ENGINEERING CHANGE NOTICE

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1. ECN 609890

Proj. ECN

2. ECN Category (mark one) Supplemental [] Direct Revision [X] Change ECN [] Temporary [] Standby [] Supersedure [] Cancel/Void []	3. Originator's Name, Organization, MSIN, and Telephone No. R. D. Crowe, SA&NE, HO-32	4. USQ Required? [] Yes [X] No	5. Date 09/05/96
	6. Project Title/No./Work Order No. TWRS FSAR/BIO	7. Bldg./Sys./Fac. No. TWRS	8. Approval Designator
	9. Document Numbers Changed by this ECN (includes sheet no. and rev.) WHC-SD-WM-CN-047, Rev. 0	10. Related ECN No(s). N/A	11. Related PO No. N/A

12a. Modification Work [] Yes (fill out Blk. 12b) [X] No (NA Blks. 12b, 12c, 12d)	12b. Work Package No. N/A	12c. Modification Work Complete N/A Design Authority/Cog. Engineer Signature & Date	12d. Restored to Original Condition (Temp. or Standby ECN only) N/A Design Authority/Cog. Engineer Signature & Date

13a. Description of Change

13b. Design Baseline Document? [] Yes [] No

Fission gas and iodine release consequences re-analyzed due to X/Q change.

14a. Justification (mark one)

Criteria Change	[X]	Design Improvement	[]	Environmental	[]	Facility Deactivation	[]
As-Found	[]	Facilitate Const	[]	Const. Error/Omission	[]	Design Error/Omission	[]

14b. Justification Details

N/A

15. Distribution (include name, MSIN, and no. of copies)

See attached.

RELEASE STAMP

SEP 09 1996

DATE:

STA: 15

HANFORD RELEASE

ID: 21

9-9-96

A-7900-013-2 (05/96) GEF095

A-7900-013-1 (06/92)

ENGINEERING CHANGE NOTICE

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1. ECN (use no. from pg. 1)
609890

16. Design Verification Required
☐ Yes
☒ No

17. Cost Impact

	ENGINEERING		CONSTRUCTION	
Additional	☐ $	Additional	☐ $
Savings	☐ $	Savings	☐ $

18. Schedule Impact (days)
Improvement ☐
Delay ☐

19. Change Impact Review: Indicate the related documents (other than the engineering documents identified on Side 1) that will be affected by the change described in Block 13. Enter the affected document number in Block 20.

SDD/DD ☐
Functional Design Criteria ☐
Operating Specification ☐
Criticality Specification ☐
Conceptual Design Report ☐
Equipment Spec. ☐
Const. Spec. ☐
Procurement Spec. ☐
Vendor Information ☐
OM Manual ☐
FSAR/SAR ☐
Safety Equipment List ☐
Radiation Work Permit ☐
Environmental Impact Statement ☐
Environmental Report ☐
Environmental Permit ☐

Seismic/Stress Analysis ☐
Stress/Design Report ☐
Interface Control Drawing ☐
Calibration Procedure ☐
Installation Procedure ☐
Maintenance Procedure ☐
Engineering Procedure ☐
Operating Instruction ☐
Operating Procedure ☐
Operational Safety Requirement ☐
IEFO Drawing ☐
Cell Arrangement Drawing ☐
Essential Material Specification ☐
Fac. Proc. Samp. Schedule ☐
Inspection Plan ☐
Inventory Adjustment Request ☐

Tank Calibration Manual ☐
Health Physics Procedure ☐
Spares Multiple Unit Listing ☐
Test Procedures/Specification ☐
Component Index ☐
ASME Coded Item ☐
Human Factor Consideration ☐
Computer Software ☐
Electric Circuit Schedule ☐
ICRS Procedure ☐
Process Control Manual/Plan ☐
Process Flow Chart ☐
Purchase Requisition ☐
Tickler File ☐
☐
☐

20. Other Affected Documents: (NOTE: Documents listed below will not be revised by this ECN.) Signatures below indicate that the signing organization has been notified of other affected documents listed below.

Document Number/Revision	Document Number/Revision	Document Number Revision

21. Approvals

	Signature	Date		Signature	Date
Design Authority			Design Agent		
Cog. Eng. R.D. Crowe		9/6/96	PE		
Cog. Mgr. D.S. Leach	DS Leach	9/6/96	QA		
QA			Safety		
Safety			Design		
Environ.			Environ.		
Other -			Other		
Peer Review J.C. Van Keuren		9/6/96			

<u>DEPARTMENT OF ENERGY</u>

Signature or a Control Number that tracks the Approval Signature

<u>ADDITIONAL</u>

A-7900-013-3 (05/96) GEF096

CALCULATION NOTES THAT SUPPORT ACCIDENT SCENARIO AND CONSEQUENCE DETERMINATION OF A WASTE TANK CRITICALITY

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U.S. Department of Energy Contract DE-AC06-87RL10930

EDT/ECN: 609890 UC: 510
Org Code: 8M720 Charge Code: N1FW1
B&R Code: EW3120071 Total Pages: 12

Key Words: Criticality, FSAR, and Safety Analysis

Abstract: The purpose of this calculation note is to provide the basis for criticality consequences for the Tank Farm Safety Analysis Report (FSAR). Criticality scenario is developed and details and description of the analysis methods are provided.

Printed in the United States of America. To obtain copies of this document, contact: WHC/BCS Document Control Services, P.O. Box 1970, Mailstop H6-08, Richland WA 99352, Phone (509) 372-2420; Fax (509) 376-4989.

SEP 09 1996
DATE:
STA: 15
HANFORD RELEASE
ID: 21

Release Stamp

Karen A. Noland 9/9/96
Release Approval Date

Approved for Public Release

RECORD OF REVISION	(1) Document Number WHC-SD-WM-CN-047	Page

(2) Title
Calculation Note that Supports Accident Scenario and Consequence Determination of a Waste Tank Criticality

CHANGE CONTROL RECORD

(3) Revision	(4) Description of Change - Replace, Add, and Delete Pages	Authorized for Release	
		(5) Cog. Engr.	(6) Cog. Mgr. Date
0	(7) Original issue (EDT 616569)	R.D. Crowe	D.S. Leach
1 RS	Replace (ECN 609890)	R.D. Crowe	D.S. Leach

Calculation Notes That Support Accident Scenario and Consequence Determination For a Waste Tank Criticality

Ralph Crowe
Nuclear Analysis and Characterization

Purpose - Although no credible scenario has been identified leading to a criticality in a waste tank, DCRT, catch tank, or 200 series tank or in a mistransfer from PFP, such a criticality is presumed and its consequences are calculated in this section.

Assumptions - The quantity of the transferred waste to be analyzed was chosen to be 500 liters of a 10 g Pu/L solution. This solution is transferred at 4.7 L/s (75 gal/min). The concentration and quantity is based on an estimate of the quantity of plutonium that could conceivably be transferred from PFP providing that multiple failures occurred. Transfers of a higher plutonium concentration would be overly conservative. Lower plutonium concentrations would require too large of a critical volume to occur. A concentration of 10 g Pu/L could constitute a critical sphere with reasonable diameter and size.

Scenario - It is assumed, notwithstanding the inordinate number of failures required, that a solution containing thousands of grams of plutonium accumulates in PFP waste receiver tankD-8 through repeated and undetected sequential process upsets to a previously empty tank. If the tank is not originally empty or other waste is dumped into the tank between the process upsets, the waste would be diluted causing a decrease in the Pu concentration. The contents of D-8 are then transferred to D-5. Both these tanks have a diameter of over 3m and require over 18 kg of Pu to achieve an areal density of 2580 g Pu/m^2, the minimum for a criticality. Since the waste transfer contains only 5 kg of Pu, there is no criticality in either D-8 or D-5 for this size transfer. The contents of tank D-5 are routed to a previously empty 244-TX DCRT. The transferred waste will not go critical in 244-TX since this tank has an even larger surface area than tank D-5. When the PFP waste is transferred to the DST, the waste is postulated to form a compact spherical shape in the existing waste. The radius of this sphere is assumed to increase until a critical volume is reached.

With the criticality, there is a fission burst followed by a rapid shutdown. The shutdown is effected as a consequence of fission energy release that results in thermal expansion, density reduction from the formation of very small bubbles, and fissile dilution through mixing from convective currents with expulsion of part of the critical mass. Early in the burst, the small bubbles are formed. As the burst continues, the amount of dissolved gas increases enough to support the formation and expansion of larger bubbles.

As the burst is terminated, there is a sudden internal pressure relief resulting in rapid steam production and the release of the dissolved gases. The gases and steam, along with the fission gas and a fraction of the waste, are carried into the headspace of the tank. The increase in the pressure in the headspace is relieved by venting a fraction of the headspace through HEPA filters. The pressure of the steam will also cause the critical volume to expand and disperse. The tank is large compared with the critical volume and the expansion will result in dilution of the fissile bearing volume. The turbulent and chaotic conditions along with the dilution should perturb fissile bearing volume sufficiently that reassembly into a new critical mass is not reasonable. The DST criticality is therefore modeled as a single burst.

Input Data

Accidental Transfer of 500 liter of 10 g/liter Pu solution transferred to DST at a rate of 75 gallons per min

Critical volume for 10 g/liter is 300 liters (Rogers 1996) $volume := 300 \cdot liter$

Critical radius $r_{crit} := \left[\frac{3 \cdot (volume)}{4 \cdot \pi}\right]^{\frac{1}{3}}$ $r_{crit} = 41.528 \cdot cm$

At the fill rate of 4.7 L/sec, it takes 63 seconds to reach a critical volume.

Time to reach critical radius $V(r) := \frac{4 \cdot \pi}{3} \cdot r^3$ $\frac{V(r_{crit})}{75 \cdot \frac{gal}{min}} = 63.401 \cdot sec$

Since the critical volume for a 10 g Pu/liter solution has been calculated to be 300 L (Rogers 1996) with a radius of 41.5 cm, the transfer of 500 liters is potentially enough to reach a critical condition. At the fill rate of 4.7L/sec, it takes 63 seconds to reach this condition. The k_{eff} of the sphere during the fill is a function of the sphere radius and can be calculated.

Nuclear Constants

Nuclear constants assumed for dilute Pu solution (Duderstadt 1971)

fermi age	$\tau := 26 \cdot cm^2$	diffusion length	$L_m := \sqrt{1.73 \cdot cm^2}$
beta effective	$\beta_{eff} := 0.002$	reflector savings	$\delta r := 5.7 \cdot cm$

The k_{eff} of the sphere during the fill as a function of the sphere radius can be calculated from the following equation.

K effective calculated from k infinity and two-group buckling.
K infinity chosen to give k = 1 at critical radius.

$$k_{inf} := 1.130 \qquad k(r) := k_{inf} \cdot \frac{\exp\left[-\tau \cdot \left(\frac{\pi}{r+\delta r}\right)^2\right]}{1 + L_m{}^2 \cdot \left(\frac{\pi}{r+\delta r}\right)^2} \qquad k\left(r_{crit}\right) = 1 \qquad r_{crit} = 41.528 \cdot \mathrm{cm}$$

This equation can be used to find the reactivity insertion rate as the sphere goes critical. The reactivity insertion rate, typically expressed in $/sec, is a measure of the rate at which the number of fissions is increasing. In the limit of a small change, the reactivity insertion rate is the change in reactivity for a small increase in the sphere radius divided by the time required for the radius to increase. The rate at which the radius increases is a function of the fill rate. From the following equation, the reactivity insertion rates for the 10 g Pu/L sphere at critical radius of are 41.5 cm is 0.57 $/sec.

$$\frac{\dfrac{k\left(r_{crit} + 0.01 \cdot \mathrm{cm}\right) - k\left(r_{crit}\right)}{\beta_{eff} \, k\left(r_{crit} + 0.01 \cdot \mathrm{cm}\right) \cdot k\left(r_{crit}\right)}}{\dfrac{V\left(r_{crit} + 0.01 \cdot \mathrm{cm}\right) - V\left(r_{crit}\right)}{75 \cdot \dfrac{\mathrm{gal}}{\mathrm{min}}}} = 0.567 \cdot \frac{\mathrm{dollar}}{\mathrm{sec}}$$

It is possible to predict the neutronic response to a reactivity driving function by using point kinetics, as long as appropriate feedback models are employed. For small systems (with tight spatial coupling), this method has produced results that replicate both experimentally measured power and pressure curves reasonably well as shown in the reference (Hetrick 1993) for both dilute plutonium and uranium solutions. These calculations are compared to critical solution excursions measured at Silene. Hetrick's point kinetics model for fissile solutions includes both the Doppler feedback (fissionable material temperature) effect and the feedback associated with the change in volume of the system. The change in volume includes thermal expansion of the fluid as well as radiolytical gas bubble formation.

For pure plutonium and very highly enriched uranium systems, it is expected that the Doppler coefficient is either nearly zero, or may in fact be positive. This is because neutron absorption resonances also include a dominant fission component, and the Doppler broadening of these resonances may increase neutron production faster than the increase in neutron loss (Hetrick 1971). For fast transients, the radiolytic gas bubble generation rate may dominate the thermal expansion effect, and so this will be a significant feedback effect for solution criticalities. The gas generation rate is calculated by using the G value for the solution, which is the quantity of gas produced per amount of energy deposited by fission in the solution. There is a threshold effect, and so some amount of energy deposition is required before the solution becomes saturated and large bubbles begin to form.

One of the cases described in the reference (Hetrick 1993) can be used for estimating the postulated tank farm criticality energy release. The particular Hetrick case of interest involves a transient for a one-region plutonium solution in a cylindrical geometry with a radius of 40 cm. The fuel concentration is 10.5 g/liter. Hetrick calculated a neutron temperature coefficient of reactivity and a volume expansion coefficient from multi-group cross sections using transport theory. The power and reactivity for a step reactivity input of 4 $ were reported. After some initial positive feedback from rising system temperature, the transient terminates rapidly with the formation of radiolytic gas. The maximum inertial pressure for the pulse is 0.58 MPa and the energy yield is 89 MJ.

The DST waste criticality has a similar volume and Pu concentration as the Hetrick's calculation. The hypothetical waste tank criticality, if it did occur, would occur in a fluid with a G value reasonably close to water. The temperature and volume expansion coefficients should be comparable with the Hetrick calculation. Since the DST criticality reactivity insertion rate is under 1 $/sec, compared to the 4$ step increase in reactivity assumed in the Hetrick calculation, the energy yield and pressure for the DST criticality will be conservatively bounded by the calculated Hetrick transient.

Based on the similarity of the postulated DST criticality with the calculations performed by Hetrick, it is assumed that 89 MJ of energy (equivalent to 2.62×10^{18} fissions) is released in the DST criticality with inertial pressures of about 0.6 MPa. Most of the 89 MJ of fission energy goes into heating the liquid within the critical volume. The temperature of the fissile bearing volume is increased from the power burst until the saturation temperature is reached and steam is generated. About 75% of 89 MJ is needed to raise the liquid temperature from a DST liquid temperature of 48°C to boiling. This leaves 25% (or 22 MJ) available to create steam. A volume of 16.7 m^3 of steam is produced, raising the pressure in the headspace of a full DST by about 0.002 MPa (6.5 inches of H_2O).

Number of fissions $\quad \mathrm{Burst} := 89 \cdot \mathrm{MJ} \qquad \dfrac{\mathrm{Burst}}{212 \cdot \dfrac{\mathrm{mev}}{\mathrm{fission}}} = 2.62 \cdot 10^{18} \cdot \mathrm{fission}$

Liquid Waste Values

Density of transfer liquid $\quad \rho_{\mathrm{waste}} := 1.03 \cdot 10^{3} \cdot \dfrac{\mathrm{kg}}{\mathrm{m}^3}$

heat capacity $\quad h_c := 4.2 \cdot \dfrac{\mathrm{joule}}{\mathrm{gm} \cdot \mathrm{K}}$

DST temperature

heat of vaporization $\quad h_{\mathrm{vap}} := 2256 \cdot \dfrac{\mathrm{joule}}{\mathrm{gm}}$

$T_{\mathrm{waste}} := 48 \cdot \mathrm{C}$

density of steam $\quad v_{\mathrm{steam}} := 1.6940 \cdot \dfrac{\mathrm{m}^3}{\mathrm{kg}}$

It takes 66 MJ to heat 300 liters of water from 48 C (115 F) to boiling

$$\text{heat}_{\text{sensible}} := (100\cdot C - T_{\text{waste}})\cdot\rho_{\text{waste}}\cdot h_c\cdot V(r_{\text{crit}}) \qquad \frac{\text{Burst} - \text{heat}_{\text{sensible}}}{\text{Burst}} = 24.17\cdot\%$$

$$\text{Burst} - \text{heat}_{\text{sensible}} = 21.514\cdot\text{MJ}$$

Starting from a liquid waste temperature of 48 C, a little less than 25 % of the energy in the critical volume is available to create steam. This percentage is only an approximation since the temperatue distribution within the critical volume is not uniform. Recognizing this, the fraction of heat available to create steam is rounded up to 25% to demonstrate the approximate nature of this value.

$$\gamma := 25\cdot\%$$

$$\gamma\cdot\text{Burst} = 22.25\cdot\text{MJ}$$

Average temperature of liquid when steam is produced

$$\frac{(1-\gamma)\cdot\text{Burst}}{V(r_{\text{crit}})\cdot\rho_{\text{waste}}\cdot h_c} + T_{\text{waste}} = 99.433\cdot C$$

Volume of steam produced

$$\text{steam} := \frac{\gamma\cdot\text{Burst}}{h_{\text{vap}}}\cdot v_{\text{steam}} \qquad \frac{\dfrac{\text{steam}}{v_{\text{steam}}}}{V(r_{\text{crit}})\cdot\rho_{\text{waste}}} = 3.192\cdot\%$$

$$\text{steam} = 16.707\cdot m^3$$

Headspace volume

$$\text{headspace} := 1050\cdot m^3 \qquad \frac{\text{steam}}{1050\cdot m^3}\cdot\text{atm} = 1.612\cdot10^{-3}\ \cdot\text{MPa}$$

Pressure in headspace

$$\frac{\text{steam}}{\text{headspace}} = 1.6\cdot10^{-2} \qquad \frac{\text{steam}}{1050\cdot m^3}\cdot\text{atm} = 6.473\cdot\text{in\_H2O}$$

Release Amounts

Source Term Analysis - The dose consequences result from the release of radioactive noble gases, iodine, and aerosolized plutonium and tank waste. The source term for the tank waste and plutonium identifies the amount of material released to the environment. The methodology and atmospheric constants used with this source term to calculate dose consequences are described in WHC-SD-WM-SAR-067, Section 3.4.1 Methodology.

Constants from WHC-SD-SAR-0067, 3.4.1, Methodology Section

$$\text{Br} := 3.3\cdot10^{-4}\cdot\frac{m^3}{\text{sec}} \qquad \chi_{\text{Q\_onsite}} := 3.41\cdot10^{-2}\cdot\frac{\text{sec}}{m^3} \qquad \chi_{\text{Q\_offsite}} := 2.83\cdot10^{-5}\cdot\frac{\text{sec}}{m^3}$$

$$\text{ULD} := 6.1\cdot10^{3}\cdot\frac{\text{Sv}}{\text{liter}} \qquad \text{DCF}_{\text{Pu239}} := 1.16\cdot10^{-4}\cdot\frac{\text{Sv}}{\text{Bq}}$$

To find the quantity of material released into the headspace by the venting steam, the aerosol is assumed to comprise 0.05% of the salt content of the solution that is evaporated (Reg Guide 3.35). The 22 MJ is enough energy to evaporate 9.6 liters of liquid. The salt content of the waste is assumed to be equivalent to 10 g Pu added to each liter of DST liquid. Applying the release fraction to the critical volume (300 liters) gives 0.0048 liters of DST waste and 48 mg of Pu released to the tank headspace. This gives concentrations of 4.56 x 10^{-6} liter DST liquid/m^3 and 0.046 mg Pu/m^3 in the headspace of a full DST.

"Aerosol should be assumed to comprise 0.05% of the salt content of the solution that is evaporated. The ventilation rate and retention time should be considered on an individual basis" NRC Regulatory Guide 3.35 page 5, Revision 1, July 1979.

$$\mathrm{evap} := \frac{\mathrm{steam}}{v_{\mathrm{steam}}}\cdot\frac{1}{\rho_{\mathrm{waste}}} \qquad \mathrm{pf} := 0.05\cdot\%\cdot\frac{\mathrm{evap}}{V\left(r_{\mathrm{crit}}\right)}$$

$$\mathrm{evap} = 9.575\cdot\mathrm{liter} \qquad \mathrm{pf} = 1.596\cdot 10^{-5}$$

Volume of headspace vented equals amount of steam produced

$$\mathrm{vent}_{\mathrm{volume}} := \mathrm{steam} \qquad \mathrm{vent}_{\mathrm{volume}} = 16.707\cdot\mathrm{m}^3$$

Waste

Headspace loading based on a fraction of the critical volume

$$\mathrm{pf}\cdot\mathrm{volume} = 4.788\cdot 10^{-3}\cdot\mathrm{liter}$$

$$\mathrm{waste} := \frac{\mathrm{pf}\cdot\mathrm{volume}}{\mathrm{headspace}} \qquad \mathrm{waste} = 4.56\cdot 10^{-6}\cdot\frac{\mathrm{liter}}{\mathrm{m}^3}$$

Plutonium

Headspace loading based on a fraction of the critical mass

$$\mathrm{pf}\cdot\mathrm{volume}\cdot 10\cdot\frac{\mathrm{gm}}{\mathrm{liter}} = 47.877\cdot\mathrm{mg}$$

$$\mathrm{Pu} := \frac{\mathrm{pf}\cdot\mathrm{volume}\cdot 10\cdot\frac{\mathrm{gm}}{\mathrm{liter}}}{\mathrm{headspace}} \qquad \mathrm{Pu} = 0.046\cdot\frac{\mathrm{mg}}{\mathrm{m}^3}$$

To find the quantity of material released to the environment, the headspace concentrations are multiplied by the volume of steam (16.7 m^3) vented from the headspace to the atmosphere. This gives 7.6 x 10^{-5} liters of DST liquid and 0.76 mg of Pu released to the environment.

$$\mathrm{vent}_{\mathrm{volume}} = 16.707\cdot\mathrm{m}^3 \qquad \frac{\mathrm{pf}\cdot\mathrm{vent}_{\mathrm{volume}}}{\mathrm{headspace}} = 2.539\cdot 10^{-7}$$

$$\mathrm{waste}\cdot\mathrm{vent}_{\mathrm{volume}} = 7.618\cdot 10^{-5}\cdot\mathrm{liter} \qquad \mathrm{Pu}\cdot\mathrm{vent}_{\mathrm{volume}} = 7.618\cdot 10^{-4}\cdot\mathrm{gm}$$

Radiological Consequences

Consequences from DST liquid

$DST_{onsite} := waste\cdot vent_{volume}\cdot ULD\cdot \chi_{Q\_onsite}\cdot Br$ $\quad DST_{onsite} = 5.2\cdot 10^{-3}\ \cdot mSv$

$DST_{offsite} := waste\cdot vent_{volume}\cdot ULD\cdot \chi_{Q\_offsite}\cdot Br$ $\quad DST_{offsite} = 4.3\cdot 10^{-6}\ \cdot mSv$

Consequences from PU release

$Pu_{onsite} := Pu\cdot vent_{volume}\cdot 6.20\cdot 10^{-2}\cdot \frac{Ci}{gm}\cdot DCF_{Pu239}\cdot \chi_{Q\_onsite}\cdot Br$ $\quad Pu_{onsite} = 2.3\ \cdot mSv$

$Pu_{offsite} := Pu\cdot vent_{volume}\cdot 6.20\cdot 10^{-2}\cdot \frac{Ci}{gm}\cdot DCF_{Pu239}\cdot \chi_{Q\_offsite}\cdot Br$ $\quad Pu_{offsite} = 1.9\cdot 10^{-3}\ \cdot mSv$

The dose consequences from the noble gases and iodine are taken from the inventory described in Regulatory Guide 3.35, *Assumptions used for Evaluating the Potential Radiological Consequences of Accidental Nuclear Criticality in Fuel Reprocessing Plant.* GENII input files are included as an attachment for the calculation of the consequences for the isotopic releasesa from a 350 MJ (10^{19} fissions) criticality.

These results can be used to calculate consequences for this accident by making corrections for the different power levels. Since the consequences are a linear function of the number of fissions, the GENII consequences for the fission gases submersion and inhalation are ratioed by either the power or the number of total fissions (2.6 x 10^{18} and 1 x 10^{19}) to get consequences for the DST criticality.

Consequence from Fission gas release (WHC-SD-WM-TI-52) based on NRC R.G. 3.35

power ratio $\quad \eta := \frac{89\cdot MJ}{350\cdot MJ}$

inhalation

$FG\_inh_{onsite} := \eta\cdot 8.3\cdot rem$ $\quad FG\_inh_{onsite} = 21\ \cdot mSv$

$FG\_inh_{offsite} := \eta\cdot 4.7\cdot 10^{-3}\cdot rem$ $\quad FG\_inh_{offsite} = 1.2\cdot 10^{-2}\ \cdot mSv$

submersion

$FG\_sub_{onsite} := \eta\cdot 5.4\cdot rem$ $\quad FG\_sub_{onsite} = 14\ \cdot mSv$

$FG\_sub_{offsite} := \eta\cdot 3.6\cdot 10^{-3}\cdot rem$ $\quad FG\_sub_{offsite} = 9.2\cdot 10^{-3}\ \cdot mSv$

See CalcNote WHC-SD-WM-CN-067 for dose calculations (Huang, CH 1996)

Sum of the Radiological Consequences

Onsite

Onsite guideline for "extremely unlikely" event

$$FG\_inh_{onsite} + FG\_sub_{onsite} + DST_{onsite} + Pu_{onsite} = 37.1 \cdot mSv \qquad 100 \cdot mSv$$

Offsite

Offsite guideline for "extremely unlikely" event

$$FG\_inh_{offsite} + FG\_sub_{offsite} + DST_{offsite} + Pu_{offsite} = 0.023 \cdot mSv \qquad 40 \cdot mSv$$

Toxicological Consequences

The toxicological consequences sum-of-the-fractions methodology is described in reference WHC (1996a). Using the previously calculated value of 7.6 x 10^{-5} liters of DST liquid released to the environment in a puff release, the calculated onsite and offsite toxicological consequences are:

Sum of the fraction numbers for an 'extremely unlikely" event

$$SoF_{onsite} := 6.0 \cdot 10^{1} \cdot liter^{-1} \qquad SoF_{offsite} := 2.5 \cdot 10^{-3} \cdot liter^{-1}$$

$$waste \cdot vent_{volume} \cdot SoF_{onsite} = 4.571 \cdot 10^{-3} \qquad waste \cdot vent_{volume} \cdot SoF_{offsite} = 1.904 \cdot 10^{-7}$$

The SoF are normalized such that if the product of the SoF and the release amount is less than 1, the Risk Guidelines are met. Risk guidelines are therefore met for this event.

Comparison to Risk Guidelines

Although no credible scenario has been identified for this accident implying a frequency beyond the "extremely unlikely" range (less than 10^{-6}), both the onsite and offsite radiological doses are shown to be acceptable for an accident in the "extremely unlikely" range (frequency of 10^{-4} to 10^{-6} per year). The toxicological sum-of-fractions are below one for an "extremely unlikely" event, and hence well below the risk evaluation guidelines, for both onsite and offsite receptors.

Small tank Criticality Criticality in D-8

For a criticality to occur in a DST in the tank farm from a PFP transfer, there must be a failure to sample and record the transfer and the size of the transfer must also be limited to tens to hundreds of liters. A larger transfer has the potential for criticality occurring in the PFP receiver tank, D-8, D-5, or DCRT, 241-TX-244 before the waste reaches the DST.

For example, tank D-8 has a 3 m diameter. Using an areal density of 240 g/ft^2, a transfer of more than 1,800 liters of 10 g/L Pu solution has the potential for a criticality in D-8. DCRT 241-TX-244 has larger dimensions and would require a larger transfer.

minimum areal density $\rho_{areal} := 240 \cdot \frac{gm}{ft^2}$

Receiver Tank D-8 diameter $10 \cdot ft = 3.048 \cdot m$

$$\pi \cdot \left(\frac{10 \cdot ft}{2}\right)^2 \cdot \rho_{areal} = 18.85 \cdot kg$$

$$\frac{\pi \cdot \left(\frac{10 \cdot ft}{2}\right)^2 \cdot \rho_{areal}}{10 \cdot \frac{gm}{liter}} = 1.885 \cdot 10^3 \cdot liter$$

References

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Regulatory Guide 3.35, *Assumptions used for Evaluating the Potential Radiological Consequences of Accidental Nuclear Criticality in Plutonium Reprocessing and Fuel Fabrication Plant*, July 1979.

Rogers, C.A., 1996, *CSER 96-010: Criticality Parameters for Tank waste Evaluation*, WHC-SD-SQA-CSA-507, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

WHC-SD-WM-SARR-037, 1996, *Development of Radiological Concentrations and Unit Liter Doses for TWRS FSAR Radiological Consequence Calculations*, Rev.0, Westinghouse Hanford Company, Richland, Washington.

Miscellaneous Constants and Conversions

$\mathrm{MPa} \equiv 10^{6} \cdot \mathrm{Pa}$ $\mathrm{in\_H2O} \equiv 1 \cdot \frac{\mathrm{gm}}{\mathrm{cm}^{3}} \cdot g \cdot 1 \cdot \mathrm{in}$ $\mathrm{ev} \equiv 1.60219 \cdot 10^{-19} \cdot \mathrm{joule}$ $\mathrm{MJ} \equiv 10^{6} \cdot \mathrm{joule}$

$\mathrm{dollar} \equiv 1$ $\mathrm{fission} \equiv 1$ $\mathrm{Sv} \equiv 1$ $\mathrm{Bq} \equiv 1$ $\mathrm{rem} \equiv 10^{-2} \cdot \mathrm{Sv}$

$\mathrm{mev} \equiv 10^{6} \cdot \mathrm{ev}$

$\mathrm{Ci} \equiv 3.7 \cdot 10^{10} \cdot \mathrm{Bq}$ $\mathrm{F} \equiv \mathrm{R}$ $\mathrm{C} \equiv \mathrm{K}$ $\mathrm{mSv} \equiv 10^{-3} \cdot \mathrm{Sv}$

PEER REVIEW CHECKLIST

Document Reviewed: Calculation Notes that Support Accident Scenario and Consequence for Determination of a Waste Tank Criticality WHC-SD-WM-CN-047, Rev 1
Author: R. D. Crowe
Date: September 4, 1996
cope of Review: Radiological Dose and toxic calculations

Yes	No	NA	
☒	☐	☐	Previous reviews complete and cover analysis, up to scope of this review, with no gaps.
☒	☐	☐	Problem completely defined.
☒	☐	☐	Accident scenarios developed in a clear and logical manner.
☒	☐	☐	Necessary assumptions explicitly stated and supported.
☐	☐	☒	Computer codes and data files documented.
☒	☐	☐	Data used in calculations explicitly stated in document.
☒	☐	☐	Data checked for consistency with original source information as applicable.
☒	☐	☐	Mathematical derivations checked including dimensional consistency of results.
☒	☐	☐	Models appropriate and used within range of validity or use outside range of established validity justified.
☒	☐	☐	Hand calculations checked for errors. Spreadsheet results should be treated exactly the same as hand calculations.
☐	☐	☒	Software input correct and consistent with document reviewed.
☐	☐	☒	Software output consistent with input and with results reported in document reviewed.
☐	☐	☒	Limits/criteria/guidelines applied to analysis results are appropriate and referenced. Limits/criteria/guidelines checked against references.
☐	☐	☒	Safety margins consistent with good engineering practices.
☒	☐	☐	Conclusions consistent with analytical results and applicable limits.
☒	☐	☐	Results and conclusions address all points required in the problem statement.
☐	☐	☒	Format consistent with appropriate NRC Regulatory Guide or other standards
☐	☐	☒	Review calculations, comments, and/or notes are attached.
☒	☐	☐	**Document approved.**

J. C. Van Keuren 9/4/96

Reviewer (Printed Name and Signature) Date

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		ECN No. 609890

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