Region	1 ft^2 (93 cm^2)	Volumetric	Pitting $a < 0.5t$ Thinning $a < 0.2t$ $\ell \leq 12"$, and $a \leq 3/16"$
KNUCKLE REGION			
High Stress Area	Accessible Area	Volumetric	Thinning $a < 0.2t$ Pitting $a < 0.5t$ All crack type flaws shall be reported
Shell-Knuckle Weld	Welds	Volumetric	Thinning $a < 0.2t$ Pitting $a < 0.5t$ All crack type flaws shall be reported
Bottom-Knuckle Weld	Welds	Volumetric	Thinning $a < 0.2t$ Pitting $a < 0.5t$ All crack type flaws shall be reported
CONTAINMENT			
Shell Wall	Lower Wall	Volumetric	Thinning $a < 0.2t$ Pitting $a < 0.5t$

[1] See Figures 2 and 3 for graphical representation of examination areas and flaw dimensions.

ASME Boiler and Pressure Vessel Code, Section XI, Inservice Inspection of Nuclear Power Plant Components, 1992 Edition (Reference 6.4). This document provides rules for inservice inspection, repairs, replacement and pressure testing of nuclear power plant components. Acceptance criteria and flaw evaluation methods are provided. This document was used as a reference for the development of the acceptance criteria in Table 1.

WHC-EP-0508 Rev.0, Parametric Studies to Support Inspection Criteria of the Double-Shell Waste Storage Tanks (Reference 6.5). This report contains calculations of stresses and stress intensity factors for cracks in DSTs. This information was used to determine where the limiting cracks may be located. This led to the development of specific acceptance criteria for DSTs.

Acceptance Criteria for Ultrasonic Flaw Indications in the Inner Liner of the Double-Shell Waste Storage Tanks (Reference 6.6). This report provides recommendations and technical bases for acceptance criteria for flaw indications detected during ultrasonic inspection of inner liners of the DSTs. The types of indications addressed are crack-like flaws, wall thinning, and pitting. In establishing acceptable flaw sizes, the evaluations have taken into consideration the potential for crack growth by the mechanism of stress corrosion cracking. Efforts were made to follow technical approaches used in ASME Codes, for reactor tanks at the Department of Energy Savannah River facilities, and in recommendations by the Tank Structural Integrity Panel. The acceptance criteria are intended to be simple to apply using a set of tables of acceptable flaw sizes. These tables are sufficiently conservative to be applicable to all DSTs. In those cases that a flaw exceeds the size permitted by the tables, it is proposed that additional criteria permit more detailed and less conservative evaluations to address specific conditions of stress levels, operating temperature, flaw location, and material properties and engineering judgement.

Considerations in the development of Table 1 included structural collapse of the primary tank wall, hydrogen accumulation, and tank over heating. Leakage into the annulus could result in blockage of the annulus ventilation system. The loss of the ventilation was evaluated to determine the resultant hydrogen accumulation in the annulus, and the resulting heat loading. These issues are addressed in Appendices 1 and 2.

Appendix 1, Calculation of Flammable Gas Accumulation in DST Annulus from a Primary Tank Leak. Accumulation of hydrogen gas in the annulus, due to failure of the primary tank was evaluated. The rates of generation and time to reach the lower flammability limit (LFL) were determined. Hydrogen in the annulus has not been addressed in the Interim Safety Basis (Reference 6.7) or other safety basis documentation. This issue is being considered and may result in an unreviewed safety question requiring resolution. This issue requires that annulus ventilation be maintained during the time the tank is leaking.

Appendix 2, Loss of Annulus Ventilation Cooling Effect on Waste Temperature in DSTs. As part of the DST acceptance criteria, it is required to evaluate the effect of waste leakage into the annulus cooling channels blocking the ventilation air flow in DSTs. The purpose of the analysis is to estimate the maximum waste temperature in DSTs for the event of loss of annulus ventilation cooling and evaluate whether the waste temperature can exceed Operational Specification Documents/Operational Safety Requirements (OSD/OSR) limits. Internal heat generation by the waste was determined not to be a safety issue. The evaluation shows that the waste temperatures of the sludge will not exceed 187 °F. The OSR limit is 350 °F for this tank (241-AZ101), well above the predicted sludge temperature. Some other tanks have a 250 °F OSR limit which is still higher than the calculated waste temperature in the hottest tank.

Data obtained during the NDE will be retained in accordance with the data management plan (Reference 6.7).

3.1 VOLUMETRIC EXAMINATIONS

The examination methods include volumetric and visual examinations. The volumetric examination to be used is ultrasonic (UT). UT examinations provide wall thickness measurements and measurement of flaws such as weld porosity, inclusions, cracks, and pitting. The flaws can be characterized and evaluated from UT results.

3.2 VISUAL EXAMINATIONS

Visual examinations are part of the UT examination to ensure that surface conditions are acceptable for the UT probes. Should a visual examination identify a leak or other problem with the tank, that problem will be reported. Note that these examinations are not the VT examinations identified in Reference 6.4.

3.3 ACCEPTABLE FLAW SIZES

The flaw sizes in Table 1 are based on elastic stress analysis, linear-elastic fracture mechanics (LEFM) and elastic-plastic fracture mechanics (EPFM) (References 6.4 and 6.5). The flaw sizes provide a reasonable assurance that a flaw will not propagate to a size that would lead to rupture the tank wall before subsequent NDE is performed on the same examination areas. Subsequent examinations could be scheduled on a ten year interval, as recommended in Reference 6.3 and specified in Reference 6.4.

There are two categories of flaws to consider, non-through wall and through wall. Non-through wall flaws (partial penetration) are evaluated to estimate the time to wall penetration. The through wall flaws are evaluated to determine the potential for tank rupture and estimate leak rates that have or may occur, to assess appropriate corrective actions.

Allowable flaw sizes in Table 1 show the allowable through wall crack length, (12 inches), the maximum allowable crack depth (3/16 inch), and the thinnest allowable wall section (0.8t).

3.3.1 Crack Like Flaws

The part through-wall flaw depth acceptance criteria is coupled with the allowable through wall length for cracks in the tank wall. The length for unstable flaw growth for through wall flaws are typically very large and it is expected that a partial penetration flaw would grow through the wall before the length is large enough to become unstable.

If flaws are found, they are most likely to be part through wall. Part through-wall flaws greater than 3/16" in depth shall be reported.

Reporting flaws greater than 3/16" in depth is based on the crack growth evaluation of the high stress region of the tank wall presented in Appendix A of Reference 6.4. For this region the tank wall is 1/2 inch thick and the stress is approximately 18 Ksi. Assuming the tank waste chemistry is conducive to stress corrosion cracking and selecting an average threshold stress intensity for crack growth of 25 Ksi$\sqrt{in}$ (Ref. 6.6), the calculated part through wall flaw size that is large enough to grow is 0.2 inch deep and 2 inches long. This flaw is deeper than the 0.1875 inch (3/16") acceptance criteria in Table 1.

Once a part through wall flaw is detected, the time it takes to grow through wall and then to critical length can be calculated. The critical or maximum allowable through wall flaw length is 12 inches and is based on the TSIP recommendations and the EPFM failure assessment diagram in Reference 6.6. The 12" length provides a margin of safety of 1.3 for the fracture resistance lower limit and 1.65 at the upper limit.

In the knuckle region all crack type flaws regardless of size, shall be reported and their acceptability will be determined by analysis and panel evaluation.

3.3.2 Pitting Type Flaws

Pitting type flaws greater than 0.5t shall be evaluated. Pitting, if found, is expected to be found at the air/liquid interface which is normally a low stress area. Several adjacent pits should be treated as individual pits if the ratio of the pit center to center distance and the pit diameter are greater than or equal to four. If this ratio is less than four, wall thinning acceptance criteria for the pits shall be considered.

3.3.3 Wall Thinning

Wall thinning greater than 0.2t shall be evaluated. Wall thinning under consideration is not the same as expected general uniform corrosion over the life of the component. Wall thinning, like pitting, if found, is expected to be found at the air/liquid interface, which is normally a low stress area. Consequently, the use of 0.2t as found in the TSIP document (Reference 6.3) is acceptable but somewhat different than the recommendations in Reference 6.6.

4.0 GUIDANCE ON THE EVALUATION OF SPECIFIC FLAWS

4.1 GENERAL EXAMINATION

The criteria in Table 1 provide flaw size and wall thickness requirements that are acceptable for continued operation of the tank. Those flaws or thinning that meet the NDE acceptance criteria require no further evaluation or examination until the next normally scheduled examination.

Figure 1 describes the ultrasonic inspection process as found in Reference 5.6. The NDE acceptance criteria shall be used to determine if the "Flaw is Greater than the Acceptance Standards."

Figures 2 and 3 provide reference information for the examination areas and flaw dimensions in Table 1.

4.2 INDICATIONS THAT EXCEED THE ACCEPTANCE CRITERIA AND ARE NOT THROUGH WALL

The flaws and wall thinning that exceed the acceptance criteria of Table 1 will be evaluated by the review panel. The panel shall consider whether to "use as is", determine remaining time until leak or structural instability, repair, or remove from service. The panel shall recommend a course of action to management.

4.2.1 Evaluation of Flaws and Wall Thinning

This evaluation shall include applicable methods that are accepted by the Department of Energy or industry practice. This includes linear-elastic fracture mechanics (LEFM), elastic-plastic fracture mechanics (EPFM), and load limit. Accepted techniques may be found in ASME B&PVC Section XI, Article IWB-3000, and appendixes to the Code, Electric Power Research Institute methods, NUREGs, and DOE/WHC approved methods.

If the evaluation determines that the flaw or thinning will not exceed a critical size before the next scheduled examination, then no further evaluation or testing is required.

A flaw or thinning that will grow to a critical value such as through wall or of sufficient size to rupture the tank before the next scheduled examination will require actions be taken. These actions may include more frequent examinations to track the growth, repairs, modifying the operation, removing the tank from service, removal of waste from tank, or continued use until the tank leaks or fails.

4.3 THROUGH WALL FLAWS AND THINNING

4.3.1 Through wall flaws and thinning shall be characterized and analyzed to determine failure mechanism(s).

4.3.2 If management and the inspection review panel (Reference 6.6) agree to keep the tank in service, without repair, the following requirements shall be performed prior to return to service:

a. Identify failure mechanism(s);

b. Predict growth rate of the flaw(s) or thinning;

c. Determine effects of flaw growth or thinning on, but not limited to, leakage rate and structural integrity;

d. Perform USQ Evaluation;

e. Revise, if necessary, safety basis documents and operations procedures;

d. Obtain necessary WHC, DOE, Ecology, EPA, and other stakeholders approval;

e. Ensure ability to remove accumulated waste in the annulus is installed and ready to operate and identify an alternate receiving tank for the waste as a contingency plan;

f. Ensure adequate annulus ventilation is available and maintained.

4.3.3 Continued operation with through wall flaws include options such as lowering the waste level below the flaw or continuously monitoring the leak site.

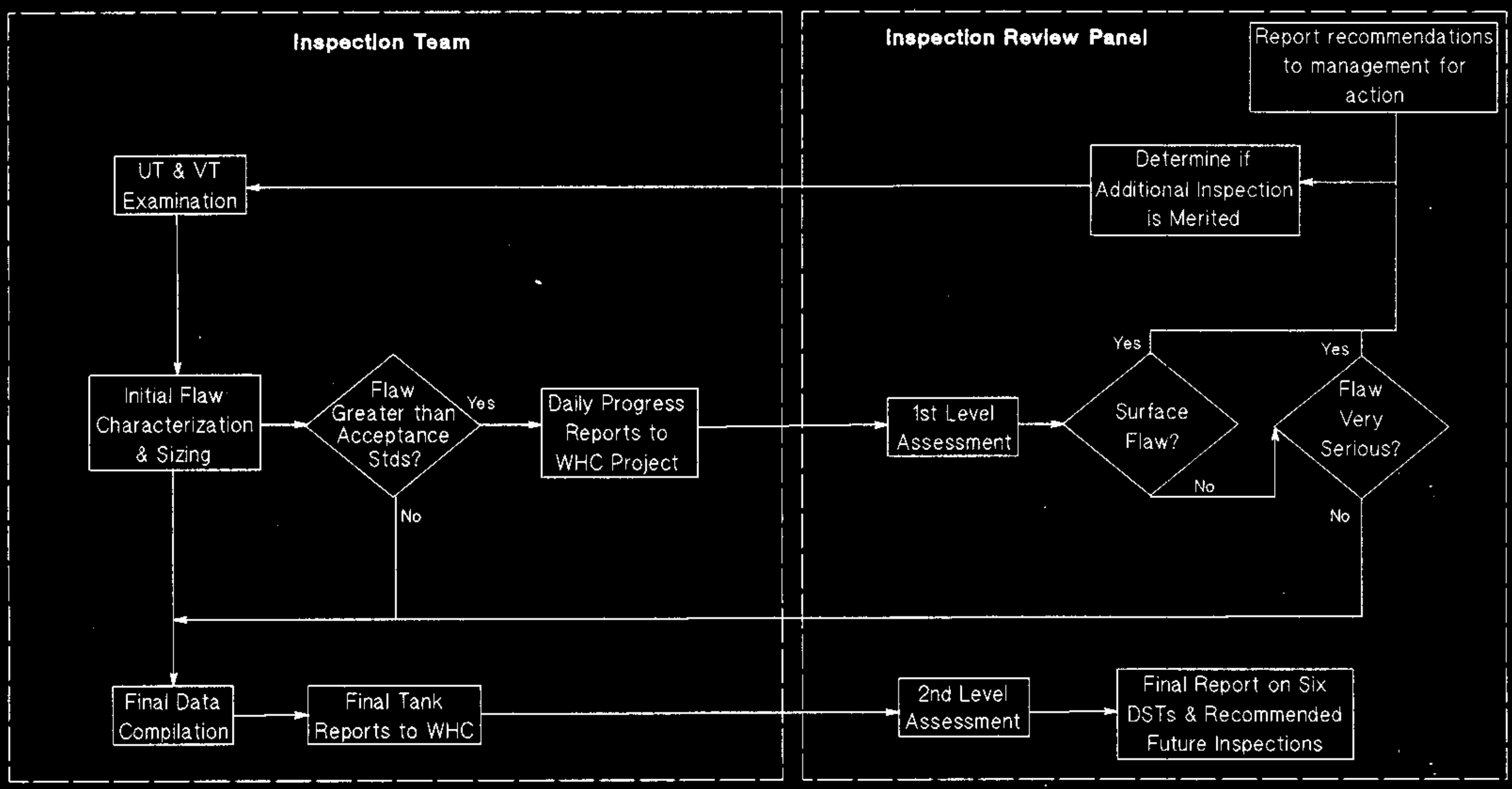
4.3.4 Repairs may be performed to keep the tank in service.

5.0 SUMMARY

The acceptance criteria developed provide a measure of the condition of the DSTs. The acceptability of certain flaws in DSTs can be determined using the criteria. Acceptance criteria also provide a basis for monitoring flaw growth and taking preventative action to prevent leakage of dangerous waste to the environment. Such actions could include periodic examinations of the affected tank to determine and monitor the rate of deterioration.

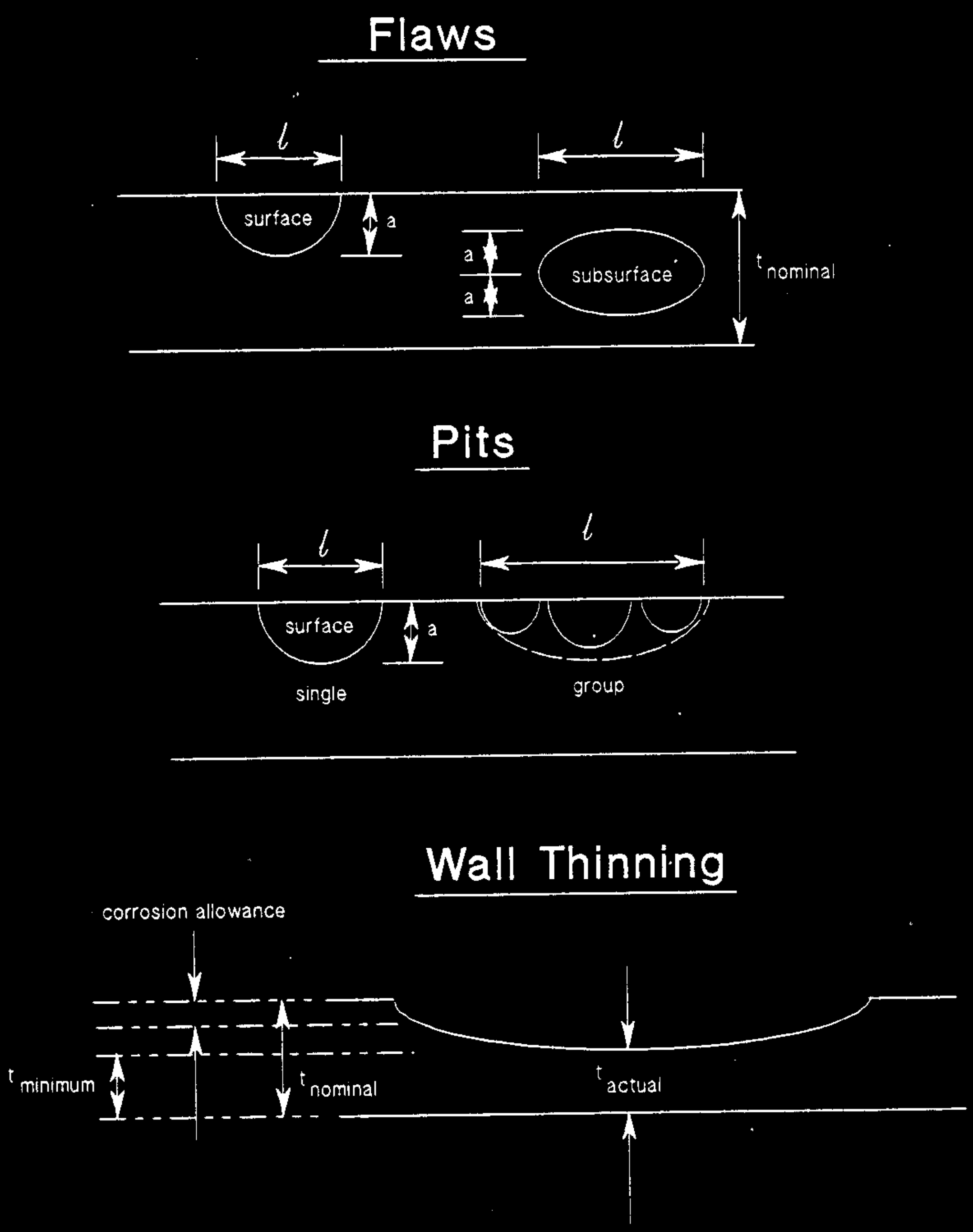
Corrective actions for flaws exceeding the acceptance criteria include repair, accept as is, modify operation, or remove the tank from service.

Figure 1. FLOW DIAGRAM for DST INSPECTION FLAW ACCEPTANCE PROCESS



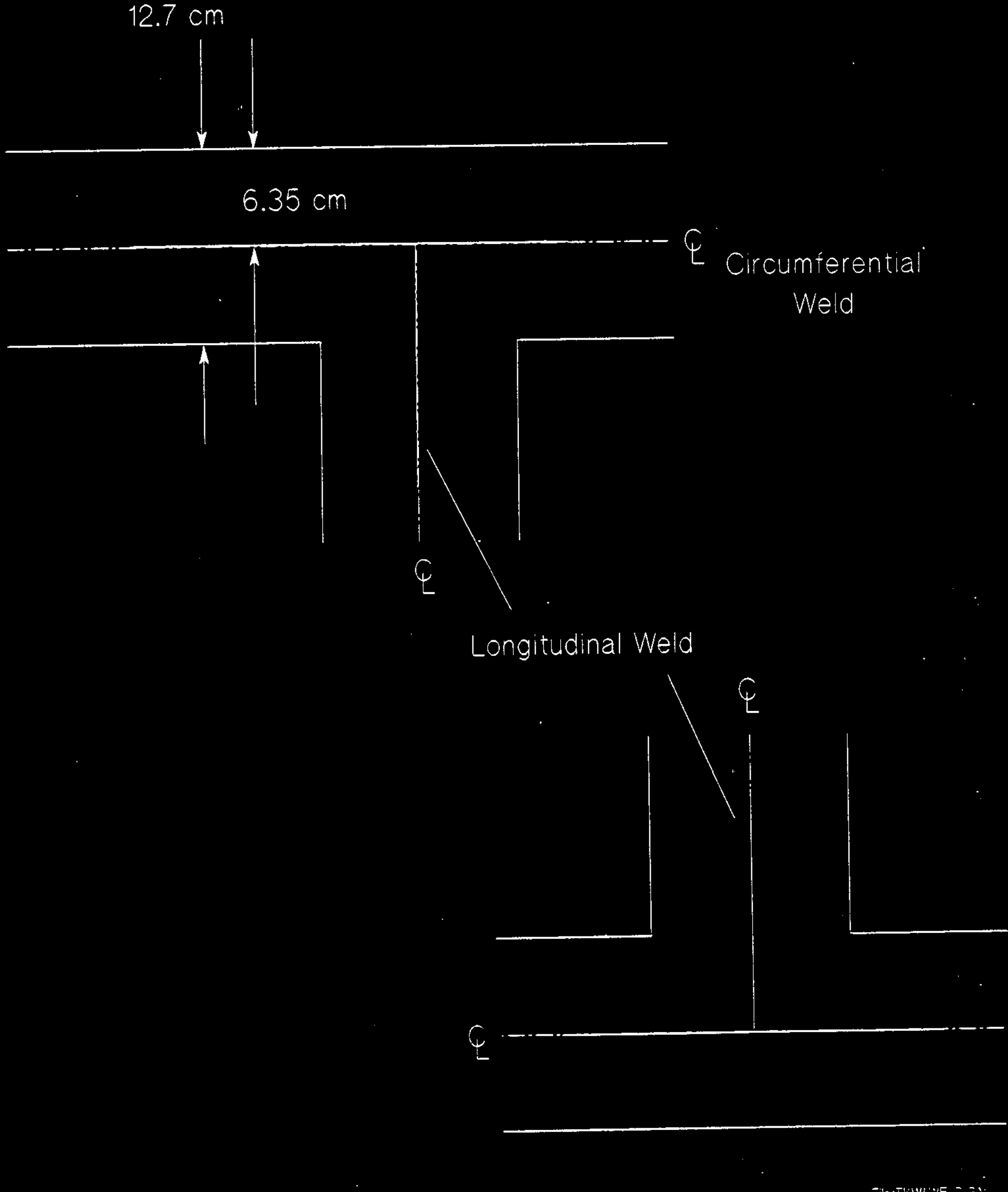
File: FLAWACE2.GAL

Figure 2.



File:THCKFLAW.GAL

Figure 3. Tank Wall "T" Weld Examination Areas



6.0 REFERENCES

6.1 *Washington Administrative Code.*

6.2 *Hanford Federal Facility Agreement and Consent Order.*

6.3 *Guidelines for Development of Structural Integrity Programs for DOE High-Level Waste Storage Tanks*, DRAFT, December 1, 1994.

6.4 *ASME Boiler and Pressure Vessel Code, Section XI, Inservice Inspection of Nuclear Power Plant Components*, 1992 Edition.

6.5 WHC-EP-0508, Rev. 0, *Parametric Studies to Support Inspection Criteria of the Double-Shell Waste Storage Tanks*, September 1991.

6.6 *Acceptance Criteria for Ultrasonic Flaw Indications in the Inner Liner of the Double-Shell Waste Storage Tanks*, May 1995.

6.7 WHC-SD-WM-DP-089, Rev. 0, *Data Management Plan for the Ultrasonic Inspection of the Double-Shell Tanks*, September 1994.

6.8 WHC-SD-WM-AP-019, Rev. 1, *Double-Shell Tank Ultrasonic Inspection Plan*, September 1994

6.9 WHC-SD-WM-ISB-001, Rev. 0E, *Hanford Site Tank Farm Facilities Interim Safety Basis*, January 1995.

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APPENDIX 1

CALCULATION OF FLAMMABLE GAS ACCUMULATION IN DST ANNULUS FROM A PRIMARY TANK LEAK

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Westinghouse Hanford Company **Internal Memo**

From: Consequence Analysis
Phone: 376-2520 H4-64

MK-8M400-95-001

Date: April 13, 1995

Subject: CALCULATION OF FLAMMABLE GAS ACCUMULATION IN DST ANNULUS FROM A PRIMARY TANK LEAK

To: R. J. Van Vleet H4-64

cc: W. G. Farley H4-62
C. E. Jensen R1-30
G. D. Johnson S7-15
A. L. Ramble H4-64
G. R. Sawtelle H4-62
MK File/LB File H4-64

References: WHC, 1995, *Tank Farms Hazard and Accident Analysis, Interim Chapter 3*, WHC-SD-WM-SAR-065, Rev. A (Review Draft), Westinghouse Hanford Company, Richland, Washington.

As requested, the estimated time to reach a flammable atmosphere in a DST annulus in case of a breach in the primary liner was calculated. The analysis included three cases, each with a different assumption about the waste composition in the tank. The first used a hypothetical composite of bounding waste parameters as used for the DST headspace deflagration accident in the reference. The second used 101-SY waste parameters and the third used 102-AN waste parameters. The 102-AN case was chosen because that tank gave the highest rate of flammable gas accumulation in the headspace if active ventilation were not operable.

For all cases, it was assumed that a major break occurred in the primary liner, allowing the waste to flow into the annulur space until the levels in the tank and the annulus were equalized. The equalized liquid level was calculated as if the volume of waste in the primary tank before the leak were placed in a vessel with an 80 ft diameter. This is the inner diameter of the secondary tank.

The volume of free air space in the annulus after the leak was calculated according to the following formula:

$$V_{HS} = \pi \left(\frac{80^2 - 75^2}{4} \right) ft^2 \times (35.2\ ft - H_L)$$

Where: V_{HS} = Volume of free air space in the annulus
H_L = Height of liquid in the annulus after the leak

The average annulus height is taken to be 35.2 ft.

Because the annulus ventilation inlet is at the bottom center of the tank, the secondary ventilation is effectively cut off. Atmospheric breathing is the only mode of air exchange between the annulus and the outside that is credited in the analysis.

A method for estimating expected gas generation rates for Hanford wastes is presented in the reference. The method focused primarily on hydrogen generation by both radiolytic and chemical means. These calculations used both empirical data from experiments on 241-SY-101 simulants and sample data from 241-SY-101 waste and dome space gases as a basis for estimating hydrogen generation rates. The method attempts to adapt the information gained from extensive studies and observations of 241-101-SY to formulate conclusions about the phenomenology of gas generation in the tank wastes.

For the purpose of this analysis, it is assumed that all the waste is liquid. All other waste parameters used are the same as those used for estimating flammable gas generation in the primary tanks, as reported in the reference.

A mass balance on the hydrogen in the air space was performed. The inlet term was the estimated hydrogen generation rate. The outlet term was the hydrogen leaving the volume as a result of atmospheric breathing, i. e., 0.45% of the mixed air space volume is exchanged with the outside each day.

The generated gases are known to contain fuel gases other than hydrogen. The presence of these other gases in a mixture with hydrogen will change the overall lower flammable limit (LFL) of the mixture. A best estimate hypothetical gas mixture was postulated, based on 101-SY and 101-AN experience (WHC 1995). If this mixture were at its LFL in air, the proportion of hydrogen in the total gases (hypothetical mixture plus air) would be 2.5% by volume. Therefore, 2.5% hydrogen is taken to correspond to the LFL for the gas mixture.

Tables 1 through 3 show the calculation of hydrogen generation rates, and time to 25% LFL and LFL (for the hypothetical gas mixture in air), for the three cases of waste parameters. For each case, the calculations were performed assuming a range of initial waste volume in the primary tank. Figures 1 through 3 display the times to 25% LFL and to LFL (again, for the hypothetical gas mixture in air) as a function of initial waste volume for the three cases.

If you have further questions, please call me on 376-2520.

Maryanne Kummerer

M. Kummerer, Senior Engineer
Consequence Analysis

ajg

Attachments

DOUBLE SHELL TANK ANNULUS													
TANK	Composite	Annulus											
WASTE MATERIAL	DSS												
TOTAL WASTE (KGAL)	1160	1160	1000	900	800	700	600	500	400	300	200	100	50
SUPERNATANT (KGAL)	1160	1160											
SLUDGE (KGAL)	0	0											
TANK WASTE HEIGHT B4 LEAK (FT)	35.10	35.10	30.26	27.24	24.21	21.18	18.16	15.13	12.10	9.08	6.05	3.03	1.51
ANNULUS WASTE HEIGHT POST LEAK (FT)		30.85	26.60	23.94	21.28	18.62	15.96	13.30	10.64	7.98	5.32	2.66	1.33
LIQUID VOLUME (L)	4.38E+06	5.31E+05	4.58E+05	4.12E+05	3.67E+05	3.21E+05	2.75E+05	2.29E+05	1.83E+05	1.37E+05	9.16E+04	4.58E+04	2.29E+04
HEADSPACE VOL. (L)	8.63E+05	7.49E+04	1.48E+05	1.94E+05	2.40E+05	2.86E+05	3.31E+05	3.77E+05	4.23E+05	4.69E+05	5.15E+05	5.61E+05	5.83E+05
AVERAGE WASTE. TEMP. (DEG. F)	140	140	140	140	140	140	140	140	140	140	140	140	140
VAPOR SPACE (DEG.F)	125	125	125	125	125	125	125	125	125	125	125	125	125
MEAN TOC (GM/L)	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4	50.4
ACTIVE VENTILATION. RATE 1/DAY)	4.73E+00	0	0	0	0	0	0	0	0	0	0	0	0
CONVERSION FACTOR	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
G(H2) (MOLECULES/100 eV)	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181	0.181
WASTE LIQUID FRACTION	100%	1	1	1	1	1	1	1	1	1	1	1	1
MAXIMUM H2 ACCUMULATION FROM SOURCE TERM HEAT LOAD DATA													
TANK HEAT LOAD (W)	20500	2485	2142	1928	1714	1499	1285	1071	857	643	428	214	107
RADIOLYTIC GENERATION RATE (L/DAY)	885.79	107.36	92.55	83.30	74.04	64.79	55.53	46.28	37.02	27.77	18.51	9.26	4.63
THERMAL GENERATION RATE (L/DAY)	3107.98	376.70	324.74	292.27	259.79	227.32	194.84	162.37	129.90	97.42	64.95	32.47	16.24
MAX (%) H2 ACCUMULATION (P)	50.70	58.95	38.49	30.08	23.62	18.52	14.37	10.94	8.06	5.60	3.48	1.63	0.79
DAYS TO 25% LFL (P)	1.36	0.97	2.24	3.26	4.55	6.22	8.46	11.64	16.49	24.82	42.49	105.93	346.95
DAYS TO LFL (P)	5.54	3.95	9.18	13.48	18.98	26.26	36.36	51.32	75.86	124.04	272.15	NEVER	NEVER
DAYS TO 25% LFL (NO VENTILATION)	1.35	0.97	2.22	3.23	4.49	6.11	8.27	11.30	15.84	23.41	38.55	83.95	174.77
DAYS TO LFL (NO VENTILATION)	5.40	3.87	8.88	12.91	17.96	24.45	33.10	45.21	63.37	93.64	154.18	335.82	699.08
REQUIRED VENTILATION RATE (CFM)	15.48	1.88	1.61	1.44	1.28	1.11	0.94	0.77	0.60	0.44	0.27	0.10	0.02

TABLE 1

DOUBLE SHELL TANK ANNULUS													
TANK	101-SY	Annulus											
WASTE MATERIAL	DSS												
TOTAL WASTE (KGAL)	1160	1160	1000	900	800	700	600	500	400	300	200	100	50
SUPERNATANT (KGAL)	1160	1160											
SLUDGE (KGAL)	0	0											
TANK WASTE HEIGHT B4 LEAK (FT)	35.10	35.10	30.26	27.24	24.21	21.18	18.16	15.13	12.10	9.08	6.05	3.03	1.51
ANNULUS WASTE HEIGHT POST LEAK (FT)		30.85	26.60	23.94	21.28	18.62	15.96	13.30	10.64	7.98	5.32	2.66	1.33
LIQUID VOLUME (L)	4.38E+06	5.31E+05	4.58E+05	4.12E+05	3.67E+05	3.21E+05	2.75E+05	2.29E+05	1.83E+05	1.37E+05	9.16E+04	4.58E+04	2.29E+04
HEADSPACE VOL. (L)	8.63E+05	7.49E+04	1.48E+05	1.94E+05	2.40E+05	2.86E+05	3.31E+05	3.77E+05	4.23E+05	4.69E+05	5.15E+05	5.61E+05	5.83E+05
AVERAGE WASTE. TEMP. (DEG. F)	119	119	119	119	119	119	119	119	119	119	119	119	119
VAPOR SPACE (DEG.F)	95	95	95	95	95	95	95	95	95	95	95	95	95
MEAN TOC (GM/L)	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8	22.8
ACTIVE VENTILATION. RATE 1/DAY)	4.73E+00	0	0	0	0	0	0	0	0	0	0	0	0
CONVERSION FACTOR	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23
G(H2) (MOLECULES/100 eV)	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110	0.110
WASTE LIQUID FRACTION	100%	1	1	1	1	1	1	1	1	1	1	1	1
MAXIMUM H2 ACCUMULATION FROM SOURCE TERM HEAT LOAD DATA													
TANK HEAT LOAD (W)	11700	1418	1222	1100	978	856	733	611	489	367	244	122	61
RADIOLYTIC GENERATION RATE (L/DAY)	291.04	35.27	30.41	27.37	24.33	21.29	18.25	15.20	12.16	9.12	6.08	3.04	1.52
THERMAL GENERATION RATE (L/DAY)	780.97	94.66	81.60	73.44	65.28	57.12	48.96	40.80	32.64	24.48	16.32	8.16	4.08
MAX (%) H2 ACCUMULATION (P)	21.64	27.82	14.38	10.35	7.67	5.75	4.31	3.19	2.30	1.57	0.96	0.44	0.21
DAYS TO 25% LFL (P)	5.10	3.64	8.45	12.41	17.45	24.10	33.30	46.85	68.88	111.27	232.61	NEVER	NEVER
DAYS TO LFL (P)	21.38	15.10	36.34	55.07	80.98	119.52	184.39	328.53	NEVER	NEVER	NEVER	NEVER	NEVER
DAYS TO 25% LFL (NO VENTILATION)	5.03	3.60	8.27	12.03	16.73	22.77	30.82	42.10	59.02	87.21	143.60	312.77	651.10
DAYS TO LFL (NO VENTILATION)	20.12	14.41	33.08	48.11	66.91	91.08	123.30	168.41	236.08	348.86	574.41	1251.08	2604.42
REQUIRED VENTILATION RATE (CFM)	4.08	0.50	0.42	0.37	0.32	0.27	0.23	0.18	0.13	0.08	0.03	0.00	0.00

TABLE 2.

DOUBLE SHELL TANK ANNULUS													
TANK	102-AN	Annulus											
WASTE MATERIAL	DSS												
TOTAL WASTE (KGAL)	1160	1160	1000	900	800	700	600	500	400	300	200	100	50
SUPERNATANT (KGAL)	1160	1160											
SLUDGE (KGAL)	0	0											
TANK WASTE HEIGHT B4 LEAK (FT)	35.10	35.10	30.26	27.24	24.21	21.18	18.16	15.13	12.10	9.08	6.05	3.03	1.51
ANNULUS WASTE HEIGHT POST LEAK (FT)		30.85	26.60	23.94	21.28	18.62	15.96	13.30	10.64	7.98	5.32	2.66	1.33
LIQUID VOLUME (L)	4.38E+06	5.31E+05	4.58E+05	4.12E+05	3.67E+05	3.21E+05	2.75E+05	2.29E+05	1.83E+05	1.37E+05	9.16E+04	4.58E+04	2.29E+04
HEADSPACE VOL. (L)	8.63E+05	7.49E+04	1.48E+05	1.94E+05	2.40E+05	2.86E+05	3.31E+05	3.77E+05	4.23E+05	4.69E+05	5.15E+05	5.61E+05	5.83E+05
AVERAGE WASTE. TEMP. (DEG. F)	106	106	106	106	106	106	106	106	106	106	106	106	106
VAPOR SPACE (DEG.F)	85	85	85	85	85	85	85	85	85	85	85	85	85
MEAN TOC (GM/L)	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7	33.7
ACTIVE VENTILATION. RATE 1/DAY)	4.73E+00	0	0	0	0	0	0	0	0	0	0	0	0
CONVERSION FACTOR	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
G(H2) (MOLECULES/100 eV)	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121	0.121
WASTE LIQUID FRACTION	100%	1	1	1	1	1	1	1	1	1	1	1	1
MAXIMUM H2 ACCUMULATION FROM SOURCE TERM HEAT LOAD DATA													
TANK HEAT LOAD (W)	11993	1454	1253	1128	1002	877	752	627	501	376	251	125	63
RADIOLYTIC GENERATION RATE (L/DAY)	321.64	38.98	33.61	30.25	26.89	23.53	20.16	16.80	13.44	10.08	6.72	3.36	1.68
THERMAL GENERATION RATE (L/DAY)	796.69	96.56	83.24	74.92	66.59	58.27	49.95	41.62	33.30	24.97	16.65	8.32	4.16
MAX (%) H2 ACCUMULATION (P)	22.36	28.68	14.91	10.75	7.97	5.98	4.49	3.33	2.40	1.63	1.00	0.46	0.22
DAYS TO 25% LFL (P)	4.89	3.49	8.10	11.88	16.70	23.05	31.82	44.70	65.55	105.36	216.19	NEVER	NEVER
DAYS TO LFL (P)	20.45	14.45	34.71	52.49	76.96	113.04	172.74	299.07	NEVER	NEVER	NEVER	NEVER	NEVER
DAYS TO 25% LFL (NO VENTILATION)	4.82	3.45	7.93	11.53	16.03	21.83	29.55	40.36	56.57	83.60	137.65	299.81	624.13
DAYS TO LFL (NO VENTILATION)	19.29	13.81	31.71	46.12	64.14	87.30	118.19	161.43	226.30	334.40	550.62	1199.26	2496.53
REQUIRED VENTILATION RATE (CFM)	4.27	0.52	0.44	0.39	0.34	0.29	0.24	0.19	0.14	0.08	0.03	0.00	0.00

TABLE 3.

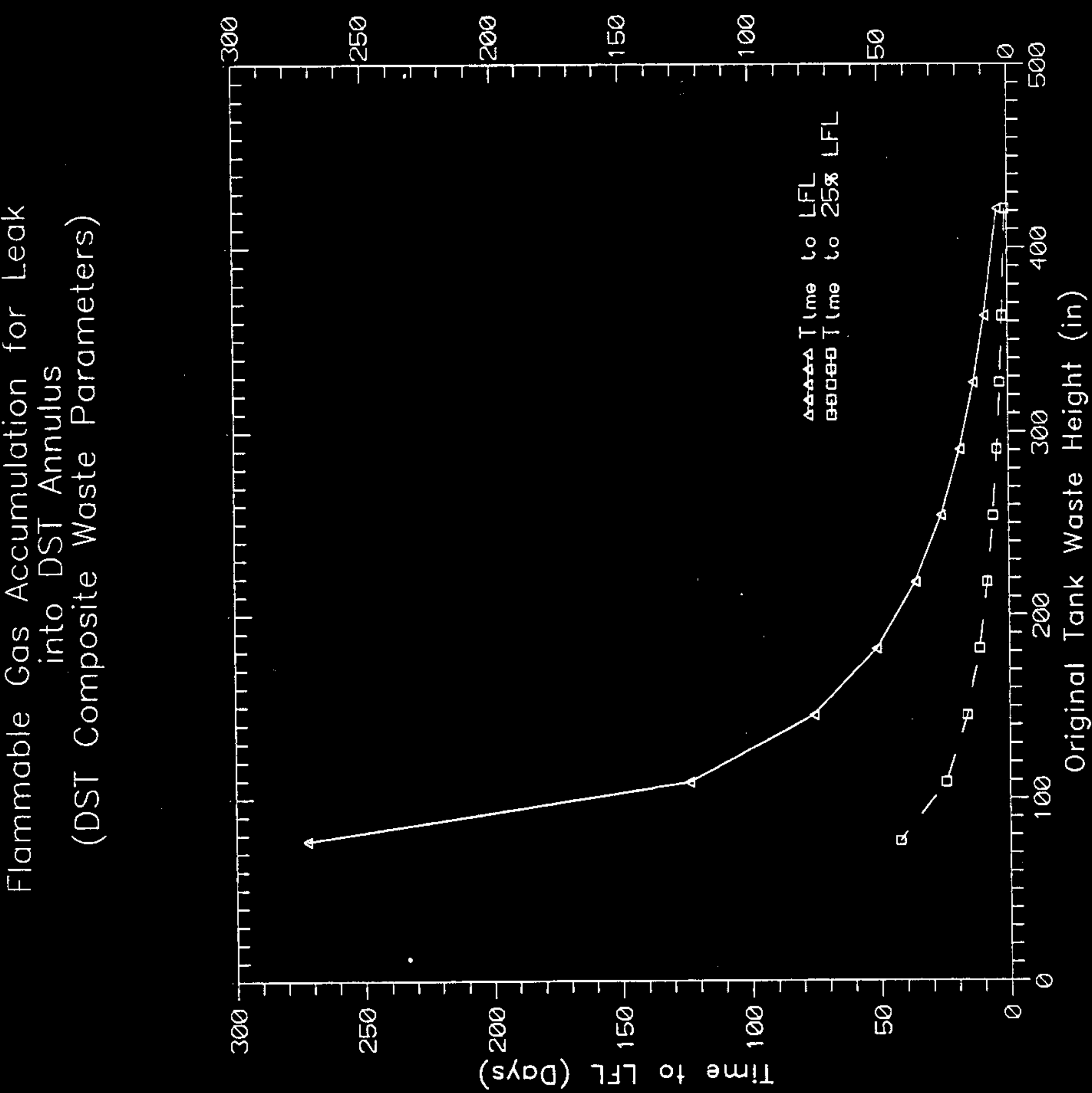
Flammable Gas Accumulation for Leak
into DST Annulus
(DST Composite Waste Parameters)
Time to LFL (Days)
Original Tank Waste Height (in)
Time to LFL
Time to 25% LFL
0
50
100
150
200
250
300
0
100
200
300
400
500

Figure 1.

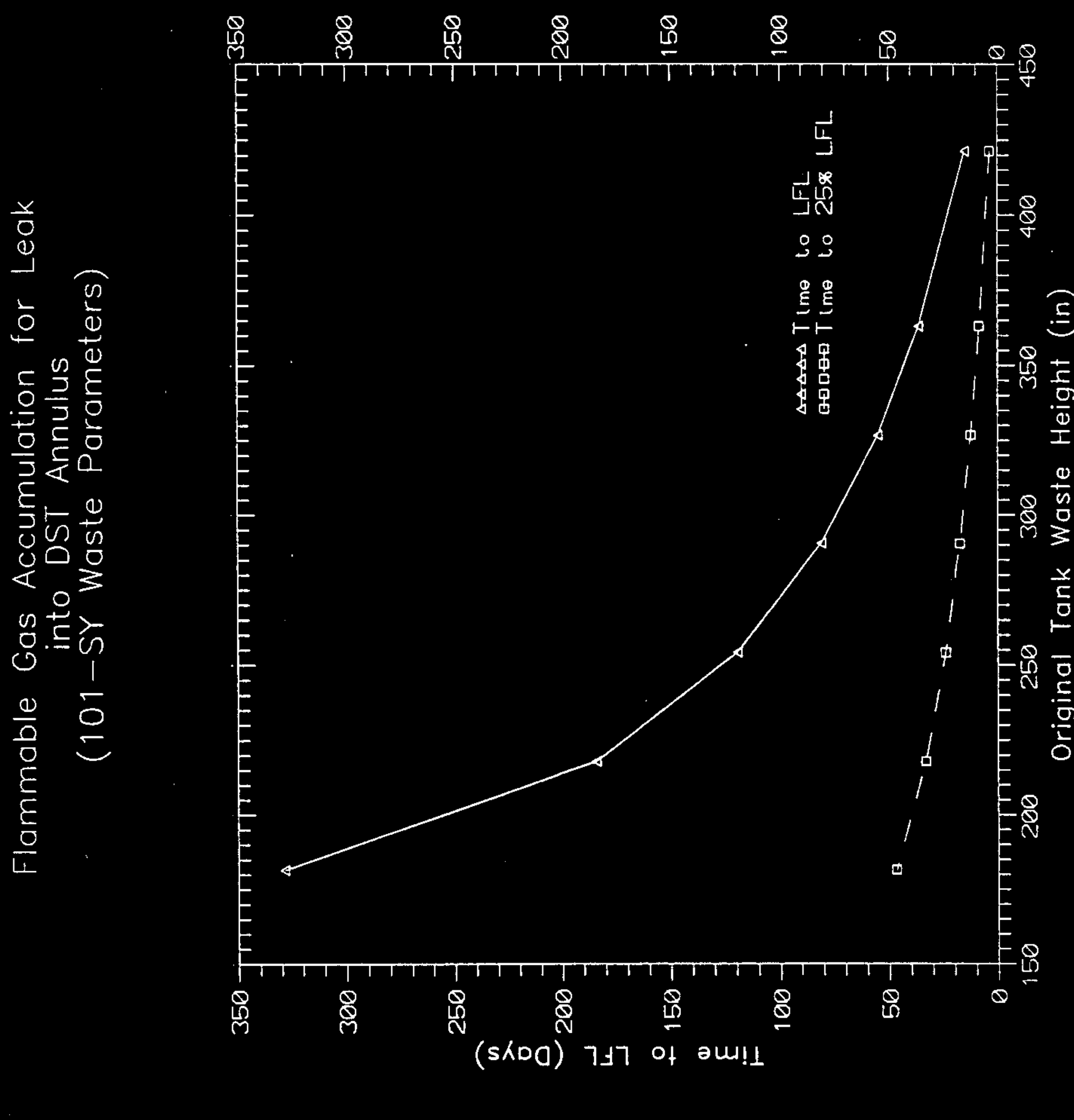
Flammable Gas Accumulation for Leak
into DST Annulus
(101-SY Waste Parameters)
Time to LFL (Days)
Original Tank Waste Height (in)
Time to LFL
Time to 25% LFL
0
50
100
150
200
250
300
350
150
200
250
300
350
400
450

FIGURE 2.

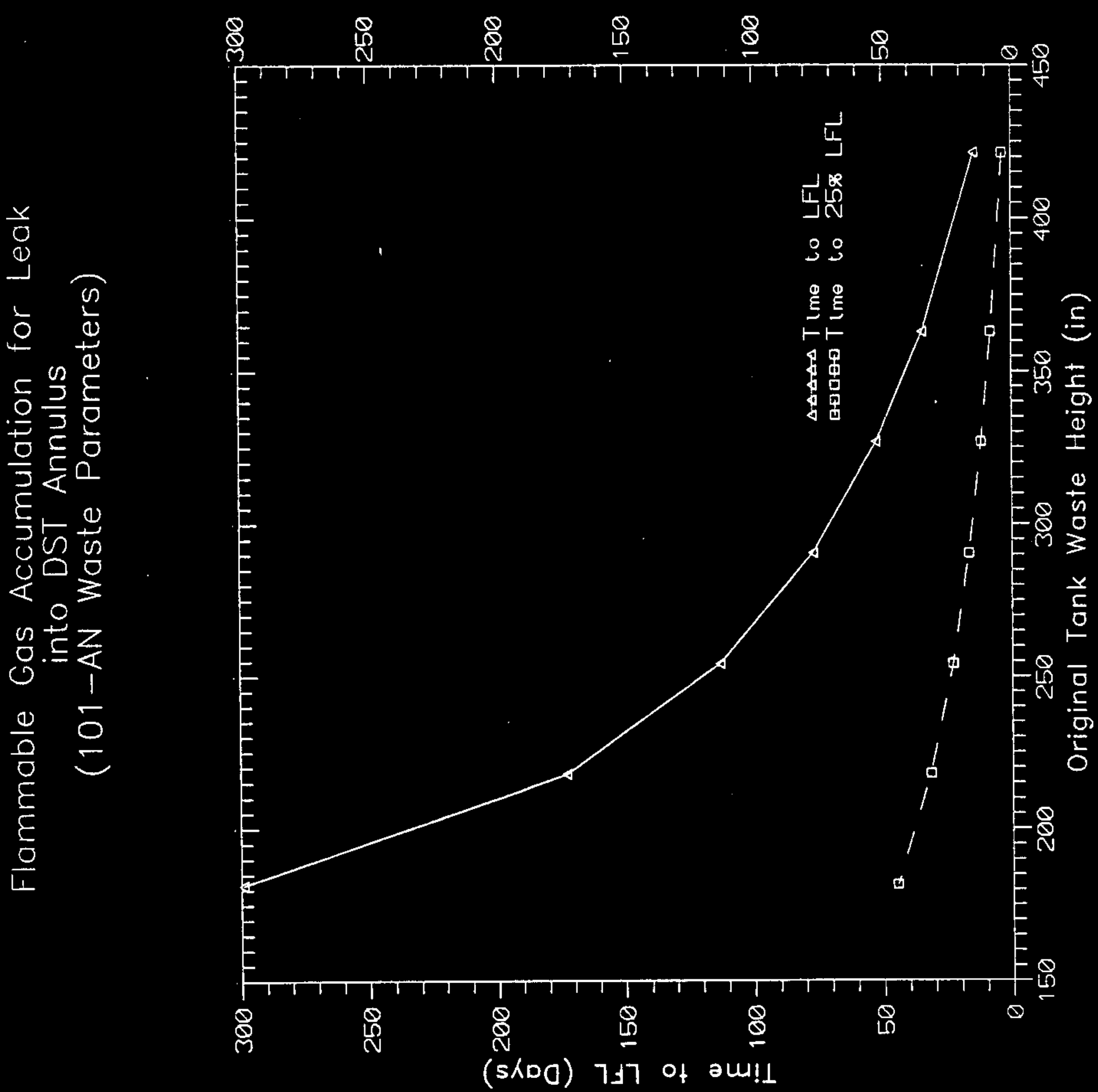
Flammable Gas Accumulation for Leak
into DST Annulus
(101-AN Waste Parameters)
Time to LFL
Time to 25% LFL
Original Tank Waste Height (in)
Time to LFL (Days)
150
200
250
300
350
400
450
0
50
100
150
200
250
300

Figure 3.

PEER REVIEW CHECKLIST

Document Reviewed: Memorandum, Kummerer to Van Vleet: *Calculation of Flammable Gas in DST Annulus from a Primary Tank Leak*
Author: Maryanne Kummerer
Date: March 27, 1995
Scope of Review: Technical Review of DST Annulus Hydrogen Generation Analysis, using WHC-SD-WM-SAR-065 methodology and assumptions.

Yes	No	NA	
[ ]	[ ]	[X]	Previous reviews complete and cover analysis, up to scope of this review, with no gaps. *[No previous reviews are applicable. The scope of this review covers the entire analysis.]*
[X]	[ ]	[ ]	Problem completely defined. *[The problem is completely defined in the memorandum.]*
[X]	[ ]	[ ]	Accident scenarios developed in a clear and logical manner. *[The memorandum builds upon the analysis methodology and scenarios presented in the reference SAR. Three cases are clearly developed.]*
[X]	[ ]	[ ]	Necessary assumptions explicitly stated and supported. *[The analysis assumes the volume of the annulus excludes the region under the tank. This assumption is conservative since the volume under the tank is small, the volume is likely offset by the thickness of the tank's steel shell and other components in the annulus, and the larger volume would increase the time to reach LFL. All other assumptions are stated explicitly and are supported in either the memorandum or the reference SAR.]*
[ ]	[ ]	[X]	Computer codes and data files documented. *[No computer codes were used in the analysis.]*
[X]	[ ]	[ ]	Data used in calculations explicitly stated in document. *[The data used is contained in the document or the reference SAR.]*
[X]	[ ]	[ ]	Data checked for consistency with original source information as applicable. *[The data is consistent with the reference SAR and its sources.]*
[X]	[ ]	[ ]	Mathematical derivations checked including dimensional consistency of results. *[Spreadsheet calculations were reviewed and confirmed consistent with the reference SAR methodology.]*
[X]	[ ]	[ ]	Models appropriate and used within range of validity or use outside range of established validity justified. *[The analysis is within the reference SAR range of validity.]*

[X] [ ] [ ] Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations. *[The spreadsheet calculations were reviewed for accuracy. Identified errors have been corrected.]*

[ ] [ ] [X] Software input correct and consistent with document reviewed. *[Computer codes were not used in the analysis.]*

[ ] [ ] [X] Software output consistent with input and with results reported in document reviewed. *[Computer codes were not used in the analysis.]*

[X] [ ] [ ] Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references. *[Limits/criteria/guidelines are consistent with the reference SAR.]*

[X] [ ] [ ] Safety margins consistent with good engineering practices. *[Appropriate levels of conservatism are maintained in the analysis assumptions and methodology. As described above, simplifying assumptions are conservative and justified.]*

[X] [ ] [ ] Conclusions consistent with analytical results and applicable limits. *[Specific conclusions are not required by the problem statement; the analysis reports results in a clear, concise manner.]*

[X] [ ] [ ] Results and conclusions address all points required in the problem statement.

[ ] [ ] [X] Format consistent with appropriate NRC Regulatory Guide or other standards. *[A specific format is not required. Memorandum content and format are consitet with engineering standards.]*

[X] [ ] [ ] Review calculations, comments, and/or notes are attached. *[Review comments are included in this Peer Review Checklist. Editorial corrections to the memorandum have been incorporated.]*

[X] [ ] [ ] Document approved.

Robert Cronin [signature] April 11, 1995
Reviewer (Printed Name and Signature) Date

APPENDIX 2

LOSS OF ANNULUS VENTILATION COOLING EFFECT ON WASTE TEMPERATURE IN DSTS

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Westinghouse
Hanford Company

Internal
Memo

From: Safety Fluid Mechanics & Computational Center 71120-95-KS-018
Phone: 376-2527 H0-34
Date: April 21, 1995
Subject: LOSS OF ANNULUS VENTILATION COOLING EFFECT ON WASTE TEMPERATURE IN DSTs

To: C. E. Jensen R1-30

cc:	R. A. Dodd	S5-05	D. M. Ogden	H0-34
	J. P. Harris	S2-48	K. V. Scott	H5-52
	G. T. MacLean	H5-49	KS File/LB	

References:

(1) Sathyanarayana, K., et al.,1993, "Development of a Dynamic Computer Simulator for Aging Waste Tank Operations and Safety Assessment," WHC-SD-WM-ER-198, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

(2) Winkler, C.M., 1994, "AZ-101 Steam Bumping and Settling Process Test Report," WHC-SD-WM-PTR-012, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

(3) Tran T. T. 1993, "Thermocouple Status of Single Shell and Double Shell Waste Tanks," WHC-SD-WM-TI-553, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

(4) Aguirre H. 1994, "Interim Safety Document-Aging Waste Facility," WHC-SD-WM-OSR-004, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Objective:

As part of the double-shell tank (DST) acceptance criteria, it is required to evaluate the effect of waste leakage into the annulus cooling channels blocking the ventilation air flow in DSTs. The purpose of the analysis is to estimate the maximum waste temperature in double-shell tanks (DSTs) for the event of loss of annulus ventilation cooling and evaluate whether the waste temperature can exceed OSD/OSR limits.

Introduction:

The maximum waste temperatures in double-shell tanks (DSTs) (Ref.3) are observed in tank AZ-101 under normal operating conditions. The waste temperatures in tank AZ-102 are also close to AZ-101. However, the heat loads and the sludge thicknesses in these tanks are not the same. The waste tanks AZ-101 and AZ-102 have about 302,600 and 168,000 Btu/hr total heat load and the sludge thickness of about 18 in. and 36 in., respectively. The detailed thermal hydraulic model was developed (Ref. 1) using the GOTH computer code to predict the temperature as well as the velocity field in the sludge, supernatant and for the air in the dome and annulus simultaneously. Using this model, GOTH simulations were performed both for normal operation and loss of annulus ventilation cooling condition. A process test (Ref. 2), conducted to demonstrate the termination of the operation of airlift circulators (ALCs), was extended to study and verify the predictions of the computer simulations for the temperature increases with the loss of annulus ventilation cooling along with ALCs.

In addition simplified model calculations were performed to estimate allowable sludge thickness using tank AZ-101 parameters with washed sludge. As the sludge thickness increases the particle loading and the heat load also increase. The allowable sludge thickness is defined as that value which has the required heat loading to increase the temperature of the sludge to local saturation value. The method assumes that the local saturation temperature is the limiting temperature; the heat loss is only due to evaporation of solution and the sludge consists of washed particles and water. The thermal conductivity of the sludge is derived from that of solid particle and water values.

Analysis and Results:

Case 1 : Computer Simulations

The thermal hydraulic simulations were performed using the waste parameters given in Table 1 and the results have shown that the heat loss in tank AZ-101 is predominantly (i.e., about 84%) through evaporation of liquid. There is also 10-12% heat removal by the annulus ventilation. The results of sludge temperature distribution for normal operating tank are shown in Figure 1 and for that for the loss of annulus ventilation condition are illustrated in Figure 2. The results of the process test (Ref. 2) have indicated that the measured temperature distribution matched well with the predictions. The predicted (Ref. 1) and the measured peak sludge temperatures were close to 187 °F. The operation of the tank with The loss of annulus cooling and the termination of ALCs has increased the peak waste temperature from about 173 to 189 °F. This increase in waste temperature is well below operating safety requirements (OSR) limit.

Case 2 : Parametric Calculations

The temperature distribution in the sludge is a function of sludge depth and its thermal conductivity for a given heat source value. The sludge thermal conductivity depends on the composition of solid and liquid and their individual conductivities. It is estimated using different models and its value with respect to volume fraction of solid particles is shown in Figure 3. The series model provides a lower conductivity value which will give lower sludge content for a specified temperature limit. The increase in heat load with the increased thickness of sludge having 18% by volume (40 wt%) of solids is shown in Figure 4.

a) Thermal Bump Limit Criteria

The maximum thickness of the sludge limited by thermal bump criteria is that required to produce saturation temperature corresponding to local hydrostatic pressure. If the sludge thickness is higher than this value, steam can form and accumulate which can lead to thermal bump conditions. For the thermal bump limiting criteria, using the sludge thermal conductivities of 0.42 and 1.195 Btu/lbm hr°F obtained from series and parallel conductor models, the maximum sludge thickness was estimated for two values of particle heat generation rates of 0.39 and 0.195 Btu/lbm hr. The results given in Table 2 show that with the loss of the annulus ventilation system, the maximum thickness of sludge that can be accommodated varies from 2.9 to 4.1 ft for heat generation rates ranging from 0.39 to 0.195 Btu/lbm hr. The temperature distribution in the sludge of 2.86 ft, 4 ft, and 6 ft is shown in Figure 5. The sludge thickness of 2.86 ft is the maximum that can be stored with no annulus ventilation without reaching local saturation temperatures.

b) OSR Temperature Limit Criteria

According to the interim safety document (Ref.4), the safety limit for the waste temperature in tank AZ-101 is 350 °F. The calculations were extended to estimate the allowable sludge thickness without exceeding OSR temperature limit. The results of the temperature distribution for the maximum allowable sludge thickness of 3.75 ft with this criteria are shown in Figure 6. This calculation is performed assuming the sludge is wet and has the thermal conductivity of 0.42 Btu/lbm hr°F . However, if the temperature reaches local saturation, the liquid starts evaporating and the conductivity value will reduce. Therefore, the calculations are repeated assuming a conductivity of 0.1475 Btu/hr ft °F for the sludge (dry) which is at or above the saturation temperature. Figure 7 shows the temperature distribution in the dry and wet sludge combination. The result suggests that up to 3.15 ft of sludge can be stored without exceeding the OSR temperature limit.

Conclusions:

From the results of computer simulations as well as from the process test, we can conclude that for the current operating conditions of aging waste tank AZ-101, the waste temperature for the loss of annulus ventilation condition with the simultaneous loss of ALCs does not reach even local saturation conditions. However, increased amount of sludge storage should be carefully planned as the results of these calculations show that the sludge temperatures can exceed thermal bump limit as well as OSR limit depending on the particle heat generation rate, solid-liquid mixture thermal conductivity, and sludge height in the tank.

C. E. Jensen
Page 4
April 21, 1995

71120-95-KS-018

K. Sathyanarayana 4/21/95
K. Sathyanarayana, Fellow Engineer
Safety Fluid Mechanics & Computational Center

bab

Attachment

CONCURRENCE:

D. M. Ogden
D. M. Ogden, Manager
Safety Fluid Mechanics and Computational Center

Date: 4/25/95

71120-95-KS-018

ATTACHMENT

Tables and Figures

Consisting of 9 pages

71120-95-KS-018

ATTACHMENT

Tables and Figures

Consisting of 9 pages

Table 1 Tank 101-AZ Normal Operation Parameters and Waste Properties.

Tank:

Primary Tank Diameter	: 75 ft.
Secondary Tank Diameter	: 80 ft.

Ventilation System:

Primary Flow (determined from ventilation flow model) with current heat load	= 576 SCFM
Annulus Flow	= 500 SCFM
Temperature and Humidity Inlet	= 70 ^{0}F, 50%

Tank Contents:

a) Unwashed Waste:

Undissolved (dry) Solids Density	ρs	= 243.4 lbm/ft3
Aqueous Solution Density	ρl	= 75.5 lbm/ft3
Slurry (Liquid-Solid Mixture) Density	ρsl	= 104.0 lbm/ft3
Supernatant (Aqueous Solution) Depth		= 28.5 ft.
Slurry (Nonconvective Layer) Depth		= 1.5 ft.

b) Washed Waste:

Solids Density	ρs	= 187.2 lbm/ft^3
Wash Solution Density	ρl	= 62.4 lbm/ft^3
Slurry Density	ρsl	= 85.1 lb/ft^3

Aqueous Solution:

Initial Temperature	= 140 ^{0}F
Heat Capacity	= 0.8 Btu/lbm^{0}F
Thermal Conductivity	= 0.35 Btu/hr-ft-^{0}F
Heat Generation Rate	= 0.019 Btu/hr-lbm
Wash Water Solution	= 0 Btu/hr-lbm

Insoluble Solids:

Initial Temperature	= 140 ^{0}F
Heat Capacity	= 0.2 Btu/lbm ^{0}F
Thermal Conductivity	= 5.0 Btu/hr ft ^{0}F
Heat Generation Rate, Unwashed Waste	= 0.39 Btu/hr-lbm
Particle Size, Washed Waste	= 1-10 μm range
	= 5 μm average
Volume Fraction of Solids, Unwashed Waste	= 17%

Table 2. Thermal Bump Limiting Sludge Thickness with Loss of Annulus Ventilation Cooling.

Heat Source in Particles (Btu/lbm hr)	0.39		0.195	
Thermal conductivity of the sludge (Btu/hr ft °F)	0.421	1.195	0.421	1.195
Sludge thickness, ft	2.9	4.5	4.1	6.7
Heat load, Btu/hr	167700	263900	120200	197000

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GOTH Version 3.4 - April 1991

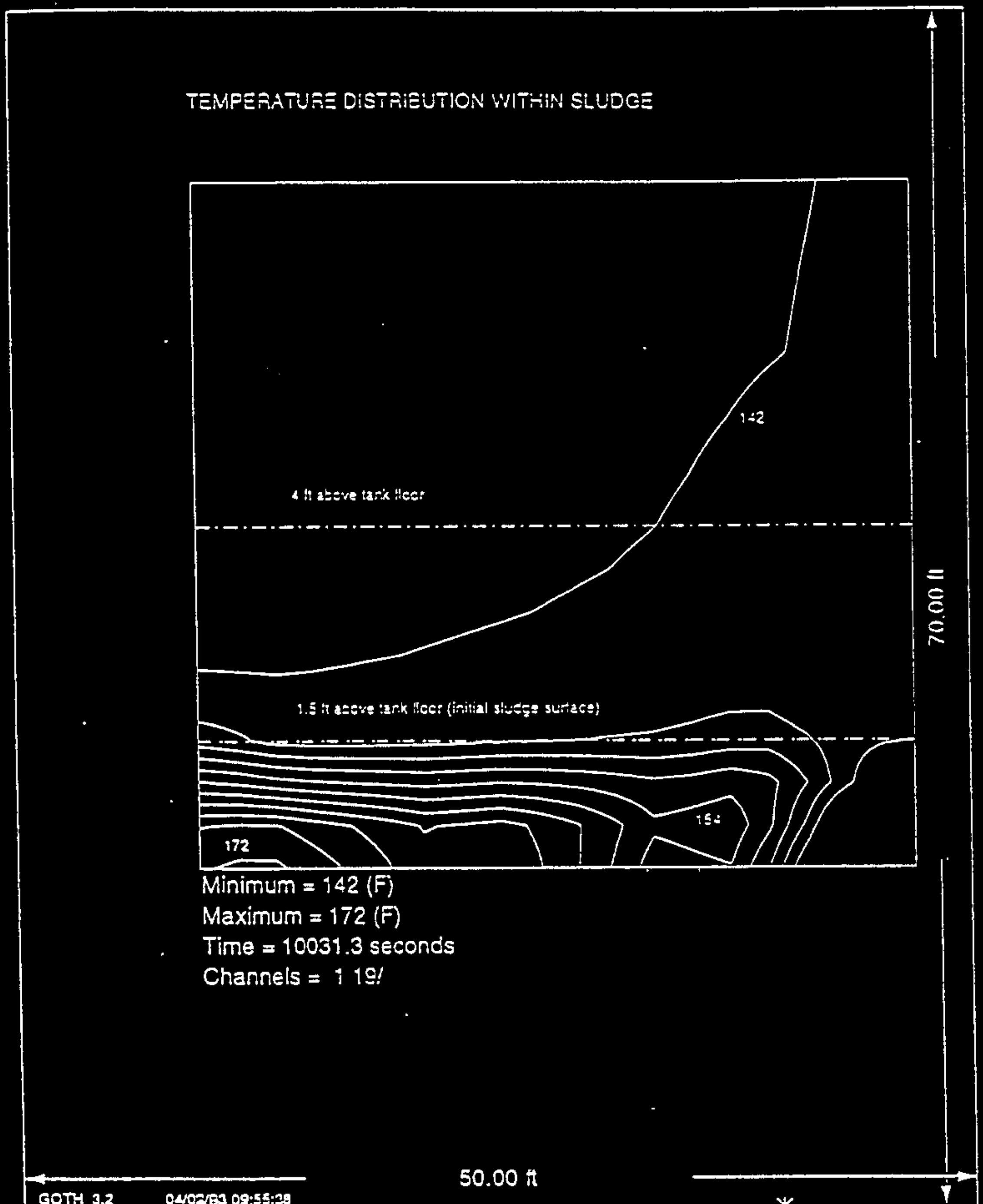

Figure 1. Temperature Contours in the Sludge of Tank AZ-101 with Current Contents and Normal Operation

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GOTH Version 3.4 - April 1991

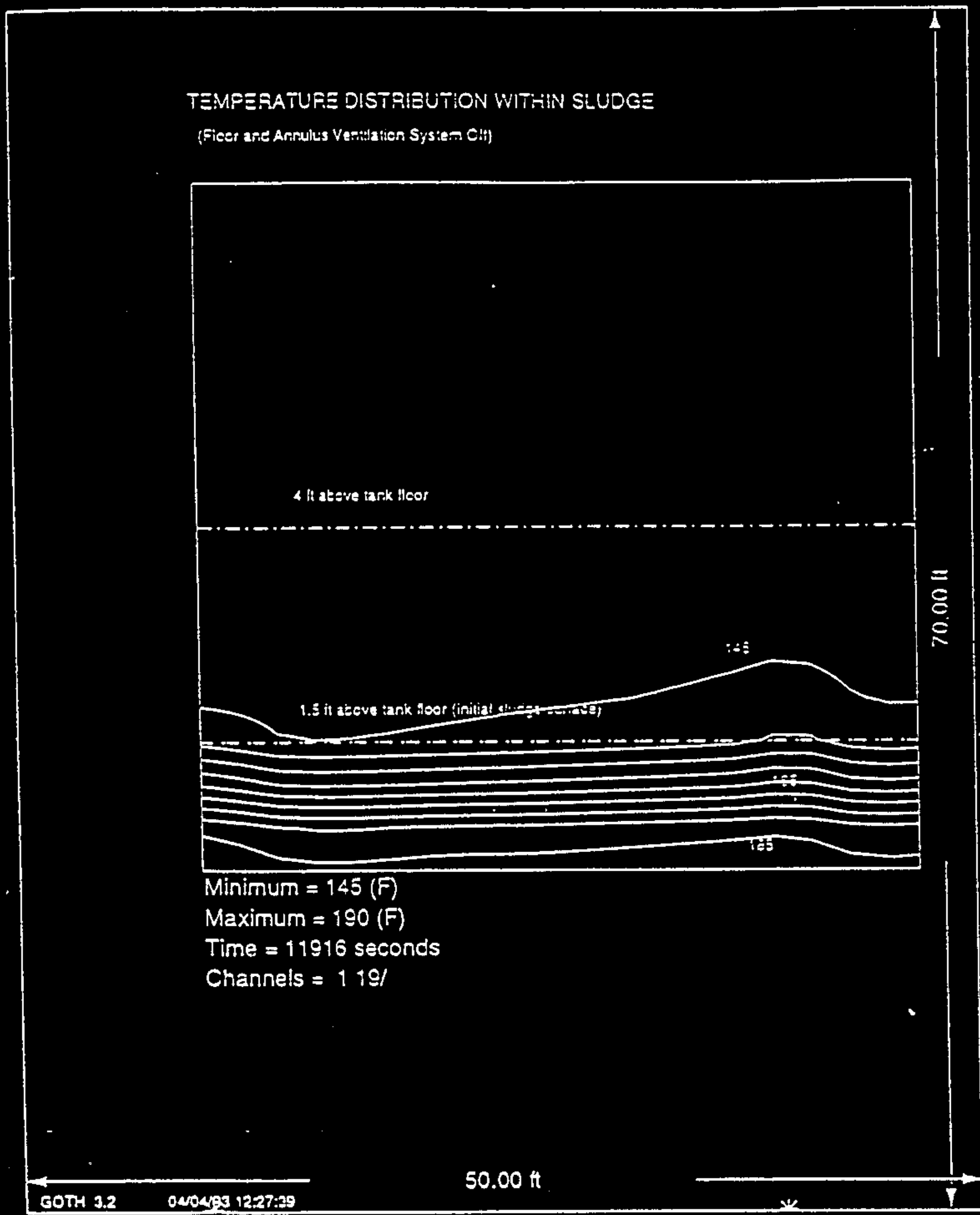

Figure 2. Temperature Contours in the Sludge of Tank AZ-101 with Current Contents and Loss of Annulus Ventilation Cooling

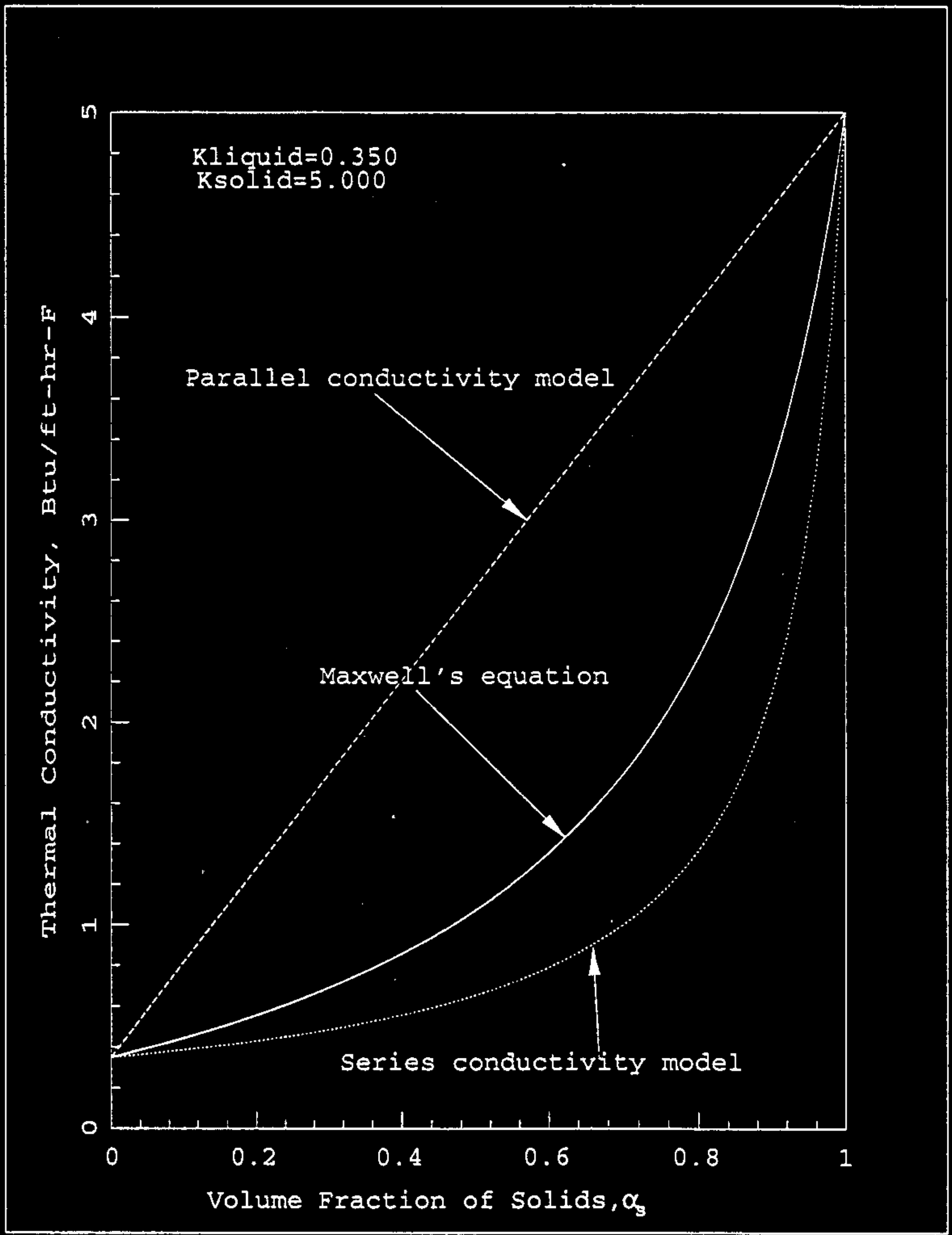

Figure 3. Solid-Liquid Mixture Thermal Conductivity with Volume Fraction of Solids Using Different Models

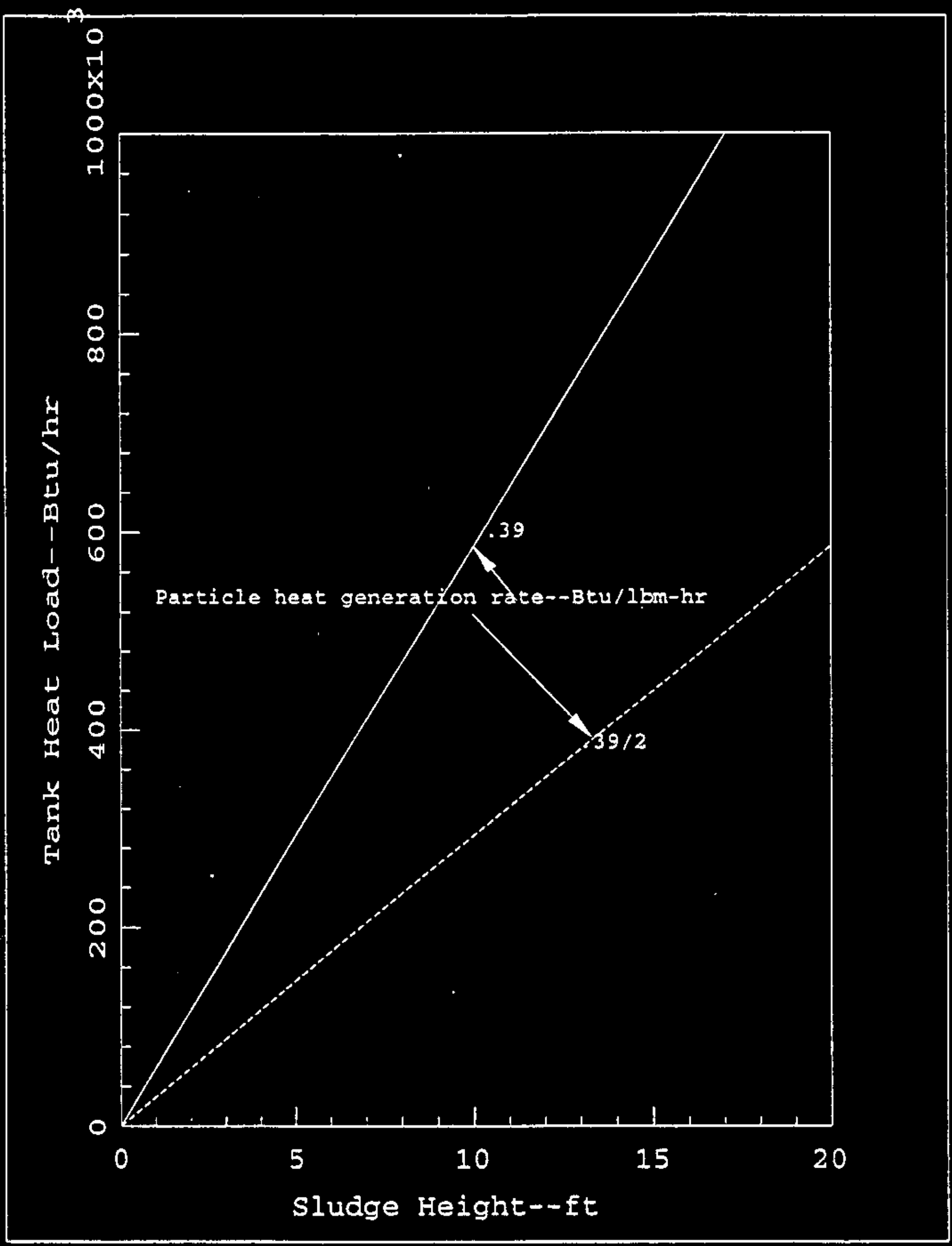

Figure 4. Tank Heat Load with Height of the Sludge Having 40 wt% of Particles with Heat Generation Rate of 0.39 and 0.195 Btu/lbm-hr

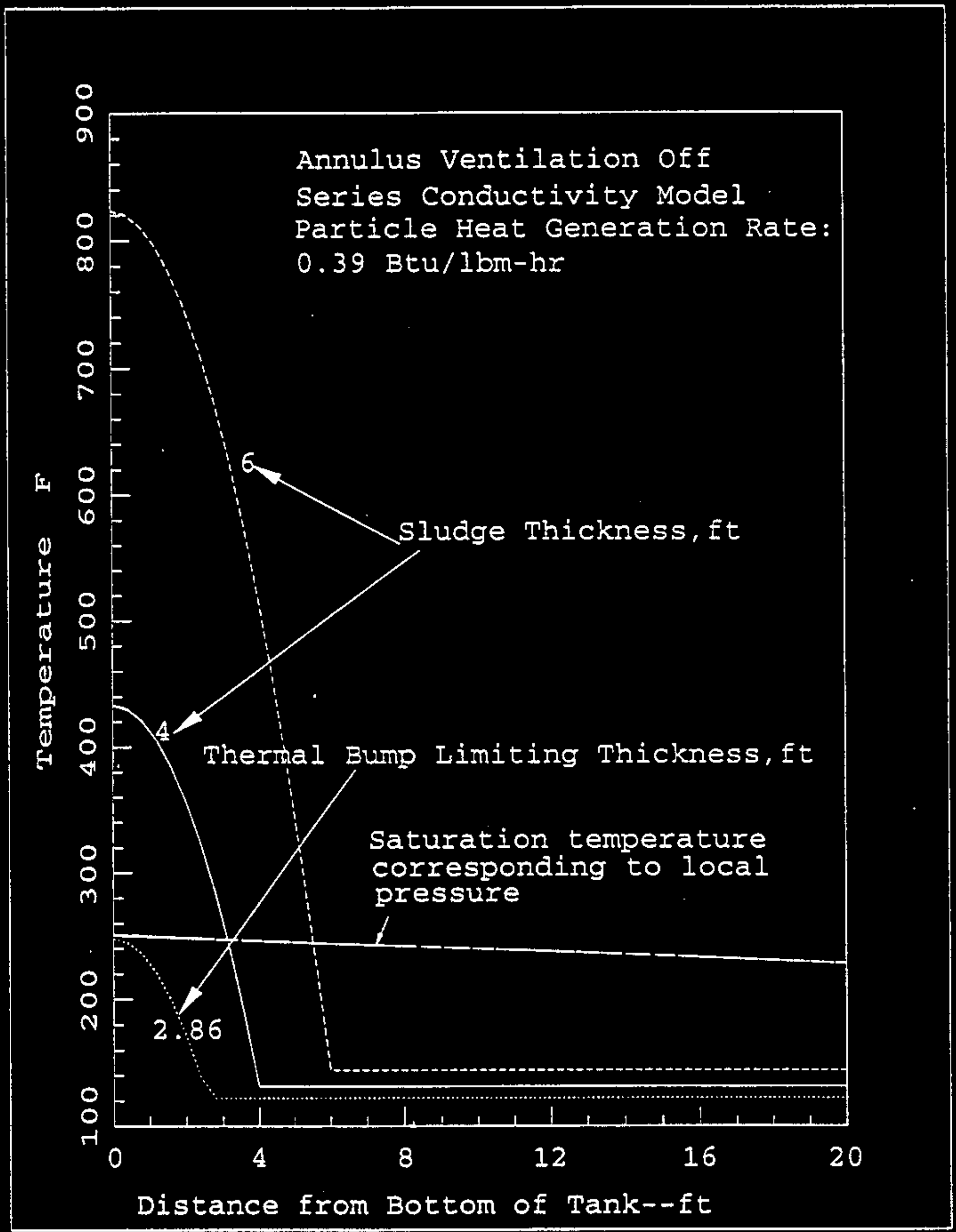

Figure 5. Tank Waste Temperature versus Sludge Thickness including Thermal Bump Limiting Value under Loss of Annulus Ventilation Conditions

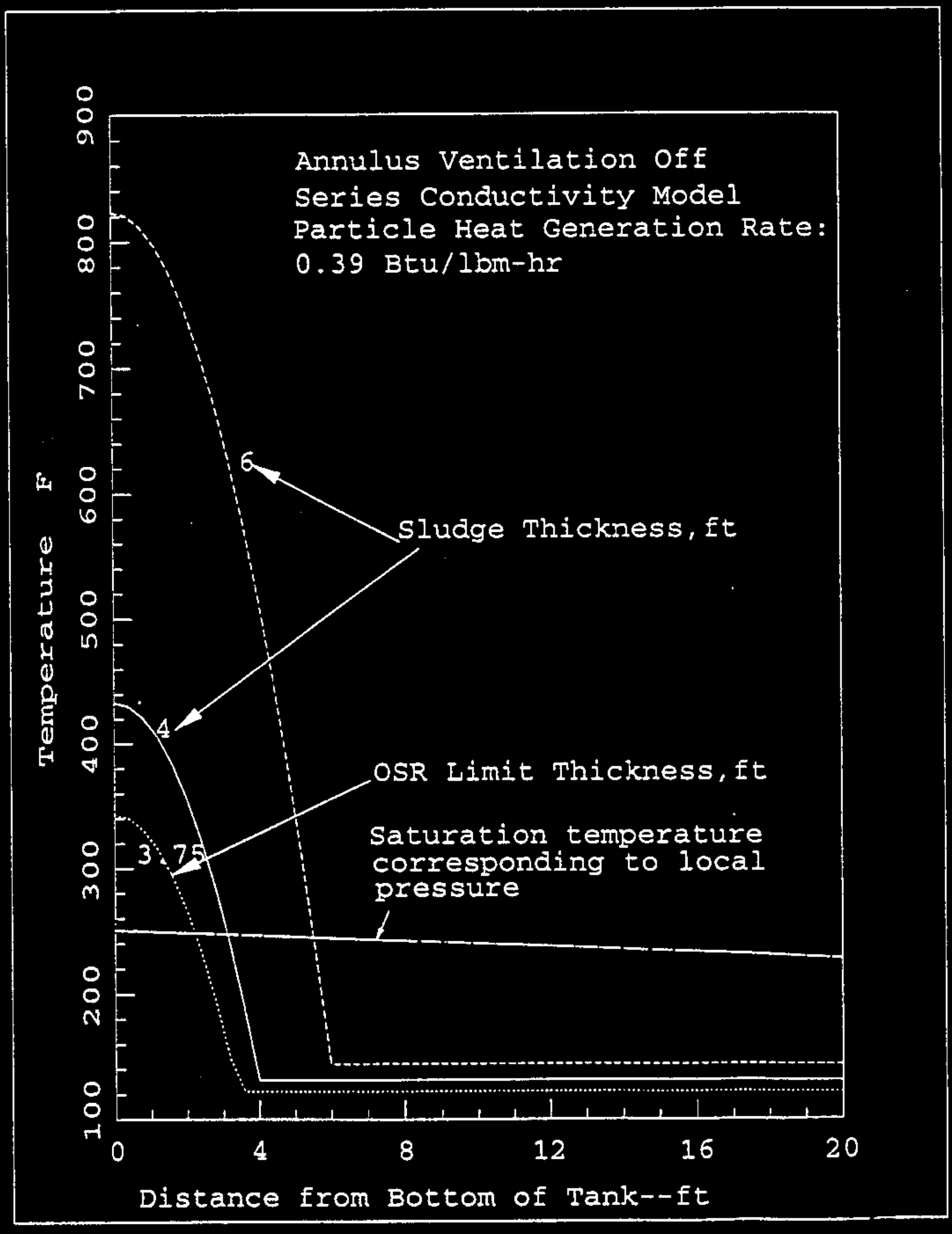

Figure 6. Tank Waste Temperature versus Sludge Thickness including OSR Limit Thickness under Loss of Annulus Ventilation Conditions For Wet Sludge Assumption

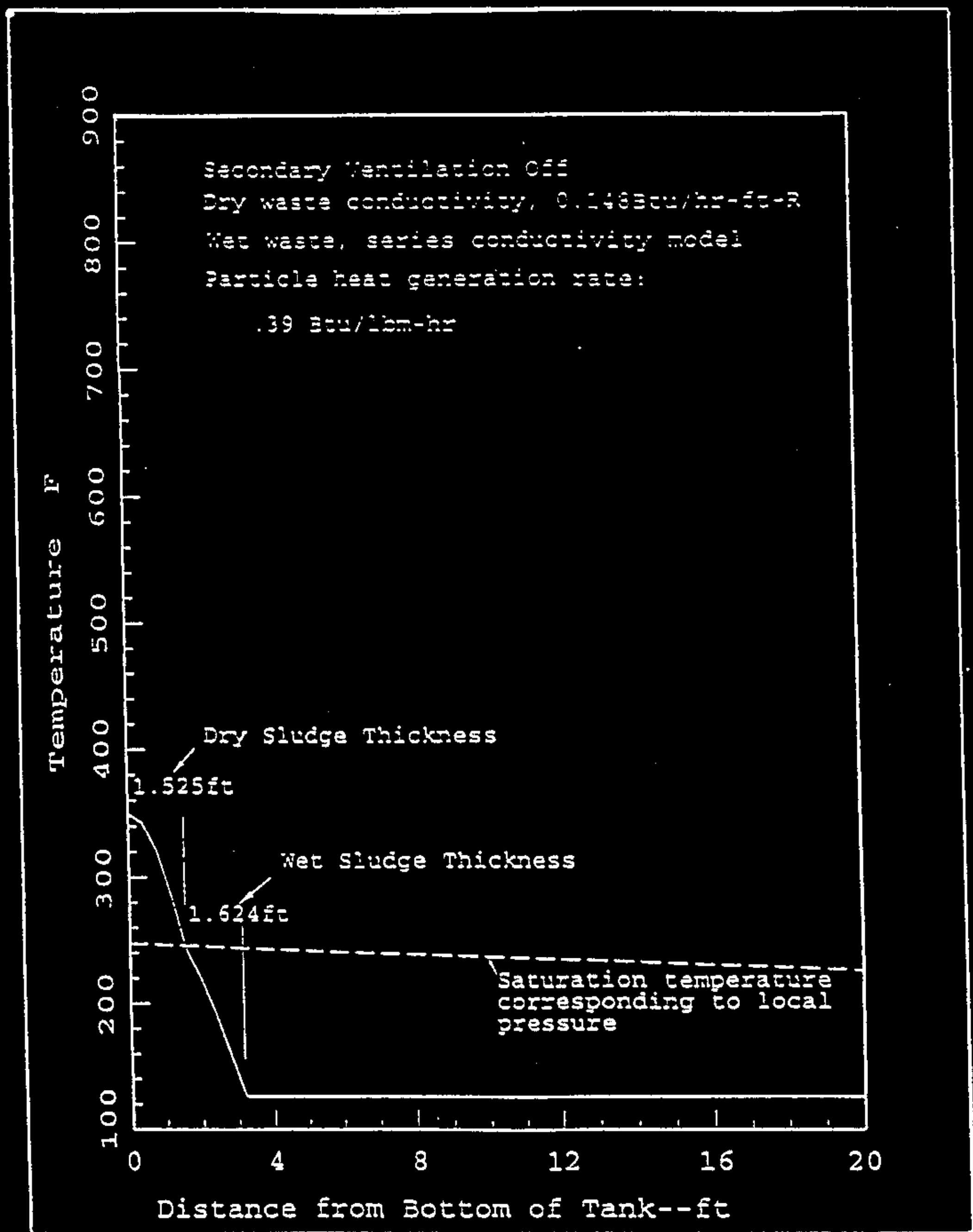

Figure 7. Tank Waste Temperature versus Sludge Thickness including OSR Limit Thickness under Loss of Annulus Ventilation Conditions for Dry and Wet sludge Combination

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