5 sta. 4

SEP 28 1994

ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT 605516

2. To: (Receiving Organization) Distribution	3. From: (Originating Organization) TWRS Thermal Hydraulics	4. Related EDT No.: N/A
5. Proj./Prog./Dept./Div.: Tank Farms	6. Cog. Engr.: T. J. Bander	7. Purchase Order No.: N/A
8. Originator Remarks: FOR ORIGINAL RELEASE		9. Equip./Component No.: N/A
		10. System/Bldg./Facility: N/A
11. Receiver Remarks:		12. Major Assm. Dwg. No.: N/A
		13. Permit/Permit Application No.: N/A
		14. Required Response Date: September 8, 1994

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	WHC-SD-WM-ER-379		0	An Assessment of the Potential for a Steam Bump in Hanford Waste Tank 241-C-106	SQ	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	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp.
1	1	Cog.Eng. T. J. Bander	TJB	9/15/94							
1	1	Cog. Mgr. T. B. McCall	TBM	9/21/94							
1	1	QA M. L. McElroy	M. L. McElroy	9/23/94							
1	1	Safety M. N. Islam	Islam	9/28/94							
		Env.									
1		O. S. Wang	OSWang	9/21/94							

18.	19.	20.	21. DOE APPROVAL (if required)
T. J. Bander TJB 9/15/94 Signature of EDT Originator Date	O. S. Wang OSWang 9/21/94 Authorized Representative for Receiving Organization Date	T. B. McCall TBM 9/21/94 Cognizant Manager Date	Ctrl. No. [ ] Approved [ ] Approved w/comments [ ] Disapproved w/comments

BD-7400-172-2 (04/94) GEF097

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

BD-7400-172-1 (07/91)

RELEASE AUTHORIZATION

Document Number:	WHC-SD-WM-ER-379, REV 0
Document Title:	An Assessment of the Potential for a Steam Bump in Hanford Waste Tank 241-C-106
Release Date:	September 28, 1994

* * * * * * * * * * * * * *

This document was reviewed following the procedures described in WHC-CM-3-4 and is:

APPROVED FOR PUBLIC RELEASE

* * * * * * * * * * * * * *

WHC Information Release Administration Specialist:

Kara Broz

Kara Broz
(Signature)

September 28, 1994
(Date)

A-6001-400 (07/94) WEF256

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

SUPPORTING DOCUMENT

1. Total Pages 34

2. Title

An Assessment of the Potential for a Steam Bump in Hanford Waste Tank 241-C-106

3. Number

WHC-SD-WM-ER-379

4. Rev No.

0

5. Key Words

Steam Bump, Tank 241-C-106, Work Restrictions, Heat Removal

KMB 9/28/94

APPROVED FOR PUBLIC RELEASE

6. Author

Name: T. J. Bander

Signature

Organization/Charge Code 7E870/N2619

7. Abstract

This document is a preliminary assessment of the potential for a "steam bump" in Tank 241-C-106. The assessment is based on currently available data from significant transients which occurred in Tank C-106. Recommendations are made for additional data needs to clarify the current behavior of this tank. General criteria are provided for making decisions on removing or returning to work restrictions on Tank Farm operations. Also provided are additional actions which should be taken on C-106 to manage tank heat removal.

8. PURPOSE AND USE OF DOCUMENT - This document was prepared for use within the U.S. Department of Energy and its contractors. It is to be used only to perform, direct, or integrate work under U.S. Department of Energy contracts. This document is not approved for public release until reviewed.

PATENT STATUS - This document copy, since it is transmitted in advance of patent clearance, is made available in confidence solely for use in performance of work under contracts with the U.S. Department of Energy. This document is not to be published nor its contents otherwise disseminated or used for purposes other than specified above before patent approval for such release or use has been secured, upon request, from the Patent Counsel, U.S. Department of Energy Field Office, Richland, WA.

DISCLAIMER - This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

9. Impact Level SQ

10. RELEASE STAMP

OFFICIAL RELEASE BY WHC (5)

DATE SEP 28 1994

Sta. 4

AN ASSESSMENT OF THE POTENTIAL FOR A STEAM BUMP IN HANFORD WASTE TANK 241-C-106

August 31, 1994

Prepared by: T J Bander
Tom Bander, Principal Engineer
TWRS Thermal Hydraulics

Blaine Crea
Blaine Crea, Principal Engineer
TWRS Thermal Hydraulics

Approved by: T B McCall
T. McCall, Manager
TWRS Thermal Hydraulics

Table of Contents

INTRODUCTION 1
Objective 1
Significant Transients in Single Shell Waste Tank 241-C-106 1

OBSERVATIONS AND CONCLUSIONS 2

BACKGROUND INFORMATION ON C-106 3
Data Sources for this Evaluation 3
Measured and Calculated Temperatures during Ventilation Outage of 1992 4
Predicted Temperatures in the Near Future 4
Estimated Liquid Saturation Temperature 5

EVALUATION OF THE POTENTIAL FOR A TANK BUMP 6
Physics of Tank Bumps 6
Evaluation Process 6
Minimum Requirements for a Bump 6
WHC Has Reasonable Assurance a "Bump" did not occur during Ventilation Outage in 1992 7
Potential Differences between the Conditions of 1992 and Present . 8
Comparison of Energy Stored in Tank Sludge 9

ADDITIONAL DATA NEEDED 11

PROPOSED CRITERIA RELATED TO WORK RESTRICTIONS FOR C-106 11
Proposed Required Conditions for Return to Normal Operations in C Farm Except for Intrusion into the C-106 Sludge 11
Proposed Conditions that Require Return to Restricted Operations . 13

PRIME CANDIDATE PREVENTATIVE ACTIONS 14

REFERENCES 16

TABLES

TABLE 1. DATA SOURCES AND THEIR CHARACTERISTICS 3
TABLE 2. MEASURED AND PREDICTED TEMPERATURES IN C-106 NORMAL AND REDUCED EVAPORATION RATE 5
TABLE 3. COMPARISON OF ENERGY STORED IN TANK SLUDGE 10

APPENDIXES

APPENDIX A 106-C HEPA FILTER CHANGE . . . . . A-i
APPENDIX B RECORDS ON RADIATION MONITORING AT C-106 EXHAUST HEPA FILTER . . . . . B-i
APPENDIX C HISTORY OF TANK BUMPS IN AGING WASTE TANKS . . . . . C-i

AN ASSESSMENT OF THE POTENTIAL FOR A STEAM BUMP IN HANFORD WASTE TANK 241-C-106

INTRODUCTION

Objective

The first objective of this paper is to address the potential for a "bump" in waste tank C-106. By "bump" we mean the following:

- o the formation and rapid expulsion of a steam bubble from the waste of adequate volume to drive the tank pressure positive with respect to atmospheric pressure, and;
- o sufficient gas flow from the tank to result in a statistically significant increase in radioactivity on the tank HEPA filter.

To clarify bump further, we do not include small steam releases that do not result in positive dome gas pressure or radioactivity to the HEPA filter.

Other objectives of this position paper are as follows:

A. Reach timely but preliminary conclusion about the likelihood of a bump as defined above;

B. Make recommendations for additional data and tank measurements to further clarify C-106 historical and current behavior;

C. Provide general criteria for making decisions on whether or not to remove the current restrictions on Tank Farm operations (i.e. work restrictions, respirators, delay of maintenance operations); and

D. Provide general criteria for making decision on whether or not additional actions should be taken on C-106 to manage tank heat removal (e.g. inlet air chiller, increase in ventilation flow, ice addition).

This paper is a preliminary assessment that makes use of current available data and makes logical, systematic, and reasonable conclusions incorporating some <u>judgement</u> and consensus among experienced thermal hydraulics experts. It is <u>not</u> the objective of this paper to provide a final, comprehensive evaluation of the possibility or consequences of a tank bump. Additional tank measurements and thermal hydraulic analyses are required for such a final and comprehensive treatise.

Significant Transients in Single Shell Waste Tank 241-C-106

The Hanford Single Shell Waste Tank 241-C-106 experienced an outage of the ventilation system (loss of exhaust fan) from January 25, 1992 to June 7, 1992. During the period from March 10 to June 15, 1994, a Process Test was conducted on the tank wherein no water was added to the tank. This was done to establish a lower liquid level in the tank to minimize the amount of liquid

lost if the tank were to develop a leak. Temperatures and other variables were measured and a video recording was made at specific times during the test. Upon addition of water at the end of the test, the three Riser #14 thermocouples in the waste exhibited a general increase in temperature reading that has resulted in a historic high temperature of 217 °F at the Riser #14 location. The thermocouples in Riser #8 continue to behave along historical patterns.

A concern has been raised (reference 1) that the evaporation rate from the pool of water overlying the waste sludge has recently diminished below expected values. This concern has been addressed in a separate position paper (reference 2). The conclusion is that current evaporation rate in C-106 is proceeding as expected based on about 14 years of historical data. Therefore, no significant thermal energy is being stored in the waste beyond historical levels.

It has also been suggested that the waste in the tank is behaving in a different manner (reference 3). It has been further suggested that a steam bump could occur in the immediate future that could result in a release of radioactivity to the environment (reference 1).

OBSERVATIONS AND CONCLUSIONS

Based on the data currently available to us, we have the following major observations and conclusions:

1. We have observed that the temperature measured at Riser #8 is presently cooler than the maximum temperatures measured during the ventilation fan outage from 1/25/92 to 6/7/92. Temperature differences between then and now are of the order of 40 °F.

2. No increase in radionuclide deposition on the discharge HEPA filter was observed from the tank in 1992 (see Appendix B, also reference 4). Also there was no replacement of the HEPA filter from 1989 to the present.

3. We conclude that the recent rapid increase in the temperatures measured by thermocouples in Riser #14 is due to sludge relocation around the thermocouple tree during or following the Process Test.

4. We conclude that there is the possibility at this time of a zone in the radial center of the sludge near the tank bottom that is at the saturation temperature. We also believe that this condition existed prior to performing the process test on C-106. The basis for this conclusion considers the uncertainties in our current calibrated 2-Dimensional thermal model.

5. It is our judgement that the zone at the saturation temperature will not initiate a bump because no bump occurred in 1992, the tank is cooler now than in 1992, and the waste properties have not significantly changed since 1992.

6. No bump is expected in the near future as a result of the Process Test because the tank is now operating at normal historical heat removal conditions.

7. A review of historical records (See Appendix C) suggest that the tank bump phenomenon occurred only in those tanks with high heat generation rates (>0.6 million Btu/hr), high hydrostatic pressure (>20 ft of head), high supernatant temperatures (> 212 °F), and high sludge temperatures (>240 °F). None of these conditions now exist in C-106. Therefore, based on historical data from several tanks we conclude that a bump in C-106 is not imminent. Furthermore no measured condition in the tank indicates a bump is likely to occur.

BACKGROUND INFORMATION ON C-106

Data Sources for this Evaluation

The data available for assessment of the possibility of a bump in the tank are listed in Table 1.

TABLE 1. DATA SOURCES AND THEIR CHARACTERISTICS.

DATA SOURCE	CHARACTERISTICS AND COMMENTS
RISER #8 T'COUPLES	Have been consistently measured over 13 years
RISER #14 T'COUPLES	Only available after 1992. Possibly not measuring sludge temperature until recently. Uncertain.
FIC GAUGE	Has consistently measured level over 18 years
IN-TANK VIDEO	Taken on 4/22/94, 6/15/94, 7/18/94, 8/2/94, 8/4/94
PSYCHROMETRIC DATA	Manually recorded infrequently
VENT FLOW RATE	Manually recorded infrequently
RADIATION LEVEL MEAS.	Frequently recorded over tank history
1986 CORE SAMPLE	Photos and data available. Sample gone.
EXHAUST PRESSURE	Manually recorded infrequently
METEOROLOGICAL DATA	Available over many years.
WATER ADDITION DATA (VOLUME, TEMPERATURE, SOURCE	Not systematically recorded

Measured and Calculated Temperatures during Ventilation Outage of 1992

During the period from 1/25/92 to 6/7/92 the ventilation fan for the tank was out of service (reference 5). During this time period the thermocouples in Riser #8 were being recorded but the thermocouples in Riser #14 were assumed inoperable, and hence not recorded.

Data provided by Tank Farm Operations (Appendix A) indicated that the C-106 HEPA filters were last replaced prior to 1990. Based on the information available from the Health Physics Group, the records show no increase in contamination on the HEPA filters from the outlet of the C106. The data on the HEPA filter surveys are included in Appendix B (also see reference 5). Therefore, we believe that there was no steam bump experienced during the ventilation outage of 1992.

Using a 2-dimensional transient thermal conduction model of the tank (reference 5), we estimate that the peak temperature on 6/7/92 in the middle of the tank was at or possibly above saturation. It was observed that the bottom thermocouple of Riser #8 peaked out at almost 200 °F (see Figure 1). The current **(8/1/94)** reading for the same thermocouple is approximately 160 °F. The current reading for the same thermocouple is slightly lower than it was prior to the ventilation outage. This small reduction from the 1992 value prior to the ventilation outage reflects the overall lower trend of tank temperatures caused by the decay of the radionuclides in the tank. From the mid-point of the ventilation outage to the present, the heat generation has decreased by about 5%.

The thermocouple readings in Riser #8 are currently quite consistent with their historical values, and imply that the heat storage and distribution mechanisms have not changed in the tank. The overall tank temperatures were 30-40 °F hotter during the ventilation outage than they are at present.

Predicted Temperatures in the Near Future

Table 2 shows the recent measured values **(8/1/94)** and current range of the predicted steady-state temperatures for the thermocouples in both trees (Risers #8 and #14). This estimate utilized the same model developed for tank C-106 using temperatures from the Riser #8 thermocouple tree calibrated to the 1992 ventilation outage event. The thermal model consists of a finite element model of the tank structure, the surrounding soil, and the waste in the tank. Appropriate boundary conditions were placed on the model based on the data available for the tank. The model assumes that all the thermocouples in Riser #14 are now in contact with radioactive sludge. Two values of evaporation heat removal were used. The first value, 75,000 Btu/hr, corresponds to the normal long-term historical evaporation rate based on FIC data and gives the lower values of predicted temperatures. The second value, 40,000 Btu/hr, corresponds to the typical short-term historical evaporation rate immediately following large water additions and gives the higher values of predicted temperatures. Figures 2 and 3 show the predicted steady-state temperature distribution in the tank for the cases of 75,000 and 40,000 Btu/hr evaporation heat removal rates. The maximum temperatures in the waste for the 75,000 and 40,000 Btu/hr evaporation rates are 233 and 240 °F respectively, and occur about 0.5 ft above the tank center bottom.

TABLE 2
MEASURED AND PREDICTED TEMPERATURES IN C-106
NORMAL AND REDUCED EVAPORATION RATE

RISER #/THERMOCOUPLE #/ELEV (ft in)[a]	MEASURED TEMPERATURE[b] 8/1/94 (°F)	STEADY-STATE PREDICTED TEMPERATURE[c,d] (°F)
RISER #14/ TC 1/ 0'0"	214	221 - 229
/ TC 2/ 2'0"	163	190 - 198
/ TC 3/ 4'0"	134	144 - 152
/ TC 4/ 6'0"	95	98 - 106
/ TC 5/ (AIR)	83	83 (INPUT)
RISER #8/ TC 1/ 0'2"	161	169 - 176
/ TC 2/ 2'2"	145	154 - 162
/ TC 3/ 4'2"	121	122 - 130
/ TC 4/ 6'2"	101	89 - 98
/ TC 5/ (AIR)	85	80 (INPUT)

a. Measured with respect to tank knuckle (reference for EIC reading)

b. Seasonal variation = (varies depending on depth, is at most about ± 5 °F)
Thermocouple accuracy = ± 5.0 °F accuracy; ± 4.0 °F repeatability (Reference 8)

c. Thermocouple location = (about 1 °F per inch in the vertical direction, uncertainty is ±2 inches)

d. The first value is for 75,000 Btu/hr evaporation; the second is for 40,000 Btu/hr evaporation

Estimated Liquid Saturation Temperature

An estimate has been made of the saturation temperature of the liquid due to both the effects of pressure and chemical constituents (reference 6). The pressure as a function of waste depth is given in Figure 4. This figure also shows the estimated saturation temperature. For example, the saturation temperature is estimated to be about 228 °F at the bottom of the tank[1]. The small increase in the saturation temperature above that of pure water is based on chemical constituents identified by a liquid grab sample taken in 1990. This number is for a liquid depth of 70 inches measured from the bottom of the tank. Tank C-106 has a "dished" bottom and liquid level (FIC) data are

[1] Tank C-106 has a dished bottom and level data are referenced to distance above the knuckle of the tank. The depression at the center of the tank is 12 inches. This increase in hydrostatic head is not accounted for in Figure 4.

referenced to distance above the knuckle of the tank[2]. The depression at the center of the tank is 12 inches. Thus for a liquid level (FIC) height of 69 in., the total depth to the bottom center is 81 in. This translates to a boiling temperature at the bottom center of the tank of about 229 °F. For a liquid level (FIC) height of 79 in., 91-in., total to bottom center, the boiling temperature is about 231 °F.

EVALUATION OF THE POTENTIAL FOR A TANK BUMP

Physics of Tank Bumps

Tank bumps are caused by the rising of steam and hot sludge or superheated water into a region of the waste with lower saturation pressure. The result is flashing of the superheated water that combined with the expansion of the steam already present produces enough steam volume to drive the tank dome space pressure positive.

Evaluation Process

We used the following steps to evaluate the potential for a bump (as defined in the Introduction):

- Define the minimum requirements (conditions) for a bump to occur;
- Determine which conditions could have been present in 1992 such that a bump did not occur during that time;
- Compare present conditions with those in 1992;
- Evaluate whether any conditions (ambient, waste, etc.) could have changed since 1992 that would affect the likelihood of a bump; and
- Reach conclusions about the likelihood of a bump occurring in the near future.

Minimum Requirements for a Bump

We have endeavored to define the conditions that must be met for a tank "bump" to occur. Repeating what was stated in the Introduction, by "bump" we mean the formation and rapid expulsion of a steam bubble from the waste of adequate volume to drive the tank pressure positive with respect to atmospheric pressure and result in a measurable increase in radioactivity on the tank HEPA filter. These requirements have been described in reference 7. All of the following conditions must be met:

1. At some location, the waste temperature must reach the liquid saturation temperature at the same location

$$T_{waste} = T_{sat}$$

[2]WC Miller, personal communication, August 8, 1994.

To achieve this requires poor heat removal ($Q_{removal} < Q_{generation}$) in a local zone caused by:

- o Low thermal conductivity, and/or
- o Low or no convection.[3]

2. There must be <u>sufficient sludge mobility</u> such that a significant mass can rise to the sludge surface without condensing.

3. For fluidic waste, there must be <u>sufficient sludge shear strength/viscosity</u> to trap enough steam bubbles such that the buoyant force exceeds the shear strength. For porous waste, the permeability is the controlling parameter.

4. There must be <u>sufficient hydrostatic head</u> in a local zone where the saturation temperature has been reached such that vapor generation (flashing) will occur if the material is transported to a higher elevation.

5. Some waste must exceed the supernatant saturation temperature.

$$T_{waste} > T_{sat\ supernatant}$$

WHC Has Reasonable Assurance a "Bump" did not occur during Ventilation Outage in 1992

It was noted that there is substantial evidence based on the absence of a radionuclide release to the HEPA filter that no bump occurred in 1992. Since there was no bump, some of the conditions defined above must have been absent.

Based on the 2-D heat conduction model that was calibrated based on the Riser #8 thermocouples, it appears that near the end of the ventilation outage, at least two of the required conditions were met as follows:

- o Some waste exceeded the supernatant saturation temperature of 214 °F, i.e.

$$T_{waste} > T_{sat\ supernatant}$$

- o It is likely that there was a zone in which the waste temperature reached the local liquid saturation temperature, i.e. $T_{waste} = T_{sat}$.

---

[3] In this context, low or no convection means either interstitial flow in porous media or refers to suspended-particle-laden flow.

Since no bump was observed in the 1992 event, we have concluded that either or both of the following two conditions existed at that time that prevented a bump:

- There was sufficient heat transport within the sludge to cool and condense the steam bubbles.
  Based on the Riser #8 thermocouple data, the temperature gradient in the tank did not increase.

- There was insufficient sludge shear strength to retain significant vapor bubbles in the local zone that was above saturation temperature.
  Based on the photographs of the core sample in 1986, it can be seen that all of the sludge possesses shear strength because the sample remained intact or retained the shape of "globs". However, this shear strength in the majority of the sludge apparently could not retain large amounts of vapor.

Several additional scenarios have been addressed. One scenario assumed that the vapor bubbles generated were retained in the sludge. Another scenario assumed that vapor bubbles were generated, migrated, and were trapped under an impenetrable surface crust. A third scenario assumed that the steam was released slowly from a low permeability crust at a rate that did not pressurize the dome gas space or transport particles to the HEPA filter. No matter which scenario is postulated, it was concluded that four months without substantial heat removal from the tank was not enough time to develop conditions that result in a bump, or the tank conditions and waste properties precluded a bump.

Potential Differences between the Conditions of 1992 and Present

This section addresses the question, If there was no "bump" in 1992, why might one occur in the future? Two conditions are suggested:

1. The local waste temperatures might be or become higher and/or

2. The local waste properties and/or configuration might be or become changed.

On evaluating these conditions, four possible changes were identified that address the two points above. These four changes are listed below with a discussion of the likelihood of each.

1. The exposed sludge surface may have dried creating a layer that is less permeable to bubbles.
   It is seen from the video of 6/17 that about 50% of the sludge was covered by water prior to water additions. Thus the process test did not dry out nearly all of the sludge surface. The temperatures in Riser #8 did not increase beyond seasonal norms even though this area was exposed to air. Also, we can observe in the video many holes in the sludge surface.

2. The energy transport properties of the upper sludge may have decreased.
   Only part of the sludge surface was exposed to air. The only zone of concern is a zone where $T_{waste} = T_{sat}$ which is presumably at the tank center, most of which remained covered by liquid based on video observations. Also see statement 1 above.

3. The sludge temperature may have increased while the sludge surface was exposed.
   Based on Riser #8 thermocouples, the temperatures since June 1992 have always been lower than they were then, and were close to seasonally adjusted historical norm.

4. The sludge may have been redistributed and become compacted.
   Sludge redistribution could not have substantially changed the shear strength. If anything, redistribution should have reduced it.

Comparison of Energy Stored in Tank Sludge

An alternate means of assessing the potential for a tank bump in C-106 is to compare the amount of energy stored in the sludge which is potentially available for a bump with the similar value for C-106 at different times in its history, and with tanks that actually experienced a bump. Waste properties are also important in assessing the potential for a bump; these data have not been evaluated for these tanks. The amount of energy which is potentially available for a bump is assumed to be the energy above the saturation temperature contained in the volume of the sludge which is above the saturation temperature. Several simplifying assumptions were necessary to make this comparison, as noted in Table 3. Conservative assumptions were also made for the current temperature of the C-106 sludge. These resulted in a maximum possible increase by a factor of approximately 3 in tank C-106 energy available for a bump after the process test as compared with that before the process test, as shown in Table 3. Even with the conservative assumptions, the results indicate that the current energy within C-106 which is potentially available for a bump is still 10 times less than that which the tank contained during the 1992 ventilation outage, and 20 to 100 times less than that estimated in tanks which did experience a bump.

These results add corroborating evidence that the conditions within C-106 are significantly below those necessary to initiate a bump event.

In summary, it is the author's judgement that the zone that might be at the saturation temperature or might reach the saturation temperature in C-106 will not initiate a bump, based on current conditions in the tank.

TABLE 3. COMPARISON OF ENERGY STORED IN TANK SLUDGE[1].

Tank	Bumped	Sludge volume > T_{sat} (gallons)[2,4]	T_{sludge}[3,5] (°F)	Energy available for bump (Btu)[6]	Stored waste energy above 70°F (Btu)[7]
C106 average	No	5000	227	0.6×10^6	3×10^8
C106 now	No	10,000	240	2×10^6	3×10^8
C106 1992	No	63,000	260	24×10^6	3×10^8
104S	Yes	220,000	>240	56×10^6	8×10^8
101S	Yes	220,000	>240	56×10^6	8×10^8
101SX	Yes	220,000	300	15×10^7	9×10^8
104SX	Yes	220,000	290	14×10^7	9×10^8
114SX	Yes	220,000	357	26×10^7	10×10^8
105A	Yes	220,000	310	17×10^7	9×10^8
101AX	Yes	220,000	260	9×10^7	8×10^8

[1] Sludge volumes are estimated and not are not based on historical records. Temperatures are measured values and may not represent peak temperatures in the waste. Therefore, energy levels are only approximations.

[2] For the historical bumps, the sludge volume above saturation is based on the tank being filled 20 to 30 ft depth with sludge and supernate and the additional assumption is made that the sludge layer makes up 1/3 of the total filled value of the tank.

[3] It is assumed that all of the sludge is at the measured sludge temperature for the tanks that bumped.

[4] For C-106 the volume of sludge that is considered to be above saturation is based on a calibrated 2-D conduction model.

[5] The sludge temperature for C-106 is taken to be the maximum temperature predicted by the same model used to evaluate the volume. The conservative assumption is made that local boiling does not occur.

[6] These values have the following bases:
a) $Q = C \times \text{sludge volume} \times (T_{sludge} - T_{sat})$
b) $C = 8.31$ Btu/gallon-°F
c) $T_{sat} = 212$ °F

[7] These values are calculated based on:
$Q = C \times [\text{sludge volume}(T_{sludge} - 70) + \text{supernate volume}(T_{sat} - 70)]$

ADDITIONAL DATA NEEDED

There are additional data that need to be gathered and analyses that need to be performed to complete the assessment of a possible bump. To complete this assessment in the most rapid and effective manner the following recommendations are made.

Based on the present information and conclusions, tank C-106 should continue to be monitored in detail. Additional data need to be obtained and these data are listed below. All of these were presented in reference 2.

1. As soon as possible, provide a means for continuous psychrometric measurements of inlet and exit air, continuous tank pressure measurements, and continuous air flow rate measurements. These are needed to independently confirm the evaporation rate.

2. When water is added to the tank, record the makeup water temperature as well as the volume. This information is needed to help confirm the evaporation rate.

3. For the next 3 water additions, have a sample of the makeup subjected to a chemical analysis for its major impurities. This information is needed to help confirm the evaporation rate by determining whether chemical reactions are initiated by makeup water addition.

4. As soon as possible, obtain a grab sample of the supernatant from the tank. This sample is needed to confirm the vapor-pressure-versus-temperature behavior of the supernatant.

5. As soon as possible, provide a means for continuous or daily measurement of the supernatant temperature. This information is needed to help confirm the evaporation rate.

6. It is desirable but not required to add an ENRAF level measurement gauge. This has the potential to provide more accurate and continuous level measurements.

PROPOSED CRITERIA RELATED TO WORK RESTRICTIONS FOR C-106

It is recognized that conclusions drawn in this report are based in part on engineering judgement. Therefore, it is prudent that criteria be established to assess when it is appropriate to remove current work restrictions in the C Farm for worker safety. In addition, it is appropriate that criteria be established for the future operations of this tank to determine if the level of uncertainty related to a potential tank bump increases. These criteria would be used to evaluate appropriate actions if tank conditions had changed.

Proposed general criteria for these evolutions are presented below.

Proposed Required Conditions for Return to Normal Operations in C Farm Except for Intrusion into the C-106 Sludge

There are three general conditions that will provide sufficient assurance a tank bump event will not occur in C-106 that normal operations can safely be resumed. These conditions are indications that no significant global energy storage is occurring. The restrictions which could be eliminated include suspending the use of respirators, removal of restrictions on access and work within C Farm, and entry into tank C-106. Disturbance of the C-106 supernatant (e.g., placement of a thermocouple) is acceptable if the conditions listed below are met. However, further evaluation is needed before a determination can be made of the need for additional conditions, if any, which might be required prior to intrusion into the C-106 sludge.

All three of following conditions should be met before removing the current work restrictions:

1. Verification of evaporative cooling -- Evaporative cooling must return to historical norms, accounting for the observed variations in evaporation rate following water additions as well as seasonal variations. This criterion could be measured as average level change in the tank from FIC data over a fixed period of time.

   Basis: This ensures that heat is being removed from the sludge at historical levels, thereby limiting the amount of heat that can be stored in the waste.

2. Measured Sludge temperature not increasing -- The temperature of the sludge must not be increasing at a rate greater than seasonally adjusted historical norms. This criterion could be measured as the average temperature increase per day over a period of several days.

   Basis: This ensures that unusual amounts of heat are not being stored in the sludge as an independent check that evaporative cooling is occurring, and that changes to the sludge which are global or local near the thermocouple trees are not occurring.

3. Measured Sludge temperature not exceeding historical norms -- The temperature of the sludge in the regions of the tank where we have reasonable historical data must not exceed historical maxima. This criterion could be measured as the temperature of each of the Riser #8 thermocouples in the sludge not having exceeded the historical maximum temperatures for those locations in the tank. The measurements should account for measurement accuracy and seasonal ambient conditions. Unusual operating periods, such as the 1992 loss of ventilation event, should be excluded.

   Basis: This is an independent assessment that heat is not being stored in the sludge at levels significantly above historical norms.

Changes in tank vapor space pressure caused by opening and closing risers have been considered and are not expected to increase the risk of a sudden vapor release from saturated liquids in the tank.

Proposed Conditions that Require Return to Restricted Operations

It is prudent to establish and maintain a set of conservative criteria which, if exceeded, would require additional evaluation, and potentially preventative actions, to assure worker safety is maintained around tank C-106. These criteria could be used as an early indication that the potential for a tank bump might be increasing in tank C-106.

If any of the criteria listed below are exceeded, the appropriate action would be to terminate all work in or on C-106 except surveillance and radiological monitoring activities. This work should remain suspended until the C-106 Technical Review Group has met and technical resolution is provided.

The general criteria for imposing work restrictions with C-106 are:

1. Sludge temperatures exceed normal historical maxima -- The temperature of the sludge in the regions of the tank where we have reasonable historical data must not exceed historical maxima beyond a small bound allowing for thermocouple repeatability error. This criterion could be measured as the temperature of each of the Riser #8 thermocouples in the sludge not having exceeded a limit (e.g., 5 °F) above the historical maximum temperatures for those locations in the tank. This criterion should include an additional requirement that the Riser #14 bottom thermocouple reach an average temperature indicative of the saturation temperature. This thermocouple is the only one in Riser #14 which appears to accurately register sludge temperature, and this thermocouple is already quite near the saturation temperature. The measurements should account for measurement accuracy and seasonal ambient conditions. Unusual operating periods, such as the 1992 loss of ventilation event, should be excluded.

   Basis: This is an assessment that heat is not being stored in the sludge at levels significantly above historical norms.

2. Sludge temperature rate of increasing -- The temperature of the sludge must not be increasing at a rate that is substantially greater than seasonally adjusted historical norms. This criterion could be measured as the average temperature increase per day over a period of several days.

   Basis: This ensures that unusual amounts of heat are not being stored in the sludge and that unusual redistribution of the sludge which is global or local near the thermocouple trees is not occurring.

3. Exhaust fan is not operational -- The C-106 exhaust fan must not be out of service for longer than a predetermined time (e.g., 2 months).

   Basis: This ensures that evaporative cooling is not lost for an unacceptable time period, thereby preventing an increase in the stored energy in the sludge to levels approaching that experienced in 1992.

PRIME CANDIDATE PREVENTATIVE ACTIONS

It is important to understand that the thermal inertia of the tank is so large that weeks are required for significant changes in the average temperature. This also means that changes in heat removal require weeks

before they will have an effect. Thus, the response time over which action can be taken is in the order of days rather than hours or seconds as in other common heat-generating systems.

It is the judgement of the authors that the following heat removal management methods have the most likely chance of rapid implementation and effective performance:

A. Increase in ventilation flow rate to the maximum capability of the existing exhaust blower.
   It is believed that the blower has a maximum capability of about 7,000 scfm. This change can be implemented in approximately one shift.
   (Note: Care must be taken, when implementing this step, that the tank limits on negative gage pressure are not exceeded.

B. Install an air chiller on the inlet to C-106.
   A chiller can be obtained within days and possibly installed within days.

C. Add chilled water (about 35 °F) to the tank.

REFERENCES

1. Agnew, S. F., July 28, 1992, CST-14:94-sfa209a, Los Alamos National Laboratory, Los Alamos, New Mexico.

2. Crea, B. A., and Bander, T. J., *Assessment of Hanford Waste Tank 241-C-106 Historical Water Addition and Evaporation Data*, draft July 31, 1994, Westinghouse Hanford Company, Richland, Washington.

3. Agnew, S. F., July 21, 1992, CST-14:94-sfa202a, Los Alamos National Laboratory, Los Alamos, New Mexico.

4. Hevland, M. E., August 1994 (To be Issued), *Reference for records on maintenance & radioactivity measurements in Tank Farms*, Westinghouse Hanford Company, Richland, Washington.

5. Bander, T. J., April 1993, *Revised Thermal History of Tank 241-C-106*, WHC-SD-WM-ER-200, Westinghouse Hanford Company, Richland, Washington.

6. Reynolds, D. A., August 3, 1994, *Estimated Boiling Point of the Liquid in 241-C-106*, 7E310-94-039, Westinghouse Hanford Company, Richland, Washington.

7. Sathyanaryana, K., Fryer, B. C., and Thurgood, M. J., July 26, 1994, *"Summary Report Thermal Hydraulic Safety Analysis of Aging Waste Tank 101-AZ"*, WHC-SD-WM-ER-335, Westinghouse Hanford Company, Richland, Washington.

8. Scaief, C. C.,June 1991, *Temperature Measurement Error Analysis*, WHC-SD-WM-TI-483, Westinghouse Hanford Company, Richland, Washington.

APPENDIX A
106-C HEPA FILTER CHANGE

[105] From: William C (Bill) Miller at ~WHC352 8/5/94 6:46AM (1044 bytes: 7 ln)
Priority: Urgent
To: Tristram B III McCall at ~WHC63, Blaine A Crea at ~WHC244, Thomas J Bander at ~WHC244, Susan K Winter at ~WHC71, Donald M Ogden at ~WHC63
Subject: 106-C HEPA FILTER CHANGE

---------- Forwarded ----------

From: Randolph Ni at ~WHC129 8/4/94 4:00PM (702 bytes: 7 ln)
To: William C (Bill) Miller at ~WHC352
Subject: 106-C HEPA FILTER CHANGE

---------- Forwarded ----------

From: John A Kimbrough at ~WHC174 8/4/94 2:58PM (510 bytes: 7 ln)
To: Randolph Ni at ~WHC129, Douglas W Craig at ~WHC129
Subject: 106-C HEPA FILTER CHANGE

---------- Message Contents ----------

Have completed a search of the JCS data base, both active and archive files, and have found no documentation showing a change out of either the inlet or outlet HEPA filters since 1989.

John K.
Production Manager, East

APPENDIX B
RECORDS ON RADIATION MONITORING AT C-106 EXHAUST HEPA FILTER

Pam Olsen: TWRS Health Physics Technical Support Group, Senior Health Physicist (8/4/94/1300)

The C-farm portable exhauster exhausts air from tanks C-105 and C-106. The exhauster readings contained in the table were taken at the location of the first HEPA filter after the de-entrainer at a predetermined checkpoint. The table is a summary of information through the dates specified. The information was summarized from Scheduled Radiation Survey Reports for East Tank Farm Health Physics' task number ED-17.

DATE	DOSE RATE (mrem/hr)
January 1, 1992	50
January 2, 1992	46
January 3, 1992	50
January 4, 1992	44
January 5, 1992	60
January 8, 1992	49
January 9, 1992	47
January 10, 1992	50
January 11, 1992	50
May 22, 1992	38
June 4, 1992	43
June 6, 1992	40
June 8, 1992	40
June 9, 1992	40
June 10, 1992	40
June 16, 1992	39
June 25, 1992	70
June 26, 1992	40
June 27, 1992	40
June 28, 1992	40
June 29, 1992	40
June 30, 1992	40
July 1, 1992	40
July 2, 1992	43

July 3, 1992	42
July 4, 1992	38
July 5, 1992	40
July 6, 1992	40
July 7, 1992	38
July 18, 1992	40
July 19, 1992	40
July 20, 1992	40
July 30, 1992	37
July 31, 1992	39
August 1, 1992	40
August 2, 1992	42
August 3, 1992	40
August 4, 1992	40
August 5, 1992	40
August 6, 1992	40
August 7, 1992	40
August 8, 1992	40
August 9, 1992	40
August 10, 1992	45
August 11, 1992	35
August 12, 1992	45
August 27, 1992	50
September 5, 1992	40
September 6, 1992	44
September 7, 1992	45
September 9, 1992	46

APPENDIX C
HISTORY OF TANK BUMPS IN AGING WASTE TANKS

1990 48

ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT 120849

(Receiving Organization) Tank Farm Projects	3. From: (Originating Organization) Waste Operations Project Safety
5. Proj/Prog/Dept/Div: Waste Management 39510	6. Cog/Proj Engr: R. B. Bendixsen

4. Related EDT No:

7. Purchase Order No:

9. Equip/Component No:

10. System/Bldg/Facility: 241-AY, AZ

12. Major Assm Dwg No:

13. Permit/Permit Application No.

14. Required Response Date: none

8. Originator Remarks:

The information in this provides safety documentation for the Aging Waste Facility.

11. Receiver Remarks:

15. DATA TRANSMITTED

(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev No.	(E) Title or Description of Data Transmitted	(F) Impact Level	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition
1	WHC-SD-WM-TA-021	All	0	History of Tank Bumps in Aging Waste Tank Farms	4	2		

16. KEY

Impact Level (F)	Reason for Transmittal (G)		Disposition (H) & (I)	
1, 2, 3, or 4 see MRP 5.43 and EP-1.7	1. Approval	4. Review	1. Approved	4. Reviewed no/comment
	2. Release	5. Post-Review	2. Approved w/comment	5. Reviewed w/comment
	3. Information	6. Dist (Receipt Acknow. Required)	3. Disapproved w/comment	6. Receipt acknowledged

17. SIGNATURE/DISTRIBUTION (See Impact Level for required signatures)

(G) Reason	(H) Disp	(J) Name	(K) Signature	(L) Date	(M) MSIN	(J) Name	(K) Signature	(L) Date	(M) MSIN	(G) Reason	(H) Disp
1	1	Cog/Proj. Eng R. B. Bendixsen (5)			R2-05	J. L. Foster			R1-51	3	
1	1	Cog/Proj. Eng. Mgr. L. E. Johnson			R2-05	J. P. Hinckley			R3-02	3	
3		QA J. A. Peltier			S1-54	E. M. Nordquist			R3-38	3	
3		Safety V. J. Moss			R3-08	J. J. Zimmer			R2-05	3	
3		L. M. Bergmann			R1-51	CENTRAL FILES (Orig + 3)			L8-04		
3		K. G. Carothers			R1-51						
		G. L. Dunford			R1-51						

Signature of EDT Originator	Date 3 Apr 1990	19. Authorized Representative for Receiving Organization	Date
20. Cognizant/Project Engineer's Manager	Date 4-3-90	21. DOE APPROVAL (if required) Ltr No. ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments	

80-7400-172 (2/89)

SUPPORTING DOCUMENT

1. Total Pages 13

2. Title
HISTORY OF TANK BUMPS IN AGING WASTE TANK FARMS

3. Number
WHC-SD- WM-TA-021

4. Rev. No.
0

5. Key Words
Tank Bumps, Aging Waste, 241-AY, 2Y-AZ

APPROVED FOR PUBLIC RELEASE
9/26/94 KMB

6. Author
R. B. Bendixsen
Name (Type or Print)
R B Bendixsen 4 Apr 1990
Signature
39510
Organization/Charge Code

7. Abstract

Irradiated fuels from the Hanford Reactors have been processed through separations facilities for recovery of Uranium Plutonium and other useful isotopes. Nearly all of the fission products are collected in a single small volume aqueous waste stream, neutralized with sodium hydroxide and stored in large underground Aging Waste Tanks. Several tanks during the history of Aging Waste tanks have had "tank bumps", a phenomena where the tank pressurizes from gas generation, principally steam generation. This report summarizes the data of tank bumps for East and West areas correlating the bumping phenomena with tank heat generating rates and air lift circulator operation. Tank bumps occurred in boiling tanks having heat generating rates greater than 1.0 million Btu/h.

8. **PURPOSE AND USE OF DOCUMENT** – This document was prepared for use within Westinghouse Hanford Company and is to be used only to perform, direct, or integrate work under U.S. Department of Energy contracts. **DISTRIBUTION EXTERNAL TO WHC REQUIRES THE APPROPRIATE DOCUMENT CLEARANCE.**

PATENT STATUS – This document copy, since it is transmitted in advance of patent clearance, is made available in confidence solely for use in performance of work under contracts with the U.S. Department of Energy. This document is not to be published nor its contents otherwise disseminated or used for purposes other than specified above before patent approval for such release or use has been secured, upon request, from the U.S. Department of Energy, Patent Attorney, Richland Operations Office, Richland, WA.

DISCLAIMER – This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors or their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or any third party's use or the results of such use of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or subcontractors. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof

9. Impact Level 4

10. L. E. Johnson
Authorized Manager's Name (Type or Print)
Authorized Manager's Signature
Specify Distribution Limit Sponsor Limited

11. **RELEASE STAMP**

RELEASED
DISTRIBUTION LIMITS
☐ INTERNAL ONLY
☒ SPONSOR LIMITED
☐ EXTERNAL
DATE: APR 6 1990

WHC-SD-WM-TA-021 Rev.0
Pages 1-2

These pages were intentionally left blank.

Introduction.

Irradiated fuels from the Hanford reactors have been processed through separations facilities (B Plant, T Plant, REDOX and PUREX) for recovery of Plutonium, Uranium and other useful isotopes. Nearly all of the fission products (>99.99%) and process chemicals are collected in a single small volume aqueous waste stream, neutralized with sodium hydroxide and stored in large underground aging waste tanks. Normal practice was to add the waste continually to an aging waste tank while holding a constant volume in the tank allowing the wastes in the tank to self-concentrate from the fission product decay heat. As the tank is filled, the waste separates into an insoluble sludge layer and a supernatant liquid. Nearly all of the fission product heat is associated with the sludge layer.

The first aging waste tanks were classified as non-boiling tanks since, in the judgement of engineering and operations, the tanks did not have the liquid level variations and temperature associated with a boiling liquid. An aging waste tank was considered to be boiling if the liquid level was unstable, i.e. the liquid level appeared to vary by more than 1 inch, and the tank supernate temperature was at or near the boiling temperature of the supernate (212 to 220 ^{o}F). The non-boiling tank farms are AW, AP, B, BX, BY, C, S, SY, T, TX, TY and U Tank Farms. Tank Farms AW, AP, C and TY did not receive aging waste directly from the separations facilities. The earlier constructed aging waste tank farms (B, BX, BY, S, T, TX and U - total of 90 tanks) received aging waste but were non-boiling tanks because the heat content of the waste stored in the tanks was not high enough to cause the tanks to boil.

Several tanks in S Tank Farm did boil (101-S, 104-S, 107-S and 110-S) even though the tank farm was classified as a non-boiling tank farm. These S Farm tanks were the first tank in a series of 3 cascading tanks. For example, Tank 110-S received waste from REDOX which overflowed to Tank 111-S which overflowed to Tank 112-S. A majority of the solids precipitated in the first tank, 110-S, bringing the tank supernate to a boil. Several changes were made for tanks receiving subsequent aging wastes which provided sufficient heat for the tanks to boil:

1. Tank size was increased from .5 and .75 million gallons of storage to 1.0 million gallons of storage. This increased the amount of heat generating radionuclides that could be stored in a tank.

2. "In November 1954, the REDOX process was modified to include a single-stage backcycle and reuse of wastes, thereby reducing the volume of stored wastes per ton of uranium processed by about 30%.", Reference 2. This also increased the amount of heat generating radionuclides in a tank.

3. The PUREX process generated an aging waste stream containing roughly twice the concentration of radionuclides and one third of the sodium molarity. Therefore, the wastes from PUREX could be concentrated about 6 times as much as the REDOX waste. This increased the amount of heat producing isotopes that could be stored in East Area aging waste tanks.

Most of the tanks in SX (except 102-SX, 103-SX, 105-SX, and 106-SX), A and AX Tank Farms were classified as boiling aging waste tanks (total of 21 aging waste tanks that were classified as boiling).

Prior to installation of air lift circulators (ALC), heat was removed from the aging waste sludge layer by conduction and percolation of supernate through the sludge with the latter perceived as being the major mechanism for heat removal. With increasing layers of sludge in an aging waste tank and as the supernate becomes more concentrated with soluble ions, heat removal from the sludge layer becomes more difficult. Past operating experience reveals that control of peak temperatures (Reference 1) and tank bumps in aging waste tanks has presented challenges for safe operation of the aging waste tanks. This report discusses the topic of tank bumps in aging waste tanks. The purpose of collecting this information is to provide information for the Aging Waste Facility Safety Analysis Report (AWF SAR) accident scenario, the "tank bump".

Discussion.

Tank bumping in aging waste tanks was first observed in the S Tank Farm in the 200 West Area. Prior to 1952, the heat content in aging waste tanks was dissipated to the ground without creating a boiling temperature in any tank. To supplement heat transfer to the ground surrounding the aging waste tanks, air cooled heat exchangers were installed above ground on the S tanks providing additional heat transfer by reflux condensing. As more aging waste was added to tanks in S Tank Farm, some of the air cooled heat exchangers were converted to a water sprayed air condenser and an auxiliary water-cooled heat exchanger was installed on Tanks 101-S and 104-S. Two ventilation systems (SX-401 and SX-402) with water cooled condensers were added in SX Tank Farm. These additional systems for S and SX Tank Farms provided more heat removal capacity to prevent steam from escaping from the boiling tanks.

A characteristic of the boiling aging waste tanks, first observed in Tank 104-S in 1953, was measurable pressure variations in the tank. Investigations of the phenomena provided measurements of both the duration and maximum pressure in the tanks. A feature of the pressure variations would be temporary increases in condensate flow from the condensers. When first observed, the pressure surges were small but increased both in intensity and duration as the heat content of the aging waste tanks was increased. The term "bumping" was first applied to tanks in which the pressure variations were responsible for contamination spread from the tanks to the area surrounding the tanks.

Bumping, as applied to aging waste tanks, is envisioned as a process occurring in or just above the sludge layer. Sludge heat transfer rates are low causing the sludge to increase in temperature above the supernate temperature. The sludge increases in temperature until either a fissure develops in the sludge, supernate percolates through the sludge or mixing by the airlift circulators (ALC) allows the supernate to mix with the hot sludge. Also, the hydrostatic head of liquid above the sludge layer may delay the formation of steam bubbles until the hot liquid rises to a point at which the decreasing liquid pressure allows the steam bubble to form. By either mechanism, the hot sludge transfers heat to the supernate causing steam bubbles to form which rise to the surface of the supernate. The steam bubbles can be small or large depending on the amount and rate of energy transferred from the hot sludge to the supernate. If the energy release is sudden and of sufficient magnitude, the steam released to the tank vapor space causes temporary pressurization of the tank with an increased condensate flow rate from the condensers. During tank pressurization (ie. the tank bumps), steam escapes from risers, pumps pits and the ventilation equipment. The escaping steam carries liquid from the tank in the form of micron size aerosol droplets. The aerosol, in most tank bumps, is transported through the atmosphere contaminating the area surrounding the tank.

There have been various methods utilized in an attempt to control pressure variations in the aging waste tanks. First, an auger was installed in Tank 101-SX which was partially successful in preventing bumping (Reference 2). The primary purpose of the auger was a "crust breaker" since many of the early aging waste tanks contained a floating crust. It was theorized that a floating crust would prevent steam bubbles from leaving the tank and the steam bubbles would collect underneath the crust. When the pressure underneath the crust became excessive, the crust would either break up or be turned over by the underneath pressure and cause a tank "roll over". The characteristics of a tank roll over was pressurization of the tank, steam escaping from tank openings and trembling of the ground. The auger also provided for mixing of the sludge layer with the supernate layer and was successful in reducing the number of tank bumps in 101-SX.

Next, an air sparger was installed in Tank 104-SX. The purpose of the sparger was to mildly agitate the supernate, thereby increasing heat transfer between the sludge and the supernate to prevent tank bumping. The sparger in 104-SX was successful in preventing tank bumping. The only recorded 104-SX bump occurred when the sparger air supply failed (Reference 3). The success of the 104-SX sparger provided the impetus for developing the ALC.

The ALC have been the most successful method used to prevent tank bumping. As succeeding tank farms have been constructed, the number of ALC per tank has been increased in an attempt to mitigate the occurrence of either a tank bump or an excessive sludge temperature. Each of the later built tanks in the SX Tank Farm (107-SX through 115-SX) and A Tank Farm contained 4 ALC and each tank in the AX Tank Farm contained 22 ALC. The current aging waste tanks in AY and AZ tank farms each contain 22 ALC. Past operating experience has shown that continuous operation of the ALC prevents tank bumping. The remainder of this report provides a list of the known tank bumps with the conditions which caused bumping, Table I.

The "tank bump" has been discussed for the past several years as one of the credible accident scenarios for the AWF SAR. Briefly, the accident scenario involves shutdown of the ALC with simultaneous loss of tank ventilation. A tornado or earthquake is the postulated initiating event triggering simultaneous loss of the air supply for the ALC and shutdown of the ventilation equipment. Without mild agitation of the aging waste solution (continuous ALC operation), the solution/sludge in the aging waste tank heats to the boiling point. The solids, without mild agitation of the supernate, heat above the boiling point of the solution providing a thermally hot sludge layer. A triggering event next occurs in which the stored heat energy in the sludge is transferred to the solution causing steam bubble formation. The steam bubbles rise to the surface of the liquid, pressurize the tank and blow a steam-aerosol mixture into the atmosphere. The aerosol, containing fission products, is subsequently transported through the atmosphere contaminating the area downwind of the tank.

The available documented information of tank bumps (Table 1) suggests that all of the following conditions are necessary for a tank bump to occur:

1. The tank contains aging waste and is boiling.

2. Heat generation of the aging waste is greater than 1.0 million Btu/hr.

3. In order to have a bump, the ALC must be off allowing the sludge to accumulate stored energy. Next, an initiating event, (ie. the ALC are turned back on or a fissure forms in the sludge) occurs providing for mixing of the hot sludge with the boiling supernate.

4. The tank sludge temperature is greater than 240 ^{o}F.

When a tank bumps, the following are likely to occur (Table 1):

1. The tank pressurizes above .7 psig (20 in. of water gage) and steam is exhausted from the tank through the available openings.

2. The area surrounding the tank becomes contaminated. There is only one case in which the area was not contaminated (101-AX).

The heat content of Tanks 101-S and 104-S in S Tank Farm are based on the measured condensate flow from the water cooled condensers installed above the tanks. These heat content values do not include heat losses through the tank walls, dome and base to the surrounding ground and do not include heat losses to the water-cooled air condensers. Heat losses to the ground have been estimated to be 250,000 to 500,000 Btu/hr (Reference 2). Heat loss to the air cooled condensers were calculated to be 240,000 Btu/hr for each condenser (101-S and 104-S each had 2 air-cooled condensers) with the water jacket increasing the heat transfer by up to 10 times the air cooling rate. Therefore, the radionuclide heat generation rate for tanks 101-S and 104-S was between 1.3 and 2 million Btu/hr. The heat generating rates for tanks 101-SX and 104-SX are based on measured condensate flow rates (Reference 2). A value of 2.0 million was selected for 114-SX taking into consideration that it had 4 operating ALC and was receiving aging waste similar to the other SX Farm aging waste tanks.

The heat content for tanks 105-A and 101-AX are based on the fill history for these two tanks and the standards for operational control of the aging waste tanks in East Area (Reference 7). The standard maximum boil-off rate (Reference 7) was established at 20 gallons per minute. A typical value of 15 gallons per minute (7 million Btu/hr) boil-off rate was selected for tanks 105-A and 101-AX considering the fill schedule and bump date for these tanks.

Tank 105-A is a special case since the tank bump was caused primarily by the bottom bulging instead of loss of air flow to the ALC and turning the ALC back on. Tank 105-A is included in Table 1 for completeness since it is also classified as a tank bump. The other tanks having a bottom bulge (107-SX, 108-SX, 111-SX and 112-SX) are not included in Table 1 since there has been no information found suggesting that these tanks had a tank bump.

Not included in Table 1 are tank pressurizations caused when the ventilation systems shut down. For instance, there have been steam releases in East Area from the 152-AX Diverter Station when the 702-A ventilation system was inadvertently shut down. Since some of the tanks were boiling, the aging waste tanks pressurized slightly exhausting steam from risers and 152-AX until the ventilation system was restored.

An aging waste tank bump was envisioned as a worst case accident for the AWF SAR when the maximum heat content of an aging waste tank was determined to be 4.0 million Btu/hr (Reference 8). This scenario is consistent with past operating experience which indicates that the heat content of 200 East Area boiling aging waste tanks, having multiple ALC, is above 3.4 million Btu/hr for the tank to be considered a boiling aging waste tank (Reference 9). With the shutdown of N Reactor and less fuel being available for processing through PUREX, the maximum heat content of an aging waste tank was estimated to be 690,000 Btu/hr (Reference 10). This estimate is based on an aggressive PUREX processing schedule. Obviously, the heat content of the maximum aging waste tank is continually decreasing since PUREX has been shutdown and PUREX restart is being pushed into the future. The fuel scheduled for processing in PUREX is being stored in the reactor basins. Therefore, the heat content of the stored fuel will be lower when processed through PUREX than the estimates used in Reference 10.

Based on the above information, the current projections for heat content in the aging waste tanks preclude the possibility of an aging waste tank boiling. No aging waste tank will contain greater than 1.0 million Btu/hr and the heat content will be much less than the 3.4 million Btu/hr needed to have a boiling 200 East Area tank. Since no future aging waste tank will boil and the heat content is projected to be less than 1.0 million Btu/hr, the first and second conditions for a tank bump have been eliminated. Instead, the aging waste tanks will "simmer" at temperatures below the supernate boiling temperature. For example, the supernate in Tank 101-AY reached an average temperature of 210 ^{o}F in March of 1972 when the radionuclides in the tank were generating heat at a rate of over 3 million Btu/hr. Tank 101-AY was not classified as a boiling aging waste tank. The tank continued to simmer at decreasing supernate temperatures for several years as the radionuclides decayed to lower heat generating rates. The average supernate temperature in Tank 101-AY in December 1973 was 165 ^{o}F.

Condition 3 for a tank bump to occur, ALC turned off with heat buildup in the sludge, is also not credible. For a non-boiling aging waste tank, heat is conducted to the soil surrounding the tank and heat accumulation in the sludge is not great enough to provide the energy source for a tank bump. Instead of a heat buildup in the sludge, the heat is transferred from the sludge to the tank walls and supernate by thermal conduction means. The heat content is so low that the sludge does not attain excessive temperatures, temperatures at which enough heat is stored to provide the energy for a tank bump. Heat buildup in the sludge would not be enough to provide the source of stored energy to cause steam bubble formation and a tank bump. Heat in the non-boiling aging waste tank is conducted through the sludge to the tank walls and to the supernate with subsequent evaporative cooling occurring at the supernate surface. At tank heat generating rates less than 1.0 million Btu/hr, there is simply not enough heat buildup in the sludge to cause a tank bump.

Currently, the estimated heat generating rates are, respectively, 400,000 and 250,000 Btu/hr for Tanks AZ-101 and AZ-102. Also, the average supernate operating temperatures for AZ-101 and AZ-102 are, respectively, 140 and 142 °F with average sludge temperatures of 180 and 201 °F. These supernate temperatures are far below the boiling temperature of 220 °F. The sludge temperatures also preclude a tank bump since condition 4, sludge temperature greater than 240 °F, is not a credible condition.

<u>Recommendation.</u>

The "tank bump" should be eliminated from the list of credible worst case accident scenarios for the AWF SAR. The conditions for a tank bump are not credible based on the projected heat loadings in the future aging waste tanks. The curie content of the wastes presently in the aging waste tanks and scheduled for storage in the aging waste tanks will not provide enough heat content for the tanks to boil or heat up the sludge to temperatures which would create the conditions necessary for a tank bump. Instead, each aging waste tank is expected to "simmer" should the worst case accident occur.

References

1) R. B. Bendixsen, Sludge in Aging Waste Tanks and Maximum Observed Temperatures, WHC-SD-WM-TA-019, April 1990, Westinghouse Hanford Company, Richland, Washington

2) R. E. Tomlinson, Storage of High Activity Wastes, HW-37207, August 1955, General Electric Company, Richland, Washington

3) G. L. Hanson, 241-SX Operation, IL 273, July 1955, General Electric Company, Richland, Washington

4) M. K. Harmon, Spread of Contamination from a Radiation Zone, Radiation Occurrence, August 1958, General Electric Company, Richland, Washington

5) S. J. Beard and P. Hatch, PUREX Tk-105-A Waste Storage Tank Liner Instability and Its Implications on Waste Containment and Control, ARH-78, October 1967, Atlantic Richfield Hanford Company, Richland, Washington

6) F. E. Boyd, Personal communication, September 1989, Westinghouse Hanford Company, Richland, Washington

7) HAPO, Specifications and Standards for Operational Control of the PUREX Self-Boiling Tank Farms, RL-SEP-269, March 1965, Hanford Atomic Products Operation, Richland, Washington

8) C. M. Kronvall, Maximum Heat Generation and Isotopic Activity Within An Aging Waste Tank, SD-WM-TI-047, November 1982, Rockwell Hanford Operations, Richland, Washington

9) R. B. Bendixsen, Heat Content of Aging Waste Tanks, IL 65260-81-187, May 1981, Rockwell Hanford Operations, RIchland, Washington

10) L. A. Mihalik, Future Aging Waste Tank Operations (No N Reactor Case), IL 13314-88-041, March 1988, Westinghouse Hanford Company, Richland, Washington

TABLE 1

Tank Bumps in Aging Waste Tanks

Tank	104-S	101-S	101-SX	104-SX	114-SX	105-A	101-AX
Date	10/53-5/54	1/54-8/54	2/55-4/55	7/55	8/58	1/65	1968-1969
Boiling	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Heat, Million Btu/hr	.6(a)	.6(a)	1.2(a)	1.9(a)	2(b)	7(c)	7(c)
Sludge Temp. F	>240	>240	300	290	357	310	260
Tank Pressure, psig	<1.6	<1.6	.7-1.8	NI	2.6	1.8	NI
Duration- minutes	8-42	8-42	3-13	70	NI	30	20
No. of events documented	Many	Many	>40	2	4	1	1
ALC	0	0	Auger	S	4	4	22
Initiating Event	None	None	None	ALC-S	ALC-S	BB	ALC-S
Area Contaminated	Yes	Yes	NI	NI	Yes	Yes	No
Vent System	No	No	No	No-1	Yes	Yes	Yes
Reference	2	2	2	3	4	5	6

a Heat generation based on measured condensate flow rate, does not include heat losses to the soil or heat removed by the water cooled air condensers.

b Assumed heat generation rate for aging waste receiver tanks in SX Farm

c Heat generation rate based on PUREX tank farm standards (Reference 7)

ALC Number of Air Lift Circulators in the tank

ALC-S ALC Shutdown, then restarted

Auger Auger installed in tank

BB Bottom of tank bulged upward

NI No information found

No-1 Tank vent systems were installed in S and SX Tanks Farms at later dates.

S A prototype air sparger was installed