AUG 02 1996

ENGINEERING DATA TRANSMITTAL

Page 1 of 1

1. EDT

516569

2. To: (Receiving Organization) TWRS SAR Engineering		3. From: (Originating Organization) TWRS SAR Engineering		4. Related EDT No.: N/A	
5. Proj./Prog./Dept./Div.: BM720		6. Cog. Engr.: R. D. Crowe		7. Purchase Order No.: N/A	
8. Originator Remarks: The attached calculation note is being submitted for approval and release.				9. Equip./Component No.: N/A	
				10. System/Bldg./Facility: TWRS	
11. Receiver Remarks: N/A				12. Major Assm. Dwg. No.: N/A	
				13. Permit/Permit Application No.: N/A	
				14. Required Response Date: 8/02/96	
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
1	WHC-SD-WM-CN-047	N/A	0	Calculation Notes That Support Accident Scenario and Consequence Determination of a Waste Tank Criticality	N/A
16. KEY					
Approval Designator (F)		Reason for Transmittal (C)		Disposition (H) & (I)	
E, S, O, 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	
(G)	(H)	17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)			
Reason	Disp.	(J) Name	(K) Signature	(L) Date	(M) MSIN
1	1	Cog. Eng. R. D. Crowe	<i>[Signature]</i>	7/24/96	0-32
1	1	Cog. Mgr. D. S. Leach	<i>[Signature]</i>	8/3/96	3-34
1	1	Mgr. A. E. Walter	<i>[Signature]</i>	7/24/96	0-32
1	1	Tech. Peer Review	J. C. Van Keuren	8/1/96	43-54
18. <i>[Signature]</i> 7/31/96 Signature of EDT Originator Date		19. _____ Authorized Representative Date for Receiving Organization		20. <i>[Signature]</i> 8/1/96 Cognizant Manager Date	
21. DOE APPROVAL (if required) Ctrl. No. ☐ Approved ☐ Approved w/comments ☐ Disapproved w/comments					

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

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EDT/ECN: 616569 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.

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James Bishop 8-22-96
Release Approval Date

Release Stamp

Approved for Public Release

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 a estimate of the quantity of plutonium that could conceivably be transferred from PFP providing that numerous failures occurred. Transfers with a higher plutonium concentration would be overly conservative. Lower concentrations would give too large critical volumes. 10 g Pu/L gives 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 tank D-8. This waste cannot go critical in tank D-8 as the layer thickness is too small. The contents of tank D-8 are routed to a previously empty 244-TX DCRT for the same reason. The transferred waste will not go critical in 244-TX either. When the PFP waste is transferred to the DST, the PFP waste forms a sphere in the existing waste. The radius of this sphere increases until a critical volume is reached and the sphere goes critical.

As the criticality proceeds, there is a burst in the curve of fission rate versus time followed by a rapid shutdown. The shutdown is effected as a consequence of the fission energy release that results in thermal expansion, density reduction from the formation of very small bubbles, 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 also will cause the critical volume to expand and disperse. Because the tank is so large as compared with the critical volume, the expansion will result in dispersal of the critical volume, without reassembly. 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-liter

The critical volume for a 10 g Pu/liter solution has been calculated to be 300 L (Rogers 1996) with a critical radius of 41.5 cm.

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

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

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

Nuclear Constants

Nuclear constants assumed for dilute Pu solution (Duderstadt 1971)

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

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.

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

This equation can be used to find the reactivity insertion rate as the sphere goes critical. The reactivity insertion rate, typically expressed in $\$/\text{sec}$, 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 41.5 cm is 0.57 $\$/\text{sec}$.

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

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 will produce 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 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 radiolytical 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 may form.

One of the cases in the reference (Hetrick 1993) is for a case similar in many respects to the postulated tank farm criticality. The calculated transient is for a one-region plutonium solution in a cylindrical geometry with a radius of 40 cm. The fuel concentration is 10.5 g/liter. A neutron temperature coefficient of reactivity and a volume expansion coefficient was calculated from multi-group cross sections using transport theory. The power and reactivity for a step reactivity input of 4 dollars are shown. After some initial positive feedback from rising system temperature, the transient terminates rapidly with the formation of radiolytical gas. The hypothetical waste tank criticality, if it did occur, would occur in a fluid with a G value reasonably close to water. The maximum inertial pressure for the pulse in the Hetrick reference is 0.58 MPa and the energy yield is 8 MJ.

For the DST criticality, there is a similar volume and Pu concentration. The temperature and volume expansion coefficients should be comparable with the Hetrick calculation. Since the DST criticality reactivity insertion rate is under 1 \$/sec, as compared to the 4\$ step increase in reactivity assumed in Hetrick's calculation, the energy yield and pressure for the DST criticality should be bounded by Hetrick's calculated transient.

Based on the similarity of the described DST criticality and 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. It is also assumed that 25% of this energy (or 22 MJ) goes into the production of steam even though without any steam production there would be less than a 55 C average temperature in liquid within the critical volume. A volume of 16.7 m³ of steam is produced raising the pressure in the headspace of a full DST by about 0.002 MPa (6.5 inches cf H₂O).

$$\begin{array}{lcl} \text{Number of fissions} & \text{Burst} := 89 \text{ MJ} & \frac{\text{Burst}}{212 \cdot \frac{\text{mev}}{\text{fission}}} = 2.62 \cdot 10^{18} \cdot \text{fission} \end{array}$$

Liquid Waste Values

$$\begin{array}{lcl} \text{Density of transfer liquid} & \rho_{\text{waste}} := 1.03 \cdot 10^3 \cdot \frac{\text{kg}}{\text{m}^3} & \text{heat capacity} \quad h_c := 4.2 \cdot \frac{\text{joule}}{\text{gm} \cdot \text{K}} \\ \text{DST temperature} & & \text{heat of vaporization} \quad h_{\text{vap}} := 2256 \cdot \frac{\text{joule}}{\text{gm}} \\ & T_{\text{waste}} := 48 \cdot \text{C} & \text{density of steam} \quad v_{\text{steam}} := 1.6940 \cdot \frac{\text{m}^3}{\text{kg}} \end{array}$$

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

$$\begin{array}{lcl} \text{heat sensible} = (100 \cdot \text{C} - T_{\text{waste}}) \cdot \rho_{\text{waste}} \cdot h_c \cdot V(r_{\text{crit}}) & & \frac{\text{Burst} - \text{heat sensible}}{\text{Burst}} = 24.17 \% \end{array}$$

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

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 temperature 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.

$$\begin{array}{lcl} \gamma := 25 \% & \text{Average temperature} & \frac{(1 - \gamma) \cdot \text{Burst}}{V(r_{\text{crit}}) \cdot \rho_{\text{waste}} \cdot h_c} + T_{\text{waste}} = 99.433 \cdot \text{C} \\ \gamma \cdot \text{Burst} = 22.25 \cdot \text{MJ} & \text{of liquid when steam} & \\ & \text{is produced} & \end{array}$$

$$\begin{array}{lcl} \text{Volume of steam} & \text{steam} := \frac{\gamma \cdot \text{Burst}}{h_{\text{vap}}} \cdot v_{\text{steam}} & \frac{\text{steam}}{V(r_{\text{crit}}) \cdot \rho_{\text{waste}}} = 3.192 \% \\ \text{produced} & & \\ & \text{steam} = 16.707 \cdot \text{m}^3 & \end{array}$$

$$\text{Headspace volume} \quad \text{headspace} = 1050 \cdot \text{m}^3 \quad \frac{\text{steam}}{1050 \cdot \text{m}^3} \cdot \text{atm} = 1.612 \cdot 10^{-3} \cdot \text{MPa}$$

$$\text{Pressure in headspace} \quad \frac{\text{steam}}{\text{headspace}} = 1.6 \cdot 10^{-2} \quad \frac{\text{steam}}{1050 \cdot \text{m}^3} \cdot \text{atm} = 6.473 \cdot \text{in}_\text{H}_2\text{O}$$

Release Amounts

Source Term Analysis

The dose consequences include contributions from 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 the source term to calculate dose consequences are described in WHC-SD-WM-SAR-067, Section 3.4.1 Methodology.

Constants from WHC-SD-SAR-0037, 3.4.1, Methodology Section

$$\text{Br} := 3.3 \cdot 10^{-4} \cdot \frac{\text{m}^3}{\text{sec}} \quad \lambda_{Q_\text{onsite}} := 3.41 \cdot 10^{-2} \cdot \frac{\text{sec}}{\text{m}^3} \quad \lambda_{Q_\text{offsite}} := 2.83 \cdot 10^{-3} \cdot \frac{\text{sec}}{\text{m}^3}$$

$$\text{ULD} := 6.0 \cdot 10^3 \cdot \frac{\text{Sv}}{\text{liter}} \quad \text{DCF}_{\text{Pu239}} := 1.16 \cdot 10^{-4} \cdot \frac{\text{Sv}}{\text{Bq}}$$

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 (NuReg 3.35). The 22 MJ is enough energy to evaporate 9.8 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 4.56×10^{-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.

$$\text{evap} := \frac{\text{steam}}{v_\text{steam}} \cdot \frac{1}{\rho_\text{waste}} \quad \text{pf} := 0.05\% \cdot \frac{\text{evap}}{V(r_\text{crit})}$$

$$\text{evap} = 9.575 \cdot \text{liter} \quad \text{pf} = 1.596 \cdot 10^{-5}$$

Volume of headspace vented equals amount of steam produced

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

Waste Headspace loading based
on a fraction of the critical volume pf volume = $4.788 \cdot 10^{-3}$ · liter

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

Plutonium

Headspace loading based
on a fraction of the critical mass pf volume $10 \cdot \frac{\text{gm}}{\text{liter}} = 47.877 \cdot \text{mg}$

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

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 7.6×10^{-5} liters of DST liquid and 0.76 mg of Pu released to the environment.

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

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

Radiological Consequences

Consequences from DST liquid

$$\text{DST}_{\text{onsite}} := \text{waste vent volume} \cdot \text{ULI} \cdot \chi_{\text{Q}_{\text{onsite}}} \cdot \text{Br} \qquad \text{DST}_{\text{onsite}} = 5.143 \cdot 10^{-3} \cdot \text{mSv}$$

$$\text{DST}_{\text{offsite}} := \text{waste vent volume} \cdot \text{ULI} \cdot \chi_{\text{Q}_{\text{offsite}}} \cdot \text{Br} \qquad \text{DST}_{\text{offsite}} = 4.269 \cdot 10^{-6} \cdot \text{mSv}$$

Consequences from PU release

$$\text{Pu}_{\text{onsite}} := \text{Pu vent volume} \cdot 6.20 \cdot 10^{-2} \cdot \frac{\text{C}}{\text{gr}} \cdot \text{DCF}_{\text{Pu239}} \cdot \chi_{\text{Q}_{\text{onsite}}} \cdot \text{Br} \qquad \text{Pu}_{\text{onsite}} = 2.281 \cdot \text{mSv}$$

$$\text{Pu}_{\text{offsite}} := \text{Pu vent volume} \cdot 6.20 \cdot 10^{-2} \cdot \frac{\text{C}}{\text{gr}} \cdot \text{DCF}_{\text{Pu239}} \cdot \chi_{\text{Q}_{\text{offsite}}} \cdot \text{Br} \qquad \text{Pu}_{\text{offsite}} = 1.893 \cdot 10^{-3} \cdot \text{mSv}$$

The dose consequences from the noble gases and iodine are taken from previous work done by Hey (1993). Using the inventory described in Regulatory Guide 3.35, *Assumptions used for Evaluating the Potential Radiological Consequences of Accidental Nuclear Criticality in Fuel Reprocessing Plant*, Hey calculated the consequences based on a burst of 10^{19} fissions (350 MJ).

Hey's values can be used to calculate consequences for this accident by making corrections for the different power levels and Chi/Q values. Since the consequences are a linear function of the number of fissions, Hey's consequences for the fission gases submersion and inhalation are ratioed by the respective number of total fissions (2.6×10^{18} and 1×10^{19}) to get consequences for the DST criticality. To first order, the Chi/Q correction is simply the ratio of the respective Chi/Qs.

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

power ratio

$$\eta := \frac{89 \text{ MJ}}{350 \text{ MJ}}$$

Chi/Q ratios

$$r_{\text{onsite}} := \frac{0.034}{0.033}$$

$$r_{\text{offsite}} := \frac{2.83 \cdot 10^{-5}}{2.21 \cdot 10^{-5}}$$

inhalation

$$FG_inh_{\text{onsite}} := \eta \cdot r_{\text{onsite}} \cdot 8.5 \cdot \text{rem}$$

$$FG_inh_{\text{onsite}} = 22 \cdot \text{mSv}$$

$$FG_inh_{\text{offsite}} := \eta \cdot r_{\text{offsite}} \cdot 3.3 \cdot 10^{-3} \cdot \text{rem}$$

$$FG_inh_{\text{offsite}} = 1.1 \cdot 10^{-2} \cdot \text{mSv}$$

submersion

$$FG_sub_{\text{onsite}} := \eta \cdot r_{\text{onsite}} \cdot 5.4 \cdot \text{rem}$$

$$FG_sub_{\text{onsite}} = 14 \cdot \text{mSv}$$

$$FG_sub_{\text{offsite}} := \eta \cdot r_{\text{offsite}} \cdot 2.5 \cdot 10^{-3} \cdot \text{rem}$$

$$FG_sub_{\text{offsite}} = 8.1 \cdot 10^{-3} \cdot \text{mSv}$$

Sum of the Radiological Consequences

Onsite

Onsite guideline for "extremely unlikely" event

$$FG_inh_{\text{onsite}} + FG_sub_{\text{onsite}} + I_{\text{ST}}_{\text{onsite}} + Pu_{\text{onsite}} = 38.703 \cdot \text{mSv}$$

100 mSv

Offsite

Offsite guideline for "extremely unlikely" event

$$FG_inh_{\text{offsite}} + FG_sub_{\text{offsite}} + I_{\text{ST}}_{\text{offsite}} + Pu_{\text{offsite}} = 0.021 \cdot \text{mSv}$$

40 mSv

Toxicological Consequences

The toxicological consequences sum-of-the-fractions methodology is described in reference WHC (1996a). Using the previously calculated value of 7.6×10^{-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

$$SoF_{\text{onsite}} := 6.0 \cdot 10^1 \cdot \text{liter}^{-1}$$

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

$$\text{waste-vent}_{\text{volume}} \cdot SoF_{\text{onsite}} = 4.571 \cdot 10^{-3}$$

$$\text{waste-vent}_{\text{volume}} \cdot SoF_{\text{offsite}} = 1.904 \cdot 10^{-7}$$

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 "unlikely" range (frequency of 10^{-2} to 10^{-4} per year). The toxicological sum-of-fractions are below one for an anticipated 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, 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/ft², 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 $\rho_{\text{areal}} = 240 \frac{\text{gm}}{\text{ft}^2}$

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

Receiver Tank D-8 diameter 10 ft = 3.048 m

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

References

- Duderstadt J. J. and L. J. Hamilton, 1976, *Nuclear Reactor Analysis*, John Wiley and Sons, New York, New York.
- Hetrick, D. L., 1993, *Computer Models for Predicting the Effects of Criticality Accidents in Solutions*, 1993 Topical Meeting on Physics and Methods in Criticality Safety, Nashville, TN, September 19-23, 1993, pp. 80-86.
- Hetrick, D.L., 1971, *Dynamics of Nuclear Reactors*, University of Chicago Press, Chicago, Illinois.

Hey, 1993, *Dose Consequences for postulated 350 MJ Hanford Site Underground Radioactive Liquid Waste Tank Criticality*, Westinghouse Hanford Company, Richland, Wa.

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

MPa = 10^6 Pa in_H2O = $1 \cdot \frac{\text{gm}}{\text{cm}^3} \cdot \text{g} \cdot \text{l} \cdot \text{in}$ eV = $1.60219 \cdot 10^{-19}$ joule MJ = 10^6 joule

dollar = 1 fission = 1 Sv = 1 Bq = 1 rem = 10^{-2} Sv

Ci = $3.7 \cdot 10^{10}$ Bq F = R C = K mSv = 10^{-3} Sv meV = 10^6 eV

PEER REVIEW CHECKLIST

Document Reviewed: Calculation Note: that Support Accident Scenario and
Consequence for Determination of a Waste Tank Criticality
Author: R. D. Crowe
Date: July 31, 1996
Scope of Review: Dose calculation portion

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

7/31/96

Reviewer (Printed Name and Signature)

Date

HEDOP REVIEW CHECKLIST

CHECKLIST FOR INDEPENDENT REVIEW

Document Reviewed: Calculation Notes That Support Accident Scenario and Consequence Determination For a Waste Tank CriticalityAuthor: Ralph Crowe

Yes No N/A

☒ ☐ ☐ Problem completely defined.
☒ ☐ ☐ Necessary assumptions explicitly stated and supported.
☒ ☐ ☐ Computer codes and data files documented.
☒ ☐ ☐ 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.
☐ ☐ ☒ Code run streams correct and consistent with analysis documentation.
☐ ☐ ☒ Code output consistent with input and with results reported in analysis documentation.
☒ ☐ ☐ Acceptability limits on analytical results applicable and supported. Limits checked against sources.
☒ ☐ ☐ 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.
☒ ☐ ☐ Have all reasonable accidents been considered?
☐ ☐ ☒ Has low density water (steam) been evaluated as a moderator?
☒ ☐ ☐ Is the fuel and other hardware composition correct?
☒ ☐ ☐ Are the cases considered conservative? Too conservative?
☐ ☐ ☒ Do the computer models adequately reflect the actual geometry? Have cross sectional cuts of the geometry been made and do they show the desired geometry?
☒ ☐ ☐ Has the analysis been reviewed by Safety? This may not be required in a preliminary design.
☒ ☐ ☐ Has the reviewer completed the Criticality Safety Course for Managers and Engineers?
 Date completed May, 1996

Reviewed by: Th. N. Schmitt Date 7/31/96

NOTE: Any hand calculations, notes, or summaries generated as part of this review should be signed, dated, and attached to this checklist. Materials should be labeled and recorded so that it is intelligible to a technically-qualified third party.

DISTRIEUTION SHEET

To	From	Page 1 of 1
Distribution	R. D. Crowe	Date 7/31/96
Project Title/Work Order		EDT No. 616569
Calculation Notes That Support Accident Scenario and Consequence Determination of a Waste Tank Criticalit/		ECN No.

Name	MSIN	Text With All Attach.	Text Only	Attach./ Appendix Only	EDT/ECN Only
E. R. Bruschi	A2-34	X			
C. Carro	A2-34	X			
R. D. Crowe (3)	H0-32	X			
D. S. Leach	A3-34	X			
R. M. Marusich	A3-34	X			
A. E. Waltar	H0-32	X			
TWRS S & L Project Files (2)	A2-26	X			
Central Files (original + 2)	A3-88	X			