New Original 3/7/97 gmmahan

ENGINEERING CHANGE NOTICE

Page 1 of 2a gm 3/7/97

1. ECN 632064

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. B.E. Hey/Safety Analysis and Risk Assessment/ A3-34/376-2921	4. USQ Required? [] Yes [X] No	5. Date 3/6/97
	6. Project Title/No./Work Order No. Supporting Calculations and Assumptions for Use in WESF Safety Analysis	7. Bldg./Sys./Fac. No. WESF/225-B	8. Approval Designator N/A
	9. Document Numbers Changed by this ECN (includes sheet no. and rev.) WHC-SD-WM-TI-733, 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

Total revision of the document.

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

14a. Justification (mark one)

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

14b. Justification Details

New technical information.

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

See Distribution List.

RELEASE STAMP

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DATE: HANFORD RELEASE

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1. ECN (use no. from pg. 1) 632064

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16. Design Verification Required	17. Cost Impact				18. Schedule Impact (days)	
	ENGINEERING		CONSTRUCTION			
[] Yes	Additional	[] $	Additional	[] $	Improvement	[X]
[X] No	Savings	[] $n/a	Savings	[] $n/a	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	[]	Seismic/Stress Analysis	[]	Tank Calibration Manual	[]
Functional Design Criteria	[]	Stress/Design Report	[]	Health Physics Procedure	[]
Operating Specification	[]	Interface Control Drawing	[]	Spares Multiple Unit Listing	[]
Criticality Specification	[]	Calibration Procedure	[]	Test Procedures/Specification	[]
Conceptual Design Report	[]	Installation Procedure	[]	Component Index	[]
Equipment Spec.	[]	Maintenance Procedure	[]	ASME Coded Item	[]
Const. Spec.	[]	Engineering Procedure	[]	Human Factor Consideration	[]
Procurement Spec.	[]	Operating Instruction	[]	Computer Software	[]
Vendor Information	[]	Operating Procedure	[]	Electric Circuit Schedule	[]
OM Manual	[]	Operational Safety Requirement	[]	ICRS Procedure	[]
FSAR/SAR	[X]	IEFD Drawing	[]	Process Control Manual/Plan	[]
Safety Equipment List	[]	Cell Arrangement Drawing	[]	Process Flow Chart	[]
Radiation Work Permit	[]	Essential Material Specification	[]	Purchase Requisition	[]
Environmental Impact Statement	[]	Fac. Proc. Samp. Schedule	[]	Tickler File	[]
Environmental Report	[]	Inspection Plan	[]		[]
Environmental Permit	[]	Inventory Adjustment Request	[]		[]

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
HNF-SD-WM-BIO-002, Rev. 0		

21. Approvals

	Signature	Date		Signature	Date
Design Authority	N/A		Design Agent		
Cog. Eng. B.E. Hey	(see page 2a for signature)		PE		
Cog. Mgr. D.S. Leach	(see page 2a for signature)		QA		
QA			Safety		
Safety			Design		
Environ.			Environ.		
Other			Other		
Peer Review P.D. Rittman(see page 2a for signature)					

DEPARTMENT OF ENERGY

Signature or a Control Number that tracks the Approval Signature

ADDITIONAL

ENGINEERING CHANGE NOTICE	Page 2a of 2a	1. ECN (use no. from pg. 1) 632064

This page for signature only. gm 3/7/97

15. Design Verification Required	16. Cost Impact				17. Schedule Impact (days)
	ENGINEERING		CONSTRUCTION		
[] Yes	Additional	[] $	Additional	[] $	Improvement [X]
[X] No	Savings	[] $	Savings	[] $	Delay []

18. 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 12. Enter the affected document number in Block 19.

SDD/DD	[]	Seismic/Stress Analysis	[]	Tank Calibration Manual	[]
Functional Design Criteria	[]	Stress/Design Report	[]	Health Physics Procedure	[]
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Equipment Spec.	[]	Maintenance Procedure	[]	ASME Coded Item	[]
Const. Spec.	[]	Engineering Procedure	[]	Human Factor Consideration	[]
Procurement Spec.	[]	Operating Instruction	[]	Computer Software	[]
Vendor Information	[]	Operating Procedure	[]	Electric Circuit Schedule	[]
OM Manual	[]	Operational Safety Requirement	[]	ICRS Procedure	[]
FSAR/SAR	[X]	IEFD Drawing	[]	Process Control Manual/Plan	[]
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Environmental Report	[]	Inspection Plan	[]		[]
Environmental Permit	[]	Inventory Adjustment Request	[]		[]

19. 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
HNF-SD-WM-BIO-002 Rev. 0		

20. Approvals

Signature	Date	Signature	Date
OPERATIONS AND ENGINEERING		ARCHITECT-ENGINEER	
Cog. Eng. B. E. Hey *B E Hey*	3/5/97	PE N/A	
Cog. Mgr. D. S. Leach *DS Leach*	3/5/97	QA N/A	
QA N/A		Safety N/A	
Safety N/A		Design N/A	
Environ. N/A		Environ. N/A	
Other:		Other N/A	
Peer Review: P. D. Rittman *Paul Rittmann*	3/5/97		
		DEPARTMENT OF ENERGY	
		Signature or a Control Number that tracks the Approval Signature N/A	
		ADDITIONAL	

Supporting Calculations and Assumptions for Use in WESF Safety Analysis

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

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Abstract: This document provides a single location for calculations and assumptions used in support of Waste Encapsulation and Storage Facility (WESF) safety analyses. It also provides the technical details and bases necessary to justify the contained results.

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RECORD OF REVISION

(1) Document Number	Page
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(2) Title
Supporting Calculations and Assumptions for Use in WESF Safety Analysis

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	Initial release (dated 11/13/96) as document WHC-SD-WM-TI-733, Rev. 0.	B. E. Hey	D. S. Leach
1 RS	Complete revision of the whole document. per ECN-632064 gm 3/7/97	B. E. Hey BEH	D. S. Leach DEH for DSL

SUPPORTING CALCULATIONS AND ASSUMPTIONS FOR USE IN WESF SAFETY ANALYSIS

FLUOR DANIEL NORTHWEST

March 6, 1997

For the U.S. Department of Energy
Contract DE-AC0696RL13200

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Supporting Calculations and Assumptions for Use in WESF Safety Analysis

1.0 PURPOSE

The purpose of this document is to provide a single location for assumptions, evaluations and calculations needed to support safety analyses contained in the Waste Encapsulation and Storage Facility (WESF) Basis for Interim Operation (BIO) (HNF 1997). This document provides the technical details and bases necessary to justify the contained results. The information contained in this document applies to WESF as of 1/1/96.

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2.0 ASSUMPTIONS AND SUPPORTING CALCULATIONS

This section details the assumptions and supporting calculations used to support the safety analysis in HNF (1997). Each subsection heading describes the area to which the assumptions and/or calculations apply. Referenced appendices contain supporting or long tabular information.

2.1 Hazard Evaluation and Accident Selection

The WESF hazards and operability study (HAZOP) (Brehm 1995) is used as the primary basis for the hazards evaluation presented in HNF (1997). In addition to the information presented in the HAZOP, this hazards evaluation also identified both engineered and administrative barriers which prevent or mitigate the consequences of the accidents along with an estimated frequency. To this end, a team of plant, safety analysis, and nuclear safety personnel was convened to discuss the accidents identified in the HAZOP for the purpose of identifying barriers and estimating accident frequencies. The team effort was conducted in two 4-hour sessions. The individuals who participated on the team are shown in Appendix A Table A-4.

2.1.1 Methodology

The WESF HAZOP used four categories of consequences: S0, S1, S2, and S3. S0 consequences are those which have no safety impacts but represent operational issues, S1 consequences are those with potential impacts to facility workers, S2 consequences are those with potential impacts to Hanford Site workers outside the WESF, and S3 consequences are those with potential impacts to offsite individuals. These consequence categories were used as the initial screening mechanism. The S0 entries in the HAZOP were not pursued here because they are not safety concerns. The S1 entries were not pursued because they pertain to worker industrial safety issues. Thus, only S2 and S3 entries in the HAZOP, i.e., those accidents with potential consequences outside the facility, were evaluated in this effort.

The methodology used to identify the facility barriers consisted of a team discussion of the accident scenario postulated in the HAZOP, and what engineered systems and administrative controls are in place to prevent or mitigate the accident. The following definitions were used in the identification of barriers:

Scenario: The sequence of events which achieve the consequences of interest for the deviation from the design/operational intent of the process activity.

Systems: The engineered features which act to prevent and/or mitigate the consequences of the scenario.

Controls: The administrative features which act to prevent and/or mitigate the consequences of the scenario.

The frequency category definitions used in this effort are shown in Appendix A Table A-1. The methodology of estimating frequencies consisted of a team consensus in assigning a frequency bin for the scenario. The considerations for assigning frequencies included the initiation and propagation of the scenario, the effects of human errors, the effects of facility equipment, and similar facility events that have occurred in the past. To gain an accurate estimate of the relative risk associated with each scenario, the team assigned frequency bins based on the likelihood of achieving the consequence of interest. Although an initiator, such as a specific ventilation upset, might be "anticipated", the likelihood of achieving the S2 or S3 consequence may be less likely because of the propagation of the scenario and human-system interactions.

Appendix A Table A-2 shows the results of this effort. Table A-2 is a repetition of the HAZOP tables, slightly modified for the purposes of the hazards evaluation. The HAZOP tables were repeated here so that the entire scope of the hazards evaluation effort could be more easily followed. The only modifications that were made to the HAZOP tables consisted of the following:

The "Detection/Mitigation" column of the HAZOP was changed to "Barriers". For the deviations which were evaluated in this effort, the column is split to distinguish between engineered systems and administrative controls. The deviations which were not evaluated in this effort remain unchanged from the original HAZOP tables.

Two new columns were added, one for the estimated frequencies and one for the risk rank. Once the frequency of the deviation was assigned, the risk rank was specified.

The "Remarks" column remained unchanged except for the inclusion of the hazards evaluation team comments. All hazard evaluation team comments are preceded by "Evaluation comments:" so as to distinguish them from comments made in the original HAZOP.

2.1.2 Results

The results of the hazards evaluation effort are shown in Table A-2.

2.1.3 Accident Selection

The accident selection results are derived from the hazards evaluation documented here. The accident selection results shown in Table A-3 are derived directly from Table A-2, the product of the hazards evaluation effort. For every S2 and S3 deviation analyzed, Table A-3 identifies the deviation and shows the risk rank, whether or not the deviation is selected for analysis, and in some cases the rationale for selecting or not selecting that deviation.

Reviewing Table A-3 shows that a large number of deviations were selected for analysis. Most of these deviations specify different causes for a more general accident scenario, such as "fire in the truck port." The deviations in these general scenarios usually have the same risk rank, and thus the dominant sequence cannot be readily identified. Therefore, all the deviations in each general scenario are addressed in the scenario development section of the appropriate accident analysis. The fact that the deviations within the general scenario may have different preventative and mitigative features is addressed in the discussion of safety class SSCs and TSR controls for the accident. In addition, if the consequences of the accident are different for two or more deviations, then the worst-case deviation is used as the basis for calculating accident consequences.

2.2 Receptor Information and Unit Dose Calculations

2.2.1 Site Boundary Definition

The current legal Hanford site boundary is the fence line which encompasses both the north slope and arid lands ecology preserve. However, using this definition as the location of the off site receptor ignores the potential public exposure that could be incurred at closer locations such as the Columbia River and Highway 240. These more conservative locations will also be considered for the establishment of SSCs and controls necessary to limit public exposure. The decision to implement these controls may involve DOE. More detailed guidance is provided in the DOE letters included in Appendix J.

2.2.2 Site Boundary Distances

The site boundary distances to be used in WESF safety analysis are provided in Table 1. Distance values were obtained from version 1.3 of the HMD (Hanford Map Distances) program developed by Paul Rittmann. This program contains Hanford site coordinate data and automatically generates site boundary distances in each of the 16 compass sectors. The distances generated here and listed in Table 1 were based on the default B-Plant center point which is approximately centered in the middle of WESF. Comparison of these values to the site map indicate that Table 1 values are sufficiently accurate for simplified atmospheric transport calculations.

Table 1. WESF Site Boundary Distances

Transport Direction	Fence-line Distance (km)	Hwy-240, Wye Barricade, and Near River Bank (km)
S	19.31	8.94
SSW	16.64	8.26
SW	18.08	8.26
WSW	19.29	9.71
W	18.89	11.04
WNW	19.39	14.36
NW	19.81	11.49
NNW	19.55	11.33
N	22.78	12.99
NNE	25.45	14.01
NE	19.88	12.27
ENE	17.04	12.14
E	16.87	13.65
ESE	21.04	20.88
SE	25.17	14.19
SSE	21.08	11.71

2.2.3 Acute Release Atmospheric Diffusion Coefficient Definition

The atmospheric diffusion coefficients (i.e., X/Q') used to estimate acute release dose consequences for WESF safety analyses will be consistent with the definition provided in NRC (1982). That is, the X/Q' will represent atmospheric conditions such that the concentration at the plume centerline could be exceeded only 40 hours out of the year. A X/Q' calculated according to this definition will simply be referred to as the 99.5% X/Q'.

An on-site 99.5% X/Q' will be used to represent the integrated dose at a receptor located 100 m from the release point, in the worst direction and in the center of the plume. Credit taken for plume meander will be based on the NRC Regulatory Guide 1.145 models when appropriate. Plume meander can be credited when the release rate is approximately constant and has a duration of one hour or more. The minimum building cross sectional area is 300 m^2. This parameter can be used to account for the effects of building wake on near field plume dispersion.

Similarly to the on-site X/Q', the off-site 99.5% X/Q' will be used to represent the integrated dose at a receptor located at the site boundary, in the worst direction and in the center of the plume. The off-site receptor location must consider the direction given in Section 2.1.2. Credit for plume meander and building wake will be taken as discussed above.

2.2.4 Atmospheric Diffusion Coefficient Values

2.2.4.1 Ground Level Releases for Acute Exposure

Both on-site and off-site 99.5% X/Q's are provided in Table 2 below. Calculations were performed using the GXQ computer code documented and verified in Hey (1995a and 1995b). This code implements the Gaussian continuous plume model. Code output files are included in Appendix B.

These coefficients are appropriate for conservatively estimating integrated dose consequences due to acute ground level releases.

As shown in Table 2, the boundary defined as Hwy-240, the Wye Barricade and the near river bank would cause a 40% increase in the estimate of dose consequences as compared to the fence-line boundary. All atmospheric dispersion calculation code output is provided in Appendix B.

Table 2. 99.5% Atmospheric Diffusion Coefficients for Use in Estimating Acute Release Exposure from Ground Level Releases

Source/Receptor Description	On-Site 100m X/Q' (s/m^3)	Fence-Line X/Q' (s/m^3)	Hwy-240, Wye Barricade, and Near River Bank X/Q' (s/m^3)
Ground level release, point source	3.41E-2	1.35E-5	1.90E-5
Ground level release with plume meander	1.13E-2	1.13E-5	1.52E-5
Ground level release with building wake	1.14E-2	1.34E-5	1.88E-5
Ground level release with plume meander and building wake	8.55E-3	1.13E-5	1.52E-5

2.2.4.2 Stack Level Releases for Acute Exposure

The WESF stack is relatively short in comparison to surrounding structures. That is, it is less than 2.5 times the height of surrounding buildings. Acceptable practice is to ignore wake effects from releases that are 2.5 times higher than surrounding structures. Simple treatment of the plume as if it were a ground level release is overly conservative and results in unacceptable dose consequences to the onsite receptor. Treatment of the plume as if it were an isolated elevated release is potentially non-conservative. In order to avoid both unnecessary conservatism and the potential underestimation of ground level plume concentrations at the onsite receptor, the interaction of the building wake with the elevated plume is considered here.

For convenience, and to facilitate the same calculation for several building heights and distances, a building wake spread enhancement model was added to the GXQ code and labeled Version 4C. A listing of the added programming statements is included in Appendix B. A description of the analytical expressions solved by GXQ Version 4C, as well as verification results, are provided in the following subsections.

2.2.4.2.1 Analysis Approach

The approach used here is to apply empirical relationships developed from wind-tunnel and field tests of effluent diffusion near obstacles. Unfortunately, such tests do not exist for the specific stack and building configuration near WESF. However, sufficient information is available to provide an improved model over a simple ground level release with building wake.

The WESF 296-B-10 stack is a 75 ft (22.9 m) fiberglass reinforced structure 42 in (1.07 m) in inside diameter. The effluent flow rate from the WESF 296-B stack is normally around 22,000 cfm (10.4 m^3/s) (H-2-66531 Rev. 6) or above. Approximately 5,500 cfm (2.4 m^3/s) is attributed to the K-3 ventilation system. Nearby structures are the 212-B Fission Products Loadout

Station, the 221-B B-Plant Building, the 222-B Office Building, the 224-B Storage Building, the 225-B main WESF structures, and the 271-B B-Plant Office and Support building. The relative positions of these structures are shown in Figure 1. Also shown are the relative locations of the various building ventilation intakes. Other structures which have a relatively small crossectional area, such as telephone poles, the water tower, crane, and nearby single story modular office buildings and trailers, would have a relatively small influence in comparison to the structures shown. For the purposes of effluent diffusion, these smaller structures are ignored.

Figure 2 is a plan view of the stack and the surrounding buildings overlaid with the sixteen compass sectors. The sixteen compass sectors are divided into five zones of influence. Stack effluent emitted into Zone I would primarily be influenced by the wake of the 225-B structure. Likewise, effluent in Zone II would be primarily affected by the 221-B structure, Zone III by the 212-B structure, and Zone IV by the 224-B structure. Zone V includes all wind directions where these buildings are upwind of the 296-B stack. It should be stressed that this is a simplification of the true effluent behavior as it would interact with the fluid flow around this cluster of buildings. None of the zones are truly independent of each other. Nevertheless, it should be possible to extract useful information from flow field studies around isolated objects and apply them here.

<u>Plume Rise Model</u>

In order to determine whether any of the buildings are high enough to cause stack plume interference, the effective plume height is calculated. The procedure used to evaluate building wake effects is similar to that used in EPA (1992). The gradual plume rise due to momentum is calculated as the plume reaches the building. If the effective plume height, h_e, given by the sum of the stack height and the momentum rise, is greater than 2.5 building heights, the plume is assumed to be unaffected by the building wake. Otherwise the plume is assumed to be affected by the building wake. For the 225-B building, the cut off height would be 2.5 x 12.2 = 30.5 m. This is 7.6 m above the 291-B stack, hence a plume rise of 7.6 m would typically be sufficient to clear the building wake zone for the 225-B building.

Figure 1. Aerial View of WESF 296-B-10 Stack and Surrounding Structures

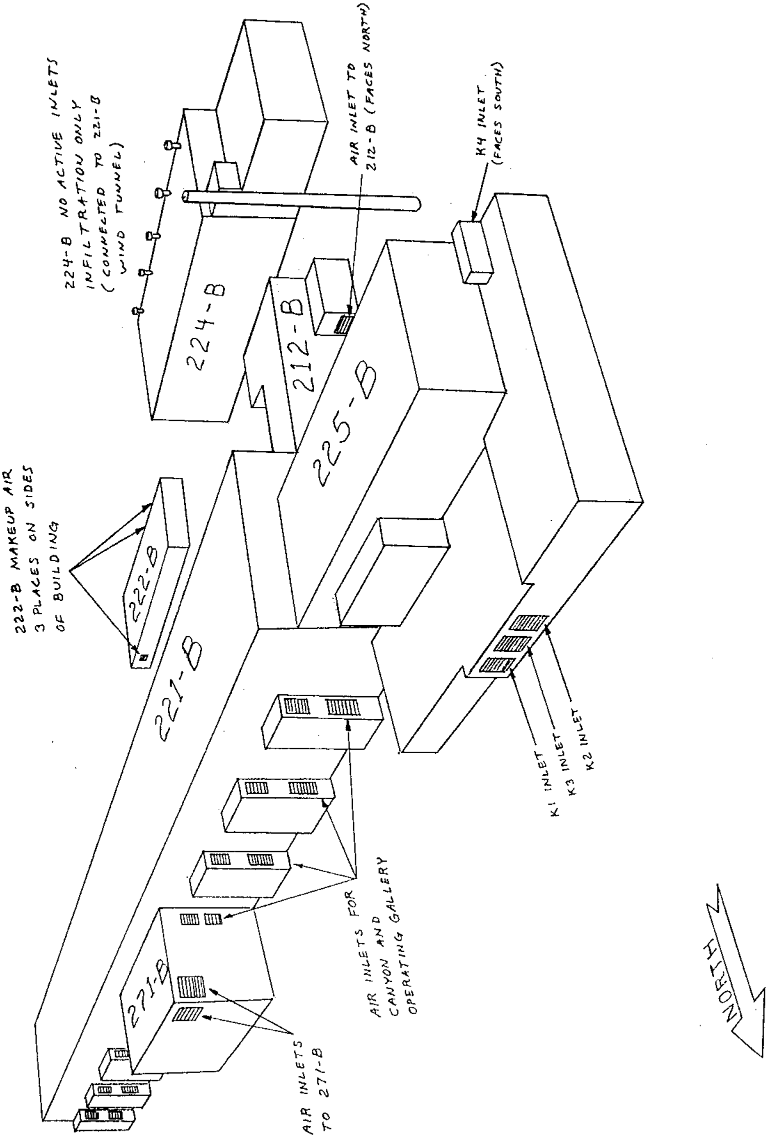
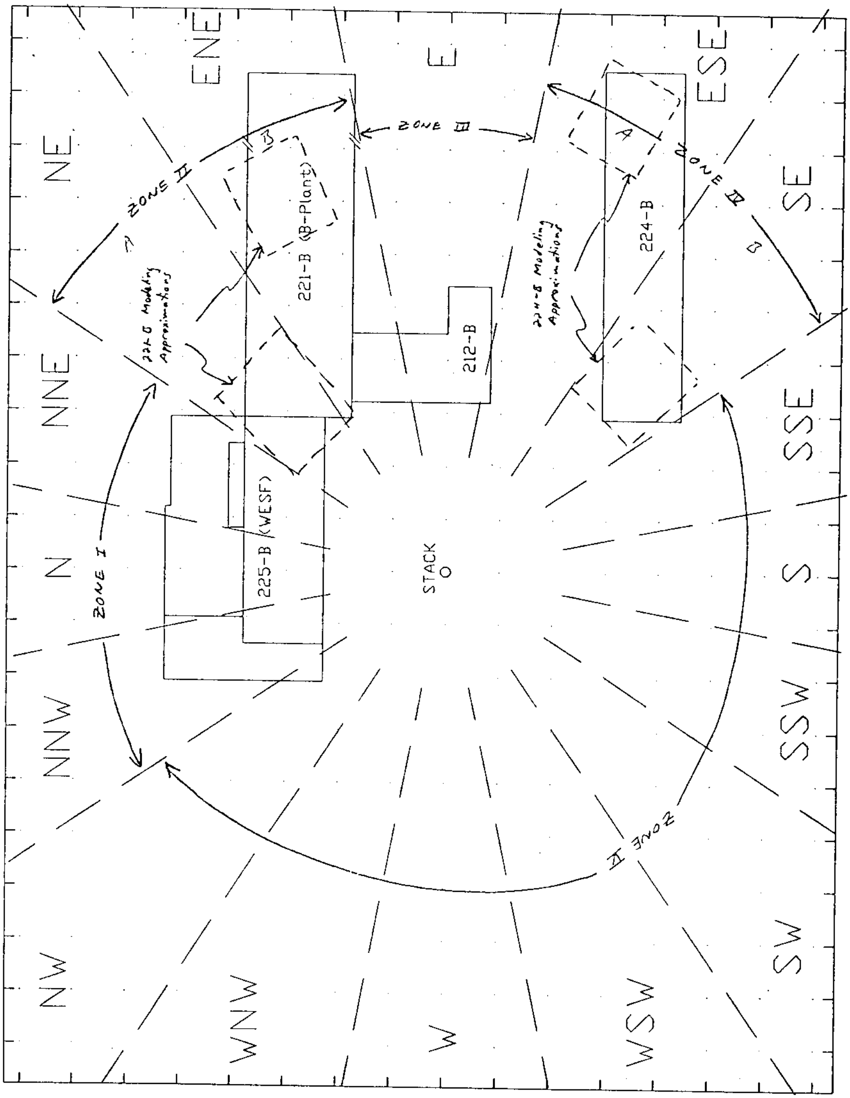


Figure 2. Plan View of WESF 296-B-10 Stack and Surrounding Structures



Wind speed, which is a function of stability class and surface roughness, is also a function of height above ground. Hanna (1982) provides the following form for the vertical wind speed profile

$$u_e = u_{10}\left(\frac{h_e}{10}\right)^p \tag{1}$$

where u_{10} is the 10 m wind speed, and p represents rural roughness factors. Power coefficients for rural areas are also taken from Hanna (1982). The power coefficient for Stability Class G is estimated from trends in the data shown in Table 3. Below 10 m and above 200 m in height there is no further adjustment to u_e.

Table 3. Rural Roughness Power Coefficients As a Function of Atmospheric Stability Class.

	STABILITY CLASS						
	A	B	C	D	E	F	G
Rural p	0.07	0.07	0.10	0.15	0.35	0.55	0.60

The average of the stack level wind speeds will be used in subsequent calculations.

$$\overline{u} = \frac{u_s + u_e}{2} \tag{2}$$

Since u_e is a function of plume height and visa versa, the GXQ Version 4C program uses iteration until difference between successively calculated plume heights differ by no more than 0.1 m.

Stack tip downwash accounts for the plume trapping effect of the stack and depends upon the ratio of the efflux velocity to the cross-flow velocity, $R=w_0/u$. Early wind tunnel work has indicated that downwash is negligible when $R>1.5$. The efflux velocity is 11.6 m/s as calculated from the flow rate and stack diameter. Thus, a stack level wind speed of 7.7 m/s would be required for stack downwash to become significant. As will be shown later, lower wind speed conditions are more conservative.

The WESF stack effluent temperature will be approximately the same as ambient conditions. Hence, the plume will have little or no buoyancy and any rise will be due to momentum only. Momentum plume rise accounts for the additional elevation reached due to vertical jet momentum. Three factors are important for estimation of momentum plume rise in this case. These are; the stability parameter, s, momentum flux, F_m, and the average wind speed, $\bar{u}$.

The stability parameter is defined as follows (Randerson 1984, eq. 8.14),

$$s = \frac{g}{T_a}\left[\frac{\partial T_a}{\partial z} + \frac{g}{c_p}\right] \tag{3}$$

where the dry adiabatic lapse rate g/c_p = 0.0098 K/m. For stability class E, F and G the ambient temperature lapse rate $\delta T_a/\delta z$ = 0.005, 0.0275 and 0.0625 K/m respectively. These midpoint values are identical to those used in the MACCS (NRC 1990) code, with the exception that MACCS does not consider the G stability class. The $\delta T_a/\delta z$ for the G stability class is taken from Sagendorf (1982). The ambient temperature, T_a, is assumed to be 20 °C (293 K) and g is gravitational acceleration (9.8 m/s^2).

The momentum flux, F_m (m^4/s^2), is calculated based on the following formula (Eq. 8.36 Randerson 1984),

$$F_m = w_0^2\ d^2\ \frac{T_a}{4T_0} \tag{4}$$

where w_0 is the efflux velocity, d is the stack diameter, and T_0 is the initial effluent temperature, also assumed to be 20 °C (i.e., no buoyant effects).

For stable conditions, the distance dependent plume rise is given by (see Eq. 1-25 in EPA [1992])

$$\Delta h = \left[3F_m\frac{\sin(x\sqrt{s}/\overline{u})}{\beta_m^2\overline{u}\sqrt{s}}\right]^{1/3} \tag{5}$$

where x is the downwind distance, with a maximum value defined by x_{max} as,

$$x_{max} = 0.5\frac{\pi\overline{u}}{\sqrt{s}} \tag{6}$$

The jet entrainment coefficient, β_m, is given by,

$$\beta_m = \frac{1}{3} + \frac{\overline{u}}{w_0} \tag{7}$$

The final plume rise is limited to the following equation (see Eq. 1-21 in EPA [1992]),

$$\Delta h_f = 1.5\left(\frac{F_m}{\overline{u}\sqrt{s}}\right)^{1/3} \tag{8}$$

or Equation 11 below, whichever is smaller.

For unstable or neutral conditions, the following equations are used to calculate a distance dependent momentum plume rise (see Eq. 1-23 in EPA [1992]),

$$\Delta h = \left(\frac{3F_m x}{\beta_m^2 \overline{u}^2}\right)^{1/3} \tag{9}$$

where x is the downwind distance, with a maximum value defined by x_{max} as follows,

$$x_{max} = \frac{4d(w_0+3\overline{u})^2}{w_0\overline{u}} \tag{10}$$

The final plume rise is limited to (see Eq. 1-16 in EPA [1992]),

$$\Delta h_f = 3d\frac{w_0}{\overline{u}} \tag{11}$$

Building Wake Model

Huber and Snyder (1976) have examined concentration in the wake of a model building for various effluent release heights. They observed that emissions between ground level and roof height were dispersed rapidly in both the vertical and crosswind directions, whereas releases above roof level experienced only enhanced vertical dispersion. The procedure used here is similar to that used in EPA (1992) in that no lateral enhancement is assumed if the effective plume height is greater than 1.2 times the building height.

Huber (1977) recommended forms based on the concept of spread enhancement generated first by the building cavity and second by the decaying turbulence excess produced by the building (Huber and Snyder, 1976). If x_{lee} represents the distance from the lee face of the building to the receptor, then for $3 \le x_{lee}/H \le 10$, these forms are, for a squat building of height H and width W

$$\begin{aligned} \sigma'_y &= 0.7\left(\frac{W}{2}\right) + 0.067\,(x_{lee} - 3H) \\ \sigma'_z &= 0.7H + 0.067\,(x_{lee} - 3H) \end{aligned} \tag{12}$$

whereas for $x_{lee}/H > 10$, the forms are

$$\begin{aligned} \sigma'_y &= \sigma_y(x_{lee} + x_{y0}) \\ \sigma'_z &= \sigma_z(x_{lee} + x_{z0}) \end{aligned} \tag{13}$$

Since WESF is wider than it is tall, it is defined as a squat building. The virtual source distances x_{y0} and x_{z0} are calculated to satisfy the condition that Equations 12 and 13 are equal at x_{lee} = 10H, as long as they remain positive, otherwise they are set to zero.

The validity of the dispersion enhancement model is established in the work of Huber and Snyder (1976) and the models developed and presented in Huber (1977). The model is applicable to building wake affects on short stack effluents, which is the case with the WESF stack and surrounding structures. Huber's model is also implemented in the Industrial Source Complex (ISC2) code (EPA 1992) developed for the U.S. Environmental Protection Agency.

In a manner that is similar to the ISC2 code, the model is applied here by modifying both σ_y and σ_z for plumes with plume height to building height ratios less than or equal to 1.2 and by modifying only σ_z for plumes from stacks with plume height to building height ratios greater than 1.2 (but less than 2.5).

Dispersion Coefficients

Pasquill Gifford (PG) dispersion coefficients for plumes which are unaffected by the building wake are taken from Tadmor and Gur (1969). They are of the same form as those used in the GENII (Napier 1988) and GXQ codes (Hey 1995). If the plume height is such that building wake affects should be considered, then the dispersion coefficients are modified according to Huber's formulae as discussed above. In cases where the PG dispersion coefficient is larger than the Huber dispersion coefficient, then the PG coefficient is used.

Reflection Factor

The plume trapping reflection parameter, F_{ref}, accounts for the boundary effects of the ground and an impenetrable mixing layer. The assumption used here is to assume that when the effluent contacts the ground it is totally reflected upwards, effectively doubling the ground level air concentration. However, since the receptor is actually 2 m above ground level (i.e., head height), the reflection factor will be somewhat less than a factor of two. The reflection parameter is approximately given by (Hey 1995)

$$F_{ref} = 1 + \exp\left(\frac{-2zh_e}{\sigma_z^2}\right) \tag{14}$$

where z is the receptor height and assumed to be 2 m. Second, third, fourth, etc. reflections can be neglected in this case since they have a negligible contribution this close to the source. When applicable, σ_z is replaced by the modified σ'_z calculated in Equations 12 and 13.

Off-Axis Correction Term

The off-axis correction term accounts for the lower effluent concentration when the receptor is offset from the plume centerline. Since in this case the release is from a stack, a receptor close to ground level will be vertically offset. The correction term applied to the Gaussian model is given by,

$$g(z) = F_{ref}\exp\left[-\frac{1}{2}\left(\frac{h_e - z}{\sigma_z}\right)^2\right] \tag{15}$$

For conservatism, the receptor is assumed to be at the horizontal centerline of the plume.

Atmospheric Diffusion Coefficient

The air concentration is represented by X and can be determined by taking the product of the atmospheric diffusion coefficient X/Q'' and the source term release rate Q'. The Gaussian straight line continuous plume model is employed here for calculating atmospheric diffusion. At the lateral centerline of the plume the atmospheric diffusion coefficient X/Q'' is given by,

$$\frac{\chi}{Q'} = \frac{g(z)}{2\pi\sigma_y\sigma_z\bar{u}} \tag{16}$$

Model Verification

To verify the GXQ Version 4C implementation of Huber's spread enhancement model (i.e., Eqs. 12 and 13) a spreadsheet was used to solve Equations 1 through 16 for all Pasquill stability classes and eight wind speeds. This calculation was performed for the special case when the 225-B building is downwind of the 296-B stack and the receptor is at 100 m from the stack (i.e., Zone I). The windward face of the 225-B building is 23 m from the stack. The 225-B building is taken to be 15 m deep in this direction (see Figure 3). The distance from the lee face of the building to the receptor, x_{lee}, is then 100 - 23 - 15 = 62 m. The ratio of this distance x_{lee} to the building height of 12.2 m is then 62/12.2 = 5.1 which is less than 10. Hence, the near field model of Equation 12 applies and this is explicitly checked in the spreadsheet. The far field model of Equation 13, is not explicitly checked here but was verified by a line-by-line check to ensure correct coding of Equation 13 (see code list in Appendix B), and a knowledge that the virtual distance subroutines in GXQ Version 4C have not been modified. Additionally, the formulae for σ'_y given in Equation 12 is also not explicitly checked here since the 296-B stack is 1.2 times higher than the 225-B building. Again, verification is accomplished via a line-by-line check of the coding which is included in Appendix B.

Figure 3 shows relevant dimensions of the WESF stack and surrounding structures. Equations 1 through 11 were solved for a range of stability classes and wind speeds. From the spreadsheet results shown in Table 4 it can be concluded that plume rise associated with very low wind speed conditions is generally sufficient to clear the 225-B building wake zone. The plume rise corresponds to a distance of 23 m which is the distance from the stack to the windward edge of the 225-B building. For stable conditions and a wind speed of 2.7 m/s, the plume rise is marginally below the 7.6 m needed to meet the 2.5 times building height criteria. Hence, for these conditions and all wind speeds greater than 2.7 m/s, Huber's spread enhancement model is utilized.

Table 5 uses the wind speed and momentum rise results of Table 4 to develop solutions to Equations 12 through 16 for stability class and wind speed combinations where the plume height is within the wake effected zone. For low wind speed conditions where plume rise is predicted to be sufficient for the plume to clear the 225-B building wake zone (i.e., values above the dark line in Table 4), a standard elevated plume model was used with no modification to the PG dispersion coefficients. These results are shown in Tables 6 and 7. As can be seen from a comparison of the results in Tables 5 and 7, the later calculations result in lower X/Q' values than those

Figure 3. WESF 296-B-10 Stack and Surrounding Structural Dimensions

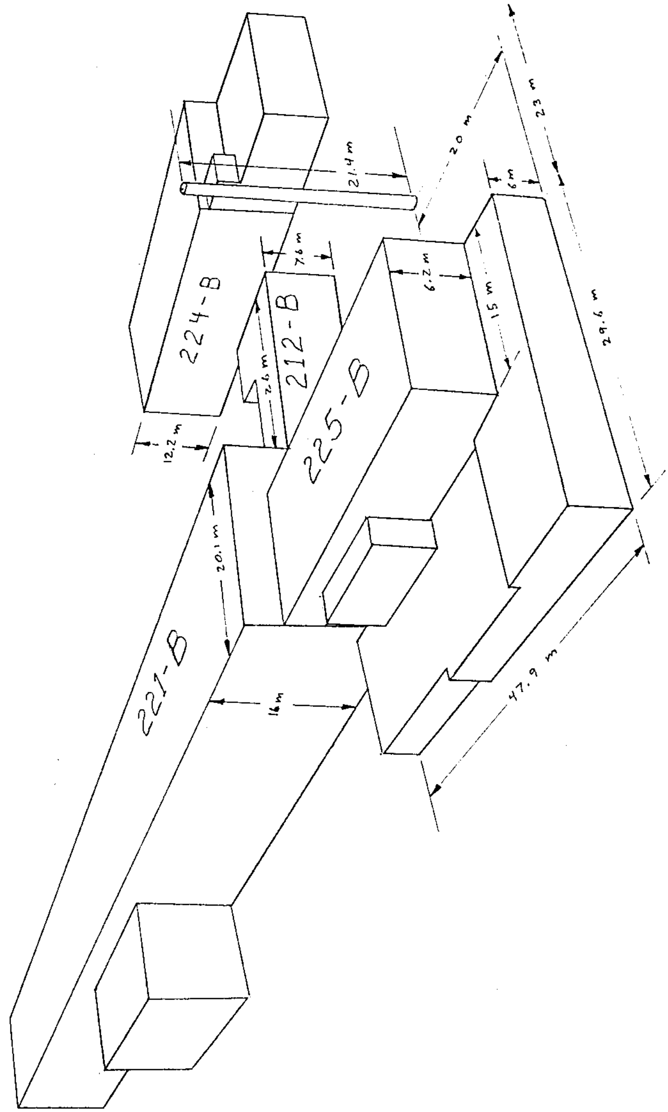


Table 4. Estimate of Momentum Plume Rise from WESF 296-B Stack at 23 m

Input Constants:

stack inside diameter	d	1.07 m
stack height	hs	22.9 m
effluent flow rate	V0	10.4 m3/s
pi	pi	3.1
ambient temperature	Ta	293 K
effluent temperature	T0	293 K
gravitational acceleration	g	9.8 m/s2
specific heat	cp	1000 N m/(kg K)
distance between building and stack	x	23 m

Calculated Parameters:

stack efflux velocity	w0	11.6 m/s
momentum flux	Fm	38.3 m4/s2

Elevation Corrected Average of Stack Level and Plume Height Level Wind Speed:

10 m wind speed (m/s)	Pasquill stability class:						
	A	B	C	D	E	F	G
	Rural roughness power coefficient (p):						
	0.07	0.07	0.10	0.15	0.35	0.55	0.60
0.89	1.0	1.0	1.0	1.1	1.3	1.6	1.7
2.7	2.9	2.9	3.0	3.1	3.8	4.6	4.8
4.7	5.0	5.0	5.2	5.4	6.5	7.7	8.1
7.2	7.7	7.7	7.9	8.2	9.8	11.7	12.2
9.8	10.4	10.4	10.7	11.2	13.3	15.7	16.4
13	13.8	13.8	14.2	14.8	17.6	20.8	21.7
16	17.0	17.0	17.4	18.2	21.6	25.5	26.6
19	20.2	20.2	20.7	21.6	25.6	30.2	31.5

Momentum Plume Rise (m)

10 m wind speed (m/s)	Pasquill stability class:						
	A	B	C	D	E	F	G
	stability parameter (s) =				0.000495	0.001248	0.002418
0.89	25.3	25.3	24.6	23.4	16.4	13.2	11.6
2.7	9.7	9.7	9.5	9.0	7.5	6.2	5.9
4.7	5.6	5.6	5.5	5.2	4.3	3.5	3.4
7.2	3.6	3.6	3.5	3.3	2.7	2.2	2.1
9.8	2.5	2.5	2.4	2.3	1.9	1.5	1.5
13	1.8	1.8	1.8	1.7	1.4	1.1	1.0
16	1.4	1.4	1.4	1.3	1.1	0.9	0.8
19	1.1	1.1	1.1	1.1	0.9	0.7	0.7

plume height above wake effected zone

plume height within wake effected zone

Table 5. Estimate of 100 m X/Q' for Cases where Huber Spread Enhancement Model is Applicable

Input Constants:

building height	Hb	12.2 m
lee distance to receptor	xlee	62 m
source distance to receptor	x	100 m
receptor height	z	2 m
Huber sigma z	hsz	10.2418 m

Atmospheric Diffusion Coefficient maximum = 5.17E-5

10 m wind speed (m/s)	Pasquill stability class:						
	A	B	C	D	E	F	G
	Pasquill sigma y based on distance x:						
	23.41	17.61	13.37	9.41	6.69	4.62	3.08
	Pasquill sigma z based on distance x (range 2):						
	14.30	10.89	7.50	4.56	3.49	2.25	1.36
0.89							
2.7					1.73E-5	2.96E-5	4.58E-5
4.7	2.67E-5	1.17E-5	1.10E-5	1.59E-5	2.36E-5	3.45E-5	5.17E-5
7.2	2.29E-5	1.22E-5	1.19E-5	1.69E-5	2.29E-5	3.13E-5	4.62E-5
9.8	1.92E-5	1.12E-5	1.12E-5	1.56E-5	2.04E-5	2.70E-5	3.95E-5
13	1.58E-5	9.79E-6	9.87E-6	1.37E-5	1.74E-5	2.25E-5	3.28E-5
16	1.34E-5	8.62E-6	8.76E-6	1.21E-5	1.52E-5	1.94E-5	2.82E-5
19	1.17E-5	7.65E-6	7.81E-6	1.08E-5	1.34E-5	1.70E-5	2.46E-5

Huber model does not apply since plume above wake effected zone.

Table 6. Estimate of Momentum Plume Rise from WESF 296-B Stack at 100 m

Input Constants:

stack inside diameter	d	1.07 m
stack height	hs	22.9 m
effluent flow rate	V0	10.4 m3/s
pi	pi	3.14
ambient temperature	Ta	293 K
effluent temperature	T0	293 K
gravitational acceleration	g	9.8 m/s2
specific heat	cp	1000 N m/(kg K)
distance between building and stack	x	100 m

Calculated Parameters:

stack efflux velocity	w0	11.6 m/s
momentum flux	Fm	38.3 m4/s2

Elevation Corrected Average of Stack Level and Plume Height Level Wind Speed:

10 m wind speed (m/s)	Pasquill stability class:						
	A	B	C	D	E	F	G
	Rural roughness power coefficient (p):						
	0.07	0.07	0.10	0.15	0.35	0.55	0.60
0.89	1.0	1.0	1.0	1.1	1.3	1.6	1.6
2.7	2.9	2.9	3.0	3.2			
4.7							
7.2							
9.8							
13							
16							
19							

See Table 4 for these stability class and wind speed combinations.

Momentum Plume Rise (m)

10 m wind speed (m/s)	Pasquill stability class:						
	A	B	C	D	E	F	G
	stability parameter (s) =				0.000495	0.001248	0.002418
0.89	38.0	38.0	36.6	34.3	16.4	13.2	9.0
2.7	12.8	12.8	12.4	11.8			
4.7							
7.2							
9.8							
13							
16							
19							

See Table 4 for these stability class and wind speed combinations.

Table 7. Estimate of 100 m X/Q' for Cases where Huber Spread Enhancement Model is Not Applicable

Input Constants:

building height	Hb		12.2 m
lee distance to receptor	xlee	na	m
source distance to receptor	x		100 m
receptor height	z		2 m
Huber sigma z	hsz		0 m

Atmospheric Diffusion Coefficient maximum = 1.53E-5

10 m wind speed (m/s)	A	B	C	D	E	F	G
	Pasquill sigma y based on distance x:						
	23.41	17.61	13.37	9.41	6.69	4.62	3.08
	Pasquill sigma z based on distance x (range 2):						
	14.30	10.89	7.50	4.56	3.49	2.25	1.36
0.89	1.31E-7	4.19E-10	2.83E-16	4.51E-35	7.74E-28	1.22E-52	5.14E-107
2.7	1.53E-5	3.11E-6	3.03E-8	8.16E-15			
4.7							
7.2							
9.8							
13							
16							
19							

(Columns A–G are Pasquill stability class.)

See Table 5 for these stability class and wind speed combinations.

incorporating Huber's spread enhancement model. Also, note that the distance used in Table 6 and 7 calculations are for the full 100 m between the stack and the receptor.

The GXQ Version 4C verification test results are provided in Appendix B under the input file name GXQ4CTST.IN. All results are virtually identical to the spreadsheet values, with differences accounted for by roundoff. Based on this check, and a check of the coding for implementation of Equation 13, it can be concluded that the GXQ Version 4C correctly implements the model discussed.

2.2.4.2.2 Application to Zone I

Located approximately 23 m north of the stack is the 225-B (i.e., WESF) building. The 225-B building actually consists of three structures separated by seismic joints. These structures are referred to in design calculations as Areas 1, 2 and 3 (see Figure 3). The Area 2 structure is the largest of the three and will be used to represent the wake affects of all three. It is approximately 12.2 m above grade and 15 m deep in the windward direction.

Wind incidence is approximately normal to the 225-B structure in the Zone I direction. No other significant structures exist in the near field in these directions.

<u>Air Concentration When 225-B Building is Downwind of Stack</u>

GXQ Version 4C was applied to Zone I and specifically in those wind directions where the 225-B building is downwind of the stack (i.e., NNW, N and NNE). To be consistent with standard conservative methodology, a 99.5% X/Q' is calculated at various receptor distances to identify the worst case location. The output of this run is included in Appendix B. The most conservative condition corresponds to stability class F with a NNW wind blowing at 2.65 m/s. The largest X/Q' occurs at 200 m with a value of 8.5E-5 s/m^3. This value is higher than what would be calculated if the building were not present (i.e., unmodified stack release X/Q' is approximately 4E-5 s/m^3), but lower than that of a ground level release with a MACCs (NRC 1990) or NRC Regulatory Guide 1.145 (NRC 1982) type building wake model applied. The later yield X/Q' values on the order of 1E-2 s/m^3 as calculated using the GXQ code.

<u>Air Concentration at the 225-B Building Intake Filters</u>

Stack effluents can only reach the K1, K2, and K3 intake filters when the wind comes from the south (see Figure 1). With stack effluents being transported to the north, the intake screens will be in the building recirculation cavity.

Because the Huber and Snyder model cannot be used to estimate concentrations in the building recirculation cavity ($x_{lee} < 3H$), concentrations at the building intakes were estimated using a minimum dilution model developed by Wilson and Lamb (1994). The Wilson-Lamb model was developed using field data to estimate the minimum dilution in plumes released from building vents and short stacks. The model development does not make or depend on a Gaussian assumption. The model should provide an upper bound on the concentration rather than the average concentration estimated by the GXQ model.

The Wilson-Lamb model is a function of wind speed and distance, but it is not a function of building area. The basic formula for the normalized time-integrated exposure is shown below.

$$X/Q' = \frac{1}{V_o\left(B_o^{0.5} + B_d^{0.5}\right)^2} \tag{17}$$

The stack exhaust flow rate, V_o, is 10.4 cubic meters per second. The initial, B_0, and downwind, B_d, dilution factors are defined below.

$$B_o = 1 + 13\left(\frac{w_o}{u_h}\right) \tag{18}$$

$$B_d = 0.089\left(\frac{u_h\, x_s^2}{V_o}\right) \tag{19}$$

The term w_o is the vertical exit speed of the exhaust gases from the stack (11.6 m/s), u_h is the wind speed at the height of the building, and x_s is the "stretched string" distance from the top of the stack to the downwind location of interest. The "stretched string" distance is the minimum distance between the release point and the receptor without passing through any solid objects.

For the K1, K2, and K3 intake screens, x_s is 56 meters. The X/Q' decreases with increasing wind speed, so this parameter should be as small as reasonably possible. From Table 4, it can be seen that the plume will not be affected by the building turbulence if the wind speed is too low. A compromise wind speed of 3.0 m/s was chosen.

The computed X/Q' for the K1, K2, and K3 intake screens turns out to be 3.7E-4 s/m^3, which is somewhat larger than the X/Q' of 8.5E-5 s/m^3 for the worker location.

The K4 filter is located on the roof of the west edge of the 225-B building which has a height of only 6 m. Since the stack is greater than 2.5 times the height of the K4 filter intake, it should be relatively free from the elevated plume. For practical purposes, the X/Q' at the K4 filter can be taken to be zero.

2.2.4.2.3 Application to Zone II

The nearest corner of the 221-B (i.e., B-Plant) building is approximately 33 m NE and ENE of the WESF stack. The wind incidence across this structure would be at a 10 to 60 degree angle in the direction of interest. Additionally, the smaller 225-B and 212-B buildings located on either side of the building would tend to complicate the already complicated wake effect. Due to a lack of quantitative methods for evaluating the wake created from angular wind incidence, relationships for normal incidence will be used with additional qualitative evaluations of the effect of angular wind incidence. No other significant structures exist in the near field and in these directions. The 221-B building is approximately 16 m above grade.

Air Concentration When 221-B Building is Downwind of WESF Stack

GXQ Version 4C was applied to Zone II and specifically in those wind directions where the 221-B building is downwind of the stack (i.e., NE, and ENE). Due to the length and orientation of the 221-B building, the zone was broken up into two separate regions, one for NE and one for ENE. For purposes of applying the Huber spread enhancement model, the 221-B building was modeled as a 20 by 20 by 16 m high building in both the NE and in the ENE directions. Due to the height relationship of the 221-B building and WESF 296-B stack, the 20 m building width approximation has no effect on the calculated result. The leading edge is 33 m from the stack in the NE direction and assumed 70 m from the stack in the ENE direction. Again, 99.5% X/Q's are calculated at various receptor distances to identify the worst case location. The output of these runs are included in Appendix B. The most conservative condition in the NE direction occurs at 250 m and corresponds to stability class E at 0.89 m/s wind speed. The X/Q' value is 1.2E-4 s/m^3. The most conservative condition in the ENE direction occurs at 250 m and corresponds to stability class G at 2.7 m/s wind speed. The X/Q' value is 1.2E-4 s/m^3.

The Wilson and Lamb model was also used for the lee side of the 221-B building in the ENE direction from the WESF stack. A person could be standing at ground level on the downwind side of the building at a distance of 100 meters. The stretched string distance is 102 meters. Using a wind speed of 3.0 m/s, the X/Q' at this location is 1.7E-4 s/m^3.

Relatively little quantitative data exists for the case where the wind is not at right angles to the building. Therefore, only a qualitative effect can be discussed here. Randerson (1984) does summarize work performed by others on the effects of wind incidence angle. Studies suggest that the vertical extent of the flow perturbation introduced by a block-like building is less when the wind is not normal to one side; the somewhat streamlined shape of such a structure when it is approached from an angle makes it easier for the flow to pass around the sides of the building rather than be deflected over its top. Huber (1989) presents wind-tunnel data for stacks on the lee face of various buildings showing an increase in air concentrations as the wind incidence angle changes from normal. He also shows cases where obliquely incident winds decrease the air concentration. Thus it is difficult to generalize on what the exact effect of off-normal winds on the 221-B estimates for X/Q' would be. The maximum near source X/Q' representing workers on the lee side of 221-B were computed using a bounding dilution factor model from Wilson and Lamb (1994). The conservatism inherent in this model should compensate for any nonconservatism which results from off-normal winds.

Another possible location of a receptor at a minimum of 100 m from the WESF stack is on the roof of the 221-B building. Several approaches are used to model this condition and then a comparison is made. First, the condition is modeled using the Huber and Snyder model with a receptor height of 18 m (i.e., the roof height plus 2 m). The second approach is the same as above but without any dispersion enhancement. The third approach is the same as the second case but modeled as a stack release having a stack height equal to the difference between the 296-B stack and the 221-B building or 22.9 - 16 = 6.9 m with a 2 m receptor height. No dispersion enhancements would be used in this case either. Computer output for each of these cases is provided in Appendix B. A fourth approach would be to use the Wilson and Lamb model with a stretched string distance of 102 m. This was previously calculated above for Zone I to be 1.7E+4 s/m^3. Of all the approaches, the first yielded the highest X/Q' with a value of 3.34E-4 s/m^3 in the ENE direction at 150 m. This is somewhat larger than the X/Q' representing a ground level receptor, as expected.

Air Concentration at 221-B Building Intake Filters

As was done for the 225-B building, the Wilson and Lamb model was used to estimate the normalized time-integrated exposures at the air intakes for 221-B, which are on the north side of the building. The stretched string distance in the NE direction to the air intakes at the west end of 221-B was 61 meters. Using a wind speed of 3.0 m/s, the X/Q' turns out to be 3.4E-4 s/m^3.

In the ENE direction, the air intakes are at a distance of about 100 meters, so the X/Q' obtained for the 100 meter receptor in this direction will also be used for the air intakes, namely, 1.7E-4 s/m^3.

2.2.4.2.4 Application to Zone III

The 212-B (Fission Products Loadout Station) building is approximately 32 m E of the WESF stack. The wind incidence on the structure is approximately normal in this zone. One would expect some channeling of the building wake where it is bordered by the 221-B B-Plant south wall. No other significant structures exist in the near field in this direction. The 212-B structure is approximately 7.6 m above grade. Since the WESF stack is more than 2.5 times higher than the building height, it is safe to treat the plume as an elevated release without consideration of building wake effects for Zone III. The X/Q' value is 3.0E-5 s/m^3.

2.2.4.2.5 Application to Zone IV

The nearest corner of the 224-B Storage Building is approximately 41 m to the SE of the WESF stack. Like Zone II, the wind incidence in this direction will be angular. Similar simplifications as applied in Zone II will also be applied here with qualitative supplemental discussion. The 224-B building is approximately 12.2 m in height. It is not normally occupied.

GXQ Version 4C was applied to Zone IV and specifically in those wind directions where the 224-B building is downwind of the stack (i.e., ESE, and SE). Due to the length and orientation of the 224-B building, the zone was broken up into two separate regions, one for ESE and one for SE. For purposes of applying the Huber spread enhancement model, the 224-B building was modeled as a 20 by 20 by 12.2 m high building in both the ESE and in the SE directions. The leading edge is assumed 80 m from the stack in the ESE direction and 41 m from the stack in the SE direction. Again, 99.5% X/Q's are calculated at various receptor distances to identify the worst case location. The output of these runs are included in Appendix B. The most conservative condition in the ESE direction occurs at 250 m and corresponds to stability class G at 4.7 m/s wind speed. The X/Q' value is 6.7E-5 s/m^3. The most conservative condition in the SE direction occurs at 200 m and corresponds to stability class G at 4.7 m/s wind speed. The X/Q' value is 8.3E-5 s/m^3.

The Wilson and Lamb model was also used for the lee side of the 224-B building in the ESE direction from the WESF stack. A person could be standing at ground level on the downwind side of the building at a distance of 100 meters. The stretched string distance is 104 meters. Using a wind speed of 3.0 m/s, the X/Q' at this location is 1.7E-4 s/m³.

2.2.4.2.6 Application to Zone V

Air Concentration When WESF Stack is Downwind of Structures

There is relatively little guidance for sources downwind of buildings. For sources downwind of buildings, Huber commented (see Randerson 1984 p. 317) that the Huber and Snyder dispersion enhancement model is best applied to sources within 2H of a building when $h_e < H + 1.5\ \zeta_b$. Length ζ_b is the smaller of the building height H or width W. The distance criteria of 2H would likely enclose the peak cavity height which could range anywhere from H/2 to 1.5H depending upon the boundary layer thickness (see discussion in Randerson [Section 7-5.2.1, 1984]). With respect to the 225-B building the nearest face is 23 m north of the stack while 2H = 24.4 m. For the 221-B building the nearest corner is 33 m from the stack while 2H = 32 m. Thus, application of Huber's model appears marginal in these cases. Huber does not state where h_e is evaluated when comparing it to the above criteria, or make any recommendations for more distant sources. For these reasons, the Huber and Snyder model is not used here when the 296-B stack is downwind of the surrounding buildings.

Briggs (1973) suggested that his method of incorporating building wake effects into the effective stack height should be confined to cases where the stack is within $3\zeta_b$ downwind of the building (i.e., within or near the end of the cavity zone) where ζ_b is the smaller value of building height H or width W. In the case of the 225-B building $3\zeta_b$ = 36.6 m which encompasses the WESF stack. If the effective plume height h_e is zero, Brigg's recommended model for computing downwind concentrations is essentially

$$\frac{\chi}{Q'} = \frac{1}{(\pi\sigma_y\sigma_z + A_p)\,\overline{u}} \tag{20}$$

where A_p is the projected frontal area of the building. If the plume remains aloft, he uses X = 0 for distances x such that $\sigma_z(x) < (2/\pi)^{1/2} h_e$, whereas for $\sigma_z(x) > (2/\pi)^{1/2} h_e$,

$$\frac{\chi}{Q'} = \frac{1}{\pi\sigma_y(\sigma_z + \sqrt{2/\pi}\,h_e)\,\overline{u}} \tag{21}$$

That is, dispersion behind the building is enhanced only in the vertical for an elevated release.

To evaluate Equation 21, it is first necessary to determine distance $x_{non\text{-}zero}$ at which concentration, X, is non-zero. Using h_e computed at 100 m from Table 6, $\sigma_z(x_{non\text{-}zero}) = (2/\pi)^{1/2} h_e$ can be evaluated. Making use of the analytical expression for the vertical dispersion coefficients from Tadmor and Gur (1969) the corresponding distance, $x_{non\text{-}zero}$, at which X is non-zero can be calculated. Although this distance will be greater than 100 m, the effective plume height h_e has reached its maximum value at 100 m as limited by Equation 11. The lateral dispersion coefficient, σ_y, can then be evaluated at $x_{non\text{-}zero}$, again using the analytical expression for dispersion coefficients from Tadmor and Gur (1969). Equation 21 can be evaluated by substituting the values for σ_y, σ_z, h_e, $\bar{u}$ where $\bar{u}$ is also taken from Table 6.

Table 8 shows the results of Equation 21 for two ground level wind speeds of 0.89 and 2.7 m/s and Pasquill stability classes A, B and C. It should be clear from trends in the results that neutral and stable conditions, and higher wind speeds will result in lower and less conservative X/Q's. The maximum X/Q' = 5.37E-5 s/m^3 occurs for stability class A at a low wind speed. This value remains below the values calculated for those zones where significant structures are downwind of the 296-B stack. For comparison purposes, an elevated release Gaussian model without a building wake correction would have yielded a X/Q' = 3.9E-5 s/m^3 (see Appendix B output results for Zone V).

2.2.4.2.7 Summary

Atmospheric diffusion coefficients were calculated for each of 16 compass sectors surrounding the WESF 296-B stack. Special consideration was given to structures, or the lack thereof, in each sector which could interact with the elevated release and cause higher ground level concentrations than would exist had the structure not been present. The methods of Huber and Snyder (1976), Huber (1977), Wilson and Lamb (1994), and Briggs (1973) were relied upon for analysis. A revision 4C to the GXQ code (Hey 1995) was created and verified to perform the calculations for the many joint combinations of wind speed, stability class and distance. This was done in order to identify an appropriately conservative diffusion coefficient in each direction, suitable for acute exposure estimates for accidental releases originating from the WESF stack. The results of these calculations are provided in Table 9. Based on these results, a X/Q' of 2E-4 s/m^3 is adequate to conservatively represent an acute exposure to a ground level receptor at a distance of 100 m or greater from the 296-B stack.

Table 8. Atmospheric Diffusion Coefficients for Use in Estimating Acute Release Exposure from WESF Stack when Stack is Downwind of Structures

Pasquill Stability Class	Average Wind Speed (m/s)	Momentum Plume Rise (m)	Effective Plume Height (m)	Vertical Dispersion Coefficient (m)	Distance at which X/Q is non-zero (m)	Horizontal Dispersion Coefficient sigma-y	Atmospheric Diffusion Coefficient (s/m3)
A	1.00	38.00	60.90	48.59	288.48	60.95	5.37E-5
B	1.00	38.00	60.90	48.59	473.52	71.71	4.57E-5
C	1.00	36.60	59.50	47.48	758.02	83.29	4.03E-5
A	2.90	12.80	35.70	28.49	199.48	43.68	4.41E-5
B	2.90	12.80	35.70	28.49	284.12	45.21	4.26E-5
C	3.00	12.40	35.30	28.17	427.35	49.64	3.79E-5

Table 9. 99.5% Atmospheric Diffusion Coefficients for Use in Estimating Acute Release Exposure from WESF Stack Level Releases

Zone	Direction of Receptor from WESF Stack	On-Site X/Q' (s/m^3) and Maximum Receptor Location
V	S	5.4E-5 at 288 m
	SSW	"
	SW	"
	WSW	"
	W	"
	WNW	"
	NW	"
I	NNW	8.5E-5 at 200 m
	N	8.5E-5 at 200 m 3.7E-4 at 225-B intake filters
	NNE	4.6E-5 at 150 m
II	NE	1.2E-4 at 250 m 3.4E-4 at 221-B intake filters
	ENE	1.7E-4 at 100 m at ground level 1.7E-4 at 221-B intake filters 3.3E-4 at 150 m on 221-B roof
III	E	3.0E-5 at 200 m
IV	ESE	1.7E-4 at 100 m
	SE	8.3E-5 at 200 m
V	SSE	5.4E-5 at 288 m

2.2.5 Inhalation Dose per Unit Intake

Consequence estimation for hypothetical WESF accidents are based on the following set of assumptions.

Table 10. Dose Calculation Parameters

Description	Sr-90 and Daughters	Cs-137 and Daughters
Committed Effective Dose Equivalent per Unit Intake (rem/Ci)[1]	2.5E+5	3.2E+4
Average Salt Specific Activity as of 1/1/96 (Ci/g)	15.2	14.7

The committed effective dose equivalent per unit intake is taken from EPA (1988) and represents the 50 year committed effective dose an individual would receive using ICRP-30 (1979) methodology.

The average salt specific activity is taken from the WESF Encapsulation Database System (EDS) (see Appendix C) and is the ratio of the average uncut capsule activity as of 1/1/96 over the average net weight of the uncut capsule contents, excluding fabricated metallic parts.

2.2.6 Inhalation Dose Calculation Method

Doses as a result of acute releases of radioactive material are calculated according to the following equation.

$$D = Q' \, t \, \frac{\mathbf{X}}{Q'} \, R \, C$$

where:

Q' = *Release Rate (Ci per unit time)*
t = *Exposure Duration* **(22)**
$\frac{\mathbf{X}}{Q}$ = *Atmospheric Dispersion Coefficient* (s/m^3)
R = *Reference Man Breathing Rate* (m^3/s)
= $3.3E\text{-}4$ m^3/s *for light activity*
C = *Dose Conversion Factor (rem/Ci)*

[1]Inhalation pathway only. Submersion doses are insignificant as demonstrated in Section 2.2.7.

The release rate, Q', and exposure duration, t, are sometimes combined into a single value, Q, representing the total release quantity during the exposure period. The assumption inherent in the steady state Gaussian plume model used in the calculation of atmospheric dispersion coefficients is that the release rate over the exposure duration is continuous and constant. The exposure duration, t, represents the estimated time the receptor is at the location of plume passage. The atmospheric dispersion coefficient, X/Q', should be taken from Table 2 or 9 and accounts for dilution of the plume in transit from the source to the receptor. The value for the reference man breathing rate, R, is taken from ICRP-23 (1975) and is consistent with that used for commercial reactor licensing criteria as well as DOE nuclear facility siting criteria (DOE 1989). The dose conversion factor, C, should be taken from Table 10 to represent the 50 year committed effective dose via the inhalation pathway. The plume submersion dose, in comparison to the inhalation pathway dose, is insignificant. Other possible dose pathways, such as ground shine and ingestion, which might occur long after the release, are not representative of the acute and unavoidable consequences for which it is the purpose of this analysis to determine.

2.2.7 Inhalation Vs. Plume Submersion Dose

For all practical purposes, the plume submersion dose for either ^{137}Cs or ^{90}Sr can be neglected in relation to the inhaled committed dose. The following discussion bears proof.

The most hazardous of the two radionuclides, from an external exposure standpoint, is ^{137}Cs. The effective dose equivalent (EDE) of ^{137}Cs and its daughter product ^{137m}Ba is 2.88E-14 Sv per Bq s m^{-3} for submersion in air; whereas, the EDE for inhalation is 8.63E-9 Sv/Bq, which when multiplied by the ICRP 23 Reference Man breathing rate of 3.3E-4 m^3/s yields 2.85E-12 Sv per Bq s m^{-3}. Thus, the EDE from the inhalation pathway is two orders of magnitude larger than that from the external dose from plume submersion. Conversion factors were taken from EPA (1988) and EPA (1993).

2.3 Facility Hazardous Material Inventory

This section provides the basis for WESF hazardous material inventories to be used for safety analyses.

2.3.1 WESF Cesium and Strontium Capsule Activity per Capsule, Rack, Pool and Total

As of 1/1/96, there are 1328 cesium and 600 strontium WESF manufactured capsules under control of the DOE-Richland operation. Most of these capsules are currently stored underwater in WESF while three are currently being stored dry in a WESF hot cell. Approximately 30 cesium capsules are located at irradiation facilities. Another 12 are located in the 324 building in the 300 Area. The average, maximums and total inventories documented in this report includes all 1928 capsules. Throughout this report, these capsules will be referred to as the "uncut capsules."

Uncut SrF_2 and CsCl activity per capsule, rack, pool and total are provided in Table 11. Information was obtained from EDS decayed to 12/31/95. WESF EDS data is reproduced in Appendix C of this report.

Table 11. Capsule, Rack, Pool and Total Activity for WESF Capsules

Description	West CsCl Rack	Middle CsCl Rack	SrF_2 Rack
Rack Array Size	13 x 17[2]	13 x 21	13 x 13
Capsule Avg. Activity	39.19 kCi	39.19 kCi	37.63 kCi
Capsule Max. Activity	53.15 kCi	53.15 kCi	91.08 kCi
Filled Rack Avg. Activity	8.66 MCi	10.70 MCi	6.36 MCi
CsCl Filled Pool Avg. Activity[3]	25.98 MCi		
Total WESF Storage Pool Area Activity[4]	52.05 MCi		22.58 MCi

To conservatively bound any single WESF pool cell ^{137}Cs inventory, a value of 31 MCi should be used. This value is 10% above the activity of 715 average cesium capsules, the maximum number of capsules that can currently fit into the existing pool cell rack design. The reason for the overestimate is to account for statistical variations in the sample population. A more complete discussion is provided in Section 2.3.4.

2.3.2 Average and Maximum Cesium and Strontium Capsule Inventory Data

The following capsule characterization information was taken from the WESF Encapsulation Database System (see Appendix C) and can be used for accident analyses involving capsules. The activity is decayed to 1/1/96.

Table 12. WESF Capsule Characterization Data

	CsCl Capsule		SrF_2 Capsule	
	Avg.	Max.	Avg.	Max.
Power (W)	188	255	254	615
Activity (kCi)	39.2	53.2	37.6	91.1
Net Mass (kg)	2.67	3.44	2.48	3.85
Load Factor (g/cc)	2.84	3.71	N/A	N/A

The specific activity of WESF cesium chloride and strontium fluoride salt can be obtained by dividing the capsule activity by the capsule net mass. The average specific activity is reported in Table 11. The density of pure CsCl and a WESF simulant CsCl at 25 °C is 4.04 and 3.29 g/cc respectively (Tingey et al. 1985).

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[2]Four most westerly rows administratively controlled to be empty.

[3]663 capsules, assumes 13 x 13 SrF_2 storage rack is also filled with CsCl capsules.

[4]Includes all 1328 CsCl and 600 SrF_2 uncut capsules as of 12/31/95.

2.3.3 Capsule Storage Pool Cesium and Strontium Thermal Heat Generation

Uncut SrF_2 and CsCl capsule thermal power generation per capsule, rack, pool and total are as given below. Thermal information was obtained from the EDS decayed to 12/31/95. A listing of this information is provided in Appendix C.

Table 13. Capsule, Rack, Pool and Total Thermal Power for WESF Capsules

Description	West CsCl Rack	Middle CsCl Rack	SrF_2 Rack
Rack Array Size	13 x 17[5]	13 x 21	13 x 13
Capsule Avg. Thermal Power	188.23 W	188.23 W	254.37 W
Capsule Max. Thermal Power	255.25 W	255.25 W	614.92 W
Filled Rack Avg. Thermal Power	41.6 kW	51.4 kW	43.0 kW
Filled Pool Avg. Thermal Power[6]	136 kW (4.6E+5 Btu/hr)		
Total WESF Storage Pool Thermal Power[7]	403 kW (1.4E+6 Btu/hr)		

2.3.4 Bounding Capsule Thermal Heat Generation Assumptions for Use in Safety Analysis

Thermal analyses documented in WHC (1996) were performed in order to predict the transient temperature increase in the capsules and various locations throughout WESF, in the event that water cover were lost for an extended period of time. Loss of water for a single pool and all pool cells were considered. In the latter case, a total thermal power of 403 KW, as shown in Table 13, is used. In the case of a single pool, it is appropriate that the assumed heat generation in the affected pool bound the range of possible values, depending upon the number and history of capsules stored in the pool. It is also desirable that the bounding value be limited to what is reasonable in order to realistically predict consequences and avoid excessive controls. An appropriately bounding value for an individual storage pool is to assume the average filled pool thermal power shown in Table 13 plus 10%. This is equal to 149 KW.

To support this assumption a statistical analysis was performed in order to show that the probability of exceeding this value was extremely low. This analysis is provided in Appendix I. The analysis assumed that the pool cell was filled 494 cesium capsules (i.e., one 17 x 21 array plus one 21 x 21 array) and 169 strontium capsules (i.e., one 13 x 13 array. The conclusions were that even the highest powered 494 cesium capsules would not exceed 110% of the average of the total population. For strontium, there was a 0.5% chance that a random sample of 169 capsules could exceed the population average by more than 10% (assuming a normal distribution). The 149 KW also

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[5]Four most westerly rows administratively controlled to be empty.

[6]Sum of above three rack powers.

[7]Includes all uncut capsules.

exceeds the thermal power generated in the above described pool cell with the additional four most westerly rows filled with cesium capsules.

2.3.5 Toxic Material Inventory and Evaluation

The March 14, 1996 WESF OSHA/Emergency Planning and Community Right-to-Know Act Inventory, Hazardous Material Inventory Database was reviewed (see Appendix D), for toxic materials stored in WESF that could potentially be released during an accident. Except for trisodium phosphate crystals (Na_3PO_4) and a clay absorbent (Absorbs-It[8]) (MSDS No. 010179), the quantities of materials identified in the database for use in WESF are extremely low (i.e., 18.93 L [5 gal] of floor wax, 36.74 kg [81 lb] of floor cleaner). Most of the materials are in use for general housekeeping purposes and are in quantities used for the typical household but are certainly not in greater quantities than found in institutions, e.g., schools, hospitals, hotels/motels, etc. Only one material, Neolube[9], is not used for general housekeeping purposes and is reviewed along with trisodium phosphate (MSDS No. 042124) and Absorbs-it[8] in the following discussion.

Trisodium phosphate is used as a decontamination agent in WESF. The dry material is a nonvolatile, noncombustible alkaline dust. The crystals are mixed with water and typically heated to form a 0.4 to 1 wt% solution. The trisodium phosphate vapor pressure from the 0.4 to 1 wt% solution would be negligible, and the solution would primarily be considered a potential skin and eye irritant with some potential for respiratory irritation should misting occur. There are no exposure limits for trisodium phosphate in either the American Conference of Governmental Industrial Hygienists (ACGIH 1991) or the National Institute of Occupational Safety and Health (NIOSH 1990). However, exposure to the dry dust would be limited to a 3 mg/m^3 (respirable) 8-hour TWA (ACGIH-particulate not otherwise classified). A spill of this material would not result in detectable concentrations at 100 m (328 ft) or the Hanford Site boundary.

Absorbs-It[8] is sedimentary opal clay used as a liquid absorbent. The material contains less than 10% crystalline silica (as quartz), and is nonvolatile and noncombustible. The exposure limit for quartz is 0.1 mg/m^3 (respirable) 8-hour TWA (ACGIH), and crystalline silica is considered a possible or reasonably anticipated carcinogen by the National Toxicological Program and the International Agency for Research on Cancer. There is some potential for exposure to employees using the material, but the material is non-toxic to the environment and a spill of this material would not result in detectable concentrations at 100 m (328 ft) or the Hanford Site Boundary. This material is directly analogous to common sand.

Neolube[9] is a mixture of isopropanol and natural graphite used when pulling wires through electrical conduit. Employee exposure limits for the Neolube[9] ingredients are: graphite, 2 mg/m^3 (respirable) 8-hour TWA (ACGIH-TLV) and isopropanol, 400 ppm 8-hour TWA, 500 ppm STEL (ACGIH-TLV). The Neolube[9] is stored in the flammable cabinet in the AMU. The material does not

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[8]Absorbs-It is a trademark of Excel-Mineral company, 111 S. La Patera Lane, Goleta, California, 93117.

[9]Neolube is a trademark of Huron Industries, Inc., P. O. Box 610104, Port Huron, MI 48061.

pose a significant exposure hazard to employees using the material, and a spill of this material would not result in detectable concentrations at 100 m (328 ft) or the Hanford Site boundary.

None of the chemicals at WESF as identified in the March 1996 inventory pose a credible onsite, 100 m (328 ft), offsite (Hanford boundary), or environmental risk based on the quantity of material and the dispersion properties due to the physical characteristics of the materials. The materials discussed in some detail above are not considered as having any significant exposure potential outside the immediate spill or work area.

2.4 Calculations Having to do with Capsule Uncovery

This section documents various calculations used to assess capsule uncovery scenarios in HNF (1997). Figure 4 summarizes dimensional data used in the calculations.

2.4.1 Time Required to Start Boiling a WESF Capsule Storage Pool Upon Loss of Heat Exchanger Cooling

To obtain a rough estimate of the minimum time it might take to reach the boiling temperature in a WESF capsule storage pool, the following assumptions and calculation is made.

Assumptions:

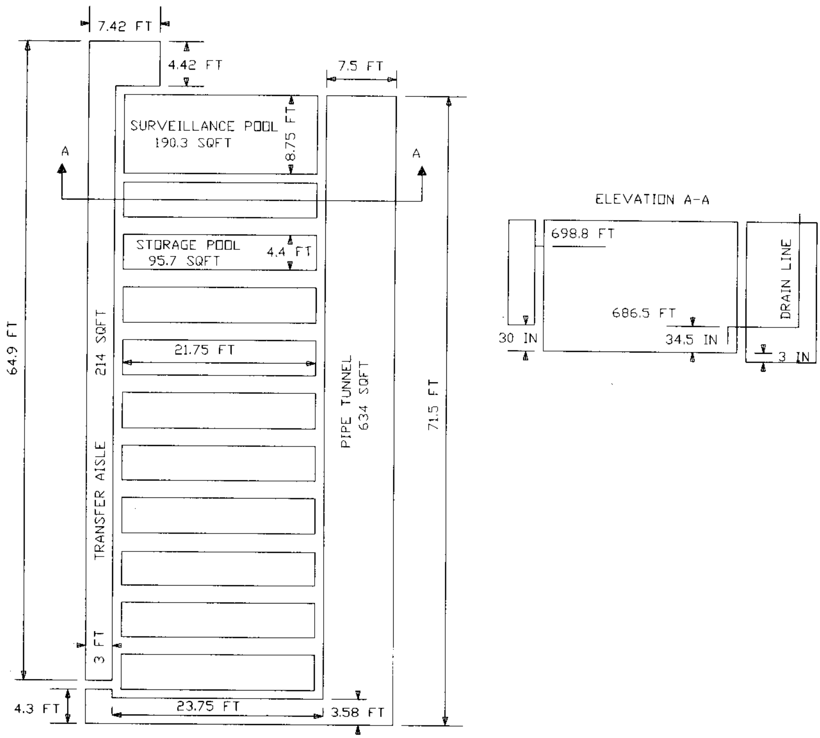
Water heat up is adiabatic,
Heat capacity and displacement of capsules and rack is neglected,
Initial temperature = 122 °F (50 °C),
Initial enthalpy = 90 Btu/lbm (from steam tables),
Initial water specific volume = 0.0162 ft^3/lbm,
Initial water level = 138 in,
Final temperature = 212 °F (100 °C),
Final enthalpy = 180 Btu/lbm (from steam tables),
Thermal power = 149 Kw (509,000 Btu/hr),

The volume of water contained by the pool is 1100 ft^3 as calculated from the pool dimensions shown in Figure 5. The time required to reach boiling is given by,

$$t = \frac{(1100\ ft^3)(180-90\ Btu/lbm)}{(0.0162\ ft^3/lbm)(509{,}000\ Btu/hr)}$$
$$= 12\ hrs$$

The actual time to boil would of course depend upon the actual number of capsules contained in the pool and the actual water level and initial temperature.

Figure 4. WESF Capsule Storage Area Pool Cell Dimensions.



2.4.2 Time Required to Boil a Capsule Storage Pool Down to the Level of the Bottom of the Capsules

The time required to boil a maximally loaded capsule storage pool (i.e., 149 Kw) down to below the level of the capsules is conservatively estimated below.

Assumptions:

Heat loss to the surrounding structure is neglected,
Heat capacity and displacement of capsules and rack is neglected,
Condensation and water addition to pool is neglected,
Initial temperature = 212 °F (100 °C),
Initial water specific volume = 0.0167 ft^3/lbm,
Initial water level = 138 in,
Final water level = 8 in,
Heat of vaporization = 970 Btu/lbm (from steam tables),
Thermal power = 149 Kw (509,000 Btu/hr),

The volume of water boiled off is 1040 ft^3 as calculated from the pool dimensions shown in Figure 4. The time required to uncover the capsules through boiling is given by,

$$t = \frac{(1040\ ft^3)(970\ Btu/lbm)}{(0.0167\ ft^3/lbm)(509{,}000\ Btu/hr)}$$

$$= 119\ hrs$$
$$= 5\ days$$

This equates to a boil off rate of approximately 1 in/hr.

2.4.3 Time Required to Boil Capsule Storage Pools Down to the Level of the Bottom of the Capsules When Pool Cell Transport Valves are Open

If all heat exchanger cooling is lost, then the total heat input would be 403 Kw and each pool will heat up and boil water. However, since not all five active pool cells can be maximally loaded, the boil off rate for each pool will be different, with highest being no greater than 1 in/hr as calculated above. In such a case the transfer port valves between pool cells 1 through 8 could be opened so that water level will equalize throughout all the pool cells. The time required to boil the storage pool water down to below the level of the capsules is conservatively estimated below.

Assumptions:

Heat loss to the surrounding structure is neglected,
Heat capacity and displacement of capsules and rack is neglected,
Condensation and water addition to pool is neglected,
Initial temperature = 212 °F (100 °C),
Initial water specific volume = 0.0167 ft^3/lbm,
Initial water level = 138 in,
Final water level = 8 in,
Heat of vaporization = 970 Btu/lbm (from steam tables),

Thermal power = 403 Kw (1,380,000 Btu/hr),

To totally uncover the capsules, the volume of water needed to be boiled off would be 11,700 ft^3 as calculated from the pool dimensions shown in Figure 4. The time required to uncover the capsules through boiling would then be,

$$t = \frac{(11{,}700\ ft^3)(970\ Btu/lbm)}{(0.0167\ ft^3/lbm)(1{,}380{,}000\ Btu/hr)}$$

$$= 492\ hrs$$
$$= 21\ days$$

This equates to a boil off rate of approximately 0.26 in/hr.

2.4.4 Pool Cell Drain Line Pipe Leak/Break Frequency

One possible mechanism for inadvertently draining water from an active pool cell is through a pipe leak or break. Such piping exists in the WESF Pool Cell Area pipe tunnel, at an elevation approximately three feet above the pool cell floor. Potential candidates for this failure are the 2 in drain line and 3 in recirculation line associated with each active pool cell. In order to determine the likelihood of such an event, industry pipe leak and rupture data were evaluated. This evaluation is documented in Appendix H. The conclusions drawn were 1) a WESF Pipe Tunnel pipe rupture frequency is on the order of 4.4E-5/yr, and 2) that a WESF Pipe Tunnel pipe leak frequency is on the order of 1.3E-3/yr.

2.4.5 Time Required for a Pool to Drain via a Pipe Break

In order to assess the response time needed for emergency response personnel to successfully respond to a pool cell pipe break event, the time to drain a pool cell is determined. Two pipe breaks could potentially cause this event. The lowest elevation of either pipe is approximately 3 ft off the pool cell liner floor. The 2 in drain line would offer the least resistance to gravity flow due to the sparger distributor on the recirculation line. Appendix H documents the hydraulic flow calculation used for the time estimate. The conclusion was that it would take approximately 1 hr to drain the pool to the 3 ft level starting from a nominal water level of 156 in. At an initial water level of 130 in the drain time would be approximately 45 minutes. These calculations assumed a clean break and would bound any other break configuration.

2.4.6 Time Required to Inadvertently Drain a Pool Cell via the Jet Pump

A possible mechanism for totally draining a pool cell is to inadvertently do so through jet pump operation. At the current time this would also require the failure of an interlock working off of pool cell water level indication. The nominal jet pump flow rate is 75 gpm for 100 psig steam. At this rate the pool cell could be totally drained in 2 to 2.6 hours for an initial water level of 10 ft and 13 ft respectively. Documentation of this calculation is also provided in Appendix H.

2.4.7 Pool Level if Pipe Break Occurs in Pool Cell Area Pipe Tunnel and Transfer Port Valves Opened

As discussed above, a pipe break in either the pool cell recirculation line or drain line could result in a rapid loss of pool cell water to the pipe tunnel. Partial and temporary level restoration could be achieved by opening the transfer port valves to allow water from other pool cells and the transfer aisle to flood into the affected cell and pipe tunnel. The final equilibrium level after this occurs is estimated below.

Assumptions:

Initial water level for all pool cells = 130 in
Initial transfer aisle water level = 100 in (i.e., same as pool cell)

The initial and final water volumes must remain the same. Therefore, using the pool cell dimensions of Figure 4, the final pool cell water level is,

$$\textit{Water volume lost} = \textit{Water volume gained}$$
$$(130\ in - x\ in) \times (214\ ft^2 + 7(95.7\ ft^2) + 190.3) = (634\ ft^2)(x\ in + 3\ in)$$
$$x = 81\ in$$

2.4.8 Pool Level if Transfer Port Valve to Empty Pool Cell were Accidentally Opened

One means for partially draining a pool cell would be to inadvertently open a transfer port valve to an empty pool cell while the affected pool cell transfer port was already open. The final level of all three pool cells is estimated below.

Assumptions:

Initial affected pool cell water level = 138 in
Initial transfer aisle water level = 108 in (i.e., same as pool cell)

The initial and final water volumes must remain the same. Therefore, using the pool cell dimensions of Figure 4, the final pool cell water level is,

$$\textit{Water volume lost} = \textit{Water volume gained}$$
$$(138\ in - x\ in)(214\ ft^2 + 95.7\ ft^2) = (95.7\ ft^2)(x\ in)$$
$$x = 105\ in$$

2.4.9 Pool Cell Sump Volume

Calculations were performed to estimate the volume of the leak detection sump boundary beneath the liner of the pool cells. For pool cells 2 through 11 this volume was calculated to be 68 gallons or equivalent to a 1.1 in drop in pool cell water level. For pool cell 1 the volume was found to be 73 gallons or equivalent to 0.61 in of pool cell water level. The calculation is contained in Appendix H.

2.5 Shielding Calculations

This section details the results of various shielding calculations used to assess radiological conditions within and near WESF in support of its basis for interim operation.

2.5.1 Dose Rates Due to Uncovery of Capsules in All Storage Pools

Calculated dose rates outside and within the WESF due to a total loss of water from all capsule storage pools are documented in the following reference which is included in Appendix G:

Internal Memorandum from K. E. Hillesland to J. M. Siemer dated November 29, 1994, "Dose Rate Calculations near the WESF Facility Due to Loss of Water in the Capsule Storage Pools," KEH-8D150-94-001, Westinghouse Hanford Company, Richland, WA.

Results of this analysis were generated for the purpose of evaluating radiation field hazards following a complete loss of capsule storage pool water. Two rack storage configurations were evaluated. Dose rates from the most conservative configuration are scaled to 52.05 MCi (see Table 11) and summarized in Table 15. To simplify the model, the capsule array was treated as a parallelepiped with zero density. Therefore, self-shielding provided by the capsule array is not accounted for and results appear to be conservative by a factor of 5 to 10.

2.5.2 Dose Rate at WESF Air Lock Due to 64 in. Water Level in One Pool

The dose rate at the WESF pool cell air lock door was calculated for a single, maximally loaded pool (i.e., 31 MCi ^{137}Cs from Section 2.3.1) with a water level of 64 in. The purpose of this calculation was to determine at what water level the gamma field would prevent operators from entering the storage pool control room. The conclusion is that the water level would have to drop below 64 in. The calculation is documented in the following reference included in Appendix G:

Internal Memorandum from K. E. Hillesland to B. E. Hey dated February 13, 1996, "Dose Rate in the WESF Capsule Storage Control Room Due to Loss of Water in a Maximally Loaded Pool," 8M730-KEH-96-001, Westinghouse Hanford Company, Richland, WA.

The result, scaled to 31 MCi of ^{137}Cs is summarized in Table 14.

2.5.3 Dose Rate Due to Partial and Complete Uncovery of Capsules in a Single Storage Pool

Calculated dose rates 18 ft over the pool cell floor, at the airlock door, and just outside the north door of the WESF pool cell area are documented in the following reference which is included in Appendix G:

Internal Memorandum from Karl Hillesland to B. E. Hey dated June 3, 1996, "Dose Rates Due to Partial and Complete Loss of Water in a Maximally Loaded WESF Capsule Storage Pool," 8M730-KEH-96-003, Westinghouse Hanford Company, Richland, WA.

These calculations are used to estimate maximum potential gamma-ray exposure rates within WESF for a water level of 36 in and no water for a single maximally loaded pool. Summarized results, scaled to 31 MCi ^{137}Cs are included in Table 14. The dose rate immediately above the pool cell is also a good estimate in the event that all pool cells drained since the shine from adjacent pool cells would be negligible in comparison to the direct dose shine from the capsules immediately below.

Table 14. Dose Fields Within and Near WESF (Pool Cell 7 with 715 Cesium Capsules or 31 MCi ^{137}Cs)

Condition	Location	Dose Rate (rem/hr)	Reference
Nominal Water Level of 156"	18 ft Over Center of Pool Cell Floor	4.4 E-06	Microshield[10]
Water Level at 110"	18 ft Over Center of Pool Cell Floor	0.057	
Water Level at 64"	18 ft Over Center of Pool Cell Floor	470	
	Airlock Door	1.3	8M730-KEH-96-01
Water Level at 36" (i.e., at drain line penetration elevation)	18 ft Over Center of Pool Cell Floor	49,000	8M730-KEH-96-03
	Airlock Door	260	
	Just Outside North Door	29	
Water Level at 28" (i.e., at top of capsules)	18 ft Over Center of Pool Cell Floor	83,000	Microshield
Dry Pool	18 ft Over Center of Pool Cell Floor	62,000	8M730-KEH-96-03
	Airlock Door	1000	
	Just Outside North Door	120	
	5 m from External Wall	20	KEH-8D150-94-01 results divided by 2[11]
	10 m " "	20	
	50 m " "	5	
	100 m " "	2	
	200 m " "	0.4	

[10]Microshield calculations appear to be conservative by a factor of 2 to MCNP calculations. This is caused by simplified homogeneous treatment of capsule array materials.

[11]This calculation did not account for the self-shielding provided by the capsule array and appears conservative by a factor of 5 to 10.

Table 15. Dose Fields Within and Near WESF (All Pools Drained 52.05 MCi ^{137}Cs)

Condition	Location	Dose rate (rem/h)	Reference
Dry pool	18 ft over center of pool cell floor	62,000	8M730-KEH-96-03
	Airlock door	5,000	KEH-8D150-94-01[12]
	Just outside north door	1,700	
	5 m from external wall	40	
	10 m from external wall	40	
	50 m from external wall	10	
	100 m from external wall	4	
	200 m from external wall	0.7	

2.5.4 Exposure Rate Above K-3 Filter Vault Per Unit Curie

The calculated dose rate performed using Microshield 4.00 (Negin and Worku 1992) (output included in Appendix G entitled "1 Ci Cs-137, Dist.=4m, Shield=20in Normal Concrete") for a 1 Ci source of Cs-137 at a distance of 4 m with 20 inches of normal density concrete is 0.05 mR/hr. This dose rate can be ratioed according to the K-3 filter pit inventory and be used to represent the dose field above the K-3 filter pit cover blocks.

2.5.5 Exposure Rate Above TK-100 Vault Per Unit Curie

The calculated dose rate performed using Microshield 4.00 (Negin and Worku 1992) (output included in Appendix G entitled "1 Ci Cs-137, Dist.=4m, Shield=24in Normal Concrete") for a 1 Ci source of Cs-137 at a distance of 4 m with 24 inches of normal density concrete is 0.01 mR/hr. This dose rate can be ratioed according to the TK-100 pit inventory and be used to represent the dose field above the TK-100 pit cover blocks.

2.5.6 Exposure Rate Outside Hot Cell Containing 24 Cesium Capsules

The calculated dose rate performed using Microshield 4.00 (Negin and Worku 1992) (output included in Appendix G entitled "Dose Rate Through Hot Cell Wall with 24 CsCl Capsules") for 9.408E+5 Ci of Cs-137 at a distance of 2 m with 35 inches of high density concrete is 0.025 mR/hr. This dose rate can be used as a conservative estimate of the dose rate in the operating gallery due to storage of 24 CsCl capsules each having an average activity of 39.2 kCi.

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[12]This calculation did not account for the self-shielding provided by the capsule array and appears conservative by a factor of 5 to 10.

2.5.7 Dose Rate Above Cesium Capsule Storage Pool as a Function of Water Level

Eight Microshield 4.00 (Negin and Worku 1992) computer runs were made in order to estimate the dose rate above a maximally loaded cesium storage pool at various water levels. Each run represents a pool inventory maximally loaded to 31 MCi ^{137}Cs (see Section 2.3.1). Figure 5 shows the dimensions used in the Microshield input files. Variable SL1 represents the water shield thickness. All code output is included in Appendix G. A summary of the results is included in Table 16. Table 14 also contains results from selected runs as indicated in the reference column.

In comparison to the MCNP (Carter 1996) run documented in Hillesland (see Appendix G 8M730-KEH-96-03), these Microshield runs appear conservative by approximately a factor of two. The reason for this is the simplified treatment of the capsule rack as a parallelepiped with a homogenized mixture of water and capsule material with a uniform density of 2.1 g/cc. On the other hand, Hillesland used MCNP to model the capsule rack as a lattice of individual capsules, each having a CsCl net density of 2.16 g/cc, surrounded by an inner and outer stainless steel capsule having a density of 8.4 g/cc. The net effect of this difference is that the gamma-rays in the MCNP model are more heavily, and realistically, self-shielded.

Figure 5. Pool Cell Dimensions Used in Microshield Calculations

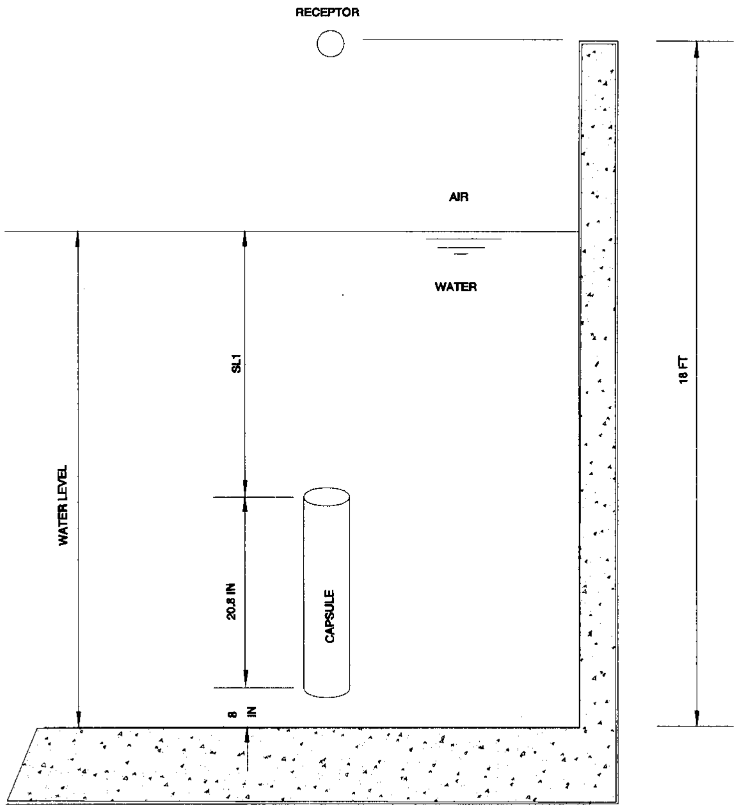

Table 16. Dose Rate Above Capsule Storage Pool w/ 31 MCi ^{137}Cs

Storage Pool Water Level (in)	SL1 (in)	Dose Rate (R/hr)
156	127.2	4.4E-6
110	81.2	0.057
100	71.2	0.43
95	66.2	1.1
64	35.2	470
36	7.0	49,000
28	0	83,000
dry	N/A	118,000

2.5.8 Dose Rate Above Drained and Fully Loaded WESF Cesium Capsule Storage Pool with Cover Blocks Installed

Microshield 4.00 (Negin and Worku 1992) was used to estimate the dose rate above a fully loaded (i.e., 715 average activity cesium capsules) cesium capsule storage pool with the 30 in. high density concrete cover blocks installed. Results indicate that a dose rate of 5 mR/hr would be possible. The output file DRAINP.MS4 is included in Appendix G.

2.5.9 Contact Dose Rate from Bagged Waste

Microshield 4.00 (Negin and Worku 1992) was used to estimate the contact dose rate from a 3 ft diameter sphere of simulated waste matter containing 1 Ci of ^{137}Cs. The media was assumed to be carbon with a density of 0.113 g/cc such that the bag weighed 100 lb (45 kg). The model was not greatly sensitive to the atomic number of the sphere material. Since the elemental form of the waste material is highly variable and largely unknown, carbon represents a sufficiently accurate description of organic material for shielding purposes. The density of 0.113 g/cc is judged to be suitably conservative (i.e., dense) in comparison to actual un-compacted waste material which is largely void (i.e., air). Results indicate that a dose rate of 1800 mR/hr would be possible from a bag containing 1 Ci of ^{137}Cs. Therefore, 30 bags each having a contact reading of 50 mR/hr would be equivalent to a bagged inventory of 0.83 Ci ^{137}Cs. If the waste material activity is assumed to be 50% ^{137}Cs and 50% ^{90}Sr, then another 0.83 Ci of ^{90}Sr could be expected. The output file BAGWASTE.MS4 is included in Appendix G.

2.5.10 Detector Reading from Cs-137 and Sr-90 on K-3 Filter

ISO-PC Version 1.98 (WHC 1995) was used to estimate the detector reading for a K-3 filter loading of either 240 curies of ^{137}Cs or 18,000 curies of ^{90}Sr. This inventory is currently assumed in the HNF (1997). The calculated dose rates were 67 and 81 R/hr for cesium and strontium respectively. The intended use of this calculation is to provide a basis for the detector set point. K-3 inventories can also be controlled at other levels by proportionally adjusting the set point higher or lower as the case may be.

The relationship between the detector reading and inventory is linear. Both the requesting DSI and the memorandum documenting the calculations are contained in Appendix G.

2.6 Hydrogen Generation

Attenuation of ionizing gamma radiation from decay of Ba-137m in water causes radiolytic decomposition and production of H_2 and O_2 molecules. This is the case for the WESF capsule storage pools. This calculation provides an analytical estimate of the hydrogen production rate. The following equation taken from Henrie et al. (1986) is used for this calculation.

$$R = E\,F\,G\,C$$

where:

$$\begin{aligned}
R &= \text{hydrogen generation rate } (L/s) \\
E &= \text{ionizing radiation release rate } (eV/s) \\
F &= \text{fraction radiation absorbed in water} \\
G &= \text{hydrogen } G \text{ value} \\
&= \frac{0.45 \text{ molecules } H_2}{100\ eV} \\
C &= \text{conversion factor} \\
&= \left(22.4 \frac{L}{g\text{-}mole}\right)\left(\frac{g\text{-}mole}{6.023 \times 10^{23}\ H_2}\right) \\
&= 3.72 \times 10^{-23} L/H_2
\end{aligned} \tag{28}$$

The ionizing radiation production rate, E, is conservatively assumed to include all 1328 uncut CsCl capsules. The total Cs-137 activity decayed to 1/1/96 is taken from the WESF Encapsulation Database System and has a value of 52.05 MCi (see Appendix C). Only the gamma-ray emitted from Ba-137m contributes significantly to the ionizing radiation escaping the capsule. The contribution from Sr-90 or its daughter product is also negligible. Accounting for gamma-ray yield for decay of Cs-137 the value of E is given by

$$\begin{aligned}
E &= (52.05 \times 10^6\ Ci)(3.7 \times 10^{10}\ dps/Ci) \\
&\quad \times (0.662 \times 10^6\ eV/d)(0.946)(0.90) \\
&= 1.07 \times 10^{24}\ eV/s
\end{aligned} \tag{29}$$

The value, F, accounts for the fraction of ionizing radiation absorbed in the hydrogen producing media. It is a function of geometry and material properties. Two sources of information were used to arrive at a proper value representing the WESF pool cells. The value of 0.23 used here is taken from the Monte Carlo calculation documented in Internal WHC Memorandum from K. E. Hillesland to B. E. Hey dated March 13, 1996 (included in Appendix F). This is slightly lower but in close agreement with the 0.26[13] cited in Spriggs et al. (1995) which was independently calculated using Monte Carlo techniques.

The $G(H_2)$ value is taken from Table 4-3 of Henrie et al. (1986) and is a function of the energy absorbing material, water in this case.

Substituting the above values into the hydrogen generation rate equation yields 0.042 L H_2/s or 5.3 CFH.

2.7 Capsule and Structural Failure Criteria

The following paragraphs discuss the basic assumptions and calculations made in order to determine the number of CsCl capsules that would fail at a given temperature. It is intended that the results of these calculations be used in conjunction with thermal analyses to support source term development work for postulated WESF capsule storage pool loss of water scenarios. Additionally, an evaluation of the thermal impact to WESF concrete structures is made in order to determine temperature limits, and assess the potential damage which might occur.

2.7.1 WESF Cesium Capsule Load Factors

A load factor for WESF capsules is defined as the mass of salt (plus impurities) in grams divided by the internal volume of the inner capsule in cm^3 at a reference temperature of 25 °C. WESF manufactured CsCl capsule load factors are accurately reflected in the Gram Salt record of the EDS. These data are provided in Appendix B and summarized in Figure 6 and Table 17.

The gram salt entry in the EDS was checked for consistency and found to be accurate and reasonable considering the tolerances of the capsule manufacturing specifications. The results of the verification performed by WESF engineering staff are included in Appendix B.

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[13]Spriggs calculates 0.215 fractional power deposition, which when converted to the fraction of gamma-ray energy, turns into 0.26.

Figure 6. Capsule Load Factor Distribution

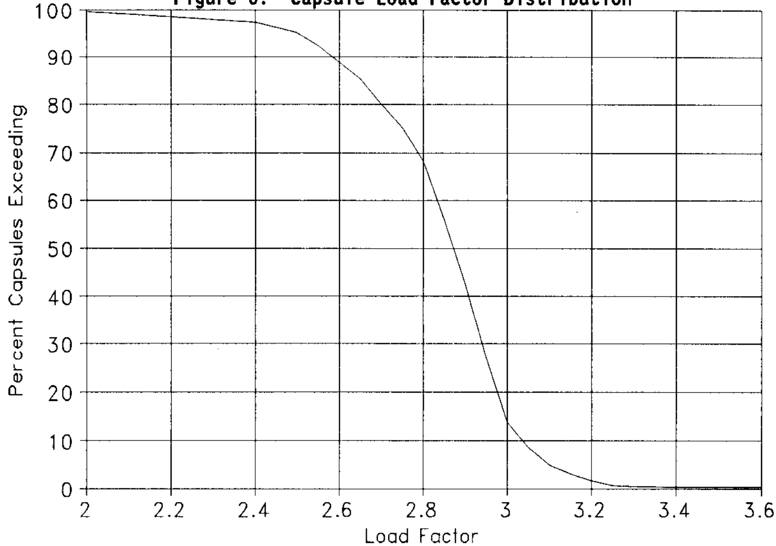

Table 17. CsCl Capsule Load Factor Distribution

Load Factor	Percent Capsules Exceeding	Number Capsules Exceeding
1	99.9	1327
2	99.5	1321
2.4	97.4	1293
2.5	95.1	1263
2.55	92.3	1226
2.6	88.8	1179
2.65	85.3	1133
2.7	80.2	1065
2.75	75.2	999
2.8	68.2	906
2.85	56	744
2.9	42.4	563
2.95	27	359
3	13.7	182
3.05	8.8	117
3.1	5	66
3.15	3.1	41
3.2	1.7	23
3.25	0.6	8
3.3	0.4	5
3.4	0.3	4
3.5	0.2	3
3.6	0.2	3
3.7	0.1	1

2.7.2 Cesium Inner Capsule Failure Criteria for Thermal Stress Rupture

Inner capsule failure is assumed to occur when salt expansion reduces the capsule void volume to zero.

Failure of the inner capsule can occur due to stress rupture. That is, the expansion of the salt exceeds the volume capacity of the capsule. Any additional expansion of the salt causes the stress to quickly exceed the maximum yield of the capsule. Although the inner capsule can accommodate a certain amount of strain and not fail, it is conservatively not accounted for and is assumed to fail at that point.

An additional mode of failure is stress corrosion cracking. Destructive examination of a CsCl test capsule (Tingey et al. 1985) subjected to a ninety minute temperature of 810 °C showed intergranular corrosion to a depth of 0.08 to 0.1 in. Thus, stress corrosion under similar high temperature conditions could cause failure of the inner capsule within an hour. This accelerated corrosion rate is not apparent without the presence of capsule stress. In fact, corrosion measurements performed on actual WESF capsules (Bryan 1987 and 1989) indicates that the depth of attack during capsule pouring was limited to less than 0.001 in. Therefore, the accelerated intergranular stress corrosion identified in Tingey et al. (1985) is not expected unless the capsules are subjected to both high temperature and stress.

2.7.3 Cesium Outer Capsule Failure Criteria for Thermal Stress Rupture

Outer capsule failure is assumed to occur when the inner capsule has failed and salt expansion reduces the annulus volume between the inner and outer capsule to zero.

Similarly to inner capsule failure, outer capsule failure can occur due to a combination of stress rupture and stress corrosion. Although the outer capsule can accommodate a certain amount of strain and not fail, it is conservatively not accounted for and is assumed to fail at that point. It might be noted that for "special form" considerations, only the outer capsule is credited as a pressure barrier.

2.7.4 Basis for Cesium Liquid Phase Release Quantity Resulting From Capsule Stress Rupture

Short term salt releases from outer capsules which have failed due to stress rupture are expected to be limited to the quantity of salt necessary to relieve the stress on the outer capsule.

Destructive testing of a simulated WESF capsule (Tingey et al. 1984) subjected to a preheated 810 °C furnace revealed a bulge of the inner capsule at what normally would be the hot weld end of the capsule. This bulge occurred due to the stress imposed on the capsule by salt expansion. The bulging stopped when the inner capsule wall made contact with the outer capsule. No significant increase in diameter of the outer capsule was apparent. The inner capsule end cap weld failed in a circumferential crack extending 90° around the capsule circumference. The crack width was 200 μm which is approximately four times the width of a human hair. Approximately 150 cm^3 of salt exited through this crack and into the annular region between the inner and outer capsule. This effectively reduced the strain on the inner capsule to zero.

A similar failure mechanism is expected in the event WESF capsules are subjected to high temperatures for extended periods. Due to the small opening of the crack and the immediate reduction of stress on the capsule caused by a small quantity of salt exiting the crack, a total release of the molten salt is not expected.

2.7.5 WESF CsCl Salt Density as a Function of Temperature

WESF CsCl salt is assumed to have a temperature dependent density as given in Table 19.

The density of pure CsCl salt as a function of temperature is well known. However, the WESF salt contains approximately 20% impurities and changes over time with radioactive decay. The net effect is a lower density for WESF CsCl, especially at lower temperatures, a lower melting point of approximately 430 °C versus 646 °C for pure CsCl, a lower thermal expansion coefficient, and a lack of a crystallographic transformation such as exists for pure CsCl (Tingey et al. 1985).

The capsule failure calculations performed below require a knowledge of WESF CsCl density as a function of temperature. However, WESF CsCl density measurements appear to be available only at room temperature (i.e., 25 °C) and at high temperature (i.e., 800 °C). Thus, density information for pure CsCl is used with appropriate adjustments to conservatively account for the effect of impurities. These adjustments are made as follows. A density decrease of 9% is experienced by pure CsCl during melting at approximately 646 °C (p. 28 Tingey et al. 1984). To account for the lower melting point of WESF CsCl and the corresponding density change, WESF CsCl densities are assumed to be 9% lower than pure CsCl densities within the temperature range of 430 °C to 646 °C.

At higher temperatures (i.e., 800 °C) the WESF CsCl and pure CsCl densities are approximately the same and no adjustment is made (Tingey et al. 1985).

2.7.6 WESF Cesium Capsule Load Factor Limits

A load factor limit is a capsule specific parameter defined as the load factor which would reduce the capsule void volume to zero at a specified temperature. For simplicity and for the purpose of calculating CsCl capsule load factor limits, WESF Type 3 CsCl capsule dimensions are assumed.

Three types of CsCl capsules, called Types 1, 2 and 3, are stored at WESF. Most (i.e., 76%) of the existing CsCl capsules are of Type 3. Type 3 capsules differ from Type 1 and 2 capsules in having a thicker inner and outer tube wall specification with essentially the same outer capsule outer diameter. This results in a slightly decreased inner capsule and annulus volume in the Type 3 capsules and a slightly conservative estimate of load factor limits. Type 3 capsule dimensions and tolerances are provided in Table 18 (Tingey et al. 1985 and Washburn 1989).

Table 18. Dimensions and Tolerances of WESF Type 3 CsCl Capsule

Capsule Dimensional Data (inches)	Inner	Outer
Height	19.725	20.775
Cap Thickness	0.4	0.4
Outside Diameter	2.250 ± 0.010	2.625 ± 0.015
Wall Thickness	0.136 ± 0.012	0.136 ± 0.012

2.7.7 Estimated Number of Cesium Outer Capsule Failures as a Function of Temperature

The purpose of this calculation is to conservatively estimate the number of CsCl inner and outer capsules which might fail due to the failure mechanisms discussed in Assumptions 1 and 2 above. This is accomplished by calculating a capsule load factor limit which would cause a capsule to experience stress due to salt expansion at a given temperature, T. The load factor limit for inner capsules is equal to the mass of salt that would fill 100% of an inner capsule at temperature T, divided by the volume of the inner capsule at a reference temperature of 25 °C. This is given by,

$$\rho_{L,inner}(T) = \frac{\rho(T)\ V_{inner}(T)}{V_{inner}(25°C)} \tag{30}$$

where:

$$\begin{aligned} \rho(T) &= \textit{salt density at temperature } T, \\ V_{inner}(T) &= \textit{inner capsule volume at temperature } T, \\ V_{inner}(25°C) &= \textit{inner capsule volume at } 25°C \end{aligned}$$

The load factor limit for outer capsules is equal to the mass of salt that would fill 100% of the inner capsule plus the annular region between the inner and outer capsule at temperature T, divided by the volume of the inner capsule at a reference temperature of 25 °C. This is given by,

$$\rho_{L,outer}(T) = \frac{\rho(T)\ (V_{inner}(T) + V_{annulus}(T))}{V_{inner}(25°C)} \tag{31}$$

where:

$$V_{annulus}(T) = \textit{annular capsule volume at temperature } T.$$

The volume capacity of the capsules is larger at higher temperatures due to thermal expansion of the metal. The temperature dependence of capsule volume is approximated by the following equation taken from Washburn (1989).

$$V(T) \approx V(25°C)\,(1+3\alpha(T)\,\Delta T)$$

where:

$$\alpha(T) = \text{mean coefficient of thermal expansion for 316L SS at temperature } T. \tag{32}$$

The mean coefficient of thermal expansion of 316 stainless steel is assumed constant at 1.921 x 10^{-5} per °C (Washburn 1989). Using Equations 29, 30 and 31, and the load factor distribution illustrated in Figure 5 and Table 17, the number of capsules exceeding the temperature dependent load factor limit is calculated and given in Table 19.

2.7.8 Estimated Quantity of Spilled CsCl Salt as a Result of Thermally Induced Outer Capsule Stress Rupture

The excess salt mass which cannot be contained by a single unstressed outer capsule having a load factor greater than the load factor limit, $\rho_{L,outer}(T)$, can be calculated using the following,

$$M_{single}(T) = \rho_{lf}\, V_{inner}(25°C) - \rho(T)(V_{inner}(T) + V_{annulus}(T))$$

where:

$$\rho_{lf} = \text{capsule load factor,} \tag{33}$$

which is simply the mass of salt less the mass capacity of the inner capsule plus annulus at temperature T. If there are N capsules having a load factor greater than the load factor limit at this temperature, then the total amount of salt released from all N capsules is given by,

$$\begin{aligned} M_{total}(T) &= \sum_{i=1}^{N} M_{single,i}(T) \\ &= \sum_{i=1}^{N} [\rho_{lf,i}\, V_{inner}(25°C) - \rho(T)(V_{inner}(T) + V_{annulus}(T))] \\ &= N\,\overline{\rho}_{lf}\, V_{inner}(25°C) - N\,\rho(T)(V_{inner}(T) + V_{annulus}(T)), \end{aligned} \tag{34}$$

where $\bar{\rho}_{lf}$ is the average load factor of failed outer capsules. The above equation is simply the total mass of salt associated with failed outer capsules less the mass capacity of these capsules at temperature T. Using Equation 33 and the WESF CsCl capsule load factor distribution, the mass of salt that would escape the outer capsules, if they were all heated to a specified temperature, can be calculated. The results of these calculations are also provided in Table 19 in the last column.

Table 19. Capsule Failure Vs. Capsule Temperature

Salt Temperature (°F)	Salt Temperature (°C)	CsCl Density (g/cc)[14]	Load Factor Limit to Cause Inner Capsule Failure/# Capsules Exceeding	Load Factor Limit to Cause Outer Capsule Failure/# Capsules Exceeding	Mass CsCl Spilled (kg)
806	430[15]	2.89[16]	2.957/332	3.406/4[17]	1
900	482	2.88[16]	2.956/335	3.404/4	1
1000	538	2.87[16]	2.955/335	3.403/4	1
1100	593	2.84[16]	2.933/421	3.378/4	1
1200	649	2.82	2.921/462	3.365/4	1
1300	704	2.76	2.868/681	3.303/4	1
1400	760	2.69	2.804/898	3.229/14	2
1500	816	2.64	2.760/978	3.179/26	3
1600	871	2.56	2.685/1088	3.092/67	6
1700	927	2.51	2.640/1144	3.041/136	11
1800	982	2.46	2.596/1181	2.989/205	19
1900	1038	2.40	2.540/1230	2.925/448	38
2000	1093	2.35[18]	2.495/1263	2.873/664	64
2100	1149	2.30[18]	2.449/1282	2.820/858	101
2200	1204	2.25[18]	2.403/1293	2.767/964	146

[14] Linearly interpolated from Tingey (1984 p 28) for pure CsCl.

[15] Assumed melting point of impure CsCl (Tingey 1985 p. 6).

[16] Density reduced 9% to account for lower melting point of impure CsCl (Tingey 1984, p. 28).

[17] Capsule nos. 1178, 1214, 1215, 1228.

[18] Extrapolated values.

From Table 19 it can be seen that approximately 0.1 kg of cesium salt is released per failed capsule. Also, aside from the one capsule, failed capsules would not be expected to occur until a temperature of 700 to 800 °C was reached. This seems to be somewhat conservative in light of the fact that cesium pours were performed at approximately this temperature. The conservatism is likely a result of a conservative estimate of capsule load factor and actual WESF cesium salt density as a function of temperature.

2.7.9 Basis for Capsule Storage Area Ventilation Flow to be Used in Thermal Analysis of Accidental Capsule Uncovery

When operating, forced ambient air is brought into the WESF capsule storage area via the K4 HVAC system at a minimum flow rate of 5,000 cfm. Three inlet diffusers are provided above the storage pools. Air is exhausted from the south end of the building via the K1 HVAC system where it passes through two NBS filters (8 and 35% efficiency respectively) and two stages of HEPA filters to the 70 ft discharge stack. Capsule storage area pressure is controlled either automatically or manually.

WESF control drawing H-2-66532 indicates the K4 system design provides forced air from the outside into the capsule storage area at a flow rate of 8,320 cfm. Historical flow balance measurements indicate that this flow rate is closer to 5,500 cfm. The safety analysis will assume 5,000 cfm.

2.7.10 Structural Evaluation of Concrete Exposed to High Temperatures

In an effort to determine the impact of a loss of pool cell water and resultant high temperatures on structural concrete, an evaluation documented in Appendix E was performed. This evaluation considered the transient thermal analysis results of WHC (1996) Cases 1 through 4. In Case 1 the scenario involved the loss of water from all pool cells in conjunction with a loss of forced ventilation flow for an extended period. This resulted in extreme temperatures. The conclusion of the Appendix E evaluation was that loss of structural confinement of the pool cell area could be expected after 5 days. For the remaining Cases 2 through 4, temperatures were not sufficient to conclude that structural confinement would fail, however, structural degradation would still be a consideration.

2.8 Pool Cell Emergency Makeup Water System Functional Requirements and System Evaluation

A pool cell Emergency Makeup Water (EMW) system is credited in HNF (1997) as performing a safety class function. That function is to maintain capsule water cover in the event of a rapid loss of pool cell water, and to restore pool cell water level to 130 in. in the event that a rapid loss of pool cell water occurs. An additional requirement is that the above be accomplished without exposing response personnel to a dose greater than 5 rem. This section provides the functional requirements for the EMW system. It also describes and evaluates the system in order to show that it meets those functional requirements.

The term "safety class" is invoked by 6430.1A, and was developed specifically for nuclear reactors. Its use for non-reactor applications requires judgement. The WESF EMW system already exists and hence falls under DOE backfit policy. There is no requirement that the WESF EMW system meet all safety class requirements. Based on the information contained here, it can be concluded that the WESF EMW system in its current configuration (i.e., as of 1/1/96) when properly controlled and protected, can be relied upon to meet this safety class function.

2.8.1 System Description

The Pool Cell Emergency Makeup Water System consists of an emergency fill pipe installed through the north wall of the 225-B Building, redundant water supplies used to provide makeup water, and various components necessary to connect the two, such as a fire hose and connections.

Fire Hose and Connections

Water for the emergency makeup water system is provided through one of several independent general service water sources located near WESF. The water supply is connected to the fill pipe by use of standard fire fighting hoses brought to the facility by the response of the Hanford Fire Department (HFD). The HFD trucks are required by law to carry several hundred feet of several hose sizes, including 2.5-in and 4-in hoses. If necessary, the flow from the hydrants can also be increased by the pumps located on the HFD truck.

Emergency Fill Pipe

The fill pipe is a 5 foot long 2.5-in diameter pipe running through the north wall of the Pool Cell Area just west of the personnel access door to Pool Cell 12. The pipe has two 90° bends and no plugs or valves except for a dust cover over a standard fire hose connection on the outside end of the pipe. The standard fire hose connection conforms to the fire fighting standards so that a fire hose of any size from the HFD would function with the system. The fill pipe can be connected from outside of the building to provide water to Pool Cell 12 (transfer aisle) and ultimately the remaining Pool Cell(s).

Raw Water Supply

Raw water is used at WESF for Pool Cell heat exchangers, air compressor after-coolers, and the hot cell fire suppression system. Raw water fire hydrant R3-B is located southwest of the 225-B building and is fed from the 282-E reservoir. Supply pressure at this hydrant is approximately 100 psi.

Deep Well Water Supply

Two diesel-driven deep well pumps identified as #1 (282-B) and #2 (282-BA) are located west of 225-B at wells 299-E28-11 and 299-E28-15, respectively. Supply pressure from the deep well pumps is approximately 30 psi.

Sanitary Water Supply

Sanitary water is used at WESF for safety showers, operating area wash down, drinking, toilet facilities, deionized water production for pool cell makeup, and a supply for the automatic fire suppression system. Sanitary water is produced in the 283-E filter plant which filters and chlorinates raw water and maintains a 1.5 million L (400,000 gal) supply in an underground clear well system containing two 760,000 L (200,000 gal) concrete tanks.

Sanitary water fire hydrant 8-B is located northeast of the 225-B building. Supply pressure at this hydrant is approximately 80 psi.

2.8.2 Functional Requirements

This section identifies the system functional requirements needed to fulfill the safety function identified above. WESF pool dimensions were taken from the WESF essential drawings. A sketch is provided in Figure 4. Specifically, this section establishes;

- initial conditions and assumptions,
- response time limitations,
- system flow rate requirements and,
- the total system water capacity needed to fulfill the safety function.

Initial Conditions and Assumptions

- Pool Cells 1-8 are filled to the 130 in. level
- Upon indication of a rapid loss of pool cell water, the level of the drained cell is assumed to be at the bottom of the drain line circumference (i.e., 34.5 in).
- Transfer port valves for Cells 9-11 are closed and ventilation holes are plugged such that water flooding the transfer aisle can not be diverted to these cells.
- Cell 12 is full to the 100 in. level. This corresponds to the 130 in. level in Cells 2-8 because the bottom of Cells 2-8 is 30 in. lower than the bottom of Cell 12.
- The transfer port between the affected cell and Cell 12 is closed. This is a conservative assumption since if the transfer port were open, it would take more time to drain the pool and a longer time to boil off water to the top of the capsules.
- The water from Cell 12 could enter the other pool cells via one of two ways: through open transfer ports and through the 4-in diameter ventilation ports (one per cell; connecting each pool cell with Cell 12). Because of the possibility of open transfer ports, uneven ventilation ports, and the desire to bound the functional requirements of the emergency makeup water system, it is assumed that all unaffected pool cells must be filled to the level of their ventilation ports before water begins to enter the affected pool cell.
- To account for possible flow paths into the pipe tunnel when flooding the transfer aisle, it is assumed that water is lost to the pipe tunnel such that it is filled up to the 37.5 in level (i.e., the lowest level of the pipe break).

Response Time

The time available for the addition of water is predicated upon the desire to maintain water coverage over the capsules. The lowest possible water level which the emergency makeup water system must be capable of mitigating is the 34.5 in. level where the bottom of piping penetrations from the pipe tunnel into the pool cells exist. The tops of the capsules are at approximately the 29 in. level, and assuming a 1 in/hr evaporative loss rate (see Section 2.4.2), this results in the capsules becoming uncovered in 5.5 hr (34.5 in. - 29 in.). With an assumed 1 hr response time (see Section 2.8.3) before the emergency makeup water system begins adding water to Cell 12, water must begin filling the affected cell within 4.5 hr.

Immediate Flow Rate Requirements

Filling Cell 12:

The dimensions of Cell 12 are a rectangular part (3.0 ft by 64.9 ft) and a square part (4.4 ft by 4.4 ft), resulting in an area of 214 ft^2. The bottom of Cell 12 is at 686.5 ft (mean sea level, MSL) and the bottom of the ventilation ports to the other cells is at 698.8 ft MSL. This is a total distance of 12.3 ft, or 147.6 in. The level assumed in Cell 12 at the beginning of the event is 100 in. Therefore, before water can begin entering the affected pool cell through the ventilation port, 147.6 in. - 100 in. = 47.6 in. of water must be added to Cell 12. This volume is 47.6 in. (4.0 ft) times 214 ft^2, or 856 ft^3 (6,420 gal).

Filling six of Cells 2-8 (Excluding the Affected Cell):

The dimensions of Cells 2-8 are 21.75 ft and 4.4 ft, resulting in an area of 95.7 ft^2 per cell. The MSL of the bottom of Cells 2-8 is 684 ft. The MSL of the bottom of the ventilation ports is 698.8 ft (from above), making the distance from the bottom of the cells to the bottom of the ventilation ports 698.8 ft - 684 ft, or 14.8 ft (177.6 in). Each of these 6 cells is assumed to be at the 130 in. level and must be brought to the 177.6 in. level. This level increase is 47.6 in. (4.0 ft) resulting in a volume requirement of 4.0 ft times 95.7 ft^2 times 6 cells, or 2,300 ft^3 (17,200 gal).

Filling Cell 1:

The dimensions of Cell 1 are 21.75 ft by 8.75 ft for an area of 190.3 ft^2. The required level rise for Cell 1 is the same as for cells 2-8, or 4.0 ft. The volume required is then 4.0 ft times 190.3 ft^2, or 761 ft^3 (5,710 gal).

Filling the Pipe Tunnel:

To account for the possibility of the need to fill the pipe tunnel, and to bound the functional requirements of the emergency makeup water system, the volume of water required to fill the pipe tunnel to the level of the original leak must be calculated. The area of the pipe tunnel can be estimated from three sections: 7.5 ft by 71.5 ft, plus 3.58 ft by 23.75 ft, plus 4.3 ft by 3.0 ft, or 634 ft^2. The bottom of the pipe tunnel is 3 in. lower than the bottom of the pool cells and so the original leak at the 34.5 in. level requires that the pipe tunnel be filled to the 37.5 in. level (34.5 in. + 3 in.). However, because the original leak was to the pipe tunnel some water would already be present. The volume of water which went to the pipe tunnel can be estimated by the drop from 130 in. to 34.5 in. (95.5 in., or 8.0 ft) in the affected cell. The area of the affected cell is equal to the area of any of the Cells 2-11, which is 95.7 ft^2. Thus, the volume of water which entered the pipe tunnel from the affected cell is 8.0 ft times 95.7 ft^2, or 762 ft^3. This volume of water would result in a water level in the pipe tunnel of 762 ft^3 divided by 634 ft^2 (the area of the pipe tunnel) which is equal to 1.2 ft, or 14 in. Therefore, the water level in the pipe tunnel has to go from 14 in. to 37.5 in.; an increase of 23 in., or 1.9 ft. This is a volume of water equal to 1.9 ft times 634 ft^2, or 1,220 ft^3 (9,100 gal).

Filling Miscellaneous Volumes:

Miscellaneous volumes such as the pool cell outlet ventilation ducts and recirculation piping were evaluated and found to total less than 1000 gal.

System Flow Rate Requirements:

The total volume necessary to satisfy the immediate requirements of the emergency makeup water system is the summation of the volumes calculated above. This volume is approximately 39,000 gal. As stated above, the calculated volume must be delivered to Cell 12 via the emergency fill pipe over a 4.5 hr period. If the entire 4.5 hr were used this would result in an average flow rate of 39,000 gal divided by 4.5 hr, or 8,700 gal/hr (150 gal/min).

Total Emergency Makeup Water Capacity

The flow rate requirements established above ensure that water begins to fill the affected pool cell before the capsules are uncovered due to evaporative losses. The emergency makeup water system must also be able to deliver sufficient water to recover from the event by increasing the water level in the affected pool cell up to the LCO level of 130 in. This also ensures that dose fields in the pool cell area are small enough to permit manned entry into the pool cell area so that additional measures, such as water addition via the deionized system or opening of transfer ports, could be accomplished.

The volume of water necessary to raise the level in the affected pool cell from the 29 in. level to the 130 in. level must include the volume of water required to increase the water in the pipe tunnel to the same level. For the affected pool cell, to go from 29 in. to 130 in. is an increase of 101 in., or 8.4 ft. The area of the affected cell (assumed to be one of Cells 2-8) from above is 95.7 ft^2, making this amount of water 805 ft^3, or 6,040 gal. For the pipe tunnel, the level has to be raised from 37.5 in. (calculated above) to 133 in. (the pipe tunnel level of 133 in. corresponds to the pool cell level of 130 in.). This is an increase of 95.5 in., or 8.0 ft. Over the area of the pipe tunnel, 634 ft^2 from above, this is a volume of 5,000 ft^3, or 38,000 gal. Once water begins to flow into the affected pool cell, the volume required to raise the pool water level to the LCO level of 130 in is 6,040 gal + 38,000 gal, or 44,000 gal.

The total system requirement is then 39,000 gal (over the first 4.5 hrs.) + 44,000 gal or 83,000 gal.

Upon reaching 130 in. in all active pool cells, the action of the emergency makeup water system is complete and the system can be deactivated. Any source of water makeup can then be used to raise the levels of the active pool cells above the 130 in. level, as necessary. In addition, during the time that the affected pool cell is being filled to the 130 in. level, the strength of the radiation fields in and near the pool cell area will diminish rapidly. As soon as the dose rates drop to acceptable levels (even if the affected pool cell level has not reached the 130 in. level), personnel may enter the pool cell area or control room to provide additional means of water makeup (e.g., opening the transfer ports).

2.8.3 System Evaluation

This section compares WESF EMW system component capabilities to functional requirements. For each comparison made, a statement of acceptance is made.

Fire Hose and Connections

The Pool Cell Water Loss Detection System credited in HNF (1997) alerts facility personnel to the condition of a rapid loss of pool cell water. The functional requirements developed above require that water addition to Pool Cell 12 begin within one hour. Facility personnel would require time to react to the alarm and make notification to the HFD. This is estimated to take 15 min based on the desire to confirm the alarm and then call for the HFD. The HFD response time to WESF is estimated to be approximately 5 min with an additional 5 min to make the necessary hose connections and begin adding water to Pool Cell 12. The total time elapsed would then be 25 min, which is within the 1 hour response time required.

The north building wall provides some shielding to emergency response personnel. Connection of the fire hose to the emergency fill standpipe could expose personnel to approximately a 29 R/hr gamma-ray field immediately adjacent to and outside the Pool Cell Area north door, assuming a 36 in water level in a drained pool cell at the time (see Section 2.5). The fire hose connection should require less than one minute stay time at this location. Therefore, the exposure to emergency response personnel will be much lower than the 5 rem limit.

Emergency Fill Pipe

The standard fire hose connection on the outside end of the emergency fill pipe conforms to NFPA requirements such that a fire hose of any size from the HFD would function with the system. Since the fill pipe is a passive component it is not required to fulfill the single-failure criteria for safety class items. Pressure drop through the fill pipe is evaluated for each source of emergency makeup water evaluated below.

Raw Water Supply

Six-hundred feet of fire hose is adequate to connect the raw water fire hydrant to the emergency fill pipe. Fluid flow analysis (see Appendix K) indicates that this water supply would provide a minimum of 283 gpm of raw water to Pool Cell 12 with essentially unlimited capacity. This exceeds the functional requirements identified above.

Deep Well Supply

Three-hundred feet of fire hose is adequate to connect the deep well water supply to the emergency fill pipe. Fluid flow analysis (see Appendix K) indicates that this water supply would provide a minimum of 211 gpm of raw water to Pool Cell 12 with essentially unlimited capacity. This exceeds the functional requirements identified above.

Sanitary Water Supply

Three-hundred feet of fire hose is adequate to connect the sanitary water fire hydrant to the emergency fill pipe. Fluid flow analysis (see Appendix K) indicates that this water supply would provide a minimum of 345 gpm of sanitary water to Pool Cell 12 with a capacity in excess of 83,000 gal. This exceeds the functional requirements identified above.

2.8.4 WESF EMW System Evaluation Conclusions

The WESF EMW system is capable of performing its safety class function. The assumptions which require control in an IOSR are as follows:

- Two independent sources of emergency makeup water are available,
- Transfer ports and air vents into the transfer aisle from pool cells 9, 10 and 11 are maintained closed,
- Fire hoses are available with the proper connectors to facilitate connection of the fill pipe to the water supply and to limit radiation exposure to response personnel,
- Water addition commences within 1 hour upon indication of a rapid loss of pool cell water event,
- Water addition occurs at a minimum flow rate of 150 gpm,
- The capacity of the emergency makeup water supply is a minimum of 83,000 gal.

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APPENDIX A - WESF Hazards Evaluation

This appendix contains:

1. Table A-1. Qualitative Frequency Definitions.
2. Table A-2. WESF Hazard Evaluation Results.
3. Table A-3. WESF Hazard Evaluation.
4. Table A-4. Hazard Evaluation Team Participants.

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Table A-1. Qualitative Frequency Definitions.

Descriptive word/frequency designator	Description	Equivalent estimated annual likelihood of occurrence
Anticipated/F3	Incidents that may occur several times during the lifetime of the facility (incidents that commonly occur).	1 E-01≥p>1 E-02
Unlikely/F2	Accidents that are not anticipated to occur during the lifetime of the facility. Natural phenomena of this class include: Uniform Building Code-level earthquake, 100-yr flood, maximum wind gust, etc.	1 E-02≥p>1 E-04
Extremely unlikely/F1	Accidents that will probably not occur during the life cycle of the facility. This class includes the design basis accidents.	1 E-04≥p>1 E-06
Beyond extremely unlikely/F0	All other accidents.	1 E-06≥p

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
1	1	Truckport--provides confinement for cask loading and unloading.	Airflow	No/none	Ventilation equipment failure	Ventilation instrumentation	Alarms	Personnel exposure or minor environmental contamination due to migration of contamination from truck port	S1		Contamination spread would be minimal, since the truck port is not normally contaminated
2					Power failure (normal and emergency)	Same	Observation	Same			
3					Human error (truck port door left open)	Same		Same			
4					Mechanical failure of doors	Same		Same			
5					Electrical failure of doors	Same		Same			
6					Vehicle impact against doors	Same		Same			
7					Seismic/natural phenomena	Same		Same			
8				Less	See above	See above		No significant	S0		
9				More (results in high negative pressure)	Ventilation control failures	Alarms		Difficulty in egress	S0		
10					Design faults resulting from loss of configuration management	Same		Same			
11				Reverse	Ventilation failure	Observation; alarms		Contamination spread within the facility	S0		The truck port area and the cask are not normally contaminated
12					Partial power failure	Same		Same			

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
13					Human error (flow improperly balanced)	Same		Same			
14				As well as (contamination)	Leaking capsule with subsequent failure of cask containment	Smears; CAM		Local contamination spread within the facility; radiation dose to worker	S1		Very unlikely
15					Gasoline fumes from leaking truck fuel system or diesel fumes from forklift fuel system	fire detection and suppression systems; K-1 ventilation system	limited combustible loading in truck port; inspection and maintenance of trucks; operator observation and action	Facility worker exposure to hazardous fumes Fire	S2	F3	(Assumed fire consequences) evaluation comment: no onsite experience with truck port fire; Hanford fuel fires have not occurred, hazard mainly when truck is in port to haul out cask, frequency of cask pickup is rare at present, forklift is in and out quickly and does not stay in truck port
16					Carbon monoxide (CO) from truck or forklift concentrates due to running engine with door closed	None		Worker asphyxiation (death) or injury	S1		Administrative controls prohibit vehicles running with doors closed
17					Contamination from externally contaminated cask	Smears		Local contamination spread within the facility	S1		(Contamination may be there when cask arrives.)

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers		Consequence	Cons Rank	Freq Rank	Remarks
						Systems	Controls				
18			Tempera-ture	High	Fire	Fire detection and suppression systems	Regular surveillance	See "as well as" above	S2	F2	Evaluation comments: could be electrical fire, 20-30 bags of solid waste in plywood boxes at risk (possibly), manipulator boots, material could be present during cask receipt; requires higher energy ignition source than fuel; less likely than vehicle fire (this deviation assumes non-vehicular fire).
19					Seasonal (high ambient)	Observed		Deterioration of worker comfort and efficiency Equipment failure	S1 S1		Potential for heat exhaustion High/low temperatures lead to difficulties with decontamination or survey efforts. The S1 rating assumes that a worker could be contaminated because of failure to discover a contaminated area.
20								Less efficient heat transfer from cask to surroundings	S0		Casks assumed to be designed for high ambient temperatures
21				Low	Seasonal (low ambient)	Observed		Mechanical failure of doors	S1		
22						Observed		Instrumentation failure	S1		
23						Observed		Potential decreased operability of transport vehicle	S0		

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers		Consequence	Cons Rank	Freq Rank	Remarks
						Systems	Controls				
24						Alarm		Loss of fire suppression system and flooding due to broken pipe (assuming wet pipe system)	S1		
25			Structural integrity	Less	Seismically induced Greater than design basis structural loading on cask from facility collapse	Facility structure K-1 ventilation system transport casks	Radiation control via surveys on casks and truck port	Potential worker injury Loss of contamination control	S1 S1 S2/S3	F2	The truck port is usually clean, so S1 would be bounding unless the cask were damaged. evaluation comments: likelihood assigned based on having natural phenomena only; casks available are BUSS and waste drum cask; K-1 ventilation system would prevent the release of contamination shaken loose.
26					Wind	Same	Same	Same	Same	Same	Same
27					Vehicle impact	Same	Driver training	Same	Same	F2	Evaluation comments: deviation would require both a large vehicle and relatively high velocity.
28					Flood	Capsule and waste container integrity	Operator actions to prepare	Same	Same	F0	Evaluation comments: probable maximum flood does not impact the 200 East Area.
29					Ashfall	Facility structure transport casks	Operator actions to secure waste material and remove roof loading	Same	Same	F2	Facility has not been evaluated for ashfall loading. evaluation comments: likelihood assigned based on having natural phenomena only; casks available are BUSS and waste drum cask.

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers		Consequence	Cons Rank	Freq Rank	Remarks
						Systems	Controls				
30					Snow load	Same	Same	Same	Same	Same	Evaluation comments: likelihood assigned based on having natural phenomena only; casks available are BUSS and waste drum cask.
31					Airplane crash	Same	None	Same	Same	F0	Evaluation comments: airplane accident determined to be incredible.
32					Range fire	Observed; Structural design of facility		same	S1		
33	2	Transport Vehicle (forklift or truck); transports casks containing canisters into truck port to area where the casks can be raised into the canyon	Operating	Erroneous (speed or placement)	Human error	Observation		Worker injury or breach of wall between truck port and other parts of facility	S1		Assumed that cask is designed to survive the accident
34					Mechanical failure (brakes)	Same		Same			
35					Operator incapacitated	Same		Same			
36					Runaway Engine	Same		Same			
37				Inoperable	Mechanical failure	Observed		Worst case--vehicle stranded in doorway--failure to complete mission)	S0		
38					Electrical failure	Same					
39					Human error	Same					

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers		Consequence	Cons Rank	Freq Rank	Remarks
						Systems	Controls				
40	3	15-Ton Crane	Operating	Inoperable	Loss of Power	Observation		Operational delay Ventilation control problems if cover block left in open position (can go down if other doors are open or if wind conditions are unfavorable or damper problems or problems with instrument air) Hoist motor failure could lead to conditions causing worker injury because of non-routine maintenance	S0 S1 S1		 Due to contamination spread Potential worker injury
41					Mechanical failure	Observation		Same			
42					Electrical failure	Observation		Same			
43					Radio failure	Observation		Same			
44					Lack of communication	Observation		Same			
45					Faulty control panel lights	Observation		Same			
46					Telephone failure	Observation		Same			
47					Uncompleted preventative maintenance	Observation/procedural check		Same			

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
48				Improper speed/ position (Note: single speed motor)	Human error	K-3 ventilation system Process cell design	Operator training	Damage cover block (loss of concrete/exposed rebar) Misplaced cover block could slip down on Cask Misplaced cask on cell cover block (cover block thinner than floor--potential for breaking)	S1 S2 S2	 F1 F1	Release of contamination due to loss of ventilation control. Very unlikely consequence of cover block drop assumed s2 Evaluation comments: canyon crane involved in decon for process cells, lifting process cell cover blocks, moving casks; human error when placing cover block; crane hook left on cover block when operator error occurs; cover block and cell interface is stepped making it difficult for cover block to fall into cell; bus cask should survive a cover block drop; waste cask may be vulnerable but inventory is low; failure of cover block due to cask placement would occur only with cable failure
49					Poor visibility (Note that there is only one camera angle)						
50					Seismic event	Observation; alarms		Contamination spread within the facility	S0		The truck port area and the cask are not normally contaminated

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
51			Structural integrity	Failure of components (hoists, cables, hooks, wheels, bridge, trolley, rails)	Beyond design basis loading	Cask design	Hoisting and Rigging controls Operator training Inspection and maintenance (crane operator performs frequently)	Cask Failure Operational Delay Worker injury	S2 S0 S1	F1	More likely to be caused by dropping a cover block on the cask Evaluation comments: facility contains no beyond design basis loads; cask lifts are treated as "critical lifts" per the hoisting and rigging manual
52					Fatigue	Same	Inspection and maintenance (crane operator performs frequently)	Same	Same	Same	Evaluation comments: assumes structural failure of crane component; cask lifts are treated as "critical lifts" per the hoisting and rigging manual
53					Lack of maintenance	Same	Same	Same	Same	Same	Evaluation comments: cask lifts are treated as "critical lifts" per the hoisting and rigging manual
54					Seismic event	Cask design Crane design		Same	Same	Same	Evaluation comments: natural phenomena are assumed unlikely, however, a cask lift would have to be in progress at time of seismic event.
55					Human error	Cask design Crane design	Operator training	Same	Same	Same	Evaluation comments: cask lifts are treated as "critical lifts" per hoisting and rigging manual;

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
56	4	Cask	Heat Transfer	Less	Cover (transport shield)	No		Potential to exceed cask design temperature or capsule temperature or affect cask seals	S1		(Potential contamination spread)
57			Tempera-ture	High	Insufficient heat transfer	No		See above and worker injury due to touching hot cask exterior	S1		(Worker injury)
58					Seasonal (high ambient/cask in sun)	Observed		See Node 1			
59					Fire	Heat detection in truck port; Visual		See Node 1 for truck port effects Also off gas from impact limiter (polyurethane foam inside)	S1		
60					Too many curies (Human error from loading wrong capsules)	Discovered when unloaded		Less efficient heat transfer from cask to surroundings	S0		Casks assumed to be designed for high ambient temperatures
61				Low	Seasonal (low ambient)	Observed		No significant effect on cask			
62			Composi-tion	As well as, (water, hydrogen)	Failure to properly purge cask	Shippers and facility loading procedure		Pressurization of cask due to steam causing personnel injury or exposure upon opening (hydrogen expected to be well below flammable limits)	S1		
63				As well as, (contami-nation)	Capsule failure during shipping	Shippers' and facility loading procedures		Spread of contamination	S1		

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
64					Failure to decontaminate capsules	Same		Same	Same		
65					Loading wrong capsule	Same		Same	Same		
66					Failure to decontaminate cask from previous use	Same		Same	Same		
67				Other than, (wrong capsule)	Violation of administrative controls	Visual, during unloading		See high temperature, Node 4			
68	5	G-Cell capsule handling (inspection and transfer to water)	Airflow	No/low	Loss of power	Backup diesel generators K-3 filters dP monitors and associated alarms		Potential for contamination spread from G-Cell Possible for breaking loose contaminated material from the K-3 system exhaust duct. (Loose contamination in the K-3 duct system could be discharged out the 296-B-12 steam jet filtered but not automatically monitored.	S1 S1-S2	 F2	Evaluation comments: steam jet is downstream of K-3 filters; assumes that filters are not bypassed or failed.
69					Failure of K-3 exhaust system	Same and K-3/K-1/K-4 interlocks	Maintenance of ventilation system components	Same	S1-S2	F2	Evaluation comments: same.
70					Seismic Event	K-3 design Facility design		Same	S1-S2	F2	Evaluation comments: seismic event could also fail filters.

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
71					Equipment Failure	K-3 steam jet K-3 filters dP monitors and associated alarms K-3/K-1/K-4 interlocks	Maintenance on accessible components Calibration of instrumentation	Same	S1-S2	F2	Evaluation comments: steam jet is downstream of K-3 filters; assumes that filters are not bypassed or failed.
72					Filter plugging (on supply or exhaust)	Same		Same	S1-S2	F1	Evaluation comments: cesium salt volume in ducting is very small and would not clog filters
73				More	Changes in system balance	K-3 filters dP monitors and associated alarms K-3/K-1/K-4 interlocks		Liberation of fixed contamination in exhaust duct (see above)	S1-S2	F2	Evaluation comments: assumed that filters do not fail; maximum flow with both K-3 fans and the steam jet operating; high flow may result from attempt to maintain negative pressure on opening large flow paths (such as process cell cover block removal).
74					Seismic event	Same		Liberation of fixed contamination in exhaust duct (see above)	S1-S2	F2	Evaluation comments: seismic event could also fail filters.
75				Reverse Flow	N/A						
76			Confinement	Less	Cerium window breached by dropping heavy object or seismic event	Visual observation; DP; high radiation field detected in the operating gallery		Potential contamination spread from G-Cell to operating areas	S1		G-Cell is not highly contaminated

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
77					Seismic event results in failed doors and other confinement breaches	Same		Same	S1		
78					Degraded manipulator boots	Visual check; dangleometer Dp check		Same	S1		
79					Failure of interlocks entering door and pass through due to seismic event	Area radiation monitors in operating and service galleries near G-Cell		Personnel exposure; stress	S1		
80			Shielding	Less	Failure of interlocks entering door and pass through due to seismic event	Area radiation monitors in operating and service galleries near G-Cell		Personnel exposure; stress	S1		
81					Failure of shielding window	See less confinement above		Same			
82	6	Process cell manipulators	Operability	No/less	Various mechanical and electrical failures--Bands breaking, misuse, holes in boots	Visual or tactile		Process delay	S1		For contamination spread from holes in boots
83					Human error including operator inexperience, operator stress, maintenance error	Same		Capsule drop with potential breach of outer capsule	S1		
84	7	Transfer cart	Operability	No/less	Cable broken, twisted, or jammed; broken cable eyelet, crank jammed	Visual or tactile		Unable to lower capsule properly to transfer aisle	S1		Would not have a capsule breach even if lowered in an improper way

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
85	8	Pool cell and transfer aisle tongs	Operability	No/less	Structural Failure	Visual/tactile		Operational delay Capsule Drop	S0 S1		Extended delays have been experienced in the past because of a lack of spare parts.
86					Misuse or other human error	Same		Operator injury	S1		
87					Incorrect assembly (water not allowed in surrounding tube)	Procedural/tactile		Operator exposure due to shine	S1		
88	9	Pool cell crane	Operability	No/less	Loss of power	Observation		Operational Delay	S0		
89					Mechanical failure	Same		Same			
90					Electrical failure	Same		Same			
91					Uncompleted PM	Same		Same			
92				Other than (imprope r speed and position)	Human error		Operator training Pool cell cover blocks not allowed over pool cells containing capsules	Operational delay Personnel injury Cover block drop due to improper hook placement resulting in capsule and/or pool cell damage with radiation dose to onsite individual and expensive recovery	S0 S1 S2	 F1	This is unlikely but not impossible Evaluation comments: pool cell cover blocks removed from cells containing capsules, no cover blocks allowed on, or moved over, those cells; cover block lifts are "critical lifts" per the hoisting and rigging manual.
93					Poor visibility (due to poor lighting or cover block recessed bail design)	Same					

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
94			Structural Integrity	No/less	Beyond design basis loading	Crane design	Operator training Pool cell cover blocks not allowed over pool cells containing capsules	Capsule failure if smashed by cover block Operational delay Worker injury	S2 S0 S1	F1	Evaluation comments: cover blocks not allowed over pool cells containing capsules; cover block lifts are "critical lifts" per the hoisting and rigging manual.
95					Fatigue		Same and maintenan ce program	Same	Same	Same	Same
96					Lack of maintenance		Same	Same	Same	Same	Same
97					Seismic Event	Crane design Facility structure		Same	Same	Same	Evaluation comments: cover blocks not allowed over pool cells containing capsules.
98					Human error (mishandling of crane or dropped hook)		Operator training Pool cell cover blocks not allowed over pool cells containing capsules	Same	Same	Same	Evaluation comments: cover blocks not allowed over pool cells containing capsules; cover block lifts are "critical lifts" per the hoisting and rigging manual.

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
99	10	Capsule	Tempera-ture	High	Lack of cooling water	Pool cell level alarms Radiation alarms Beta alarms Temperature alarms Demin water makeup Raw water makeup K-1 ventilation system Pool cell steam jet to xfer water from one cell to another 2 deep well pump systems	Regular surveillance	Potential for capsule structural failure due to high temperature	S3	F2	Evaluation comments: Same as Node 16 (Pool Cell, Level, None). From Node 16, assume s3 consequence instead of s2.
100					Seismic induced loss of cooling water	Same and: Facility structure Pool cell liner Pool cell structure		Potential for capsule structural failure due to high temperature	S3	F2	Evaluation comments: Same pool cell liner and facility structure are seismically qualified.

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
101					Proximity to other capsules	See lack of cooling water		None unless pool water lost	S3	F2	Evaluation Comment: same.
102					Diesel fire in Truckport	See Node 1		See Node 1	See node 1	See node 1	Evaluation comments: see node 1.
103			Structural Integrity	No/less	High temperature	See high temperature deviation above		See above	See above	See above	Evaluation comments: see above.
104					Impact (object dropped on it)	See Node 9		See node 9	See Node 9	See node 9	Evaluation comments: see node 9.
105					Material failure due to corrosion or bad weld	Radiation alarms Beta monitors inspection, visual detection, CAM alarm; observation of steam from outer capsule	Visual inspection of newly received capsules Clunk test Visual inspection of capsules in pool	See node 10 - capsule leak in pool cell	S2	F3	Evaluation comments: inspection of returned capsules may find soft metal indicating that failure has already occurred.
106					Human error	Same	Same	Same	Same	Same	Evaluation comments: same.
107	11	F Cell (Capsule Decontamination and Storage)	Airflow	Refer to "G-Cell" with changes radiolytic hydrogen in TK-F5	See G-Cell	K-3 filters		Note potential high rate of production of contamination dispersed by explosion	S2	F1	Only if explosion Evaluation comments: Tank F5 is believed to contain no water; assume S2 consequences for a Tank F5 explosion

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
108			Inventory	More (too many capsules) Storage tank or bubbler tank	Procedure violation	Visual Mitigation: fire/fog system		Fire in cell: combustion from excess heat generated by dry stored capsules	S2	f2	this accident was S1 severity in the original HAZOP, since only a few capsules were expected to be stored there. However, since the completion of the HAZOP the mission for F cell has changed and the facility needs appropriate limits on the number of capsules allowable in F cell. Therefore the possibility of overloading F cell with capsules was included here.
109				More (too much contamination)	Erroneous storage of too much contaminated material	Cell smears		Potential for contamination spread to personnel-occupied areas	S1		See airflow. Unexpected contamination will increase solid waste flow
110				Capsule leak	See capsule	Cell smears		Potential for contamination spread to personnel-occupied areas	S1		Assumes small leak

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
111				As well as (water)	Actuation or leak of fire/fog system (manual with required valve alignment)	K-3 ventilation system Cell sump alarm 1 inch K-3 duct dam directs water to Tank 100		Flood of F Cell from water Contamination spread to other cells Potential damage to or flooding of filters and ductwork/dampers Increased waste water generation	S1 S1 S2/S3 S0	F3	If K3 contamination dissolved Evaluation comments: flooding a process cell could lead to flood of K-3 duct, K-3 filter, and/or Tank 100; assume S2 consequence; fire suppression system is manually activated; fire suppression system activation is not interlocked with K-3 ventilation system.
112					Use/leak of water from decontaminatio n wash system	Same	Water flow monitored Operator training	Flood of F Cell from water Contamination spread to other cells Potential damage to or flooding of filters and ductwork/dampers Increased waste water generation	S1 S1 S2/S3 S0		If K3 contamination dissolved
113				As well as (TSP)	Leakage of TSP from capsule decontaminatio n system (requires special valve alignment) Human error	Observation		No significant	S0		Note that gross leakage could flood TK-100/K-3 filter. (See TK-100 node)

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers		Consequence	Cons Rank	Freq Rank	Remarks
						Systems	Controls				
114				As well as (steam)	Closed valve with steam supply on	See as well as (water) above	See as well as (water) above	Filter damage	See above	See above	See as well as (water) above
115				As well as (solid waste)	Poor housekeeping, lack of manpower	Visual observation		Increased fire hazard	S1		
116			See G-Cell for additional parameters and deviations								Note that loss of confinement would result in higher consequences
117	12	Water supply to pool cells	Flow	No/low	Shut valve Deionized supply system not operable Break in line Pump failure Loss of power Human error Poor maintenance	No flow alarm Audible Visual to Tk-210 Level in Tk-210 Level in pool cell		No immediate unless catastrophic leak; (see loss of pool cell water) slow heat up	S1		From additional direct radiation exposure to facility worker Slow heat up of pool cell (Normal evaporation rate is about 2"/week)
118				High	System malfunction Human error Water drawn from TK-210 versus usual route ??	Audible Visual High Level alarm		See pool cell--high level			

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems / Controls	Consequence	Cons Rank	Freq Rank	Remarks
119				As well as (minerals)	System error in deionization Addition of water from other source	Conductivity alarms Weekly sampling	Possible increased corrosion of capsules Algae bloom	S0		
120			Tempera-ture	High	High ambient temperature	Alarms in pool cell	No significant	S0		
121	13	Pool cell flow through Heat Exchanger to Ion Exchange Bleed off	Flow	No/low	Improper valve alignment	Visual observation Temperature alarm/recorder (checked twice a shift)	Pool heat up	s1		consequence rank assumes no capsule failure due to loss of pool cell water.
122					Pump failure	Temperature alarm/recorder	Same	s1		same
123					Valve failure	Temperature alarm/recorder	Same	See pool cell tempera-ture (high)		(Potential contamination spread)
124					Pipe break upstream of heat exchanger	Visual; pool cell low level	Water leak with potential contamination spread Level drop with direct radiation exposure	S1 S1		Pool cell water is clean unless failed capsule or contaminated capsule is present Intake for heat exchanger is above low-level alarm point
125				High	Heat exchanger tube failure	Conductivity in pool	Impurities in water (possibly removing IX resin from bed)	S0		
126					Wrong pump (configuration management breakdown)	Level instrumentation Visual	No significant	S0		
127				As well as (raw water)	See high flow, previous node loading wrong capsules)	Conductivity in pool	Impurities in water	S0		

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers		Consequence	Cons Rank	Freq Rank	Remarks
						Systems	Controls				
128				As well as (radiological contamination)	Capsule failure	Radiation alarms in IX BETA monitor in pool cell		Radiation exposure	S1		
129				Reverse	Heat exchanger tube failure and pump failure	See heat exchanger tube failure					
130			Temperature	High	See pool cell level and temperature						
131	14	CDL discharge	Flow	As well as (radioactive contamination)	Heat exchange leak and low pressure in raw water	B-Plant discharge alarm for radiation (not direct indication)		Increased liquid waste volume discharged to 216 B pond	S0		
132					Undiscovered contamination in pool cell 9 or 10	Sampling for pool cell		Same	Same		
133				As well as (Chemical, TSP)	Spill of TSP into pool cell 9 or pool cell 10	Visual		Potentially mixed waste	S0		Note that one of the TSP utility headers is capped, limiting the quantity which might be spilled.
134	15	Ion exchange loop	Flow	No/low	Valve closed	Alarms, no cooling water flow		Lowered water quality			
135					Filters plugged	Same		Same	S1 S1-S2		Evaluation comments: S2 not applicable.
136					High radiation interlock shuts off flow to ion exchange	Radiation alarm		Personnel direct radiation exposure	S1		
137					See no flow, heat exchanger	See no flow, heat exchanger		Same			

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers		Consequence	Cons Rank	Freq Rank	Remarks
						Systems	Controls				
138				As well as (algae/resin)	Algae growing on pool cell walls pulled in by the flow	High dP across filter		Decreased flow across ion exchange loop Could result in necessity for resin change	S0 S1		
139					Failure of resin column results in resin in pool	Same		Plugged filters; necessity for resin change	S1		
140				As well as (ionic species)	Ion exchange media saturated	Conductivity alarm??		Change out of resin required	S1		Change out of the ion exchange resin does not occur frequently. Since it is time-consuming and has not been performed during the era of increased safety requirements, it is suggested that consideration be given to using a column which can be exchanged as a unit.
141				High	Same as primary loop	Resin displacement (visual, sampling in pool cell)		Clogged filters	S1		
142					Raw water incursion	Conductivity alarm		Decreased water quality			
143					Closed recirculation valve	Pool temperature		Same			
144	16	Pool Cell	Level	High	Human error	High level alarm Visual Conductivity alarm if raw water involved		Decreased water quality	S0		
145					Leak in Heat exchanger	Same		Same			

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers		Consequence	Cons Rank	Freq Rank	Remarks
						Systems	Controls				
146					Misvalving (see deionized supply and ion exchange loop)	Same		Same			

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
147				None	Pool liner failure from seismic event or other beyond design basis load	Pool cell liner Pool cell structure Facility structure Pool cell level alarms Radiation alarms Beta alarms Temperature alarms Demin water makeup Raw water makeup 2 deep well pump systems K-1 ventilation system Pool cell steam jet to xfer water from one cell to another	Regular surveillance	High direct radiation dose Capsule failure Potential "Meltdown of capsules"	S2 S3 S2	F2 F2 F2	Analyzed as a beyond design basis accident

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers		Consequence	Cons Rank	Freq Rank	Remarks
						Systems	Controls				
148					Evaporation without makeup	Same	Same	Same	Same	Same	Evaluation comments: long duration required before accident condition is reached, less if cooling is also lost.
149				Low	Same as above with human error	Same	Same	Same	Same	Same	Evaluation comments: assumed to include inadvertent draining of pool cell.
150				As well as radiological contamination	From low level waste header	Leak		Worker exposure	S1		
151					Failed capsule	See Capsule		See Capsule			
152				As well as algae proliferation	See IX loop flow	See IX loop flow					
153				As well as resin	See IX loop flow	See IX loop flow					
154	16	Pool Cell	Composition of pool atmosphere	Part of	Low or no dilution airflow due to Loss of ventilation; power loss (normal and emergency); or blocked intake (foreign matter or high pool level)	See node 17	See node 17	Hydrogen explosion	S2	See node 17	No direct measurement of hydrogen concentration. New calculation of hydrogen generation and dilution rates must be performed due to new capsule wattage Evaluation comments: assumed applicable to the configuration with cover blocks on the pool cells, since this configuration no longer exists this deviation is equal to node 17, airflow, no/less.

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
155			Structural Integrity	Less than (leak)	Seismic event or crane hook drop or motorized catwalk failure	See node 9,10	See node 9,10	See node 9,10	S3	F1	Not that the catwalk would only fall into the pool cell if it were damaged. It is designed to be longer than the cell.
156					Corrosion	see pool cell level, none above	see pool cell level, none above	see pool cell level, none above	S3	F1	
157					Explosion	See node 17, airflow	See node 17, airflow	See node 17, airflow	See node 17	See node 17	Evaluation comments: see node 17, airflow.
158			Inventory (per pool cell)	More	Procedure violation; Human error	Periodic visual inspection Pool temperature and level (long term) records		Increased pool temperature (see pool cell high temperature below) Increased dose rate from pool cell Operational delay Increased rate of radiolysis	See below S1 S0 S1		Evaluation comments: high pool cell temperature is covered under node 16, pool cell, temperature, high.
159					Emergency situation (leaking liner or failed recirculation pump causes capsules to be relocated)	Same		Same	Same		
160				Other than (wrong arrangement)	Seismic event	Visual observation		Increased fire hazard	S1		See above

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
161					Beyond design basis loading for capsule racks (dropped cover block or trolley section of crane)	Same		Localized (hot spot) region of high heat loading potentially leading to capsule or line failure or leak See high temperature, low or no level or other than for capsule			
162					Breakdown in configuration management	Same		Same	Same		Slow heat up of pool cell (Normal evaporation rate is about 2"/week)
163			Temperatu re	High	Heat exchanger not working	Temperature instrumentation and alarms/recorder (checked twice per shift)		Increased corrosion rates of capsules Increased evaporation rates (potentially boiling) Deterioration of K-1 ventilation system exhaust filters	S0 S1 S0		
164					Recirculation pump failure	Same		Same			
165					Power outage	Same		Same			
166					Instrumentation error	Same		Same			
167					Low water level	Same		Same			

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
168	17	Pool Cell area (room)	Structural integrity	Less	Seismic	Facility structure		Loss of contamination control Equipment Damage Potential for heavy object falling in pool Foreign Matter in pool affecting water quality	S1 S1 S2-S3 S1	F1	Building is designed to handle wind and snow loading. Seismic design unknown, ashfall design unknown Evaluation comments: assumed that S2 is for water remaining in pool, S3 is for facility structural member causing loss of cooling water.
169					Airplane Crash	Same		Same	Same	F0	
170					Vehicle impact	Same		Same	Same	F2	
171					Wind loading	Same		Same	Same	F1	
172					Projectile (gas bottle)	Same	No gas bottles allowed in pool cell area	Same	S2	F1	consequence rank was assumed to be S2.
173					Ashfall	Same		Same	Same	F2	
174					Snow	Same		Same	Same	F2	
175			Airflow	No/less	Loss of power	K1 and K4 ventilation systems (and alarms) Facility structure Backup diesel generator		Potential minor contamination spread to the environment Buildup of hydrogen in room Worker discomfort	S1 S2-S3 S1	F2	Evaluation comments: explosion in pool cell area has no direct impact on inventory: no direct connection to K-3 system or capsules, and there is no contamination present in the pool cell area; facility structure may collapse.
176					Failure of K1 exhaust system water	Same		Same	Same	Same	Evaluation comments: Same

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
177					Failure of K4 supply system	Same		Same	Same	Same	
178					Loss of ventilation control instrumentation	Same		Same	Same	Same	
179					Opening of doors	Same		Potential minor contamination spread to environment	S1		
180				More	Improper ventilation balance allowing both fans to run at once	Flowmeters/alarms		Same	S1 S1-S2		Evaluation comments: S1 consequence only; lack of contamination available for dispersal in the pool cell area or the K-1 and K-2 ventilation systems
181					Human error	Same		Same	Same		Same
182				As well as (dust)	Wind infiltration through roof	facility structure K-4 pre-filters K-4, K-1, and K-3 ventilation systems	Routine maintenance	Pool cell water quality problems Instrumentation damage potentially leading to inability to add water to pool cell Electrical failures	S0 S2-S3 S1	F1	Evaluation comments: would require an intense long-duration storm; instrument failure does not in itself cause the accident; the accident scenario for this deviation is loss of pool cell water with failure of instrumentation due to previous or ongoing sandstorm; damaged instrumentation would be tested and fixed immediately following storm.
183				As well as (steam)	Steam leak	Same		Worker injury	S1		
184				As well as (contamination)	Infiltration from surface contamination areas or truck port	CAMs; HP routines BETA monitors		Worker contamination	S1		

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers		Consequence	Cons Rank	Freq Rank	Remarks
						Systems	Controls				
185				As well as (oil, condensation)	Process and instrument air lines	Compressor design	Instrument air from B Plant not allowed Routine surveillance Maintenance program Manual fill from compressed air	Pool cell water quality problems Instrumentation damage potentially leading to inability to add water to pool cell Electrical problems	S0 S2/S3 S1	F1	Evaluation comments: same as in "as well as (dust)" above and: B Plant instrument air system contains oil; compressor failure could also add oil to instrument air
186				As well as (rain water)	Infiltration through leaky roof, doors	Visual		Pool cell water quality problems	S0		
187				As well as (insects)	Same	Visual		Pool cell water quality problems	S0		
188				As well as (resin)	High flow to resin bed	Visual		Same	S0		
189				Exhaust filter media	Failure of exhaust filter	Pool temperature		Pool cell water quality problems	S0		
190			Temperature	High	High ambient temperature combined with ventilation failure	Room thermometer Surveillance		Worker heat exhaustion	S1		
191					Steam line break	Same		Loss of instrument air Worker thermal hazard	S1 S1		

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
192				Low	Loss of steam, Loss of K4 air supply and low ambient temperature	Same		Rotameter for K4 flow freezes	S0		
193	18	Piping from pool cell sumps' foul water collection to TK-39-1	Flow	No/less	Plugging	Visual TK-39-1 level Sump alarm clears		Overflow of contaminated water from sumps	S1		
194					Loss of steam supply to jet	Same		Same			
195					Leaks	Same		Same			
196					High level in TK-39-1	Same		Lack of ability to feed and bleed	S1		If feed and bleed is necessary, this line is where the wastewater would be routed
197				Other than (steam)	Failure to shut off jet after transfer from foul water collection	Visual in pool cell (during surveillance) Weight factor instrumentation fails high (foul water cell) B Plant temperature/pressure rise on TK-39-1		Pressurization of TK-39-1 Erosion of transfer pipe	S1 S1		In B Plant if line pressurized
198					Valve failure	Same		Same	Same		Same
199				Reverse	Loss of P-Trap seal	Sump overflow (visual) Low level on TK-39-1		Contaminated waste water transferred to pool cells	S1		This is highly unlikely because it would take at least three failures.
200			Tempera-ture	High	See other than (Steam) above	See other than (Steam) above		See other than (Steam) above			

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
201				Low	N/A						Line is insulated and protected from the weather
202			Structural integrity	Leak/ rupture	Earthquake	Pool cell level alarms Radiation alarms Beta monitors Steam jet water transfer system TK-10-1 (hot pipe trench drain collection level)		Couldn't feed and bleed per approved procedure Environmental spill under some circumstances	S1-2 S1-2	F1 F1	Evaluation comment: assumed from pool cells 9 and 10 only; loss of pool cell water in active cells is covered in node 16, pool cell, level, none.
203					Erosion/ corrosion	Same	Water quality requirement	Same	Same	Same	Evaluation comments: same
204					Steam or water hammer	Same	Operator training	Same	Same	Same	Evaluation comments: same
205	19	Low level waste piping from hot cell drain to TK-39-1	Same deviations and results as Node 18	See node 18	See node 18	See node 18	See node 18	See node 18			
206			Flow	Reverse	Improper valving and DOV failure when steam jet is used	Visual (steam blows into another cell)		Cross contamination of process cells Operational delay	S1 S0		

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
207	20	Tank 100 (low level waste collection tank)	Level	High	Rain water, fire water, or other leakage draining from truck port drain Flushing K3 filter	TK-100 level instrumentation Leak detector in Tank 100 sump 1 inch dam in K-3 ducting to divert water to Tank 100 Bubbler level detector in K-3 sumps Pumps in K-3 filter sump (to Tank 100) Pumps in K-3 pit sump (to tank 100) K-3 pre-filter moisture separators K-3 heaters to reduce moisture in air (+20 degree capability) ^O^A^G^A ^Ac^W&	Contamination of pit Floating the tank, with damage to the attached piping High Radiation Increased waste volume Flooding K-3 filter	S1 S1 S2 S0 S2	F2	TK-100 in the past has filled fairly rapidly with rainwater Note that during the K-3 flush, shine through the cover block could be a problem Evaluation comments: Consequences assumed to be S2 based on environmental release. abnor	

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
240					Leaks into contact-handled drums (rare)	Visual		Same			
241				As well as (oil/organics)	Cleanup of oil-filled window leak with failure to properly rinse rags	Visual		Increased hydrogen generation rate Increased reactivity Increased corrosion rates	S1 S1 S1		
242					Cleanup of TSP spill	Same		Cross contamination of process cells Operational delay	S1 S0		
243				As well as hazardous/ regulated materials	Human error	Inventory/audit sampling of drums		Fines if 90-day storage rule is exceeded Increase cost of disposal Violation of land disposal restrictions	S0 S0 S0		More likely in contact-handled drums
244					Inadequate communication of current regulations	Same		Same			
245			Integrity	Decreased	Manufacturing defect undiscovered by inspection	Visual Administrative		Contamination spread Operational delays Worker injury	S1 S1 S1		
246					Exceeding shelf life of gasket	Same		Same			
247					Handling accident	Same		Same			

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
248				Low	Exposure to adverse environmental conditions	Same		Same			
249					Contents create high temperature (heat-producing isotopes) or high pressure (hydrogen)	Same		Same			
250			Tempera-ture	High	Chemical Reaction	Drum confinement	No reactive chemicals allowed in drum	Loss of drum integrity Worker injury Facility damage (loss of window)	S2 S1 S1	F1	Evaluation comments: no reactive chemicals present in facility.
251					Spontaneous combustion of oils or organics	Drum confinement Fire detection and suppression system	Same	Same	Same	Same	Evaluation comments: no reactive chemicals or chemicals subject to spontaneous combustion present in facility.
252					External fire (low likelihood)	Same		Same	Same	F1	Evaluation comments: cell A has no combustibles exterior to waste drums; electrical short could be initiator.

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
253					Proximity to TK-B-4 (Sr waste receiver tank)	Same		Same	Same	Same	Evaluation comments: Tank B-4 is located in B cell, drum could enter B cell only by removal of B cell cover block and solid waste is removed from process cells by movement to A cell where it is packaged in drums (drums do not enter cells other than A and G)
254					Inadvertent actuation of B/C cell furnace	Same		Same	Same	Same	This equipment has been turned off for 10 years with a lock and tagout Evaluation comments: drums are not used in B & C cells.
255			Pressure	High	See high temperature and decreased structural integrity	See high temperatur e and decreased integrity	See high temperatur e and decreased integrity	See high temperature and decreased integrity			
256	23	Truckport Waste Accumulation Area)	Inventory	High	Lack of manpower to ship waste out	Fire detection and suppressio n system	Regular surveillanc e	Increased fire hazards Increased dose rates Potential contamination spread within facility and to environment Increased likelihood of worker injury Operational delay	S2 S1 S1 S1 SO	See node 1	Evaluation comments: see node 1, as well as (fuel fumes) and node 1, temperature, high.
257					Higher priorities for other work	Same	Same	Same	Same	Same	Evaluation comments: same

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers		Consequence	Cons Rank	Freq Rank	Remarks
						Systems	Controls				
258					Bad communication with B Plant causing problems with integration with B Plant solid waste handling	Same	Same	Same	Same	Same	Evaluation comments: same
259					Insufficient records at WESF	Same	Same	Same	Same	Same	Evaluation comments: same
260					Lack of funding	Same	Same	Same	Same	Same	Evaluation comments: same
261	23	Currently un-utilized process cells (A, B, C, D, E)	Airflow	Low/no	See F/G cells						Evaluation comments: all process cells share the same ventilation system (K-3).
262				High	Same						Evaluation comments: same
263				As well as (steam, TSP, water vapor, contamination)	Same						Evaluation comments: same
264			Tempera-ture	High	Tank heat sources	Visual		No significant	S0		
265					Sintering furnaces	Same		Same			Note that the sintering furnace has been locked out for 10 years and would take an incredible effort to start.

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers		Consequence	Cons Rank	Freq Rank	Remarks
						Systems	Controls				
266					Fire in waste	Rate of rise heat detectors		Contamination spread through ventilation and through smoke leakage through the manipulators Filter loading/damage	S1 S1		
267			Inventory	As well as (water, steam, hydrogen)	Fire/fog system inadvertently actuated	Visual (steam rising from vessels) Sump detectors		Contamination spread to operating gallery Leakage of material into and deposition on K-3 ventilation ductwork	S1 S1		
268					Utility header piping failure						
269					Human error						
270	24	K-3 Supply from intake to cell takeoff	Flow	No/low	Loss of power	Instruments Dp gauges Audible change Visually (could see plug through surveillance)		Operational delay Cell temperature rise (see high temperature, cells) Hydrogen/combustibl e gas from plastics/oil in hot cell waste If system down for an extended period, contamination migration from hot cells	S0 S1 S1 S1		
271					Cell flooding	Same		Same			
272					Plugged supply filters	Same		Same			
273					Faulty damper control	Same		Same			

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers		Consequence	Cons Rank	Freq Rank	Remarks
						Systems	Controls				
274					Loss of supply fans, exhaust fans and K-3 emergency steam jet	Same		Same			
275					Breach in ductwork	Same		Same			
276					Plugged K-3 exhaust filters	Same		Same			
277				More	Initial startup after maintenance (control settings)	See above		Suspension of residual contamination Migration of contamination out of cells (loss of negative pressure)	S1 S1		
278					Failure of exhaust-supply interlock	Same		Same			
279					High winds and control failure	Same		Same			
280		K-3 Supply from intake to cell	Flow	More	Human error	Same		Same			
281					Lack of configuration control	Same		Same			

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers		Consequence	Cons Rank	Freq Rank	Remarks
						Systems	Controls				
282				As well as (steam, ice, snow, moisture, contamination, diesel fumes, ash, smoke, tumbleweeds)	Weather conditions	Dp instrumentation Visual Warning		Plugging filters Supply fan shutdown (cold) Corrosion (moisture) Personnel hazard from diesel or smoke Contamination spread through building filters (external sources) Filter contamination above ALARA levels	See above See above S0 S1 S1 S1		
283					Poor inlet filter performance	Same		Same			
284					Breach of inlet filter	Same		Same			
285					Standby generator	Same		Same			
286					Other facility accidents	Same		Same			
287					Excavation	Same		Same			
288					Natural phenomenon	Same		Same			
289					Range fire/filter fire	Same		Same			
290					Winds	Same		Same			
291				Reverse	Earthquake	Visual		See above			
292					Loss of shutdown interlock	Same		Same			

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers		Consequence	Cons Rank	Freq Rank	Remarks
						Systems	Controls				
293					Cell explosion	Same		Same			Not very likely to blow back through interlock
294			Tempera-ture	High	Fire (see above)	Temperature instrumentation/ surveillance		See above			
295					Hot weather	Same		Failure of instrumentation due to heat	S1		
296					Thermostat not cutting back on inlet heater	Same		Higher cell temperature	S1		
297					Loss of chiller	Same		Same			
298					Steam leak	Same		See other than (steam) above			
299			Low (see other than, ice)		Bad communication with B Plant causing problems with integration with B Plant solid waste handling	Same		Same	Same		
300	25	K3 supply from takeoff to typical cell	Flow	No/low	Broken damper actuator	See above		See above	See above		
301					Loss of exhaust fans	Same		Same	Same		
302				More	Loss of fan dP causing flow from cell to canyon (not likely)	dP instrumentation		Contamination spread	S1		

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
303	26	K-3 exhaust duct (canyon and cells) to stack	Flow	No/low	See previous node and stack collapse	See node 25 Stack radiation alarm Flow instrumentation Filter dP alarms K-1, K-3, and K-4 interlocks K-3 steam jet	Routine maintenance	Loss of confinement Contamination spread Hydrogen buildup (see other scenarios) Shutdown of other systems Temperature buildup (see above)	S2 S1 S2 S1 S1	F1 F1	Evaluation comments: the buildup of hydrogen requires the long-term presence of water and the cessation of ventilation. Lower frequency than Node 27- pressure-high-h2 explosion based on lack of water.
304					Loss of instrument air	See node 17, as well as (dust)	See node 17, as well as (dust)	Loss of confinement Contamination spread Hydrogen buildup (see other scenarios) Shutdown of other systems Temperature buildup (see above)	S2 S1 S2 S1 S1	F2 FO	Evaluation comments: maintenance error has caused the loss of instrument air and subsequent shutdown of the K-3 system, but an additional event, or a very long outage, is needed to get the release; the buildup of hydrogen does not occur because of loss of instrument air - another event is required to introduce water into the vent system.
305					Dampers fail closed		Same	Same	Same	Same	
306	27	K-3 Exhaust from cell outlet to stack	Flow	No/low	Loss of power	Visual Flowmeters		Operational delay Migration of contamination Hydrogen in cells	SO S1 S1		

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers		Consequence	Cons Rank	Freq Rank	Remarks
						Systems	Controls				
307					Filter plug	Same		Same			
308					MOV inoperable	Same		Same			
309					Poorly maintained equipment	Same		Same			
310					Loss of exhaust fans and steam jet	Same		Same			
311					Instrumentation failures	Same		Same			

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
312					Water in K-3 filter	TK-100 level instrumentation 1 inch dam in K-3 ducting to divert water to Tank 100 Bubbler level detector in K-3 sumps Pumps in K-3 sump (to Tank 100) K-3 pre-filter moisture separators K-3 heaters to reduce moisture in air (+20 degree capability)	Operator training Operating procedures for duct/filter flushing Routine maintenance	Same and, if sump plugged, could flood to duct work and release contamination	S2/S3	F3	Evaluation comments: F3 based on the greatest frequency assigned when evaluating node 20, Tank 100, high level (an subsequent flooding of K-3 filter). S2 assumed based on release to soil and shine.

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
313					Fire in K-3 filter	K-3 filter K-3 moisture separators (baffles act to keep hot embers away from filter media) Filter house design Fire detection and suppression systems K-3 filter dP alarms Process cell ventilation outlet filters		Major contamination release from filter and duct work	S3	F2	Evaluation comments: filter house design is such that the ventilation air must follow a convoluted path to reach the filters; deviation assumes that a fire occurs elsewhere in the facility and propagates to the filter media; filter media is nuclear grade, fire resistant with a minimum combustible loading.
314					Human error	See above	See above	See above	S2	F2	
315				More	Instrumentation failure (multiple fans and/or steamjet going at once)	K-3 Flow instrumentation K-3 filter dP alarms K-3 filters		Doors will not open Cycling with exhaust fans causing building to go static (see No/low above) Additional re-suspension of contamination in exhaust duct	S1 S1 S2	 F2	worker injury Evaluation comments: see node 5, more flow; assumed that filter survives but is challenged by contamination in ducting.

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
316	27				Block removal/ replacement	Same		Same	Same	Same	Evaluation comments: same
317				As well as (steam, water, hydrogen, dust, insects, ash, excess contami-nation, burning debris)	See K-3 inlet. See low/no flow above.	Same and: Pre-filters before HEPA filters		Same	Same	Same	
318			Tempera-ture	High	Fires	Fire detection and suppression systems Process cell ventilation outlet filters K-3 filter dP alarms		Filter damage Resuspension Operational delay	S2 S2 S0	F2 F2	Assuming doesn't propagate to filter Evaluation comments: K-3 filter fire is covered under node 27, flow, no/low, fire.
319					Steam leak	K-3 steam jet design K-3 filter dP alarms K-3 flow alarms		Same	Same	Same	Evaluation comments: K-3 steam jets could be blocked (reverse flow) or steam line could leak.
320					High cell temperature			Same	Same	F1	Evaluation comments: very little heat loading present in process cells; B/C cell furnace not in use.

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
321					Chiller units not working on a hot day	Chiller units	Routine maintenance	Same	Same	F1	Evaluation comments: temperature would have to extreme and prolonged in conjunction with chiller failure.
322				Low	Low ambient	System behavior		Freezing water line for flushing, possible flooding Damper actuator failure Damper control (moisture in air and grease frozen) See flow parameters	S1 S1		
323					Heater failure	Same		Same			

Table A-2. WESF Hazard Evaluation Results.

Item	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Barriers: Systems	Barriers: Controls	Consequence	Cons Rank	Freq Rank	Remarks
324			Pressure	High	Hydrogen explosion	TK-100 level instrumentation 1 inch dam in K-3 ducting to divert water to Tank 100 Bubbler level detector in K-3 sumps Pumps in K-3 sump (to Tank 100) K-3 pre-filter moisture separators K-3 heaters to reduce moisture in air (+20 degree capability)	Operator training Operating procedures for duct/filter flushing Routine maintenance	See above See no flow Filter damage, contamination spread	S2	F2	Evaluation comments: this deviation assumes that the hydrogen explosion is in the K-3 filter considering all causes for the introduction of water into the K-3 system listed in node 20 in addition to other events required to achieve the explosion; hydrogen explosion covered for Tank 100 in node 20, and for F cell in node 11; see also comments for node 20, level, high. See also, node 26.
325					Undetected high filter dP	K-3 filter dP alarms K-3 high flow alarms	Routine maintenance	Same	Same	F1	
326				Low	Blocked actuators	See node 27, low flow above		Filter damage	See node 27		Evaluation comments: assumed that low pressure is tantamount to node 27, low flow.

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
169	externally initiated man-made	Airplane Crash	17	Pool Cell area (room)	Structural integrity	Less	Airplane Crash	Loss of contamination control Equipment Damage Potential for heavy object falling in pool Foreign Matter in pool affecting water quality	n/a	y	FO frequency was assigned based on commercial flights. However, the frequency of intentional overflight is unknown, therefore the accident was selected for evaluation.
31	externally initiated man-made	Airplane Crash	1	Truckport--provides confinement for cask loading and unloading.	Structural integrity	Less	Airplane crash	Potential worker injury Loss of contamination control	n/a	y	FO frequency was assigned based on commercial flights. However, the frequency of intentional overflight is unknown, therefore the accident was selected for evaluation.
68	externally initiated man-made events	LOEP	5	G-Cell capsule handling (inspection and transfer to water)	Airflow	No/low	Loss of power	Potential for contamination spread from G-Cell Possible for breaking loose contaminated material from the K-3 system exhaust duct. (Loose contamination in the K-3 duct system could be discharged out the 296-B-12 steam jet filtered but not automatically monitored.	R2	y	LOEP is expected to bound this category.
175	externally initiated man-made events	LOEP	17	Pool Cell area (room)	Airflow	No/less	Loss of power	Potential minor contamination spread to the environment Buildup of hydrogen in room Worker discomfort	R3	y	LOEP is expected to bound this category.

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
170	externally initiated man-made events	Transporta tion Accident	17	Pool Cell area (room)	Structural integrity	Less	Vehicle impact	Loss of contamination control Equipment Damage Potential for heavy object falling in pool Foreign Matter in pool affecting water quality	R3	n	Not analyzed since hydrogen deflagration in the pool cell area has similar consequences.
27	externally initiated man-made events	Transporta tion Accident	1	Truckport--provides confinement for cask loading and unloading.	Structural integrity	Less	Vehicle impact	Potential worker injury Loss of contamination control	R2	y	Not analyzed due to its lower risk rank compared to other items in this category. However, certain other locations at risk for a vehicle impact are discussed in the accident analysis
15	internally initiated operational events	Facility Fire	1	Truckport--provides confinement for cask loading and unloading.	Airflow	As well as (contami-nation)	Gasoline fumes from leaking truck fuel system or diesel fumes from forklift fuel system	Facility worker exposure to hazardous fumes Fire	R3	y	selected due to high risk rank and different physical location from a process cell fire.
18	internally initiated operational events	Facility Fire	1	Truckport--provides confinement for cask loading and unloading.	Tempera-ture	High	Fire	Facility worker exposure to hazardous fumes Fire	R2	n	assumed not to be a vehicle fuel fire. Not selected due to lower risk rank than vehicle fuel fire.
102	internally initiated operational events	Facility Fire	10	Capsule	Tempera-ture	High	Diesel fire in Truckport	See item 15	R3	y	see item 15 remarks

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
237	internally initiated operational events	Facility Fire	22	55-gallon solid waste drum	Composi-tion (radio-active material)	High	Inability to estimate curie content at WESF	Heat damage to drum and perhaps fire Excessive dose rate to facility personnel Repackaging if it does not meet acceptance criteria	R1	n	not analyzed due to low risk rank
257	internally initiated operational events	Facility Fire	23	Truckport Waste Accumulatio n Area)	Inventory	High	Higher priorities for other work	Increased fire hazards Increased dose rates Potential contamination spread within facility and to environment Increased likelihood of worker injury Operational delay	R2	n	similar to item 18. Not selected due to lower risk rank than gasoline fire.
313	internally initiated operational events	Facility Fire	27	K-3 Exhaust from cell outlet to stack	Flow	No/low	Fire in K-3 filter	Major contamination release from filter and duct work	R3	y	analyzed as a hot cellfire. Propagation to the K-3 filters was shown to be incredible
258	internally initiated operational events	Facility Fire	23	Truckport Waste Accumulatio n Area)	Inventory	High	Bad communication with B Plant causing problems with integration with B Plant solid waste handling	Increased fire hazards Increased dose rates Potential contamination spread within facility and to environment Increased likelihood of worker injury Operational delay	R2	n	similar to item 18. Not selected due to lower risk rank than gasoline fire.

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
251	internally initiated operational events	Facility Fire	22	55-gallon solid waste drum	Tempera-ture	High	Spontaneous combustion of oils or organics	Loss of drum integrity Worker injury Facility damage (loss of window)	R1	n	Not analyzed due to low risk rank.
252	internally initiated operational events	Facility Fire	22	55-gallon solid waste drum	Tempera-ture	High	External fire (low likelihood)	Loss of drum integrity Worker injury Facility damage (loss of window)	R1	n	Not analyzed duet o low risk rank.
253	internally initiated operational events	Facility Fire	22	55-gallon solid waste drum	Tempera-ture	High	Proximity to TK-B-4 (Sr waste receiver tank)	Loss of drum integrity Worker injury Facility damage (loss of window)	R1	n	Not analyzed duet o low risk rank.
318	internally initiated operational events	Facility Fire	27	K-3 Exhaust from cell outlet to stack	Tempera-ture	High	Fires	Filter damage Resuspension Operational delay	R2	n	Not analyzed due to low risk rank.
254	internally initiated operational events	Facility Fire	22	55-gallon solid waste drum	Tempera-ture	High	Inadvertent actuation of B/C cell furnace	Loss of drum integrity Worker injury Facility damage (loss of window)	R1	n	Not analyzed due to low risk rank.

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
256	internally initiated operational events	Facility Fire	23	Truckport Waste Accumulatio n Area)	Inventory	High	Lack of manpower to ship waste out	Increased fire hazards Increased dose rates Potential contamination spread within facility and to environment Increased likelihood of worker injury Operational delay	R2	n	similar to item 18. Not selected due to lower risk rank than gasoline fire.
259	internally initiated operational events	Facility Fire	23	Truckport Waste Accumulatio n Area)	Inventory	High	Insufficient records at WESF	Increased fire hazards Increased dose rates Potential contamination spread within facility and to environment Increased likelihood of worker injury Operational delay	R2	n	similar to item 18. Not selected due to lower risk rank than gasoline fire.
260	internally initiated operational events	Facility Fire	23	Truckport Waste Accumulatio n Area)	Inventory	High	Lack of funding	Increased fire hazards Increased dose rates Potential contamination spread within facility and to environment Increased likelihood of worker injury Operational delay	R2	n	similar to item 18. Not selected due to lower risk rank than gasoline fire.

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
107	internally initiated operational events	Hydrogen deflagratio n	11	F Cell (Capsule Decontamin ation and Storage)	Airflow	Refer to "G-Cell" with changes radiolytic hydrogen in TK-F5	See G-Cell	Note potential high rate of production of contamination dispersed by explosion	R1	n	assumed to be a hydrogen deflagration (see 68,71-74 for g cell airflow). Not selected for analysis due to low risk rank.
154	internally initiated operational	Hydrogen deflagratio n	16	Pool Cell	Compositio n of pool atmosphere	Part of	Low or no dilution airflow due to Loss of ventilation; power loss (normal and emergency); or blocked intake (foreign matter or high pool level)	Hydrogen explosion	R2	n	this accident is lower consequence than a hydrogen deflagration involving the entire pool cell room (items 176-178), therefore it was not selected for analysis.
176	internally initiated operational	Hydrogen deflagratio n	17	Pool Cell area (room)	Airflow	No/less	Failure of K1 exhaust system water	Potential minor contamination spread to the environment Buildup of hydrogen in room Worker discomfort	R3	y	selected for analysis due to its high risk rank. consequences already captured by loss of pool cell water and leaking capsule except k-1 exhaust may be damaged.
177	internally initiated operational	Hydrogen deflagratio n	17	Pool Cell area (room)	Airflow	No/less	Failure of K4 supply system	Potential minor contamination spread to the environment Buildup of hydrogen in room Worker discomfort	R3	y	see item 176
178	internally initiated operational	Hydrogen deflagratio n	17	Pool Cell area (room)	Airflow	No/less	Loss of ventilation control instrumentation	Potential minor contamination spread to the environment Buildup of hydrogen in room Worker discomfort	R3	y	see item 176

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
316	internally initiated operational events	Loss of Confineme nt	27	K-3 Exhaust from cell outlet to stack	Flow	More	Block removal/ replacement	Doors will not open Cycling with exhaust fans causing building to go static (see No/less above) Additional re-suspension of contamination in exhaust duct	R2	y	see item 73
315	internally initiated operational events	Loss of Confineme nt	27	K-3 Exhaust from cell outlet to stack	Flow	More	Instrumentation failure (multiple fans and/or steamjet going at once)	Doors will not open Cycling with exhaust fans causing building to go static (see No/less above) Additional re-suspension of contamination in exhaust duct	R2	y	see item 73
218	internally initiated operational	Loss of Confineme nt	20	Tank 100 (low level waste collection tank)	Composi-tion	As well as (excess strontium)	Excess SR from K-3 duct washing	Hydrogen explosion Hot spots in tank caused by SR in heel overstressing the tank Increased dose rates to workers Difficulty in decontaminating tank Difficulty handling wastes in B Plant	R2	y	selected for analysis due to different physical location from K-3 filter pit.
314	internally initiated operational events	Loss of Confineme nt	27	K-3 Exhaust from cell outlet to stack	Flow	No/low	Human error	Major contamination release from filter and duct work	R2	y	selected for analysis due to unique challenge to the K-3 filters.

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
312	internally initiated operational events	Loss of Confineme nt	27	K-3 Exhaust from cell outlet to stack	Flow	No/low	Water in K-3 filter	Operational delay Migration of contamination Hydrogen in cells if sump plugged, could flood to duct work and release contamination	R3	y	see item 111 remarks. All known mechanisms for flooding the K-3 filter were included.
208	internally initiated operational events	Loss of Confineme nt	20	Tank 100 (low level waste collection tank)	Level	High	Leaks inside WESF	Contamination of pit Floating the tank, with damage to the attached piping High Radiation Increased waste volume Flooding K-3 filter	R3	y	see item 111 remarks. All known mechanisms for flooding the K-3 filter were included.
207	internally initiated operational events	Loss of Confineme nt	20	Tank 100 (low level waste collection tank)	Level	High	Rain water, fire water, or other leakage draining from truck port drain Flushing K3 filter	Contamination of pit Floating the tank, with damage to the attached piping High Radiation Increased waste volume Flooding K-3 filter	R2	y	see item 111 remarks. All known mechanisms for flooding the K-3 filter were included.

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
72	internally initiated operational events	Loss of Confineme nt	5	G-Cell capsule handling (inspection and transfer to water)	Airflow	No/low	Filter plugging (on supply or exhaust)	Potential for contamination spread from G-Cell Possible for breaking loose contaminated material from the K-3 system exhaust duct. (Loose contamination in the K-3 duct system could be discharged out the 296-B-12 steam jet filtered but not automatically monitored.	R1	y	selected for analysis due to unique challenge to the K-3 filters.
217	internally initiated operational	Loss of Confineme nt	20	Tank 100 (low level waste collection tank)	Composi-tion	As well as (excess cesium)	High cesium solution causing higher than normal radiolysis rate	Hydrogen explosion	R2	y	chosen for analysis in addition to the process cell fire due to its unique physical location.
111	internally initiated operational events	Loss of Confineme nt	11	F Cell (Capsule Decontamin ation and Storage)	Airflow	As well as (water)	Actuation or leak of fire/fog system (manual with required valve alignment)	Flood of F Cell from water Contamination spread to other cells Potential damage to or flooding of filters and ductwork/dampers Increased waste water generation	R3	y	all known mechanisms for flooding the k-3 filter pit are included in the accident analysis because of their similar consequences. All are assumed to cause worst-case consequences.

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
112	internally initiated operational events	Loss of Confineme nt	11	F Cell (Capsule Decontamin ation and Storage)	Airflow	As well as (water)	Use/leak of water from decontamination wash system	Flood of F Cell from water Contamination spread to other cells Potential damage to or flooding of filters and ductwork/dampers Increased waste water generation	R3	y	see item 111 remarks. All known mechanisms for flooding the K-3 filter were included.
114	internally initiated operational events	Loss of Confineme nt	11	F Cell (Capsule Decontamin ation and Storage)	Airflow	As well as (steam)	Closed valve with steam supply on	Filter damage	R3	y	see item 111 remarks. All known mechanisms for flooding the K-3 filter were included.
321	internally initiated operational events	Loss of Confineme nt	27	K-3 Exhaust from cell outlet to stack	Tempera-ture	High	Chiller units not working on a hot day	Filter damages Resuspension Operational delay	R1	n	not selected for analysis since K-3 filter pit flooding was judged to pose a higher risk.
320	internally initiated operational events	Loss of Confineme nt	27	K-3 Exhaust from cell outlet to stack	Tempera-ture	High	High cell temperature	Filter damages Resuspension Operational delay	R1	n	not selected for analysis since K-3 filter pit flooding was judged to pose a higher risk.
108	internally initiated operational events	Loss of Confineme nt	11	F Cell (Capsule Decontamin ation and Storage)	Inventory	More (too many capsules) Storage tank or bubbler tank	Procedure violation	Fire in cell: combustion from excess heat generated by dry stored capsules	R2	Y	this accident was S1 severity in the original HAZOP, since only a few capsules were expected to be stored there. However, since the completion of the HAZOP the mission for F cell has changed and the facility needs appropriate limits on the number of capsules allowable in F cell. Therefore the possibility of overloading F cell with capsules was included here.

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
325	internally initiated operational events	Loss of Confineme nt	27	K-3 Exhaust from cell outlet to stack	Pressure	High	Undetected high filter dP	Filter damage, contamination spread	R1	y	selected for analysis due to unique challenge to the K-3 filters.
69	internally initiated operational events	Loss of Confineme nt	5	G-Cell capsule handling (inspection and transfer to water)	Airflow	No/low	Failure of K-3 exhaust system	Potential for contamination spread from G-Cell Possible for breaking loose contaminated material from the K-3 system exhaust duct. (Loose contamination in the K-3 duct system could be discharged out the 296-B-12 steam jet filtered but not automatically monitored.	R2	y	selected for analysis due to unique challenge to the K-3 ventilation.
209	internally initiated operational events	Loss of Confineme nt	20	Tank 100 (low level waste collection tank)	Level	High	Loss of level instrumentation to TK-100	Contamination of pit Floating the tank, with damage to the attached piping High Radiation Increased waste volume Flooding K-3 filter	R2	y	see item 111 remarks. All known mechanisms for flooding the K-3 filter were included.
210	internally initiated operational events	Loss of Confineme nt	20	Tank 100 (low level waste collection tank)	Level	High	Failure to correctly calibrate level instrumentation	Contamination of pit Floating the tank, with damage to the attached piping High Radiation Increased waste volume Flooding K-3 filter	R2	y	see item 111 remarks. All known mechanisms for flooding the K-3 filter were included.

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
211	internally initiated operational events	Loss of Confinement	20	Tank 100 (low level waste collection tank)	Level	High	Loss of power to or failure of TK-100 pump so that transfers out of the tank cannot be performed	Contamination of pit Floating the tank, with damage to the attached piping High Radiation Increased waste volume Flooding K-3 filter	R2	y	see item 111 remarks. All known mechanisms for flooding the K-3 filter were included.
214	internally initiated operational events	Loss of Confinement	20	Tank 100 (low level waste collection tank)	Temperature	High	Self-heating material in tank Steam leak	Boiling water might pressurize or rupture tank Filters could be damaged from moisture released from tank Increased dose rate	R2	n	filter damage has lower consequence than flooding, not selected
215	internally initiated operational events	Loss of Confinement	20	Tank 100 (low level waste collection tank)	Temperature	High	Steam from sump jet	Boiling water might pressurize or rupture tank Filters could be damaged from moisture released from tank	R2	n	see 214, not selected
73	internally initiated operational events	Loss of Confinement	5	G-Cell capsule handling (inspection and transfer to water)	Airflow	More	Changes in system balance	Liberation of fixed contamination in exhaust duct	R2	y	chosen in addition to flooding due to different physical effect on filters.
319	internally initiated operational events	Loss of Confinement	27	K-3 Exhaust from cell outlet to stack	Temperature	High	Steam leak	Filter damages Resuspension Operational delay	R2	n	filter damage has lower consequence than flooding, not selected

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
317	internally initiated operational events	Loss of Confineme nt	27	K-3 Exhaust from cell outlet to stack	Flow	As well as (steam, water, hydrogen, dust, insects, ash, excess contami-nation, burning debris)	See K-3 inlet. See low/no flow above.	Doors will not open Cycling with exhaust fans causing building to go static (see No/less above) Additional re-suspension of contamination in exhaust duct	R2	n	not selected due to its lower risk rank compared to K-3 filter pit flooding
71	internally initiated operational events	Loss of Confineme nt	5	G-Cell capsule handling (inspection and transfer to water)	Airflow	No/low	Equipment Failure	Potential for contamination spread from G-Cell Possible for breaking loose contaminated material from the K-3 system exhaust duct. (Loose contamination in the K-3 duct system could be discharged out the 296-B-12 steam jet filtered but not automatically monitored.	R2	y	same as item 69.selected for analysis due to unique challenge to the K-3 filters.
53	internally initiated operational events	Loss of containme nt	3	15-Ton Crane	Structural integrity	Failure of components (hoists, cables, hooks, wheels, bridge, trolley, rails)	Lack of maintenance	Cask Failure Operational Delay Worker injury	R1	n	pool cell capsule impact is of higher consequence Cover block drop will not fail BUSS cask (see McCormick 94).
104	internally initiated operational events	Loss of containme nt	10	Capsule	Structural Integrity	No/less	Impact (object dropped on it)	see item 92	R1	y	see item 92

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
51	internally initiated operational events	Loss of containme nt	3	15-Ton Crane	Structural integrity	Failure of components (hoists, cables, hooks, wheels, bridge, trolley, rails)	Beyond design basis loading	Cask Failure Operational Delay Worker injury	R1	n	pool cell capsule impact is of higher consequence Cover block drop will not fail BUSS cask (see McCormick 94).
52	internally initiated operational events	Loss of containme nt	3	15-Ton Crane	Structural integrity	Failure of components (hoists, cables, hooks, wheels, bridge, trolley, rails)	Fatigue	Cask Failure Operational Delay Worker injury	R1	n	pool cell capsule impact is of higher consequence Cover block drop will not fail BUSS cask (see McCormick 94).
172	internally initiated operational events	Loss of containme nt	17	Pool Cell area (room)	Structural integrity	Less	Projectile (gas bottle)	Loss of contamination control Equipment Damage Potential for heavy object falling in pool Foreign Matter in pool affecting water quality	R1	n	Not analyzed due to low risk rank.
48	internally initiated operational events	Loss of containme nt	3	15-Ton Crane	Operating	Improper speed/ position (Note: single speed motor)	Human error	Damage cover block (loss of concrete/exposed rebar) Misplaced cover block could slip down on Cask Misplaced cask on cell cover block (cover block thinner than floor--potential for breaking)	R1	n	pool cell capsule impact is of higher consequence

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
55	internally initiated operational events	Loss of containme nt	3	15-Ton Crane	Structural integrity	Failure of components (hoists, cables, hooks, wheels, bridge, trolley, rails)	Human error	Cask Failure Operational Delay Worker injury	R1	n	pool cell capsule impact is of higher consequence Cover block drop will not fail BUSS cask (see McCormick 94).
204	internally initiated operational events	Loss of containme nt	18	Piping from pool cell sumps' foul water collection to TK-39-1	Structural integrity	Leak/ rupture	Steam or water hammer	see item 202	R1	n	see item 202. Not selected due to its low risk compared to other entries in this category
203	internally initiated operational events	Loss of containme nt	18	Piping from pool cell sumps' foul water collection to TK-39-1	Structural integrity	Leak/ rupture	Erosion/ corrosion	see item 202	R1	n	see item 202. Not selected due to its low risk compared to other entries in this category
98	internally initiated operational events	Loss of containme nt	9	Pool cell crane	Structural Integrity	No/less	Human error (mishandling of crane or dropped hook)	Capsule failure if smashed by cover block Operational delay Worker injury	R1	y	see item 92 remarks
96	internally initiated operational events	Loss of containme nt	9	Pool cell crane	Structural Integrity	No/less	Lack of maintenance	Capsule failure if smashed by cover block Operational delay Worker injury	R1	y	see item 92 remarks
95	internally initiated operational events	Loss of containme nt	9	Pool cell crane	Structural Integrity	No/less	Fatigue	Capsule failure if smashed by cover block Operational delay Worker injury	R1	y	see item 92 remarks

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
93	internally initiated operational events	Loss of containme nt	9	Pool cell crane	Operability	Other than (improper speed and position)	Poor visibility (due to poor lighting or cover block recessed bail design)		R1	y	see item 92 remarks
92	internally initiated operational events	Loss of containme nt	9	Pool cell crane	Operability	Other than (improper speed and position)	Human error	Operational delay Personnel injury Cover block drop due to improper hook placement resulting in capsule and/or pool cell damage with radiation dose to onsite individual and expensive recovery	R1	y	all known drop/impact events for a capsule ina pool cell were included in the accident analysis and were assumed to cause a worst case capsule failure.
94	internally initiated operational events	Loss of containme nt	9	Pool cell crane	Structural Integrity	No/less	Beyond design basis loading	Capsule failure if smashed by cover block Operational delay Worker injury	R1	y	see item 92 remarks
106	internally initiated operational events	Loss of Containme nt	10	Capsule	Structural Integrity	No/less	Human error	see item 92	R3	y	see 105
105	internally initiated operational events	Loss of Containme nt	10	Capsule	Structural Integrity	No/less	Material failure due to corrosion or bad weld	see item 92	R3	y	Selected for analysis due to high risk rank.
212	internally initiated operational events	Loss of Containme nt	20	Tank 100 (low level waste collection tank)	Level	Low	Leak in TK-100 or attached piping	Contamination spread in pit Potential leak to soil Operational problems due to inability to transfer low level waste	R2	n	K-3 filter pit flooding is expected to have more severe consequences.

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
250	internally initiated operational events	Loss of Containment	22	55-gallon solid waste drum	Tempera- ture	High	Chemical Reaction	Loss of drum integrity Worker injury Facility damage (loss of window)	R1	n	not analyzed due to low risk rank.
185	internally initiated operational events	Loss of Pool Cell Water	17	Pool Cell area (room)	Airflow	As well as (oil, conden- sation)	Process and instrument air lines	Pool cell water quality problems Instrumentation damage potentially leading to inability to add water to pool cell Electrical problems	R2	y	see item 99 remarks
156	internally initiated operational events	Loss of Pool Cell Water	16	Pool Cell	Structural Integrity	Less than (leak)	Corrosion	see item 99	R3	y	see item 99 remarks
149	internally initiated operational events	Loss of Pool Cell Water	16	Pool Cell	Level	Low	Same as above with human error	High direct radiation dose Capsule failure Potential "Meltdown of capsules"	R2	y	see item 99 remarks
148	internally initiated operational events	Loss of Pool Cell Water	16	Pool Cell	Level	None	Evaporation without makeup	High direct radiation dose Capsule failure Potential "Meltdown of capsules"	R3	y	see item 99 remarks
99	internally initiated operational events	Loss of Pool Cell Water	10	Capsule	Tempera- ture	High	Lack of cooling water	Potential for capsule structural failure due to high temperature	R3	y	all known mechanisms for losing pool cell water are included in the accident analysis and are assumed to cause worst- case consequences.

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
74	natural phenomena	Design Basis Earthquake	5	G-Cell capsule handling (inspection and transfer to water)	Airflow	More	Seismic event	Liberation of fixed contamination in exhaust duct	R2	y	see 25
25	natural phenomena	Design Basis Earthquake	1	Truckport--provides confinement for cask loading and unloading.	Structural integrity	Less	Seismically induced Greater than design basis structural loading on cask from facility collapse	Potential worker injury Loss of contamination control	R2	y	Seismic Event is expected to bound all natural phenomena due its common cause effect on all facility systems.
54	natural phenomena	Design Basis Earthquake	3	15-Ton Crane	Structural integrity	Failure of components (hoists, cables, hooks, wheels, bridge, trolley, rails)	Seismic event	Cask Failure Operational Delay Worker injury	R1	n	pool cell capsule impact is of higher consequence
70	natural phenomena	Design Basis Earthquake	5	G-Cell capsule handling (inspection and transfer to water)	Airflow	No/low	Seismic Event	Potential for contamination spread from G-Cell Possible for breaking loose contaminated material from the K-3 system exhaust duct. (Loose contamination in the K-3 duct system could be discharged out the 296-B-12 steam jet filtered but not automatically monitored.	R2	y	see item 25 remarks

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
97	natural phenomena	Design Basis Earthquake	9	Pool cell crane	Structural Integrity	No/less	Seismic Event	Capsule failure if smashed by cover block Operational delay Worker injury	R1	y	see item 92 remarks
100	natural phenomena	Design Basis Earthquake	10	Capsule	Tempera-ture	High	Seismic induced loss of cooling water	Potential for capsule structural failure due to high temperature	R3	y	see item 25 remarks
168	natural phenomena	Design Basis Earthquake	17	Pool Cell area (room)	Structural integrity	Less	Seismic	Loss of contamination control Equipment Damage Potential for heavy object falling in pool Foreign Matter in pool affecting water quality	R2	y	see item 25
202	natural phenomena	Design Basis Earthquake	18	Piping from pool cell sumps' foul water collection to TK-39-1	Structural integrity	Leak/ rupture	Earthquake	Couldn't feed and bleed per approved procedure Environmental spill under some circumstances	R1	y	see item 25 remarks Also, complete draining of pool cell and multiple capsule failure is excluded from consequences by assumption.
28	natural phenomena	Flood	1	Truckport--provides confinement for cask loading and unloading.	Structural integrity	Less	Flood	Potential worker injury Loss of contamination control	n/a	n	FO frequencies were not analyzed This event is also discussed in the NPHS.
29	natural phenomena	Snow and Ash Fall	1	Truckport--provides confinement for cask loading and unloading.	Structural integrity	Less	Ashfall	Potential worker injury Loss of contamination control	R2	n	This event is also discussed in the NPHS.

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
30	natural phenomena	Snow and Ash Fall	1	Truckport--provides confinement for cask loading and unloading.	Structural integrity	Less	Snow load	Potential worker injury Loss of contamination control	R2	n	This event is also discussed in the NPHS.
173	natural phenomena	Snow and Ash Fall	17	Pool Cell area (room)	Structural integrity	Less	Ashfall	Loss of contamination control Equipment Damage Potential for heavy object falling in pool Foreign Matter in pool affecting water quality	R3	n	This event is also discussed in the NPHS.
174	natural phenomena	Snow and Ash Fall	17	Pool Cell area (room)	Structural integrity	Less	Snow	Loss of contamination control Equipment Damage Potential for heavy object falling in pool Foreign Matter in pool affecting water quality	R3	n	This event is also discussed in the NPHS.
171	natural phenomena	wind	17	Pool Cell area (room)	Structural integrity	Less	Wind loading	Loss of contamination control Equipment Damage Potential for heavy object falling in pool Foreign Matter in pool affecting water quality	R2	n	This event is also discussed in the NPHS.

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selec ted	Remarks
182	natural phenomena	wind	17	Pool Cell area (room)	Airflow	As well as (dust)	Wind infiltration through roof	Pool cell water quality problems Instrumentation damage potentially leading to inability to add water to pool cell Electrical failures	R2	n	This event is also discussed in the NPHS.
26	natural phenomena	Wind	1	Truckport--provides confinement for cask loading and unloading.	Structural integrity	Less	Wind	Potential worker injury Loss of contamination control	R2	n	This event is also discussed in the NPHS.
101	see item 99		10	Capsule	Tempera-ture	High	Proximity to other capsules	None unless pool water lost	R3	y	see item 99 remarks
103	see items 99-102		10	Capsule	Structural Integrity	No/less	High temperature	See items 99-102	see 99-102	see 99-102	see items 99-102

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selected	Remarks
116	see items 68-74		11	F Cell (Capsule Decontamination and Storage)	See G-Cell for additional parameters and deviations				see 68-74	see 68-74	see items 68-74
147	see items 99-100		16	Pool Cell	Level	None	Pool liner failure from seismic event or other beyond design basis load	High direct radiation dose Capsule failure Potential "Meltdown of capsules"	R3	y	This accident was analyzed as a beyond design basis accident.
155	see item 147		16	Pool Cell	Structural Integrity	Less than (leak)	Seismic event or crane hook drop or motorized catwalk failure	see item 147	see 147	see 147	see 147
157	see 154		16	Pool Cell	Structural Integrity	Less than (leak)	Explosion	see item 154	see 154	see 154	see item 154
255	see items 237-254		22	55-gallon solid waste drum	Pressure	High	See high temperature and decreased structural integrity	See high temperature and decreased integrity	see 237-254	see 237-254	see items 237-254
261	see items 68-74		23	Currently un-utilized process cells (A, B, C, D, E)	See F/G cells				see 68-74	see 68-74	see items 68-74
303	see items 68-72		26	K-3 exhaust duct (canyon and cells) to stack	Flow	No/low	See previous node and stack collapse	Loss of confinement Contamination spread Hydrogen buildup (see other scenarios) Shutdown of other systems Temperature buildup	see 68-72	see 68-72	see items 68-72

Table A-3. WESF Hazard Evaluation.

item no.	Category	Type	Node	Description	Process Parameter	Guide Word/ Deviation	Possible Causes	Consequence	Risk Rank	selected	Remarks
304	see item 71		26	K-3 exhaust duct (canyon and cells) to stack	Flow	No/low	Loss of instrument air	Loss of confinement Contamination spread Hydrogen buildup (see other scenarios) Shutdown of other systems Temperature buildup	see 71	see 71	see item 71
305	see item 72		26	K-3 exhaust duct (canyon and cells) to stack	Flow	No/low	Dampers fail closed	Loss of confinement Contamination spread Hydrogen buildup (see other scenarios) Shutdown of other systems Temperature buildup	see 72	see 72	see item 72
324	see 75,76,90,91		27	K-3 Exhaust from cell outlet to stack	Pressure	High	Hydrogen explosion	Filter damage, contamination spread	R2	y	Similar to k-3 flooding scenario except ignition of hydrogen is also required. Consequences may be worse than a filter fire
326	see item 72		27	K-3 Exhaust from cell outlet to stack	Pressure	Low	Blocked actuators	Filter damage	see 72	see 72	see item 72
205	similar to item 202	see item 202	19	Low level waste piping from hot cell drain to TK-39-1	Structural integrity	Leak/ rupture	Earthquake	item 202	R1	n	does not contribute significantly to the consequences of an earthquake.

Table A-4. Hazard Evaluation Team Participants.

WESF ISB Team Meeting, DAY 1 of 2
January 9, 1996

Attendee	Area of Responsibility
Mark Medsker	Safety Analysis, Team Lead
Dennis Clapp	Safety Analysis, Assisstant Lead, Assisstant Scribe
Brian Vonderfecht	Safety Analysis, Scribe
Lori Covey	WESF Engineering
Larry Brist	WESF Engineering
Wil Nelson	Independent Nuclear Safety
Roy Shepard	WESF Operations
Brit Hey	Safety Analysis
Larry Nunn	WESF Engineering

WESF ISB TEAM MEETING, DAY 2 of 2
January 10, 1996

Attendee	Area of Responsibility
Mark Medsker	Safety Analysis, Team Lead
Dennis Clapp	Safety Analysis, Assisstant Lead, Assisstant Scribe
Brian Vonderfecht	Safety Analysis, Scribe
Lori Covey	WESF Engineering
Larry Brist	WESF Engineering
Wil Nelson	Independent Nuclear Safety
Roy Shepard	WESF Operations
Larry Nunn	WESF Engineering

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APPENDIX B - GXQ Version 4.0 and 4C Code Output

This appendix contains:

1. GXQ 4.0 Output File for point source ground level release 99.5% sector dependent X/Q, onsite, fence line site boundary, and alternate site boundary receptors, input file xq.IN.

2. GXQ 4.0 Output File for building wake ground level release 99.5% sector dependent X/Q, onsite, fence line site boundary, and alternate site boundary receptors, input file bw.IN.

3. GXQ 4.0 Output File for plume meander ground level release 99.5% sector dependent X/Q, onsite, fence line site boundary, and alternate site boundary receptors, input file pm.IN.

4. GXQ 4.0 Output File for building wake and plume meander ground level release 99.5% sector dependent X/Q, onsite, fence line site boundary, and alternate site boundary receptors, input file bwpm.IN.

5. GXQ 4.0 Output File for point source ground level release 95% overall site X/Q, onsite, fence line site boundary, and alternate site boundary receptors, input file xq-o.IN.

6. GXQ 4.0 Output File for building wake ground level release 95% overall site X/Q, onsite, fence line site boundary, and alternate site boundary receptors, input file bw-o.IN.

7. GXQ 4.0 Output File for plume meander ground level release 95% overall site X/Q, onsite, fence line site boundary, and alternate site boundary receptors, input file pm-o.IN.

8. GXQ 4.0 Output File for building wake and plume meander ground level release 95% overall site X/Q, onsite, fence line site boundary, and alternate site boundary receptors, input file bwpm-o.IN.

9. GXQ 4C code changes to implement Huber dispersion enhancement model.

10. GXQ 4C verification run, input file gxq4ctst.in.

11. GXQ 4C Output File for stack level release in Zone I, input file zonel.in.

12. GXQ 4C Output Files for stack level release in Zone IIA and B, input files zone2a.in and zone2b.in.

13. GXQ 4C Output Files for stack level release for roof level receptors, input files roofl.in, roof2.in, roof3.in.

14. GXQ 4C Output File for stack level release in Zone III, input file zone3.in.

15. GXQ 4C Output Files for stack level release in Zone IV, input files zone4a.in, zone4b.in.

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Current Input File Name: c:\p\wesf\xq\xq.IN

GXQ Version 4.0
December 19, 1994

General Purpose Atmospheric Dispersion Code
Produced by Westinghouse Hanford Company

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
Westinghouse Hanford Company
P.O. Box 1970
Richland, WA 99352
(509) 376-2921

Run Date = 08/30/96
Run Time = 13:59:20.03

```
INPUT ECHO:
Atmospheric Dispersion Coefficients for WESF (Onsite, Site Boundary and River)
c GXQ Version 4.0 Input File
c   mode
    1
c
c MODE CHOICE:
c mode = 1 then X/Q based on Hanford site specific meteorology
c mode = 2 then X/Q based on atmospheric stability class and wind speed
c mode = 3 then X/Q plot file is created
c
c LOGICAL CHOICES:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F
c ifox  = t then joint frequency used to compute frequency to exceed X/Q
c       = f then joint frequency used to compute annual average X/Q
c inorm = t then joint frequency data is normalized (as in GENII)
c       = f then joint frequency data is un-normalized
c icdf  = t then cumulative distribution file created (CDF.OUT)
c       = f then no cumulative distribution file created
c ichk  = t then X/Q parameter print option turned on
c       = f then no parameter print
c isite = t then X/Q based on joint frequency data for all 16 sectors
c       = f then X/Q based on joint frequency data of individual sectors
c ipop  = t then X/Q is population weighted
c       = f then no population weighting
c
c X/Q AND WIND SPEED ADJUSTMENT MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENT MODELS:
c   iwake ipm   iflow ientr
    0     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENT MODELS:
c  (irise igrnd)iwash igrav
    0     0     0     0
c ipuff = 1 then X/Q calculated using puff model
c       = 0 then X/Q calculated using default continuous plume model
c idep  = 1 then plume depletion model turned on (Chamberlain model)
c isrc  = 1 then X/Q multiplied by scalar
c       = 2 then X/Q adjusted by wind speed function
c iwind = 1 then wind speed corrected for plume height
c iwake = 1 then NRC RG 1.145 building wake model turned on
c       = 2 then MACCS virtual distance building wake model turned on
c ipm   = 1 then NRC RG 1.145 plume meander model turned on
c       = 2 then 5th Power Law plume meander model turned on
c       = 3 then sector average model turned on
c iflow = 1 then sigmas adjusted for volume flow rate
c ientr = 1 then method of Pasquill used to account for entrainment
c irise = 1 then MACCS buoyant plume rise model turned on
c       = 2 then ISC2 momentum/buoyancy plume rise model turned on
c igrnd = 1 then Mills buoyant plume rise modification for ground effects
c iwash = 1 then stack downwash model turned on
```

```
c igrav = 1 then gravitational settling model turned on
c       = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c                  reference                    frequency
c  release         anemometer     mixing        to
c  height          height         height        exceed
c  hs(m)           ha(m)          hm(m)         Cx(%)
c  ____________    ____________   ____________  ____________
   0.00000E+00     1.00000E+01    1.00000E+03   5.00000E-01
c
c  initial         initial                                     gravitational
c  plume           plume          release       deposition    settling
c  width           height         duration      velocity      velocity
c  Wb(m)           Hb(m)          trd(hr)       vd(m/s)       vg(m/s)
c  ____________    ____________   ____________  ____________  ____________
   0.00000E+00     0.00000E+00    1.00000E+00   1.00000E-03   1.00000E-03
c
c                  initial        initial                     convective
c  ambient         plume          plume         release       heat release
c  temperature     temperature    flow rate     diameter      rate(1)
c  Tamb(C)         TO(C)          VO(m3/s)      d(m)          qh(w)
c  ____________    ____________   ____________  ____________  ____________
   2.00000E+01     2.00000E+01    1.00000E+00   1.00000E+00   0.00000E+00
c
c (1) If zero then buoyant flux based on plume/ambient temperature difference.
c
c  X/Q             Wind
c  scaling         Speed
c  factor          Exponent
c  c(?)            a(?)
c  ____________    ____________
   1.00000E+00     7.80000E-01
c
c RECEPTOR DEPENDENT DATA (no line limit)
c FOR MODE     make         RECEPTOR DEPENDENT DATA
c 1 (site specific)         sector distance receptor-height
c 2 (by class & wind speed) class windspeed distance offset receptor-height
c 3 (create plot file)      class windspeed xmax imax ymax jmax xqmin power
c
c RECEPTOR PARAMETER DESCRIPTION
c sector = 0, 1, 2... (all, S, SSW, etc.)
c distance = receptor distance (m)
c receptor height = height of receptor (m)
c class = 1, 2, 3, 4, 5, 6, 7 (P-G stability class A, B, C, D, E, F, G)
c windspeed = anemometer wind speed (m/s)
c offset = offset from plume centerline (m)
c xmax = maximum distance to plot or calculate to (m)
c imax = distance intervals
c ymax = maximum offset to plot (m)
c jmax = offset intervals
c xqmin = minimum scaled X/Q to calculate
c power = exponent in power function step size

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for single sector.

MODELS SELECTED:
Default Gaussian plume model selected.

WARNING/ERROR MESSAGES:

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR
```

Atmospheric Dispersion Coefficients for WESF (Onsite, Site Boundary and River)

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
S	100	0	6.30	1	1.56E-02	1.56E-02	E	0.89
SSW	100	0	4.53	1	1.13E-02	1.13E-02	F	2.65
SW	100	0	2.93	1	1.21E-02	1.21E-02	F	2.65
WSW	100	0	2.72	1	1.22E-02	1.22E-02	F	2.65
W	100	0	4.80	1	2.80E-02	2.80E-02	G	2.65
WNW	100	0	3.98	1	1.60E-02	1.60E-02	G	4.70
NW	100	0	4.72	1	2.89E-02	2.89E-02	G	2.65
NNW	100	0	4.58	1	2.90E-02	2.90E-02	G	2.65
N	100	0	4.36	1	3.12E-02	3.12E-02	G	2.65
NNE	100	0	2.49	1	1.54E-02	1.54E-02	E	0.89
NE	100	0	3.90	1	1.57E-02	1.57E-02	E	0.89
ENE	100	0	6.17	1	2.52E-02	2.52E-02	G	2.65
E	100	0	14.05	1	3.41E-02	3.41E-02	F	0.89
ESE	100	0	18.80	1	3.25E-02	3.25E-02	F	0.89
SE	100	0	10.83	1	3.07E-02	3.07E-02	G	2.65
SSE	100	0	4.78	1	1.58E-02	1.58E-02	G	4.70
S	19310	0	6.30	1	4.85E-06	4.85E-06	E	0.89
SSW	16640	0	4.53	1	3.72E-06	3.72E-06	F	2.65
SW	18080	0	2.93	1	4.30E-06	4.30E-06	F	2.65
WSW	19290	0	2.72	1	3.97E-06	3.97E-06	F	2.65
W	18890	0	4.80	1	9.65E-06	9.65E-06	G	2.65
WNW	19390	0	3.98	1	5.24E-06	5.24E-06	G	4.70
NW	19810	0	4.72	1	9.45E-06	9.45E-06	G	2.65
NNW	19550	0	4.58	1	9.64E-06	9.64E-06	G	2.65
N	22780	0	4.36	1	8.54E-06	8.54E-06	G	2.65
NNE	25450	0	2.49	1	3.24E-06	3.24E-06	E	0.89
NE	19880	0	3.90	1	4.78E-06	4.78E-06	E	0.89
ENE	17040	0	6.17	1	9.93E-06	9.93E-06	G	2.65
E	16870	0	14.05	1	1.35E-05	1.35E-05	F	0.89
ESE	21040	0	18.80	1	9.78E-06	9.78E-06	F	0.89
SE	25170	0	10.83	1	7.45E-06	7.45E-06	G	2.65
SSE	21080	0	4.78	1	4.47E-06	4.47E-06	G	4.70
S	8940	0	6.30	1	1.32E-05	1.32E-05	E	0.89
SSW	8260	0	4.53	1	9.02E-06	9.02E-06	F	2.65
SW	8260	0	2.93	1	1.16E-05	1.16E-05	F	2.65
WSW	9710	0	2.72	1	9.48E-06	9.48E-06	F	2.65
W	11040	0	4.80	1	1.89E-05	1.89E-05	G	2.65
WNW	14360	0	3.98	1	7.63E-06	7.63E-06	G	4.70
NW	11490	0	4.72	1	1.86E-05	1.86E-05	G	2.65
NNW	11330	0	4.58	1	1.90E-05	1.90E-05	G	2.65
N	12990	0	4.36	1	1.72E-05	1.72E-05	G	2.65
NNE	14010	0	2.49	1	7.03E-06	7.03E-06	E	0.89
NE	12270	0	3.90	1	8.86E-06	8.86E-06	E	0.89
ENE	12140	0	6.17	1	1.52E-05	1.52E-05	G	2.65
E	13650	0	14.05	1	1.75E-05	1.75E-05	F	0.89
ESE	20880	0	18.80	1	9.88E-06	9.88E-06	F	0.89
SE	14190	0	10.83	1	1.51E-05	1.51E-05	G	2.65
SSE	11710	0	4.78	1	9.48E-06	9.48E-06	G	4.70

Current Input File Name: c:\p\wesf\xq\bw.IN

GXQ Version 4.0
December 19, 1994

General Purpose Atmospheric Dispersion Code
Produced by Westinghouse Hanford Company

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
Westinghouse Hanford Company
P.O. Box 1970
Richland, WA 99352
(509) 376-2921

Run Date = 08/30/96
Run Time = 13:59:21.56

```
INPUT ECHO:
Atmospheric Dispersion Coefficients for WESF (Onsite, Site Boundary and River)
c GXQ Version 4.0 Input File
c   mode
    1
c
c MODE CHOICE:
c mode = 1 then X/Q based on Hanford site specific meteorology
c mode = 2 then X/Q based on atmospheric stability class and wind speed
c mode = 3 then X/Q plot file is created
c
c LOGICAL CHOICES:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F
c ifox  = t then joint frequency used to compute frequency to exceed X/Q
c       = f then joint frequency used to compute annual average X/Q
c inorm = t then joint frequency data is normalized (as in GENII)
c       = f then joint frequency data is un-normalized
c icdf  = t then cumulative distribution file created (CDF.OUT)
c       = f then no cumulative distribution file created
c ichk  = t then X/Q parameter print option turned on
c       = f then no parameter print
c isite = t then X/Q based on joint frequency data for all 16 sectors
c       = f then X/Q based on joint frequency data of individual sectors
c ipop  = t then X/Q is population weighted
c       = f then no population weighting
c
c X/Q AND WIND SPEED ADJUSTMENT MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENT MODELS:
c   iwake ipm   iflow ientr
    1     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENT MODELS:
c  (irise igrnd)iwash igrav
    0     0     0     0
c ipuff = 1 then X/Q calculated using puff model
c       = 0 then X/Q calculated using default continuous plume model
c idep  = 1 then plume depletion model turned on (Chamberlain model)
c isrc  = 1 then X/Q multiplied by scalar
c       = 2 then X/Q adjusted by wind speed function
c iwind = 1 then wind speed corrected for plume height
c iwake = 1 then NRC RG 1.145 building wake model turned on
c       = 2 then MACCS virtual distance building wake model turned on
c ipm   = 1 then NRC RG 1.145 plume meander model turned on
c       = 2 then 5th Power Law plume meander model turned on
c       = 3 then sector average model turned on
c iflow = 1 then sigmas adjusted for volume flow rate
c ientr = 1 then method of Pasquill used to account for entrainment
c irise = 1 then MACCS buoyant plume rise model turned on
c       = 2 then ISC2 momentum/buoyancy plume rise model turned on
c igrnd = 1 then Mills buoyant plume rise modification for ground effects
c iwash = 1 then stack downwash model turned on
```

```
c igrav = 1 then gravitational settling model turned on
c       = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c                  reference                           frequency
c   release        anemometer      mixing              to
c   height         height          height              exceed
c   hs(m)          ha(m)           hm(m)               Cx(%)
c   ___________    ___________     ___________         ___________
    0.00000E+00    1.00000E+01     1.00000E+03         5.00000E-01
c
c   initial        initial                                              gravitational
c   plume          plume           release             deposition       settling
c   width          height          duration            velocity         velocity
c   Wb(m)          Hb(m)           trd(hr)             vd(m/s)          vg(m/s)
c   ___________    ___________     ___________         ___________      ___________
    2.00000E+01    1.50000E+01     1.00000E+00         1.00000E-03      1.00000E-03
c
c                  initial         initial                              convective
c   ambient        plume           plume               release          heat release
c   temperature    temperature     flow rate           diameter         rate(1)
c   Tamb(C)        TO(C)           VO(m3/s)            d(m)             qh(w)
c   ___________    ___________     ___________         ___________      ___________
    2.00000E+01    2.00000E+01     1.00000E+00         1.00000E+00      0.00000E+00
c
c (1) If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q            Wind
c   scaling        Speed
c   factor         Exponent
c   c(?)           a(?)
c   ___________    ___________
    1.00000E+00    7.80000E-01
c
c RECEPTOR DEPENDENT DATA (no line limit)
c FOR MODE     make          RECEPTOR DEPENDENT DATA
c 1 (site specific)          sector distance receptor-height
c 2 (by class & wind speed) class windspeed distance offset receptor-height
c 3 (create plot file)       class windspeed xmax imax ymax jmax xqmin power
c
c RECEPTOR PARAMETER DESCRIPTION
c sector = 0, 1, 2... (all, S, SSW, etc.)
c distance = receptor distance (m)
c receptor height = height of receptor (m)
c class = 1, 2, 3, 4, 5, 6, 7 (P-G stability class A, B, C, D, E, F, G)
c windspeed = anemometer wind speed (m/s)
c offset = offset from plume centerline (m)
c xmax = maximum distance to plot or calculate to (m)
c imax = distance intervals
c ymax = maximum offset to plot (m)
c jmax = offset intervals
c xqmin = minimum scaled X/Q to calculate
c power = exponent in power function step size

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for single sector.

MODELS SELECTED:
NRC RG 1.145 building wake model selected.
Default Gaussian plume model selected.

WARNING/ERROR MESSAGES:

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR
```

Atmospheric Dispersion Coefficients for WESF (Onsite, Site Boundary and River)

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
S	100	0	6.30	1	5.21E-03	5.21E-03	E	0.89
SSW	100	0	4.53	1	4.61E-03	4.61E-03	E	0.89
SW	100	0	2.93	1	4.73E-03	4.73E-03	E	0.89
WSW	100	0	2.72	1	4.76E-03	4.76E-03	E	0.89
W	100	0	4.80	1	9.32E-03	9.32E-03	G	2.65
WNW	100	0	3.98	1	5.33E-03	5.33E-03	G	4.70
NW	100	0	4.72	1	9.64E-03	9.64E-03	G	2.65
NNW	100	0	4.58	1	9.68E-03	9.68E-03	G	2.65
N	100	0	4.36	1	1.04E-02	1.04E-02	G	2.65
NNE	100	0	2.49	1	5.14E-03	5.14E-03	E	0.89
NE	100	0	3.90	1	5.24E-03	5.24E-03	E	0.89
ENE	100	0	6.17	1	8.41E-03	8.41E-03	G	2.65
E	100	0	14.05	1	1.14E-02	1.14E-02	F	0.89
ESE	100	0	18.80	1	1.08E-02	1.08E-02	F	0.89
SE	100	0	10.83	1	1.02E-02	1.02E-02	G	2.65
SSE	100	0	4.78	1	5.25E-03	5.25E-03	G	4.70
S	19310	0	6.30	1	4.84E-06	4.84E-06	E	0.89
SSW	16640	0	4.53	1	3.72E-06	3.72E-06	F	2.65
SW	18080	0	2.93	1	4.29E-06	4.29E-06	F	2.65
WSW	19290	0	2.72	1	3.97E-06	3.97E-06	F	2.65
W	18890	0	4.80	1	9.61E-06	9.61E-06	G	2.65
WNW	19390	0	3.98	1	5.22E-06	5.22E-06	G	4.70
NW	19810	0	4.72	1	9.41E-06	9.41E-06	G	2.65
NNW	19550	0	4.58	1	9.60E-06	9.60E-06	G	2.65
N	22780	0	4.36	1	8.53E-06	8.53E-06	G	2.65
NNE	25450	0	2.49	1	3.24E-06	3.24E-06	E	0.89
NE	19880	0	3.90	1	4.77E-06	4.77E-06	E	0.89
ENE	17040	0	6.17	1	9.89E-06	9.89E-06	G	2.65
E	16870	0	14.05	1	1.34E-05	1.34E-05	F	0.89
ESE	21040	0	18.80	1	9.76E-06	9.76E-06	F	0.89
SE	25170	0	10.83	1	7.44E-06	7.44E-06	G	2.65
SSE	21080	0	4.78	1	4.46E-06	4.46E-06	G	4.70
S	8940	0	6.30	1	1.31E-05	1.31E-05	E	0.89
SSW	8260	0	4.53	1	8.98E-06	8.98E-06	F	2.65
SW	8260	0	2.93	1	1.16E-05	1.16E-05	F	2.65
WSW	9710	0	2.72	1	9.45E-06	9.45E-06	F	2.65
W	11040	0	4.80	1	1.88E-05	1.88E-05	G	2.65
WNW	14360	0	3.98	1	7.59E-06	7.59E-06	G	4.70
NW	11490	0	4.72	1	1.85E-05	1.85E-05	G	2.65
NNW	11330	0	4.58	1	1.89E-05	1.89E-05	G	2.65
N	12990	0	4.36	1	1.71E-05	1.71E-05	G	2.65
NNE	14010	0	2.49	1	7.02E-06	7.02E-06	E	0.89
NE	12270	0	3.90	1	8.82E-06	8.82E-06	E	0.89
ENE	12140	0	6.17	1	1.51E-05	1.51E-05	G	2.65
E	13650	0	14.05	1	1.75E-05	1.75E-05	F	0.89
ESE	20880	0	18.80	1	9.86E-06	9.86E-06	F	0.89
SE	14190	0	10.83	1	1.51E-05	1.51E-05	G	2.65
SSE	11710	0	4.78	1	9.43E-06	9.43E-06	G	4.70

```
   Current Input File Name: c:\p\wesf\xq\pm.IN


                              GXQ Version 4.0
                             December 19, 1994

General Purpose Atmospheric Dispersion Code
Produced by Westinghouse Hanford Company

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                   Westinghouse Hanford Company
                   P.O. Box 1970
                   Richland, WA 99352
                   (509) 376-2921


Run Date = 08/30/96
Run Time = 13:59:23.05


INPUT ECHO:
Atmospheric Dispersion Coefficients for WESF (Onsite, Site Boundary and River)
c GXQ Version 4.0 Input File
c   mode
    1
c
c MODE CHOICE:
c mode = 1 then X/Q based on Hanford site specific meteorology
c mode = 2 then X/Q based on atmospheric stability class and wind speed
c mode = 3 then X/Q plot file is created
c
c LOGICAL CHOICES:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F
c ifox  = t then joint frequency used to compute frequency to exceed X/Q
c       = f then joint frequency used to compute annual average X/Q
c inorm = t then joint frequency data is normalized (as in GENII)
c       = f then joint frequency data is un-normalized
c icdf  = t then cumulative distribution file created (CDF.OUT)
c       = f then no cumulative distribution file created
c ichk  = t then X/Q parameter print option turned on
c       = f then no parameter print
c isite = t then X/Q based on joint frequency data for all 16 sectors
c       = f then X/Q based on joint frequency data of individual sectors
c ipop  = t then X/Q is population weighted
c       = f then no population weighting
c
c X/Q AND WIND SPEED ADJUSTMENT MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENT MODELS:
c   iwake ipm   iflow ientr
    0     1     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENT MODELS:
c  (irise igrnd)iwash igrav
    0     0     0     0
c ipuff = 1 then X/Q calculated using puff model
c       = 0 then X/Q calculated using default continuous plume model
c idep  = 1 then plume depletion model turned on (Chamberlain model)
c isrc  = 1 then X/Q multiplied by scalar
c       = 2 then X/Q adjusted by wind speed function
c iwind = 1 then wind speed corrected for plume height
c iwake = 1 then NRC RG 1.145 building wake model turned on
c       = 2 then MACCS virtual distance building wake model turned on
c ipm   = 1 then NRC RG 1.145 plume meander model turned on
c       = 2 then 5th Power Law plume meander model turned on
c       = 3 then sector average model turned on
c iflow = 1 then sigmas adjusted for volume flow rate
c ientr = 1 then method of Pasquill used to account for entrainment
c irise = 1 then MACCS buoyant plume rise model turned on
c       = 2 then ISC2 momentum/buoyancy plume rise model turned on
c igrnd = 1 then Mills buoyant plume rise modification for ground effects
c iwash = 1 then stack downwash model turned on
```

```
c igrav = 1 then gravitational settling model turned on
c       = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c                 reference                      frequency
c  release        anemometer     mixing          to
c  height         height         height          exceed
c  hs(m)          ha(m)          hm(m)           Cx(%)
c  ___________    ___________    ___________     ___________
   0.00000E+00    1.00000E+01    1.00000E+03     5.00000E-01
c
c  initial        initial                                       gravitational
c  plume          plume          release         deposition     settling
c  width          height         duration        velocity       velocity
c  Wb(m)          Hb(m)          trd(hr)         vd(m/s)        vg(m/s)
c  ___________    ___________    ___________     ___________    ___________
   0.00000E+00    0.00000E+00    1.00000E+00     1.00000E-03    1.00000E-03
c
c                 initial        initial                        convective
c  ambient        plume          plume           release        heat release
c  temperature    temperature    flow rate       diameter       rate(1)
c  Tamb(C)        T0(C)          V0(m3/s)        d(m)           qh(w)
c  ___________    ___________    ___________     ___________    ___________
   2.00000E+01    2.00000E+01    1.00000E+00     1.00000E+00    0.00000E+00
c
c (1) If zero then buoyant flux based on plume/ambient temperature difference.
c
c  X/Q            Wind
c  scaling        Speed
c  factor         Exponent
c  c(?)           a(?)
c  ___________    ___________
   1.00000E+00    7.80000E-01
c
c RECEPTOR DEPENDENT DATA (no line limit)
c FOR MODE      make          RECEPTOR DEPENDENT DATA
c 1 (site specific)           sector distance receptor-height
c 2 (by class & wind speed)   class windspeed distance offset receptor-height
c 3 (create plot file)        class windspeed xmax imax ymax jmax xqmin power
c
c RECEPTOR PARAMETER DESCRIPTION
c sector = 0, 1, 2... (all, S, SSW, etc.)
c distance = receptor distance (m)
c receptor height = height of receptor (m)
c class = 1, 2, 3, 4, 5, 6, 7 (P-G stability class A, B, C, D, E, F, G)
c windspeed = anemometer wind speed (m/s)
c offset = offset from plume centerline (m)
c xmax = maximum distance to plot or calculate to (m)
c imax = distance intervals
c ymax = maximum offset to plot (m)
c jmax = offset intervals
c xqmin = minimum scaled X/Q to calculate
c power = exponent in power function step size

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for single sector.

MODELS SELECTED:
NRC RG 1.145 plume meander model selected.
Default Gaussian plume model selected.

WARNING/ERROR MESSAGES:

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR
```

Atmospheric Dispersion Coefficients for WESF (Onsite, Site Boundary and River)

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
S	100	0	6.30	1	5.96E-03	5.96E-03	E	0.89
SSW	100	0	4.53	1	4.54E-03	4.54E-03	F	7.15
SW	100	0	2.93	1	4.80E-03	4.80E-03	F	4.70
WSW	100	0	2.72	1	4.80E-03	4.80E-03	F	4.70
W	100	0	4.80	1	7.43E-03	7.43E-03	G	2.65
WNW	100	0	3.98	1	6.67E-03	6.67E-03	G	2.65
NW	100	0	4.72	1	7.65E-03	7.65E-03	G	2.65
NNW	100	0	4.58	1	8.06E-03	8.06E-03	G	2.65
N	100	0	4.36	1	8.29E-03	8.29E-03	F	0.89
NNE	100	0	2.49	1	5.36E-03	5.36E-03	E	0.89
NE	100	0	3.90	1	6.02E-03	6.02E-03	E	0.89
ENE	100	0	6.17	1	7.79E-03	7.79E-03	G	2.65
E	100	0	14.05	1	1.09E-02	1.09E-02	G	4.70
ESE	100	0	18.80	1	1.13E-02	1.13E-02	G	4.70
SE	100	0	10.83	1	8.37E-03	8.37E-03	F	0.89
SSE	100	0	4.78	1	6.20E-03	6.20E-03	E	0.89
S	19310	0	6.30	1	4.51E-06	4.51E-06	E	0.89
SSW	16640	0	4.53	1	3.43E-06	3.43E-06	F	2.65
SW	18080	0	2.93	1	3.87E-06	3.87E-06	F	2.65
WSW	19290	0	2.72	1	3.60E-06	3.60E-06	F	2.65
W	18890	0	4.80	1	8.32E-06	8.32E-06	G	2.65
WNW	19390	0	3.98	1	5.03E-06	5.03E-06	G	4.70
NW	19810	0	4.72	1	8.18E-06	8.18E-06	G	2.65
NNW	19550	0	4.58	1	8.33E-06	8.33E-06	G	2.65
N	22780	0	4.36	1	7.49E-06	7.49E-06	G	2.65
NNE	25450	0	2.49	1	3.01E-06	3.01E-06	E	0.89
NE	19880	0	3.90	1	4.49E-06	4.49E-06	E	0.89
ENE	17040	0	6.17	1	8.66E-06	8.66E-06	G	2.65
E	16870	0	14.05	1	1.13E-05	1.13E-05	F	0.89
ESE	21040	0	18.80	1	8.48E-06	8.48E-06	F	0.89
SE	25170	0	10.83	1	6.61E-06	6.61E-06	G	2.65
SSE	21080	0	4.78	1	4.23E-06	4.23E-06	G	4.70
S	8940	0	6.30	1	1.15E-05	1.15E-05	E	0.89
SSW	8260	0	4.53	1	7.79E-06	7.79E-06	F	2.65
SW	8260	0	2.93	1	9.52E-06	9.52E-06	F	2.65
WSW	9710	0	2.72	1	7.94E-06	7.94E-06	F	2.65
W	11040	0	4.80	1	1.50E-05	1.50E-05	G	2.65
WNW	14360	0	3.98	1	7.24E-06	7.24E-06	G	4.70
NW	11490	0	4.72	1	1.49E-05	1.49E-05	G	2.65
NNW	11330	0	4.58	1	1.52E-05	1.52E-05	G	2.65
N	12990	0	4.36	1	1.39E-05	1.39E-05	G	2.65
NNE	14010	0	2.49	1	6.21E-06	6.21E-06	E	0.89
NE	12270	0	3.90	1	8.06E-06	8.06E-06	E	0.89
ENE	12140	0	6.17	1	1.27E-05	1.27E-05	G	2.65
E	13650	0	14.05	1	1.42E-05	1.42E-05	F	0.89
ESE	20880	0	18.80	1	8.56E-06	8.56E-06	F	0.89
SE	14190	0	10.83	1	1.25E-05	1.25E-05	G	2.65
SSE	11710	0	4.78	1	8.63E-06	8.63E-06	G	4.70

```
Current Input File Name: c:\p\wesf\xq\bwpm.IN

                    ____________________
                      GXQ Version 4.0
                     December 19, 1994
                    ____________________

General Purpose Atmospheric Dispersion Code
Produced by Westinghouse Hanford Company

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                   Westinghouse Hanford Company
                   P.O. Box 1970
                   Richland, WA 99352
                   (509) 376-2921


Run Date = 08/30/96
Run Time = 13:59:24.59


INPUT ECHO:
Atmospheric Dispersion Coefficients for WESF (Onsite, Site Boundary and River)
c GXQ Version 4.0 Input File
c   mode
    1
c
c MODE CHOICE:
c mode = 1 then X/Q based on Hanford site specific meteorology
c mode = 2 then X/Q based on atmospheric stability class and wind speed
c mode = 3 then X/Q plot file is created
c
c LOGICAL CHOICES:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F
c ifox  = t then joint frequency used to compute frequency to exceed X/Q
c       = f then joint frequency used to compute annual average X/Q
c inorm = t then joint frequency data is normalized (as in GENII)
c       = f then joint frequency data is un-normalized
c icdf  = t then cumulative distribution file created (CDF.OUT)
c       = f then no cumulative distribution file created
c ichk  = t then X/Q parameter print option turned on
c       = f then no parameter print
c isite = t then X/Q based on joint frequency data for all 16 sectors
c       = f then X/Q based on joint frequency data of individual sectors
c ipop  = t then X/Q is population weighted
c       = f then no population weighting
c
c X/Q AND WIND SPEED ADJUSTMENT MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENT MODELS:
c   iwake ipm   iflow ientr
    1     1     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENT MODELS:
c  (irise igrnd)iwash igrav
    0     0     0     0
c ipuff = 1 then X/Q calculated using puff model
c       = 0 then X/Q calculated using default continuous plume model
c idep  = 1 then plume depletion model turned on (Chamberlain model)
c isrc  = 1 then X/Q multiplied by scalar
c       = 2 then X/Q adjusted by wind speed function
c iwind = 1 then wind speed corrected for plume height
c iwake = 1 then NRC RG 1.145 building wake model turned on
c       = 2 then MACCS virtual distance building wake model turned on
c ipm   = 1 then NRC RG 1.145 plume meander model turned on
c       = 2 then 5th Power Law plume meander model turned on
c       = 3 then sector average model turned on
c iflow = 1 then sigmas adjusted for volume flow rate
c ientr = 1 then method of Pasquill used to account for entrainment
c irise = 1 then MACCS buoyant plume rise model turned on
c       = 2 then ISC2 momentum/buoyancy plume rise model turned on
c igrnd = 1 then Mills buoyant plume rise modification for ground effects
c iwash = 1 then stack downwash model turned on
```

```
c igrav = 1 then gravitational settling model turned on
c       = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c                    reference                          frequency
c   release          anemometer       mixing            to
c   height           height           height            exceed
c   hs(m)            ha(m)            hm(m)             Cx(%)
c   ____________     ____________     ____________      ____________
    0.00000E+00      1.00000E+01      1.00000E+03       5.00000E-01
c
c   initial          initial                                             gravitational
c   plume            plume            release           deposition       settling
c   width            height           duration          velocity         velocity
c   Wb(m)            Hb(m)            trd(hr)           vd(m/s)          vg(m/s)
c   ____________     ____________     ____________      ____________     ____________
    2.00000E+01      1.50000E+01      1.00000E+00       1.00000E-03      1.00000E-03
c
c                    initial          initial                            convective
c   ambient          plume            plume             release          heat release
c   temperature      temperature      flow rate         diameter         rate(1)
c   Tamb(C)          T0(C)            V0(m3/s)          d(m)             qh(w)
c   ____________     ____________     ____________      ____________     ____________
    2.00000E+01      2.00000E+01      1.00000E+00       1.00000E+00      0.00000E+00
c
c (1) If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q              Wind
c   scaling          Speed
c   factor           Exponent
c   c(?)             a(?)
c   ____________     ____________
    1.00000E+00      7.80000E-01
c
c RECEPTOR DEPENDENT DATA (no line limit)
c FOR MODE      make          RECEPTOR DEPENDENT DATA
c 1 (site specific)           sector distance receptor-height
c 2 (by class & wind speed) class windspeed distance offset receptor-height
c 3 (create plot file)        class windspeed xmax imax ymax jmax xqmin power
c
c RECEPTOR PARAMETER DESCRIPTION
c sector = 0, 1, 2... (all, S, SSW, etc.)
c distance = receptor distance (m)
c receptor height = height of receptor (m)
c class = 1, 2, 3, 4, 5, 6, 7 (P-G stability class A, B, C, D, E, F, G)
c windspeed = anemometer wind speed (m/s)
c offset = offset from plume centerline (m)
c xmax = maximum distance to plot or calculate to (m)
c imax = distance intervals
c ymax = maximum offset to plot (m)
c jmax = offset intervals
c xqmin = minimum scaled X/Q to calculate
c power = exponent in power function step size
```

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for single sector.

MODELS SELECTED:
NRC RG 1.145 building wake model selected.
NRC RG 1.145 plume meander model selected.
Default Gaussian plume model selected.

WARNING/ERROR MESSAGES:

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR

Atmospheric Dispersion Coefficients for WESF (Onsite, Site Boundary and River)

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
S	100	0	6.30	1	5.21E-03	5.21E-03	E	0.89
SSW	100	0	4.53	1	4.61E-03	4.61E-03	E	0.89
SW	100	0	2.93	1	4.73E-03	4.73E-03	E	0.89
WSW	100	0	2.72	1	4.76E-03	4.76E-03	E	0.89
W	100	0	4.80	1	7.43E-03	7.43E-03	G	2.65
WNW	100	0	3.98	1	5.33E-03	5.33E-03	G	4.70
NW	100	0	4.72	1	7.61E-03	7.61E-03	G	2.65
NNW	100	0	4.58	1	7.63E-03	7.63E-03	G	2.65
N	100	0	4.36	1	8.02E-03	8.02E-03	G	2.65
NNE	100	0	2.49	1	5.14E-03	5.14E-03	E	0.89
NE	100	0	3.90	1	5.24E-03	5.24E-03	E	0.89
ENE	100	0	6.17	1	6.96E-03	6.96E-03	G	2.65
E	100	0	14.05	1	8.55E-03	8.55E-03	F	0.89
ESE	100	0	18.80	1	8.25E-03	8.25E-03	F	0.89
SE	100	0	10.83	1	7.94E-03	7.94E-03	G	2.65
SSE	100	0	4.78	1	5.25E-03	5.25E-03	G	4.70
S	19310	0	6.30	1	4.51E-06	4.51E-06	E	0.89
SSW	16640	0	4.53	1	3.43E-06	3.43E-06	F	2.65
SW	18080	0	2.93	1	3.87E-06	3.87E-06	F	2.65
WSW	19290	0	2.72	1	3.60E-06	3.60E-06	F	2.65
W	18890	0	4.80	1	8.32E-06	8.32E-06	G	2.65
WNW	19390	0	3.98	1	5.03E-06	5.03E-06	G	4.70
NW	19810	0	4.72	1	8.18E-06	8.18E-06	G	2.65
NNW	19550	0	4.58	1	8.33E-06	8.33E-06	G	2.65
N	22780	0	4.36	1	7.49E-06	7.49E-06	G	2.65
NNE	25450	0	2.49	1	3.01E-06	3.01E-06	E	0.89
NE	19880	0	3.90	1	4.49E-06	4.49E-06	E	0.89
ENE	17040	0	6.17	1	8.66E-06	8.66E-06	G	2.65
E	16870	0	14.05	1	1.13E-05	1.13E-05	F	0.89
ESE	21040	0	18.80	1	8.48E-06	8.48E-06	F	0.89
SE	25170	0	10.83	1	6.61E-06	6.61E-06	G	2.65
SSE	21080	0	4.78	1	4.23E-06	4.23E-06	G	4.70
S	8940	0	6.30	1	1.15E-05	1.15E-05	E	0.89
SSW	8260	0	4.53	1	7.79E-06	7.79E-06	F	2.65
SW	8260	0	2.93	1	9.52E-06	9.52E-06	F	2.65
WSW	9710	0	2.72	1	7.94E-06	7.94E-06	F	2.65
W	11040	0	4.80	1	1.50E-05	1.50E-05	G	2.65
WNW	14360	0	3.98	1	7.24E-06	7.24E-06	G	4.70
NW	11490	0	4.72	1	1.49E-05	1.49E-05	G	2.65
NNW	11330	0	4.58	1	1.52E-05	1.52E-05	G	2.65
N	12990	0	4.36	1	1.39E-05	1.39E-05	G	2.65
NNE	14010	0	2.49	1	6.21E-06	6.21E-06	E	0.89
NE	12270	0	3.90	1	8.06E-06	8.06E-06	E	0.89
ENE	12140	0	6.17	1	1.27E-05	1.27E-05	G	2.65
E	13650	0	14.05	1	1.42E-05	1.42E-05	F	0.89
ESE	20880	0	18.80	1	8.56E-06	8.56E-06	F	0.89
SE	14190	0	10.83	1	1.25E-05	1.25E-05	G	2.65
SSE	11710	0	4.78	1	8.63E-06	8.63E-06	G	4.70

```
   Current Input File Name: c:\p\wesf\xq\xq-o.IN


                                  GXQ Version 4.0
                                 December 19, 1994

General Purpose Atmospheric Dispersion Code
Produced by Westinghouse Hanford Company

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                   Westinghouse Hanford Company
                   P.O. Box 1970
                   Richland, WA 99352
                   (509) 376-2921


Run Date = 08/30/96
Run Time = 13:59:26.12


INPUT ECHO:
Atmospheric Dispersion Coefficients for WESF (Onsite, Site Boundary and River)
c GXQ Version 4.0 Input File
c   mode
    1
c
c MODE CHOICE:
c mode = 1 then X/Q based on Hanford site specific meteorology
c mode = 2 then X/Q based on atmospheric stability class and wind speed
c mode = 3 then X/Q plot file is created
c
c LOGICAL CHOICES:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     T     F
c ifox  = t then joint frequency used to compute frequency to exceed X/Q
c       = f then joint frequency used to compute annual average X/Q
c inorm = t then joint frequency data is normalized (as in GENII)
c       = f then joint frequency data is un-normalized
c icdf  = t then cumulative distribution file created (CDF.OUT)
c       = f then no cumulative distribution file created
c ichk  = t then X/Q parameter print option turned on
c       = f then no parameter print
c isite = t then X/Q based on joint frequency data for all 16 sectors
c       = f then X/Q based on joint frequency data of individual sectors
c ipop  = t then X/Q is population weighted
c       = f then no population weighting
c
c X/Q AND WIND SPEED ADJUSTMENT MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENT MODELS:
c   iwake ipm   iflow ientr
    0     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENT MODELS:
c  (irise igrnd)iwash igrav
    0     0     0     0
c ipuff = 1 then X/Q calculated using puff model
c       = 0 then X/Q calculated using default continuous plume model
c idep  = 1 then plume depletion model turned on (Chamberlain model)
c isrc  = 1 then X/Q multiplied by scalar
c       = 2 then X/Q adjusted by wind speed function
c iwind = 1 then wind speed corrected for plume height
c iwake = 1 then NRC RG 1.145 building wake model turned on
c       = 2 then MACCS virtual distance building wake model turned on
c ipm   = 1 then NRC RG 1.145 plume meander model turned on
c       = 2 then 5th Power Law plume meander model turned on
c       = 3 then sector average model turned on
c iflow = 1 then sigmas adjusted for volume flow rate
c ientr = 1 then method of Pasquill used to account for entrainment
c irise = 1 then MACCS buoyant plume rise model turned on
c       = 2 then ISC2 momentum/buoyancy plume rise model turned on
c igrnd = 1 then Mills buoyant plume rise modification for ground effects
c iwash = 1 then stack downwash model turned on
```

```
c igrav = 1 then gravitational settling model turned on
c       = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c                  reference                              frequency
c   release        anemometer     mixing                  to
c   height         height         height                  exceed
c   hs(m)          ha(m)          hm(m)                   Cx(%)
c   ___________    ___________    ___________    ___________
    0.00000E+00    1.00000E+01    1.00000E+03    5.00000E+00
c
c   initial        initial                                               gravitational
c   plume          plume          release        deposition     settling
c   width          height         duration       velocity       velocity
c   Wb(m)          Hb(m)          trd(hr)        vd(m/s)        vg(m/s)
c   ___________    ___________    ___________    ___________    ___________
    0.00000E+00    0.00000E+00    1.00000E+00    1.00000E-03    1.00000E-03
c
c                  initial        initial                       convective
c   ambient        plume          plume          release        heat release
c   temperature    temperature    flow rate      diameter       rate(1)
c   Tamb(C)        T0(C)          V0(m3/s)       d(m)           qh(w)
c   ___________    ___________    ___________    ___________    ___________
    2.00000E+01    2.00000E+01    1.00000E+00    1.00000E+00    0.00000E+00
c
c (1) If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q            Wind
c   scaling        Speed
c   factor         Exponent
c   c(?)           a(?)
c   ___________    ___________
    1.00000E+00    7.80000E-01
c
c RECEPTOR DEPENDENT DATA (no line limit)
c FOR MODE     make         RECEPTOR DEPENDENT DATA
c 1 (site specific)         sector distance receptor-height
c 2 (by class & wind speed) class windspeed distance offset receptor-height
c 3 (create plot file)      class windspeed xmax imax ymax jmax xqmin power
c
c RECEPTOR PARAMETER DESCRIPTION
c sector = 0, 1, 2... (all, S, SSW, etc.)
c distance = receptor distance (m)
c receptor height = height of receptor (m)
c class = 1, 2, 3, 4, 5, 6, 7 (P-G stability class A, B, C, D, E, F, G)
c windspeed = anemometer wind speed (m/s)
c offset = offset from plume centerline (m)
c xmax = maximum distance to plot or calculate to (m)
c imax = distance intervals
c ymax = maximum offset to plot (m)
c jmax = offset intervals
c xqmin = minimum scaled X/Q to calculate
c power = exponent in power function step size

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for overall site.

MODELS SELECTED:
Default Gaussian plume model selected.

WARNING/ERROR MESSAGES:

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR
```

Atmospheric Dispersion Coefficients for WESF (Onsite, Site Boundary and River)

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
ALL	100	0	99.94	1	3.28E-02	3.28E-02	F	0.89
ALL	21080	0	99.94	1	1.13E-05	1.13E-05	G	2.65
ALL	11710	0	99.94	1	1.83E-05	1.83E-05	G	2.65

Current Input File Name: c:\p\wesf\xq\bw-o.IN

```
GXQ Version 4.0
December 19, 1994

General Purpose Atmospheric Dispersion Code
Produced by Westinghouse Hanford Company

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                   Westinghouse Hanford Company
                   P.O. Box 1970
                   Richland, WA 99352
                   (509) 376-2921


Run Date = 08/30/96
Run Time = 13:59:31.89


INPUT ECHO:
Atmospheric Dispersion Coefficients for WESF (Onsite, Site Boundary and River)
c GXQ Version 4.0 Input File
c   mode
    1
c
c MODE CHOICE:
c mode = 1 then X/Q based on Hanford site specific meteorology
c mode = 2 then X/Q based on atmospheric stability class and wind speed
c mode = 3 then X/Q plot file is created
c
c LOGICAL CHOICES:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     T     F
c ifox  = t then joint frequency used to compute frequency to exceed X/Q
c       = f then joint frequency used to compute annual average X/Q
c inorm = t then joint frequency data is normalized (as in GENII)
c       = f then joint frequency data is un-normalized
c icdf  = t then cumulative distribution file created (CDF.OUT)
c       = f then no cumulative distribution file created
c ichk  = t then X/Q parameter print option turned on
c       = f then no parameter print
c isite = t then X/Q based on joint frequency data for all 16 sectors
c       = f then X/Q based on joint frequency data of individual sectors
c ipop  = t then X/Q is population weighted
c       = f then no population weighting
c
c X/Q AND WIND SPEED ADJUSTMENT MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENT MODELS:
c   iwake ipm   iflow ientr
    1     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENT MODELS:
c  (irise igrnd)iwash igrav
    0     0     0     0
c ipuff = 1 then X/Q calculated using puff model
c       = 0 then X/Q calculated using default continuous plume model
c idep  = 1 then plume depletion model turned on (Chamberlain model)
c isrc  = 1 then X/Q multiplied by scalar
c       = 2 then X/Q adjusted by wind speed function
c iwind = 1 then wind speed corrected for plume height
c iwake = 1 then NRC RG 1.145 building wake model turned on
c       = 2 then MACCS virtual distance building wake model turned on
c ipm   = 1 then NRC RG 1.145 plume meander model turned on
c       = 2 then 5th Power Law plume meander model turned on
c       = 3 then sector average model turned on
c iflow = 1 then sigmas adjusted for volume flow rate
c ientr = 1 then method of Pasquill used to account for entrainment
c irise = 1 then MACCS buoyant plume rise model turned on
c       = 2 then ISC2 momentum/buoyancy plume rise model turned on
c igrnd = 1 then Mills buoyant plume rise modification for ground effects
c iwash = 1 then stack downwash model turned on
```

```
c igrav = 1 then gravitational settling model turned on
c       = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c               reference                     frequency
c   release     anemometer     mixing         to
c   height      height         height         exceed
c   hs(m)       ha(m)          hm(m)          Cx(%)
c
    0.00000E+00  1.00000E+01   1.00000E+03    5.00000E+00
c
c   initial     initial                                     gravitational
c   plume       plume          release        deposition    settling
c   width       height         duration       velocity      velocity
c   Wb(m)       Hb(m)          trd(hr)        vd(m/s)       vg(m/s)
c
    2.00000E+01  1.50000E+01   1.00000E+00    1.00000E-03   1.00000E-03
c
c               initial        initial                      convective
c   ambient     plume          plume          release       heat release
c   temperature temperature    flow rate      diameter      rate(1)
c   Tamb(C)     T0(C)          V0(m3/s)       d(m)          qh(w)
c
    2.00000E+01  2.00000E+01   1.00000E+00    1.00000E+00   0.00000E+00
c
c (1) If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q         Wind
c   scaling     Speed
c   factor      Exponent
c   c(?)        a(?)
c
    1.00000E+00  7.80000E-01
c
c RECEPTOR DEPENDENT DATA (no line limit)
c FOR MODE     make          RECEPTOR DEPENDENT DATA
c 1 (site specific)         sector distance receptor-height
c 2 (by class & wind speed) class windspeed distance offset receptor-height
c 3 (create plot file)      class windspeed xmax imax ymax jmax xqmin power
c
c RECEPTOR PARAMETER DESCRIPTION
c sector = 0, 1, 2... (all, S, SSW, etc.)
c distance = receptor distance (m)
c receptor height = height of receptor (m)
c class = 1, 2, 3, 4, 5, 6, 7 (P-G stability class A, B, C, D, E, F, G)
c windspeed = anemometer wind speed (m/s)
c offset = offset from plume centerline (m)
c xmax = maximum distance to plot or calculate to (m)
c imax = distance intervals
c ymax = maximum offset to plot (m)
c jmax = offset intervals
c xqmin = minimum scaled X/Q to calculate
c power = exponent in power function step size

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for overall site.

MODELS SELECTED:
NRC RG 1.145 building wake model selected.
Default Gaussian plume model selected.

WARNING/ERROR MESSAGES:

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR
```

Atmospheric Dispersion Coefficients for WESF (Onsite, Site Boundary and River)

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
ALL	100	0	99.94	1	1.09E-02	1.09E-02	F	0.89
ALL	21080	0	99.94	1	1.12E-05	1.12E-05	G	2.65
ALL	11710	0	99.94	1	1.82E-05	1.82E-05	G	2.65

Current Input File Name: c:\p\wesf\xq\pm-o.IN

GXQ Version 4.0
December 19, 1994

General Purpose Atmospheric Dispersion Code
Produced by Westinghouse Hanford Company

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
Westinghouse Hanford Company
P.O. Box 1970
Richland, WA 99352
(509) 376-2921

Run Date = 08/30/96
Run Time = 13:59:37.71

```
INPUT ECHO:
Atmospheric Dispersion Coefficients for WESF (Onsite, Site Boundary and River)
c GXQ Version 4.0 Input File
c   mode
    1
c
c MODE CHOICE:
c mode = 1 then X/Q based on Hanford site specific meteorology
c mode = 2 then X/Q based on atmospheric stability class and wind speed
c mode = 3 then X/Q plot file is created
c
c LOGICAL CHOICES:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     T     F
c ifox  = t then joint frequency used to compute frequency to exceed X/Q
c       = f then joint frequency used to compute annual average X/Q
c inorm = t then joint frequency data is normalized (as in GENII)
c       = f then joint frequency data is un-normalized
c icdf  = t then cumulative distribution file created (CDF.OUT)
c       = f then no cumulative distribution file created
c ichk  = t then X/Q parameter print option turned on
c       = f then no parameter print
c isite = t then X/Q based on joint frequency data for all 16 sectors
c       = f then X/Q based on joint frequency data of individual sectors
c ipop  = t then X/Q is population weighted
c       = f then no population weighting
c
c X/Q AND WIND SPEED ADJUSTMENT MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENT MODELS:
c   iwake ipm   iflow ientr
    0     1     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENT MODELS:
c  (irise igrnd)iwash igrav
    0     0     0     0
c ipuff = 1 then X/Q calculated using puff model
c       = 0 then X/Q calculated using default continuous plume model
c idep  = 1 then plume depletion model turned on (Chamberlain model)
c isrc  = 1 then X/Q multiplied by scalar
c       = 2 then X/Q adjusted by wind speed function
c iwind = 1 then wind speed corrected for plume height
c iwake = 1 then NRC RG 1.145 building wake model turned on
c       = 2 then MACCS virtual distance building wake model turned on
c ipm   = 1 then NRC RG 1.145 plume meander model turned on
c       = 2 then 5th Power Law plume meander model turned on
c       = 3 then sector average model turned on
c iflow = 1 then sigmas adjusted for volume flow rate
c ientr = 1 then method of Pasquill used to account for entrainment
c irise = 1 then MACCS buoyant plume rise model turned on
c       = 2 then ISC2 momentum/buoyancy plume rise model turned on
c igrnd = 1 then Mills buoyant plume rise modification for ground effects
c iwash = 1 then stack downwash model turned on
```

```
c igrav = 1 then gravitational settling model turned on
c       = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c                  reference                     frequency
c   release        anemometer     mixing         to
c   height         height         height         exceed
c   hs(m)          ha(m)          hm(m)          Cx(%)
c   ___________    ___________    ___________    ___________
    0.00000E+00    1.00000E+01    1.00000E+03    5.00000E+00
c
c   initial        initial                                      gravitational
c   plume          plume          release        deposition     settling
c   width          height         duration       velocity       velocity
c   Wb(m)          Hb(m)          trd(hr)        vd(m/s)        vg(m/s)
c   ___________    ___________    ___________    ___________    ___________
    0.00000E+00    0.00000E+00    1.00000E+00    1.00000E-03    1.00000E-03
c
c                  initial        initial                       convective
c   ambient        plume          plume          release        heat release
c   temperature    temperature    flow rate      diameter       rate(1)
c   Tamb(C)        T0(C)          V0(m3/s)       d(m)           qh(w)
c   ___________    ___________    ___________    ___________    ___________
    2.00000E+01    2.00000E+01    1.00000E+00    1.00000E+00    0.00000E+00
c
c (1) If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q            Wind
c   scaling        Speed
c   factor         Exponent
c   c(?)           a(?)
c   ___________    ___________
    1.00000E+00    7.80000E-01
c
c RECEPTOR DEPENDENT DATA (no line limit)
c FOR MODE    make          RECEPTOR DEPENDENT DATA
c 1 (site specific)         sector distance receptor-height
c 2 (by class & wind speed) class windspeed distance offset receptor-height
c 3 (create plot file)      class windspeed xmax imax ymax jmax xqmin power
c
c RECEPTOR PARAMETER DESCRIPTION
c sector = 0, 1, 2... (all, S, SSW, etc.)
c distance = receptor distance (m)
c receptor height = height of receptor (m)
c class = 1, 2, 3, 4, 5, 6, 7 (P-G stability class A, B, C, D, E, F, G)
c windspeed = anemometer wind speed (m/s)
c offset = offset from plume centerline (m)
c xmax = maximum distance to plot or calculate to (m)
c imax = distance intervals
c ymax = maximum offset to plot (m)
c jmax = offset intervals
c xqmin = minimum scaled X/Q to calculate
c power = exponent in power function step size

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for overall site.

MODELS SELECTED:
NRC RG 1.145 plume meander model selected.
Default Gaussian plume model selected.

WARNING/ERROR MESSAGES:

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR
```

Atmospheric Dispersion Coefficients for WESF (Onsite, Site Boundary and River)

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
ALL	100	0	99.94	1	9.40E-03	9.40E-03	F	0.89
ALL	21080	0	99.94	1	9.60E-06	9.60E-06	G	2.65
ALL	11710	0	99.94	1	1.46E-05	1.46E-05	G	2.65

Current Input File Name: c:\p\wesf\xq\bwpm-o.IN

GXQ Version 4.0
December 19, 1994

General Purpose Atmospheric Dispersion Code
Produced by Westinghouse Hanford Company

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
Westinghouse Hanford Company
P.O. Box 1970
Richland, WA 99352
(509) 376-2921

Run Date = 08/30/96
Run Time = 13:59:43.53

```
INPUT ECHO:
Atmospheric Dispersion Coefficients for WESF (Onsite, Site Boundary and River)
c GXQ Version 4.0 Input File
c   mode
    1
c
c MODE CHOICE:
c mode = 1 then X/Q based on Hanford site specific meteorology
c mode = 2 then X/Q based on atmospheric stability class and wind speed
c mode = 3 then X/Q plot file is created
c
c LOGICAL CHOICES:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     T     F
c ifox  = t then joint frequency used to compute frequency to exceed X/Q
c       = f then joint frequency used to compute annual average X/Q
c inorm = t then joint frequency data is normalized (as in GENII)
c       = f then joint frequency data is un-normalized
c icdf  = t then cumulative distribution file created (CDF.OUT)
c       = f then no cumulative distribution file created
c ichk  = t then X/Q parameter print option turned on
c       = f then no parameter print
c isite = t then X/Q based on joint frequency data for all 16 sectors
c       = f then X/Q based on joint frequency data of individual sectors
c ipop  = t then X/Q is population weighted
c       = f then no population weighting
c
c X/Q AND WIND SPEED ADJUSTMENT MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     0
c DIFFUSION COEFFICIENT ADJUSTMENT MODELS:
c   iwake ipm   iflow ientr
    1     1     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENT MODELS:
c  (irise igrnd)iwash igrav
    0     0     0     0
c ipuff = 1 then X/Q calculated using puff model
c       = 0 then X/Q calculated using default continuous plume model
c idep  = 1 then plume depletion model turned on (Chamberlain model)
c isrc  = 1 then X/Q multiplied by scalar
c       = 2 then X/Q adjusted by wind speed function
c iwind = 1 then wind speed corrected for plume height
c iwake = 1 then NRC RG 1.145 building wake model turned on
c       = 2 then MACCS virtual distance building wake model turned on
c ipm   = 1 then NRC RG 1.145 plume meander model turned on
c       = 2 then 5th Power Law plume meander model turned on
c       = 3 then sector average model turned on
c iflow = 1 then sigmas adjusted for volume flow rate
c ientr = 1 then method of Pasquill used to account for entrainment
c irise = 1 then MACCS buoyant plume rise model turned on
c       = 2 then ISC2 momentum/buoyancy plume rise model turned on
c igrnd = 1 then Mills buoyant plume rise modification for ground effects
c iwash = 1 then stack downwash model turned on
```

```
c igrav = 1 then gravitational settling model turned on
c       = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c                  reference                 frequency
c   release        anemometer    mixing      to
c   height         height        height      exceed
c   hs(m)          ha(m)         hm(m)       Cx(%)
c   ___________    ___________   ___________ ___________
    0.00000E+00    1.00000E+01   1.00000E+03 5.00000E+00
c
c   initial        initial                                 gravitational
c   plume          plume         release     deposition    settling
c   width          height        duration    velocity      velocity
c   Wb(m)          Hb(m)         trd(hr)     vd(m/s)       vg(m/s)
c   ___________    ___________   ___________ ___________   ___________
    2.00000E+01    1.50000E+01   1.00000E+00 1.00000E-03   1.00000E-03
c
c                  initial       initial                   convective
c   ambient        plume         plume       release       heat release
c   temperature    temperature   flow rate   diameter      rate(1)
c   Tamb(C)        T0(C)         V0(m3/s)    d(m)          qh(w)
c   ___________    ___________   ___________ ___________   ___________
    2.00000E+01    2.00000E+01   1.00000E+00 1.00000E+00   0.00000E+00
c
c (1) If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q            Wind
c   scaling        Speed
c   factor         Exponent
c   c(?)           a(?)
c   ___________    ___________
    1.00000E+00    7.80000E-01
c
c RECEPTOR DEPENDENT DATA (no line limit)
c FOR MODE     make          RECEPTOR DEPENDENT DATA
c 1 (site specific)          sector distance receptor-height
c 2 (by class & wind speed) class windspeed distance offset receptor-height
c 3 (create plot file)       class windspeed xmax imax ymax jmax xqmin power
c
c RECEPTOR PARAMETER DESCRIPTION
c sector = 0, 1, 2... (all, S, SSW, etc.)
c distance = receptor distance (m)
c receptor height = height of receptor (m)
c class = 1, 2, 3, 4, 5, 6, 7 (P-G stability class A, B, C, D, E, F, G)
c windspeed = anemometer wind speed (m/s)
c offset = offset from plume centerline (m)
c xmax = maximum distance to plot or calculate to (m)
c imax = distance intervals
c ymax = maximum offset to plot (m)
c jmax = offset intervals
c xqmin = minimum scaled X/Q to calculate
c power = exponent in power function step size

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for overall site.

MODELS SELECTED:
NRC RG 1.145 building wake model selected.
NRC RG 1.145 plume meander model selected.
Default Gaussian plume model selected.

WARNING/ERROR MESSAGES:

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR
```

Atmospheric Dispersion Coefficients for WESF (Onsite, Site Boundary and River)

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
ALL	100	0	99.94	1	8.31E-03	8.31E-03	F	0.89
ALL	21080	0	99.94	1	9.60E-06	9.60E-06	G	2.65
ALL	11710	0	99.94	1	1.46E-05	1.46E-05	G	2.65

GXQ 4C Major Code Changes to Implement Huber Building Wake Plume Spread Enhancement Model

```
!
! If iwake=3 then adjust sigmas according to Huber spread enhancement model
! xsb = distance from stack to building windward side (m)
!
      if(iwake.eq.3)then
! Calculate effective release height at xsb
      hexsb=fhe(xsb,ue,uhe,urel,ua,uc,iclass,hprb,hprm,hprl,fm,fb,hwash,hgrav,w0)
! If effective release height at xsb < 2.5*hb then spread enhancement
! model applies.  Limit effective plume height to that which occurs at building.
      if(hexsb.lt.2.5*hb)then
        he=hexsb
        xlee=x-xsb-db
        tmp=xlee/hb
! If receptor distance less than 10 building heights then near field model
        if(tmp.le.10.0)then
! If effective release height below 1.2 times building height,
! then account for enhanced lateral spread also
          if(he.lt.(1.2*hb))then
            sy6=0.7*(wb/2.)+0.067*(xlee-3.*hb)
          else
            sy6=sy1
          endif
          sz6=0.7*hb+0.067*(xlee-3.*hb)
! Receptor distance greater than 10 building heights then far field model
        else
! If effective release height below 1.2 times building height,
! then account for enhanced lateral spread also
          if(he.lt.(1.2*hb))then
            xvy3=xvy(iclass,0.7*wb/2.+0.5*hb)
            xvy3=xvy3-10*hb
            xvy3=max(xvy3,0.0)
            sy6=sigmay(iclass,xlee+xvy3)
          else
            sy6=sy1
          endif
          xvz3=xvz(iclass,1.2*hb)
          xvz3=xvz3-10*hb
          xvz3=max(xvz3,0.0)
          sz6=sigmaz(iclass,xlee+xvz3)
        endif
        sx6=sy6
      endif
      endif
```

```
   Current Input File Name: gxq4ctst.IN


                              ___________________________

                                   GXQ Version 4.0C
                                   December 20, 1996
                              ___________________________

General Purpose Atmospheric Dispersion Code
Produced by Fluor Daniel Northwest

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                   Fluor Daniel Northwest
                   P.O. Box 1050
                   Richland, WA 99352-1050
                   (509) 376-2921


Run Date = 02/14/97
Run Time = 12:45:23.36


INPUT ECHO:
Test of Building Cavity Model
c GXQ Version 4.0c Input File
c   mode
    2
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
    3     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c  (irise igrnd)iwash igrav
    2     0     0     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c         = 3 then Huber building cavity dispersion model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
```

```
c    igrav = 1 then gravitational settling model turned on
c          = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c    release         anemometer      mixing          frequency
c    height          height          height          to
c    (m)             (m)             (m)             exceed
     2.29000E+01     1.00000E+01     1.00000E+03     5.00000E-01
c
c                                                    stack to
c    building        building        building        building
c    width           height          depth           distance
c    Wb(m)           Hb(m)           Db(m)           xsb(m)
     4.90000E+01     1.22000E+01     1.50000E+01     2.30000E+01
c
c                                    gravitational
c    release         deposition      settling
c    duration        velocity        velocity
c    (hour)          (m/s)           (m/s)
     0.00000E+00     1.00000E-03     1.00000E-03
c
c                    initial         initial                         convective
c    ambient         plume           plume           release         heat release
c    temperature     temperature     flow rate       diameter        rate*
c    (°C)            (°C)            (m3/s)          (m)             (watts)
     2.00000E+01     2.00000E+01     1.04000E+01     1.07000E+00     0.00000E+00
c    *If zero then buoyant flux based on plume/ambient temperature difference.
c
c    X/Q             Wind
c    scaling         Speed
c    factor          Exponent
     1.00000E+00     0.00000E+00
c
c RECEPTOR LOCATIONS (no line limit)
c    MODE                RECEPTOR DEPENDENT DATA
c    1 (site winds)      sector, distance, receptor height
c    2 (special case)    class, windspeed, distance, offset, receptor height
c    3 (plot file)       class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c    sector = 0, 1, 2... (all, S, SSW, etc.)
c    distance = receptor distance (m)
c    receptor height = height of receptor (m)
c    class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c    windspeed = anemometer wind speed (m/s)
c    offset = offset from plume centerline (m)
c    xmax  = maximum distance to plot or calculate to (m)
c    imax  = distance intervals
c    ymax  = maximum offset to plot (m)
c    jmax  = offset intervals
c    xqmin = minimum scaled X/Q to calculate
c    power = exponent in power function step size

MODE:
X/Q calculated by stability class and wind speed.

LOGICAL CHOICES:

MODELS SELECTED:
Huber building cavity entrainment model selected.
ISC2 momentum/buoyancy plume model based on temperature difference.
Default Gaussian plume model selected.
Wind velocity corrected for average plume height.

WARNING/ERROR MESSAGES:
WARNING #10 - X/Q may be underestimated for plume rise scenario without
              accounting for entrainment.
```

Test of Building Cavity Model

ATM. STAB. CLASS	WIND SPEED (m/s)	DISTANCE (m)	OFFSET (m)	RECEPTOR HEIGHT (m)	SCALED X/Q (s/m3)
A	0.89	100	0	2	1.32E-07
A	2.70	100	0	2	1.54E-05
A	4.70	100	0	2	2.67E-05
A	7.20	100	0	2	2.29E-05
A	9.80	100	0	2	1.92E-05
A	13.00	100	0	2	1.58E-05
A	16.00	100	0	2	1.34E-05
A	19.00	100	0	2	1.17E-05
B	0.89	100	0	2	4.22E-10
B	2.70	100	0	2	3.12E-06
B	4.70	100	0	2	1.17E-05
B	7.20	100	0	2	1.22E-05
B	9.80	100	0	2	1.12E-05
B	13.00	100	0	2	9.79E-06
B	16.00	100	0	2	8.62E-06
B	19.00	100	0	2	7.65E-06
C	0.89	100	0	2	2.87E-16
C	2.70	100	0	2	3.04E-08
C	4.70	100	0	2	1.10E-05
C	7.20	100	0	2	1.19E-05
C	9.80	100	0	2	1.12E-05
C	13.00	100	0	2	9.87E-06
C	16.00	100	0	2	8.76E-06
C	19.00	100	0	2	7.81E-06
D	0.89	100	0	2	4.60E-35
D	2.70	100	0	2	8.20E-15
D	4.70	100	0	2	1.59E-05
D	7.20	100	0	2	1.69E-05
D	9.80	100	0	2	1.56E-05
D	13.00	100	0	2	1.37E-05
D	16.00	100	0	2	1.21E-05
D	19.00	100	0	2	1.08E-05
E	0.89	100	0	2	7.61E-28
E	2.70	100	0	2	1.73E-05
E	4.70	100	0	2	2.36E-05
E	7.20	100	0	2	2.29E-05
E	9.80	100	0	2	2.04E-05
E	13.00	100	0	2	1.74E-05
E	16.00	100	0	2	1.52E-05
E	19.00	100	0	2	1.34E-05
F	0.89	100	0	2	0.00E+00
F	2.70	100	0	2	2.96E-05
F	4.70	100	0	2	3.45E-05
F	7.20	100	0	2	3.13E-05
F	9.80	100	0	2	2.70E-05
F	13.00	100	0	2	2.25E-05
F	16.00	100	0	2	1.94E-05
F	19.00	100	0	2	1.70E-05
G	0.89	100	0	2	0.00E+00
G	2.70	100	0	2	4.58E-05
G	4.70	100	0	2	5.17E-05
G	7.20	100	0	2	4.62E-05
G	9.80	100	0	2	3.95E-05
G	13.00	100	0	2	3.28E-05
G	16.00	100	0	2	2.82E-05
G	19.00	100	0	2	2.46E-05

```
   Current Input File Name: zone1.IN


                               ____________________

                                  GXQ Version 4.0C
                                  December 20, 1996
                               ____________________

General Purpose Atmospheric Dispersion Code
Produced by Fluor Daniel Northwest

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                   Fluor Daniel Northwest
                   P.O. Box 1050
                   Richland, WA 99352-1050
                   (509) 376-2921


Run Date = 02/14/97
Run Time = 12:45:23.91


INPUT ECHO:
Atmospheric Diffusion Coefficients for Zone I
c GXQ Version 4.0c Input File
c   mode
    1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
    3     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c  (irise igrnd)iwash igrav
    2     0     1     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c         = 3 then Huber building cavity dispersion model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
```

```
c    igrav = 1 then gravitational settling model turned on
c          = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c    release          anemometer       mixing           frequency
c    height           height           height           to
c    (m)              (m)              (m)              exceed
     2.29000E+01      1.00000E+01      1.00000E+03      5.00000E-01
c
c                                                       stack to
c    building         building         building         building
c    width            height           depth            distance
c    Wb(m)            Hb(m)            Db(m)            xsb(m)
     4.90000E+01      1.22000E+01      1.50000E+01      2.30000E+01
c
c                                      gravitational
c    release          deposition       settling
c    duration         velocity         velocity
c    (hour)           (m/s)            (m/s)
     0.00000E+00      1.00000E-03      1.00000E-03
c
c                     initial          initial                           convective
c    ambient          plume            plume            release          heat release
c    temperature      temperature      flow rate        diameter         rate*
c    (°C)             (°C)             (m3/s)           (m)              (watts)
     2.00000E+01      2.00000E+01      1.04000E+01      1.07000E+00      0.00000E+00
c    *If zero then buoyant flux based on plume/ambient temperature difference.
c
c    X/Q              Wind
c    scaling          Speed
c    factor           Exponent
     1.00000E+00      0.00000E+00
c
c RECEPTOR LOCATIONS (no line limit)
c    MODE                RECEPTOR DEPENDENT DATA
c    1 (site winds)      sector, distance, receptor height
c    2 (special case)    class, windspeed, distance, offset, receptor height
c    3 (plot file)       class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c    sector = 0, 1, 2... (all, S, SSW, etc.)
c    distance = receptor distance (m)
c    receptor height = height of receptor (m)
c    class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c    windspeed = anemometer wind speed (m/s)
c    offset = offset from plume centerline (m)
c    xmax  = maximum distance to plot or calculate to (m)
c    imax  = distance intervals
c    ymax  = maximum offset to plot (m)
c    jmax  = offset intervals
c    xqmin = minimum scaled X/Q to calculate
c    power = exponent in power function step size

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for single sector.

MODELS SELECTED:
Huber building cavity entrainment model selected.
ISC2 momentum/buoyancy plume model based on temperature difference.
Stack downwash model selected.
Default Gaussian plume model selected.
Wind velocity corrected for average plume height.

WARNING/ERROR MESSAGES:
WARNING #10 - X/Q may be underestimated for plume rise scenario without
              accounting for entrainment.

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR
```

Atmospheric Diffusion Coefficients for Zone I

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
NNW	100	2	4.58	1	3.32E-05	3.32E-05	F	4.70
N	100	2	4.36	1	3.22E-05	3.22E-05	F	4.70
NNE	100	2	2.49	1	2.64E-05	2.64E-05	E	7.15
NNW	150	2	4.58	1	8.42E-05	8.42E-05	F	2.65
N	150	2	4.36	1	8.07E-05	8.07E-05	F	2.65
NNE	150	2	2.49	1	4.64E-05	4.64E-05	E	7.15
NNW	200	2	4.58	1	8.53E-05	8.53E-05	F	2.65
N	200	2	4.36	1	8.50E-05	8.50E-05	F	2.65
NNE	200	2	2.49	1	4.58E-05	4.58E-05	E	7.15
NNW	250	2	4.58	1	7.67E-05	7.67E-05	F	2.65
N	250	2	4.36	1	7.56E-05	7.56E-05	F	2.65
NNE	250	2	2.49	1	4.59E-05	4.59E-05	A	0.89
NNW	300	2	4.58	1	6.94E-05	6.94E-05	F	2.65
N	300	2	4.36	1	6.89E-05	6.89E-05	F	2.65
NNE	300	2	2.49	1	4.36E-05	4.36E-05	E	4.70

Current Input File Name: zone2a.IN

```
                    GXQ Version 4.0C
                    December 20, 1996

General Purpose Atmospheric Dispersion Code
Produced by Fluor Daniel Northwest

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                   Fluor Daniel Northwest
                   P.O. Box 1050
                   Richland, WA 99352-1050
                   (509) 376-2921


Run Date = 02/14/97
Run Time = 12:45:25.40


INPUT ECHO:
Atmospheric Diffusion Coefficients for Zone IIA
c GXQ Version 4.0c Input File
c   mode
    1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
    3     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c  (irise igrnd)iwash igrav
    2     0     1     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c         = 3 then Huber building cavity dispersion model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
```

```
c   igrav = 1 then gravitational settling model turned on
c         = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c   release        anemometer     mixing         frequency
c   height         height         height         to
c   (m)            (m)            (m)            exceed
    2.29000E+01    1.00000E+01    1.00000E+03    5.00000E-01
c
c                                                stack to
c   building       building       building       building
c   width          height         depth          distance
c   Wb(m)          Hb(m)          Db(m)          xsb(m)
    2.00000E+01    1.60000E+01    2.00000E+01    3.30000E+01
c
c                                 gravitational
c   release        deposition     settling
c   duration       velocity       velocity
c   (hour)         (m/s)          (m/s)
    0.00000E+00    1.00000E-03    1.00000E-03
c
c                  initial        initial                       convective
c   ambient        plume          plume          release        heat release
c   temperature    temperature    flow rate      diameter       rate*
c   (°C)           (°C)           (m3/s)         (m)            (watts)
    2.00000E+01    2.00000E+01    1.04000E+01    1.07000E+00    0.00000E+00
c   *If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q            Wind
c   scaling        Speed
c   factor         Exponent
    1.00000E+00    0.00000E+00
c
c RECEPTOR LOCATIONS (no line limit)
c   MODE               RECEPTOR DEPENDENT DATA
c   1 (site winds)     sector, distance, receptor height
c   2 (special case)   class, windspeed, distance, offset, receptor height
c   3 (plot file)      class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax  = maximum distance to plot or calculate to (m)
c   imax  = distance intervals
c   ymax  = maximum offset to plot (m)
c   jmax  = offset intervals
c   xqmin = minimum scaled X/Q to calculate
c   power = exponent in power function step size

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for single sector.

MODELS SELECTED:
Huber building cavity entrainment model selected.
ISC2 momentum/buoyancy plume model based on temperature difference.
Stack downwash model selected.
Default Gaussian plume model selected.
Wind velocity corrected for average plume height.

WARNING/ERROR MESSAGES:
WARNING #10 - X/Q may be underestimated for plume rise scenario without
              accounting for entrainment.

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR
```

Atmospheric Diffusion Coefficients for Zone IIA

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
NE	100	2	3.90	1	3.87E-05	3.87E-05	F	2.65
NE	150	2	3.90	1	9.13E-05	9.13E-05	F	2.65
NE	200	2	3.90	1	1.20E-04	1.20E-04	G	4.70
NE	250	2	3.90	1	1.23E-04	1.23E-04	E	0.89
NE	300	2	3.90	1	1.13E-04	1.13E-04	E	0.89

```
Current Input File Name: zone2b.IN

                         GXQ Version 4.0C
                         December 20, 1996

General Purpose Atmospheric Dispersion Code
Produced by Fluor Daniel Northwest

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                   Fluor Daniel Northwest
                   P.O. Box 1050
                   Richland, WA 99352-1050
                   (509) 376-2921


Run Date = 02/14/97
Run Time = 12:45:26.39


INPUT ECHO:
Atmospheric Diffusion Coefficients for Zone IIB
c GXQ Version 4.0c Input File
c   mode
    1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
    3     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c  (irise igrnd)iwash igrav
    2     0     1     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c         = 3 then Huber building cavity dispersion model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
```

```
c   igrav = 1 then gravitational settling model turned on
c         = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c   release        anemometer     mixing         frequency
c   height         height         height         to
c   (m)            (m)            (m)            exceed
    2.29000E+01    1.00000E+01    1.00000E+03    5.00000E-01
c
c                                                stack to
c   building       building       building       building
c   width          height         depth          distance
c   Wb(m)          Hb(m)          Db(m)          xsb(m)
    2.00000E+01    1.60000E+01    2.00000E+01    7.00000E+01
c
c                                 gravitational
c   release        deposition     settling
c   duration       velocity       velocity
c   (hour)         (m/s)          (m/s)
    0.00000E+00    1.00000E-03    1.00000E-03
c
c                  initial        initial                       convective
c   ambient        plume          plume          release        heat release
c   temperature    temperature    flow rate      diameter       rate*
c   (°C)           (°C)           (m3/s)         (m)            (watts)
    2.00000E+01    2.00000E+01    1.04000E+01    1.07000E+00    0.00000E+00
c   *If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q            Wind
c   scaling        Speed
c   factor         Exponent
    1.00000E+00    0.00000E+00
c
c RECEPTOR LOCATIONS (no line limit)
c   MODE                RECEPTOR DEPENDENT DATA
c   1 (site winds)      sector, distance, receptor height
c   2 (special case)    class, windspeed, distance, offset, receptor height
c   3 (plot file)       class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax  = maximum distance to plot or calculate to (m)
c   imax  = distance intervals
c   ymax  = maximum offset to plot (m)
c   jmax  = offset intervals
c   xqmin = minimum scaled X/Q to calculate
c   power = exponent in power function step size

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for single sector.

MODELS SELECTED:
Huber building cavity entrainment model selected.
ISC2 momentum/buoyancy plume model based on temperature difference.
Stack downwash model selected.
Default Gaussian plume model selected.
Wind velocity corrected for average plume height.

WARNING/ERROR MESSAGES:
WARNING #10 - X/Q may be underestimated for plume rise scenario without
              accounting for entrainment.

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR
```

Atmospheric Diffusion Coefficients for Zone IIB

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
ENE	100	2	6.17	1	1.93E-05	1.93E-05	A	7.15
ENE	150	2	6.17	1	3.80E-05	3.80E-05	F	4.70
ENE	200	2	6.17	1	9.53E-05	9.53E-05	F	0.89
ENE	250	2	6.17	1	1.24E-04	1.24E-04	G	2.65
ENE	300	2	6.17	1	1.15E-04	1.15E-04	G	2.65
ENE	350	2	6.17	1	1.03E-04	1.03E-04	G	2.65
ENE	400	2	6.17	1	9.25E-05	9.25E-05	G	2.65

Current Input File Name: roof1.IN

GXQ Version 4.0C
December 20, 1996

General Purpose Atmospheric Dispersion Code
Produced by Fluor Daniel Northwest

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
Fluor Daniel Northwest
P.O. Box 1050
Richland, WA 99352-1050
(509) 376-2921

Run Date = 01/12/97
Run Time = 15:17:24.13

```
INPUT ECHO:
Atmospheric Diffusion Coefficients for Zone IIB
c GXQ Version 4.0c Input File
c   mode
    1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
    3     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c  (irise igrnd)iwash igrav
    2     0     1     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c         = 3 then Huber building cavity dispersion model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
```

```
c   igrav = 1 then gravitational settling model turned on
c         = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c   release        anemometer     mixing         frequency
c   height         height         height         to
c   (m)            (m)            (m)            exceed
    2.29000E+01    1.00000E+01    1.00000E+03    5.00000E-01
c
c                                                stack to
c   building       building       building       building
c   width          height         depth          distance
c   Wb(m)          Hb(m)          Db(m)          xsb(m)
    2.00000E+01    1.60000E+01    2.00000E+01    7.00000E+01
c
c                                 gravitational
c   release        deposition     settling
c   duration       velocity       velocity
c   (hour)         (m/s)          (m/s)
    0.00000E+00    1.00000E-03    1.00000E-03
c
c                  initial        initial                       convective
c   ambient        plume          plume          release        heat release
c   temperature    temperature    flow rate      diameter       rate*
c   (°C)           (°C)           (m3/s)         (m)            (watts)
    2.00000E+01    2.00000E+01    1.04000E+01    1.07000E+00    0.00000E+00
c   *If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q            Wind
c   scaling        Speed
c   factor         Exponent
    1.00000E+00    0.00000E+00
c
c RECEPTOR LOCATIONS (no line limit)
c   MODE               RECEPTOR DEPENDENT DATA
c   1 (site winds)     sector, distance, receptor height
c   2 (special case)   class, windspeed, distance, offset, receptor height
c   3 (plot file)      class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax  = maximum distance to plot or calculate to (m)
c   imax  = distance intervals
c   ymax  = maximum offset to plot (m)
c   jmax  = offset intervals
c   xqmin = minimum scaled X/Q to calculate
c   power = exponent in power function step size

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for single sector.

MODELS SELECTED:
Huber building cavity entrainment model selected.
ISC2 momentum/buoyancy plume model based on temperature difference.
Stack downwash model selected.
Default Gaussian plume model selected.
Wind velocity corrected for average plume height.

WARNING/ERROR MESSAGES:
WARNING #10 - X/Q may be underestimated for plume rise scenario without
              accounting for entrainment.

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR
```

Atmospheric Diffusion Coefficients for Zone IIB

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
ENE	100	18	6.17	1	2.91E-04	2.91E-04	F	0.89
ENE	150	18	6.17	1	3.34E-04	3.34E-04	G	2.65
ENE	200	18	6.17	1	2.66E-04	2.66E-04	G	2.65
ENE	250	18	6.17	1	2.27E-04	2.27E-04	E	0.89
ENE	300	18	6.17	1	2.03E-04	2.03E-04	E	0.89
ENE	350	18	6.17	1	1.78E-04	1.78E-04	E	0.89
ENE	400	18	6.17	1	1.59E-04	1.59E-04	E	0.89

```
Current Input File Name: roof2.IN

                         GXQ Version 4.0C
                         December 20, 1996

General Purpose Atmospheric Dispersion Code
Produced by Fluor Daniel Northwest

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                   Fluor Daniel Northwest
                   P.O. Box 1050
                   Richland, WA 99352-1050
                   (509) 376-2921


Run Date = 01/15/97
Run Time = 07:30:07.46


INPUT ECHO:
Atmospheric Diffusion Coefficients for Zone IIB
c GXQ Version 4.0c Input File
c   mode
    1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
    0     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c  (irise igrnd)iwash igrav
    2     0     1     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c         = 3 then Huber building cavity dispersion model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
```

```
c   igrav = 1 then gravitational settling model turned on
c         = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c   release        anemometer     mixing         frequency
c   height         height         height         to
c   (m)            (m)            (m)            exceed
    2.29000E+01    1.00000E+01    1.00000E+03    5.00000E-01
c
c                                                stack to
c   building       building       building       building
c   width          height         depth          distance
c   Wb(m)          Hb(m)          Db(m)          xsb(m)
    2.00000E+01    1.60000E+01    2.00000E+01    7.00000E+01
c
c                                 gravitational
c   release        deposition     settling
c   duration       velocity       velocity
c   (hour)         (m/s)          (m/s)
    0.00000E+00    1.00000E-03    1.00000E-03
c
c                  initial        initial                       convective
c   ambient        plume          plume          release        heat release
c   temperature    temperature    flow rate      diameter       rate*
c   (°C)           (°C)           (m3/s)         (m)            (watts)
    2.00000E+01    2.00000E+01    1.04000E+01    1.07000E+00    0.00000E+00
c   *If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q            Wind
c   scaling        Speed
c   factor         Exponent
    1.00000E+00    0.00000E+00
c
c RECEPTOR LOCATIONS (no line limit)
c   MODE               RECEPTOR DEPENDENT DATA
c   1 (site winds)     sector, distance, receptor height
c   2 (special case)   class, windspeed, distance, offset, receptor height
c   3 (plot file)      class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax  = maximum distance to plot or calculate to (m)
c   imax  = distance intervals
c   ymax  = maximum offset to plot (m)
c   jmax  = offset intervals
c   xqmin = minimum scaled X/Q to calculate
c   power = exponent in power function step size

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for single sector.

MODELS SELECTED:
ISC2 momentum/buoyancy plume model based on temperature difference.
Stack downwash model selected.
Default Gaussian plume model selected.
Wind velocity corrected for average plume height.

WARNING/ERROR MESSAGES:
WARNING #10 - X/Q may be underestimated for plume rise scenario without
              accounting for entrainment.

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR
```

Atmospheric Diffusion Coefficients for Zone IIB

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
ENE	100	18	6.17	1	9.16E-05	9.16E-05	C	9.80
ENE	150	18	6.17	1	8.87E-05	8.87E-05	D	9.80
ENE	200	18	6.17	1	8.14E-05	8.14E-05	F	7.15
ENE	250	18	6.17	1	7.95E-05	7.95E-05	E	4.70
ENE	300	18	6.17	1	6.85E-05	6.85E-05	E	7.15
ENE	350	18	6.17	1	6.77E-05	6.77E-05	E	2.65
ENE	400	18	6.17	1	6.81E-05	6.81E-05	F	4.70

Current Input File Name: roof3.IN

```
                    GXQ Version 4.0C
                    December 20, 1996

General Purpose Atmospheric Dispersion Code
Produced by Fluor Daniel Northwest

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                   Fluor Daniel Northwest
                   P.O. Box 1050
                   Richland, WA 99352-1050
                   (509) 376-2921


Run Date = 12/22/96
Run Time = 09:49:54.97


INPUT ECHO:
Atmospheric Diffusion Coefficients for Zone IIB
c GXQ Version 4.0c Input File
c   mode
    1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
    0     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c  (irise igrnd)iwash igrav
    2     0     1     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c         = 3 then Huber building cavity dispersion model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
```

```
c   igrav = 1 then gravitational settling model turned on
c         = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c   release        anemometer     mixing         frequency
c   height         height         height         to
c   (m)            (m)            (m)            exceed
    6.90000E+00    1.00000E+01    1.00000E+03    5.00000E-01
c
c                                                stack to
c   building       building       building       building
c   width          height         depth          distance
c   Wb(m)          Hb(m)          Db(m)          xsb(m)
    2.00000E+01    1.60000E+01    2.00000E+01    7.00000E+01
c
c                                 gravitational
c   release        deposition     settling
c   duration       velocity       velocity
c   (hour)         (m/s)          (m/s)
    0.00000E+00    1.00000E-03    1.00000E-03
c
c                  initial        initial                       convective
c   ambient        plume          plume          release        heat release
c   temperature    temperature    flow rate      diameter       rate*
c   (°C)           (°C)           (m3/s)         (m)            (watts)
    2.00000E+01    2.00000E+01    1.04000E+01    1.07000E+00    0.00000E+00
c   *If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q            Wind
c   scaling        Speed
c   factor         Exponent
    1.00000E+00    0.00000E+00
c
c RECEPTOR LOCATIONS (no line limit)
c   MODE              RECEPTOR DEPENDENT DATA
c   1 (site winds)    sector, distance, receptor height
c   2 (special case)  class, windspeed, distance, offset, receptor height
c   3 (plot file)     class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax  = maximum distance to plot or calculate to (m)
c   imax  = distance intervals
c   ymax  = maximum offset to plot (m)
c   jmax  = offset intervals
c   xqmin = minimum scaled X/Q to calculate
c   power = exponent in power function step size

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for single sector.

MODELS SELECTED:
ISC2 momentum/buoyancy plume model based on temperature difference.
Stack downwash model selected.
Default Gaussian plume model selected.
Wind velocity corrected for average plume height.

WARNING/ERROR MESSAGES:
WARNING #10 - X/Q may be underestimated for plume rise scenario without
              accounting for entrainment.

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR
```

Atmospheric Diffusion Coefficients for Zone IIB

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
ENE	100	2	6.17	1	1.24E-04	1.24E-04	B	7.15
ENE	150	2	6.17	1	1.16E-04	1.16E-04	C	7.15
ENE	200	2	6.17	1	1.12E-04	1.12E-04	D	7.15
ENE	250	2	6.17	1	1.13E-04	1.13E-04	D	4.70
ENE	300	2	6.17	1	1.10E-04	1.10E-04	E	7.15
ENE	350	2	6.17	1	1.03E-04	1.03E-04	E	7.15
ENE	400	2	6.17	1	1.02E-04	1.02E-04	E	0.89

```
Current Input File Name: zone3.IN

                    GXQ Version 4.0C
                    December 20, 1996

General Purpose Atmospheric Dispersion Code
Produced by Fluor Daniel Northwest

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                   Fluor Daniel Northwest
                   P.O. Box 1050
                   Richland, WA 99352-1050
                   (509) 376-2921

Run Date = 02/14/97
Run Time = 12:45:27.54

INPUT ECHO:
Atmospheric Diffusion Coefficients for Zone III
c GXQ Version 4.0c Input File
c   mode
    1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
    0     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c  (irise igrnd)iwash igrav
    2     0     1     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c         = 3 then Huber building cavity dispersion model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
```

```
c   igrav = 1 then gravitational settling model turned on
c         = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c   release        anemometer     mixing         frequency
c   height         height         height         to
c   (m)            (m)            (m)            exceed
    2.29000E+01    1.00000E+01    1.00000E+03    5.00000E-01
c
c                                                stack to
c   building       building       building       building
c   width          height         depth          distance
c   Wb(m)          Hb(m)          Db(m)          xsb(m)
    2.50000E+01    7.60000E+00    1.30000E+01    3.20000E+01
c
c                                 gravitational
c   release        deposition     settling
c   duration       velocity       velocity
c   (hour)         (m/s)          (m/s)
    0.00000E+00    1.00000E-03    1.00000E-03
c
c                  initial        initial                       convective
c   ambient        plume          plume          release        heat release
c   temperature    temperature    flow rate      diameter       rate*
c   (°C)           (°C)           (m3/s)         (m)            (watts)
    2.00000E+01    2.00000E+01    1.04000E+01    1.07000E+00    0.00000E+00
c   *If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q            Wind
c   scaling        Speed
c   factor         Exponent
    1.00000E+00    0.00000E+00
c
c RECEPTOR LOCATIONS (no line limit)
c   MODE               RECEPTOR DEPENDENT DATA
c   1 (site winds)     sector, distance, receptor height
c   2 (special case)   class, windspeed, distance, offset, receptor height
c   3 (plot file)      class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax  = maximum distance to plot or calculate to (m)
c   imax  = distance intervals
c   ymax  = maximum offset to plot (m)
c   jmax  = offset intervals
c   xqmin = minimum scaled X/Q to calculate
c   power = exponent in power function step size

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for single sector.

MODELS SELECTED:
ISC2 momentum/buoyancy plume model based on temperature difference.
Stack downwash model selected.
Default Gaussian plume model selected.
Wind velocity corrected for average plume height.

WARNING/ERROR MESSAGES:
WARNING #10 - X/Q may be underestimated for plume rise scenario without
              accounting for entrainment.

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR
```

Atmospheric Diffusion Coefficients for Zone III

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
E	100	2	14.05	1	1.93E-05	1.93E-05	A	7.15
E	150	2	14.05	1	2.89E-05	2.89E-05	A	4.70
E	200	2	14.05	1	2.98E-05	2.98E-05	A	4.70
E	250	2	14.05	1	2.89E-05	2.89E-05	B	4.70
E	300	2	14.05	1	2.69E-05	2.69E-05	A	2.65
E	350	2	14.05	1	2.11E-05	2.11E-05	C	7.15
E	400	2	14.05	1	1.91E-05	1.91E-05	B	4.70

Current Input File Name: zone4a.IN

```
                              GXQ Version 4.0C
                              December 20, 1996

General Purpose Atmospheric Dispersion Code
Produced by Fluor Daniel Northwest

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                   Fluor Daniel Northwest
                   P.O. Box 1050
                   Richland, WA 99352-1050
                   (509) 376-2921


Run Date = 02/14/97
Run Time = 12:45:28.36


INPUT ECHO:
Atmospheric Diffusion Coefficients for Zone IV
c GXQ Version 4.0c Input File
c   mode
    1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
    3     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c  (irise igrnd)iwash igrav
    2     0     1     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c         = 3 then Huber building cavity dispersion model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
```

```
c   igrav = 1 then gravitational settling model turned on
c         = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c   release         anemometer      mixing          frequency
c   height          height          height          to
c   (m)             (m)             (m)             exceed
    2.29000E+01     1.00000E+01     1.00000E+03     5.00000E-01
c
c                                                   stack to
c   building        building        building        building
c   width           height          depth           distance
c   Wb(m)           Hb(m)           Db(m)           xsb(m)
    2.00000E+01     1.22000E+01     2.00000E+01     8.00000E+01
c
c                                   gravitational
c   release         deposition      settling
c   duration        velocity        velocity
c   (hour)          (m/s)           (m/s)
    0.00000E+00     1.00000E-03     1.00000E-03
c
c                   initial         initial                         convective
c   ambient         plume           plume           release         heat release
c   temperature     temperature     flow rate       diameter        rate*
c   (°C)            (°C)            (m3/s)          (m)             (watts)
    2.00000E+01     2.00000E+01     1.04000E+01     1.07000E+00     0.00000E+00
c   *If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q             Wind
c   scaling         Speed
c   factor          Exponent
    1.00000E+00     0.00000E+00
c
c RECEPTOR LOCATIONS (no line limit)
c   MODE                RECEPTOR DEPENDENT DATA
c   1 (site winds)      sector, distance, receptor height
c   2 (special case)    class, windspeed, distance, offset, receptor height
c   3 (plot file)       class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax  = maximum distance to plot or calculate to (m)
c   imax  = distance intervals
c   ymax  = maximum offset to plot (m)
c   jmax  = offset intervals
c   xqmin = minimum scaled X/Q to calculate
c   power = exponent in power function step size

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for single sector.

MODELS SELECTED:
Huber building cavity entrainment model selected.
ISC2 momentum/buoyancy plume model based on temperature difference.
Stack downwash model selected.
Default Gaussian plume model selected.
Wind velocity corrected for average plume height.

WARNING/ERROR MESSAGES:
WARNING #10 - X/Q may be underestimated for plume rise scenario without
              accounting for entrainment.

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR
```

Atmospheric Diffusion Coefficients for Zone IV

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
ESE	100	2	18.80	1	1.93E-05	1.93E-05	A	7.15
ESE	200	2	18.80	1	5.35E-05	5.35E-05	G	4.70
ESE	250	2	18.80	1	6.68E-05	6.68E-05	G	4.70
ESE	300	2	18.80	1	5.80E-05	5.80E-05	G	4.70
ESE	350	2	18.80	1	5.17E-05	5.17E-05	G	4.70
ESE	400	2	18.80	1	4.68E-05	4.68E-05	G	4.70

Current Input File Name: zone4b.IN

GXQ Version 4.0C
December 20, 1996

General Purpose Atmospheric Dispersion Code
Produced by Fluor Daniel Northwest

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                   Fluor Daniel Northwest
                   P.O. Box 1050
                   Richland, WA 99352-1050
                   (509) 376-2921

Run Date = 02/14/97
Run Time = 12:45:29.35

```
INPUT ECHO:
Atmospheric Diffusion Coefficients for Zone IV
c GXQ Version 4.0c Input File
c   mode
    1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
    3     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c  (irise igrnd)iwash igrav
    2     0     1     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c         = 3 then Huber building cavity dispersion model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
```

```
c   igrav = 1 then gravitational settling model turned on
c         = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c   release         anemometer      mixing          frequency
c   height          height          height          to
c   (m)             (m)             (m)             exceed
    2.29000E+01     1.00000E+01     1.00000E+03     5.00000E-01
c
c                                                   stack to
c   building        building        building        building
c   width           height          depth           distance
c   Wb(m)           Hb(m)           Db(m)           xsb(m)
    2.00000E+01     1.22000E+01     2.00000E+01     4.10000E+01
c
c                                   gravitational
c   release         deposition      settling
c   duration        velocity        velocity
c   (hour)          (m/s)           (m/s)
    0.00000E+00     1.00000E-03     1.00000E-03
c
c                   initial         initial                         convective
c   ambient         plume           plume           release         heat release
c   temperature     temperature     flow rate       diameter        rate*
c   (°C)            (°C)            (m3/s)          (m)             (watts)
    2.00000E+01     2.00000E+01     1.04000E+01     1.07000E+00     0.00000E+00
c   *If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q             Wind
c   scaling         Speed
c   factor          Exponent
    1.00000E+00     0.00000E+00
c
c RECEPTOR LOCATIONS (no line limit)
c   MODE                RECEPTOR DEPENDENT DATA
c   1 (site winds)      sector, distance, receptor height
c   2 (special case)    class, windspeed, distance, offset, receptor height
c   3 (plot file)       class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax  = maximum distance to plot or calculate to (m)
c   imax  = distance intervals
c   ymax  = maximum offset to plot (m)
c   jmax  = offset intervals
c   xqmin = minimum scaled X/Q to calculate
c   power = exponent in power function step size

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for single sector.

MODELS SELECTED:
Huber building cavity entrainment model selected.
ISC2 momentum/buoyancy plume model based on temperature difference.
Stack downwash model selected.
Default Gaussian plume model selected.
Wind velocity corrected for average plume height.

WARNING/ERROR MESSAGES:
WARNING #10 - X/Q may be underestimated for plume rise scenario without
              accounting for entrainment.

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR
```

Atmospheric Diffusion Coefficients for Zone IV

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
SE	100	2	10.83	1	2.11E-05	2.11E-05	A	7.15
SE	150	2	10.83	1	4.40E-05	4.40E-05	F	7.15
SE	200	2	10.83	1	8.27E-05	8.27E-05	G	4.70
SE	250	2	10.83	1	7.06E-05	7.06E-05	G	4.70
SE	300	2	10.83	1	6.23E-05	6.23E-05	G	4.70

```
   Current Input File Name: zone5.IN


                               ________________________

                                  GXQ Version 4.0C
                                  December 20, 1996
                               ________________________

General Purpose Atmospheric Dispersion Code
Produced by Fluor Daniel Northwest

Users Guide documented in WHC-SD-GN-SWD-30002 Rev. 1.
Validation documented in WHC-SD-GN-SWD-30003 Rev. 1.
Code Custodian is: Brit E. Hey
                   Fluor Daniel Northwest
                   P.O. Box 1050
                   Richland, WA 99352-1050
                   (509) 376-2921


Run Date = 02/14/97
Run Time = 12:45:30.29


INPUT ECHO:
Atmospheric Diffusion Coefficients for Zone V
c GXQ Version 4.0c Input File
c   mode
    1
c MODE SELECTION:
c   1 - X/Q based on Hanford site specific meteorology
c   2 - X/Q based on atmospheric stability class and wind speed
c   3 - X/Q plot file is created
c
c SITE WIND & POPULATION OPTIONS:
c   ifox  inorm icdf  ichk  isite ipop
    T     F     F     F     F     F
c   ifox  = t then joint frequency used to compute frequency-to-exceed X/Q
c         = f then joint frequency used to compute annual average X/Q
c   inorm = t then joint frequency data is normalized (as in GENII)
c         = f then joint frequency data is un-normalized
c   icdf  = t then cumulative distribution file created (CDF.OUT)
c         = f then no cumulative distribution file created
c   ichk  = t then X/Q parameter print option turned on
c         = f then no parameter print
c   isite = t then X/Q based on joint frequency data for all 16 sectors
c         = f then X/Q based on joint frequency data of individual sectors
c   ipop  = t then X/Q is population weighted
c         = f then no population weighting
c
c PUFF, DEPOSITION, & WIND SPEED MODELS:
c   ipuff idep  isrc  iwind
    0     0     0     1
c DIFFUSION COEFFICIENT ADJUSTMENTS:
c   iwake ipm   iflow ientr
    0     0     0     0
c EFFECTIVE RELEASE HEIGHT ADJUSTMENTS:
c  (irise igrnd)iwash igrav
    2     0     1     0
c   ipuff = 1 then X/Q calculated using puff model
c         = 0 then X/Q calculated using default continuous plume model
c   idep  = 1 then plume depletion model turned on (Chamberlain model)
c   isrc  = 1 then X/Q multiplied by scalar
c         = 2 then X/Q adjusted by wind speed function
c   iwind = 1 then wind speed corrected for plume height
c   iwake = 1 then NRC RG 1.145 building wake model turned on
c         = 2 then MACCS virtual distance building wake model turned on
c         = 3 then Huber building cavity dispersion model turned on
c   ipm   = 1 then NRC RG 1.145 plume meander model turned on
c         = 2 then 5th Power Law plume meander model turned on
c         = 3 then sector average model turned on
c   iflow = 1 then sigmas adjusted for volume flow rate
c   ientr = 1 then method of Pasquill used to account for entrainment
c   irise = 1 then MACCS buoyant plume rise model turned on
c         = 2 then ISC2 momentum/buoyancy plume rise model turned on
c   igrnd = 1 then Mills' buoyant plume rise modification for ground effects
c   iwash = 1 then stack downwash model turned on
```

```
c   igrav = 1 then gravitational settling model turned on
c         = 0 unless specified otherwise, 0 turns model off
c
c PARAMETER INPUT:
c   release          anemometer      mixing          frequency
c   height           height          height          to
c   (m)              (m)             (m)             exceed
    2.29000E+01      1.00000E+01     1.00000E+03     5.00000E-01
c
c                                                    stack to
c   building         building        building        building
c   width            height          depth           distance
c   Wb(m)            Hb(m)           Db(m)           xsb(m)
    0.00000E+00      0.00000E+00     0.00000E+00     0.00000E+00
c
c                                    gravitational
c   release          deposition      settling
c   duration         velocity        velocity
c   (hour)           (m/s)           (m/s)
    0.00000E+00      1.00000E-03     1.00000E-03
c
c                    initial         initial                         convective
c   ambient          plume           plume           release         heat release
c   temperature      temperature     flow rate     . diameter        rate*
c   (°C)             (°C)            (m3/s)          (m)             (watts)
    2.00000E+01      2.00000E+01     1.04000E+01     1.07000E+00     0.00000E+00
c   *If zero then buoyant flux based on plume/ambient temperature difference.
c
c   X/Q              Wind
c   scaling          Speed
c   factor           Exponent
    1.00000E+00      0.00000E+00
c
c RECEPTOR LOCATIONS (no line limit)
c   MODE                RECEPTOR DEPENDENT DATA
c   1 (site winds)      sector, distance, receptor height
c   2 (special case)    class, windspeed, distance, offset, receptor height
c   3 (plot file)       class, windspeed, xmax, imax, ymax, jmax, xqmin, power
c
c RECEPTOR PARAMETERS
c   sector = 0, 1, 2... (all, S, SSW, etc.)
c   distance = receptor distance (m)
c   receptor height = height of receptor (m)
c   class = 1,2,3,4,5,6,7 (Pasquill stability A,B,C,D,E,F,G)
c   windspeed = anemometer wind speed (m/s)
c   offset = offset from plume centerline (m)
c   xmax  = maximum distance to plot or calculate to (m)
c   imax  = distance intervals
c   ymax  = maximum offset to plot (m)
c   jmax  = offset intervals
c   xqmin = minimum scaled X/Q to calculate
c   power = exponent in power function step size

MODE:
Site specific X/Q calculated.

LOGICAL CHOICES:
Joint frequency used to calculate X/Q based on frequency of exceedance.
No normalization of joint frequency.
X/Q calculated for single sector.

MODELS SELECTED:
ISC2 momentum/buoyancy plume model based on temperature difference.
Stack downwash model selected.
Default Gaussian plume model selected.
Wind velocity corrected for average plume height.

WARNING/ERROR MESSAGES:
WARNING #10 - X/Q may be underestimated for plume rise scenario without
              accounting for entrainment.

JOINT FREQUENCY DATA:
200 AREA (HMS) - 10 M - Pasquill A - G (1983 - 1991 Average)
Created 8/26/92 KR
```

Atmospheric Diffusion Coefficients for Zone V

SECTOR	DISTANCE (m)	RECEPT HEIGHT (m)	SECT. FREQ. (%)	POPULATION	TOTAL POPULATION SCALED X/Q (s/m3)	AVERAGE INDIVIDUAL SCALED X/Q (s/m3)	ATM. STAB. CLASS	WIND SPEED (m/s)
S	100	2	6.30	1	1.51E-05	1.51E-05	A	15.60
S	200	2	6.30	1	3.85E-05	3.85E-05	A	2.65
S	250	2	6.30	1	3.93E-05	3.93E-05	B	2.65
S	300	2	6.30	1	3.73E-05	3.73E-05	B	2.65
S	350	2	6.30	1	3.73E-05	3.73E-05	B	0.89
S	400	2	6.30	1	3.60E-05	3.60E-05	C	2.65
S	3677	2	6.30	1	2.09E-05	2.09E-05	E	0.89
SSW	100	2	4.53	1	1.51E-05	1.51E-05	A	2.65
SSW	200	2	4.53	1	3.49E-05	3.49E-05	B	2.65
SSW	250	2	4.53	1	3.61E-05	3.61E-05	A	2.65
SSW	300	2	4.53	1	3.05E-05	3.05E-05	B	0.89
SSW	350	2	4.53	1	3.47E-05	3.47E-05	B	2.65
SSW	400	2	4.53	1	3.12E-05	3.12E-05	B	2.65
SSW	3677	2	4.53	1	1.66E-05	1.66E-05	E	0.89
SW	100	2	2.93	1	5.06E-06	5.06E-06	B	2.65
SW	200	2	2.93	1	2.81E-05	2.81E-05	A	4.70
SW	250	2	2.93	1	3.30E-05	3.30E-05	A	2.65
SW	300	2	2.93	1	2.80E-05	2.80E-05	C	4.70
SW	350	2	2.93	1	2.23E-05	2.23E-05	B	4.70
SW	400	2	2.93	1	2.29E-05	2.29E-05	C	0.89
SW	3677	2	2.93	1	1.76E-05	1.76E-05	E	0.89
WSW	100	2	2.72	1	2.64E-07	2.64E-07	C	4.70
WSW	200	2	2.72	1	2.80E-05	2.80E-05	A	0.89
WSW	250	2	2.72	1	3.49E-05	3.49E-05	A	2.65
WSW	300	2	2.72	1	2.93E-05	2.93E-05	B	0.89
WSW	350	2	2.72	1	3.45E-05	3.45E-05	B	2.65
WSW	400	2	2.72	1	3.02E-05	3.02E-05	B	2.65
WSW	3677	2	2.72	1	1.75E-05	1.75E-05	E	0.89
W	100	2	4.80	1	1.22E-05	1.22E-05	A	2.65
W	200	2	4.80	1	3.74E-05	3.74E-05	B	2.65
W	250	2	4.80	1	3.94E-05	3.94E-05	B	2.65
W	300	2	4.80	1	3.76E-05	3.76E-05	B	2.65
W	350	2	4.80	1	3.79E-05	3.79E-05	B	0.89
W	400	2	4.80	1	3.61E-05	3.61E-05	C	2.65
W	3677	2	4.80	1	2.16E-05	2.16E-05	G	0.89
WNW	100	2	3.98	1	1.11E-05	1.11E-05	B	4.70
WNW	200	2	3.98	1	3.60E-05	3.60E-05	B	2.65
WNW	250	2	3.98	1	3.68E-05	3.68E-05	A	2.65
WNW	300	2	3.98	1	3.09E-05	3.09E-05	B	0.89
WNW	350	2	3.98	1	3.47E-05	3.47E-05	B	2.65
WNW	400	2	3.98	1	3.12E-05	3.12E-05	B	2.65
WNW	3677	2	3.98	1	2.09E-05	2.09E-05	E	0.89
NW	100	2	4.72	1	1.01E-05	1.01E-05	B	4.70
NW	200	2	4.72	1	3.49E-05	3.49E-05	B	2.65
NW	250	2	4.72	1	3.53E-05	3.53E-05	A	2.65
NW	300	2	4.72	1	3.02E-05	3.02E-05	B	0.89
NW	350	2	4.72	1	3.41E-05	3.41E-05	B	2.65
NW	400	2	4.72	1	2.99E-05	2.99E-05	B	2.65
NW	3677	2	4.72	1	2.12E-05	2.12E-05	E	0.89
SSE	100	2	4.78	1	1.40E-05	1.40E-05	A	2.65
SSE	200	2	4.78	1	3.57E-05	3.57E-05	B	2.65
SSE	250	2	4.78	1	3.67E-05	3.67E-05	A	2.65
SSE	300	2	4.78	1	3.16E-05	3.16E-05	C	2.65
SSE	350	2	4.78	1	3.49E-05	3.49E-05	B	2.65
SSE	400	2	4.78	1	3.19E-05	3.19E-05	B	2.65
SSE	3677	2	4.78	1	2.08E-05	2.08E-05	E	0.89

APPENDIX C - Encapsulation Database System Information

This appendix contains:

1. SrF_2 Capsule EDS Information Decayed to 1/1/96
2. CsCl Capsule EDS Information Decayed to 1/1/96
3. DSI from Mario M. Pereira to Brit Hey, "Verification of EDS Gram Salt/cc Field," dated January 29, 1996.

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BEST AVAILABLE COPY

B PLANT/WESF COMPLEX
TRANSITION PROJECTS
WESTINGHOUSE HANFORD COMPANY

To: Brit Hey **Phone No:** 376-2921

FAX Number: 376-5396

Confirmation No:

From: Karen Bender **Phone No:** 372-0293

Comments: This fax was obtained for the purpose of selecting bounding & best estimate thermal & radioactive inventories for 1) a single capsule, and 2) all capsules manufactured.

Brit Hey

Pages Including COVER SHEET: 2

EDS CAPSULE INFORMATION
Decayed to 12/31/95

	Uncut Capsules	
kCi Decayed	Cesium (1328)	Strontium (600)*
Total	52047.57	22575.62
Average	39.19	37.63
Maximum	53.15	91.08
Minimum	25.65	4.23
Median Value	39.03	36.69

	Uncut Capsules	
Wattage Decayed	Cesium (1328)	Strontium (600)*
Total	249969.62	152621.60
Average	188.23	254.37
Maximum	255.25	614.92
Minimum	122.99	28.85
Median Value	187.44	248.64

*Does not include Tracer Capsule S-2

SrF_2 Capsule EDS Information Decayed to 1/1/96

Outer Capsule ID #	Thermal Power (W)	Net Wt. (kg)
S-10	293	3.111
S-100	465	2.82
S-1000	95	1.69
S-1001	87	1.448
S-1004	380	2.669
S-1005	510	2.693
S-1006	109	2.23
S-1007	481	2.741
S-1010	383	2.82
S-1013	270	2.525
S-1014	459	2.503
S-1015	373	2.858
S-1016	426	2.761
S-1017	534	2.73
S-1018	210	2.931
S-1019	115	1.891
S-1020	93	2.879
S-1021	105	2.362
S-1022	373	2.52
S-1024	112	2.266
S-1025	148	2.294
S-1026	117	2.361
S-104	431	3.055
S-106	441	2.715
S-107	440	2.832
S-109	511	2.939
S-11	294	2.955
S-110	503	2.831
S-111	521	2.847
S-112	615	2.945
S-113	504	2.753
S-117	506	2.828
S-119	157	1.519
S-12	271	3.009
S-121	451	2.782
S-123	444	2.67
S-125	468	2.854
S-129	515	2.895
S-14	281	2.942
S-15	277	3.077
S-16	284	3.136
S-17	256	3.854
S-18	272	2.954
S-19	273	3.271
S-20	277	2.982
S-21	217	3.17
S-22	100	2.488
S-23	313	2.956
S-24	295	3.062
S-25	313	3.192
S-26	328	3.158
S-28	314	3.203
S-3	337	3.087
S-30	321	3.19
S-31	298	3.246
S-34	357	3.13
S-35	299	3.105
S-36	302	3.081
S-37	290	3.075
S-38	297	3.291
S-39	310	3.029
S-4	253	2.759
S-40	309	3.069
S-400	481	2.848
S-401	520	2.912
S-402	507	3.092
S-404	237	1.633
S-405	504	3.095
S-408	434	2.999
S-41	290	2.974
S-410	525	2.87
S-412	205	1.861
S-413	206	1.636
S-414	138	1.689
S-415	476	2.926
S-416	217	2.284
S-417	481	2.938
S-419	483	3.153
S-421	449	3.016
S-422	495	3.044
S-423	201	1.557
S-424	263	1.916
S-425	252	1.868
S-426	158	1.468
S-428	454	2.887
S-429	279	2.05
S-43	297	2.979
S-430	469	2.843
S-432	461	2.951
S-433	473	2.757
S-434	497	3.043
S-435	449	2.942
S-436	480	3.002
S-437	479	2.949
S-438	486	2.911
S-439	303	2.36
S-44	293	2.935
S-440	480	2.917
S-441	514	3.05
S-442	454	3.055
S-445	487	3.108
S-446	276	2.428
S-448	468	3.053
S-449	453	2.726
S-45	288	2.996
S-450	376	2.634
S-451	508	3.129
S-452	488	2.805
S-453	243	2.481
S-454	470	2.929
S-455	484	2.87
S-456	278	1.585
S-457	474	2.903
S-458	450	3.006
S-459	490	2.96
S-46	313	3.08
S-461	454	2.776
S-462	482	2.654
S-464	457	2.688
S-465	466	2.828
S-466	494	3.005
S-467	514	2.948
S-468	417	2.917
S-469	418	2.847
S-470	523	3.069
S-471	563	2.73
S-472	246	2.656
S-473	521	2.895
S-474	463	2.939
S-475	391	2.651
S-48	315	2.88
S-482	224	2.488
S-483	136	1.759
S-485	172	1.677
S-488	394	2.828
S-489	498	2.418
S-49	312	2.992
S-490	404	2.602
S-491	316	2.749
S-492	188	2.556
S-493	163	2.214
S-494	477	2.945
S-497	497	2.54
S-498	451	2.701
S-5	287	3.093
S-50	339	3.001
S-501	229	2.564
S-502	242	2.154

S-503	233	2.274
S-504	205	1.975
S-505	242	2.553
S-506	275	2.384
S-507	391	2.303
S-508	452	2.086
S-509	459	2.65
S-51	296	2.911
S-511	325	2.993
S-512	94	2.194
S-514	52	2.061
S-515	282	1.972
S-516	260	2.434
S-517	318	1.926
S-518	300	2.533
S-519	218	2.031
S-52	471	2.944
S-520	529	2.681
S-521	462	2.38
S-522	403	2.322
S-524	278	3.008
S-53	320	2.928
S-533	544	2.628
S-534	449	2.368
S-535	414	2.196
S-536	472	2.72
S-537	90	1.867
S-54	312	2.95
S-543	455	3.076
S-544	460	2.943
S-545	513	2.887
S-546	449	2.533
S-547	252	1.611
S-55	96	1.541
S-551	478	2.976
S-553	239	2.678
S-554	216	2.47
S-558	151	2.014
S-559	118	1.483
S-56	330	3.125
S-560	261	2.597
S-562	151	2.135
S-564	279	2.831
S-565	73	1.546
S-567	206	2.59
S-568	108	2.27
S-569	186	2.58
S-57	312	3.076
S-570	99	1.723
S-571	266	3.079
S-573	72	1.834
S-574	88	2.127
S-575	78	1.971
S-576	99	1.877
S-577	510	2.588
S-578	178	2.633
S-579	112	2.117
S-58	312	3.186
S-580	69	1.995
S-582	307	2.824
S-583	249	2.644
S-584	287	2.71
S-586	162	2.493
S-587	136	2.731
S-588	140	2.684
S-589	176	1.871
S-59	275	3.148
S-590	259	2.676
S-591	243	2.109
S-592	337	3.038
S-593	102	2.377
S-594	348	2.927
S-595	331	2.585
S-596	320	2.623
S-598	272	2.749
S-599	279	2.67
S-60	284	2.883
S-600	342	2.854
S-601	334	2.742
S-602	311	2.782
S-603	270	2.574
S-604	279	2.682
S-605	309	2.58
S-607	272	2.574
S-609	289	2.627
S-61	305	3.089
S-610	284	2.592
S-611	310	2.759
S-612	265	2.765
S-613	267	2.571
S-615	95	2.683
S-616	95	1.759
S-617	56	2.011
S-619	300	2.723
S-62	326	3.126
S-620	282	2.897
S-621	289	2.538
S-623	288	2.834
S-624	306	2.452
S-626	284	2.735
S-627	183	1.712
S-628	287	2.658
S-63	320	2.966
S-630	351	2.874
S-631	285	2.429
S-632	253	2.994
S-633	213	2.494
S-634	217	2.55
S-635	258	2.692
S-636	264	2.731
S-637	248	2.654
S-64	332	3.092
S-640	189	2.49
S-641	212	2.479
S-644	303	2.369
S-645	237	2.782
S-646	237	2.494
S-647	283	2.889
S-648	271	2.788
S-649	242	2.459
S-650	267	2.549
S-651	219	2.621
S-652	321	2.891
S-653	287	2.741
S-654	289	2.606
S-655	216	2.372
S-656	276	2.651
S-657	269	2.679
S-658	290	2.583
S-659	290	2.777
S-66	294	3.091
S-661	251	2.97
S-662	266	2.458
S-663	305	3.01
S-664	252	2.595
S-665	177	2.682
S-666	207	2.469
S-667	322	2.757
S-668	282	2.735
S-669	221	2.723
S-67	308	3.107
S-671	303	3.058
S-672	114	2.465
S-673	93	2.292
S-674	94	2.444
S-675	287	2.725
S-676	81	2.472
S-677	229	2.932
S-678	213	2.616
S-679	175	2.801
S-68	321	3.258
S-680	80	1.916
S-681	206	2.843
S-682	77	2.144
S-683	337	2.798
S-684	321	2.708

S-685	227	2.625
S-686	107	2.653
S-687	236	2.546
S-688	47	1.985
S-689	60	2.091
S-69	279	2.947
S-690	158	2.879
S-691	63	2.162
S-692	55	2.836
S-694	237	2.568
S-695	184	2.702
S-696	340	2.79
S-697	103	2.627
S-698	255	2.399
S-699	69	2.568
S-7	251	3.239
S-70	328	3.143
S-700	60	2.738
S-701	153	2.771
S-702	105	2.671
S-703	292	2.868
S-704	260	2.676
S-705	97	2.405
S-706	192	2.589
S-707	246	2.561
S-708	166	2.69
S-709	269	2.708
S-71	307	3.088
S-710	218	2.696
S-712	49	0.986
S-713	111	1.671
S-714	74	1.923
S-715	238	2.853
S-716	226	2.751
S-717	131	2.658
S-718	249	2.398
S-719	308	3.334
S-72	316	2.758
S-720	175	2.714
S-721	208	2.642
S-722	242	2.246
S-723	268	2.568
S-726	261	2.508
S-727	90	2.462
S-728	255	2.188
S-729	270	2.618
S-73	232	2.695
S-730	179	2.558
S-731	202	2.648
S-732	50	1.407
S-733	218	2.794
S-734	281	2.701
S-735	86	2.337
S-736	203	2.237
S-737	275	2.684
S-738	188	2.677
S-739	170	2.492
S-74	78	1.689
S-740	221	2.818
S-741	238	2.706
S-742	143	2.296
S-743	225	2.591
S-744	205	1.819
S-745	151	2.866
S-746	235	2.431
S-747	139	2.188
S-749	230	2.356
S-75	522	2.969
S-751	226	2.628
S-752	165	2.63
S-753	102	2.516
S-754	257	2.445
S-755	315	2.763
S-756	72	3.236
S-757	220	2.678
S-759	223	2.079
S-76	135	2.166
S-760	161	2.618
S-761	124	2.945
S-762	178	2.526
S-763	60	1.483
S-764	257	2.603
S-765	85	2.049
S-766	60	1.46
S-768	191	1.728
S-769	254	2.726
S-77	480	3.024
S-770	245	2.41
S-771	67	1.34
S-772	128	1.583
S-773	59	1.357
S-774	231	2.483
S-776	243	2.728
S-777	245	2.518
S-778	255	2.67
S-779	233	2.415
S-78	517	2.867
S-781	253	2.573
S-783	305	2.874
S-784	236	2.748
S-786	239	2.38
S-787	165	2.427
S-789	51	1.791
S-790	161	2.577
S-791	152	2.904
S-792	171	2.343
S-794	258	2.705
S-795	82	1.592
S-798	211	2.606
S-799	159	2.575
S-8	340	3.018
S-800	147	2.443
S-801	153	1.95
S-802	63	1.883
S-803	59	2.082
S-804	86	1.644
S-805	130	2.648
S-806	182	2.709
S-807	144	2.225
S-809	173	2.262
S-810	75	1.817
S-811	113	2.297
S-812	132	2.342
S-813	217	2.626
S-815	292	2.611
S-816	307	2.603
S-817	102	2.046
S-818	121	1.726
S-821	116	1.665
S-823	202	2.576
S-824	79	1.931
S-825	78	2.224
S-826	71	2.209
S-827	56	1.582
S-828	66	1.646
S-829	83	1.763
S-83	481	2.952
S-830	144	2.067
S-831	55	1.616
S-832	161	1.769
S-834	193	2.095
S-835	215	2.498
S-836	203	2.117
S-837	65	1.803
S-838	274	2.308
S-839	82	2.381
S-840	226	2.398
S-841	197	2.36
S-842	186	1.748
S-843	85	1.404
S-844	163	1.834
S-845	258	2.118
S-848	203	2.084
S-849	208	2.438
S-850	123	1.574
S-851	193	1.901

S-852	53	1.438
S-853	96	1.948
S-854	106	1.053
S-855	120	2.251
S-856	97	1.968
S-857	213	1.963
S-858	159	1.732
S-86	430	2.985
S-860	216	2.109
S-861	210	2.203
S-862	186	2.084
S-863	216	2.294
S-864	236	2.189
S-866	131	1.215
S-867	182	1.58
S-868	332	2.462
S-870	161	2.066
S-871	77	2.028
S-872	141	2.199
S-873	231	2.113
S-874	160	1.408
S-875	102	2.108
S-877	122	1.863
S-878	235	3.258
S-88	526	2.957
S-880	250	2.555
S-881	296	2.382
S-882	271	3.228
S-883	294	2.542
S-884	84	1.36
S-885	126	2.002
S-886	73	1.512
S-887	239	2.378
S-888	172	1.973
S-889	114	2.318
S-890	107	2.443
S-891	120	1.387
S-892	59	1.343
S-893A	141	2.519
S-894	201	2.309
S-895A	221	2.427
S-896A	127	1.767
S-897	255	2.618
S-898	251	2.268
S-899	249	2.391
S-9	289	2.906
S-90	522	2.872
S-900A	203	2.448
S-901	163	2.359
S-902	156	2.373
S-903	187	2.455
S-904	241	2.315
S-905	202	2.085
S-906	129	2.162
S-908	120	1.356
S-909	142	1.517
S-910	170	2.405
S-911	67	1.096
S-913	244	2.576
S-914	187	2.401
S-915	196	2.479
S-916	112	2.444
S-917	289	2.453
S-918	106	1.725
S-919	284	2.476
S-920	262	2.54
S-921	251	2.029
S-922	241	2.622
S-923	189	2.334
S-924	155	1.973
S-925	130	2.265
S-926	250	2.015
S-927	177	1.466
S-928	125	2.309
S-929	125	2.26
S-930	103	2.448
S-931	69	2.195
S-932	298	2.758
S-933	53	1.208
S-934	38	1.71
S-935	450	2.838
S-936	185	2.295
S-937	58	2.033
S-938	337	2.598
S-94	445	2.788
S-940	252	2.423
S-941	276	2.46
S-942	355	2.763
S-943	294	2.569
S-944	55	2.194
S-945	225	2.185
S-947	199	2.54
S-948	104	2.168
S-949	103	1.603
S-950	341	2.678
S-951	260	2.489
S-952	192	2.443
S-954	292	2.678
S-955	80	1.715
S-956	58	1.923
S-957	176	2.5
S-958	330	2.823
S-960	331	2.498
S-961	110	2.525
S-962	87	2.156
S-963	352	2.39
S-964	47	1.235
S-965	347	2.808
S-966	162	2.16
S-967	202	1.826
S-968	235	2.105
S-969	306	2.605
S-970	95	2.049
S-971	290	2.34
S-972	60	1.984
S-973	270	2.329
S-974	202	2.438
S-975	108	2.229
S-976	321	2.643
S-978	62	1.943
S-98	116	1.678
S-980	416	2.883
S-981	392	2.664
S-982	281	2.914
S-983	123	2.213
S-984	127	2.231
S-985	29	0.362
S-987	444	2.533
S-988	434	2.87
S-989	429	2.87
S-99	36	0.963
S-990	98	2.204
S-991	458	2.927
S-992	388	2.894
S-993	423	2.626
S-994	449	2.674
S-995	407	2.785

S-997	486	2.859
S-998	479	2.589
S-999	114	1.68

CsCl Capsule EDS Information Decayed to 1/1/96

Outer Capsule ID #	Capsule Type	Double Pour	Net Wt. (kg)	Load Factor (g/cc)	Thermal Power (W)	Destination
C-100	1	NO	2.793	2.818	201	RSI-A/RET
C-1000	3	NO	2.72	2.935	198	RESERVE
C-1001	3	NO	2.288	2.469	160	IOTECH/RE
C-1002	3	NO	2.353	2.539	164	RESERVE
C-1003	3	NO	1.858	2.005	193	RSI-A/RET
C-1004	3	NO	2.311	2.494	177	RESERVE
C-1005	3	NO	2.708	2.923	201	IOTECH/RE
C-1006	3	NO	2.689	2.902	195	IOTECH/RE
C-1007	3	NO	2.719	2.934	201	RSI-A/RET
C-1008	3	NO	2.673	2.885	200	RSI-A/RET
C-1009	3	NO	2.7	2.914	195	RESERVE
C-1010	3	NO	2.725	2.941	179	RESERVE
C-1011	3	NO	2.606	2.812	184	IOTECH/RE
C-1012	3	NO	2.708	2.923	175	RSI-A/RET
C-1013	3	NO	1.946	2.1	172	IOTECH/RE
C-1014	3	NO	2.928	3.16	186	RSI-A/RET
C-1015	3	NO	2.603	2.809	174	IOTECH/RE
C-1016	3	YES	1.917	2.069	171	RESERVE
C-1017	3	NO	1.965	2.121	174	RESERVE
C-1018	3	NO	2.598	2.804	177	IOTECH/RE
C-1019	3	NO	2.674	2.886	181	RSI-A/RET
C-1020	3	NO	2.613	2.82	181	RESERVE
C-1021	3	NO	2.636	2.845	186	RESERVE
C-1022	3	NO	2.657	2.867	184	RESERVE
C-1023	3	NO	2.778	2.998	185	RSI-A/RET
C-1024	3	NO	2.74	2.957	179	RESERVE
C-1025	3	NO	2.645	2.855	201	RSI-A/RET
C-1026	3	NO	2.64	2.849	198	RSI-A/RET
C-1027	3	NO	2.671	2.883	197	RESERVE
C-1028	3	NO	2.543	2.744	194	RESERVE
C-1030	3	NO	2.653	2.863	198	IOTECH/RE
C-1031	3	NO	2.664	2.875	191	RESERVE
C-1032	3	NO	2.638	2.847	183	IOTECH/RE
C-1033	3	NO	2.655	2.865	192	RESERVE
C-1034	3	NO	2.578	2.782	196	RESERVE
C-1035	3	NO	2.657	2.867	182	RESERVE
C-1036	3	NO	2.613	2.82	193	IOTECH/RE
C-1038	3	NO	2.591	2.796	206	RESERVE
C-1039	3	NO	2.736	2.953	177	IOTECH/RE
C-104		NO	2.835	2.814	200	ARECO
C-1040	3	NO	2.647	2.857	179	IOTECH/RE
C-1041	3	NO	2.51	2.709	167	RSI-A/RET
C-1043	3	NO	2.749	2.967	186	RESERVE
C-1044	3	NO	2.617	2.824	190	RSI-A/RET
C-1046	3	NO	2.351	2.537	163	RESERVE
C-1047	3	NO	2.74	2.957	195	RESERVE
C-1048	3	NO	2.685	2.898	199	RESERVE
C-1049	3	NO	2.743	2.96	194	RESERVE
C-105		YES	2.904	2.883	231	PNL-300
C-1050	3	NO	2.597	2.803	204	IOTECH/RE
C-1051	3	NO	2.636	2.845	224	RESERVE
C-1052	3	NO	2.63	2.838	215	RESERVE
C-1054	3	NO	2.698	2.912	203	RESERVE
C-1055	3	NO	2.643	2.852	204	RESERVE
C-1057	3	NO	2.712	2.927	215	RESERVE
C-1059	3	NO	2.705	2.919	190	IOTECH/RE
C-1060	3	NO	2.676	2.888	183	RESERVE
C-1061	3	NO	2.217	2.393	206	IOTECH/RE
C-1062	3	NO	2.681	2.893	207	RESERVE
C-1065	3	NO	2.354	2.54	162	RSI-A/PNL
C-1066	3	NO	2.745	2.962	201	RSI-A/RET
C-1067	3	NO	2.736	2.953	203	RESERVE
C-1068	3	NO	2.705	2.919	198	RESERVE
C-1069	3	NO	2.71	2.925	200	RESERVE
C-1070	3	NO	2.717	2.932	194	RSI-A/RET
C-1071	3	NO	2.725	2.941	220	RESERVE
C-1072	3	NO	2.714	2.929	201	RESERVE
C-1073	3	NO	2.683	2.896	192	RESERVE

C-1074	3	NO	2.673	2.885	189	RESERVE
C-1075	3	NO	2.635	2.844	196	RSI-A/RET
C-1076	3	NO	2.655	2.865	255	RESERVE
C-1078	3	NO	2.602	2.808	198	IOTECH/RE
C-108		NO	2.66	2.683	163	IOTECH/RE
C-1080	3	NO	2.615	2.822	184	RSI-A/RET
C-1081	3	NO	2.755	2.973	194	RSI-W/RET
C-1082	3	NO	2.703	2.917	230	RESERVE
C-1084	3	NO	2.637	2.846	191	IOTECH/RE
C-1085	3	NO	2.708	2.923	188	IOTECH/RE
C-1086	3	NO	2.743	2.96	196	RESERVE
C-1087	3	NO	2.695	2.908	178	RSI-A/RET
C-1088	3	NO	2.747	2.965	195	RSI-A/RET
C-1089	3	YES	2.767	2.986	203	RSI-A/RET
C-109		YES	2.366	2.387	174	RESERVE
C-1090	3	NO	2.493	2.69	182	RSI-A/RET
C-1091	3	NO	2.6	2.806	200	RESERVE
C-1092	3	NO	2.624	2.832	218	RESERVE
C-1093	3	NO	2.639	2.848	207	RSI-A/PNL
C-1094	3	NO	2.719	2.934	187	RESERVE
C-1095	3	NO	2.734	2.951	201	RESERVE
C-1096	3	NO	2.721	2.937	200	RESERVE
C-1097	3	NO	2.74	2.957	197	IOTECH/RE
C-110	2	NO	2.49	2.512	183	RSI-A/RET
C-1100	3	NO	2.734	2.951	196	IOTECH/RE
C-1101	3	NO	2.344	2.53	176	RESERVE
C-1102	3	NO	2.411	2.602	172	RESERVE
C-1103	3	NO	2.65	2.86	189	RESERVE
C-1104	3	NO	2.363	2.55	167	IOTECH/RE
C-1105	3	NO	2.349	2.535	171	RESERVE
C-1106	3	NO	2.312	2.495	169	RSI-A/RET
C-1107	3	NO	2.458	2.653	160	RSI-A/RET
C-1108	3	NO	2.365	2.552	168	RSI-A/RET
C-1109	3	NO	2.707	2.921	184	RESERVE
C-1110	3	NO	2.666	2.877	191	RESERVE
C-1111	3	NO	2.724	2.94	198	IOTECH/RE
C-1112	3	NO	2.581	2.785	190	RESERVE
C-1113	3	NO	2.671	2.883	188	RESERVE
C-1114	3	NO	2.584	2.789	187	IOTECH/RE
C-1115	3	NO	2.773	2.993	179	RESERVE
C-1116	3	NO	2.475	2.671	169	IOTECH/RE
C-1117	3	NO	2.697	2.911	191	IOTECH/RE
C-1118	3	NO	2.681	2.893	195	RESERVE
C-1119	3	NO	2.308	2.491	169	RSI-A/RET
C-1120	3	NO	2.693	2.906	197	RSI-A/RET
C-1121	3	NO	2.731	2.947	198	RESERVE
C-1122	3	NO	2.704	2.918	166	IOTECH/RE
C-1125	3	NO	2.732	2.948	200	IOTECH/RE
C-1126	3	NO	2.705	2.919	196	RSI-A/RET
C-1127	3	NO	2.658	2.869	188	RSI-A/RET
C-1128	3	NO	2.339	2.524	182	ARECO
C-1130	3	NO	2.699	2.913	186	RESERVE
C-1131	3	NO	2.73	2.946	214	RESERVE
C-1132	3	NO	2.608	2.815	182	RESERVE
C-1134	3	NO	2.347	2.533	168	RSI-A/OR/
C-1135	3	NO	2.405	2.596	186	RSI-A/RET
C-1136	3	NO	2.685	2.898	193	RSI-A/RET
C-1137	3	NO	2.686	2.899	203	IOTECH/RE
C-1138	3	NO	2.718	2.933	242	PNL-TPCI/
C-1139	3	NO	2.679	2.891	186	RESERVE
C-114	2	NO	2.83	2.809	202	SANDIA-CP
C-1140	3	NO	2.695	2.908	195	IOTECH/RE
C-1141	3	NO	2.703	2.917	187	RSI-A/RET
C-1142	3	NO	2.682	2.894	179	IOTECH/RE
C-1143	3	NO	2.736	2.953	193	IOTECH/RE
C-1144	3	NO	2.71	2.925	197	RSI-A/RET
C-1145	3	NO	2.649	2.859	187	IOTECH/RE
C-1146	3	NO	2.715	2.93	201	RSI-A/RET
C-1148	3	NO	2.716	2.931	203	IOTECH/RE
C-1149	3	NO	2.674	2.886	182	IOTECH/RE
C-115	2	NO	2.056	2.041	146	IOTECH/RE
C-1150	3	NO	2.391	2.58	173	RSI-A/RET
C-1151	3	NO	2.641	2.85	179	RESERVE
C-1152	3	NO	2.61	2.817	182	IOTECH/RE
C-1153	3	NO	2.578	2.782	182	IOTECH/RE
C-1154	3	NO	2.738	2.955	196	IOTECH/RE
C-1155	3	NO	2.587	2.792	194	RSI-A/RET
C-1156	3	NO	2.729	2.945	200	RESERVE

C-1157	3	NO	2.699	2.913	229	RESERVE
C-1158	3	NO	2.69	2.903	184	RSI-A/RET
C-1159	3	YES	2.705	2.955	209	RSI-A/RET
C-116	2	NO	2.698	2.722	191	SANDIA-CP
C-1160	3	NO	2.694	2.907	176	IOTECH/RE
C-1161	3	NO	2.687	2.9	200	RSI-A/RET
C-1162	3	NO	2.621	2.829	194	IOTECH/RE
C-1163	3	NO	2.726	2.942	191	IOTECH/RE
C-1165	3	NO	2.709	2.924	194	IOTECH/RE
C-1166	3	NO	2.704	2.918	208	RESERVE
C-1167	3	NO	2.705	2.919	192	IOTECH/RE
C-1169	3	NO	2.715	2.93	195	RSI-W/RET
C-1170	3	NO	2.731	2.947	198	RSI-A/RET
C-1171	3	NO	2.702	2.916	200	RESERVE
C-1172	3	NO	2.606	2.812	195	RESERVE
C-1173	3	NO	2.721	2.937	200	RESERVE
C-1174	3	NO	2.721	2.937	191	RSI-A/PNL
C-1175	3	NO	2.695	2.908	186	RESERVE
C-1176	3	YES	2.672	2.884	218	RESERVE
C-1177	3	NO	2.701	2.915	199	RSI-W/RET
C-1179	3	NO	2.378	2.566	205	IOTECH/RE
C-118	2	YES	2.824	2.804	207	SANDIA-CP
C-1180	3	NO	2.641	2.85	215	RESERVE
C-1181	3	NO	2.624	2.832	199	IOTECH/RE
C-1182	3	NO	2.636	2.845	219	RESERVE
C-1183	3	NO	2.657	2.867	205	RESERVE
C-1184	3	NO	2.625	2.833	224	RESERVE
C-1185	3	NO	2.487	2.684	166	RSI-A/RET
C-1186	3	NO	2.603	2.809	176	RSI-A/RET
C-1187	3	NO	2.517	2.716	179	RESERVE
C-1188	3	NO	2.505	2.703	180	RSI-A/RET
C-1189	3	NO	2.532	2.733	172	RSI-W/RET
C-119	2	NO	2.764	2.744	206	SANDIA-CP
C-1190	3	NO	2.477	2.673	166	RSI-W/RET
C-1191	3	NO	2.554	2.756	177	RESERVE
C-1192	3	NO	2.617	2.824	174	RESERVE
C-1195	3	NO	2.618	2.825	174	RSI-W/RET
C-1196	3	NO	2.595	2.801	174	RSI-A/PNL
C-1197	3	NO	2.668	2.879	187	RSI-W/RET
C-1198	3	NO	2.637	2.846	212	RESERVE
C-1199	3	NO	2.627	2.835	171	RESERVE
C-120		NO	2.728	2.708	205	SANDIA-CP
C-1200	3	NO	2.617	2.824	182	RESERVE
C-1201	3	NO	2.662	2.873	184	RESERVE
C-1202	3	NO	2.663	2.874	175	IOTECH/RE
C-1203	3	NO	2.737	2.954	189	RESERVE
C-1204	3	NO	2.735	2.952	189	RSI-W/RET
C-1205	3	NO	2.651	2.861	197	RSI-A/RET
C-1206	3	NO	2.708	2.923	190	RSI-W/RET
C-1207	3	NO	2.757	2.975	196	RSI-W/RET
C-1208	3	NO	2.735	2.952	189	IOTECH/RE
C-1209	3	NO	2.759	2.978	200	RSI-W/RET
C-121		NO	2.732	2.712	205	SANDIA-CP
C-1210	3	NO	2.831	3.055	184	RSI-W/RET
C-1211	3	NO	2.825	3.049	180	IOTECH/RE
C-1212	3	NO	2.831	3.055	190	IOTECH/RE
C-1213	3	NO	2.806	3.028	178	RSI-W/RET
C-1214	3	NO	2.782	3.002	181	RESERVE
C-1215	3	NO	2.82	3.043	180	RSI-A/RET
C-1216	3	NO	2.983	3.219	184	IOTECH/RE
C-1217	3	NO	2.825	3.049	188	RESERVE
C-1218	3	NO	2.98	3.216	182	RSI-A/RET
C-1219	3	NO	2.928	3.16	183	IOTECH/RE
C-1220	3	NO	3.009	3.247	182	PNL-300
C-1221	3	NO	2.943	3.176	175	IOTECH/RE
C-1222	3	NO	3.008	3.246	184	PNL-300
C-1223	3	YES	2.99	3.227	185	IOTECH/RE
C-1224	3	NO	2.912	3.143	180	RSI-W/RET
C-1225	3	YES	3.031	3.271	184	PNL-300/R
C-1226	3	NO	2.98	3.216	189	RSI-A/RET
C-1227	3	NO	2.717	2.932	196	RESERVE
C-1228	3	NO	2.968	3.203	185	RESERVE
C-1229	3	NO	2.904	3.134	181	RESERVE
C-1230	3	NO	2.891	3.12	176	RSI-W/RET
C-1231	3	NO	2.877	3.105	197	RESERVE
C-1232	3	NO	2.904	3.134	187	RSI-A/RET
C-1233	3	NO	2.923	3.155	184	RESERVE
C-1234	3	NO	2.89	3.119	186	IOTECH/RE

C-1235	3	NO	2.88	3.108	185	RESERVE
C-1236	3	NO	3.055	3.297	192	PNL-300
C-1238	3	NO	2.445	2.639	162	RSI-A/RET
C-1239	3	NO	2.77	2.989	189	ARECO
C-1240	3	NO	2.799	3.021	195	RSI-A/RET
C-1242	3	NO	2.792	3.013	189	RSI-A/RET
C-1243	3	NO	2.784	3.005	200	RSI-W/RET
C-1244	3	NO	2.668	2.879	197	RESERVE
C-1245	3	NO	2.794	3.015	199	RSI-A/RET
C-1246	3	NO	2.784	3.005	201	RSI-W/RET
C-1247	3	NO	2.746	2.964	205	RSI-A/RET
C-1249	3	NO	2.779	2.999	198	RSI-W/RET
C-1251	3	NO	2.849	3.075	195	IOTECH/RE
C-1252	3	NO	2.674		193	RESERVE
C-1253	3	NO	2.698	2.912	197	RESERVE
C-1254	3	NO	2.625	2.833	191	RSI-A/RET
C-1255	3	NO	2.684	2.897	204	RESERVE
C-1260	3	NO	2.764	2.983	179	RSI-A/RET
C-1261	3	NO	2.757	2.975	183	RESERVE
C-1262	3	NO	2.764	2.983	184	RESERVE
C-1263	3	NO	2.654	2.864	180	RSI-W/RET
C-1264	3	NO	2.759	2.978	189	IOTECH/RE
C-1265	3	NO	2.748	2.966	190	IOTECH/RE
C-1267	3	NO	2.779	2.999	177	RSI-A/RET
C-1269	3	NO	2.488	2.685	165	RESERVE
C-127		NO	2.777	2.757	217	RESERVE
C-1270	3	NO	2.532	2.733	174	IOTECH/RE
C-1271	3	NO	2.524	2.724	164	RSI-A/RET
C-1273	3	NO	2.695	2.908	193	RSI-W/RET
C-1275	3	NO	2.666	2.877	176	ARECO
C-1276	3	NO	2.639	2.848	179	RESERVE
C-1277	3	NO	2.625	2.833	178	RSI-W/RET
C-1278	3	NO	2.705	2.919	190	RSI-W/RET
C-1279	3	NO	2.798	3.02	195	IOTECH/RE
C-128		YES	2.867	2.846	218	RESERVE
C-1281	3	NO	2.64	2.849	190	RSI-A/RET
C-1283	3	NO	2.695	2.908	191	IOTECH/RE
C-1284	3	NO	2.694	2.907	199	RSI-W/RET
C-1285	3	NO	2.694	2.907	190	RSI-W/RET
C-1286	3	NO	2.663	2.874	190	IOTECH/RE
C-1288	3	NO	2.667	2.878	195	RSI-A/RET
C-129		NO	2.975	3.001	226	RESERVE
C-1290	3	NO	2.668	2.879	183	RESERVE
C-1291	3	NO	2.672	2.884	175	RESERVE
C-1292	3	NO	2.706	2.92	177	RSI-A/RET
C-1293	3	NO	2.698	2.912	181	RSI-W/RET
C-1294	3	NO	2.625	2.833	170	RESERVE
C-1295	3	NO	2.714	2.929	182	IOTECH/RE
C-1296	3	NO	2.761	2.98	196	IOTECH/RE
C-1297	3	NO	2.76	2.979	194	RSI-W/RET
C-1298	3	NO	2.76	2.979	190	RESERVE
C-13	1	NO	2.886	2.911	204	RESERVE
C-1300	3	NO	2.773	2.993	185	RSI-A/RET
C-1301	3	NO	2.639	2.848	183	IOTECH/RE
C-1302	3	NO	2.658	2.869	185	RESERVE
C-1303	3	NO	2.653	2.863	186	RESERVE
C-1304	3	NO	2.755	2.973	183	RSI-W/RET
C-1305	3	NO	2.442	2.635	168	RESERVE
C-1306	3	NO	2.278	2.458	176	RESERVE
C-1307	3	NO	2.468	2.664	165	IOTECH/RE
C-1308	3	NO	2.353	2.539	172	IOTECH/RE
C-1309	3	NO	2.738	2.955	180	IOTECH/RE
C-131		NO	2.974	3	226	RESERVE
C-1311	3	YES	2.453	2.647	167	IOTECH/RE
C-1312	3	YES	2.517	2.716	172	RESERVE
C-1313	3	NO	2.733	2.949	188	RESERVE
C-1315	3	NO	2.267	2.447	164	ARECO
C-1321	3	NO	2.478	2.674	185	RESERVE
C-1322	3	NO	2.596	2.802	171	RESERVE
C-1323	3	NO	2.723	2.939	193	RESERVE
C-1324	3	NO	2.684	2.897	179	RESERVE
C-1325	3	NO	2.751	2.969	197	IOTECH/RE
C-1326	3	NO	2.826	3.05	198	RSI-A/RET
C-1328	3	NO	2.387	2.576	171	IOTECH/RE
C-1329	3	NO	2.83	3.054	204	RESERVE
C-1330	3	NO	2.228	2.404	161	RSI-A/RET
C-1331	3	NO	2.689	2.902	189	RSI-A/RET
C-1332	3	NO	2.483	2.68	166	RESERVE

C-1334	3	NO	2.686	2.899	179	RESERVE
C-1335	3	NO	2.681	2.893	194	RESERVE
C-1336	3	NO	1.748	1.886	126	IOTECH/RE
C-1338	3	NO	2.51	2.709	167	RESERVE
C-1339	3	NO	2.524	2.724	179	RSI-A/RET
C-1341	3	NO	2.39	2.579	162	IOTECH/RE
C-1342	3	NO	2.45	2.644	172	IOTECH/RE
C-1343	3	NO	2.768	2.987	174	RSI-W/RET
C-1345	3	NO	2.759	2.978	174	RSI-A/RET
C-1346	3	YES	2.387	2.576	186	IOTECH/RE
C-1347	3	NO	2.744	2.961	164	RSI-A/RET
C-135		NO	2.721	2.745	211	IOTECH/RE
C-1350	3	NO	2.558	2.761	155	IOTECH/RE
C-1353	3	NO	2.63	2.838	162	IOTECH/RE
C-1357	3	NO	2.661	2.872	175	RESERVE
C-1358	3	NO	2.633	2.842	188	RSI-A/RET
C-136		NO	2.806	2.786	219	RESERVE
C-1360	3	NO	2.884	3.112	187	IOTECH/RE
C-1361	3	NO	2.946	3.179	183	RSI-A/RET
C-1364	3	NO	2.902	3.132	191	PNL-300/R
C-1368	3	NO	2.895	3.124	192	RSI-W/PNL
C-1369	3	NO	2.63	2.838	181	RESERVE
C-137		NO	2.78	2.76	217	RESERVE
C-1370	3	NO	2.662	2.873	188	RESERVE
C-1371	3	YES	2.67	2.882	178	IOTECH/RE
C-1373	3	NO	2.644	2.853	177	RSI-W/RET
C-1374	3	NO	2.654	2.864	186	RESERVE
C-1375	3	NO	2.648	2.858	191	RSI-W/RET
C-1376	3	YES	2.611	2.818	195	RSI-A/RET
C-1377	3	NO	2.694	2.907	184	RESERVE
C-1378	3	NO	2.669	2.88	177	RESERVE
C-1379	3	NO	2.688	2.901	178	IOTECH/RE
C-138		NO	2.765	2.789	216	RESERVE
C-1380	3	NO	2.672	2.884	177	IOTECH/RE
C-1382	3	NO	2.338	2.523	153	IOTECH/RE
C-1385	3	NO	2.555	2.757	174	RSI-W/RET
C-1386	3	NO	2.725	2.941	188	RSI-W/RET
C-1387	3	NO	2.688	2.901	190	RSI-W/RET
C-139		NO	2.798	2.778	218	RESERVE
C-1394	3	NO	2.634	2.843	176	IOTECH/RE
C-1395	3	NO	2.712	2.927	187	ARECO
C-1396	3	NO	2.538	2.739	168	RSI-A/RET
C-1397	3	NO	2.563	2.766	171	IOTECH/RE
C-1398	3	NO	2.718	2.933	193	IOTECH/RE
C-1399	3	NO	2.749	2.967	196	RESERVE
C-140	1	NO	2.153	2.137	168	RSI-A/RET
C-1400	3	NO	2.574	2.778	218	RESERVE
C-1401	3	NO	2.789	3.01	197	RESERVE
C-1402	3	NO	2.577	2.781	208	RSI-A/RET
C-1403	3	NO	2.766	2.985	193	IOTECH/RE
C-1404	3	NO	2.727	2.943	191	RESERVE
C-1405	3	NO	2.757	2.975	194	IOTECH/RE
C-1407	3	NO	2.673	2.885	181	RSI-W/RET
C-1408	3	NO	2.541	2.742	164	RESERVE
C-1409	3	NO	2.595	2.801	171	IOTECH/RE
C-1410	3	NO	2.678	2.89	191	RSI-A/RET
C-1412	3	NO	2.689	2.902	188	RESERVE
C-1414	3	NO	2.686	2.899	182	RSI-A/RET
C-1415	3	NO	2.674	2.886	175	IOTECH/RE
C-1416	3	NO	2.756	2.974	181	IOTECH/RE
C-1417	3	NO	2.705	2.919	182	RESERVE
C-1419	3	NO	2.741	2.958	187	RESERVE
C-142	1	NO	2.713	2.737	202	IOTECH/RE
C-1420	3	NO	2.617	2.824	176	RESERVE
C-1423	3	NO	2.576	2.78	166	IOTECH/RE
C-1426	3	NO	2.676	2.888	195	RESERVE
C-1427	3	NO	2.702	2.916	195	RESERVE
C-1429	3	NO	2.666	2.877	185	RSI-W/RET
C-143	1	NO	2.72	2.7	218	RESERVE
C-1430	3	NO	2.627	2.835	164	RSI-W/RET
C-1431	3	NO	2.432	2.625	163	RSI-W/RET
C-1432	3	NO	2.683	2.896	194	RESERVE
C-1434	3	NO	2.386	2.575	156	IOTECH/RE
C-1435	3	NO	2.56	2.763	176	RESERVE
C-1438	3	NO	2.558	2.761	163	RESERVE
C-144	1	NO	2.52	2.502	195	RSI-A/RET
C-1440	3	NO	2.65	2.86	190	RSI-W/RET
C-1441	3	YES	2.682	2.894	174	IOTECH/RE

C-1442	3	NO	2.672	2.884	178	IOTECH/RE
C-1443	3	NO	2.693	2.906	161	RSI-W/RET
C-1444	3	NO	2.677	2.889	187	IOTECH/RE
C-1445	3	NO	2.647	2.857	171	IOTECH/RE
C-1446	3	NO	2.647	2.856	183	RSI-A/RET
C-1447	3	NO	2.74	2.957	181	RSI-W/RET
C-1448	3	NO	2.76	2.979	174	RESERVE
C-1449	3	NO	2.699	2.913	181	RSI-A/RET
C-145	1	NO	2.391	2.412	161	RESERVE
C-1450	3	NO	2.744	2.961	178	RESERVE
C-1452	3	NO	2.747	2.965	182	IOTECH/RE
C-1453	3	NO	2.737	2.954	178	IOTECH/RE
C-1454	3	NO	2.646	2.856	183	RSI-A/RET
C-1455	3	NO	2.633	2.842	193	RESERVE
C-1456	3		2.741	2.958	183	RESERVE
C-1457	3	NO	2.74	2.957	189	IOTECH/RE
C-1458	3	NO	2.653	2.863	178	RESERVE
C-1459	3	NO	2.759	2.978	186	RESERVE
C-146	1	NO	2.737	2.717	204	RESERVE
C-1460	3	NO	2.752	2.97	195	RESERVE
C-1461	3	NO	2.753	2.971	188	RESERVE
C-1462	3	NO	2.552	2.754	165	RESERVE
C-1464	3	NO	2.552	2.754	164	IOTECH/RE
C-147	1	NO	2.731	2.755	203	RSI-A/RET
C-1471	3	NO	2.697	2.911	190	RESERVE
C-1475	3	NO	2.579	2.783	175	RSI-A/RET
C-1477	3	NO	2.577	2.781	181	RESERVE
C-1478	3	NO	2.626	2.834	183	RESERVE
C-1479	3	NO	2.689	2.902	188	IOTECH/RE
C-148		NO	2.728	2.708	211	IOTECH/RE
C-1480	3	NO	2.684	2.897	190	IOTECH/RE
C-1481	3	NO	2.652	2.862	186	RESERVE
C-1482	3	NO	2.689	2.902	186	RESERVE
C-1484	3	NO	2.674	2.886	176	IOTECH/RE
C-1485	3	NO	2.705	2.919	179	IOTECH/RE
C-1487	3	NO	2.701	2.915	176	RSI-W/RET
C-1488	3	NO	2.713	2.928	177	IOTECH/RE
C-1489	3		2.706	2.92	181	RSI-W/RET
C-149	2	NO	2.401	2.422	177	RSI-A/RET
C-1490	3	NO	2.655	2.865	193	RSI-A/RET
C-1491	3	NO	2.677	2.889	201	RSI-W/RET
C-1493	3	NO	2.715	2.93	184	IOTECH/RE
C-1494	3	NO	2.717	2.932	174	IOTECH/RE
C-1497	3	NO	2.704	2.918	211	PNL-300
C-1499	3	NO	2.937	3.17	187	RESERVE
C-15	2	NO	2.877	2.902	203	RSI-W/RET
C-150	1	NO	2.802	2.782	204	RSI-A/RET
C-1500	3	NO	2.698	2.912	177	RESERVE
C-1501	3	NO	2.685	2.898	188	RSI-A/PNL
C-1503	3	NO	2.691	2.904	186	RSI-W/PNL
C-1504	3	NO	2.311	2.494	181	RSI-A/OR/
C-1505	3	NO	2.957	3.191	181	RSI-W/RET
C-1506	3	NO	2.697	2.911	176	RESERVE
C-1507	3	NO	2.698	2.912	179	RSI-A/OR/
C-1508	3	NO	2.693	2.906	186	RESERVE
C-1509	3	NO	2.718	2.933	180	RESERVE
C-151	1	NO	2.697	2.677	197	RSI-A/RET
C-1510	3	NO	2.65	2.86	168	RESERVE
C-1511	3	NO	2.639	2.848	192	RESERVE
C-1512	3	NO	2.651	2.861	183	RSI-W/RET
C-1514	3	NO	2.772	2.992	187	RESERVE
C-1516	3	NO	2.841	3.066	167	RSI-A/RET
C-1518	3	NO	2.836	3.061	178	RESERVE
C-1519	3	NO	2.732	2.948	178	RSI-W/RET
C-152	1	NO	2.691	2.671	196	RESERVE
C-1520	3	NO	2.742	2.959	182	RESERVE
C-1521	3	NO	2.743	2.96	179	IOTECH/RE
C-1522	3	NO	2.731	2.947	243	PNL-TPCI/
C-1523	3	NO	2.886	3.115	182	RESERVE
C-1524	3	NO	2.62	2.828	185	IOTECH/RE
C-1525	3	NO	2.611	2.818	188	RESERVE
C-1527	3	NO	2.614	2.821	175	RESERVE
C-1528	3	NO	2.589	2.794	192	RESERVE
C-1529	3	NO	2.59	2.795	209	IOTECH/RE
C-153	1	NO	2.67	2.651	195	IOTECH/RE
C-1530	3	NO	2.581	2.785	166	RSI-A/RET
C-1533	3	NO	2.622	2.83	198	IOTECH/RE
C-1534	3	NO	2.187	2.36	173	RSI-A/RET

C-1535	3	NO	2.503	2.701	169	IOTECH/RE
C-1536	3	NO	2.762	2.981	179	RESERVE
C-1537	3	NO	2.556	2.758	168	RSI-A/RET
C-1538	3	NO	2.676	2.888	171	RSI-W/RET
C-1539	3	NO	2.579	2.783	168	IOTECH/RE
C-154	1	NO	2.655	2.636	194	RSI-A/RET
C-1541	3	NO	2.632	2.84	175	RESERVE
C-1544	3	NO	2.704	2.918	183	RESERVE
C-1545	3	NO	2.716	2.931	183	RESERVE
C-1546	3	NO	2.673	2.885	175	RSI-W/RET
C-1548	3	NO	2.573	2.777	175	IOTECH/RE
C-1549	3	NO	2.617	2.824	187	RESERVE
C-155	1	NO	2.653	2.634	193	RESERVE
C-1551	3	NO	2.679	2.891	194	IOTECH/RE
C-1552	3	NO	2.72	2.935	191	IOTECH/RE
C-1553	3	NO	2.725	2.941	177	RSI-A/PNL
C-1554	3	NO	2.712	2.927	185	RESERVE
C-1555	3	NO	2.683	2.896	190	RESERVE
C-1556	3	NO	2.667	2.878	176	RSI-A/RET
C-1557	3	NO	2.68	2.892	187	IOTECH/RE
C-1558	3	NO	2.674	2.886	188	RSI-W/RET
C-156	1	YES	2.799	2.779	201	RSI-A/RET
C-1560	3	NO	2.703	2.917	195	RSI-W/RET
C-1561	3	NO	2.676	2.888	171	RSI-A/PNL
C-1562	3	NO	2.692	2.905	190	RSI-A/PNL
C-1563	3	NO	2.624	2.832	176	RSI-A/RET
C-1564	3	NO	2.73	2.946	181	RESERVE
C-1566	3	NO	2.719	2.934	185	IOTECH/RE
C-1568	3	NO	2.668	2.879	159	IOTECH/RE
C-1569	3	NO	2.716	2.931	178	RESERVE
C-157	1	YES	2.817	2.797	203	IOTECH/RE
C-1570	3	NO	2.7	2.914	187	RESERVE
C-1571	3	NO	2.695	2.908	178	IOTECH/RE
C-1573	3	NO	2.628	2.836	178	RESERVE
C-1574	3	NO	2.624	2.832	166	RSI-W/RET
C-1575	3	NO	2.656	2.866	165	RSI-W/RET
C-1576	3	NO	2.699	2.913	192	IOTECH/RE
C-1577	3	NO	2.753	2.971	185	RESERVE
C-1578	3	NO	2.8	3.022	191	RSI-A/RET
C-1579	3	NO	2.793	3.014	181	RSI-A/RET
C-158	1	YES	2.828	2.808	203	IOTECH/RE
C-1581	3	NO	2.803	3.025	181	RESERVE
C-1582	3	NO	2.701	2.915	200	IOTECH/RE
C-1583	3	NO	2.788	3.009	184	RSI-A/RET
C-1584	3	NO	2.791	3.012	186	IOTECH/RE
C-1585	3	NO	2.781	3.001	191	ARECO
C-1586	3	NO	2.841	3.066	163	RSI-W/RET
C-1587	3	NO	2.834	3.058	165	RESERVE
C-1588	3	NO	2.64	2.849	173	IOTECH/RE
C-159	1	NO	2.868	2.847	202	RSI-W/RET
C-1591	3	NO	2.784	3.005	179	RESERVE
C-1592	3	NO	2.651	2.861	177	RSI-W/RET
C-1593	3	NO	2.796	3.017	180	IOTECH/RE
C-1594	3	NO	2.82	3.043	188	RESERVE
C-1595	3	NO	2.724	2.94	183	IOTECH/RE
C-1596	3	NO	2.804	3.026	191	RESERVE
C-1598	3	NO	2.658	2.869	172	RSI-W/RET
C-1599	3	NO	2.627	2.835	177	RESERVE
C-160	1	NO	2.884	2.863	203	IOTECH/RE
C-1600	3	NO	2.625	2.833	176	RSI-A/PNL
C-1602	3	NO	2.515	2.714	143	IOTECH/RE
C-1603	3	NO	2.566	2.769	169	RESERVE
C-1606	3	NO	2.594	2.799	176	RESERVE
C-1607	3	NO	2.848	3.074	188	RESERVE
C-1608	3	NO	2.765	2.984	191	IOTECH/RE
C-1609	3	NO	2.993	3.23	190	IOTECH/RE
C-161	1	NO	2.882	2.861	203	RESERVE
C-1610	3	NO	2.881	3.109	186	RSI-W/RET
C-1611	3	NO	2.485	2.682	162	RESERVE
C-1612	3	NO	2.833	3.057	170	RSI-A/RET
C-1613	3	NO	2.901	3.131	180	RESERVE
C-1614	3	NO	2.899	3.129	179	IOTECH/RE
C-1615	3	NO	2.881	3.109	187	RSI-W/RET
C-1616	3	NO	2.814	3.037	162	IOTECH/RE
C-1617	3	NO	2.921	3.152	183	PNL-300/R
C-1618	3	NO	2.935	3.167	179	RESERVE
C-1619	3	NO	2.812	3.035	187	RSI-A/RET
C-162	1	NO	2.794	2.774	201	IOTECH/RE

C-1621	3	NO	2.479	2.675	168	RESERVE
C-1623	3	NO	2.849	3.075	183	RESERVE
C-1624	3	NO	2.856	3.082	185	RESERVE
C-1625	3	NO	2.83	3.054	193	RSI-W/RET
C-1627	3	NO	2.836	3.061	174	RSI-A/RET
C-1628	3	NO	2.921	3.152	180	RSI-W/RET
C-163	1	NO	2.79	2.814	201	RSI-A/RET
C-1631	3	NO	2.564	2.767	174	RESERVE
C-1632	3	NO	2.728	2.944	183	RESERVE
C-1633	3	NO	2.681	2.893	188	RSI-A/RET
C-1634	3	NO	2.847	3.073	196	RESERVE
C-1635	3	NO	2.786	3.007	176	RSI-A/RET
C-1637	3	NO	2.642	2.851	172	RSI-W/RET
C-1639	3	NO	2.702	2.916	181	RESERVE
C-164		NO	2.809	2.789	202	IOTECH/RE
C-1640	3	NO	2.772	2.992	197	RSI-W/RET
C-1641	3	NO	2.814	3.037	185	RESERVE
C-1642	3	NO	2.746	2.964	180	RESERVE
C-1645	3	NO	2.705	2.919	179	RESERVE
C-1646	3	NO	2.699	2.913	193	IOTECH/RE
C-1647	3	NO	2.84	3.065	188	RSI-W/RET
C-1648	3	NO	2.854	3.08	192	RSI-A/RET
C-1649	3	NO	2.351	2.537	167	IOTECH/RE
C-1651	3	NO	1.891	2.041	142	IOTECH/RE
C-1652	3	NO	2.842	3.067	210	RSI-W/RET
C-1653	3	NO	2.843	3.068	195	RESERVE
C-1654	3	NO	2.846	3.071	192	RESERVE
C-1655	3	NO	2.497	2.695	173	IOTECH/RE
C-1656	3	NO	2.64	2.849	169	ARECO
C-1657	3	NO	2.554	2.756	169	IOTECH/RE
C-1659	3	NO	2.843	3.068	183	RSI-W/RET
C-166		YES	2.789	2.769	197	RESERVE
C-1660	3	NO	2.81	3.033	185	RSI-W/RET
C-1662	3	NO	2.428	2.62	160	RSI-W/RET
C-1664	3	NO	2.833	3.057	175	RESERVE
C-1665	3	NO	3.001	3.239	184	IOTECH/RE
C-1666	3	NO	2.819	3.042	184	RESERVE
C-1667	3	NO	2.421	2.613	171	RSI-W/RET
C-1668	3	NO	2.447	2.641	162	RSI-A/RET
C-167		YES	2.77	2.75	195	RESERVE
C-1671	3	NO	2.778	2.998	189	IOTECH/RE
C-1672	3	NO	2.764	2.983	188	IOTECH/RE
C-1674	3	NO	2.825	3.049	220	RESERVE
C-1677	3	NO	2.856	3.082	215	RESERVE
C-1679	3	NO	2.613	2.82	192	IOTECH/RE
C-1685	3	NO	2.831	3.055	203	RSI-W/RET
C-1686	3	NO	2.829	3.053	212	RESERVE
C-1687	3	NO	2.729	2.945	188	RSI-W/RET
C-1688	3	NO	2.597	2.803	208	IOTECH/RE
C-1689	3	NO	2.718	2.933	224	RESERVE
C-1690	3	NO	2.775	2.995	217	RESERVE
C-1691	3	NO	2.716	2.931	202	RSI-A/RET
C-1692	3	NO	2.633	2.842	218	RESERVE
C-1693	3	NO	2.607	2.814	211	RSI-A/RET
C-1694	3	NO	2.638	2.847	164	RSI-A/RET
C-1697	3	NO	2.744	2.961	189	IOTECH/RE
C-1698	3	NO	2.766	2.985	196	ARECO
C-1699	3	NO	2.752	2.97	188	RESERVE
C-1700	3	NO	2.86	3.087	204	IOTECH/RE
C-1701	3	NO	2.863	3.09	186	RESERVE
C-1703	3	NO	2.806	3.028	230	RESERVE
C-1704	3	NO	2.852	3.078	235	RESERVE
C-1705	3	NO	2.841	3.066	206	RESERVE
C-1706	3	NO	2.843	3.068	203	IOTECH/RE
C-1707	3	NO	2.838	3.063	187	RSI-W/RET
C-1709	3	NO	2.759	2.978	184	RESERVE
C-1710	3	NO	2.549	2.751	178	RSI-W/RET
C-1711	3	NO	2.767	2.986	185	RESERVE
C-1712	3	NO	2.796	3.017	183	RESERVE
C-1713	3	NO	2.758	2.976	186	RESERVE
C-1715	3	NO	2.826	3.05	246	RESERVE
C-1716	3	NO	2.812	3.035	213	RESERVE
C-1717	3	NO	2.771	2.991	188	IOTECH/RE
C-1718	3	NO	2.826	3.05	209	RSI-W/RET
C-1720	3	NO	2.823	3.047	185	IOTECH/RE
C-1722	3	NO	2.835	3.06	190	RSI-W/RET
C-1724	3	NO	2.764	2.983	200	IOTECH/RE
C-1725	3	NO	2.844	3.069	204	RSI-A/RET

C-1726	3	NO	2.78	3	171	RSI-W/RET
C-1727	3	NO	2.775	2.995	205	RESERVE
C-1728	3	NO	2.821	3.044	176	RESERVE
C-1729	3	NO	2.65	2.86	251	RESERVE
C-173		NO	2.801	2.826	183	IOTECH/RE
C-1730	3	NO	2.801	3.023	192	RSI-W/RET
C-1731	3	NO	2.822	3.046	204	RESERVE
C-1732	3	NO	2.838	3.063	196	RSI-A/RET
C-1733	3	NO	2.822	3.046	205	RESERVE
C-1734	3	NO	2.755	2.973	223	RESERVE
C-1735	3	NO	2.765	2.984	227	RESERVE
C-1736	3	NO	2.709	2.924	167	RESERVE
C-1737	3	NO	2.769	2.988	184	ARECO
C-1738	3	NO	2.7	2.914	183	RSI-A/RET
C-174	1	NO	2.768	2.748	195	RSI-W/RET
C-1740	3	NO	2.764	2.983	198	RESERVE
C-1742	3	NO	2.672	2.884	180	RESERVE
C-1744	3	NO	2.734	2.951	208	RSI-W/RET
C-1745	3	NO	2.699	2.913	185	IOTECH/RE
C-1746	3	NO	2.752	2.97	184	RSI-W/RET
C-175	1	NO	2.739	2.719	193	RSI-W/RET
C-1750	3	NO	2.771	2.991	188	RSI-W/RET
C-1751	3	NO	2.75	2.968	197	RSI-W/RET
C-1752	3	YES	2.501	2.699	185	RSI-W/RET
C-1753	3	NO	2.737	2.954	226	RESERVE
C-1754	3	NO	2.555	2.757	169	RESERVE
C-1755	3	YES	1.914	2.066	132	IOTECH/RE
C-1758	3	YES	2.808	3.03	193	RESERVE
C-176		NO	2.846	2.825	201	ARECO
C-1760	3	NO	2.672	2.884	150	IOTECH/RE
C-1761	3	NO	2.685	2.898	180	RSI-W/RET
C-1762	3	NO	2.767	2.986	176	RESERVE
C-1763	3	NO	2.773	2.993	190	IOTECH/RE
C-1764	3	NO	2.762	2.981	179	RSI-A/RET
C-1765	3	NO	2.731	2.947	189	RSI-W/RET
C-1766	3	NO	2.756	2.974	189	RESERVE
C-1767	3	NO	2.818	3.041	182	RSI-W/RET
C-1768	3	NO	2.744	2.961	176	RESERVE
C-1769	3	NO	2.814	3.037	207	RSI-W/RET
C-177	1	YES	2.606	2.587	187	RSI-A/RET
C-1770	3	NO	2.818	3.041	182	RSI-A/RET
C-1771	3	NO	2.821	3.044	181	RESERVE
C-1772	3	NO	2.729	2.945	196	RSI-W/RET
C-1773	3	NO	2.704	2.918	211	RSI-A/RET
C-1774	3	NO	2.672	2.884	189	RESERVE
C-1776	3	NO	2.607	2.814	186	RESERVE
C-1778	3	NO	2.844	3.069	195	RESERVE
C-1779	3	NO	2.7	2.914	168	RESERVE
C-178	1	YES	2.848	2.827	204	RSI-A/RET
C-1781	3	NO	2.593	2.798	162	RSI-W/RET
C-1782	3	NO	2.735	2.952	191	IOTECH/RE
C-1783	3	NO	2.87	3.097	188	IOTECH/RE
C-1784	3	NO	2.665	2.876	179	RESERVE
C-1785	3	NO	2.626	2.834	174	RESERVE
C-179		YES	2.827	2.807	203	RESERVE
C-1790	3	NO	2.669	2.88	183	IOTECH/RE
C-18	2	NO	2.851	2.876	186	RSI-A/RET
C-180	2	YES	2.831	2.856	185	RSI-A/RET
C-1803	3	NO	2.551	2.753	180	RSI-A/RET
C-1804	3	NO	2.613	2.82	201	RESERVE
C-1805	3	NO	2.739	2.956	201	RESERVE
C-1806	3	YES	2.716	2.696	171	RESERVE
C-1807	3	YES	2.843	2.868	197	RSI-W/RET
C-181	1	YES	2.541	2.563	197	IOTECH/RE
C-182	1	NO	2.7	2.724	209	IOTECH/RE
C-183	1	YES	2.5	2.522	194	RESERVE
C-184	2	YES	2.925	2.951	191	RSI-W/RET
C-185	1	NO	2.687	2.668	195	RESERVE
C-186	1	YES	2.787	2.767	197	IOTECH/RE
C-187	1	NO	2.808	2.788	201	RSI-A/RET
C-188	1	NO	2.696	2.676	196	RSI-W/RET
C-189	1	NO	2.724	2.704	201	RESERVE
C-19	1	YES	2.859	2.884	187	RESERVE
C-190	1	NO	2.804	2.784	201	RESERVE
C-191	1	NO	2.727	2.707	192	RESERVE
C-194	1	NO	2.669	2.65	168	RSI-A/RET
C-195	1	NO	2.661	2.642	168	RSI-W/RET
C-196	1	NO	2.679	2.66	169	RSI-W/RET

C-197	1	NO	2.655	2.636	167	RESERVE
C-198	1	NO	2.648	2.629	167	IOTECH/RE
C-199	1	NO	2.795	2.775	204	RESERVE
C-200	1	NO	2.818	2.798	202	RESERVE
C-201	1	NO	2.823	2.803	200	RESERVE
C-202	1	NO	2.707	2.687	198	RESERVE
C-203	1	YES	2.989	2.967	216	RSI-A/RET
C-204	2	NO	2.709	2.733	210	RSI-A/RET
C-205		NO	2.876	2.901	208	IOTECH/RE
C-207		YES	2.888	2.913	189	IOTECH/RE
C-208		NO	2.948	2.974	228	RESERVE
C-209		YES	3.063	3.041	228	RESERVE
C-210		YES	2.886	2.865	207	IOTECH/RE
C-211	1	NO	2.944	2.97	213	RESERVE
C-212	1	YES	2.785	2.809	204	IOTECH/RE
C-213	1	YES	2.715	2.739	207	RSI-A/RET
C-214	1	NO	2.685	2.666	195	RSI-A/RET
C-215	1		2.613	2.594	166	RESERVE
C-216	1		2.636	2.659	167	RESERVE
C-217	1		2.785	2.765	177	RSI-W/RET
C-218	1	YES	2.684	2.708	205	RSI-A/RET
C-220	1	NO	2.641	2.664	203	RESERVE
C-221	1	NO	2.735	2.759	188	RSI-A/RET
C-222	1	YES	2.533	2.555	175	RESERVE
C-223	1	YES	2.77	2.75	191	RESERVE
C-224	1	NO	2.698	2.722	186	IOTECH/RE
C-225	1	NO	2.709	2.689	204	IOTECH/RE
C-226	1	NO	2.719	2.699	205	RSI-W/RET
C-227	1	YES	2.693	2.673	203	RESERVE
C-228	1	NO	2.67	2.693	204	RSI-A/RET
C-229		YES	2.609	2.632	190	RESERVE
C-230		NO	2.697	2.677	196	IOTECH/RE
C-231		YES	2.651	2.674	193	RESERVE
C-232		YES	2.665	2.688	194	RESERVE
C-233	1	NO	2	1.986	204	RSI-W/RET
C-234		NO	2	1.986	204	RESERVE
C-235	1	YES	2.733	2.713	200	RSI-A/RET
C-236	1	NO	2.811	2.791	199	IOTECH/RE
C-237	1	NO	2.74	2.72	200	RESERVE
C-238	1	NO	2.728	2.708	199	IOTECH/RE
C-239	1	YES	2.758	2.738	201	RESERVE
C-240	1	NO	2.642	2.623	210	RESERVE
C-241	1	YES	2.717	2.697	191	RESERVE
C-242	1	NO	2.822	2.802	199	RSI-A/RET
C-243	1	YES	2.742	2.722	193	RESERVE
C-244	1	NO	2.853	2.832	227	RESERVE
C-245	1	YES	2.614	2.637	208	RSI-A/RET
C-246	1	NO	2.645	2.626	210	RESERVE
C-247	1	NO	2.741	2.765	193	RESERVE
C-248	1	NO	2.656	2.637	211	RESERVE
C-249	1		2.692	2.716	167	RSI-A/RET
C-250	1		2.853	2.832	177	IOTECH/RE
C-251	1		2.738	2.718	179	RESERVE
C-254			2.719	2.699	169	IOTECH/RE
C-255		NO	2.745	2.769	213	RESERVE
C-256	1	YES	2.578	2.559	198	RSI-W/RET
C-258		YES	2.454	2.476	189	IOTECH/RE
C-259		YES	2.35	2.371	181	RESERVE
C-262		NO	2.505	2.527	190	RESERVE
C-263	2	NO	2.723	2.747	211	RSI-A/RET
C-264		NO	2.879	2.904	210	IOTECH/RE
C-265		NO	2.92	2.946	213	RESERVE
C-266		NO	2.914	2.94	212	RESERVE
C-267		NO	2.677	2.7	194	IOTECH/RE
C-268	2	NO	2.804	2.829	203	RSI-W/RET
C-269		NO	2.996	3.022	225	RESERVE
C-27		YES	2.848	2.873	186	IOTECH/RE
C-270		NO	2.937	2.963	214	RESERVE
C-271		NO	2.962	2.988	216	RESERVE
C-272		NO	2.574	2.597	195	RESERVE
C-273		NO	2.523	2.545	195	IOTECH/RE
C-274	2	NO	2.784	2.808	203	RSI-A/RET
C-275	2	YES	2.41	2.431	177	RSI-A/RET
C-276	2	NO	2.553	2.575	193	RSI-A/RET
C-278	2	NO	2.561	2.583	188	RSI-A/RET
C-28	1	NO	2.914	2.94	222	RESERVE
C-280	2	YES	2.799	2.824	196	RSI-A/RET
C-283		NO	2.781	2.805	194	RESERVE

C-284		NO	2.628	2.651	189	RESERVE
C-285		NO	2.623	2.646	191	RESERVE
C-286		YES	2.688	2.712	188	RESERVE
C-287		NO	2.652	2.675	193	IOTECH/RE
C-29	1	NO	2.933	2.959	223	RESERVE
C-291	2	NO	3.027	3.054	199	RSI-W/RET
C-292	2	NO	3.036	3.063	200	RSI-A/RET
C-293		NO	3.047	3.074	200	RESERVE
C-294		NO	3.042	3.069	200	RESERVE
C-295		NO	3.047	3.074	201	IOTECH/RE
C-296	2	NO	2.997	3.023	203	RSI-W/RET
C-297		NO	3.015	3.041	205	RESERVE
C-299	2	NO	2.987	3.013	203	RSI-W/RET
C-30	2	NO	2.747	2.771	206	RSI-A/RET
C-301		NO	3.019	3.045	218	RESERVE
C-303		YES	3.054	3.081	220	RESERVE
C-306		NO	3.127	3.154	225	RESERVE
C-31		NO	2.949	2.975	221	RESERVE
C-314		NO	3.018	3.044	227	RESERVE
C-315		NO	2.997	3.023	225	RESERVE
C-316		NO	3.018	3.044	227	RESERVE
C-317		NO	2.549	2.571	180	RESERVE
C-318		NO	2.897	2.922	203	RESERVE
C-319		YES	3.002	3.028	207	RESERVE
C-32		NO	2.602	2.625	196	RESERVE
C-320		YES	2.825	2.85	198	RESERVE
C-322		NO	2.938	2.964	206	RESERVE
C-324	2	NO	2.74	2.764	194	RSI-W/RET
C-325		NO	2.979	3.005	210	RESERVE
C-326		YES	3.119	3.146	215	RESERVE
C-33		NO	2.942	2.968	220	RESERVE
C-330	2	NO	2.586	2.609	183	RSI-W/RET
C-332		NO	2.99	3.016	211	RESERVE
C-334		YES	2.9	3.13	210	RESERVE
C-335		NO	2.515	2.714	172	IOTECH/RE
C-336	2	NO	2.882	2.907	202	RSI-A/RET
C-338	2	NO	2.879	2.904	201	RSI-A/RET
C-339		NO	2.98	3.006	208	RESERVE
C-34		YES	2.69	2.671	208	RESERVE
C-340	2	NO	2.972	2.998	208	RSI-W/RET
C-342		YES	2.989	3.015	203	RESERVE
C-346		NO	2.568	2.591	189	RESERVE
C-348		NO	2.459	2.481	181	IOTECH/RE
C-349		NO	2.948	2.974	224	RESERVE
C-35		NO	2.967	2.945	213	RESERVE
C-350		NO	2.96	2.986	225	RESERVE
C-351		NO	2.939	2.965	224	RESERVE
C-353		NO	2.619	2.826	189	IOTECH/RE
C-354		YES	2.677	2.889	180	RESERVE
C-355		NO	2.647	2.857	179	RESERVE
C-357		NO	2.632	2.84	171	RESERVE
C-358	3	YES	2.691	2.904	180	RSI-W/RET
C-359	3	YES	2.672	2.884	172	RSI-A/PNL
C-363	3	NO	2.718	2.933	167	RSI-W/RET
C-367		YES	2.947	2.973	184	IOTECH/RE
C-372		NO	2.583	2.606	180	IOTECH/RE
C-373		NO	2.866	2.891	200	IOTECH/RE
C-376		NO	2.676	2.888	196	RESERVE
C-377		NO	2.722	2.938	197	RESERVE
C-379		NO	2.945	2.971	215	RESERVE
C-38		NO	2.94	2.919	211	RESERVE
C-380		NO	2.673	2.885	198	IOTECH/RE
C-381		NO	2.682	2.894	181	IOTECH/RE
C-384		NO	2.64	2.849	177	RESERVE
C-386	3		2.322	2.506	166	RSI-W/RET
C-387	3	NO	2.864	2.889	198	RSI-A/RET
C-390		NO	2.655	2.865	191	RESERVE
C-391		NO	2.347	2.533	185	IOTECH/RE
C-392		YES	3.01	3.036	236	RESERVE
C-393		YES	3.011	3.037	220	RESERVE
C-394		YES	2.683	2.707	227	RESERVE
C-396		NO	2.922	3.153	214	RESERVE
C-397		NO	2.886	2.911	211	RESERVE
C-398		NO	2.928	2.954	214	RESERVE
C-400	3	NO	2.838	2.863	203	RSI-W/RET
C-401		NO	2.887	2.912	197	ARECO
C-402		NO	2.637	2.66	190	IOTECH/RE
C-403		NO	2.821	2.846	197	RESERVE

C-405	3	NO	2.676	2.699	192	RSI-W/RET
C-406		NO	2.872	2.897	208	IOTECH/RE
C-408		NO	2.892	2.917	209	RESERVE
C-409	2	YES	2.851	2.876	206	RSI-W/RET
C-41		YES	2.689	2.67	200	IOTECH/RE
C-410		NO	2.87	2.895	207	RESERVE
C-411		NO	2.855	2.88	206	IOTECH/RE
C-412	2	NO	2.789	2.813	191	RSI-A/RET
C-414	2		2.803	2.828	197	RSI-A/RET
C-415	2		2.672	2.695	188	RSI-A/RET
C-416	2		2.753	2.777	194	RSI-W/RET
C-417			2.703	2.727	190	RESERVE
C-418			2.665	2.688	188	RESERVE
C-42	1	NO	2.583	2.564	200	RSI-A/RET
C-420		NO	2.617	2.824	169	RESERVE
C-421	3	NO	2.641	2.85	187	RSI-W/RET
C-424	3	NO	2.625	2.833	186	RSI-W/RET
C-425		YES	2.908	3.138	165	IOTECH/RE
C-426		NO	2.239	2.416	171	RESERVE
C-427		YES	2.94	2.966	193	RESERVE
C-428		YES	2.473	2.669	161	IOTECH/RE
C-429	3	NO	2.631	2.839	190	RSI-W/RET
C-43	1	NO	2.872	2.851	203	RSI-A/RET
C-430		NO	2.637	2.846	197	RESERVE
C-431		NO	2.639	2.848	176	IOTECH/RE
C-432		NO	2.481	2.678	189	IOTECH/RE
C-434	3	NO	2.632	2.84	181	RSI-W/RET
C-435		NO	2.398	2.588	183	RESERVE
C-436		NO	2.625	2.833	200	RESERVE
C-44		NO	2.842	2.821	200	IOTECH/RE
C-440	3	YES	2.546	2.748	196	RSI-W/RET
C-441		NO	2.28	2.461	174	RESERVE
C-442	3	NO	2.176	2.348	167	RSI-W/RET
C-443		YES	2.634	2.843	180	IOTECH/RE
C-446		NO	2.151	2.321	165	RESERVE
C-447	3	YES	2.622	2.83	194	RSI-W/RET
C-448		NO	2.638	2.847	189	RESERVE
C-452		NO	2.855	2.88	212	RESERVE
C-454	3	YES	2.682	2.894	188	RSI-A/RET
C-455		NO	2.202	2.376	169	RESERVE
C-457		YES	2.528	2.728	194	RESERVE
C-459		NO	2.471	2.667	190	RESERVE
C-46	1	NO	2.932	2.958	211	RSI-W/RET
C-460		NO	2.525	2.725	194	IOTECH/RE
C-461	3	YES	2.628	2.836	184	RSI-W/RET
C-467	3	NO	2.626	2.834	173	RSI-W/RET
C-468	3	NO	2.475	2.671	190	RSI-A/RET
C-469		NO	2.624	2.832	176	RESERVE
C-47		NO	2.899	2.924	221	RESERVE
C-470		NO	2.63	2.838	180	IOTECH/RE
C-471	3	NO	2.176	2.348	167	RSI-A/RET
C-472	3	NO	2.193	2.367	168	RSI-W/RET
C-473	3	NO	2.609	2.816	201	RSI-W/RET
C-474	3	NO	2.441	2.634	169	RSI-A/RET
C-476		NO	2.578	2.782	199	IOTECH/RE
C-477		NO	1.913	2.065	148	IOTECH/RE
C-479		NO	2.758	2.976	189	RESERVE
C-48		NO	2.787	2.767	197	SANDIA-CP
C-480		YES	2.638	2.847	168	RESERVE
C-481		NO	2.999	3.025	202	RESERVE
C-483	3	NO	3.023	3.05	204	RSI-W/RET
C-484		NO	2.952	2.978	199	RESERVE
C-485		NO	2.493	2.69	192	RESERVE
C-486	3	NO	2.554	2.756	165	RSI-A/RET
C-487		NO	2.688	2.901	207	RESERVE
C-488		NO	1.99	2.148	128	IOTECH/RE
C-489		YES	3.12	3.147	214	RESERVE
C-491		NO	2.613	2.82	190	RESERVE
C-492		NO	3.043	3.07	221	RESERVE
C-493		NO	2.96	2.986	215	RESERVE
C-494		NO	2.935	2.961	214	RESERVE
C-495		NO	2.952	2.978	215	RESERVE
C-497		NO	2.643	2.852	177	RESERVE
C-498		NO	2.562	2.765	163	RESERVE
C-500		NO	1.945	2.099	123	IOTECH/RE
C-501		NO	2.356	2.543	169	IOTECH/RE
C-505	3	NO	2.588	2.793	183	RSI-W/RET
C-506	3	NO	2.623	2.831	185	RSI-A/RET

C-507	3	NO	2.701	2.915	186	RSI-A/RET
C-508	3	NO	2.59	2.795	170	RSI-W/RET
C-510		NO	2.378	2.566	147	IOTECH/RE
C-511		NO	2.61	2.817	169	RESERVE
C-514		NO	2.603	2.809	177	RESERVE
C-515		YES	2.59	2.795	177	RESERVE
C-517		NO	2.629	2.837	189	RESERVE
C-518		NO	2.643	2.852	187	RESERVE
C-52		NO	2.858	2.883	218	RESERVE
C-521		YES	2.963	2.989	210	RESERVE
C-523	3	NO	3.037	3.064	205	RSI-W/RET
C-524	3	NO	2.613	2.82	163	RSI-A/RET
C-525	3	NO	2.683	2.896	193	RSI-A/RET
C-526		NO	2.611	2.818	163	IOTECH/RE
C-527	3	NO	2.673	2.885	184	RSI-W/RET
C-530		NO	2.948	2.974	199	RESERVE
C-531		NO	2.696	2.91	203	RESERVE
C-532		YES	2.644	2.853	166	RESERVE
C-536		NO	2.555	2.757	184	IOTECH/RE
C-537		NO	2.627	2.835	195	RESERVE
C-539	3	YES	1.669	1.801	161	RSI-A/RET
C-540		NO	2.658	2.681	179	IOTECH/RE
C-543	3	NO	2.382	2.571	169	RSI-W/RET
C-544		NO	2.584	2.789	169	RESERVE
C-545	3	NO	2.461	2.656	165	RSI-W/RET
C-547		YES	2.506	2.705	197	IOTECH/RE
C-550		NO	2.639	2.848	203	ARECO
C-552		NO	2.588	2.793	199	RESERVE
C-553	3	NO	2.471	2.667	192	RSI-A/RET
C-554		YES	2.433	2.626	187	IOTECH/RE
C-555	3	NO	2.82	3.043	171	RSI-W/RET
C-557		NO	2.376	2.564	168	RESERVE
C-560		NO	2.395	2.585	160	IOTECH/RE
C-562	3	YES	2.416	2.607	161	RSI-W/RET
C-564	3	NO	2.223	2.399	171	RSI-A/RET
C-565	3	YES	2.695	2.908	187	RSI-W/RET
C-566	3	NO	2.778	2.998	176	RSI-W/RET
C-567	3	NO	2.907	3.137	162	RSI-W/RET
C-568	3	NO	2.448	2.642	186	RSI-A/RET
C-569	3	NO	2.347	2.533	178	RSI-W/RET
C-57		NO	2.769	2.749	206	SANDIA-CP
C-572	3	NO	2.66	2.683	182	RSI-W/RET
C-573	3	NO	2.583	2.788	177	RSI-W/RET
C-575		NO	2.288	2.308	176	RESERVE
C-576	3	NO	2.327	2.511	177	RSI-W/RET
C-578		NO	2.419	2.611	184	RESERVE
C-579		NO	2.668	2.879	187	IOTECH/RE
C-58		NO	2.775	2.755	206	SANDIA-CP
C-580		NO	2.538	2.739	193	RESERVE
C-581	2	NO	2.399	2.42	175	RSI-A/RET
C-582		YES	2.381	2.57	177	IOTECH/RE
C-583		NO	2.46	2.655	183	RESERVE
C-584	3	NO	2.311	2.494	192	RSI-A/RET
C-588	3	YES	2.323	2.507	173	RESERVE
C-590	3	NO	2.371	2.559	168	RESERVE
C-591	3	YES	2.562	2.765	181	IOTECH/RE
C-592	3	YES	2.61	2.817	184	IOTECH/RE
C-594	3	NO	2.679	2.891	173	IOTECH/RE
C-595	3	NO	2.654	2.864	168	IOTECH/RE
C-597	3	NO	2.556	2.705	179	RSI-A/RET
C-598	3	NO	2.667	2.878	173	RESERVE
C-602	3	YES	2.71	2.925	179	RSI-W/RET
C-604	3	NO	2.682	2.894	178	RSI-A/RET
C-605	3	NO	2.744	2.961	167	RSI-W/RET
C-606	3	NO	2.716	2.931	170	RSI-A/RET
C-608	3	NO	2.754	2.972	173	RESERVE
C-609	3	NO	2.755	2.973	168	RESERVE
C-610	3	NO	2.735	2.908	158	IOTECH/RE
C-611	3	NO	2.642	2.851	166	RESERVE
C-612	3	NO	2.621	2.829	176	IOTECH/RE
C-613	3	NO	2.72	2.935	183	IOTECH/RE
C-614	3	NO	2.655	2.865	178	RSI-W/RET
C-616	3	YES	2.676	2.888	172	RSI-A/RET
C-617	3	NO	2.693	2.906	171	RSI-A/RET
C-619	3	NO	2.891	3.12	179	RESERVE
C-620	3	YES	2.736	2.953	161	IOTECH/RE
C-622	3	NO	2.724	2.94	142	IOTECH/RE
C-623	3	NO	2.707	2.921	175	RSI-A/RET

C-624	3	YES	2.729	2.945	191	IOTECH/RE
C-625	3	NO	2.74	2.957	176	RSI-W/RET
C-626	3	NO	2.744	2.961	174	RSI-W/RET
C-627	3	YES	2.674	2.886	176	IOTECH/RE
C-628	3	NO	2.717	2.932	172	RESERVE
C-63		NO	2.688	2.669	203	RESERVE
C-630	3	NO	2.59	2.795	180	RESERVE
C-631	3	NO	2.649	2.859	179	RSI-W/RET
C-632	3	NO	2.851	3.077	185	ARECO
C-633	3	NO	2.615	2.822	184	RSI-W/RET
C-634	3	NO	2.631	2.843	179	RSI-A/RET
C-635	3	NO	2.411	2.602	162	RSI-A/RET
C-636	3	NO	2.283	2.464	151	IOTECH/RE
C-637	3	NO	2.657	2.867	193	RESERVE
C-640	3	NO	2.659	2.87	176	RESERVE
C-641	3	NO	2.618	2.825	171	RESERVE
C-642	3	YES	2.725	2.941	179	RSI-W/RET
C-643	3	YES	2.604	2.81	169	IOTECH/RE
C-644	3	NO	2.591	2.796	157	IOTECH/RE
C-646	3	YES	2.752	2.97	184	RESERVE
C-647	3	NO	2.356	2.543	148	IOTECH/RE
C-648	3	NO	2.672	2.884	182	RSI-A/RET
C-649	3	NO	2.673	2.885	170	IOTECH/RE
C-65		YES	2.822	2.847	218	RESERVE
C-652	3	NO	2.725	2.941	190	RSI-A/RET
C-653	3	NO	2.66	2.871	192	IOTECH/RE
C-654	3	NO	2.657	2.867	185	RESERVE
C-655	3	NO	2.66	2.871	191	RESERVE
C-656	3	NO	2.56	2.763	190	RESERVE
C-657	3	YES	2.645	2.855	168	RSI-W/RET
C-659	3	YES	2.707	2.921	199	RESERVE
C-66		NO	2.713	2.737	210	IOTECH/RE
C-660	3	NO	2.612	2.819	181	IOTECH/RE
C-661	3	NO	2.741	2.958	190	IOTECH/RE
C-662	3	YES	2.776	2.996	209	RESERVE
C-663	3	NO	2.649	2.859	193	RSI-A/RET
C-665	3	NO	2.656	2.866	188	RESERVE
C-666	3	NO	2.524	2.724	181	RESERVE
C-667	3	NO	2.699	2.913	182	RESERVE
C-668	3	NO	2.763	2.982	190	RSI-W/RET
C-669	3	NO	2.665	2.876	178	RESERVE
C-670	3	NO	2.656	2.866	188	RSI-W/RET
C-671	3	NO	2.73	2.946	187	RSI-A/RET
C-672	3	NO	2.447	2.641	187	RESERVE
C-673	3	NO	2.665	2.876	208	RESERVE
C-674	3	NO	2.453	2.647	182	RESERVE
C-675	3	NO	2.496	2.694	188	IOTECH/RE
C-676	3	NO	2.544	2.746	188	IOTECH/RE
C-677	3	NO	2.263	2.442	166	RESERVE
C-678	3	NO	2.28	2.461	166	RESERVE
C-679	3	NO	2.273	2.453	163	RESERVE
C-68		NO	2.741	2.721	212	RESERVE
C-681	3	NO	2.264	2.443	161	RSI-W/RET
C-682	3	YES	2.742	2.959	197	IOTECH/RE
C-685	3	NO	2.74	2.957	199	RESERVE
C-686	3	NO	2.919	3.15	214	RESERVE
C-689	3	NO	2.705	2.919	210	IOTECH/RE
C-69		NO	2.937	2.916	211	RESERVE
C-690	3	NO	2.523	2.723	173	RESERVE
C-691	3	NO	2.757	2.975	193	RESERVE
C-692	3	NO	2.393	2.583	173	RESERVE
C-694	3	NO	2.341	2.526	175	RSI-W/RET
C-695	3	NO	2.279	2.46	164	RSI-W/RET
C-697	3	NO	2.383	2.572	183	RSI-W/RET
C-698	3	NO	2.416	2.607	183	RSI-A/RET
C-699	3	NO	2.401	2.591	173	IOTECH/RE
C-700	3	NO	2.738	2.955	206	ARECO
C-701	3	NO	2.421	2.613	178	RSI-A/RET
C-702	3	NO	2.386	2.575	172	RSI-W/RET
C-704	3	NO	2.422	2.614	177	RESERVE
C-705	3	YES	2.411	2.602	179	RSI-A/RET
C-706	3	YES	2.377	2.565	177	IOTECH/RE
C-708	3	NO	2.535	2.736	169	RESERVE
C-709	3	NO	2.561	2.764	178	RESERVE
C-71		NO	2.736	2.716	210	ARECO
C-711	3	NO	2.562	2.765	187	RESERVE
C-712	3	NO	2.401	2.591	168	RSI-A/RET
C-713	3	NO	2.376	2.564	176	RSI-A/RET

C-714	3	NO	2.398	2.588	171	RESERVE
C-715	3	NO	2.373	2.561	172	RESERVE
C-716	3	NO	2.352	2.538	172	RESERVE
C-717	3	NO	2.379	2.567	172	RESERVE
C-718	3	NO	2.42	2.612	171	RSI-A/RET
C-719	3	NO	2.034	2.195	151	IOTECH/RE
C-721	3	NO	2.351	2.537	166	RESERVE
C-722	3	NO	2.396	2.586	174	ARECO
C-723	3	NO	2.597	2.803	192	IOTECH/RE
C-724	3	NO	1.774	1.915	132	IOTECH/RE
C-725	3	NO	2.692	2.905	194	ARECO
C-726	3	NO	2.398	2.588	178	RESERVE
C-729	3	NO	2.719	2.934	201	RESERVE
C-730	3	NO	2.708	2.923	192	RSI-A/RET
C-732	3	NO	2.657	2.867	198	RESERVE
C-733	3	NO	2.643	2.852	193	RESERVE
C-734	3	NO	2.648	2.858	185	RESERVE
C-735	3	NO	2.652	2.862	192	IOTECH/RE
C-737	3	NO	2.706	2.92	195	RESERVE
C-738	3	NO	2.726	2.942	191	RSI-A/RET
C-739	3	NO	2.499	2.697	197	RSI-A/RET
C-741	3	NO	2.748	2.966	193	RESERVE
C-742	3	NO	2.501	2.699	195	RESERVE
C-743	3	NO	2.406	2.597	166	RSI-A/RET
C-744	3	NO	2.5	2.698	172	RSI-A/RET
C-745	3	YES	2.432	2.625	184	RSI-A/RET
C-746	3	NO	2.396	2.586	165	RSI-A/RET
C-748	3	NO	2.425	2.617	169	RESERVE
C-749	3	NO	2.604	2.81	186	IOTECH/RE
C-750	3	NO	2.356	2.543	176	RESERVE
C-751	3	NO	2.389	2.578	183	IOTECH/RE
C-752	3	NO	2.438	2.631	187	IOTECH/RE
C-753	3	NO	2.858	3.084	219	RESERVE
C-756	3	NO	2.306	2.489	174	RSI-A/RET
C-76		NO	2.791	2.771	203	SANDIA-CP
C-760	3	NO	2.85	3.076	214	RESERVE
C-761	3	NO	2.521	2.721	187	RESERVE
C-762	3	NO	2.576	2.78	195	IOTECH/RE
C-763	3	NO	2.536	2.737	183	RESERVE
C-765	3	NO	2.286	2.467	167	ARECO
C-767	3	NO	2.479	2.675	192	RESERVE
C-768	3	NO	2.641	2.85	201	RSI-W/RET
C-769	3	NO	2.599	2.805	193	IOTECH/RE
C-77		NO	2.667	2.648	190	SANDIA-CP
C-770	3	NO	2.465	2.66	167	RESERVE
C-771	3	NO	2.551	2.753	185	RESERVE
C-772	3	NO	2.459	2.654	185	RESERVE
C-773	3	YES	2.504	2.702	168	RESERVE
C-774	3	NO	3.023	3.262	234	PNL-300/R
C-775	3	NO	3.247	3.504	235	PNL-300
C-778	3	NO	3.058	3.3	237	PNL-300/R
C-78		NO	2.731	2.755	211	RESERVE
C-780	3	NO	2.637	2.846	204	IOTECH/RE
C-781	3	NO	2.658	2.869	202	IOTECH/RE
C-782	3	NO	2.658	2.869	206	IOTECH/RE
C-783	3	NO	2.431	2.624	175	RSI-W/RET
C-784	3	NO	2.634	2.843	191	RESERVE
C-786	3	NO	2.395	2.585	171	IOTECH/RE
C-787	3	NO	2.45	2.644	182	IOTECH/RE
C-788	3	NO	2.535	2.736	204	RESERVE
C-791	3	NO	2.576	2.78	202	RESERVE
C-792	3	NO	2.594	2.799	186	RSI-A/RET
C-793	3	NO	2.635	2.844	195	RSI-W/RET
C-795	3	NO	2.369	2.557	185	RESERVE
C-796	3	NO	2.929	3.161	214	RESERVE
C-798	3	NO	2.758	2.976	201	IOTECH/RE
C-799	3	NO	2.72	2.935	205	RSI-A/RET
C-80		NO	2.727	2.707	211	IOTECH/RE
C-800	3	NO	2.715	2.93	196	IOTECH/RE
C-801	3	NO	2.771	2.991	207	RESERVE
C-802	3	NO	2.718	2.933	195	RSI-A/RET
C-807	3	NO	2.222	2.398	184	RSI-A/RET
C-808	3	NO	2.32	2.504	162	RESERVE
C-810	3	NO	2.324	2.508	181	IOTECH/RE
C-811	3	NO	2.337	2.522	173	RSI-A/PNL
C-812	3	NO	2.341	2.526	178	RESERVE
C-813	3	NO	2.413	2.604	193	IOTECH/RE
C-814	3	NO	2.438	2.631	184	RESERVE

C-815	3	NO	2.688	2.901	186	RESERVE
C-816	3	NO	2.581	2.785	176	IOTECH/RE
C-817	3	NO	2.685	2.898	184	RSI-A/RET
C-819	3	NO	2.697	2.911	181	RESERVE
C-82	1	NO	2.764	2.744	209	RSI-A/RET
C-820	3	NO	2.717	2.932	190	RESERVE
C-821	3	NO	2.766	2.985	184	IOTECH/RE
C-822	3	NO	3.427	3.698	172	PNL-300/R
C-823	3	NO	3.212	3.466	186	PNL-300
C-825	3	NO	2.765	2.984	190	RSI-A/RET
C-826	3	NO	2.708	2.923	194	IOTECH/RE
C-828	3	YES	2.649	2.859	190	ARECO
C-829	3	NO	2.635	2.844	241	RESERVE
C-83		NO	2.738	2.762	214	RESERVE
C-830	3	YES	2.636	2.845	187	RESERVE
C-831	3	NO	2.443	2.637	178	RESERVE
C-832	3	NO	2.718	2.933	195	RSI-W/RET
C-833	3	NO	2.975	3.211	186	RESERVE
C-834	3	NO	3.004	3.242	191	RSI-W/RET
C-835	3	NO	2.952	3.186	185	RSI-A/RET
C-836	3	NO	2.768	2.987	177	RESERVE
C-837	3	NO	3.435	3.707	179	PNL-300/R
C-838	3	NO	2.764	2.983	198	RSI-A/RET
C-839	3	NO	2.998	3.235	178	ARECO
C-84		NO	2.861	2.886	137	IOTECH/RE
C-840	3	NO	2.976	3.212	190	RSI-A/RET
C-841	3	NO	2.954	3.188	207	RESERVE
C-842	3	NO	2.93	3.162	192	RESERVE
C-843	3	NO	2.977	3.213	175	RESERVE
C-844	3	NO	2.937	3.17	185	RSI-W/RET
C-848	3	NO	2.736	2.953	186	RESERVE
C-849	3	NO	2.607	2.814	185	RSI-A/PNL
C-85		YES	2.76	2.74	198	RESERVE
C-850	3	NO	2.638	2.847	236	PNL-TPCI/
C-851	3	NO	2.756	2.974	185	IOTECH/RE
C-852	3	NO	2.74	2.957	198	RSI-A/RET
C-853	3	NO	2.753	2.971	186	IOTECH/RE
C-854	3	NO	2.758	2.976	193	RESERVE
C-855	3	NO	2.752	2.97	185	IOTECH/RE
C-856	3	NO	2.748	2.966	208	RESERVE
C-857	3	NO	2.742	2.959	190	IOTECH/RE
C-858	3	NO	2.723	2.939	189	RSI-A/RET
C-86	1	YES	2.818	2.798	199	RSI-W/RET
C-860	3	NO	2.898	3.128	185	IOTECH/RE
C-861	3	NO	2.714	2.929	191	IOTECH/RE
C-862	3	NO	2.722	2.938	187	IOTECH/RE
C-863	3	NO	2.325	2.509	174	RESERVE
C-864	3	NO	2.545	2.747	171	RSI-A/RET
C-865	3	NO	2.449	2.643	163	RESERVE
C-866	3	NO	2.514	2.713	168	RESERVE
C-867	3	NO	2.494	2.692	174	IOTECH/RE
C-868	3	NO	2.492	2.689	185	RSI-A/RET
C-869	3	NO	2.606	2.812	193	RSI-W/RET
C-870	3	YES	2.671	2.883	198	RESERVE
C-872	3	NO	2.652	2.862	192	RESERVE
C-873	3	YES	2.677	2.889	192	RESERVE
C-874	3	NO	2.66	2.871	182	RESERVE
C-875	3	NO	2.718	2.933	186	RSI-A/RET
C-877	3	NO	2.675	2.887	185	RSI-W/RET
C-879	3	NO	2.106	2.273	144	IOTECH/RE
C-881	3	NO	2.706	2.92	162	IOTECH/RE
C-882	3	NO	2.739	2.956	158	IOTECH/RE
C-883	3	NO	2.912	3.143	183	RSI-W/RET
C-884	3	NO	2.923	3.155	177	IOTECH/RE
C-885	3	NO	2.909	3.139	181	RESERVE
C-886	3	NO	2.901	3.131	179	RESERVE
C-887	3	NO	2.654	2.864	247	RESERVE
C-888	3	NO	2.683	2.896	186	RSI-A/RET
C-889	3	NO	2.689	2.902	188	RESERVE
C-890	3	NO	2.637	2.846	182	IOTECH/RE
C-891	3	NO	2.594	2.799	174	RESERVE
C-892	3	YES	2.721	2.937	195	RESERVE
C-893	3	NO	2.601	2.807	181	ARECO
C-894	3	NO	2.624	2.832	223	RESERVE
C-895	3	NO	2.598	2.804	190	RSI-W/RET
C-896	3	NO	2.747	2.965	237	PNL-TPCI/
C-897	3	NO	2.761	2.98	207	RSI-A/RET
C-898	3	NO	2.737	2.954	204	IOTECH/RE

C-899	3	YES	2.701	2.915	195	IOTECH/RE
C-900	3	NO	2.723	2.939	193	ARECO
C-901	3		2	2.158	240	RESERVE
C-902	3	NO	2.748	2.966	201	RESERVE
C-904	3	NO	2.737	2.954	193	RSI-W/RET
C-905	3	NO	2.748	2.966	194	RSI-W/RET
C-906	3	NO	2.751	2.969	250	RESERVE
C-907	3	NO	2.717	2.932	188	RESERVE
C-908	3	NO	2.751	2.969	194	IOTECH/RE
C-909	3	NO	2.367	2.555	165	IOTECH/RE
C-91	2	NO	2.93	2.956	219	RESERVE
C-910	3	NO	2.302	2.484	166	RSI-A/RET
C-911	3	NO	2.367	2.555	175	RESERVE
C-912	3	NO	2.337	2.522	164	RESERVE
C-913	3	NO	2.225	2.401	195	RSI-A/PNL
C-914	3	NO	2.347	2.533	167	IOTECH/RE
C-915	3	NO	2.345	2.531	166	IOTECH/RE
C-916	3	NO	2.742	2.959	188	RSI-A/RET
C-917	3	NO	1.778	1.919	156	IOTECH/RE
C-918	3	NO	2.354	2.54	167	IOTECH/RE
C-919	3	NO	2.282	2.463	165	RESERVE
C-922	3	NO	2.617	2.824	186	ARECO
C-924	3	NO	2.324	2.508	160	RSI-W/RET
C-926	3	NO	2.151	2.321	154	IOTECH/RE
C-928	3	NO	2.245	2.423	155	IOTECH/RE
C-929	3	NO	2.656	2.866	189	IOTECH/RE
C-93	2	NO	2.691	2.671	191	SANDIA-CP
C-930	3	NO	2.654	2.864	185	RSI-A/PNL
C-932	3	NO	2.666	2.877	198	RESERVE
C-933	3	NO	2.662	2.873	200	IOTECH/RE
C-934	3	NO	2.649	2.859	194	IOTECH/RE
C-935	3	NO	2.381	2.57	162	RSI-A/RET
C-936	3	NO	2.784	3.005	204	RSI-W/RET
C-937	3	NO	2.77	2.989	189	RESERVE
C-938	3	NO	2.765	2.984	201	RESERVE
C-939	3	NO	2.58	2.784	159	RESERVE
C-941	3	NO	2.793	3.014	212	RESERVE
C-942	3	NO	2.761	2.98	172	ARECO
C-943	3	NO	2.771	2.991	184	IOTECH/RE
C-944	3	NO	2.742	2.959	189	RSI-A/RET
C-945	3	NO	2.765	2.984	192	RESERVE
C-946	3	NO	2.775	2.995	202	RESERVE
C-947	3	NO	2.605	2.811	182	RSI-A/RET
C-948	3	NO	2.634	2.843	191	RSI-A/RET
C-949	3	NO	2.66	2.871	177	RSI-A/RET
C-95	2	NO	2.648	2.671	196	RSI-A/RET
C-950	3	NO	2.688	2.901	181	RSI-A/RET
C-951	3	NO	2.708	2.923	185	IOTECH/RE
C-952	3	NO	2.726	2.942	189	RSI-W/RET
C-956	3	NO	2.577	2.781	174	RSI-A/RET
C-957	3	NO	2.774	2.994	245	RESERVE
C-958	3	NO	2.769	2.988	187	RSI-A/RET
C-96	2	YES	2.804	2.784	201	IOTECH/RE
C-960	3	NO	2.701	2.915	182	RSI-A/RET
C-961	3	NO	2.62	2.828	187	RESERVE
C-962	3	YES	2.646	2.856	190	RESERVE
C-963	3	NO	2.732	2.948	179	RSI-A/RET
C-965	3	NO	2.691	2.904	179	IOTECH/RE
C-966	3	NO	2.624	2.832	216	RESERVE
C-968	3	NO	2.685	2.898	187	RSI-A/RET
C-969	3	NO	2.718	2.933	182	RSI-A/RET
C-970	3	NO	2.749	2.967	194	RESERVE
C-971	3	NO	2.693	2.906	181	IOTECH/RE
C-972	3	NO	2.723	2.939	175	IOTECH/RE
C-973	3	NO	2.691	2.904	176	RSI-A/RET
C-974	3	NO	2.717	2.932	181	RESERVE
C-975	3	NO	2.693	2.906	184	RESERVE
C-976	3	NO	2.696	2.91	186	RSI-A/RET
C-977	3	NO	2.761	2.98	184	RESERVE
C-978	3	NO	2.555	2.757	185	RSI-A/RET
C-979	3	YES	2.666	2.877	184	RSI-A/RET
C-98	2	NO	2.817	2.842	135	IOTECH/RE
C-980	3	NO	2.609	2.816	185	RSI-A/RET
C-981	3	NO	2.279	2.46	168	IOTECH/RE
C-983	3	NO	2.336	2.521	168	IOTECH/RE
C-984	3	NO	2.599	2.805	191	RSI-A/RET
C-985	3	NO	2.628	2.836	200	IOTECH/RE
C-986	3	NO	2.231	2.408	179	RSI-A/RET

C-987	3	NO	2.75	2.968	190	RESERVE
C-988	3	NO	2.738	2.955	196	IOTECH/RE
C-989	3	NO	2.661	2.872	200	RSI-A/RET
C-990	3	NO	2.722	2.938	193	RSI-A/RET
C-991	3	NO	2.733	2.949	185	RESERVE
C-992	3	NO	2.656	2.866	183	RSI-A/RET
C-993	3	NO	2.746	2.964	195	RESERVE
C-994	3	NO	2.542	2.743	183	RESERVE
C-996	3	NO	2.487	2.684	182	IOTECH/RE
C-997	3	NO	2.727	2.943	194	IOTECH/RE
C-998	3	NO	2.75	2.968	200	RESERVE
C-999	3	NO	2.714	2.929	194	RSI-A/RET

DON'T SAY IT --- *Write It!*

DATE: January 29, 1996

TO: [redacted] A3-34

FROM: Mario M. Pereira S6-65

Telephone: 372-0036

CC: L. I. Covey S6-70
J. R. Brehm A2-25
MMP/LB

SUBJECT: Verification of EDS "Gram Salt/cc" Field

At your request, hand calculations were used to determine the basis for the number listed in the "gram salt" EDS field. This field is actually "gram salt/cc", but field length limits the amount of characters shown. From the investigation it was determined that the subject number is the net weight of the material within the cesium capsule divided by the internal volume of the inner capsule (in grams/cubic centimeter).

Please note the material at question includes all radioactive and inert materials and does not represent the grams of CsCl per cubic centimeter.

An example calculation is as follows:

For capsule C-1180, taken at random:

The net weight of salt for capsule C-1180 is 8.770 kg as indicated by both the data base and run book #81-49. The EDS uses 926.6 cc as the internal volume consistently among all capsule checked (10 taken at random, data attached). The following discussion validates the number within the tolerances of the capsule.

Hence for capsule C-1180 8770g salt/926.6cc= 2.850 g/cc which is consistent with the EDS output (attached)

Capsule Internal Volume:

The net weight of capsule salt is not in dispute, however the internal volume of the inner capsule, specifically Type III capsules, requires further discussion.

Nominal Case:

The capsule internal volume (type III) can be determined from the current drawing H-2-66760, Rev 12. "Cs Inner Capsule Assembly & Details" and tubing specifications. Nominally, the capsule outer diameter is 2.255" with a wall thickness of 0.136". Hence the inner diameter is nominally 1.983". The height of the space occupied only by salt inside the inner capsule was determined to be 18.025 inches, neglecting the capsule ring. This is the height of the "usable" volume and is determined as follows:

A-3000-723 (01/95) GEF014

Overall inner capsule tubing height (no endcaps)	19.125 in.
Height occupied by top cap disk, ring	<1.00 in.>
Bottom endcap overlap	<0.100 in.>
Net height of usable volume	18.025 in.

Capsule Ring Volume

Some additional capsule internal volume can be attributed to the space encompassed by the inner capsule ring. This ring was used to seal against the tilt-pour nozzles during the manufacturing process. This volume diameter of this volume is nominally 1.740 in. and has a height of 0.50 in. The diameter widens to accept the an O-ring. This widened area, or O-ring seat area, is essentially filled by the O-ring. Therefore, the nominal 1.740 in diameter can be used to estimate the volume attributable to the inner capsule ring.

The internal volume of a type III capsule can therefore be calculated as follows:

Usable Volume:	$\pi/4(1.983)^2 \times 18.025$	$= 55.67\ in^2$	$= 912.3$ cc
Ring Volume :	$\pi/4(1.740)^2 \times 0.50$	$= 1.19\ in^2$	$= 19.5$ cc
Total Volume		$= 56.86\ in^2$	$= 931.8$ cc

Other volume considerations:

Additional capsule internal volume can be attributed to the space between the sintered disk and the endcap, areas around the sintered disk, and around the O-ring. These have been neglected in this discussion.

Effect of capsule tolerances on volume:

The inner capsule diameter can vary significantly. Type III capsule specifications allow for 0.012 in tolerance in wall thickness and the OD of the capsule by 0.01 inches. The inner diameter, therefore could vary from 1.949 to 2.017 inches. Using the same calculations as above, neglecting the tolerances of the other components (ring, sintered disc, O-ring), and the space between the sintered disk and the endcap. The volume of the capsule could vary from 900.7 cc and 963.3 cc. Under these considerations, average internal volume is 932 cc, however the use of 926.6 cc in the EDS system is still reasonable.

Attachements (2)

1/18/96 Page 1

Outer Capsule ID: C-1180
Inner Capsule ID: C-1257
Production #: 81-49
Calibration Date: 8/06/81
Capsule Type: 3
Double Capsule: NO
Capsule Age: 173
Gross Wt.: 8.770
Net Wt.: 2.641
Tare Wt.: 6.129
Melter Location: 1
Pour Temperature: 745
Pour Date: 8/05/81
Pool Cell Date: 8/07/81
PC Location: 6-2-D-03
Original KCi: 62
Original Wattage: 299
Curies per gram: 17
Wattage Decayed: 214
Watt Decay Date: 1/15/96
KCi Decayed: 45
KCi Decay Date: 1/15/96
Wattage per gram: 81
Gram Salt: 2.850
Remarks: DOE/ TO BE SHIPPED
Remarks2:
QC Initials: TWT
OP Initials: KPB
Destination: RESERVE
Date Shipped:
Date Updated: 5/04/95
DSI Number: DSI 15

Gram salt per cubic centimeter is the ~~gross~~ net weight divided by the internal volume of the inner capsule.

Ten "Type 3" Cesium Capsules

Outer Capsule ID	Capsule Type	Net Wt.	Gram Salt	
C-1000	3	2.720	2.935	926.75
C-1001	3	2.288	2.469	926.69
C-1002	3	2.353	2.539	926.74
C-1003	3	1.858	2.005	926.68
C-1004	3	2.311	2.494	926.62
C-1005	3	2.708	2.923	926.45
C-1006	3	2.689	2.902	926.60
C-1007	3	2.719	2.934	926.72
C-1008	3	2.673	2.885	926.52
C-1009	3	2.700	2.914	926.56

$\frac{\text{net weight}}{\text{gram salt}} \times 1000$ g/Kg

APPENDIX D - WESF Hazardous Material Inventory Estimate

This appendix contains:

1. Internal memorandum from L. I. Covey to B. E. Hey, "Technically Reviewed WESF Radioactive Inventory Estimates," dated March 20, 1996, Westinghouse Hanford Company, Richland, WA.

2. Internal memorandum from L. I. Covey to B. E. Hey, "WESF Chemical Inventory," dated April 30, 1996, Westinghouse Hanford Company, Richland, WA.

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Westinghouse Hanford Company **Internal Memo**

From: WESF Engineering 16E20-96-054
Phone: 372-0296 S6-70
Date: March 20, 1996
Subject: TECHNICALLY REVIEWED WESF RADIOACTIVE INVENTORY ESTIMATES

To: B. E. Hey A3-34

cc: J. R. Brehm A2-25
K. A. Jennings-Mills S4-70
L. E. Johnson A2-25
D. S. Leach A3-34
J. L. Pennock S4-70
LIC/LB

Reference: Memorandum, J. W. Gehrke to D. K. Smith, "B Plant Transition Engineering Radioactive Inventory and Material Status (RIMS)," 16D20-96-JWG-004, dated January 10, 1996.

The purpose of this report is to provide the current "maximum" estimate of strontium (^{90}Sr) and cesium (^{137}Cs) inventories in the WESF facility. Inventories presented in curies ^{137}Cs or curies ^{90}Sr do not include daughters barium (^{137}Ba) or yttrium (^{90}Y). Although curie values are changing due to radioactive decay, only the capsule values in the WESF Radiological Inventory table (Attachment) have been decayed.

If you have any questions, please call me on 372-0296.

L. I. Covey, Engineer
WESF Engineering

Technical Reviewer
L. D. Brist, Engineer
WESF Engineering

pan

Attachment

WESF RADIOLOGICAL INVENTORY

LOCATION	SYSTEM/COMPONENTS	Max ^{137}Cs	Max ^{90}Sr
WESF K-3 Filter	East HEPA Filter [1,8]	480 Ci	35,000 Ci
	West HEPA Filter [1,8]	480 Ci	35,000 Ci
	K-3 Duct [2] 100% ^{137}Cs 100% ^{90}Sr 10% ^{137}Cs, 90% ^{90}Sr 85% ^{137}Cs, 15% ^{90}Sr	 5,100 Ci 0 Ci 510 Ci 4,400 Ci	 0 Ci 200,000 Ci 180,000 Ci 30,000 Ci
WESF Hot Cells	Process Cell A [3] (Unknown isoptopic mix of Cs and Sr)	Drum waste - assume maximum of 10 drums at 2 R/hr (or material equivalent to 10 drums).	
	Process Cell B [3]	2 kCi	20 kCi
	Process Cell C [3]	2 kCi	20 kCi
	Process Cell D/E [3]	20 kCi	0 kCi
	Process Cell F (temporary storage of 3 Suspect Cs Capsules [4])	Maximum limit will be determined by the ISB.	
WESF Pool Cells	Capsules currently store in Pool Cells 3, 4, 5, 6, and 7 [5]. (Capsule can also be store in Pool Cell 1 and 12.)	49,875 kCi	22,554 kCi
Capsules to be Returned to WESF	51 Cs Capsules	2,008 kCi	0 kCi
WESF Truck Port	30 (max) bags of low level solid waste [6,8]	Max dose readings of 50 mR/hr (mixed Cs and Sr)	
TK-100	Collection tank	Negligible contamination during normal operations [7,8]	

1. RHO-CD-1033, "K-3 Ventilation Systems Evaluation Waste Encapsulation and Storage Facility;" These curies estimates are based on the existing changeout limit of 40 R/hr readings in the filters.

2. RHO-CD-1033, "K-3 Ventilation Systems Evaluation Waste Encapsulation and Storage Facility;" Curie estimates were based on radiation readings taken in 1980. Since the isotopic split is not known, curie estimates for all 137Cs, all 90Sr, and potential isotopic splits are given.

3. The WESF hot cells were shutdown in the mid 1980's and some of the process equipment was removed. No documented inventory estimates are known. In approximately 1992, dose measurements of 3500 R/hr were obtained in D/E cell. This is approximately 10,000 curies Cs at 1 meter, unshielded. It will be assumed that there are 20,000 curies of cesium in D/E cell; 20,000 curies Sr in B/C plus 10% of the Cs quantity in D/E Cell. G cell inventory is negligible except when capsules are in the cell.

A Cell was originally design for manned entry and is cleaner than B, C, and D/E cells. A Cell has been contaminated by packaging waste in the cell. Sample dose rates for random drums moved from A Cell to B Plant Cell 4 were approximately 2 R/hr. There are 5 drums in A Cell and material for approximately 5 more drums. Cell contamination will be assumed to be mixed Cs and Sr.

4. WESF Encapsulation Database System (QC verified) decayed to January 15, 1996. Three cesium capsules are temporarily stored in F cell (116 kCi Cs). Inner capsule numbers: C-1636, C-1596, and outer capsule number C-287. The capsule limit for F Cell is in SD-SM-SAR-005, section 6.8.1.7.

5. WESF Encapsulation Database System (QC verified) decayed to January 15, 1996.

6. The maximum dose rates are approximately 20 to 25 mR/hr. The average dose rates are approximately 10 mR/hr. The maximum dose rates occur when material (rags, protective clothing, etc.) comes from the "hot" manipulator shop and usually only consists of one or two bags. Bagged material is stored until approximately 20 bags have accumulated and is then transported to 212B.

7. Radiation readings showed negligible contamination in the tanks except for small spots of 20 mR/hr.

8. The maximum values indicated in the table are what is expected during normal operations and do not include potential accident conditions.

Westinghouse Hanford Company **Internal Memo**

From: WESF Engineering 16E20-96-086
Phone: 372-0296 S6-70
Date: April 30, 1996
Subject: WESF CHEMICAL INVENTORY

To: B. E. Hey A3-34

cc: J. R. Brehm A2-25
K. A. Jennings-Mills S4-70
L. E. Johnson A2-25
J. L. Pennock S4-70
LIC/LB

The purpose of this letter is to provide the current and maximum estimate of chemical inventories in the WESF facility. Attached is the March 1996 Occupational Safety and Health Administration (OSHA)/Emergency Planning and Community Right-to-Know Act (EPCRA) Inventory list. The column with the heading "Local Name" contains reference numbers which correspond to descriptions of the product contained in the last page of the attachment.

The only non-typical household chemicals contained at the facility are trisodium phosphate, sodium nitrate, and ion exchange resin. Below is a description of each and the expected maximum quantity.

- Trisodium phosphate is used to decontaminate equipment. It is received dry (max 500 pounds) and used as a decontaminating agent when mixed with water and heated. A normal concentration consists of 20 pounds of crystal per 600 gallons water (0.4 wt%). The maximum concentration of the mixture is not expected to exceed 1 wt%.
- Sodium nitrate is added to sumps in areas were deionized water is used to ensure the solution is conductive. It is received dry and less than 10 pounds are typically stored in the facility. A normal solution consists of less than 2 table spoons added to 8 fluid ounces of water. No more than 20 bottles of this solution is expected to be stored in the facility.
- Ion exchange resin is used to maintain the pool cell water quality. The existing system contains less than 8 cubic feet with a maximum of 50 cubic feet contained within the facility.

The quantities of any other chemicals used during past processing are present only in residual quantities in the inactive transfer lines.

If you have any questions, please call me on 372-0296.

L. I. Covey, Engineer
WESF Engineering

Larry Brist

Technical Reviewer
L. D. Brist, Engineer
WESF Engineering

Attachment

16E20-96-086

ATTACHMENT

OSHA/EPCRA INVENTORY

Consisting of 7 pages

XG25

MARCH 1996

WESF
OSHA/EPCRA INVENTORY

THE FOLLOWING ATTACHED INVENTORY IS ACCURATE AND TRUE TO THE BEST OF MY KNOWLEDGE FOR **DATA COLLECTION FORMS** PAGE 92 THRU 96, AND **INVENTORY SUPPLEMENT SHEETS** PAGE -0- THRU -0-.

G.L. GARMAN	64056	3-25-96
Person Obtaining Inventory	Payroll Number	Date
[signature]	84470	3/25/96
Supervisor's Signature	Payroll Number	Date

Post-it® Fax Note 7671	Date 3/26/96 # of pages ▸ 6
To Larry Brist	From Karen B.
Co./Dept.	Co.
Phone #	Phone # 2-0293
Fax # 372-0050	Fax #

HAZARDOUS MATERIAL INVENTORY DATABASE
Data Collection Form

Rep Id 122 BENDER, KAREN P

Contact WESF-2AMU CHEM STR

Facility Id	Rep Loc	Detailed Location	MSDS	Name	Local Name	Cntnr	Size	UOM	Container Type	Base Inv Id	Qty	UOM	Qty Used	Previous Quantity	UOM
225B	2AMU	CHEMICAL STORAG	27625	ECLIPSE GOLD WAX. EG2502	FLOOR WAX		5	GAL	PLASTIC BUCKET OR PAIL	15057	1	5 GAL	0	5	GAL
			31481	GLANCE RTU		1	32	FLOZ	PLASTIC BOTTLES OR JUGS	8821	1	32 oz	0	32	FLOZ
			31480	GO-GETTER READY-TO-USE		2	32	FLOZ	PLASTIC BOTTLES OR JUGS	13587	10	32 OZ	0	320	FLOZ
			15012	IRN-150 AMBERLITE RESIN	3 CUFT = 183 LBS	3	1	CUFT	FIBER DRUM	9696	0	0	0	0	LBS
			14542A	PINK CREME. DECKER'S (REVISED)		4	1	QT	PLASTIC BOTTLES OR JUGS	8386	17	1 QT	0	17	QT
			29805	PUROLITE NRW-37 ION EXCHANGE RESIN	5 CUFT = 375 LBS	3	5	CUFT	FIBER DRUM	9695	0	0	0	0	LBS
			1506	SODIUM NITRATE	SODIUM - NITRATE	5	32	LBS	METAL BUCKET OR PAIL	283	1	BUCKET	0	32	LBS
			12304	SPIC AND SPAN (PHOSPHATE)		6	54	WTOZ	FIBER/CARDBOARD BOX	8827	24	54	0	1296	WTOZ
			42124	TRISODIUM PHOSPHATE CRYSTALS		7	50	LBS	PAPER BAG	15842	0	0	0	0	LBS
			42124	TRISODIUM PHOSPHATE CRYSTALS		7		LBS	PLASTIC GARBAGE CAN	16432	1	200 LB	0	200	LBS

HMID222A

03/14/96

HAZARDOUS MATERIAL INVENTORY DATABASE
Data Collection Form

Rep Id 122 BENDER, KAREN P

Contact WESF-2AMU CHEM STR

Facility Id	Rep Loc	Detailed Location	MSDS	Name	Local Name	Cntnr Size	UOM	Container Type	Base Inv Id	Qty	UOM	Qty Used	Previous Quantity	UOM
225B	2AMU	SPILL KIT	18237	CLEAN UP	B	25	LBS	METAL BUCKET OR PAIL	8813	1	25 LB	0	25	LBS

HHID222A

HAZARDOUS MATERIAL INVENTORY DATABASE
Data Collection Form

Rep Id 122 BENDER, KAREN P

Contact WESF-CONNEX BOX 2

Facility Id	Rep Loc	Detailed Location	MSDS	Name	Local Name	Cntnr	Size	UOM	Container Type	Base Inv Id	Qty	UOM	Qty Used	Previous Quantity	UOM
2258	CONEX	CONNEX BOX 2	10179	ABSORBS-IT		9	50	LBS	BAG	8389	8	50 LB	0	400	LBS
			27610	FIRST STEP SEALER		10	5	GAL	PLASTIC BUCKET OR PAIL	15058	1	5 GAL	0	5	GAL

HMID222A

HAZARDOUS MATERIAL INVENTORY DATABASE
Data Collection Form

Rep Id 122 BENDER, KAREN P

Contact WESF-FLAM CAB 5

Facility Id	Rep Loc	Detailed Location	MSDS	Name	Local Name	Cntnr	Size UOM	Container Type	Base Inv Id	Qty	UOM	Qty Used	Previous Quantity UOM
225B	2AMU	FLAM CAB 5	33117	KLEERSHIELD CONC - 1/55 GAL	HI SHEEN GLASS CLEAN	11	1 GAL	PLASTIC BOTTLES OR JUGS	10528	2	1GAL	0	2 GAL
			11702	ND-150 CLEANER		12	16 FLOZ	PLASTIC SPRAY BOTTLE	17805	1	16 FL OZ	0	16 FLOZ
			16976	NEOLUBE NO. 1 DRY FILM CONDUCTIVE LUBRICANT		13	16 WTOZ	CAN	4645	1	16 OZ	0	16 WTOZ
			22539	TRAFFIC PASTE WAX		14	5 LBS	METAL PAINT CAN	9689	1	5 LB	0	5 LBS
			16360	ZERACOL	SOLVENT ALCOHOL	15	5 GAL	CAN	298	2	5 GAL	0	10 GAL

HMI0222A

HAZARDOUS MATERIAL INVENTORY DATABASE
Data Collection Form

Rep Id 122 BENDER, KAREN P

Contact WESF-OPS GALLERY

Facility Id	Rep Loc	Detailed Location	MSDS	Name	Local Name	Cntnr	Size UOM	Container Type	Base Inv Id	Qty	UOM	Qty Used	Previous Quantity UOM
225B	OPSGL	STORAGE CABINET	31481	GLANCE RTU		16	32 FLOZ	PLASTIC BOTTLES OR JUGS	14467	0	0	0	0 FLOZ
			31480	GO-GETTER READY-TO-USE		17	32 FLOZ	PLASTIC BOTTLES OR JUGS	14468	0	0	0	0 FLOZ
			13324	TIDE		18	49 WTOZ	FIBER/CARDBOARD BOX	8814	1	49oz	0	49 WTOZ

HMID222A

Many of the products listed are household cleaning products.

1 window cleaner

2 window cleaner

3 resin used in the ion exchange column to maintain pool cell water quality located in pool cell 11. This exact resin may not be used in the future. But any resin used must be strong acid (hydrogen form), strong base (hydroxide form), and be low Cl^-.

4 toilet bowl cleaner sometimes used when decontaminating.

5 $NaNO_3$ is the formula for sodium nitrate.

6 floor cleaner

7 Na_3PO_4 is the formula for trisodium phosphate. This product is received in crystal form and mixed with water and typically heated for a decontaminating agent. A 0.4 wt% mixture is the typical concentration used with a maximum of a 1 wt% solution. A full tank batch is 600 gallons. (a good degreaser or "soap")

8 kitty litter type absorbent

9 kitty litter type absorbent

10 a sealer used before waxing after the floor has been striped

11 glass cleaner

12 degreaser

13 lubricant used during wire pulls

14 floor wax

15 solvent alcohol

16 all purpose cleaner

17 all purpose cleaner

18 laundry soap

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APPENDIX E - Pool Cell Building Structural Evaluation For Drain Accident Thermal Conditions

This appendix contains:

1. Internal Memorandum from Ray Vollert to B. E. Hey dated March 18, 1996, "WESF Pool Cell building Structural Evaluation for Drain Accident Thermal Conditions," 74E30-96-FRV-019, Westinghouse Hanford Company, Richland, WA.

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Westinghouse Hanford Company **Internal Memo**

From: TWRS Design Basis Equipment Engineering 74E30-96-FRV-019
Phone: 376-9842 H5-09
Date: March 18, 1996
Subject: WESF POOL CELL BUILDING STRUCTURAL EVALUATION FOR DRAIN ACCIDENT THERMAL CONDITIONS

To: B. E. Hey A3-34

cc: W. W. Jenkins S2-24
K. A. Jennings-Mills S4-70
L. E. Johnson A2-25
K. V. Scott H5-52
FRV File/LB

References:

1) Report, Fauske & Associates for WHC, *Thermal Analyses of Hypothetical WESF Pool Drain Accidents* (Draft), February 1996.

2) ACI-216, American Concrete Institute Committee 216, *Standard Method for Determining Fire Endurance of Concrete and Masonry Construction Assemblies* (Draft), Detroit, Michigan, 1995.

3) Book; American Standards for Testing Materials, Chapter E 119, *Standard Fire Test*, Philadelphia, Pennsylvania, 1982.

The results of the Thermal Analyses of Hypothetical Waste Encapsulation and Storage Facility Pool Drain Accidents (Reference 1) have been reviewed. The purpose is to assess the potential structural effects of temperature conditions predicted for the capsule storage reinforced concrete pool cell building. Specifically, for the four cell drain analysis cases, estimates of whether the structure could be expected to continue to confine radioactive releases from potentially failed capsules, and for how long.

The thermal analyses (Reference 1, Table 5-4) predicts maximum temperatures in the pool cell floor to be 648° C for the most severe case, and 230° C for the least severe. The approach for assessing the possible structural effects was to compare the predicted temperature histories in the cells and building to structural temperatures that would be the result of fire exposure. The fire endurance of the pool cell building was preliminarily evaluated. The estimates whether the structure could continue to provide confinement were made based on these results.

This assessment, based on fire endurance, of the pool cell structural effects due to the hypothetical elevated temperatures in the pool cell building was made using the American Concrete Institute (ACI) 216 method for determining fire endurance of concrete (Reference 2).

B. E. Hey
Page 2
March 18, 1996

74E30-96-FRV-019

Generally, the pool cell building walls are 12 inch thick reinforced concrete. There is 3/4 inch minimum concrete cover on the reinforcing steel. Based on those values, the minimum fire endurance for the building, according to ACI 216, is 4 hours. Also, according to ACI 216, concrete compressive strength is quickly lost above 350° C, and the yield strength of the reinforcing steel reduces significantly above 400° C. ACI 216 provides American Society for Testing and Materials E 119 (Reference 3) standard fire test conditions (temperatures) within concrete slabs. These data show that after 1 hour fire test time the temperature is 350° C about 1 to 1-1/2 inch in from the fire exposed surface. For this assessment it is presumed that if the pool cell wall temperatures approach this value, the structure will quickly exceed its fire endurance, and could no longer be relied upon to provide confinement.

The thermal analyses results for Case 1, all pool cells drained and no heating, ventilating and air conditioning operation, show that the temperature throughout the interior of the pool cell building reaches 350° C in 5 days. In this event, it is estimated that the structure would not continue to provide confinement.

The thermal analyses results for the remaining 3 cases show the temperature throughout the building to remain considerably below 350° C. Therefore, for those cases as predicted, it is estimated that the building would continue to maintain its fire endurance, and provide confinement indefinitely. However, the predicted elevated temperatures, in these 3 cases, for the structure in many locations would degrade the concrete properties. There could be visible structural distress due to degraded concrete properties and temperature gradients. The ability of the building to withstand wind and seismic loads could eventually be greatly reduced. These factors would impede the necessary recovery operations.

Ray Vollert

F. R. Vollert, Principal Engineer
TWRS Design Basis Equipment Engineering

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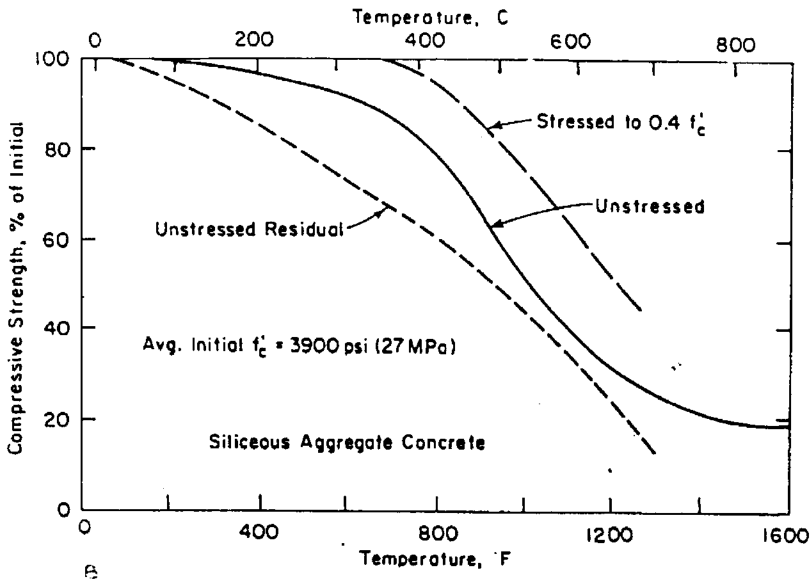

Figure 6. Compressive Strength of Siliceous Aggregate Concrete at High Temperatures and After Cooling.

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APPENDIX F - Ionizing Energy Absorbed by Water for Hydrogen Calculation

This appendix contains:

1. Internal Memorandum from Karl Hillesland to B. E. Hey dated March 13, 1996, "Energy Absorbed in the Water of a Maximally Loaded WESF Capsule Storage Pool," 8M730-KEH-96-002, Westinghouse Hanford Company, Richland, WA.

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Westinghouse Hanford Company **Internal Memo**

From: Nuclear Physics and Shielding 8M730-KEH-96-002
Phone: 373-4078 H0-35
Date: March 13, 1996
Subject: ENERGY ABSORBED IN THE WATER OF A MAXIMALLY LOADED WESF CAPSULE STORAGE POOL

To: B. E. Hey A3-34

cc: J. R. Brehm A2-25
J. Greenborg H0-35
A. L. Ramble A3-38*
*w/o attachment
KEH File/LB

References:

1. L. L. Carter, "Certification of MCNP Version 4A for WHC Computer Platforms", SD-MP-SWD-30001, Rev. 7, dated January 26, 1995.

2. B. E. Hey, "Supporting Calculations and Assumptions for Use in WESF Interim Safety Basis", WHC-SD-WM-TI-733, DRAFT, dated February 16, 1996.

3. Internal Memo, K. E. Hillesland to J. M. Siemer, "Dose Rate Calculations Near the WESF Facility Due to Loss of Water In the Capsule Storage Pools", dated November 29, 1994.

4. F. A. Schmittroth, "Conversion of ORIGEN2 to the Sun Workstations," WHC-SD-NR-SWD-006, Rev. 1, August 1994.

5. E. Browne, and R. B. Firestone, "Table of Radioactive Isotopes", John Wiley & Sons, Inc., New York, New York, 1986.

1.0 PURPOSE

The amount of gamma energy absorbed in the water of a maximally loaded WESF capsule storage pool has been calculated to be 1.33E+17 MeV/s (21 kW). This information will be used to determine the amount of hydrogen generated in the pool water due to radiolysis.

2.0 METHODOLOGY

The MCNP computer code (Reference 1) was used to calculate the amount of gamma energy absorbed in the WESF capsule storage pool water using an f6 (energy deposition) tally.

3.0 SOURCE

The total source activity is 28.6 MCi of Cs-137 (Reference 2). This corresponds to 663 cesium capsules with an average activity of 39.19 kCi plus and additional 10 percent safety margin. Only the .662 MeV gamma of the Cs/Ba decay was considered. Beta and lower energy gamma (x-ray) radiations, constituting approximately 30 percent of the total energy produced, are assumed to be absorbed within the capsule, and are therefore neglected from this analysis.

4.0 GEOMETRY

The MCNP input file is provided in Attachment 1. The MCNP model was developed from a model used in a previous analysis (Reference 3). The pools are 18 ft (5.48 m) deep and are separated from one another by 15 ft (4.57 m) high walls. The width of the pool is 4 ft 5 in (135 cm). The capsules are each 20.8 in (52.8 cm) tall, and sit approximately 8.2 in (20.8 cm) off the bottom of the pool in three separate racks. The water is 13 ft (3.96 m) deep. Concrete was modeled with a density of 2.35 g/cc, and water at 1.0 g/cc.

The capsules consist of CsCl salt encased in steel. They were modeled with an outside diameter of 2.6 in (6.7 cm), and a height of 20.8 in (52.8 cm). The thickness of steel at each end of the capsule was modeled as 0.79 in (2 cm), and the side thickness as .24 in (0.6 cm), including both inner and outer capsules. The thicknesses of the steel are based on dimensions given in Reference 2. The model assumed 2.5 kg CsCl and 5.9 kg 316 SST in each capsule, corresponding to the averages given by the Encapsulation Database System (EDS) maintained by WESF engineering.

Each pool contains racks for storing the capsules in arrays of 13 x 17, 13 x 21 and 13 x 13 capsules. This amounts to 663 capsules in a maximally loaded pool. The capsules are spaced at 3.75 in (9.5 cm) intervals within each rack.

B. E. Hey
Page 3
February 13, 1996

8M730-KEH-96-002

5.0 RESULTS

Table 1 below shows the average amount of gamma energy absorbed in each material per .662 MeV gamma emitted.

Table 1. Gamma Energy Absorbed in Each Material for a .662 MeV Photon

Material	Energy Absorbed (MeV)	Uncertainty[1]
cesium chloride salt	.257	.76 %
steel casing	.241	.83 %
water	.148	1.4 %
concrete	.020	5.4 %

[1]This is the one standard deviation statistical uncertainty given by MCNP.

For 28.6 MCi of Cs-137 this amounts to a total of 1.33E17 MeV/s (21 kW) absorbed in the water, based on a .946 branching ratio for decay from Cs-137 to Ba-137m (ORIGEN2 database, Reference 4) and a .901 abundance of the .662 MeV gamma in the decay of Ba-137m (Reference 5).

6.0 ARCHIVAL

The input and output files are stored with this report on a DOS formatted 3.5 inch floppy. The MCNP input and output file names are heat.inp and heat.out respectively. Attachment 1 is a source listing of the MCNP input file.

K E Hillesland

K. E. Hillesland, Engineer
Nuclear Physics and Shielding

Concurrence: J. Greenborg
J. Greenborg, Manager

llp

Attachment

MCNP Input File Listing

```
WESF Facility, 13 feet of water in pool 7
c   Energy absorption calculation
   1     1  -0.0012  -3 -5 1 4 6 -7 210
 301     5  -1.0000  -3 -5 4 6 -7 -210
   2     1  -0.0012  1 -3 -7 6 8 -9 210
 302     5  -1.0000  1 -3 -7 6 8 -9 -210
   3     1  -0.0012  1 -3 -7 6 10 -11 210
 303     5  -1.0000  1 -3 -7 6 10 -11 -210
   4     1  -0.0012  -3 1 6 -7 12 -13 210
 304     5  -1.0000  -3 1 6 -7 12 -13 -210
   5     1  -0.0012  -3 1 -7 6 14 -15 210
 305     5  -1.0000  -3 1 -7 6 14 -15 -210
   6     1  -0.0012  -3 1 -7 6 16 -17 210
 306     5  -1.0000  -3 1 -7 6 16 -17 -210
   7     1  -0.0012  -3 1 -7 6 18 -19 308
 751     5  -1.0000  -7 6 18 -19  307 -308 $ 13
 750     2  -2.3500  -31 298 -44 33 274 -28
 749     5  -1.0000  -7 6 18 -19  306 -307 $ 12
 748     5  -1.0000  -7 6 18 -19  305 -306 $ 11
 747     2  -2.3500  -31 298 -44 33 273 -274
 746     2  -2.3500  17 -18 -3 6 -7 306 -308
 745     2  -2.3500  19 -20 -3 6 -7 306 -308
 744     5  -1.0000  -7 6 18 -19  304 -305 $ 10
 743     2  -2.3500  17 -18 -3 6 -7 305 -306
 742     2  -2.3500  19 -20 -3 6 -7 305 -306
 741     5  -1.0000  -7 6 18 -19  303 -304 $ 9
 740     2  -2.3500  -31 298 -44 33 272 -273
 739     2  -2.3500  17 -18 -3 6 -7 304 -305
 738     2  -2.3500  19 -20 -3 6 -7 304 -305
 737     5  -1.0000  -7 6 18 -19  302 -303 $ 8
 736     2  -2.3500  17 -18 -3 6 -7 303 -304
 735     2  -2.3500  19 -20 -3 6 -7 303 -304
 734     5  -1.0000  -7 6 18 -19  301 -302 $ 7
 733     2  -2.3500  -31 298 -44 33 271 -272
 732     2  -2.3500  17 -18 -3 6 -7 302 -303
 731     2  -2.3500  19 -20 -3 6 -7 302 -303
 730     5  -1.0000  -7 6 18 -19  300 -301 $ 6
 729     2  -2.3500  17 -18 -3 6 -7 301 -302
 728     2  -2.3500  19 -20 -3 6 -7 301 -302
 727     5  -1.0000  -7 6 18 -19  #771 #772 #773 299 -300 $ 5
 726     2  -2.3500  -31 298 -44 33 7 -271
 725     2  -2.3500  17 -18 -3 6 -7 300 -301
 724     2  -2.3500  19 -20 -3 6 -7 300 -301
 723     5  -1.0 (205:-206:209) 211 u=5
 722     5 -1.0 211 u=4
 721     3  -8.40 -205 206 -209 (204:-207:208) u=5  $ Steel casing
 720     5  -1.0000  -7 6 18 -19  #771 #772 #773 298 -299 $ 4
 719     2  -2.3500  17 -18 -3 6 -7 299 -300
 718     2  -2.3500  19 -20 -3 6 -7 299 -300
 717     5  -1.0 (205:-206:209) 212 -211 u=5
 716     5 -1.0 212 -211 u=4
 205     6 -2.16 -204 207 -208 u=5      $ CsCl
 715     5  -1.0000  -7 6 18 -19  #771 #772 #773 297 -298 $ 3
 714     2  -2.3500  17 -18 -3 6 -7 298 -299
 713     2  -2.3500  19 -20 -3 6 -7 298 -299
 712     5  -1.0 (205:-206:209) 213 -212 u=5
 711     5 -1.0 213 -212 u=4
 710     5  -1.0000  -7 6 18 -19  #771 #772 #773 296 -297 $ 2
 709     2  -2.3500  17 -18 -3 6 -7 297 -298
 708     2  -2.3500  19 -20 -3 6 -7 297 -298
 707     5  -1.0 (205:-206:209) 214 -213 u=5
 706     5 -1.0 214 -213 u=4
 705     5  -1.0000  1 -7 6 18 -19  #771 #772 #773 -296 $ 1
 704     2  -2.3500  17 -18 -3 6 -7 1 -297
 703     2  -2.3500  19 -20 -3 6 -7 1 -297
 702     5  -1.0 (205:-206:209) -214 u=5
 701     5 -1.0 -214 u=4
   8     1  -0.0012  -3 1 -7 6 20 -21 210
 308     5  -1.0000  -3 1 -7 6 20 -21 -210
   9     1  -0.0012  -3 1 -7 6 22 -23 210
 309     5  -1.0000  -3 1 -7 6 22 -23 -210
  10     1  -0.0012  -3 1 -7 6 24 -25 210
 310     5  -1.0000  -3 1 -7 6 24 -25 -210
```

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 11     1  -0.0012  -3 1 -7 6 26 -27 210
311     5  -1.0000  -3 1 -7 6 26 -27 -210
 12     1  -0.0012  -31 30 28 -29 33 -32
 13     1  -0.0012  35 -36 -34 38 40 -41
 14     1  -0.0012  37 -31 -34 38 -41 40
 15     1  -0.0012  3 -31 6 -7 -27 4
 16     1  -0.0012  (43 -41 34 -29 35 -36 )(44 :28 )
 17     1  -0.0012  (34 -41 43 -29 37 -31 )(44 :28 )
 18     1  -0.0012  -46 47 -50 38 -49 48
 19     1  -0.0012  -52 48 46 -45 38 -51
 20     1  -0.0012  -55 38 53 -40 54 -49
 21     1  -0.0012  40 -49 31 -41 38 -50
 22     2  -2.3500  5 -8 -3 1 -7 6
 23     2  -2.3500  9 -10 -3 1 -7 6
 24     2  -2.3500  11 -12 -3 1 6 -7
 25     2  -2.3500  -3 1 6 -7 13 -14
 26     2  -2.3500  -16 15 -3 1 6 -7
 27     2  -2.3500  17 -18 -3 6 -7 308
 28     2  -2.3500  19 -20 -3 6 -7 308
 29     2  -2.3500  21 -22 -3 1 6 -7
 30     2  -2.3500  23 -24 -3 1 6 -7
 31     2  -2.3500  -26 25 -3 1 6 -7
 32     2  -2.3500  27 -44 6 -7 -31 1
 33     2  -2.3500  -298 7 -28 2 -44 33
 34     2  -2.3500  -6 -31 34 2 -44 40
 35     2  -2.3500  2 -1 -7 6 -44 63
 36     2  -2.3500  28 -29 -30 2 33 -32
 37     2  -2.3500  29 -31 -50 2 33 -41
 38     2  -2.3500  -37 36 -34 38 40 -41
 39     2  -2.3500  -35 2 38 -34 40 -41
 42     2  -2.3500  (36 -37 -29 34 43 -41 )(28 :44 )
 44     2  -2.3500  (34 -35 2 -29 43 -41 )(44 :28 )
 47     1  -0.0012  53 -40 -49 31 55 -50
 48     2  -2.3500  (-52 2 -51 38 45 -40 )(80 :-79 :78 :-31 )
 49     2  -2.3500  52 -54 53 -40 -55 38
 50     2  -2.3500  -55 51 -40 46 -52 61
 51     2  -2.3500  55 -50 -53 46 -49 61
 53     2  -2.3500  -48 61 -46 47 38 -50
 55     2  -2.3500  63 -4 -31 1 6 -7
 57     4  -1.5000  38 -61 -50 2 -53 62
 58     4  -1.5000  (-126 2 -64 )(58 :56 :-62 :-57 )
 59     2  -2.3500  -29 28 -43 32 -31 2
 60     2  -2.3500  70 -33 7 -50 2 -31
 61     2  -2.3500  -53 46 52 -49 -55 38
 62     2  -2.3500  ((71 -31 6 -63 -50 53 )(-7 :-70 ))(40 :55 )
 63     2  -2.3500  -48 61 46 -45 -51 38
 64     4  -1.5000  ((61 -71 6 -63 -50 53 )(-7 :-70 ))(40 :55 )
 65     4  -1.5000  ((53 -63 6 -50 2 -61 )(40 :51 ))(-7 :-70 )
 66     4  -1.5000  -45 -51 38 53 -61 2
 69     1  -0.0012  48 72 -74 -73 57 -38
 70     1  -0.0012  -77 -75 76 48 57 -38
 71     1  -0.0012  79 -80 31 -78 45 -40
 72     1  -0.0012  -82 -80 81 31 50 -56
 73     1  -0.0012  -84 85 83 -86 -56 50
 74     1  -0.0012  -87 31 88 -80 50 -56
 75     1  -0.0012  -80 90 -89 31 -58 41
 76     1  -0.0012  (-99 91 -95 103 64 -107 )(58 :56 :-62 :-57 )
 77     1  -0.0012  (-100 92 104 -96 64 -107 )(99 :-91 :-103 :95 )
 78     1  -0.0012  (-93 -107 64 )(100 :96 :-104 :-92 )
 79     1  -0.0012  (-94 64 -107 ) 93
 80     1  -0.0012  (-93 107 -108 (-57 :58 :56 :-62 :59 ))
           (114 :-115 :56 :-62 :116 )
 81     1  -0.0012  (-94 -108 107 ) 93
 82     1  -0.0012  108 -69 -93
 83     1  -0.0012  (108 -69 -94 ) 93
 84     1  -0.0012  ((64 -69 -65 )( 94 ))(-107 )
 85     1  -0.0012  -109 110 47 -50 59 -111
 86     1  -0.0012  112 110 -113 -50 59 -111
 88     2  -2.3500  109 -112 -111 59 -50 110
 93     2  -2.3500  ((((50 -56 -49 2 -41 62 )(82 :-81 :80 :-31 ))
           (-85 :86 :84 :-83 ))(87 :-88 :-31 :80 ))(-119 )
 94     2  -2.3500  ((((50 -56 -49 2 -41 62 )(82 :-81 :80 :-31 ))
           (-85 :86 :84 :-83 ))(87 :-88 :-31 :80 ))(119 )
 95     2  -2.3500  (((57 -38 -49 2 62 -41 )(-72 :73 :74 :-48 ))
           (-48 :77 :-76 :75 ))(118 )
 96     2  -2.3500  (((57 -38 -49 2 62 -41 )(-72 :73 :74 :-48 ))
```

```
               (-48 :77 :-76 :75 ))(-118 )
97       2  -2.3500  ((-58 41 -49 2 -56 57 )(-31 :80 :89 :-90 ))(-117 )
98       2  -2.3500  ((-58 41 -49 2 -56 57 )(-31 :80 :89 :-90 ))117
99       2  -2.3500  (-59 49 57 -58 -56 62 )(-121 )
100      2  -2.3500  (-59 49 57 -58 -56 62 )(121 )
101      2  -2.3500  (62 -47 -49 61 -50 38 )(120 )
102      2  -2.3500  (62 -47 -49 61 -50 38 )(-120 )
103      2  -2.3500  (62 -47 -50 110 59 -111 )(120 )
104      2  -2.3500  (62 -47 -50 110 59 -111 )(-120 )
105      2  -2.3500  (113 -114 -50 110 59 -111 )(-125 )
106      2  -2.3500  (113 -114 -50 110 59 -111 )(125 )
107      1  -0.0012  -56 50 62 -114 59 -111
109      2  -2.3500  (115 -110 -111 59 62 -114 )(124 )
110      2  -2.3500  (115 -110 -111 59 62 -114 )(-124 )
111      2  -2.3500  (111 -116 62 -114 -56 115 )(-123 )
112      2  -2.3500  (111 -116 62 -114 -56 115 )(123 )
113      1  -0.0012  (-126 64 -107 )( 65 )
114      1  -0.0012  (107 -108 -65 )( 94 )
115      1  -0.0012  (107 -108 -126 )( 65 )
116      1  -0.0012  (108 -69 -65 )( 94 )
117      1  -0.0012  (-69 108 -126 )( 65 )
201      0  -200 201 -202 203 lat=1 u=1 fill=-1:21 -1:13 0:0
            4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
            4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
202      0  -200 201 -202 203 lat=1 u=2 fill=-1:21 -1:13 0:0
            4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
203      0  -200 201 -202 203 lat=1 u=3 fill=-1:13 -1:13 0:0
            4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
            4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
771      0  -701 700 -703 702 704 -705  trcl=771
         fill=1
772      0  -701 700 -703 702 704 -705  trcl=772
         fill=2
773      0  -706 700 -703 702 704 -705  trcl=773
         fill=3
900      0  -2 :69 :126
```

```
      1   pz  -487.68
      2   pz  -548.64
c     3   pz   22.86  Old model 16' 9" deep pits
      3   pz  -30.48  $ 15' deep pits
      4   py  0.0000
      5   py   266.7
      6   px  0.0000
      7   px  662.94
    271   px  668.94
    272   px  674.94
    273   px  680.94
    274   px  686.94
      8   py  297.18
      9   py   431.8
     10   py  462.28
     11   py   596.9
     12   py  627.38
     13   py  762.0000
     14   py  792.48
     15   py   927.1
     16   py  957.58
     17   py  1092.2
     18   py  1122.68
     19   py  1257.3
     20   py  1287.78
     21   py  1422.4
     22   py  1452.88
     23   py  1587.5
     24   py  1617.98
     25   py  1752.6
     26   py  1783.08
     27   py  1917.7
     28   px  693.42
     29   px  784.86
     30   pz  -411.48
     31   pz   60.96
     32   py  1865.63
     33   py  -113.03
     34   px  -30.48
     35   pz  -495.3
     36   pz  -121.92
     37   pz  -91.44
     38   px  -259.08
     40   py  -142.24
     41   py  2026.92
     43   py  1896.11
     44   py  1948.18
     45   py  -162.56
     46   py  -330.2
     47   py  -708.66
     48   pz   15.24
     49   pz  476.25
     50   px  853.44
     51   px  287.02
     52   pz  297.18
     53   py  -304.8
     54   pz  312.42
     55   px  307.34
     56   px  883.92
     57   px  -289.56
     58   py  2052.3
     59   pz  486.41
     61   pz   -5.08
     62   py  -739.14
     63   py   -50.8
     64   pz  0.0000
     65   c/z 297.18 656.58 20000
     69   pz  30000.0000
     70   py  -143.51
     71   pz   30.48
     72   py  -697.23
     73   py  -361.95
     74   pz  447.04
     75   py  -177.8
     76   py  -269.24
     77   pz   228.6
```

```
  78        px  271.78
  79        px  180.34
  80        pz  274.32
  81        py  -693.42
  82        py  -510.54
  83        py  449.58
  84        py   571.5
  85        pz  223.52
  86        pz  345.44
  87        py  1231.9
  88        py  1109.98
  89        px   838.2
  90        px  746.76
  91        px  -789.56
  92        px  -1289.56
  93        c/z 297.18 656.58 5000
  94        c/z 297.18 656.58 10000
  95        px  1383.92
  96        px  1883.92
  99        py  2552.3
 100        py  3052.3
 103        py  -1239.14
 104        py  -1739.14
 107        pz  200.0000
 108        pz  15000.0000
 109        py   -7.62
 110        px  312.42
 111        pz  1224.28
 112        py   30.48
 113        py  678.18
 114        py  708.48
 115        px  281.94
 116        pz  1235.71
 117        py  2039.61
 118        px  -274.32
 119        px  868.68
 120        py  -723.9
 121        pz  481.33
 123        pz  1229.995
 124        px  297.18
 125        py  693.33
 126        c/z 297.18 656.58 30000
 200        px  9.5
 201        px  0.00
 202        py  9.5
 203        py  0.00
 204        c/z 4.75 4.75 2.75
 205        c/z 4.75 4.75 3.35
 206        pz 0.00
 207        pz 2.00
 208        pz 50.8
 209        pz 52.8
 210        pz -121.92
 211  pz 40
 212  pz 28
 213  pz 16
 214  pz 4
 296  1 pz -48
 297  1 pz -36
 298  1 pz -24
 299  1 pz -12
 300  1 pz 0.1
 301  1     pz 12
 302  1     pz 24
 303  1     pz 36
 304  1 pz 48
 305  1 pz 60
 306  1 pz 72
 307  1 pz 84
c 308  1 pz 91.44
 308  1 pz 343.44
 700        px     -0.1
 701        px  200.125
 702        py     -0.1
 703        py  122.655
 704        pz     -0.1
```

```
c 705         pz  51.154
  705         pz  52.83
  706         px  123.925
c      tally surfaces
 1000         px  403

tr1    0 0 -414.025     $ top of pins
tr771  34.6163 1128.6100 -466.8250
tr772  269.4580 1128.6100 -466.8250
tr773  504.2990 1128.6100 -466.8250
mode   p
c    MATERIALS ***********
m1       8000      .21        $O air number fraction
         7000      .79        $N
m2       8000     -.4407      $O concrete weight fraction
        14000     -.2157      $Si
        20000     -.1306      $Ca
        26000     -.0788      $Fe
        13000     -.0607      $Al
        12000     -.0376      $Mg
        19000     -.0066      $K
        11000     -.0182      $Na
        22000     -.0049      $Ti
         1000     -.0031      $H
        25000     -.0013      $Mn
        15000     -.0009      $P
        16000     -.0009      $S
m3      26000     1.0         $Fe iron
m4      14000      .2813      $Si  hanford soil number fraction
         8000      .6556      $O
        13000      .0123      $Al
        26000      .0084      $Fe
        20000      .0149      $Ca
        12000      .0103      $Mg
        19000      .0022      $K
        11000      .0034      $Na
         1000      .0116      $H
m5      1000 1  8000 1        $Water
m6      55000 1  17000 1      $CsCl
c SOURCE *******
c       28.6MCi Cs * 3.7e10 dis/Ci * .946 Ba/Cs * .901(abundance) = 9.02e17
sdef    cel=d1
        pos=4.75 4.75 0  axs=0 0 1  ext=d3
        rad d4 erg .66166 wgt=1
c       rad d4 erg .66166 wgt=9.02e17
c       End Cs rack
si1 l   771:201(4 0 0):205  771:201(5 0 0):205
        771:201(6 0 0):205  771:201(7 0 0):205  771:201(8 0 0):205
        771:201(9 0 0):205  771:201(10 0 0):205  771:201(11 0 0):205
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        773:203(12 11 0):205
        773:203(0 12 0):205  773:203(1 12 0):205  773:203(2 12 0):205
        773:203(3 12 0):205  773:203(4 12 0):205  773:203(5 12 0):205
        773:203(6 12 0):205  773:203(7 12 0):205  773:203(8 12 0):205
        773:203(9 12 0):205  773:203(10 12 0):205  773:203(11 12 0):205
        773:203(12 12 0):205
sp1     1 662r
si3     2.00 50.8
si4     0 2.75
imp:p
c         1 301 2 302 3 303 4 304 5 305 6 306 7
          1   1 1   1 1   1 1   1 1   1 1   1 1
c         751
            1
c         750 749 748 747 746 745 744 743 742 741
            r   r   r   r   r   r   r   r   r   r
c         740 739 738 737 736 735 734 733 732 731
            r   r   r   r   r   r   r   r   r   r
c         730 729 728 727 726 725 724 723 722 721
            r   r   r   r   r   r   r   r   r   r
c         720 719 718 717 716 205 715 714 713 712 711
            r   r   r   r   r   r   r   r   r   r   r
c         710 709 708 707 706 705 704 703 702 701
            r   r   r   r   r   r   r   r   r   r
c         8 308 9 309 10 310 11 311
          1   1 1   1  1   1  1   1
c        12  13  14 15   16  17  18  19  20
          1 8r
```

```
c       21  22  23  24  25  26  27  28  29  30
         1 9r
c       31  32  33  34  35  36  37  38  39
         1   1   1   1   1   1   1   1   1
c           42      44          47  48  49  50
             1       1           1   1   1   1
c       51      53      55      57  58  59  60
         1       1       1       1   1   1   1
c       61  62  63  64  65  66          69  70
         1   1   1   1   1   1           1   1
c       71  72  73  74  75  76  77  78  79  80
         1   1   1   1   1   4   4   4   0   4
c       81  82  83  84  85  86      88
         0   0   0   0   0   4       4
c               93  94  95  96  97  98  99 100
                 2   4   2   4   2   4   2   4
c      101 102 103 104 105 106 107     109 110
         4   4   4   4   4   4   4       4   4
c      111 112 113 114 115 116 117
         4   6   0   0   0   0   0
c      201 202 203
         1   1   1
c      771 772 773
        1 2r
c      900
       0
fc6     MeV absorbed in water
f6:p    (701 702 705 706 707 710 711 712 715 716 717 720 722
         723 727 730 734 737 741 744 749 748 751)
sd6      1
fc16    MeV absorbed in steel casing
f16:p   721
sd16     1
fc26    MeV absorbed in CsCl
f26:p   205
sd26     1
fc36    MeV absorbed in concrete
f36:p   (750 747 746 745 743 742 738 739 740 735 736
         731 732 733 728 729 724 725 726 718 719 713 714
         708 709 703 704 22 23 24 25 26 27 28 29 30 31 32
         33 34 35 36 37 38 39 42 44 48 49 50 51 53 55
         59 60 61 62 63 93 94 95 96 97 98 99 100 101 102
         103 104 105 106 109 110 111 112)
sd36     1
fc46    MeV absorbed in dirt
f46:p   (57 58 64 65 66)
sd46     1
fc56    MeV absorbed in other water
f56:p    (301 302 303 304 305 306 308 309 310 311)
sd56     1
nps     10000
print 10 126 150 160 170
```

CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

DOCUMENT REVIEWED Energy Absorbed in the Water of a Maximally Loaded WESF Capsule Storage Pool

AUTHOR(s) K E Hillesland

I. Method(s) of Review

- (✓) Input data checked for accuracy
- ( ) Independent calculation performed
  - ( ) Hand calculation
  - ( ) Alternate computer code: ______
- ( ) Comparison to experiment or previous results
- ( ) Alternate method (define) ______

II. Checklist (either check or enter NA if not applied)

- (✓) Task completely defined
- (✓) Activity consistent with task specification
- (✓) Necessary assumptions explicitly stated and supported
- (✓) Resources properly identified and referenced
- (✓) Resource documentation appropriate for this application
- (✓) Input data explicitly stated
- (✓) Input data verified to be consistent with original source
- (✓) Geometric model adequate representation of actual geometry
- (✓) Material properties appropriate and reasonable
- (✓) Mathematical derivations checked including dimensional consistency
- (✓) Hand calculations checked for errors
- (✓) Assumptions explicitly stated and justified
- (✓) Computer software appropriate for task and used within range of validity
- (NA) Use of resource outside range of established validity is justified
- (✓) Software runstreams correct and consistent with results
- (✓) Software output consistent with input
- (NA) Results consistent with applicable previous experimental or analytical findings
- (✓) Results and conclusions address all points and are consistent with task requirements and/or established limits or criteria
- (NA) Conclusions consistent with analytical results and established limits
- (✓) Uncertainty assesment appropriate and reasonable
- ( ) Other (define)

______

______

III. Comments:

______

______

IV. REVIEWER: Victor Rotman DATE: 12 March 1996

APPENDIX G - Shielding Calculations

This appendix contains:

1. Internal Memorandum from Karl Hillesland to J. M. Siemer dated November 29, 1994, "Dose Rate Calculations Near the WESF Facility Due to Loss of Water in the Capsule Storage Pools," KEH-8D150-94-001, Westinghouse Hanford Company, Richland, WA.

2. Internal Memorandum from Karl Hillesland to B. E. Hey dated February 13, 1996, "Dose Rate in the WESF Capsule Storage Control Room Due to Loss of Water in a Maximally Loaded Pool," 8M730-KEH-96-001, Westinghouse Hanford Company, Richland, WA.

3. Internal Memorandum from Karl Hillesland to B. E. Hey dated June 3, 1996, "Dose Rates Due to Partial and Complete Loss of Water in a Maximally Loaded WESF Capsule Storage Pool," 8M730-KEH-96-003, Westinghouse Hanford Company, Richland, WA.

4. MicroShield 4.00 output entitled "1 Ci Cs-137, Dist.=4m, Shield=20in Normal Concrete," DOS File 4M20IN.MS4. Used to estimate exposure above K-3 Filter Pit.

5. MicroShield 4.00 output entitled "1 Ci Cs-137, Dist.=4m, Shield=24in Normal Concrete," DOS File 4M24IN.MS4. Used to estimate exposure above TK-100 Pit.

6. MicroShield 4.00 output entitled "Dose Rate Outside Hot Cell w/ 24 Capsules," DOS File HCWALL.MS4. Used to estimate exposure outside hot cell containing 24 capsules.

7. MicroShield 4.00 output entitled "Dose Rate Above Capsule Storage Pool with 156 in Water," DOS File POOL156.MS4. Used to estimate exposure above capsule storage pool with 156 in water level.

8. MicroShield 4.00 output entitled "Dose Rate Above Capsule Storage Pool with 110 in Water," DOS File POOL110.MS4. Used to estimate exposure above capsule storage pool with 110 in water level.

9. MicroShield 4.00 output entitled "Dose Rate Above Capsule Storage Pool with 100 in Water," DOS File POOL100.MS4. Used to estimate exposure above capsule storage pool with 100 in water level.

10. MicroShield 4.00 output entitled "Dose Rate Above Capsule Storage Pool with 95 in Water," DOS File POOL95.MS4. Used to estimate exposure above capsule storage pool with 95 in water level.

11. MicroShield 4.00 output entitled "Dose Rate Above Capsule Storage Pool with 64 in Water," DOS File POOL64.MS4. Used to estimate exposure above capsule storage pool with 64 in water level.

12. MicroShield 4.00 output entitled "Dose Rate Above Capsule Storage Pool with 36 in Water," DOS File POOL36.MS4. Used to estimate exposure above capsule storage pool with 36 in water level.

13. MicroShield 4.00 output entitled "Dose Rate Above Capsule Storage Pool

with 28 in Water," DOS File POOL28.MS4. Used to estimate exposure above capsule storage pool with 28 in water level.

14. MicroShield 4.00 output entitled "Dose Rate Above Capsule Storage Pool with no water," DOS File POOLDRY.MS4. Used to estimate exposure above capsule storage pool with no water.

15. MicroShield 4.00 output entitled "Dose Rate Above Capsule Storage Pool with no water and coverblocks in place," DOS File DRAINP.MS4. Used to estimate exposure above drained capsule storage pool with coverblocks in place.

16. MicroShield 4.00 output entitled "Contact Dose Rate from 3 ft Sphere Containing 1 Ci Cs-137," DOS File BAGWASTE.MS4. Used to estimate curie content of 3 ft diameter waste bag containing equivalent shielding content of carbon at 0.113 g/cc (i.e., 100 lb bag).

17. Requesting DSI to Jennifer Stewart from Tom Gainey for K-3 filter dose calculation.

18. Internal Memorandum from P. D. Rittmann to B. E. Hey dated October 22, 1996, "Estimated Dose Rates for the K3 Filters," Fluor Daniel Northwest, Inc., Richland, WA.

Westinghouse Hanford Company **Internal Memo**

From: Criticality and Radiological Analyses
Phone: 376-9236 H4-64
Date: November 29, 1994
Subject: DOSE RATE CALCULATIONS NEAR THE WESF FACILITY DUE TO LOSS OF WATER IN THE CAPSULE STORAGE POOLS

To: J. M. Siemer H4-66

cc:	J. W. Daughtry	H4-64	J. D. Guberski	R2-06
	B. E. Hey	H4-64	A. L. Ramble	H4-68
	J. P. Hinckley	H4-66	J. C. Van Keuren	H4-64

Reference: L. L. Carter, *Certification of MCNP Version 4A for the WHC Computer Platforms*, ECN-186710, SD-MP-SWD-30001, Rev. 6, January 1994.

1.0 SUMMARY

The WESF capsule storage pools contain a large inventory of cesium and strontium capsules submersed in water. The water acts as an important radiation shield. Dose Rates have been calculated using MCNP (Reference 1) in the event that all the water in the WESF capsule storage pools is lost and the concrete cover blocks are removed. The analysis assumed 55.1 MCi of cesium-137. Strontium capsules were not included in the analysis, as they would not contribute appreciably to dose rates outside the capsule storage area. Two spatial distributions of the source were considered. One calculation assumed all cesium capsules were concentrated towards the center pools. The second calculation assumed the capsules were evenly dispersed amongst all eleven storage pools. Dose rates as a function of distance from the WESF capsule storage area are reported in Table 1. Dose rates in some adjoining sections of the WESF facility are reported in Table 2 and Figure 3.

2.0 GEOMETRY

Only the area of the WESF facility where the storage pools reside was modeled. This includes the pool area, truck port, and the portion of the second floor above the pool area. Figure 1 shows the MCNP model used with the first and second floor ceilings removed for illustrative purposes. The dimensions of the model, including the building, capsules, and storage racks, come from the drawings listed in Attachment B. Attachment C is a sample MCNP input file listing.

Because the model assumes that the cell cover blocks are removed, and there is no water in the pool cells, the primary shielding in terms of dose rates outside the complex is the first floor walls and ceiling. Figure 2 shows various dimensions of the complex. The walls are generally 30.5 cm (1 ft) thick concrete. The ceilings were modeled as 10.1 cm (4 in) concrete. The remainder of the building to the east would provide shielding, and was conservatively left out of the model.

The outside dimensions of each cesium capsule are 6.7 cm (2.6 in) OD x 52.8 cm (20.8 in) length. The capsule itself is made from 316 stainless steel, and is filled with a cesium chloride salt. The total steel thickness at each end of the capsule is 2.0 cm (.8 in), and the total steel thickness at the sides is .6 cm (.24 in).

Each pool has three storage racks for holding the capsules, two cesium racks and one strontium rack. A cesium rack is a 21 x 13 grid measuring 200 cm x 127 cm (6 ft 7 in x 4 ft 2 in). A strontium rack is a 13 x 13 grid measuring 124 cm x 127 cm (4 ft 1 in x 4 ft 2 in). The west and center racks of each pool are cesium racks. The eastern rack of each pool is a strontium rack. The four western most rows of the west cesium rack in each pool are left empty. Although generally restricted to cesium racks, cesium capsules are occasionally placed in strontium racks.

Rather than modeling each capsule within a rack, each rack and its capsules were modeled as a box. The box had dimensions reflecting that of a filled rack. The material of the box was conservatively left void. This setup was necessary because of the unpredictability in how the capsules might be arranged in the racks.

Because the pools are below ground level, the primary source of dose rates to people outside the facility will be due to scattering from air (skyshine). Air was modeled as 79% nitrogen, 21% oxygen by atom fraction at a density of 1200 g/m^3 (STP).

In order to study the effect of meteorology, separate calculations were done using 100% humidity. At 25° C (77° F), 100 kPa (1 atm), 100% relative humidity, there is approximately 24 g water per cubic meter of dry air. The calculations included the following scenarios: 1) the air of the entire area at 100% humidity, 2) a column of 100% humidity air out to a radius of 50 m, 3) a layer of 100% humidity air starting at 50 m elevation (cloud layer).

3.0 SOURCE

The source term consisted of 1370 cesium capsules, amounting to 55.1 MCi of cesium-137 as of 11/1/94. The total curies for this model was based on a total curie content of 51.7 MCi for 1328 uncut cesium capsules as of 4/1/96 as given by the Encapsulation Database System (see attachment A). It was assumed that the 42 cut capsules would have the average curie content of the uncut 1328 capsules if they were to be re-encapsulated. The 55.1 MCi comes from multiplying the 51.7 MCi by a weighing factor of 1370/1328 to include the contents of the cut capsules in the total inventory, and reverse decaying the inventory at 4/1/96 to an inventory at 11/1/94.

The capsules were distributed in two different configurations amongst the pools. One calculation put all the capsules possible in pools 5 and 6 (663 in each) with the remainder divided evenly amongst rack 2 of pools 4 and 7 (center rack used for conservatism). The second calculation divided the 1370 capsules evenly amongst cesium racks in all eleven pools.

The beta particles and low energy bremsstrahlung photons produced by strontium-90 will not penetrate the concrete walls and ceiling of the facility well enough to contribute appreciably to dose rates outside of the capsule storage area. For this reason, the strontium capsules were left out of the analysis.

4.0 RESULTS

Dose rates out to 200 m from the WESF capsule storage area are shown in Table 1. The numbers reported are the highest dose rates calculated in any compass direction for a given distance from the WESF capsule storage area, excluding to the east where the remainder of the WESF facility is located. Dose rates were taken at 5 m and 10 m from the external walls of the capsule storage area and truck port. Dose rates were also taken 50 m, 100 m, and 200 m, measured from the center of the storage area. Table 2 and Figure 3 show dose rates in adjoining sections of the WESF facility.

A number of different scenarios were investigated to find the effects of extreme meteorological conditions on dose rates. There were no significant changes in dose rates observed in any of the scenarios investigated.

Table 1. Upper Bound Dose Rates Outside the WESF Facility

Distance from WESF capsule storage area, in meters	5 m	10	50	100	200
Dose rates (Sv/hr) for capsules in center pools	.4	.4	.1	.04	.008
Dose rates (Sv/hr) for capsules evenly distributed amongst all pools	.4	.4	.1	.04	.007

J. M. Siemer
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Table 2. Dose Rates in Adjoining Sections of the WESF Facility

	Dose rates (Sv/hr) for capsules in center pools	Dose rates (Sv/hr) for capsules evenly distributed amongst all pools
truck port/capsule storage area door	9	30
capsule storage area north door to outside	6	17
changing room door	50	40
west end of canyon (second floor)	.04	5
west end of maintenance area (second floor)	5	50

K E Hillesland
K. E. Hillesland, Rotational Engineer
Criticality and Radiological Analyses

B E Hey
Reviewer: B. E. Hey
Principal Engineer

Attachments

Concurrence: J W Daughtry
J. W. Daughtry
Manager

PEER REVIEW CHECKLIST

Document Reviewed: Internal Memorandum KEH-8D150-94-001
Author: K. E. Hillesland
Date: November 29, 1994
Scope of Review: Entire Document

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

Brit E. Hey [signature] 11/29/94

Reviewer (Printed Name and Signature) Date

N/A

(Printed Name and Signature) Date

Figure 1. MCNP Model of WESF Capsule Storage Area

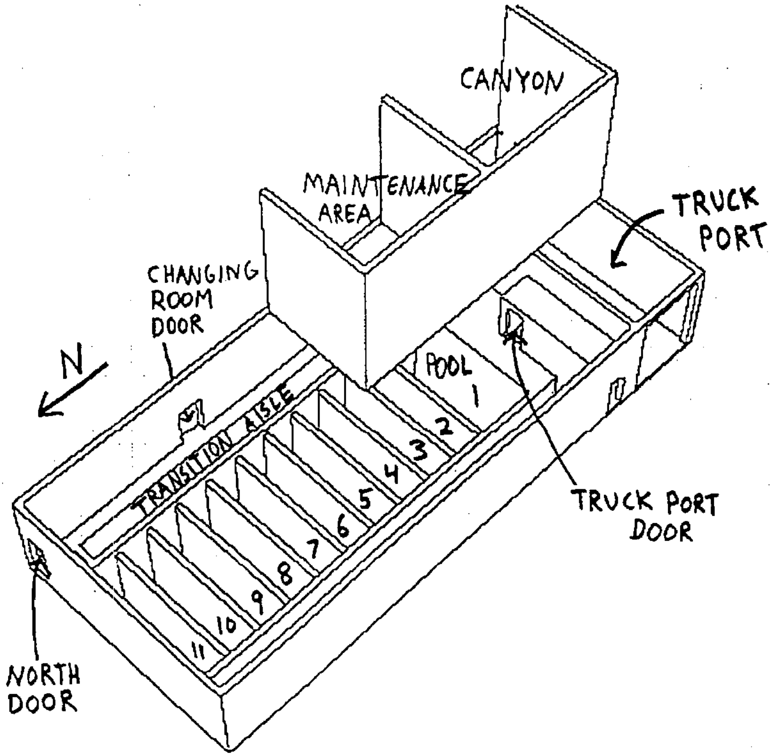
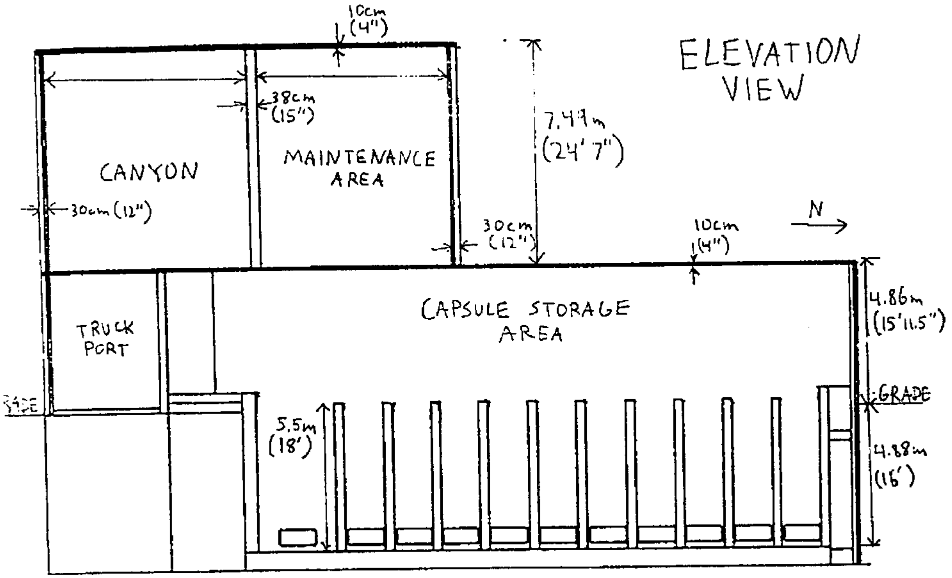


Figure 2. Diagrams of WESF Capsule Storage Area with Dimensions



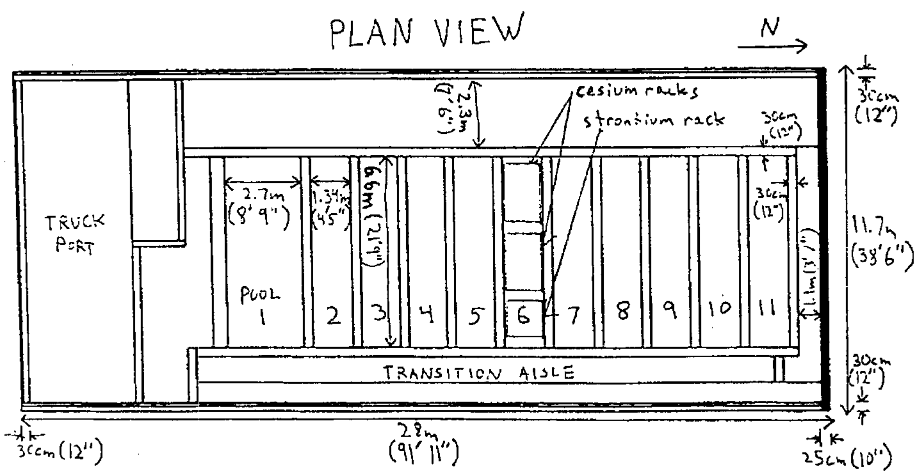
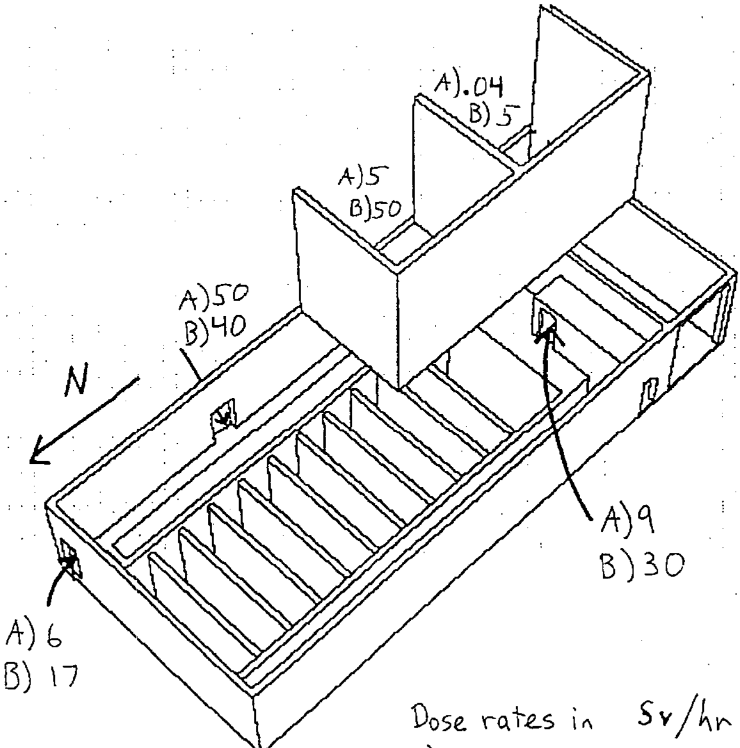


Figure 3. Dose Rates in Adjoining Sections of WESF Capsule Storage Area



Dose rates in Sv/hr
A) Capsules in center pools
B) Capsules evenly distributed amongst pools

TOTAL NUMBER OF CESIUM AND STRONTIUM CAPSULES EXPECTED AT HANFORD:

CESIUM

WESF	1041*
ARECO	25
IOTECH	229
PNL	33
	1328

+ THE FOLLOWING CUT CAPSULES

ORNL-CUT	37
PNL-CUT	5
	1370

STRONTIUM

WESF	601

+ THE FOLLOWING CUT CAPSULES

ORNL-CUT	28
PNL-CUT	5
	634

INTACT CESIUM CAPSULES ARE EXPECTED TO BE RETURNED TO HANFORD BY MID-FY96. TIME-FRAME FOR RETURN OF CUT CAPSULES FROM ORNL AND PNL NOT KNOWN.

CESIUM CAPSULES	Total MCi
INTACT CESIUM CAPSULES (1328)	51.7**

STRONTIUM CAPSULES	Total MCi
INTACT STRONTIUM CAPSULES (601)	22.4**

*INVENTORY INCLUDES 5 SHIPMENTS FROM IOTECH
**DECAYED TO 4/01/96

KPB (per EDS)
10/05/94

ATTACHMENT B. Drawing List

H-2-66403, Rev. 4, "Architectural, First Floor Plan, Area 3".

H-2-66404, Rev. 2, "Architectural, Second Floor Plan".

H-2-66407, Rev. 2, "Architectural, Door Schedule & Details, Interior Room Finish, Schedule".

H-2-66413, Rev. 2, "Structural, Capsule Storage Rack, Plan. Sections & Details".

H-2-66420, Rev. 2, "Structural, Sections, Area 2".

H-2-66421, Rev. 3, "Structural, Foundation & Floor Plan, Area 3".

H-2-66422, Rev. 3, "Structural, Sections, Area 3".

H-2-66760, Rev. 12, "Cs Inner Capsule, Assembly & Details".

H-2-66761, Rev. 10, "Cs Outer Capsule, Assembly & Details".

ATTACHMENT C. MCNP Input for Capsules in Center Pool Cells

```
WESF Facility
   1    1  -0.0012  -3 -5 1 4 6 -7  #711 #712 #713
   2    1  -0.0012  1 -3 -7 6 8 -9  #721 #722 #723
   3    1  -0.0012  1 -3 -7 6 10 -11  #731 #732 #733
   4    1  -0.0012  -3 1 6 -7 12 -13  #741 #742 #743
   5    1  -0.0012  -3 1 -7 6 14 -15  #751 #752 #753
   6    1  -0.0012  -3 1 -7 6 16 -17  #761 #762 #763
   7    1  -0.0012  -3 1 -7 6 18 -19  #771 #772 #773
   8    1  -0.0012  -3 1 -7 6 20 -21  #781 #782 #783
   9    1  -0.0012  -3 1 -7 6 22 -23  #791 #792 #793
  10    1  -0.0012  -3 1 -7 6 24 -25  #801 #802 #803
  11    1  -0.0012  -3 1 -7 6 26 -27  #811 #812 #813
  12    1  -0.0012  -31 30 28 -29 33 -32
  13    1  -0.0012  35 -36 -34 38 40 -41
  14    1  -0.0012  37 -31 -34 38 -41 40
  15    1  -0.0012  3 -31 6 -7 -27 4
  16    1  -0.0012  (43 -41 34 -29 35 -36 )(44 :28 )
  17    1  -0.0012  (34 -41 43 -29 37 -31 )(44 :28 )
  18    1  -0.0012  -46 47 -50 38 -49 48
  19    1  -0.0012  -52 48 46 -45 38 -51
  20    1  -0.0012  -55 38 53 -40 54 -49
  21    1  -0.0012  40 -49 31 -41 38 -50
  22    2  -2.3500  5 -8 -3 1 -7 6
  23    2  -2.3500  9 -10 -3 1 -7 6
  24    2  -2.3500  11 -12 -3 1 6 -7
  25    2  -2.3500  -3 1 6 -7 13 -14
  26    2  -2.3500  -16 15 -3 1 6 -7
  27    2  -2.3500  17 -18 -3 1 6 -7
  28    2  -2.3500  19 -20 -3 1 6 -7
  29    2  -2.3500  21 -22 -3 1 6 -7
  30    2  -2.3500  23 -24 -3 1 6 -7
  31    2  -2.3500  -26 25 -3 1 6 -7
  32    2  -2.3500  27 -44 6 -7 -31 1
  33    2  -2.3500  -31 7 -28 2 -44 33
  34    2  -2.3500  -6 -31 34 2 -44 40
  35    2  -2.3500  2 -1 -7 6 -44 63
  36    2  -2.3500  28 -29 -30 2 33 -32
  37    2  -2.3500  29 -31 -50 2 33 -41
  38    2  -2.3500  -37 36 -34 38 40 -41
  39    2  -2.3500  -35 2 38 -34 40 -41
  42    2  -2.3500  (36 -37 -29 34 43 -41 )(28 :44 )
  44    2  -2.3500  (34 -35 2 -29 43 -41 )(44 :28 )
  47    1  -0.0012  53 -40 -49 31 55 -50
  48    2  -2.3500  (-52 2 -51 38 45 -40 )(80 :-79 :78 :-31 )
  49    2  -2.3500  52 -54 53 -40 -55 38
  50    2  -2.3500  -55 51 -40 46 -52 61
  51    2  -2.3500  55 -50 -53 46 -49 61
  53    2  -2.3500  -48 61 -46 47 38 -50
  55    2  -2.3500  63 -4 -31 1 6 -7
  57    4  -1.5000  38 -61 -50 2 -53 62
  58    4  -1.5000  (-126 2 -64 )(58 :56 :-62 :-57 )
  59    2  -2.3500  -29 28 -43 32 -31 2
  60    2  -2.3500  70 -33 7 -50 2 -31
  61    2  -2.3500  -53 46 52 -49 -55 38
  62    2  -2.3500  ((71 -31 6 -63 -50 53 )(-7 :-70 ))(40 :55 )
  63    2  -2.3500  -48 61 46 -45 -51 38
  64    4  -1.5000  ((61 -71 6 -63 -50 53 )(-7 :-70 ))(40 :55 )
  65    4  -1.5000  ((53 -63 6 -50 2 -61 )(40 :51 ))(-7 :-70 )
  66    4  -1.5000  -45 -51 38 53 -61 2
  69    1  -0.0012  48 72 -74 -73 57 -38
  70    1  -0.0012  -77 -75 76 48 57 -38
  71    1  -0.0012  79 -80 31 -78 45 -40
  72    1  -0.0012  -82 -80 81 31 50 -56
  73    1  -0.0012  -84 85 83 -86 -56 50
  74    1  -0.0012  -87 31 88 -80 50 -56
  75    1  -0.0012  -80 90 -89 31 -58 41
  76    1  -0.0012  (-99 91 -95 103 64 -107 )(58 :56 :-62 :-57 )
  77    1  -0.0012  (-100 92 104 -96 64 -107 )(99 :-91 :-103 :95 )
  78    1  -0.0012  (-93 -107 64 )(100 :96 :-104 :-92 )
  79    1  -0.0012  (-94 64 -107 ) 93
  80    1  -0.0012  (-93 107 -108 (-57 :58 :56 :-62 :59 ))
        (114 :-115 :56 :-62 :116 )
  81    1  -0.0012  (-94 -108 107 ) 93
  82    1  -0.0012  108 -69 -93
  83    1  -0.0012  (108 -69 -94 ) 93
  84    1  -0.0012  ((64 -69 -65 )( 94 ))(-107 )
```

```
85      1  -0.0012  -109 110 47 -50 59 -111
86      1  -0.0012  112 110 -113 -50 59 -111
88      2  -2.3500  109 -112 -111 59 -50 110
93      2  -2.3500  ((((50 -56 -49 2 -41 62 )(82 :-81 :80 :-31 ))
           (-85 :86 :84 :-83 ))(87 :-88 :-31 :80 ))(-119 )
94      2  -2.3500  ((((50 -56 -49 2 -41 62 )(82 :-81 :80 :-31 ))
           (-85 :86 :84 :-83 ))(87 :-88 :-31 :80 ))(119 )
95      2  -2.3500  (((57 -38 -49 2 62 -41 )(-72 :73 :74 :-48 ))
           (-48 :77 :-76 :75 ))(118 )
96      2  -2.3500  (((57 -38 -49 2 62 -41 )(-72 :73 :74 :-48 ))
           (-48 :77 :-76 :75 ))(-118 )
97      2  -2.3500  ((-58 41 -49 2 -56 57 )(-31 :80 :89 :-90 ))(-117 )
98      2  -2.3500  ((-58 41 -49 2 -56 57 )(-31 :80 :89 :-90 ))117
99      2  -2.3500  (-59 49 57 -58 -56 62 )(-121 )
100     2  -2.3500  (-59 49 57 -58 -56 62 )(121 )
101     2  -2.3500  (62 -47 -49 61 -50 38 )(120 )
102     2  -2.3500  (62 -47 -49 61 -50 38 )(-120 )
103     2  -2.3500  (62 -47 -50 110 59 -111 )(120 )
104     2  -2.3500  (62 -47 -50 110 59 -111 )(-120 )
105     2  -2.3500  (113 -114 -50 110 59 -111 )(-125 )
106     2  -2.3500  (113 -114 -50 110 59 -111 )(125 )
107     1  -0.0012  -56 50 62 -114 59 -111
109     2  -2.3500  (115 -110 -111 59 62 -114 )(124 )
110     2  -2.3500  (115 -110 -111 59 62 -114 )(-124 )
111     2  -2.3500  (111 -116 62 -114 -56 115 )(-123 )
112     2  -2.3500  (111 -116 62 -114 -56 115 )(123 )
113     1  -0.0012  (-126 64 -107 )( 65 )
114     1  -0.0012  (107 -108 -65 )( 94 )
115     1  -0.0012  (107 -108 -126 )( 65 )
116     1  -0.0012  (108 -69 -65 )( 94 )
117     1  -0.0012  (-69 108 -126 )( 65 )
711     0  -701 700 -703 702 704 -705  trcl=711
712     0  -701 700 -703 702 704 -705  trcl=712
713     0  -706 700 -703 702 704 -705  trcl=713
721     0  -701 700 -703 702 704 -705  trcl=721
722     0  -701 700 -703 702 704 -705  trcl=722
723     0  -706 700 -703 702 704 -705  trcl=723
731     0  -701 700 -703 702 704 -705  trcl=731
732     0  -701 700 -703 702 704 -705  trcl=732
733     0  -706 700 -703 702 704 -705  trcl=733
741     0  -701 700 -703 702 704 -705  trcl=741
742     0  -701 700 -703 702 704 -705  trcl=742
743     0  -706 700 -703 702 704 -705  trcl=743
751     0  -701 700 -703 702 704 -705  trcl=751
752     0  -701 700 -703 702 704 -705  trcl=752
753     0  -706 700 -703 702 704 -705  trcl=753
761     0  -701 700 -703 702 704 -705  trcl=761
762     0  -701 700 -703 702 704 -705  trcl=762
763     0  -706 700 -703 702 704 -705  trcl=763
771     0  -701 700 -703 702 704 -705  trcl=771
772     0  -701 700 -703 702 704 -705  trcl=772
773     0  -706 700 -703 702 704 -705  trcl=773
781     0  -701 700 -703 702 704 -705  trcl=781
782     0  -701 700 -703 702 704 -705  trcl=782
783     0  -706 700 -703 702 704 -705  trcl=783
791     0  -701 700 -703 702 704 -705  trcl=791
792     0  -701 700 -703 702 704 -705  trcl=792
793     0  -706 700 -703 702 704 -705  trcl=793
801     0  -701 700 -703 702 704 -705  trcl=801
802     0  -701 700 -703 702 704 -705  trcl=802
803     0  -706 700 -703 702 704 -705  trcl=803
811     0  -701 700 -703 702 704 -705  trcl=811
812     0  -701 700 -703 702 704 -705  trcl=812
813     0  -706 700 -703 702 704 -705  trcl=813
900     0  -2 :69 :126

  1        pz  -487.68
  2        pz  -548.64
  3        pz   22.86
  4        py  0.0000
  5        py   266.7
  6        px  0.0000
  7        px  662.94
  8        py  297.18
  9        py   431.8
 10        py  462.28
 11        py   596.9
 12        py  627.38
 13        py  762.0000
 14        py  792.48
```

```
15    py   927.1
16    py  957.58
17    py  1092.2
18    py  1122.68
19    py  1257.3
20    py  1287.78
21    py  1422.4
22    py  1452.88
23    py  1587.5
24    py  1617.98
25    py  1752.6
26    py  1783.08
27    py  1917.7
28    px  693.42
29    px  784.86
30    pz  -411.48
31    pz   60.96
32    py  1865.63
33    py  -113.03
34    px  -30.48
35    pz  -495.3
36    pz  -121.92
37    pz  -91.44
38    px  -259.08
40    py  -142.24
41    py  2026.92
43    py  1896.11
44    py  1948.18
45    py  -162.56
46    py  -330.2
47    py  -708.66
48    pz   15.24
49    pz  476.25
50    px  853.44
51    px  287.02
52    pz  297.18
53    py  -304.8
54    pz  312.42
55    px  307.34
56    px  883.92
57    px  -289.56
58    py  2052.3
59    pz  486.41
61    pz   -5.08
62    py  -739.14
63    py   -50.8
64    pz  0.0000
65    c/z 297.18 656.58 20000
69    pz  30000.0000
70    py  -143.51
71    pz   30.48
72    py  -697.23
73    py  -361.95
74    pz  447.04
75    py  -177.8
76    py  -269.24
77    pz   228.6
78    px  271.78
79    px  180.34
80    pz  274.32
81    py  -693.42
82    py  -510.54
83    py  449.58
84    py   571.5
85    pz  223.52
86    pz  345.44
87    py  1231.9
88    py  1109.98
89    px   838.2
90    px  746.76
91    px  -789.56
92    px  -1289.56
93    c/z 297.18 656.58 5000
94    c/z 297.18 656.58 10000
95    px  1383.92
96    px  1883.92
99    py  2552.3
100   py  3052.3
103   py  -1239.14
104   py  -1739.14
```

```
  107         pz  200.0000
  108         pz  15000.0000
  109         py    -7.62
  110         px  312.42
  111         pz  1224.28
  112         py   30.48
  113         py  678.18
  114         py  708.48
  115         px  281.94
  116         pz  1235.71
  117         py  2039.61
  118         px  -274.32
  119         px  868.68
  120         py  -723.9
  121         pz  481.33
  123         pz  1229.995
  124         px  297.18
  125         py  693.33
  126         c/z 297.18 656.58 30000
  700         px    -0.1
  701         px  200.125
  702         py    -0.1
  703         py  122.655
  704         pz    -0.1
  705         pz  51.154
  706         px  123.925
c     tally surfaces
 1000         px  403
 1001         p   -1 1 0 359.40
 1002         p    1 1 0 953.76

tr711  34.6163 71.9725 -466.8250
tr712  269.4580 71.9725 -466.8250
tr713  504.2990 71.9725 -466.8250
tr721  34.6163 303.1130 -466.8250
tr722  269.4580 303.1130 -466.8250
tr723  504.2990 303.1130 -466.8250
tr731  34.6163 468.2130 -466.8250
tr732  269.4580 468.2130 -466.8250
tr733  504.2990 468.2130 -466.8250
tr741  34.6163 633.3130 -466.8250
tr742  269.4580 633.3130 -466.8250
tr743  504.2990 633.3130 -466.8250
tr751  34.6163 798.4130 -466.8250
tr752  269.4580 798.4130 -466.8250
tr753  504.2990 798.4130 -466.8250
tr761  34.6163 963.5130 -466.8250
tr762  269.4580 963.5130 -466.8250
tr763  504.2990 963.5130 -466.8250
tr771  34.6163 1128.6100 -466.8250
tr772  269.4580 1128.6100 -466.8250
tr773  504.2990 1128.6100 -466.8250
tr781  34.6163 1293.7100 -466.8250
tr782  269.4580 1293.7100 -466.8250
tr783  504.2990 1293.7100 -466.8250
tr791  34.6163 1458.8101 -466.8250
tr792  269.4580 1458.8101 -466.8250
tr793  504.2990 1458.8101 -466.8250
tr801  34.6163 1623.9100 -466.8250
tr802  269.4580 1623.9100 -466.8250
tr803  504.2990 1623.9100 -466.8250
tr811  34.6163 1789.0100 -466.8250
tr812  269.4580 1789.0100 -466.8250
tr813  504.2990 1789.0100 -466.8250
mode   p
c       55.1 MCi Cs * 3.7e10 dps/Ci * .95 Ba137m/Cs = 1.94e18 dps Ba137m
c
c       Ba137m         .662 MeV   1.94e18 dps * .9 p/dis = 1.75e18 p/s
c                 ---------------------------------------------------
c                                                Total          1.75e18 p/s
c   ***************
c        Computing relative probabilities that a given photon will come
c        from a given rack.
c        Two center pools will have all the Cs capsules it can hold,
c        with Cs capsules also occupying Sr racks.
c        rack 1: 221    rack 2: 273    rack 3: 169    Total: 663
c        The remainder will be split between two pools:
c        (1370 Cs capsules -  2*663)/2 = 22 in each pool
c        putting them all in rack 2.
c
```

```
c    ******************
sdef     cel=d1  wgt=1.75e18  erg=.662
         x fcel d3  y fcel d5  z d6
sc1  CELL **************
si1  l   742  751 752 753  761 762 763  772
c    probability = number of capsules in the rack
sp1       22  221 273 169  221 273 169   22
sc3  X ******************
ds3   s   31   30  31  32   30  31  32   31
sc30     First Cs rack, first four rows left empty
si30      72.7164 234.7402
sp30      0  1
sc31     Second Cs rack
si31     269.459 469.581
sp31     0 1
sc32     Sr rack
si32     504.300 628.222
sp32     0 1
sc5   Y ********************
ds5  s     54   55  55  55   56  56  56   57
sc54    Pool 4  y
si54    633.314  755.966
sp54    0 1
sc55    Pool 5  Y
si55    798.414  921.066
sp55    0 1
sc56    Pool 6  Y
si56    963.514  1086.166
sp56    0 1
sc57    Pool 7  Y
si57    1128.611  1251.263
sp57    0 1
sc6    Z *********************
si6    -466.824  -415.673
sp6    0 1
c    MATERIALS ***********
m1        8016.50  .21        $O air number fraction
          7014.50  .79        $N
m2        8016.50 -.4407      $O concrete weight fraction
         14000.50 -.2157      $Si
         20000.50 -.1306      $Ca
         26000.55 -.0788      $Fe
         13027.50 -.0607      $Al
         12000.50 -.0376      $Mg
         19000.50 -.0066      $K
         11023.50 -.0182      $Na
         22000.50 -.0049      $Ti
          1001.50 -.0031      $H
         25055.50 -.0013      $Mn
         15031.50 -.0009      $P
         16032.50 -.0009      $S
m3       26000.55 1.0         $Fe iron
m4       14000.50  .2813      $Si  hanford soil number fraction
          8016.50  .6556      $O
         13027.50  .0123      $Al
         26000.55  .0084      $Fe
         20000.50  .0149      $Ca
         12000.50  .0103      $Mg
         19000.50  .0022      $K
         11023.50  .0034      $Na
          1001.50  .0116      $H
c      ansi/ans-6.1.1-1991 fluence-to-dose,photons(mrem/hr/(p/cm**2/s)
de0      log  .01 .015 .02 .03 .04 .05
              .06 .08 .10 .15 .20 .30
              .40 .50 .60 .80 1.0 1.5
              2.0 3.0 4.0 5.0 6.0 8.0
              10. 12.
df0      log  2.232e-5 5.652e-5 8.568e-5 1.184e-4 1.314e-4 1.382e-4
              1.440e-4 1.624e-4 1.919e-4 2.797e-4 3.708e-4 5.616e-4
              7.416e-4 9.144e-4 1.076e-3 1.379e-3 1.656e-3 2.246e-3
              2.758e-3 3.672e-3 4.500e-3 5.292e-3 6.012e-3 7.488e-3
              8.892e-3 1.040e-2
phys:p     j 1 1
prdmp     j -240 1 3
imp:p
c         1   2   3   4   5   6   7   8   9   10
          1 9r
c        11  12  13  14  15  16  17  18  19  20
          1 9r
c        21  22  23  24  25  26  27  28  29  30
```

```
        1 9r
c      31  32  33  34  35  36  37  38  39
        1 8r
c          42      44          47  48  49  50
            1       1           1   1   1   1
c      51      53      55      57  58  59  60
        1       1       1       1   1   1   1
c      61  62  63  64  65  66          69  70
        1   1   1   1   1   1           1   1
c      71  72  73  74  75  76  77  78  79  80
        1   1   1   1   1   6   6   6   9   6
c      81  82  83  84  85  86      88
        8   4   4  15   4   4       4
c              93  94  95  96  97  98  99 100
                2   4   2   4   2   4   2   4
c     101 102 103 104 105 106 107     109 110
        2   4   4   6   4   6   4       4   6
c     111 112 113 114 115 116 117
        4   6  10   8   4   2   1
c     711 712 713 721 722 723 731 732 733
      1 8r
c     741 742 743 751 752 753 761 762 763
      1 8r
c     771 772 773 781 782 783 791 792 793
      1 8r
c     801 802 803 811 812 813
      1 5r
c     900
      0
fc4   Dose inside pool area
f4:p   21
fs4   -6 7 -12 -13 -14 -15 -16 -17 -18 -19
fc14   Dose just above pools
f14:p   15
fs14   -12 -13 -14 -15 -16 -17 -18 -19
fc24   Dose in doorways
f24:p   69 70 71 72 73 74 75
fc34   Dose in each pool
f34:p   3 4 5 6 7 8
fc44   Dose in maintenance area
f44:p  85 86
fs44   -1000
fc52   5m North/South
f52:p   99 103
fs52   -38 50
fc54   5m North/South
f54:p  76
fs54   -38 50 58
fc62   5m North/South Center
f62:p   99 103
fs62   -6 7
fc64   5m North/South Center
f64:p   76
fs64   -6 7 58
fc72   5m West/East
f72:p   91 95
fs72   41 -40
fc74   5m West/East
f74:p   76
fs74   41 -40 -57
fc82   5m West/East Center
f82:p   91 95
fs82   17 -14
fc84   5m West/East Center
f84:p   76
fs84   17 -14 -57
fc92   10m North/South
f92:p   100 104
fs92   -38 50
fc94   10m North/South
f94:p  77
fs94   -38 50 58
fc102   10m North/South Center
f102:p   100 104
fs102   -6 7
fc104   10m North/South Center
f104:p   77
fs104   -6 7 58
fc112   10m West/East
f112:p   92 96
```

```
fs112    41 -40
fc114    10m West/East
f114:p    77
fs114    41 -40 -57
fc122    10m West/East Center
f122:p    92 96
fs122    17 -14
fc124    10m West/East Center
f124:p    77
fs124    17 -14 -57
fc132    50m N, W
f132:p    93
fs132    107 -1001 1002
sd132    1e20 3.141e6 1.571e6 1.571e6
fc142    50m S, E
f142:p    93
fs142    107 1001 -1002
sd142    1e20 3.141e6 1.571e6 1.571e6
fc144    50m
f144:p    78
sd144    1.267e10
fc152    100m N, W
f152:p    94
fs152    107 -1001 1002
sd152    1e20 6.283e6 3.141e6 3.141e6
fc162    100m S, E
f162:p    94
fs162    107 1001 -1002
sd162    1e20 6.283e6 3.141e6 3.141e6
fc164    100m
f164:p    79
fc172    200m N, W
f172:p    65
fs172    107 -1001 1002
sd172    1e20 1.257e7 6.283e6 6.283e6
fc182    200m S, E
f182:p    65
fs182    107 1001 -1002
sd182    1e20 1.257e7 6.283e6 6.283e6
fc184    200m
f184:p    84
nps       10000000
ctme      360
```

Westinghouse Hanford Company | **Internal Memo**

From: Nuclear Physics and Shielding — 8M730-KEH-96-001
Phone: 373-4078 H0-35
Date: February 13, 1996
Subject: DOSE RATE IN THE WESF CAPSULE STORAGE CONTROL ROOM DUE TO LOSS OF WATER IN A MAXIMALLY LOADED POOL

To: [redacted]

cc: J. R. Brehm A2-25
J. Greenborg H0-35
A. L. Ramble A3-38*
*w/o attachment
KEH File/LB

References:

1. DSI, B. E. Hey to K. E. Hillesland, "Work Scope for Additional Shine Calculations for Postulated WESF Capsule Storage Area Loss of Water Accident", dated December 21, 1995.

2. L. L. Carter, "Certification of MCNP Version 4A for WHC Computer Platforms", SD-MP-SWD-30001, Rev. 7, dated January 26, 1995.

3. Internal Memo, K. E. Hillesland to J. M. Siemer, "Dose Rate Calculations Near the WESF Facility Due to Loss of Water In the Capsule Storage Pools", dated November 29, 1994.

4. B. E. Hey, "Supporting Calculations and Assumptions for Use in WESF Interim Safety Basis", WHC-SD-WM-TI-733, DRAFT, dated January 16, 1996.

1.0 SUMMARY

In the event that water is inadvertently drained from a WESF capsule storage pool, it will be necessary for an operator to enter the control room to correct the situation. The purpose of this analysis is to determine the water level at which access to the control room is restricted by dose rates in excess of 100 rem/hr. This water level was calculated to be less than three feet (91 cm) above the top of the capsules.

MCNP (Ref. 2) calculations indicate that an inadvertent drain of a maximally loaded WESF pool to a water level three feet (91 cm) above the top of the capsules will result in dose rates less than 1.2 rem/hr in the operating gallery and instrument shop. The 1.2 rem/hr is the dose rate at the air lock as calculated by MCNP (Ref. 2), thus representing an upper bound on dose rates in the control room for this water level.

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2.0 GEOMETRY

The control room is currently located about eight feet west of the capsule storage area, just west of the air lock. The dose rate at the air lock door will represent a conservative upper bound on dose rates in the control room and any other rooms outside of the capsule storage area on the first floor. Lower dose rates in the control room and other first floor rooms are due to separation by greater distance and one or more concrete/cinder block walls.

The MCNP model was developed from a model used in a previous analysis (Ref. 3). Figures 1 and 2 show dimensions used in the MCNP model. The pools in the capsule storage area are 18 ft (5.48 m) deep and are separated from one another by 15 ft (4.57 m) high walls. The capsules are each 20.8 in (52.8 cm) tall, and sit approximately 8.2 in (20.8 cm) off the bottom of the pool in three separate racks. This model assumes there is three feet of water above the top of the capsules. The air lock door is 6 ft 3 in (1.9 m) from the edge of the pool. Concrete was modeled with a density of 2.35 g/cc, and water at 1.0 g/cc.

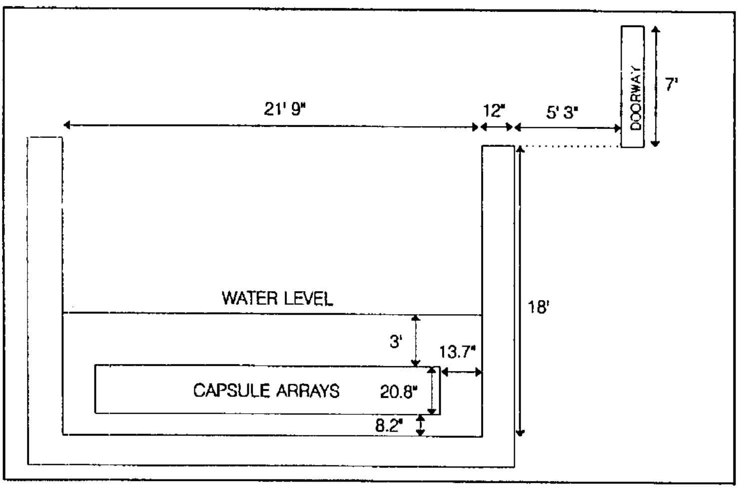

Figure 1 Elevation View of WESF Pool 7 and Airlock Doorway

The capsules consist of CsCl salt encased in steel. They were modeled with an outside diameter of 2.6 in (6.7 cm), and a height of 20.8 in (52.8 cm).

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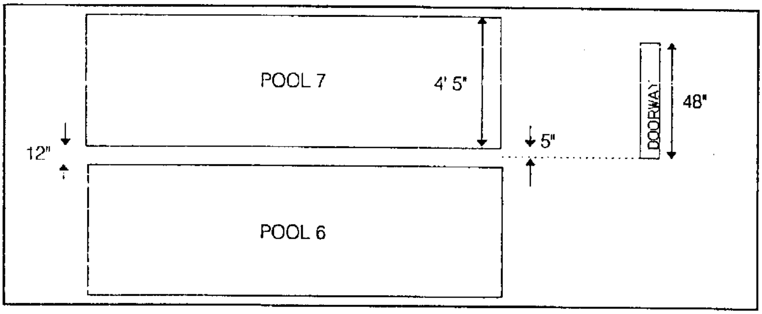

Figure 2 Plan View of WESF Pool 7 and Airlock Doorway

The thickness of steel at each end of the capsule was modeled as 0.79 in (2 cm), and the side thickness as .24 in (0.6 cm). The model assumed 2.5 kg CsCl and 5.9 kg 316 SST in each capsule, corresponding to the averages given by the Encapsulation Database System (EDS) maintained by WESF engineering.

Each pool contains racks for storing the capsules in arrays of 13 x 17, 13 x 21 and 13 x 13 capsules. This amounts to 663 capsules in a maximally loaded pool. The capsules are spaced at 3.75 in (9.5 cm) intervals within each rack. For this scenario, capsules were placed in pool 7, the pool nearest the air lock door.

3.0 SOURCE

The total source activity is 28.6 MCi of Cs-137 (References 1 and 4). This corresponds to 663 cesium capsules with an average activity of 39.19 kCi plus an additional 10% safety margin. Only the .662 MeV gamma of the Cs/Ba decay was considered, as it is assumed to be the dominant contributor to dose rate.

4.0 RESULTS

The dose rate at the air lock door was calculated to be 1.2 rem/hr. As mentioned in section 2 above, the dose rate at the air lock door bounds dose rates in the control room and all other rooms outside of the capsule storage area on the first floor.

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The statistical uncertainty for the dose rate calculation is 3.5%. This is a measure of the precision of the Monte Carlo calculation. Other uncertainties are in the material compositions and densities, physical dimensions, source activity, and simplifying assumptions made for the source.

5.0 ARCHIVAL

The input and output files are stored with this report on the network drive \\WHC276\KE_HILLE\ under subdirectory \PROJECTS\WESF. The MCNP input and output file names are 3feet.inp and 3feet.outp respectively. Attacment 1 is a source listing of the MCNP input file.

K E Hillesland
K. E. Hillesland, Engineer
Nuclear Physics and Shielding

Concurrence: J. Greenborg, Manager

llp

Attachment

MCNP Input File Listing

```
WESF Facility, 3 feet of water above capsules in pool 7
c     Dose points for the NE door
    1      1   -0.0012   -3 -5 1 4 6 -7 210
  301      5   -1.0000   -3 -5 4 6 -7 -210
    2      1   -0.0012   1 -3 -7 6 8 -9 210
  302      5   -1.0000   1 -3 -7 6 8 -9 -210
    3      1   -0.0012   1 -3 -7 6 10 -11 210
  303      5   -1.0000   1 -3 -7 6 10 -11 -210
    4      1   -0.0012   -3 1 6 -7 12 -13 210
  304      5   -1.0000   -3 1 6 -7 12 -13 -210
    5      1   -0.0012   -3 1 -7 6 14 -15 210
  305      5   -1.0000   -3 1 -7 6 14 -15 -210
    6      1   -0.0012   -3 1 -7 6 16 -17 210
  306      5   -1.0000   -3 1 -7 6 16 -17 -210
    7      1   -0.0012   -3 1 -7 6 18 -19 308
  751      5   -1.0000   -7 6 18 -19  307 -308 $ 13
  750      2   -2.3500   -31 298 -44 33 274 -28
  749      5   -1.0000   -7 6 18 -19  306 -307 $ 12
  748      5   -1.0000   -7 6 18 -19  305 -306 $ 11
  747      2   -2.3500   -31 298 -44 33 273 -274
  746      2   -2.3500   17 -18 -3 6 -7 306 -308
  745      2   -2.3500   19 -20 -3 6 -7 306 -308
  744      5   -1.0000   -7 6 18 -19  304 -305 $ 10
  743      2   -2.3500   17 -18 -3 6 -7 305 -306
  742      2   -2.3500   19 -20 -3 6 -7 305 -306
  741      5   -1.0000   -7 6 18 -19  303 -304 $ 9
  740      2   -2.3500   -31 298 -44 33 272 -273
  739      2   -2.3500   17 -18 -3 6 -7 304 -305
  738      2   -2.3500   19 -20 -3 6 -7 304 -305
  737      5   -1.0000   -7 6 18 -19  302 -303 $ 8
  736      2   -2.3500   17 -18 -3 6 -7 303 -304
  735      2   -2.3500   19 -20 -3 6 -7 303 -304
  734      5   -1.0000   -7 6 18 -19  301 -302 $ 7
  733      2   -2.3500   -31 298 -44 33 271 -272
  732      2   -2.3500   17 -18 -3 6 -7 302 -303
  731      2   -2.3500   19 -20 -3 6 -7 302 -303
  730      5   -1.0000   -7 6 18 -19  300 -301 $ 6
  729      2   -2.3500   17 -18 -3 6 -7 301 -302
  728      2   -2.3500   19 -20 -3 6 -7 301 -302
  727      5   -1.0000   -7 6 18 -19  #771 #772 #773 299 -300 $ 5
  726      2   -2.3500   -31 298 -44 33 7 -271
  725      2   -2.3500   17 -18 -3 6 -7 300 -301
  724      2   -2.3500   19 -20 -3 6 -7 300 -301
  723      5   -1.0 (205:-206:209) 211 u=5
  722      5 -1.0 211 u=4
  721      3   -8.40 -205 206 -209 (204:-207:208) u=5  $ Steel casing
  720      5   -1.0000   -7 6 18 -19  #771 #772 #773 298 -299 $ 4
  719      2   -2.3500   17 -18 -3 6 -7 299 -300
  718      2   -2.3500   19 -20 -3 6 -7 299 -300
  717      5   -1.0 (205:-206:209) 212 -211 u=5
  716      5 -1.0 212 -211 u=4
  205      6 -2.16 -204 207 -208 u=5      $ CsCl
  715      5   -1.0000  -7 6 18 -19  #771 #772 #773 297 -298 $ 3
  714      2   -2.3500  17 -18 -3 6 -7 298 -299
  713      2   -2.3500  19 -20 -3 6 -7 298 -299
  712      5   -1.0 (205:-206:209) 213 -212 u=5
  711      5 -1.0 213 -212 u=4
  710      5   -1.0000  -7 6 18 -19  #771 #772 #773 296 -297 $ 2
  709      2   -2.3500  17 -18 -3 6 -7 297 -298
  708      2   -2.3500  19 -20 -3 6 -7 297 -298
  707      5   -1.0 (205:-206:209) 214 -213 u=5
  706      5 -1.0 214 -213 u=4
  705      5   -1.0000  1 -7 6 18 -19  #771 #772 #773 -296 $ 1
  704      2   -2.3500  17 -18 -3 6 -7 1 -297
  703      2   -2.3500  19 -20 -3 6 -7 1 -297
  702      5   -1.0 (205:-206:209) -214 u=5
  701      5 -1.0 -214 u=4
    8      1   -0.0012  -3 1 -7 6 20 -21 210
  308      5   -1.0000  -3 1 -7 6 20 -21 -210
    9      1   -0.0012  -3 1 -7 6 22 -23 210
  309      5   -1.0000  -3 1 -7 6 22 -23 -210
   10      1   -0.0012  -3 1 -7 6 24 -25 210
  310      5   -1.0000  -3 1 -7 6 24 -25 -210
```

11	1	-0.0012	-3 1 -7 6 26 -27 210
311	5	-1.0000	-3 1 -7 6 26 -27 -210
12	1	-0.0012	-31 30 28 -29 33 -32
13	1	-0.0012	35 -36 -34 38 40 -41
14	1	-0.0012	37 -31 -34 38 -41 40
15	1	-0.0012	3 -31 6 -7 -27 4
16	1	-0.0012	(43 -41 34 -29 35 -36)(44 :28)
17	1	-0.0012	(34 -41 43 -29 37 -31)(44 :28)
18	1	-0.0012	-46 47 -50 38 -49 48
19	1	-0.0012	-52 48 46 -45 38 -51
20	1	-0.0012	-55 38 53 -40 54 -49
21	1	-0.0012	40 -49 31 -41 38 -50
22	2	-2.3500	5 -8 -3 1 -7 6
23	2	-2.3500	9 -10 -3 1 -7 6
24	2	-2.3500	11 -12 -3 1 6 -7
25	2	-2.3500	-3 1 6 -7 13 -14
26	2	-2.3500	-16 15 -3 1 6 -7
27	2	-2.3500	17 -18 -3 6 -7 308
28	2	-2.3500	19 -20 -3 6 -7 308
29	2	-2.3500	21 -22 -3 1 6 -7
30	2	-2.3500	23 -24 -3 1 6 -7
31	2	-2.3500	-26 25 -3 1 6 -7
32	2	-2.3500	27 -44 6 -7 -31 1
33	2	-2.3500	-298 7 -28 2 -44 33
34	2	-2.3500	-6 -31 34 2 -44 40
35	2	-2.3500	2 -1 -7 6 -44 63
36	2	-2.3500	28 -29 -30 2 33 -32
37	2	-2.3500	29 -31 -50 2 33 -41
38	2	-2.3500	-37 36 -34 38 40 -41
39	2	-2.3500	-35 2 38 -34 40 -41
42	2	-2.3500	(36 -37 -29 34 43 -41)(28 :44)
44	2	-2.3500	(34 -35 2 -29 43 -41)(44 :28)
47	1	-0.0012	53 -40 -49 31 55 -50
48	2	-2.3500	(-52 2 -51 38 45 -40)(80 :-79 :78 :-31)
49	2	-2.3500	52 -54 53 -40 -55 38
50	2	-2.3500	-55 51 -40 46 -52 61
51	2	-2.3500	55 -50 -53 46 -49 61
53	2	-2.3500	-48 61 -46 47 38 -50
55	2	-2.3500	63 -4 -31 1 6 -7
57	4	-1.5000	38 -61 -50 2 -53 62
58	4	-1.5000	(-126 2 -64)(58 :56 :-62 :-57)
59	2	-2.3500	-29 28 -43 32 -31 2
60	2	-2.3500	70 -33 7 -50 2 -31
61	2	-2.3500	-53 46 52 -49 -55 38
62	2	-2.3500	((71 -31 6 -63 -50 53)(-7 :-70))(40 :55)
63	2	-2.3500	-48 61 46 -45 -51 38
64	4	-1.5000	((61 -71 6 -63 -50 53)(-7 :-70))(40 :55)
65	4	-1.5000	((53 -63 6 -50 2 -61)(40 :51))(-7 :-70)
66	4	-1.5000	-45 -51 38 53 -61 2
69	1	-0.0012	48 72 -74 -73 57 -38
70	1	-0.0012	-77 -75 76 48 57 -38
71	1	-0.0012	79 -80 31 -78 45 -40
72	1	-0.0012	-82 -80 81 31 50 -56
73	1	-0.0012	-84 85 83 -86 -56 50
74	1	-0.0012	-87 31 88 -80 50 -56
75	1	-0.0012	-80 90 -89 31 -58 41
76	1	-0.0012	(-99 91 -95 103 64 -107)(58 :56 :-62 :-57)
77	1	-0.0012	(-100 92 104 -96 64 -107)(99 :-91 :-103 :95)
78	1	-0.0012	(-93 -107 64)(100 :96 :-104 :-92)
79	1	-0.0012	(-94 64 -107) 93
80	1	-0.0012	(-93 107 -108 (-57 :58 :56 :-62 :59))
			(114 :-115 :56 :-62 :116)
81	1	-0.0012	(-94 -108 107) 93
82	1	-0.0012	108 -69 -93
83	1	-0.0012	(108 -69 -94) 93
84	1	-0.0012	((64 -69 -65)(94))(-107)
85	1	-0.0012	-109 110 47 -50 59 -111
86	1	-0.0012	112 110 -113 -50 59 -111
88	2	-2.3500	109 -112 -111 59 -50 110
93	2	-2.3500	((((50 -56 -49 2 -41 62)(82 :-81 :80 :-31))
			(-85 :86 :84 :-83))(87 :-88 :-31 :80))(-119)
94	2	-2.3500	((((50 -56 -49 2 -41 62)(82 :-81 :80 :-31))
			(-85 :86 :84 :-83))(87 :-88 :-31 :80))(119)
95	2	-2.3500	(((57 -38 -49 2 62 -41)(-72 :73 :74 :-48))
			(-48 :77 :-76 :75))(118)
96	2	-2.3500	(((57 -38 -49 2 62 -41)(-72 :73 :74 :-48))

```
           (-48 :77 :-76 :75 ))(-118 )
97      2  -2.3500  ((-58 41 -49 2 -56 57 )(-31 :80 :89 :-90 ))(-117 )
98      2  -2.3500  ((-58 41 -49 2 -56 57 )(-31 :80 :89 :-90 ))117
99      2  -2.3500  (-59 49 57 -58 -56 62 )(-121 )
100     2  -2.3500  (-59 49 57 -58 -56 62 )(121 )
101     2  -2.3500  (62 -47 -49 61 -50 38 )(120 )
102     2  -2.3500  (62 -47 -49 61 -50 38 )(-120 )
103     2  -2.3500  (62 -47 -50 110 59 -111 )(120 )
104     2  -2.3500  (62 -47 -50 110 59 -111 )(-120 )
105     2  -2.3500  (113 -114 -50 110 59 -111 )(-125 )
106     2  -2.3500  (113 -114 -50 110 59 -111 )(125 )
107     1  -0.0012  -56 50 62 -114 59 -111
109     2  -2.3500  (115 -110 -111 59 62 -114 )(124 )
110     2  -2.3500  (115 -110 -111 59 62 -114 )(-124 )
111     2  -2.3500  (111 -116 62 -114 -56 115 )(-123 )
112     2  -2.3500  (111 -116 62 -114 -56 115 )(123 )
113     1  -0.0012  (-126 64 -107 )( 65 )
114     1  -0.0012  (107 -108 -65 )( 94 )
115     1  -0.0012  (107 -108 -126 )( 65 )
116     1  -0.0012  (108 -69 -65 )( 94 )
117     1  -0.0012  (-69 108 -126 )( 65 )
201     0  -200 201 -202 203 lat=1 u=1 fill=-1:21 -1:13 0:0
           4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
           4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
202     0  -200 201 -202 203 lat=1 u=2 fill=-1:21 -1:13 0:0
           4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
203     0  -200 201 -202 203 lat=1 u=3 fill=-1:13 -1:13 0:0
           4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
           4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
771     0  -701 700 -703 702 704 -705  trcl=771
        fill=1
772     0  -701 700 -703 702 704 -705  trcl=772
        fill=2
773     0  -706 700 -703 702 704 -705  trcl=773
        fill=3
900     0  -2 :69 :126
```

```
      1   pz  -487.68
      2   pz  -548.64
c     3   pz   22.86  Old model 16' 9" deep pits
      3   pz  -30.48  $ 15' deep pits
      4   py  0.0000
      5   py   266.7
      6   px  0.0000
      7   px  662.94
    271   px  668.94
    272   px  674.94
    273   px  680.94
    274   px  686.94
      8   py  297.18
      9   py   431.8
     10   py  462.28
     11   py   596.9
     12   py  627.38
     13   py  762.0000
     14   py  792.48
     15   py   927.1
     16   py  957.58
     17   py  1092.2
     18   py  1122.68
     19   py  1257.3
     20   py  1287.78
     21   py  1422.4
     22   py  1452.88
     23   py  1587.5
     24   py  1617.98
     25   py  1752.6
     26   py  1783.08
     27   py  1917.7
     28   px  693.42
     29   px  784.86
     30   pz  -411.48
     31   pz   60.96
     32   py  1865.63
     33   py  -113.03
     34   px  -30.48
     35   pz  -495.3
     36   pz  -121.92
     37   pz  -91.44
     38   px  -259.08
     40   py  -142.24
     41   py  2026.92
     43   py  1896.11
     44   py  1948.18
     45   py  -162.56
     46   py  -330.2
     47   py  -708.66
     48   pz   15.24
     49   pz  476.25
     50   px  853.44
     51   px  287.02
     52   pz  297.18
     53   py  -304.8
     54   pz  312.42
     55   px  307.34
     56   px  883.92
     57   px  -289.56
     58   py  2052.3
     59   pz  486.41
     61   pz   -5.08
     62   py  -739.14
     63   py   -50.8
     64   pz  0.0000
     65   c/z 297.18 656.58 20000
     69   pz  30000.0000
     70   py  -143.51
     71   pz   30.48
     72   py  -697.23
     73   py  -361.95
     74   pz  447.04
     75   py  -177.8
     76   py  -269.24
     77   pz   228.6
```

```
 78        px  271.78
 79        px  180.34
 80        pz  274.32
 81        py  -693.42
 82        py  -510.54
 83        py  449.58
 84        py   571.5
 85        pz  223.52
 86        pz  345.44
 87        py  1231.9
 88        py  1109.98
 89        px   838.2
 90        px  746.76
 91        px  -789.56
 92        px  -1289.56
 93        c/z 297.18 656.58 5000
 94        c/z 297.18 656.58 10000
 95        px  1383.92
 96        px  1883.92
 99        py  2552.3
100        py  3052.3
103        py  -1239.14
104        py  -1739.14
107        pz  200.0000
108        pz  15000.0000
109        py   -7.62
110        px  312.42
111        pz  1224.28
112        py   30.48
113        py  678.18
114        py  708.48
115        px  281.94
116        pz  1235.71
117        py  2039.61
118        px  -274.32
119        px  868.68
120        py  -723.9
121        pz  481.33
123        pz  1229.995
124        px  297.18
125        py  693.33
126        c/z 297.18 656.58 30000
200        px  9.5
201        px  0.00
202        py  9.5
203        py  0.00
204        c/z 4.75 4.75 2.75
205        c/z 4.75 4.75 3.35
206        pz 0.00
207        pz 2.00
208        pz 50.8
209        pz 52.8
210        pz -121.92
211  pz 40
212  pz 28
213  pz 16
214  pz 4
296  1 pz -48
297  1 pz -36
298  1 pz -24
299  1 pz -12
300  1 pz 0.1
301  1      pz 12
302  1      pz 24
303  1      pz 36
304  1 pz 48
305  1 pz 60
306  1 pz 72
307  1 pz 84
308  1 pz 91.44
700        px     -0.1
701        px  200.125
702        py     -0.1
703        py  122.655
704        pz     -0.1
c 705      pz  51.154
```

```
 705          pz  52.83
 706          px  123.925
c     tally surfaces
 1000         px  403

tr1    0 0 -414.025    $ top of pins
tr771  34.6163 1128.6100 -466.8250
tr772  269.4580 1128.6100 -466.8250
tr773  504.2990 1128.6100 -466.8250
mode   p
c    MATERIALS ***********
m1        8000      .21       $O air number fraction
          7000      .79       $N
m2        8000     -.4407     $O concrete weight fraction
         14000     -.2157     $Si
         20000     -.1306     $Ca
         26000     -.0788     $Fe
         13000     -.0607     $Al
         12000     -.0376     $Mg
         19000     -.0066     $K
         11000     -.0182     $Na
         22000     -.0049     $Ti
          1000     -.0031     $H
         25000     -.0013     $Mn
         15000     -.0009     $P
         16000     -.0009     $S
m3       26000     1.0        $Fe iron
m4       14000      .2813     $Si  hanford soil number fraction
          8000      .6556     $O
         13000      .0123     $Al
         26000      .0084     $Fe
         20000      .0149     $Ca
         12000      .0103     $Mg
         19000      .0022     $K
         11000      .0034     $Na
          1000      .0116     $H
m5       1000 1  8000 1       $Water
m6       55000 1  17000 1     $CsCl
c SOURCE *******
c       28.6MCi Cs * 3.7e10 dis/Ci * .946 Ba/Cs * .901(abundance) = 9.02e17
sdef    cel=d1
        pos=4.75 4.75 0  axs=0 0 1  ext=d3
        rad d4 erg .66166 wgt=9.02e17
c       End Cs rack
si1 l   771:201(4 0 0):205  771:201(5 0 0):205
        771:201(6 0 0):205  771:201(7 0 0):205  771:201(8 0 0):205
        771:201(9 0 0):205  771:201(10 0 0):205  771:201(11 0 0):205
        771:201(12 0 0):205  771:201(13 0 0):205  771:201(14 0 0):205
        771:201(15 0 0):205  771:201(16 0 0):205  771:201(17 0 0):205
        771:201(18 0 0):205  771:201(19 0 0):205  771:201(20 0 0):205
        771:201(4 1 0):205  771:201(5 1 0):205
        771:201(6 1 0):205  771:201(7 1 0):205  771:201(8 1 0):205
        771:201(9 1 0):205  771:201(10 1 0):205  771:201(11 1 0):205
        771:201(12 1 0):205  771:201(13 1 0):205  771:201(14 1 0):205
        771:201(15 1 0):205  771:201(16 1 0):205  771:201(17 1 0):205
        771:201(18 1 0):205  771:201(19 1 0):205  771:201(20 1 0):205
        771:201(4 2 0):205  771:201(5 2 0):205
        771:201(6 2 0):205  771:201(7 2 0):205  771:201(8 2 0):205
        771:201(9 2 0):205  771:201(10 2 0):205  771:201(11 2 0):205
        771:201(12 2 0):205  771:201(13 2 0):205  771:201(14 2 0):205
        771:201(15 2 0):205  771:201(16 2 0):205  771:201(17 2 0):205
        771:201(18 2 0):205  771:201(19 2 0):205  771:201(20 2 0):205
        771:201(4 3 0):205  771:201(5 3 0):205
        771:201(6 3 0):205  771:201(7 3 0):205  771:201(8 3 0):205
        771:201(9 3 0):205  771:201(10 3 0):205  771:201(11 3 0):205
        771:201(12 3 0):205  771:201(13 3 0):205  771:201(14 3 0):205
        771:201(15 3 0):205  771:201(16 3 0):205  771:201(17 3 0):205
        771:201(18 3 0):205  771:201(19 3 0):205  771:201(20 3 0):205
        771:201(4 4 0):205  771:201(5 4 0):205
        771:201(6 4 0):205  771:201(7 4 0):205  771:201(8 4 0):205
        771:201(9 4 0):205  771:201(10 4 0):205  771:201(11 4 0):205
        771:201(12 4 0):205  771:201(13 4 0):205  771:201(14 4 0):205
        771:201(15 4 0):205  771:201(16 4 0):205  771:201(17 4 0):205
        771:201(18 4 0):205  771:201(19 4 0):205  771:201(20 4 0):205
        771:201(4 5 0):205  771:201(5 5 0):205
        771:201(6 5 0):205  771:201(7 5 0):205  771:201(8 5 0):205
```

771:201(9 5 0):205 771:201(10 5 0):205 771:201(11 5 0):205
771:201(12 5 0):205 771:201(13 5 0):205 771:201(14 5 0):205
771:201(15 5 0):205 771:201(16 5 0):205 771:201(17 5 0):205
771:201(18 5 0):205 771:201(19 5 0):205 771:201(20 5 0):205
771:201(4 6 0):205 771:201(5 6 0):205
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sp1     1 662r
si3     2.00 50.8
si4     0 2.75
c       ansi/ans-6.1.1-1991 fluence-to-dose,photons(mrem/hr/(p/cm**2/s)
de0     log  .01 .015 .02 .03 .04 .05
             .06 .08 .10 .15 .20 .30
             .40 .50 .60 .80 1.0 1.5
             2.0 3.0 4.0 5.0 6.0 8.0
             10. 12.
df0     log  2.232e-5 5.652e-5 8.568e-5 1.184e-4 1.314e-4 1.382e-4
             1.440e-4 1.624e-4 1.919e-4 2.797e-4 3.708e-4 5.616e-4
             7.416e-4 9.144e-4 1.076e-3 1.379e-3 1.656e-3 2.246e-3
             2.758e-3 3.672e-3 4.500e-3 5.292e-3 6.012e-3 7.488e-3
             8.892e-3 1.040e-2
phys:p    j 1 1
prdmp    j -240 1 3
imp:p
c       1 301 2 302 3 303 4 304 5 305 6 306 7
        0   0 0   0 0   0 0   0 0   0 0   0 1
c       751
          1
c       750 749 748 747 746 745 744 743 742 741
          r .5m .5m   r   r   r .5m   r   r .5m
c       740 739 738 737 736 735 734 733 732 731
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          r    r    r .5m   r    r .5m   r    r    r
c        730 729 728 727 726 725 724 723 722 721
         .5m   r    r .5m   r    r    r    r    r    r
c        720 719 718 717 716 205 715 714 713 712 711
         .5m   r    r    r    r    r .5m   r    r    r    r
c        710 709 708 707 706 705 704 703 702 701
         .5m   r    r    r    r .5m   r    r    r    r
c        8 308 9 309 10 310 11 311
         0   0 0   0  0  0  0   0
c       12  13  14 15   16  17  18  19  20
         1 8r
c       21  22  23  24  25  26  27  28  29  30
         1 9r
c       31  32  33  34  35  36  37  38  39
         1   1   0   0   0  .1   1   1   1
c           42      44          47  48  49  50
             1       1           1   1   1   1
c       51      53      55      57  58  59  60
         1       1       1       1   1   1   1
c       61  62  63  64  65  66          69  70
         1   1   1   1   1   1           1   1
c       71  72  73  74  75  76  77  78  79  80
         1   1   1   1   1   4   4   4   0   4
c       81  82  83  84  85  86      88
         0   0   0   0   0   4       4
c               93  94  95  96  97  98  99 100
                 2   4   2   4   2   4   2   4
c      101 102 103 104 105 106 107     109 110
         4   4   4   4   4   4   4       4   4
c      111 112 113 114 115 116 117
         4   6   0   0   0   0   0
c      201 202 203
         1   1   1
c      771 772 773
       1 2r
c      900
       0
fc24   Dose in doorway to airlock
f24:p   74
cf24   99
fc52   5m North/South
f52:p   99 103
fs52   -38 50
fc54   5m North/South
f54:p  76
fs54   -38 50 58
fc72   5m West/East
f72:p   91 95
fs72   41 -40
fc74   5m West/East
f74:p   76
fs74   41 -40 -57
fc92   10m North/South
f92:p   100 104
fs92   -38 50
fc94   10m North/South
f94:p  77
fs94   -38 50 58
fc112   10m West/East
f112:p   92 96
fs112   41 -40
fc114   10m West/East
f114:p   77
fs114   41 -40 -57
ctme     900
print 10 126 150 160 170
```

CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

DOCUMENT REVIEWED
NUMBER: 8M730-KEH-96-001
TITLE: DOSE RATE IN THE WESF CAPSULE STORAGE CONTROL ROOM DUE TO LOSS OF WATER IN A MAXIMALLY LOADED POOL
Reviewer(s): V. E. Roetman

I. Method(s) of Review

(✓) Input data checked for accuracy
( ) Independent calculation performed
( ) Hand calculation
( ) Alternate computer code:
( ) Comparison to experiment or previous results
( ) Alternate method (define)

II. Checklist (either check or enter NA if not applied)

(✓) Task completely defined
(✓) Activity consistent with task specification
(✓) Necessary assumptions explicitly stated and supported
(✓) Resources properly identified and referenced
(✓) Resource documentation appropriate for this application
(✓) Input data explicitly stated
(✓) Input data verified to be consistent with original source
(✓) Geometric model adequate representation of actual geometry
(✓) Material properties appropriate and reasonable
(NA) Mathematical derivations checked including dimensional consistency
(NA) Hand calculations checked for errors
(✓) Assumptions explicitly stated and justified
(✓) Computer software appropriate for task and used within range of validity
(✓) Use of resource outside range of established validity is justified
(✓) Software runstreams correct and consistent with results
(✓) Software output consistent with input
(NA) Results consistent with applicable previous experimental or analytical findings
(✓) Results and conclusions address all points and are consistent with task requirements and/or established limits or criteria
(NA) Conclusions consistent with analytical results and established limits
(✓) Uncertainty assessment appropriate and reasonable
(NA) Other (define)

III. Comments:

IV. REVIEWER: Victor Roetman

Westinghouse Hanford Company **Internal Memo**

From: Criticality and Shielding 8M730-KEH-96-003
Phone: 373-4078 H0-35
Date: June 3, 1996
Subject: DOSE RATES DUE TO PARTIAL AND COMPLETE LOSS OF WATER IN A MAXIMALLY LOADED WESF CAPSULE STORAGE POOL

To: B. E. Hey A3-34

cc: J. Greenborg H0-35
A. L. Ramble A3-38*
*w/o attachment
KEH File/LB

References:

1. L. L. Carter, "Certification of MCNP Version 4A for WHC Computer Platforms", SD-MP-SWD-30001, Rev. 7, dated January 26, 1995.

2. B. E. Hey, "Supporting Calculations and Assumptions for Use in WESF Interim Safety Basis", WHC-SD-WM-TI-733, DRAFT, dated February 16, 1996.

3. F. A. Schmittroth, "Conversion of ORIGEN2 to the Sun Workstations," WHC-SD-NR-SWD-006, Rev. 1, August 1994.

4. E. Browne, and R. B. Firestone, "Table of Radioactive Isotopes", John Wiley & Sons, Inc., New York, New York, 1986.

5. Internal Memo, K. E. Hillesland to J. M. Siemer, "Dose Rate Calculations Near the WESF Facility Due to Loss of Water In the Capsule Storage Pools", dated November 29, 1994.

1.0 SUMMARY

Dose rates due to partial and complete drainage of a maximally loaded capsule storage pool have been calculated using the MCNP computer code (Reference 1). Dose rates at the north and northeast (airlock) door as well as 18 ft over the center of the pool cell floor for both complete drainage and drainage to a 3 ft (91 cm) water level are given in Table 1.

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Table 1. Dose Rates for a Dry Pool and 3 ft Water Level

Condition	Location	Dose Rate (rem/hr)
Water Level at 3 ft	18 ft Over Center of Pool Cell Floor	17,000 (3%)
	Airlock Door	240 (4%)
	Just Outside of North Door	27 (9%)
Dry Pool	18 ft Over Center of Pool Cell Floor	57,000 (3%)
	Airlock Door	970 (3%)
	Just Outside of North Door	110 (7%)

[1]This is the one standard deviation statistical uncertainty given by MCNP.

2.0 SOURCE

The total source activity is 28.6 MCi of Cs-137 (Reference 2). This corresponds to 663 cesium capsules with an average activity of 39.19 kCi as of 12/31/95 plus an additional 10% safety margin. Only the .662 MeV gamma of the Cs/Ba decay was considered. The branching ratio for decay from Cs-137 to Ba-137m is .946 (ORIGEN2 database, Reference 3). The abundance of the .662 MeV gamma in the decay of Ba-137m is .901 (Reference 4). Thus, the total number of .662 MeV photons per second is:

$$(28.6\ \text{MCi})(3.7\text{E+10}\ s^{-1}\text{Ci}^{-1})(.946)(.901) = 9.02\text{E+17}\ s^{-1}$$

Beta and lower energy gamma (x-ray) radiations, constituting approximately 30% of the total energy produced, are assumed to be absorbed within the capsule, and are therefore neglected from this analysis.

3.0 GEOMETRY

The MCNP input file is provided in Attachment 1. The MCNP model was developed from a model used in a previous analysis (Reference 5). The pools are 18 ft (5.48 m) deep and are separated from one another by 15 ft (4.57 m) high walls. The width of the pool is 4 ft 5 in (135 cm). The capsules are each 20.8 in (52.8 cm) tall, and sit approximately 8.2 in (20.8 cm) off the bottom of the pool in three separate racks. When the water level is at 3 ft (91.4 cm) above the bottom of the pool, there is 7.0 in (17.8 cm) of water above the top of the capsules. Concrete was modeled with a density of 2.35 g/cc, and water at 1.0 g/cc.

The bottom of both the airlock and north door are 18 ft (5.48 m) above the pool cell floor. The center of the airlock door is 5.4 m east and 19.1 cm

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south of the center of pool 7 on the east wall. The center of the north door is 4.6 m east and 8.5 m north of the center of pool 7.

The capsules consist of CsCl salt encased in steel. They were modeled with an outside diameter of 2.6 in (6.7 cm), and a height of 20.8 in (52.8 cm). The thickness of steel at each end of the capsule was modeled as 0.79 in (2 cm), and the side thickness as .24 in (0.6 cm), including both inner and outer capsules. The thicknesses of the steel are based on dimensions given in Reference 2. The model assumed 2.5 kg CsCl and 5.9 kg 316 SST in each capsule, corresponding to the averages given by the Encapsulation Database System (EDS) maintained by WESF engineering.

Each pool contains racks for storing the capsules in arrays of 13 x 17, 13 x 21 and 13 x 13 capsules. This amounts to 663 capsules in a maximally loaded pool. The capsules are spaced at 3.75 in (9.5 cm) intervals within each rack. In this analysis, the capsules were placed in pool 7. Pool 7 is both the pool nearest the airlock door and the pool currently used for capsule storage closest to the north wall.

4.0 RESULTS

Table 1 above shows the dose rates calculated for both a dry pool and a pool with a water level at 3 ft (91.4 cm).

6.0 ARCHIVAL

The input and output files are stored on floppy with this report in the 1996 letterbook. The MCNP input and output file names for the three foot water level are i3feet and oc3feet respectively. The MCNP input and output file names for the empty pool are iempty and ocempty respectively. Attacment 1 is a source listing of the i3feet input file with additional internal documentation. The iempty file was created from the i3feet file by changing all cells containing water into air in pool 7, and changing all importances in cell 7 to one.

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Criticality and Shielding

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Attachment

MCNP Input File Listing

```
WESF facility, 3 feet of water in pool 7
c   #1 Air in pool 1
    1     1     -0.001200 -3 -5 1 4 6 -7 210
c   #301 Water in pool 1
  301     5      -1.00000 -3 -5 4 6 -7 -210
c   #2 Air in pool 2
    2     1     -0.001200 1 -3 -7 6 8 -9 210
c   #302 Water in pool 2
  302     5      -1.00000 1 -3 -7 6 8 -9 -210
c   #3 Air in pool 3
    3     1     -0.001200 1 -3 -7 6 10 -11 210
c   #303 Water in pool 3
  303     5      -1.00000 1 -3 -7 6 10 -11 -210
c   #4 Air in pool 4
    4     1     -0.001200 -3 1 6 -7 12 -13 210
c   #304 Water in pool 4
  304     5      -1.00000 -3 1 6 -7 12 -13 -210
c   #5 Air in pool 5
    5     1     -0.001200 -3 1 -7 6 14 -15 210
c   #305 Water in pool 5
  305     5      -1.00000 -3 1 -7 6 14 -15 -210
c   #6 Air in pool 6
    6     1     -0.001200 -3 1 -7 6 16 -17 210
c   #306 Water in pool 6
  306     5      -1.00000 -3 1 -7 6 16 -17 -210
c   #7 Air in pool 7
    7     1     -0.001200 -3 1 -7 6 18 -19 309
c
c   NOTE:  Cells below with -309 may not appear in geometry.
c          Surface 309 is top of water in cell 7
c
c   All of cells number 700-799 correspond to pool 7
  751     5      -1.00000 -7 6 18 -19 307 -308 -309
c   #750 East wall of pool 7, 5th imp cell
  750     2      -2.35000 -31 298 -44 33 274 -28
c   #749 12th water imp cell in pool 7
  749     5      -1.00000 -7 6 18 -19 306 -307 -309
c   #748 11th water imp cell in pool 7
  748     5      -1.00000 -7 6 18 -19 305 -306 -309
c   #747 East wall of pool 7, 4th imp region
  747     2      -2.35000 -31 298 -44 33 273 -274
c   #746 S wall of pool 7, 11th imp cell
  746     2      -2.35000 17 -18 -3 6 -7 306 -308
c   #745 N wall of pool 7
  745     2      -2.35000 19 -20 -3 6 -7 306 -308
c   #744 10th water imp cell in pool 7
  744     5      -1.00000 -7 6 18 -19 304 -305 -309
c   #743 S wall of pool 7, 10th imp cell
  743     2      -2.35000 17 -18 -3 6 -7 305 -306
c   #742 N wall of pool 7
  742     2      -2.35000 19 -20 -3 6 -7 305 -306
c   #741 9th water imp cell in pool 7
  741     5      -1.00000 -7 6 18 -19 303 -304 -309
c   #740 E wall of pool 7, 3rd imp cell
  740     2      -2.35000 -31 298 -44 33 272 -273
c   #739 S wall of pool 7, 9th imp cell
  739     2      -2.35000 17 -18 -3 6 -7 304 -305
c   #738 N wall of pool 7, 8th imp cell
  738     2      -2.35000 19 -20 -3 6 -7 304 -305
c   #737 8th water imp cell in pool 7
  737     5      -1.00000 -7 6 18 -19 302 -303 -309
c   #736 S wall of pool 7, 8th imp cell
  736     2      -2.35000 17 -18 -3 6 -7 303 -304
c   #735 N wall of pool 7, 8th imp region
  735     2      -2.35000 19 -20 -3 6 -7 303 -304
c   #734 7th water imp cell in pool 7
  734     5      -1.00000 -7 6 18 -19 301 -302 -309
c   #733 E wall of pool 7, 2nd imp cell
  733     2      -2.35000 -31 298 -44 33 271 -272
c   #732 S wall of pool 7, 7th imp cell
  732     2      -2.35000 17 -18 -3 6 -7 302 -303
c   #731 N wall of pool 7, 7th imp region
  731     2      -2.35000 19 -20 -3 6 -7 302 -303
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c   #730 6th water imp cell in pool 7
  730     5       -1.00000 -7 6 18 -19 300 -301 -309
c   #729  S wall of pool 7, 6th imp cell
  729     2       -2.35000 17 -18 -3 6 -7 301 -302
c   #728 N wall of pool 7, 6th imp region
  728     2       -2.35000 19 -20 -3 6 -7 301 -302
c   #727 5th water imp cell in pool 7
  727     5       -1.00000 -7 6 18 -19 299 -300  #771 #772 #773
c   #726 E wall of pool 7, E imp cell
  726     2       -2.35000 -31 298 -44 33 7 -271
c   #725 S wall of pool 7, 5th imp cell
  725     2       -2.35000 17 -18 -3 6 -7 300 -301
c   #724 N wall of pool 7, 5th imp cell
  724     2       -2.35000 19 -20 -3 6 -7 300 -301
c   #723 Water in pool 7 array, filled regions, top imp region
  723     5       -1.00000 (205 :-206 :209 )211  u=5
c   #722 Water in pool 7 array, empty regions, top imp region
  722     5       -1.00000 211  u=4
c   #721 Capsule steel casing
  721     3       -8.40000 -205 206 -209 (204 :-207 :208 ) u=5
c   #720 4th water imp cell in pool 7
  720     5       -1.00000 -7 6 18 -19 298 -299  #771 #772 #773
c   #719 S wall of pool 7, 4th imp cell
  719     2       -2.35000 17 -18 -3 6 -7 299 -300
c   #718 N wall of pool 7, 4th imp cell
  718     2       -2.35000 19 -20 -3 6 -7 299 -300
c   #717 Water in pool 7 array, filled regions, 4th region
  717     5       -1.00000 (205 :-206 :209 )212 -211  u=5
c   #716 Water in pool 7 array, empty regions, 4th region
  716     5       -1.00000 212 -211  u=4
c   #205 CsCl source cell
  205     6       -2.16000 -204 207 -208  u=5
c   #715 3rd water imp cell in pool 7
  715     5       -1.00000 -7 6 18 -19 297 -298  #771 #772 #773
c   #714 S wall of pool 7, 3rd imp cell
  714     2       -2.35000 17 -18 -3 6 -7 298 -299
c   #713 N wall of pool 7, 3rd imp cell
  713     2       -2.35000 19 -20 -3 6 -7 298 -299
c   #712 Water in pool 7 array, filled regions, 3nd region
  712     5       -1.00000 (205 :-206 :209 )213 -212  u=5
c   #711 Water in pool 7 array, empty regions, 3nd region
  711     5       -1.00000 213 -212  u=4
c   #710 2nd water imp cell in pool 7
  710     5       -1.00000 -7 6 18 -19 296 -297  #771 #772 #773
c   #709 S wall of pool 7, 2nd imp cell
  709     2       -2.35000 17 -18 -3 6 -7 297 -298
c   #708 N wall of pool 7, 2nd imp cell
  708     2       -2.35000 19 -20 -3 6 -7 297 -298
c   #707 Water in pool 7 array, filled regions, 2nd region
  707     5       -1.00000 (205 :-206 :209 )214 -213  u=5
c   #706 Water in pool 7 array, empty regions, 2nd region
  706     5       -1.00000 214 -213  u=4
c   #705 Bottom water imp cell in pool 7
  705     5       -1.00000 1 -7 6 18 -19 -296  #771 #772 #773
c   #704  S wall of pool 7, bottom imp cell
  704     2       -2.35000 17 -18 -3 6 -7 1 -297
c   #703 N wall of pool 7, bottom imp cell
  703     2       -2.35000 19 -20 -3 6 -7 1 -297
c   #702 Water in pool 7 array, filled regions, bottom region
  702     5       -1.00000 (205 :-206 :209 )-214  u=5
c   #701 Water in pool 7 array, empty regions, bottom region
  701     5       -1.00000 -214  u=4
c   #8 Air in pool 8
    8     1      -0.001200 -3 1 -7 6 20 -21 210
c   #308 Water in pool 8
  308     5       -1.00000 -3 1 -7 6 20 -21 -210
c   #9 Air in pool 9
    9     1      -0.001200 -3 1 -7 6 22 -23 210
c   #309 Water in pool 9
  309     5       -1.00000 -3 1 -7 6 22 -23 -210
c   #10 Air in pool 10
   10     1      -0.001200 -3 1 -7 6 24 -25 210
c   #310 Water in pool 10
  310     5       -1.00000 -3 1 -7 6 24 -25 -210
c   #11 Air in pool 11
   11     1      -0.001200 -3 1 -7 6 26 -27 210
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c   #311 Water in pool 11
  311     5      -1.00000 -3 1 -7 6 26 -27 -210
c  #12  Transition aisle
   12     1     -0.001200 -31 30 28 -29 33 -32
c  #13  Air W of pools
   13     1     -0.001200 35 -36 -34 38 40 -41
c  #14   Below grating W of pools
   14     1     -0.001200 37 -31 -34 38 -41 40
c   Air above pools
   15     1     -0.001200 3 -31 6 -7 -27 4
c   Bottom air N of pools
   16     1     -0.001200 (43 -41 34 -29 35 -36 )(44 :28 )
c   Top air N of pools
   17     1     -0.001200 (34 -41 43 -29 37 -31 )(44 :28 )
c  #18 Truck port
   18     1     -0.001200 -46 47 -50 38 -49 48
c  #19 Under mezzanine
   19     1     -0.001200 -52 48 46 -45 38 -51
c   mezzanine air
   20     1     -0.001200 -55 38 53 -40 54 -49
c   #21 Air in WESF capsule storage area
   21     1     -0.001200 40 -49 31 -41 38 -50
c   #22 Wall between pools 1 and 2
   22     2      -2.35000 5 -8 -3 1 -7 6
c   #23 Wall between pools 2 and 3
   23     2      -2.35000 9 -10 -3 1 -7 6
c   #24 wall between pools 3 and 4
   24     2      -2.35000 11 -12 -3 1 6 -7
c   #25 wall between pools 4 and 5
   25     2      -2.35000 -3 1 6 -7 13 -14
c   #26 wall between pools 5 and 6
   26     2      -2.35000 -16 15 -3 1 6 -7
c   #27 W wall of pool 7, top portion
   27     2      -2.35000 17 -18 -3 6 -7 308
c   #28 E wall of pool 7, top cell
   28     2      -2.35000 19 -20 -3 6 -7 308
c   #29 wall between pools 8 and 9
   29     2      -2.35000 21 -22 -3 1 6 -7
c   #30 wall between pools 9 and 10
   30     2      -2.35000 23 -24 -3 1 6 -7
c   #31 wall between pools 10 and 11
   31     2      -2.35000 -26 25 -3 1 6 -7
c   #32 wall between pools 11 and 12
   32     2      -2.35000 27 -44 6 -7 -31 1
c   #33 Bottom of pool 7 E wall
   33     2      -2.35000 -298 7 -28 2 -44 33
   34     2      -2.35000 -6 -31 34 2 -44 40
c   #35 Bottom of pools
   35     2      -2.35000 2 -1 -7 6 -44 63
c   #36 Concrete bottom of transition aisle
   36     2      -2.35000 28 -29 -30 2 33 -32
c  #37  East wall of transition aisle
   37     2      -2.35000 29 -31 -50 2 33 -41
c  #38  Horiz conc W of pools
   38     2      -2.35000 -37 36 -34 38 40 -41
c   #39 Bottom of area west of pools
   39     2      -2.35000 -35 2 38 -34 40 -41
c   #42 Top concrete N of pools
   42     2      -2.35000 (36 -37 -29 34 43 -41 )(28 :44 )
c   #44 Bottom concrete N of pools
   44     2      -2.35000 (34 -35 2 -29 43 -41 )(44 :28 )
c   #47 SE corner of capsule storage area
   47     1     -0.001200 53 -40 -49 31 55 -50
   48     2      -2.35000 (-52 2 -51 38 45 -40 )(80 :-79 :78 :-31 )
c   #49 mezzanine floor
   49     2      -2.35000 52 -54 53 -40 -55 38
   50     2      -2.35000 -55 51 -40 46 -52 61
c   #51 SE wall of capsule storage area
   51     2      -2.35000 55 -50 -53 46 -49 61
c   #53 Floor of truck port
   53     2      -2.35000 -48 61 -46 47 38 -50
c   #55 South wall of pools
   55     2      -2.35000 63 -4 -31 1 6 -7
c   #57 Ground beneath truck port
   57     4      -1.50000 38 -61 -50 2 -53 62
c   #58 Outside ground
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   58     4      -1.50000 (-126 2 -64 )(58 :56 :-62 :-57 )
   59     2      -2.35000 -29 28 -43 32 -31 2
   60     2      -2.35000 70 -33 7 -50 2 -31
c   #61 S wall of mezzanine
   61     2      -2.35000 -53 46 52 -49 -55 38
c   #62 floor at S end of capsule storage area
   62     2      -2.35000 ((71 -31 6 -63 -50 53 )(-7 :-70 ))(40 :55 )
   63     2      -2.35000 -48 61 46 -45 -51 38
c   #63 Ground beneath S end of capsule storage area
   64     4      -1.50000 ((61 -71 6 -63 -50 53 )(-7 :-70 ))(40 :55 )
c   #64 Ground beneath S end of capsule storage area
   65     4      -1.50000 ((53 -63 6 -50 2 -61 )(40 :51 ))(-7 :-70 )
   66     4      -1.50000 -45 -51 38 53 -61 2
c   #69 Truck door
   69     1     -0.001200 48 72 -74 -73 57 -38
c   #70 NW door of truck port
   70     1     -0.001200 -77 -75 76 48 57 -38
   71     1     -0.001200 79 -80 31 -78 45 -40
c   #72 E door of truck port
   72     1     -0.001200 -82 -80 81 31 50 -56
   73     1     -0.001200 -84 85 83 -86 -56 50
c   #74 Airlock door
   74     1     -0.001200 -87 31 88 -80 50 -56
c   #75 North door
   75     1     -0.001200 -80 90 -89 31 -58 41
c   #76 Outside air
   76     1     -0.001200 (-99 91 -95 103 64 -107 )(58 :56 :-62 :-57 )
c   #77 Outside air
   77     1     -0.001200 (-100 92 104 -96 64 -107 )(99 :-91 :-103 :95 )
c   #78 Outside air
   78     1     -0.001200 (-93 -107 64 )(100 :96 :-104 :-92 )
c   #79 Outside air
   79     1     -0.001200 (-94 64 -107 )93
c   #80 Outside air
   80     1     -0.001200 (-93 107 -108 (-57 :58 :56 :-62 :59 ))
            (114 :-115 :56 :-62 :116 )
c   #81 Outside air
   81     1     -0.001200 (-94 -108 107 )93
c   #82 Outside air
   82     1     -0.001200 108 -69 -93
c   #83 Outside air
   83     1     -0.001200 (108 -69 -94 )93
c   #84 Outside air
   84     1     -0.001200 ((64 -69 -65 )(94 ))(-107 )
c   #85 Outside air
   85     1     -0.001200 -109 110 47 -50 59 -111
c   #86 Outside air
   86     1     -0.001200 112 110 -113 -50 59 -111
c   #88 Outside air
   88     2      -2.35000 109 -112 -111 59 -50 110
c   #93 East wall, west imp cell
   93     2      -2.35000 ((((50 -56 -49 2 -41 62 )(82 :-81 :80 :-31 ))
            (-85 :86 :84 :-83 ))(87 :-88 :-31 :80 ))(-119 )
c   #94 East wall, east imp cell
   94     2      -2.35000 ((((50 -56 -49 2 -41 62 )(82 :-81 :80 :-31 ))
            (-85 :86 :84 :-83 ))(87 :-88 :-31 :80 ))(119 )
c   #95 W wall, E imp region
   95     2      -2.35000 (((57 -38 -49 2 62 -41 )(-72 :73 :74 :-48 ))
            (-48 :77 :-76 :75 ))(118 )
c   #96 W wall, W imp region
   96     2      -2.35000 (((57 -38 -49 2 62 -41 )(-72 :73 :74 :-48 ))
            (-48 :77 :-76 :75 ))(-118 )
c   #97 N wall, S imp region
   97     2      -2.35000 ((-58 41 -49 2 -56 57 )(-31 :80 :89 :-90 ))(-117 )
c   #98 N wall, N imp region
   98     2      -2.35000 ((-58 41 -49 2 -56 57 )(-31 :80 :89 :-90 ))117
c   #99 ceiling, bottom imp cell
   99     2      -2.35000 (-59 49 57 -58 -56 62 )(-121 )
c   #100 ceiling, top imp cell
  100     2      -2.35000 (-59 49 57 -58 -56 62 )(121 )
c   #101 S wall, N imp region
  101     2      -2.35000 (62 -47 -49 61 -50 38 )(120 )
c   #102 S wall, S imp region
  102     2      -2.35000 (62 -47 -49 61 -50 38 )(-120 )
c   #103 upper room walls
  103     2      -2.35000 (62 -47 -50 110 59 -111 )(120 )
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c   #104 upper room walls
  104     2      -2.35000 (62 -47 -50 110 59 -111 )(-120 )
c   #105 upper room walls
  105     2      -2.35000 (113 -114 -50 110 59 -111 )(-125 )
c   #106 upper room walls
  106     2      -2.35000 (113 -114 -50 110 59 -111 )(125 )
c   #107 upper room geomery
  107     1     -0.001200 -56 50 62 -114 59 -111
c   #109 upper room geomery
  109     2      -2.35000 (115 -110 -111 59 62 -114 )(124 )
c   #110 upper room geomery
  110     2      -2.35000 (115 -110 -111 59 62 -114 )(-124 )
c   #111 upper room geomery
  111     2      -2.35000 (111 -116 62 -114 -56 115 )(-123 )
c   #112 upper room geomery
  112     2      -2.35000 (111 -116 62 -114 -56 115 )(123 )
  113     1     -0.001200 (-126 64 -107 )(65 )
  114     1     -0.001200 (107 -108 -65 )(94 )
  115     1     -0.001200 (107 -108 -126 )(65 )
  116     1     -0.001200 (108 -69 -65 )(94 )
  117     1     -0.001200 (-69 108 -126 )(65 )
c   #201 W Cs rack lattice
  201       0  -200 201 -202 203 lat=1 u=1 fill=-1:21 -1:13 0:0
              4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
              4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
c   #202 E Cs rack lattice
  202       0  -200 201 -202 203 lat=1 u=2 fill=-1:21 -1:13 0:0
              4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
c   #203 Sr rack lattice
  203       0  -200 201 -202 203 lat=1 u=3 fill=-1:13 -1:13 0:0
              4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 5 5 5 5 5 5 5 5 5 5 5 5 5 4
              4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
c   #771 W Cs rack
  771       0  -701 700 -703 702 704 -705   trcl=771
           fill=1
c   #772 E Cs rack
```

```
  772      0  -701 700 -703 702 704 -705  trcl=772
           fill=2
c   #773 Sr rack
  773      0  -706 700 -703 702 704 -705  trcl=773
           fill=3
c   #900 Outside world
  900      0  -2 :69 :126

c  #1 bottom of pools
    1         pz      -487.68000
    2         pz      -548.64000
c   3         pz    22.86  Old model 16' 9" deep pits
    3         pz      -30.480000
    4         py      0.0000000
    5         py      266.70000
    6         px      0.0000000
    7         px      662.94000
  271         px      668.94000
  272         px      674.94000
  273         px      680.94000
  274         px      686.94000
    8         py      297.18000
    9         py      431.80000
   10         py      462.28000
   11         py      596.90000
   12         py      627.38000
   13         py      762.00000
   14         py      792.48000
   15         py      927.10000
   16         py      957.58000
c   #17 S wall of pool 7
   17         py      1092.2000
c   #18 N wall of pool 7
   18         py      1122.6800
   19         py      1257.3000
   20         py      1287.7800
   21         py      1422.4000
   22         py      1452.8800
   23         py      1587.5000
   24         py      1617.9800
   25         py      1752.6000
   26         py      1783.0800
   27         py      1917.7000
   28         px      693.42000
   29         px      784.86000
   30         pz      -411.48000
   31         pz      60.960000
   32         py      1865.6300
   33         py      -113.03000
   34         px      -30.480000
   35         pz      -495.30000
   36         pz      -121.92000
   37         pz      -91.440000
   38         px      -259.08000
   40         py      -142.24000
   41         py      2026.9200
   43         py      1896.1100
   44         py      1948.1800
   45         py      -162.56000
   46         py      -330.20000
   47         py      -708.66000
   48         pz      15.240000
   49         pz      476.25000
c  #50  E wall, W side
   50         px      853.44000
   51         px      287.02000
   52         pz      297.18000
   53         py      -304.80000
   54         pz      312.42000
   55         px      307.34000
c  #56  E wall, E side
   56         px      883.92000
   57         px      -289.56000
   58         py      2052.3000
   59         pz      486.41000
   61         pz      -5.0800000
```

```
    62          py        -739.14000
    63          py        -50.800000
    64          pz         0.0000000
    65          c/z        297.18000       656.58000       20000.000
    69          pz         30000.000
    70          py        -143.51000
    71          pz         30.480000
    72          py        -697.23000
    73          py        -361.95000
    74          pz         447.04000
    75          py        -177.80000
    76          py        -269.24000
    77          pz         228.60000
    78          px         271.78000
    79          px         180.34000
c   #80 Top of Airlock and N door
    80          pz         274.32000
    81          py        -693.42000
    82          py        -510.54000
    83          py         449.58000
    84          py         571.50000
    85          pz         223.52000
    86          pz         345.44000
c   #87 N side of Airlock door
    87          py         1231.9000
c   #88 S side of Airlock door
    88          py         1109.9800
c   #89 E side of N door
    89          px         838.20000
c   #90 W side of N door
    90          px         746.76000
    91          px        -789.56000
    92          px        -1289.5600
    93          c/z        297.18000       656.58000       5000.0000
    94          c/z        297.18000       656.58000       10000.000
    95          px         1383.9200
    96          px         1883.9200
    99          py         2552.3000
   100          py         3052.3000
   103          py        -1239.1400
   104          py        -1739.1400
   107          pz         200.00000
   108          pz         15000.000
   109          py        -7.6200000
   110          px         312.42000
   111          pz         1224.2800
   112          py         30.480000
   113          py         678.18000
   114          py         708.48000
   115          px         281.94000
   116          pz         1235.7100
   117          py         2039.6100
   118          px        -274.32000
c  #119 E wall, center surf
   119          px         868.68000
   120          py        -723.90000
   121          pz         481.33000
   123          pz         1229.9950
   124          px         297.18000
   125          py         693.33000
   126          c/z        297.18000       656.58000       30000.000
c  #200 +px surface of array element
   200          px         9.5000000
c  #200 -py surface of array element
   201          px         0.0000000
c  #202 +py surf of array element
   202          py         9.5000000
c  #203 -py surf of array element
   203          py         0.0000000
c  #204 CsCl radius
   204          c/z        4.7500000       4.7500000       2.7500000
c  #205 Capsule outer radius
   205          c/z        4.7500000       4.7500000       3.3500000
c  #206 Bottom of capsule
   206          pz         0.0000000
c  #207 Bottom of CsCl
```

```
  207          pz        2.0000000
c  #208 Top of CsCl
  208          pz        50.800000
c  #209 Top of capsule
  209          pz        52.800000
c  #210-308 imp surfaces
  210          pz       -121.92000
  211          pz        40.000000
  212          pz        28.000000
  213          pz        16.000000
  214          pz        4.0000000
  296      1   pz       -48.000000
  297      1   pz       -36.000000
  298      1   pz       -24.000000
  299      1   pz       -12.000000
  300      1   pz        0.1000000
  301      1   pz        12.000000
  302      1   pz        24.000000
  303      1   pz        36.000000
  304      1   pz        48.000000
  305      1   pz        60.000000
  306      1   pz        72.000000
  307      1   pz        84.000000
  308      1   pz        91.440000
c  #309 Water level
  309          pz       -396.24000
c  #701 -px of Arrays
  700          px       -0.1000000
c  #702 +px of CsCl Arrays
  701          px        200.12500
c  #703 -py of Arrays
  702          py       -0.1000000
c  #704 +py of Arrays
  703          py        122.65500
c  #704 bottom of arrays
  704          pz       -0.1000000
c 705          pz  51.154
c  #705 top of arrays
  705          pz        52.830000
c  #706 +px of Sr arrays
  706          px        123.92500
c     tally surfaces
 1000          px        403.00000
 1001          c/z       331.47000      1189.9900      15.000000

c  tr1 is top of capsules
tr1   0  0 -414.0250
c  tr771 is transformation for E Cs rack in pool 7
tr771  34.6163 1128.6100 -466.8250
c  tr772 is for W Cs rack in pool 7
tr772  269.4580 1128.6100 -466.8250
c  tr773 is for Sr rack in pool 7
tr773  504.2990 1128.6100 -466.8250
mode   p
c    MATERIALS ***********
m1        8000       .21       $O air number fraction
          7000       .79       $N
m2        8000      -.4407     $O concrete weight fraction
         14000      -.2157     $Si
         20000      -.1306     $Ca
         26000      -.0788     $Fe
         13000      -.0607     $Al
         12000      -.0376     $Mg
         19000      -.0066     $K
         11000      -.0182     $Na
         22000      -.0049     $Ti
          1000      -.0031     $H
         25000      -.0013     $Mn
         15000      -.0009     $P
         16000      -.0009     $S
m3       26000      1.0        $Fe iron
m4       14000       .2813     $Si  hanford soil number fraction
          8000       .6556     $O
         13000       .0123     $Al
         26000       .0084     $Fe
         20000       .0149     $Ca
```

```
        12000      .0103      $Mg
        19000      .0022      $K
        11000      .0034      $Na
         1000      .0116      $H
m5      1000 1  8000 1        $Water
m6      55000 1  17000 1      $CsCl
c SOURCE *******
c       28.6MCi Cs * 3.7e10 dis/Ci * .946 Ba/Cs * .901(abundance) = 9.02e17
sdef    cel=d1
        pos=4.75 4.75 0  axs=0 0 1  ext=d3
        rad d4 erg .66166 wgt=9.02e17
c       End Cs rack
si1 L   771:201(4 0 0):205  771:201(5 0 0):205
        771:201(6 0 0):205  771:201(7 0 0):205  771:201(8 0 0):205
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      772:202(3 12 0):205  772:202(4 12 0):205  772:202(5 12 0):205
      772:202(6 12 0):205  772:202(7 12 0):205  772:202(8 12 0):205
      772:202(9 12 0):205  772:202(10 12 0):205  772:202(11 12 0):205
      772:202(12 12 0):205  772:202(13 12 0):205  772:202(14 12 0):205
      772:202(15 12 0):205  772:202(16 12 0):205  772:202(17 12 0):205
      772:202(18 12 0):205  772:202(19 12 0):205  772:202(20 12 0):205
c    Sr rack
      773:203(0 0 0):205  773:203(1 0 0):205  773:203(2 0 0):205
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      773:203(0 3 0):205  773:203(1 3 0):205  773:203(2 3 0):205
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      773:203(6 7 0):205  773:203(7 7 0):205  773:203(8 7 0):205
      773:203(9 7 0):205  773:203(10 7 0):205  773:203(11 7 0):205
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      773:203(9 8 0):205  773:203(10 8 0):205  773:203(11 8 0):205
      773:203(12 8 0):205
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          773:203(0 9 0):205  773:203(1 9 0):205  773:203(2 9 0):205
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          773:203(3 11 0):205  773:203(4 11 0):205  773:203(5 11 0):205
          773:203(6 11 0):205  773:203(7 11 0):205  773:203(8 11 0):205
          773:203(9 11 0):205  773:203(10 11 0):205  773:203(11 11 0):205
          773:203(12 11 0):205
          773:203(0 12 0):205  773:203(1 12 0):205  773:203(2 12 0):205
          773:203(3 12 0):205  773:203(4 12 0):205  773:203(5 12 0):205
          773:203(6 12 0):205  773:203(7 12 0):205  773:203(8 12 0):205
          773:203(9 12 0):205  773:203(10 12 0):205  773:203(11 12 0):205
          773:203(12 12 0):205
sp1       1 662r
si3       2.00 50.8
si4       0 2.75
c         ansi/ans-6.1.1-1991 fluence-to-dose,photons(mrem/hr/(p/cm**2/s)
de0       log  .01 .015 .02 .03 .04 .05
               .06 .08 .10 .15 .20 .30
               .40 .50 .60 .80 1.0 1.5
               2.0 3.0 4.0 5.0 6.0 8.0
               10. 12.
df0       log  2.232e-5 5.652e-5 8.568e-5 1.184e-4 1.314e-4 1.382e-4
               1.440e-4 1.624e-4 1.919e-4 2.797e-4 3.708e-4 5.616e-4
               7.416e-4 9.144e-4 1.076e-3 1.379e-3 1.656e-3 2.246e-3
               2.758e-3 3.672e-3 4.500e-3 5.292e-3 6.012e-3 7.488e-3
               8.892e-3 1.040e-2
phys:p       j 1 1
prdmp       j -240 1 3
imp:p
c          1 301 2 302 3 303 4 304 5 305 6 306 7
           0   0 0   0 0   0 0   0 0   0 0   0 1
c         751
            1
c          750 749 748 747 746 745 744 743 742 741
             r   r   r   r   r   r   r   r   r   r
c          740 739 738 737 736 735 734 733 732 731
             r   r   r   r   r   r   r   r   r   r
c          730 729 728 727 726 725 724 723 722 721
             r   r   r .5m   r   r   r   r   r   r
c          720 719 718 717 716 205 715 714 713 712 711
           .5m   r   r   r   r   r .5m   r   r   r   r
c          710 709 708 707 706 705 704 703 702 701
           .5m   r   r   r   r .5m   r   r   r   r
c          8 308 9 309 10 310 11 311
           0   0 0   0  0   0  0   0
c         12  13  14 15   16  17  18  19  20
           1 8r
c         21  22  23  24  25  26  27  28  29  30
           1 9r
c         31  32  33  34  35  36  37  38  39
           1   1 .01  .1   0  .1   1   1   1
c             42      44              47  48  49  50
               1       1               1   1   1   1
c         51      53      55      57  58  59  60
           1       1       1       1   1   1   1
c         61  62  63  64  65  66          69  70
           1   1   1   1   1   1           1   1
c         71  72  73  74  75  76  77  78  79  80
           1   1   1   1   1   4   4   4   0   4
c         81  82  83  84  85  86      88
           0   0   0   0   0   4       4
c                 93  94  95  96  97  98  99 100
                   2   2   2   2   2   2   2   2
c        101 102 103 104 105 106 107     109 110
           2   2   2   2   2   2   2       2   2
c        111 112 113 114 115 116 117
           2   2   0   0   0   0   0
c        201 202 203
```

```
        1   1   1
c       771 772 773
        1 2r
c       900
        0
fc2  Dose at top of pool
f2:p  4
fs2  -1001
sd2   706.86 1e20
fc24   Dose in Airlock and N doorways
f24:p   74 75
cf24   99
ctme     9
print 10 126 150 160 170
```

CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

DOCUMENT REVIEWED Dose Rates due to Partial & Complete Loss of Water in A Maximally Load WESF Capsule Storage Pool - about 30 May 1996
AUTHOR(s) Karl E. Hillesland

I. Method(s) of Review

(X) Input data checked for accuracy
( ) Independent calculation performed
  (X) Hand calculation of Input Activity
  ( ) Alternate computer code: ______
( ) Comparison to experiment or previous results
( ) Alternate method (define) ______

II. Checklist (either check or enter NA if not applied)

(X) Task completely defined
(X) Activity consistent with task specification
(X) Necessary assumptions explicitly stated and supported
(X) Resources properly identified and referenced
(X) Resource documentation appropriate for this application
(X) Input data explicitly stated
(X) Input data verified to be consistent with original source
(X) Geometric model adequate representation of actual geometry
(X) Material properties appropriate and reasonable
(X) Mathematical derivations checked including dimensional consistency
(X) Hand calculations checked for errors
(X) Assumptions explicitly stated and justified
(X) Computer software appropriate for task and used within range of validity
(NA) Use of resource outside range of established validity is justified
(X) Software runstreams correct and consistent with results
(X) Software output consistent with input
(X) Results consistent with applicable previous experimental or analytical findings
(X) Results and conclusions address all points and are consistent with task requirements and/or established limits or criteria
(X) Conclusions consistent with analytical results and established limits
(X) Uncertainty assesment appropriate and reasonable
( ) Other (define)

______

______

III. Comments:

MCNP Code Input Could use Some Internal Documentation

______

IV. REVIEWER: Warren D. Wittekind DATE: 3 June 1996

K-3 - Filter Pit

MicroShield 4.00 - Serial #4.00-00128
Westinghouse Hanford Company

Page : 1
DOS* File: 4M20IN.MS4
Run Date: April 19, 1996
Run Time: 9:35 a.m. Friday
Duration: 0:00:01

File Ref: ________
Date: ___/___/___
By: ________
Checked: ________

Case Title: 1 Ci Cs-137, Dist.=4m, Shield=20in Normal Concrete

GEOMETRY 1 - Point

	centimeters	feet and inches	
Dose point coordinate X:	400.0	13.0	1.5
Dose point coordinate Y:	0.0	0.0	.0
Dose point coordinate Z:	0.0	0.0	.0
Shield 1:	50.8	1.0	8.0
Air Gap:	349.2	11.0	5.5

MATERIAL DENSITIES (g/cm^3)

Material	Shield 1 Slab	Air Gap
Air		0.00122
Concrete	2.35	

BUILDUP
Method: Buildup Factor Tables
The material reference is Shield 1

INTEGRATION PARAMETERS
Case solved analytically.

SOURCE NUCLIDES

Nuclide		Nuclide	
Ba-137m	9.4594e-001	Cs-137	9.9994e-001

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec) No Buildup	Energy Fluence Rate (MeV/sq cm/sec) With Buildup	Exposure Rate In Air (mR/hr) No Buildup	Exposure Rate In Air (mR/hr) With Buildup
0.6616	3.149e+010	9.816e-001	2.561e+001	1.903e-003	4.965e-002
TOTAL:	3.149e+010	9.816e-001	2.561e+001	1.903e-003	4.965e-002

*~~DOS MS-DOS~~ is a trademark of the Microsoft Corporation.

MicroShield 4.00 - Serial #4.00-00128
Westinghouse Hanford Company

Page : 1
DOS File: 4M20IN.MS4
Run Date: April 19, 1996
Run Time: 9:36 a.m. Friday
Duration: 0:00:01

File Ref: ___________
Date: ___/___/___
By: ___________
Checked: ___________

Case Title: 1 Ci Cs-137, Dist.=4m, Shield=24in Normal Concrete

GEOMETRY 1 - Point

	centimeters	feet	and inches
Dose point coordinate X:	400.0	13.0	1.5
Dose point coordinate Y:	0.0	0.0	.0
Dose point coordinate Z:	0.0	0.0	.0
Shield 1:	60.96	2.0	.0
Air Gap:	339.04	11.0	1.5

MATERIAL DENSITIES (g/cm^3)

Material	Shield 1 Slab	Air Gap
Air		0.00122
Concrete	2.35	

BUILDUP
Method: Buildup Factor Tables
The material reference is Shield 1

INTEGRATION PARAMETERS
Case solved analytically.

SOURCE NUCLIDES

Nuclide		Nuclide	
Ba-137m	9.4594e-001	Cs-137	9.9994e-001

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec) No Buildup	Energy Fluence Rate (MeV/sq cm/sec) With Buildup	Exposure Rate In Air (mR/hr) No Buildup	Exposure Rate In Air (mR/hr) With Buildup
0.6616	3.149e+010	1.551e-001	5.403e+000	3.006e-004	1.047e-002
TOTAL:	3.149e+010	1.551e-001	5.403e+000	3.006e-004	1.047e-002

Dose Rate ... Cell w/ 24 Capsules

MicroShield 4.00 - Serial #4.00-00128
Westinghouse Hanford Company

Page	: 1	File Ref:	______
DOS File:	HCWALL.MS4	Date:	__/__/__
Run Date:	June 18, 1996	By:	______
Run Time:	2:23 p.m. Tuesday	Checked:	______
Duration:	0:00:01		

Case Title: Dose Rate Through Hot Cell Wall with 24 CsCl Capsules

GEOMETRY 1 - Point

	centimeters	feet and	inches
Dose point coordinate X:	200.0	6.0	6.7
Dose point coordinate Y:	0.0	0.0	.0
Dose point coordinate Z:	0.0	0.0	.0
Shield 1:	88.9	2.0	11.0
Air Gap:	111.1	3.0	7.7

35 in thick wall

MATERIAL DENSITIES (g/cm^3)

Material	Shield 1 Slab	Air Gap
Air		0.00122
Concrete	3.76	

High density concrete

BUILDUP
Method: Buildup Factor Tables
The material reference is Shield 1

INTEGRATION PARAMETERS
Case solved analytically.

SOURCE NUCLIDES

Nuclide
Ba-137m 9.4080e+005 *= 24 capsules × 39.2 kCi/capsule avg.*

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec) No Buildup	Energy Fluence Rate (MeV/sq cm/sec) With Buildup	Exposure Rate In Air (mR/hr) No Buildup	Exposure Rate In Air (mR/hr) With Buildup
0.6	3.132e+016	6.985e-002	1.297e+001	1.363e-004	2.532e-002
TOTAL:	3.132e+016	6.985e-002	1.297e+001	1.363e-004	2.532e-002

Pool at 156 in level

MicroShield 4.00 - Serial #4.00-00128
Westinghouse Hanford Company

Page	: 1	File Ref:	________
DOS File:	POOL156.MS4	Date:	___/___/___
Run Date:	July 19, 1996	By:	________
Run Time:	2:55 p.m. Friday	Checked:	________
Duration:	0:00:05		

Case Title: Dose Rate Above Capsule Storage Pool with 156 in Water

GEOMETRY 11 - Rectangular Volume

	centimeters	feet and	inches
Dose point coordinate X:	528.32	17.0	4.0
Dose point coordinate Y:	198.12	6.0	6.0
Dose point coordinate Z:	60.96	2.0	.0
Rectangular volume width :	121.92	4.0	.0
Rectangular volume length:	52.832	1.0	8.8
Rectangular volume height:	640.08	21.0	.0
Shield 1:	323.088	10.0	7.2
Air Gap:	152.4	5.0	.0

Source Volume: 4.12293e+6 cm^3 145.6 cu ft. 251597. cu in.

MATERIAL DENSITIES (g/cm^3)

Material	Source Shield	Shield 1 Slab	Air Gap
Air			0.00122
Water		1.0	
CsCl Array	2.1		

BUILDUP
Method: Buildup Factor Tables
The material reference is Shield 1

INTEGRATION PARAMETERS

	Quadrature Order
X Direction	10
Y Direction	10
Z Direction	10

SOURCE NUCLIDES

Nuclide	curies	µCi/cm^3	Nuclide	curies	µCi/cm^3
Ba-137m	2.9324e+007	7.1125e+006	Cs-137	3.0998e+007	7.5185e+006

Page : 2
DOS File: POOL156.MS4
Run Date: July 19, 1996
Run Time: 2:55 p.m. Friday
Title : Dose Rate Above Capsule Storage Pool with 156 in Water

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.6616	9.763e+017	7.534e-003	2.289e+000	1.461e-005	4.438e-003
TOTAL:	9.763e+017	7.534e-003	2.289e+000	1.461e-005	4.438e-003

Pool at 110 IN Level

MicroShield 4.00 - Serial #4.00-00128
Westinghouse Hanford Company

Page	: 1	File Ref:	________
DOS File:	POOL110.MS4	Date:	__/__/__
Run Date:	July 19, 1996	By:	________
Run Time:	3:03 p.m. Friday	Checked:	________
Duration:	0:00:04		

Case Title: Dose Rate Above Capsule Storage Pool with 110 in Water

GEOMETRY 11 - Rectangular Volume

	centimeters	feet	inches
Dose point coordinate X:	528.32	17.0	4.0
Dose point coordinate Y:	320.04	10.0	6.0
Dose point coordinate Z:	60.96	2.0	.0
Rectangular volume width :	121.92	4.0	.0
Rectangular volume length:	52.832	1.0	8.8
Rectangular volume height:	640.08	21.0	.0
Shield 1:	206.248	6.0	9.2
Air Gap:	269.24	8.0	10.0

Source Volume: 4.12293e+6 cm^3 145.6 cu ft. 251597. cu in.

MATERIAL DENSITIES (g/cm^3)

Material	Source Shield	Shield 1 Slab	Air Gap
Air			0.00122
Water		1.0	
CsCl Array	2.1		

BUILDUP
Method: Buildup Factor Tables
The material reference is Shield 1

INTEGRATION PARAMETERS

	Quadrature Order
X Direction	10
Y Direction	10
Z Direction	10

SOURCE NUCLIDES

Nuclide	curies	µCi/cm^3	Nuclide	curies	µCi/cm^3
Ba-137m	2.9324e+007	7.1125e+006	Cs-137	3.0998e+007	7.5185e+006

Page : 2
DOS File: POOL110.MS4
Run Date: July 19, 1996
Run Time: 3:03 p.m. Friday
Title : Dose Rate Above Capsule Storage Pool with 110 in Water

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.6616	9.763e+017	2.113e+002	2.945e+004	4.097e-001	5.709e+001
TOTAL:	9.763e+017	2.113e+002	2.945e+004	4.097e-001	5.709e+001

Pool at 100 in Level

MicroShield 4.00 - Serial #4.00-00128
Westinghouse Hanford Company

Page	: 1	File Ref:	________
DOS File:	POOL100.MS4	Date:	__/__/__
Run Date:	July 19, 1996	By:	________
Run Time:	2:58 p.m. Friday	Checked:	________
Duration:	0:00:04		

Case Title: Dose Rate Above Capsule Storage Pool with 100 in Water

GEOMETRY 11 - Rectangular Volume

	centimeters	feet and	inches
Dose point coordinate X:	528.32	17.0	4.0
Dose point coordinate Y:	320.04	10.0	6.0
Dose point coordinate Z:	60.96	2.0	.0
Rectangular volume width :	121.92	4.0	.0
Rectangular volume length:	52.832	1.0	8.8
Rectangular volume height:	640.08	21.0	.0
Shield 1:	180.848	5.0	11.2
Air Gap:	294.64	9.0	8.0

Source Volume: 4.12293e+6 cm^3   145.6 cu ft.   251597. cu in.

MATERIAL DENSITIES (g/cm^3)

Material	Source Shield	Shield 1 Slab	Air Gap
Air			0.00122
Water		1.0	
CsCl Array	2.1		

BUILDUP
Method: Buildup Factor Tables
The material reference is Shield 1

INTEGRATION PARAMETERS

	Quadrature Order
X Direction	10
Y Direction	10
Z Direction	10

SOURCE NUCLIDES

Nuclide	curies	µCi/cm^3	Nuclide	curies	µCi/cm^3
Ba-137m	2.9324e+007	7.1125e+006	Cs-137	3.0998e+007	7.5185e+006

Page : 2
DOS File: POOL100.MS4
Run Date: July 19, 1996
Run Time: 2:58 p.m. Friday
Title : Dose Rate Above Capsule Storage Pool with 100 in Water

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.6616	9.763e+017	1.976e+003	2.209e+005	3.830e+000	4.282e+002
TOTAL:	9.763e+017	1.976e+003	2.209e+005	3.830e+000	4.282e+002

Pool at 95 in Level

MicroShield 4.00 - Serial #4.00-00128
Westinghouse Hanford Company

Page :	1	File Ref:	________
DOS File:	POOL95.MS4	Date:	__/__/__
Run Date:	July 19, 1996	By:	________
Run Time:	2:54 p.m. Friday	Checked:	________
Duration:	0:00:04		

Case Title: Dose Rate Above Capsule Storage Pool with 95 in Water

GEOMETRY 11 - Rectangular Volume

	centimeters	feet and	inches
Dose point coordinate X:	528.32	17.0	4.0
Dose point coordinate Y:	198.12	6.0	6.0
Dose point coordinate Z:	60.96	2.0	.0
Rectangular volume width :	121.92	4.0	.0
Rectangular volume length:	52.832	1.0	8.8
Rectangular volume height:	640.08	21.0	.0
Shield 1:	168.148	5.0	6.2
Air Gap:	307.34	10.0	1.0

Source Volume: 4.12293e+6 cm^3 145.6 cu ft. 251597. cu in.

MATERIAL DENSITIES (g/cm^3)

Material	Source Shield	Shield 1 Slab	Air Gap
Air			0.00122
Water		1.0	
CsCl Array	2.1		

BUILDUP
Method: Buildup Factor Tables
The material reference is Shield 1

INTEGRATION PARAMETERS

	Quadrature Order
X Direction	10
Y Direction	10
Z Direction	10

SOURCE NUCLIDES

Nuclide	curies	µCi/cm^3	Nuclide	curies	µCi/cm^3
Ba-137m	2.9324e+007	7.1125e+006	Cs-137	3.0998e+007	7.5185e+006

Page : 2
DOS File: POOL95.MS4
Run Date: July 19, 1996
Run Time: 2:54 p.m. Friday
Title : Dose Rate Above Capsule Storage Pool with 95 in Water

================================ RESULTS ================================

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.6616	9.763e+017	5.805e+003	5.717e+005	1.125e+001	1.108e+003
TOTAL:	9.763e+017	5.805e+003	5.717e+005	1.125e+001	1.108e+003

Pool at 64 in Level

MicroShield 4.00 - Serial #4.00-00128
Westinghouse Hanford Company

Page : 1
DOS File: POOL64.MS4
Run Date: July 19, 1996
Run Time: 3:25 p.m. Friday
Duration: 0:00:04

File Ref: ________
Date: __/__/__
By: ________
Checked: ________

Case Title: Dose Rate Above Capsule Storage Pool with 64 in Water

GEOMETRY 11 - Rectangular Volume

	centimeters	feet and	inches
Dose point coordinate X:	528.32	17.0	4.0
Dose point coordinate Y:	320.04	10.0	6.0
Dose point coordinate Z:	60.96	2.0	.0
Rectangular volume width :	121.92	4.0	.0
Rectangular volume length:	52.832	1.0	8.8
Rectangular volume height:	640.08	21.0	.0
Shield 1:	89.408	2.0	11.2
Air Gap:	386.08	12.0	8.0

Source Volume: 4.12293e+6 cm^3   145.6 cu ft.   251597. cu in.

MATERIAL DENSITIES (g/cm^3)

Material	Source Shield	Shield 1 Slab	Air Gap
Air			0.00122
Water		1.0	
CsCl Array	2.1		

BUILDUP
Method: Buildup Factor Tables
The material reference is Shield 1

INTEGRATION PARAMETERS

	Quadrature Order
X Direction	10
Y Direction	10
Z Direction	10

SOURCE NUCLIDES

Nuclide	curies	µCi/cm^3	Nuclide	curies	µCi/cm^3
Ba-137m	2.9324e+007	7.1125e+006	Cs-137	3.0998e+007	7.5185e+006

Page : 2
DOS File: POOL64.MS4
Run Date: July 19, 1996
Run Time: 3:25 p.m. Friday
Title : Dose Rate Above Capsule Storage Pool with 64 in Water

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.6616	9.763e+017	6.521e+006	2.399e+008	1.264e+004	4.650e+005
TOTAL:	9.763e+017	6.521e+006	2.399e+008	1.264e+004	4.650e+005

Pool at 36 in Level

MicroShield 4.00 - Serial #4.00-00128
Westinghouse Hanford Company

Page	: 1	File Ref:	______
DOS File:	POOL36.MS4	Date:	__/__/__
Run Date:	July 19, 1996	By:	______
Run Time:	3:19 p.m. Friday	Checked:	______
Duration:	0:00:04		

Case Title: Dose Rate Above Capsule Storage Pool with 36 in Water

GEOMETRY 11 - Rectangular Volume

	centimeters	feet and	inches
Dose point coordinate X:	528.32	17.0	4.0
Dose point coordinate Y:	320.04	10.0	6.0
Dose point coordinate Z:	60.96	2.0	.0
Rectangular volume width :	121.92	4.0	.0
Rectangular volume length:	52.832	1.0	8.8
Rectangular volume height:	640.08	21.0	.0
Shield 1:	17.78	0.0	7.0
Air Gap:	457.708	15.0	.2

Source Volume: 4.12293e+6 cm^3 145.6 cu ft. 251597. cu in.

MATERIAL DENSITIES (g/cm^3)

Material	Source Shield	Shield 1 Slab	Air Gap
Air			0.00122
Water		1.0	
CsCl Array	2.1		

BUILDUP
Method: Buildup Factor Tables
The material reference is Shield 1

INTEGRATION PARAMETERS

	Quadrature Order
X Direction	10
Y Direction	10
Z Direction	10

SOURCE NUCLIDES

Nuclide	curies	µCi/cm^3	Nuclide	curies	µCi/cm^3
Ba-137m	2.9324e+007	7.1125e+006	Cs-137	3.0998e+007	7.5185e+006

Page : 2
DOS File: POOL36.MS4
Run Date: July 19, 1996
Run Time: 3:19 p.m. Friday
Title : Dose Rate Above Capsule Storage Pool with 36 in Water

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.6616	9.763e+017	4.061e+009	2.544e+010	7.873e+006	4.933e+007
TOTAL:	9.763e+017	4.061e+009	2.544e+010	7.873e+006	4.933e+007

Pool at 28 in Level

MicroShield 4.00 - Serial #4.00-00128
Westinghouse Hanford Company

Page : 1		File Ref:	______
DOS File: POOL28.MS4		Date:	__/__/__
Run Date: July 19, 1996		By:	______
Run Time: 3:21 p.m. Friday		Checked:	______
Duration: 0:00:05			

Case Title: Dose Rate Above Capsule Storage Pool with 28 in Water

GEOMETRY 11 - Rectangular Volume

	centimeters	feet and inches	
Dose point coordinate X:	528.32	17.0	4.0
Dose point coordinate Y:	320.04	10.0	6.0
Dose point coordinate Z:	60.96	2.0	.0
Rectangular volume width :	121.92	4.0	.0
Rectangular volume length:	52.832	1.0	8.8
Rectangular volume height:	640.08	21.0	.0
Air Gap:	475.488	15.0	7.2

Source Volume: 4.12293e+6 cm^3 145.6 cu ft. 251597. cu in.

MATERIAL DENSITIES (g/cm^3)

Material	Source Shield	Air Gap
Air		0.00122
CsCl Array	2.1	

BUILDUP
Method: Buildup Factor Tables
The material reference is Source

********** CAUTION **********
This buildup reference material is a mixed material with a high atomic number element (55). Buildup Factors less than and somewhat greater than 36 keV may be incorrect. Please understand your results!
****

INTEGRATION PARAMETERS

	Quadrature Order
X Direction	10
Y Direction	10
Z Direction	10

SOURCE NUCLIDES

Nuclide	curies	µCi/cm^3	Nuclide	curies	µCi/cm^3
Ba-137m	2.9324e+007	7.1125e+006	Cs-137	3.0998e+007	7.5185e+006

Page : 2
DOS File: POOL28.MS4
Run Date: July 19, 1996
Run Time: 3:21 p.m. Friday
Title : Dose Rate Above Capsule Storage Pool with 28 in Water

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.6616	9.763e+017	2.039e+010	4.261e+010	3.952e+007	8.260e+007
TOTAL:	9.763e+017	2.039e+010	4.261e+010	3.952e+007	8.260e+007

Pool Dry

MicroShield 4.00 - Serial #4.00-00128
Westinghouse Hanford Company

Page	: 1	File Ref:	______
DOS File:	POOLDRY.MS4	Date:	__/__/__
Run Date:	July 19, 1996	By:	______
Run Time:	3:23 p.m. Friday	Checked:	______
Duration:	0:00:05		

Case Title: Dose Rate Above Capsule Storage Pool with 0 in Water

GEOMETRY 11 - Rectangular Volume

	centimeters	feet	and inches
Dose point coordinate X:	528.32	17.0	4.0
Dose point coordinate Y:	320.04	10.0	6.0
Dose point coordinate Z:	60.96	2.0	.0
Rectangular volume width :	121.92	4.0	.0
Rectangular volume length:	52.832	1.0	8.8
Rectangular volume height:	640.08	21.0	.0
Air Gap:	475.488	15.0	7.2

Source Volume: 4.12293e+6 cm^3 145.6 cu ft. 251597. cu in.

MATERIAL DENSITIES (g/cm^3)

Material	Source Shield	Air Gap
Air		0.00122
Dry CsCl Rck	1.4	

BUILDUP
Method: Buildup Factor Tables
The material reference is Source

INTEGRATION PARAMETERS

	Quadrature Order
X Direction	10
Y Direction	10
Z Direction	10

SOURCE NUCLIDES

Nuclide	curies	µCi/cm^3	Nuclide	curies	µCi/cm^3
Ba-137m	2.9324e+007	7.1125e+006	Cs-137	3.0998e+007	7.5185e+006

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec) No Buildup	Energy Fluence Rate (MeV/sq cm/sec) With Buildup	Exposure Rate In Air (mR/hr) No Buildup	Exposure Rate In Air (mR/hr) With Buildup
0.6616	9.763e+017	3.183e+010	6.101e+010	6.170e+007	1.183e+008
TOTAL:	9.763e+017	3.183e+010	6.101e+010	6.170e+007	1.183e+008

Dry Pool w/ 30 Coverblock

MicroShield 4.00 - Serial #4.00-00128
Westinghouse Hanford Company

Page	: 1	File Ref:	________
DOS File:	DRAINP.MS4	Date:	__/__/__
Run Date:	June 18, 1996	By:	________
Run Time:	2:19 p.m. Tuesday	Checked:	________
Duration:	0:00:01		

Case Title: Dose Rate Above Drained Pool Cell Containing 715 CsCl Caps.

GEOMETRY 1 - Point

	centimeters	feet and	inches
Dose point coordinate X:	457.2	15.0	.0
Dose point coordinate Y:	0.0	0.0	.0
Dose point coordinate Z:	0.0	0.0	.0
Shield 1:	76.2	2.0	6.0
Air Gap:	381.0	12.0	6.0

30 in thick coverblock

MATERIAL DENSITIES (g/cm^3)

Material	Shield 1 Slab	Air Gap
Air		0.00122
Concrete	3.76	

High density Concrete

BUILDUP
Method: Buildup Factor Tables
The material reference is Shield 1

INTEGRATION PARAMETERS
Case solved analytically.

SOURCE NUCLIDES

Nuclide
Ba-137m 2.8000e+007 = 715 capsules x 39.2 kCi/capsule avg.

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec) No Buildup	Energy Fluence Rate (MeV/sq cm/sec) With Buildup	Exposure Rate In Air (mR/hr) No Buildup	Exposure Rate In Air (mR/hr) With Buildup
0.6	9.322e+017	1.832e+001	2.567e+003	3.576e-002	5.010e+000
TOTAL:	9.322e+017	1.832e+001	2.567e+003	3.576e-002	5.010e+000

MicroShield 4.00 - Serial #4.00-00128
Westinghouse Hanford Company

Page	: 1	File Ref:	________
DOS File:	BAGWASTE.MS4	Date:	___/___/___
Run Date:	October 28, 1996	By:	________
Run Time:	9:56 a.m. Monday	Checked:	________
Duration:	0:00:05		

Case Title: Contact Dose Rate from 3 ft Sphere Containing 1 Ci Cs-137

GEOMETRY 6 - Sphere Volume

	centimeters	feet	and inches
Dose point coordinate X:	48.26	1.0	7.0
Dose point coordinate Y:	0.0	0.0	.0
Dose point coordinate Z:	0.0	0.0	.0
Sphere radius:	45.72	1.0	6.0
Air Gap:	2.54	0.0	1.0

Source Volume: 400320. cm^3   14.1372 cu ft.   24429. cu in.

MATERIAL DENSITIES (g/cm^3)

Material	Source Shield	Transition Shield	Air Gap
Air		0.00122	0.00122
Carbon	0.113		

BUILDUP
Method: Buildup Factor Tables
The material reference is Source

INTEGRATION PARAMETERS

	Quadrature Order
Radial	20
Angle	20

SOURCE NUCLIDES

Nuclide	curies	µCi/cm^3	Nuclide	curies	µCi/cm^3
Ba-137m	9.4594e-001	2.3630e+000	Cs-137	9.9994e-001	2.4978e+000

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec) No Buildup	Energy Fluence Rate (MeV/sq cm/sec) With Buildup	Exposure Rate In Air (mR/hr) No Buildup	Exposure Rate In Air (mR/hr) With Buildup
0.6616	3.149e+010	7.369e+005	9.395e+005	1.429e+003	1.821e+003
TOTAL:	3.149e+010	7.369e+005	9.395e+005	1.429e+003	1.821e+003

DON'T SAY IT --- *Write It!*

DATE: 7/1/96

TO: Jennifer Stewart

FROM: Tom Gainey

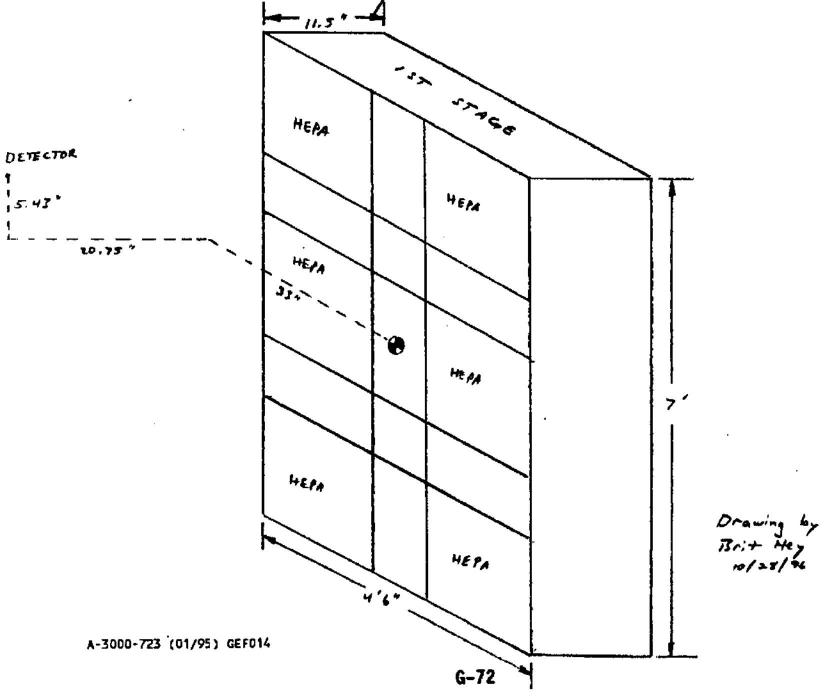
Telephone: 373-0964

cc: Lori Covey

SUBJECT: K3 Filter Radiation Detector

Per request I have estimated the distance of the radiation detector from the first HEPA bank of the K3 filter. The radiation detectors are placed within the K3 filter pit (225BB) alongside the K3 filter. Drawing H-2-99454 Sheet 1, shows the penetrations for the radiation detectors to be 6' from each end, 5' 2" down from the cover blocks, and 6" from the pit wall. Drawing H-2-99442 Sheet 1, shows the filter assembly as it is installed in the pit. I scaled, and drew in the location of the radiation detector, then using the measurable distances, calculated the distance from the detector to the center of the first HEPA filter bank. This distance is 39.4" (see attached sketch)

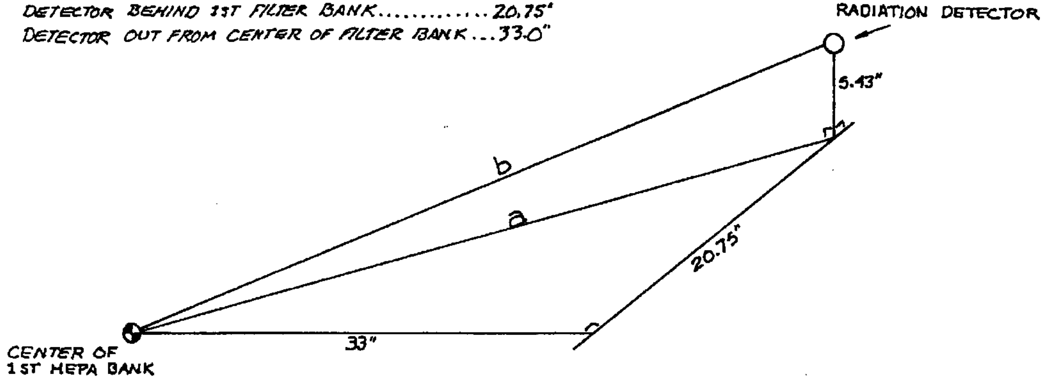
Tom Gainey 7/1/96



A-3000-723 (01/95) GEF014

DISTANCES MEASURABLE AFTER
MARKING LOCATION OF DETECTOR
ON DRAWING H-2-99442:

DETECTOR ABOVE CENTER LINE OF FILTERS .... 5.43"
DETECTOR BEHIND 1ST FILTER BANK .... 20.75"
DETECTOR OUT FROM CENTER OF FILTER BANK ... 33.0"



CALCULATED DISTANCES:

a = 38.98"

b = 39.36"

∴ DISTANCE FROM RADIATION DETECTOR TO CENTER OF 1 ST K3 FILTER HEPA BANK IS <u>39.4"</u>

FLUOR DANIEL NORTHWEST, INC.
INTEROFFICE CORRESPONDENCE

TO:	B. E. Hey	**DATE:**	October 22, 1996
LOCATION:	A3-34	**REFERENCE:**	"ISO-PC Version 1.98 - User's Guide", WHC-SD-WM-UM-030, Rev 0, May, 1995.
FROM:	P. D. Rittmann PDR		
LOCATION:	H0-31	**CLIENT:**	
EXTENSION:	376-8715	**SUBJECT:**	Estimated Dose Rates for the K3 Filters

cc: PDR-File/LB

The K3 HEPA filters will have two radiation detectors located in the cells near the filter banks. The purpose of this memo is to report estimates of the dose rates expected on the detector nearest the filters for an assumed activity loading of either 18,000 curies of Sr-90 or 240 curies of Cs-137.

The ISO-PC program was used for the calculations. The first stage of 6 HEPA filters was assumed to be the radiation source. The second stage will have very little activity compared to the first stage. The radiation detector is assumed to be positioned 6 inches (15.24 cm) to the side and 20 inches (50.8 cm) in front of the filter bank. This position estimate comes from drawings H-2-99442 and H-2-99454. The 6 HEPA filters comprising the filter bank are assumed to have 6 inch gaps between them, so that the filter stage is 4.5 feet (137.16 cm) wide and 7 feet (213.36 cm) tall.

The HEPA filter bank is assumed to be 11.5 inches (29.21 cm) thick, and have a density of 0.125 g/cc. The filter material is modelled as concrete with this low density. In addition, a thin layer of iron was used to represent the filter enclosure. The iron has a density of 7.86 g/cc and is 1/16 inch (0.16 cm) thick. The material used for computation of the buildup factor is concrete.

To estimate the dose rates to the side of the rectangular source, the source width was doubled and increased by 1 foot (30.48 cm) to give a total width of 10 feet (304.8 cm). The source strength was increased by the factor 10/9 to account for the extra foot of width. A second case was run using just the one foot width and a source activity of 1/10 the total. The dose rate from the one foot case was subtracted from the dose rate for the 10 foot case to give the final answer. The ISO-PC input file is attached for reference.

Exposure Rates from ISO-PC

	10 foot width	1 foot width	Difference
Sr-90	98.8 R/h	17.8 R/h	81.0 R/h
Cs-137	81.2 R/h	14.3 R/h	66.9 R/h
The Sr-90 source is 18,000 Ci Sr-90 and 18,000 Ci Y-90. The Cs-137 source is 240 Ci Cs-137 and 227 Ci Ba-137m.			

If you have any questions about these calculations, please call.

ATTACHMENT: ISO-PC INPUT FILE

```
0        2  Dose Rates at the WESF K3 Filter Radiation Detector
Sr-90 -- Full Virtual Width
 &Input  IGeom= 10,  SLTH= 213.36,  Y= 304.80,  T= 29.21,0.16,
  X= 80,  NShld= 2,  JBuf= 1,  NTheta= 31,  NPsi= 35,
  SFact= 20000,  Weight(82)= 1,0,1   &
  Metal  9          7.86
1 Media 16   0.125
Sr-90 -- Portion to be Subtracted
 &Input  Y= 30.48,  SFact= 2000,   Next= 4  &
Cs-137 -- Full Virtual Width
 &Input  Y= 304.80, SFact= 266.667,
  Weight(82)= 3*0,  Weight(335)= 1,0.946  &
Cs-137 -- Portion to be Subtracted
 &Input  Y= 30.48,  SFact= 26.667  &
This is the End of the Filter Cases !!
 &Input Next= 6  &
```

The filter array is 7 feet by 4.5 feet.
The detector is 6 inches to the side and 20 inches ahead of the filters.

PEER REVIEW CHECKLIST

Document Reviewed: Interoffice Correspondence from P.D. Rittmann to B.E. Hey, "Estimated Dose Rates for the K3 Filters", October 22, 1996

Scope of Review: Use of ISO-PC

Yes	No	NA	
[✓]	[ ]	[ ]	Necessary assumptions explicitly stated and supported.
[✓]	[ ]	[ ]	Computer codes and data files identified in document.
[✓]	[ ]	[ ]	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 (including spreadsheets) checked for errors.
[✓]	[ ]	[ ]	Software input correct and consistent with descriptions in the document.
[✓]	[ ]	[ ]	Software output consistent with input and with results reported in the document.
[ ]	[ ]	[✓]	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.
[ ]	[✓]		Review calculations, comments, and/or notes are attached.
[ ]	[✓]		Document approved by: Harvey J. Goldberg, PhD CHP

Signature: [illegible signature] Date: 21 Oct 96

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APPENDIX H - Supporting Calculations for Storage Pool Drain Accidents

This appendix contains:

1. Requesting DSI.

2. Calculation entitled "WESF Capsule Storage Pool - Dranage and Evaporation Calculations," by D. L. Scott dated 3/4/96.

3. Peer review checklist.

4. Internal Memorandum from J. E. Kelley to B. E. Hey dated May 15, 1996, "Drain Pipe Rupture Frequency at WESF," 8M400-JEK-96010, Westinghouse Hanford Company, Richland, WA.

5. WESF capsule storage pool sump volume calculations.

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DON'T SAY IT --- *Write It!*

DATE: February 6, 1996

TO: Dave L. Scott

FROM: Brit E. Hey

Telephone: 376-2921

CC: J. R. Brehm
L. I. Covey
W. R. Shannon
BEH/LB

SUBJECT: Technical Review and Supporting Calculations for WESF ISB

As discussed with you earlier today, please find attached a February 6, 1996 draft of WHC-SD-WM-TI-733 entitled "Supporting Calculations and Assumptions for Use in WESF ISB." Of particular need is a technical review of Section 2.2.4 "Capsule Failure Criteria" of this document in order to ensure its validity prior to the completion of dependent work. This review is needed by February 9, 1996.

A second request derives from an action item assigned to me during a recent WESF status meeting. We would like to know how long it would take for a single WESF capsule storage pool to drain down to the level where capsules would become uncovered. This drain down could occur via the steam jet pump system or via a hypothetical break and gravity drain through the pool drain line system. Mr. Wayne Shannon (372-0273) is the cognizant engineer for this system and should be able to provide you the information you need.

The charge code for this task is KW4C5. Please let me know if you have any questions.

Attachment (D. L. Scott only)

File Name: WESFPool

Date: 3-4-96

Author: D. L. Scott

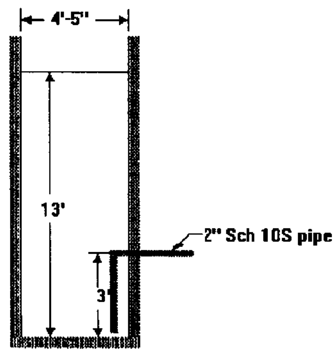
WESF CAPSULE STORAGE POOL----DRAINAGE AND EVAPORATION CALCULATIONS

To document and perform these calculations version 4.0 of Mathcad for windows was used.

GIVEN: A typical WESF capsule storage pool is 21'-9" long x 4'-5" wide per H-2-66421. Normal water depth is 156" = 13' per H-2-66422 Section 2. Each pool cell is provided with a 2" Sch. 10S stainless steel water removal pipe extending from an open end 1/2" above the pool cell floor, through the pool cell liner (3' from cell floor to centerline of pipe, see Detail IV of H-2-67019) and wall into the pipe tunnel. From there the pipe extends horizontally 7.5' to the exterior wall, then vertically up 9' where it penetrates the pipe tunnel ceiling. The waste water removal pipe in the pipe tunnel is all welded pipe having no valves or flanged connections. If the waste water removal pipe were to rupture in the pipe tunnel, the pool cell would be in jeopardy of draining down to the 3' level. If the waste water removal pipe were to rupture above the pipe tunnel ceiling, the pool cell would not be jeopardy of draining. The pipe rupture would be above the water level in the pool cell.

DETERMINE: 1) How long it would take for a single WESF capsule storage pool to drain down to the level where capsules would become uncovered. This drain down could occur via the steam jet pump system or via a hypothetical break and gravity drain through the drain line system.

2) How long it would take to evaporate the water out starting at a normal pool level of 13'.



Cross section of WESF capsule storage pool

CALCULATIONS:

Since the pool is at atmospheric pressure, Equation 4-21 of Crowl, D.A. and Louvar, J.F, *Chemical Process Safety: Fundamentals with Applications*, applies. It gives the time t for a vessel to empty to the level of the leak.

$$t := \frac{1}{C_o \cdot g} \cdot \left(\frac{A_v}{A}\right) \cdot \sqrt{2 \cdot g \cdot h_L}$$

where C_o is a discharge coefficient. For a short section of pipe attached to the vessel, the suggested guideline value is 0.81.

$C_o := 0.81$

$W := 4.417 \cdot ft$ width of pool

$L := 21.75 \cdot ft$ length of pool

A_v is the inside cross sectional area of the vessel, $A_v := W \cdot L$ $A_v = 96.07 \cdot ft^2$

A is the inside cross sectional area of the 2" Sch 10S pipe, $A := 0.02538 \cdot ft^2$ (Crane, p. B-16)

g is the gravitational accelaration constant of the earth, $g = 32.174 \cdot \frac{ft}{sec^2}$

and h_L is the head of liquid in the vessel above the leak.

For ease of calculation, the time equation will be expressed as a function of h_L.

$$t(h_L) := \frac{1}{C_o \cdot g} \cdot \frac{A_v}{A} \cdot \sqrt{2 \cdot g \cdot h_L} \qquad h_L := 1 \cdot ft, 2 \cdot ft .. 13 \cdot ft$$

depth vector in ft corresponding time vector in hr

$\frac{h_L}{ft}$	$\frac{t(h_L)}{3600 \cdot sec}$	
1	0.324	
2	0.458	
3	0.561	
4	0.647	
5	0.724	
6	0.793	
7	0.856	
8	0.915	
9	0.971	
10	1.023	<----- time in hours required to drain down to the 2" drain pipe
11	1.073	
12	1.121	
13	1.167	<----- time in hours required to drain the pool

Time Required to Jet out Liquid

B Plant engineers say that the pool water can be jetted out with a steam jet ejector at a rate of approximately 1-inch of pool depth per minute. When the liquid level arrives at 148 inch level, however, an interlock device shuts steam off almost instantaneously. Thus, the interlock must fail in order to jet all the liquid out of the pool cell.

$$\frac{10 \cdot ft \cdot \left(12 \cdot \frac{in}{ft}\right)}{1 \cdot \frac{in}{min}} = 2 \cdot hr$$ time needed to jet out 10 ft of water

$$\frac{13 \cdot ft \cdot \left(12 \cdot \frac{in}{ft}\right)}{1 \cdot \frac{in}{min}} = 2.6 \cdot hr$$ time needed to jet out 13 ft of water

Check: From H-2-66986 Sheet 4, the steam jet is listed at 75 gpm for 100 psig steam.

$Q := 75 \cdot \frac{gal}{min}$ $Q = 601.563 \cdot \frac{ft^3}{hr}$

$t_{10} := \frac{A_v \cdot 10 \cdot ft}{Q}$ $t_{10} = 1.597 \cdot hr$

$t_{13} := \frac{A_v \cdot 13 \cdot ft}{Q}$ $t_{13} = 2.076 \cdot hr$

Since the jet rate depends on steam pressure, and the steam pressure is usually less than 100 psig, I recommend that the former values be accepted; i.e., 2 hrs down to 10 ft; 2.6 hrs down to 13 ft.

Time Required to Evaporate Pool Water

Assume there is no heat loss through the side walls and bottom of the pool. It is postulated that the once-through cooling system for the pool is lost. Next, the water is heated by decay heat from the capsules from an assumed temperature of 100 F to boiling, 212 F.

$H_{x100F} := 67.97 \cdot \frac{BTU}{lb}$ enthalpy of liquid water at 100 F from steam tables

$H_{x212F} := 180.07 \cdot \frac{BTU}{lb}$ enthalpy of liquid water at 212 F from steam tables

$\Delta H_{vap} := 970.3 \cdot \frac{BTU}{lb}$ latent heat of vaporization of water at 212 F

$\Delta H_{total} := H_{x212F} - H_{x100F} + \Delta H_{vap}$

$\Delta H_{total} = 1.082 \cdot 10^3 \cdot \frac{BTU}{lb}$ total heat added per lb of water

$v_{x100F} := 0.01613 \cdot \frac{ft^3}{lb}$ specific volume of liquid water at 100 F

$$m_{total} := \frac{A_v \cdot 13 \cdot ft}{v_{x100F}}$$

$m_{total} = 7.743 \cdot 10^4 \cdot lb$ total mass of water in the pool

$$m_{10} := \frac{A_v \cdot 10 \cdot ft}{v_{x100F}}$$

$m_{10} = 5.956 \cdot 10^4 \cdot lb$ mass of 10 ft of water in the pool

$P := 150 \cdot kW$ $P = 5.118 \cdot 10^5 \cdot \frac{BTU}{hr}$ energy given up by capsules plus 10% per Table 5 of WHC 1996 (WHC-SD-WM-TI-733 draft)

$$t_{all} := \frac{\Delta H_{total} \cdot m_{total}}{P}$$

$t_{all} = 163.744 \cdot hr$ $t_{all} = 6.823 \cdot day$ time required to evaporate all the water in the pool assuming no heat loss (adiabatic process)

$$t_{10} := \frac{\Delta H_{total} \cdot m_{10}}{P}$$

$t_{10} = 125.957 \cdot hr$ $t_{10} = 5.248 \cdot day$ time required to evaporate 10 ft of water in the pool assuming no heat loss (adiabatic process)

REFERENCES

Crane, 1982, Flow of Fluids through Valves, Fittings, and Pipe, Technical Paper No. 410, Crane Company, New York, New York.

Crowl, D.A. and Louvar, J.F, *Chemical Process Safety: Fundamentals with Applications*, Prentice Hall, Englewood Cliffs, New Jersey, 1990.

Steam Tables, 1967, Combustion Engineering, Inc., Windsor, Connecticut.

WHC 1996, *Supporting Calculations and Assumptions for use in WESF ISB*, WHC-SD-WM-TI-733, DRAFT, Westinghouse Hanford Company, Richland, Washington.

PEER REVIEW CHECKLIST

Document Reviewed: WESF CAPSULE STORAGE POOL--DRAINAGE AND EVAPORATION CALCULATIONS

Author: David L. Scott

Date: February 29, 1996

Scope of Review: Mathcad calculations dated February 29, 1996

Yes	No	NA	
[ ]	[ ]	[X]	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.**

Brett Hall Brett Hall 3/6/96

Reviewer (Printed Name and Signature) Date

*Mathcad calculations treated like hand calculations. BH

Westinghouse Hanford Company **Internal Memo**

From: Consequence Analysis
Phone: 376-9219 A3-34
Date: May 15, 1996
8M400-JEK-96010
Subject: DRAIN PIPE RUPTURE FREQUENCY AT WESF

To: B. E. Hey A3-34

cc: T. B. Powers A3-34
JEK LB

References:

(1) WHC-CM-4-46, "Nonreactor Facility Safety Analysis Manual," Rev. 4, April, 1996, Westinghouse Hanford Company, Richland, Washington.

(2) WSRC TR-93-262, "Savannah River Site Generic Data Base Development (U)," C. H. Blanton, S. A. Eide, Westinghouse Savannah River Company, Savannah River Site, Aiken, SC 29808, June, 1993.

(3) NUREG-75/014, "An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants," NRC, 1975.

Per a discussion with B. E. Hey and J. E. Kelly, an assessment was requested of the potential failure mode of the Waste Encapsulation and Storage Facility drain line described. It was assumed that such an assessment could be made by comparison to historical pipe failure data. Also requested is a conservative estimate of the failure frequency of that portion of the drain line at the three foot level. Altogether, there are five drain lines coming from five active pool cells. As discussed earlier, the drain line pressure is limited to ten feet of water head, a maximum temperature of 45° C., and is rarely ever used. The drain line has been in operation for approximately 20 years. The plant staff has stated that only de-ionized water has been put in this pipe and that water quality has been maintained over the operating lifetime. No attempt has been made to retrieve pipe weld inspection and continuous quality records. Their availability is unknown.

Historical data has been found for pipe rupture. A pipe rupture for a pipe less than three inches in diameter is assessed at 1.0E-09/hr by Reference 3. Note, this reference is not in terms of feet. However, using 8760 hours in year yields a frequency of 8.8E-06/yr. A pipe leak would have a more probable failure rate. No failure mode for pipe leakage is mentioned in this data base. Reference 2 assessed a pipe rupture at 1.0E-10/hr-ft and 3.0E-09/hr-ft for leakage. The Westinghouse Savannah River Company (WSRC) data base is the latest document available at Hanford. There are five pool cells with a ten foot drain line that would drain the pool cells if ruptured. Therefore, for 50 feet of pipe, the failure rate is 5.0E-09/hr (50 x 1.0E-10). Multiplying 5.0E-09/hr by 8760 hours per year yields 4.4E-05/yr as the failure rate to compare to Reference 1 and would lead to an extremely unlikely event. However, the two data bases are not that much different in their results. The above failure rates are listed for a water system. It is not clear whether that means under pressure or not. The pipe of interest is under static head. If we reduced the failure rate by an

Mr. B. E. Hey
Page 2
May 15, 1996

8M400-JEK-96010

order of magnitude to account for something we are not sure of, we would still be in the same category. I do not have a reference for some NRC work done several years ago on crack growth. The theory was that a rupture began with a crack that took time to develop into a rupture. The WSRC document has pipe leakage with a failure rate of 3.0E-09/hr-ft. It is unclear what the difference is in a leak and a rupture. If we use the leak rate, we obtain 1.3E-03/yr for the leak. In the case of the leak, we assume that we would need a leak detector to detect a leak before break and mitigate before it ruptures. Probe type leak detectors have a failure rate of 5.3E-06/hr or 4.6E-02 probability for a year. Multiplying the two together (1.3E-03/yr x 4.6E-02) would yield 5.98E-05/yr.

Data was reviewed in a 21 year old data base and compared to a three year old data base. Very little difference was found in the two data bases. One order of magnitude in the failure rate was gained by using the newer data base. The newer data base sub-heading was titled "Water System Recommended Generic Failure Rates." No data base that would lower the failure rate more could be found.

If you have any questions, please call me on 376-9219.

J E Kelly

J. E. Kelly, P.E.
Fellow Engineer
Risk Analysis Team

gjr

Attachment

Concurrence:

D S Leach Date 5/15/96
D. S. Leach, Manager
Consequence Analysis

ATTACHMENT

to

8M400-JEK-96010

CHECKLIST FOR PEER REVIEW

Document Reviewed: LETTER FROM JOHN KELLY TO BRIT HEY DATED MAY 13, 1996 TITLED "DRAIN PIPE RUPTURE FREQUENCY AT WESF

Scope of Review: TECHNICAL REVIEW OF LETTER

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

THOMAS B. POWERS Thomas B. Powers 5/13/96

Reviewer (Printed Name and Signature) Date

* Any calculations, comments, or notes generated as part of this review should be signed, dated and attached to this checklist. Such material should be labeled and recorded in such a manner as to be intelligible to a technically qualified third party.

BEST AVAILABLE COPY

CALCULATION OF VOLUME OF TROUGHS UNDER LINER, SUMP, 6" RISER AND 1" RISER.

SOURCE OF FACTS

H-2-66421 ~~[illegible]~~ STRUCTURAL FOUNDATION AND FLOOR PLAN AREA 3

H-2-66422 STRUCTURAL SECTIONS AREA 3

FACTS: CALCULATION VALID FOR POOL CELLS 2-11. DUE TO DESIGN POOL CELL 1 AND 12 WILL HAVE DIFFERENT VOLUMES.

FEEDER TROUGHS # = 10
MAX DEPTH 1¼" MIN DEPTH 1"
BOTTOM WIDTH 1"
WALL SLOPE 4/2 → MAX WIDTH AT START 1.75"
WIDTH AT END 2.00"

COMMON COLLECTING TROUGH - LENGTH = 19'9"
BOTTOM WIDTH 1"
WALL SLOPE 4/2 → WIDTH AT START 2.0"
WIDTH AT END 4.0"

ASSUMPTIONS TO BE CONSERVATIVE (I.E. OVER EST. POSS. VOLUME OR MAXIMIZE DROP IN POOL CELL.
- ALLOWING 1" LINE TO SUMP AS 3'
- SIZE OF TROUGHS
- IGNORE AIR TRAPPED IN SUMP PREVENTING COMPLETE FILLING
- OVER ESTIMATE HEIGHT OF RISER FILLING

FEEDER TRENCHES HAVE (1.25" x 2.00" x 3.08') 10 = ~~[illegible]~~ = $.5 ft^3$ ~~[illegible]~~

ASSUME CROSSSECTION IS SQUARE AND USE MAX WIDTH + DEPTH

COLLECTING TRENCH IS (3" x 4" x 19.75') = $1.6 ft^3$

TOTAL CAPACITY OF TROUGHS $\underline{1.7 ft^3}$

1' PIPE BETWEEN TROUGH + SUMP

LENGTH 3'
INSIDE DIAMETER 1.049"

VOLUME $3' \pi \left(\frac{1.049/2}{12}\right)^2 = .018\ ft^3$

SUMP
DIA 20"
HEIGHT 1'
VOLUME $1' \pi \left(\frac{10}{12}\right)^2 = 2.2\ ft^3$

6" RISER

INSIDE DIA 6.065"
HEIGHT (677.5' - 663.75') = 13.75'

VOLUME = $h\pi r^2$ = $13.75\,\pi\left(\frac{6.065''/2}{12}\right)^2$ = 2.8 ft³

1" RISER
INSIDE DIA 1.049"
HEIGHT (SAME AS ABOVE) = 13.75'

VOLUME $h\pi r^2$ = $13.75'\,\pi\left(\frac{1.049/2}{12}\right)^2$ = 1.9 ft³

TOTAL VOLUME

FEEDER TROUGHS	~~.045~~ .54 ft³
COLLECTION TROUGHS	1.6
1" PIPE FROM TROUGH TO SUMP	.018
SUMP	2.2
6" RISER	2.8
1" RISER	1.9
	~~8.6~~ ft³ 9.1

CONVERT TO GALLONS

7.4805 gal/ft³

GALLONS = $7.4805\,\frac{gal}{ft^3} \cdot$ ~~8.6~~ 9.1 ft³ = ~~64~~ 68 gallons

SIZE OF POOL CELL
WIDTH 4' 5" = 4.417'
LENGTH 21'9" = 21.75'

NUMBER OF GALLONS PER 1" OF DEPTH

4.417' * 21.75' * .083' = 8.0 ft³/1" HEIGHT OF POOL CELL

GALLONS/1" OF P.C. DEPTH = ~~59.5~~ 60 gallons

MAX DROP TO TOTALLY FILL THIS AREA. ⇒ $\frac{X}{68} = \frac{1''}{60}$ ⇒ 1.1" or $1\frac{1}{8}$" DROP

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To Burt Hey	From Larry Best
Co.	Co.
Dept. Phone 376-2921	Phone # 372-0173
Fax # 376-5396	Fax #

PC 1

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FEEDER TROUGHS

NUMBER 10
LENGTH 7'9" (ACTUALLY THIS IS SAME AS TROUGHS FEED TO CENTRAL COLLECTION TROUGH)

BOTTOM WIDTH 1"
WALL SLOPE 4/12
MIN TOP WIDTH 1.75'
MAX TOP " 2.0
MAX DEPTH 1.25"

$$VOL = 10\left(\frac{2}{12} \times \frac{1.25}{12} \times 7.75\right) = 1.3 ft^3$$

COMMON COLLECTION TROUGH IS SAME VOLUME
1" LINE FROM TROUGH TO SUMP " "
SUMP " "
6" RISER " "
1" RISER " "

TOTAL VOLUME OF PC1 LEAK DETECTION VOIDS

FEED TROUGHS	$1.3 ft^3$
COLLECTION TROUGHS	1.6
1" FEED LINE	.018
SUMP	2.2
6" RISER	2.8
1" RISER	1.9
	$9.8 ft^3$

GALLONS 73.3 gallons

MAX DROP IN PC1

WIDTH OF PC1 - 8.75'
LENGTH OF PC1 21.75'
1" DEPTH 1/12'

VOLUME IN 1" 16 ft^3 ⇒ gallons 120

$$DROP \quad \frac{1''}{120} = \frac{X\ DROP}{73} \Rightarrow .61'' \text{ OR } < 5/8''$$

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PC 12 OR TRANSFER ISLE

FEEDER TROUGHS

LENGHT 2' (NOT KNOWN BUT CAN'T BE MORE)

MAX ~~MAX~~ DEPTH 1.25" ~~[illegible]~~

MAX WIDTH 2.0"

VOLUME OF 1 TROUGH $\left(\frac{1.25}{12} * \frac{2}{12} * 2'\right) = .035\ ft^3$

COLLECTION TROUGH TO SUMP 12-1

NORTH PART 8'9" + 21'6" = 33.75'

SOUTH PART ~18'

COLLECTION TROUGH TO SUMP 12-2

$[(23' - 1'10" - 4'6") + 5' + 11'] +$?

MAX DEPTH 3"

MAX WITH 4"

$\frac{5.5}{1.8} = \frac{x}{1.1}$

LENGTH OF 1" FEEDER LINE

~5'6" + 3.4 =

TROUGH IN CASK BASIN TO 12-2

MAX DEPH - 1.25"

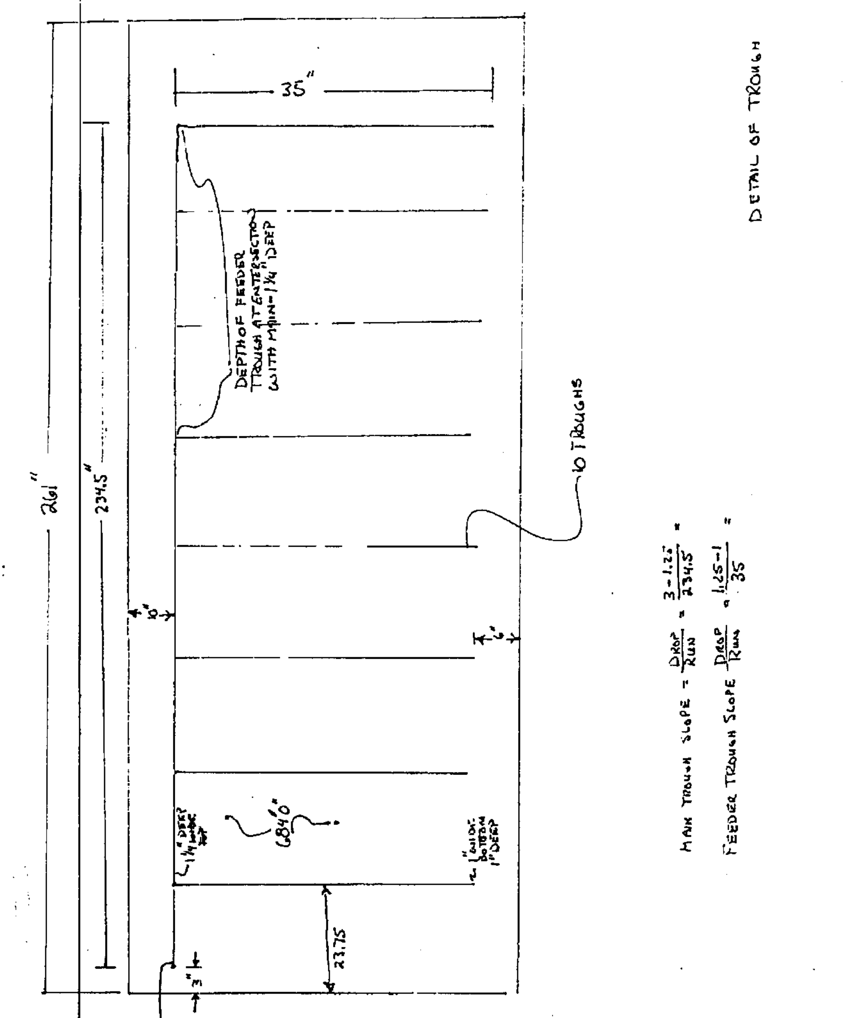
MAX WIDTH - 2.00"

LENGHT - 7'

LENGHT OF 1" FEEDER LINE

~4'

FROM PHOTOS IT IS ASSUMED THERE ARE 24 FEEDER TROUGHS UNDER TRANSFER ISLE. 8 PER SECTION ~~[illegible]~~



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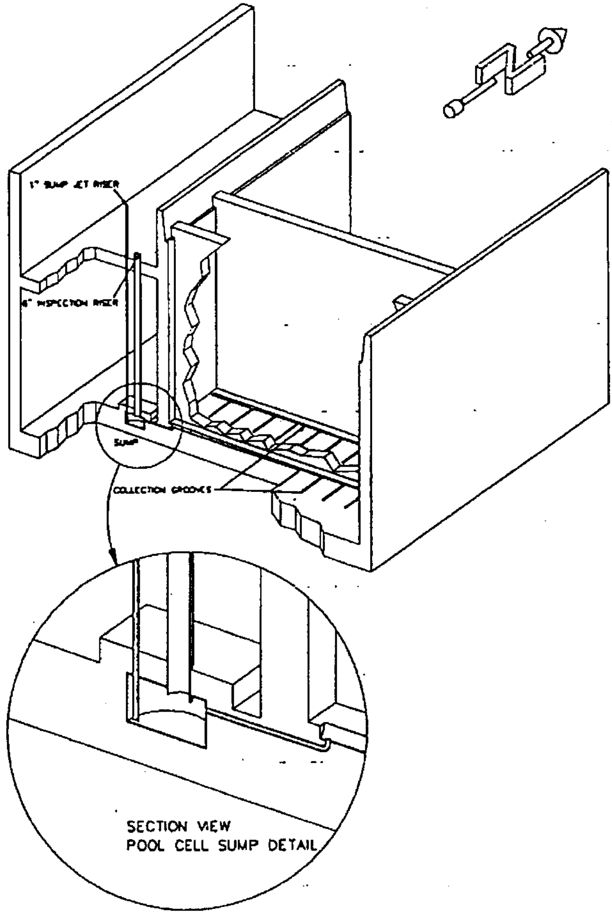
To Brian Vonderfecht	From Larry Briss
Co. Fluor	Co.
Dept. 943-6413	Phone # 372-0173
Fax # 943-6517	Fax #

FIGURE 6.1.1 WESF Pool Cell Typical Sump Arrangement



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To BRIT HEY	From LARRY BRIST
Co.	Co.
Dept. PHONE 376-2921	Phone # 372-0123
Fax # 376-5396	Fax #

APPENDIX I - Statistical Analysis of Capsule Power Distribution

This appendix contains:

1. Internal Memorandum from Milton Shultz to Brit Hey dated March 20, 1996, "Statistical Analysis of Strontium and Cesium Capsule Power Data in Support of Hypothetical Pool Drain Accident Analysis" 8M400-MVS-96006, Westinghouse Hanford Company, Richland, WA.

2. Peer review checklist.

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Westinghouse Hanford Company

Internal Memo

From: Consequence Analysis — 8M400-MVS-96006
Phone: 376-2215 A3-34
Date: March 20, 1996
Subject: STATISTICAL ANALYSIS OF STRONTIUM AND CESIUM CAPSULE POWER DATA IN SUPPORT OF HYPOTHETICAL POOL DRAIN ACCIDENT ANALYSIS

To: Brit Hey

cc: MVS: File/LB

The attached statistical analyses was performed to support the Hypothetical Pool Drain Analysis for WESF. This memo is intended to be included as part of the documentation contained in that analysis.

Prepared by:

Milton V. Shultz Date 3/21/96
Milton Shultz, Sr. Principal Engineer
Risk Assessment Team of Consequence Analysis Group

mvs

Attachment

Concurrence:

K. S. Leach Date 3/21/96
Dirk Leach, Manager
Consequence Analysis

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ATTACHMENT
TO
8M400-MVS-96006

STATISTICAL ANALYSIS OF STRONTIUM AND CESIUM CAPSULE POWER DATE IN SUPPORT OF HYPOTHETICAL POOL DRAIN ACCIDENT ANALYSIS

PREPARED BY: MILTON V. SHULTZ

RISK ANALYSIS TEAM
MARCH 20, 1996

8M400-MVS-96006
MARCH 20, 1996

Title

Statistical Analysis of Strontium and Cesium Capsule Power data in Support of Hypothetical Pool Drain Accident Analysis

Purpose

An analysis of a hypothetical pool drain accident has been performed for the current pool storage of Cesium (Cs) and Strontium (Sr) capsules at the WESF storage facility. This analysis is being performed to determine the probability that the 110 percent power assumption used to calculate heatup in accident model may be nonconservative due to the random nature of capsule selection for storage in a given pool.

Methodology

This analysis is divided into two parts. The first part deals with the Cs capsules and the second with the Sr capsules. This was done because the Cs capsule power distribution is much narrower than the Sr power distribution and lends itself to a simpler solution.

The approach used in the Cs capsule case is a simple comparison of average power for the total population with the average power of the 494 highest power capsules. The Sr capsule analysis uses a statistical approach to determine the Standard Error of The Mean to quantify the probability that a random sample of 169 capsules will have an average power that exceeds the average of all Sr capsules by more than 10 percent.

Assumptions

Sr Capsule Data Assumptions

In order to answer this question using a simple statistical calculation, the condition that the population has the characteristics of a normal (sometimes referred to a "bell curve") distribution has to be validated. In many cases it is possible to verify that the population is normally distributed simply by knowing the data source; such as the case for measured heights of adults living in the United States. In the case of the Sr capsule power data, such a "a priori" determination is not possible. However, a simple way of observing the data distribution character is to plot the data as a histogram and compare the shape of the histogram with the shape of a Normal Distribution curve.

Figure 1 shows the Sr capsule data divided into 40 "bins" and plotted against a Normal Distribution curve. In this case it is apparent that there is some deviation from Normal Distribution character. By contrast, the Cs data shown in Figure 2, has a higher degree of conformance to the shape of a Normal Distribution. However, the Sr capsule power data, in general, does fit the character of a Normal Distribution. The shape of the histogram does show a significant concentration of low power data and a small concentration of data at powers at the high end of the distribution. This condition will tend to result in higher probabilities of lower averages of random samples than would be expected if the histogram shape more closely approximated a Normal Distribution. It appears that if the excess low power data points could be transferred to the "valley" near the higher power data concentration on the right side of the histogram, a histogram with a high degree of conformity to a Normal Distribution would be obtained. Therefore, the assumption of a Normal Distribution characteristic of the Sr data is considered valid for the purposes of this analysis and possibly conservative. However, no attempt was made to quantify this conservatism.

Input Data

The quantity of Cs and Sr capsules is based on the rack loading assumptions contained in the pool drain accident analysis.

The measured powers of the Cs and Sr capsules contained in Appendix B of WHC-SD-WM-TI-733, "Supporting Calculations and Assumptions for Use in WESF ISB," dated January, 1996, B.E. Hey author, were used in this statistical analysis. Statistical summaries for the Cs and Sr capsule power data are shown in Tables 1 and 2. The summaries were obtained using the statistical analysis package STATGRAPHICS Plus, Version 6.0, run on an IBM PC. Standard statistical calculation techniques are used in the program.

Calculations

Analysis of the Cs Capsules

A simplistic approach was taken for the Cs capsules. The sample data was sorted in descending order and the first 494 powers were averaged using Quattro Pro, Version 4.0, (input data set shown in Table 3). The average was computed by summing the 494 powers and dividing by 494. The average power of all Cs capsules is 188.22 watts. The average of the highest 494 capsules is 204.76 watts. A power level 10 percent greater than the all capsules average is 207.42 watts. Therefore by comparison, there is a zero percent probability that a random sample of 494 Cs capsules will have an average power 10 percent greater than the all Cs capsule average.

Analysis of the Sr Capsules

One of the standard problems that statistical analysis is asked to solve is what is the probability that the mean of a sample of a given size will be within a specified range of the true mean of the population from which the sample was taken?

In order to provide an answer to the question of probability of accuracy of estimate, a value is calculated called the standard error of the mean (SEM). The formula for this value is

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SEM = population standard deviation / square root of the sample size.

The SEM represents the size of the deviation necessary to represent one standard deviation on the Standard Normal Distribution curve.

In the case of the Sr capsules, with a population standard deviation of 130.41 and a sample size of 169, the standard error is 10.03. Therefore one standard deviation of error for this sample size is 10.03 watts.

The question to be answered for the Sr capsules is what is the probability of obtaining an average power from a random sample of 169 capsules that is more than 10 percent higher than the population average? This is most directly answered by determining the probability that the average power does not differ greater than ten percent from the population average.

To do this, take ten percent of the population average for the Sr capsules of 254.35 watts (25.44) and divide by the standard error (10.03). This gives a value of 2.54 standard deviations.

Utilizing standard statistical tables (Reference 2) (copy attached as table 4), 2.54 standard deviations translates to a standard normal distribution value of 0.989 or 98.9 percent of the area under the curve. Therefore, there is a 98.9 percent probability that the average power level of random sample of 169 capsules will not vary more than 10 percent from the population average. Another way of stating this is that there is only a 0.55 percent probability that the average power of a random sample of 169 Sr capsules will exceed the population average power level by 10 percent and a 0.55 percent probability that the average power of a random sample will be greater than 10 percent below than the population average. This is because standard normal statistics are two sided, that is, the probability takes into account powers exceeding the average as well as powers less than the average. If only values that are greater than 110 percent of the population average are of concern, the probability of exceedance (one minus the calculated non exceedance probability) is divided by two.

Stated most simply, there is a 99.45 percent probability that a random sample of 169 Sr capsules will not have an average power that exceeds the population average power by 10 percent.

Results

There is a zero percent probability that a random sample of 494 Cs capsules will have an average power 10 percent greater than the all CS capsule average.

There is a 99.45 percent probability that a random sample of 169 Sr capsules will not have an average power that exceeds the population average power by 10 percent.

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Conclusions

There is a zero percent likelihood that a random sample of 494 Cs capsules will have an average power 10 percent higher than the average power for all the Cs capsules. There is a 0.55 percent probability that the average power for a random sample of 169 Sr capsules will exceed the average power of the total number of Sr capsules.

It should be noted that if the sample sizes are increased, the probability of exceedance will become even smaller and if the sample size is decreased the exceedance probability increases.

References

WHC-SD-WM-TI-733, "Supporting Calculations and Assumptions for Use in WESF ISB," dated January, 1996, B.E. Hey

Basic Statistics for Business and Economics, Paul G. Hoel and Raymond J. Jessen, John Wiley & Sons, Inc., 1971

8M400-MVS-96006
MARCH 20, 1996

Table 1
Statistical Summary for Cs Data

Variable:	CS_Wattage
Sample size	1328.
Average	188.218294
Median	187.4321
Mode	205.5917
Geometric mean	187.477581
Variance	279.531103
Standard deviation	16.719184
Standard error	0.458792
Minimum	122.9859
Maximum	255.2294
Range	132.2435
Lower quartile	177.36945
Upper quartile	197.7707
Interquartile range	20.40125
Skewness	0.279161
Standardized skewness	4.153149
Kurtosis	1.248526
Standardized kurtosis	9.287333
Coeff. of variation	8.882869
Sum	249953.8949

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MARCH 20, 1996

Table 2
Statistical Summary for Sr Data

Variable:	SR_Wattage
Sample size	600.
Average	254.352682
Median	248.84715
Mode	60.35498
Geometric mean	217.076163
Variance	17006.613122
Standard deviation	130.409406
Standard error	5.323942
Minimum	28.84859
Maximum	614.8839
Range	586.03531
Lower quartile	152.54495
Upper quartile	317.2243
Interquartile range	164.67935
Skewness	0.431616
Standardized skewness	4.31616
Kurtosis	-0.595524
Standardized kurtosis	-2.977618
Coeff. of variation	51.271095
Sum	152611.60949

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Table 3
Quattro Pro Spreadsheet of 494 Highest Cs Capsules Power
Average = 204.76 watts

Capsule #	Watts	Capsule #	Watts	Capsule #	Watts
C-1076	255.2294	C-33	220.1431	C-1198	212.3558
C-1729	250.6785	C-303	220.1069	C-1686	211.7879
C-906	249.8119	C-393	219.6422	C-68	211.778
C-887	247.0379	C-753	219.4364	C-941	211.7558
C-1715	245.8586	C-1182	219.2847	C-148	211.3829
C-957	244.9011	C-91	219.2598	C-135	211.1927
C-1522	243.3938	C-136	219.0602	C-332	211.126
C-1138	242.3256	C-139	218.4274	C-38	211.1147
C-829	241.4501	C-1692	218.3568	C-248	211.0756
C-901	240.3843	C-143	218.2642	C-1773	211.0623
C-778	237.2837	C-52	218.2381	C-397	211.0368
C-896	236.567	C-1400	218.1962	C-263	210.9796
C-850	236.4208	C-128	218.1649	C-78	210.9613
C-392	236.2515	C-65	217.9976	C-69	210.8609
C-1704	235.3124	C-1176	217.7627	C-1693	210.7572
C-775	234.9833	C-301	217.6171	C-1497	210.669
C-774	234.2166	C-1092	217.5573	C-80	210.6472
C-105	230.7829	C-137	216.9721	C-46	210.5436
C-1082	230.0811	C-1690	216.9139	C-325	210.4522
C-1703	229.8137	C-127	216.7686	C-521	210.4335
C-1157	228.5211	C-966	216.3292	C-689	210.2359
C-208	228.4087	C-271	215.9168	C-246	210.168
C-209	227.7896	C-203	215.9079	C-240	209.9736
C-394	227.2922	C-138	215.8964	C-1652	209.9063
C-244	226.8933	C-326	215.4389	C-204	209.8945
C-314	226.699	C-493	215.3317	C-264	209.8795
C-316	226.699	C-379	215.3187	C-71	209.7677
C-1735	226.5748	C-1677	215.2647	C-66	209.5792
C-1753	226.4901	C-495	214.7876	C-334	209.562
C-131	226.2942	C-1052	214.6872	C-182	209.2164
C-129	226.2309	C-1180	214.5442	C-1159	209.0832
C-350	225.4398	C-1057	214.5074	C-408	208.9538
C-306	225.3555	C-489	214.2585	C-82	208.8619
C-315	225.2173	C-796	214.1513	C-662	208.8046
C-269	225.15	C-1131	214.1131	C-1529	208.5684
C-349	224.4889	C-398	214.0953	C-1718	208.5646
C-1184	224.3844	C-270	214.0852	C-856	208.4214
C-1689	224.0566	C-760	213.9697	C-34	208.4039
C-1051	223.8716	C-83	213.7316	C-339	208.3856
C-351	223.8097	C-494	213.6994	C-1402	208.3079
C-894	223.4578	C-396	213.6875	C-1688	208.1989
C-29	223.3342	C-686	213.5594	C-1166	207.9993
C-1734	223.0345	C-1716	213.2915	C-340	207.7786
C-28	221.9078	C-35	213.0183	C-673	207.7537
C-492	221.3849	C-265	212.8642	C-205	207.7471
C-47	220.7531	C-255	212.675	C-245	207.7046
C-31	220.6866	C-211	212.6307	C-1744	207.5539
C-1674	220.2834	C-452	212.4812	C-406	207.5346
C-1071	220.2521	C-266	212.4572	C-841	207.4692

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Capsule #	Watts	Capsule #	Watts	Capsule #	Watts
C-410	207.3319	C-1725	203.6378	C-1146	201.0667
C-213	207.2445	C-1050	203.5653	C-1005	201.0658
C-1093	207.2248	C-146	203.5611	C-1805	201.0543
C-801	207.2147	C-1685	203.4426	C-190	200.9946
C-897	207.1811	C-160	203.3727	C-176	200.9335
C-1062	207.1205	C-158	203.3721	C-1007	200.9229
C-210	207.0639	C-15	203.3703	C-162	200.8989
C-1769	206.9077	C-76	203.3653	C-1066	200.8728
C-118	206.8473	C-296	203.3037	C-768	200.8628
C-487	206.8187	C-161	203.2458	C-100	200.8355
C-319	206.5851	C-227	203.2276	C-295	200.8069
C-782	206.4551	C-220	203.1339	C-1804	200.7818
C-1038	206.2938	C-147	203.1175	C-729	200.7717
C-411	206.2506	C-63	203.0956	C-1491	200.7486
C-409	205.9803	C-1148	203.0716	C-239	200.6658
C-700	205.9554	C-550	203.0584	C-938	200.6506
C-1061	205.9013	C-1706	202.9217	C-163	200.6453
C-30	205.6028	C-400	202.816	C-1091	200.4799
C-58	205.5917	C-1089	202.8126	C-293	200.4707
C-119	205.5917	C-531	202.798	C-294	200.4707
C-57	205.5917	C-318	202.7444	C-1161	200.4634
C-322	205.5744	C-1137	202.6802	C-1096	200.4185
C-1705	205.5571	C-1054	202.6802	C-44	200.3912
C-1183	205.3505	C-274	202.6366	C-1171	200.3804
C-226	205.2301	C-342	202.6312	C-373	200.3604
C-1179	205.2068	C-299	202.6312	C-1724	200.2486
C-120	204.964	C-268	202.6013	C-292	200.1346
C-218	204.8557	C-1067	202.589	C-42	200.1007
C-523	204.7329	C-43	202.548	C-1173	200.0941
C-1247	204.7003	C-157	202.5477	C-1069	200.0861
C-1727	204.6426	C-179	202.5065	C-237	200.084
C-1733	204.6426	C-336	202.3835	C-1209	200.0624
C-799	204.6262	C-159	202.2943	C-436	200.0281
C-121	204.5873	C-946	202.2148	C-998	200.0278
C-297	204.5815	C-481	202.2045	C-1243	199.9835
C-199	204.4549	C-791	202.0314	C-1582	199.9619
C-225	204.4549	C-164	201.977	C-989	199.9563
C-1700	204.4148	C-114	201.938	C-41	199.9487
C-898	204.4044	C-200	201.865	C-201	199.8901
C-234	204.3257	C-781	201.8092	C-985	199.8755
C-150	204.3097	C-142	201.7232	C-1008	199.7797
C-1731	204.2403	C-1691	201.5758	C-1125	199.6522
C-936	204.2185	C-189	201.4466	C-933	199.6142
C-1055	204.1884	C-798	201.4082	C-104	199.6013
C-1329	204.1332	C-338	201.372	C-1156	199.5932
C-178	203.9818	C-96	201.3426	C-235	199.5668
C-13	203.9786	C-187	201.3175	C-291	199.4623
C-788	203.9708	C-902	201.305	C-1245	199.334
C-212	203.9249	C-1072	201.3018	C-238	199.1789
C-483	203.8446	C-1095	201.2973	C-552	199.1613
C-780	203.8343	C-1025	201.2936	C-1284	199.0887
C-228	203.8227	C-156	201.2794	C-484	199.0611
C-1255	203.8214	C-473	201.2453	C-685	199.043
C-233	203.6798	C-1246	201.1382	C-236	198.985

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Capsule #	Watts	Capsule #	Watts	Capsule #	Watts
C-86	198.9611	C-1253	196.5915	C-1172	194.7983
C-476	198.8511	C-1144	196.5409	C-1653	194.7901
C-1177	198.8018	C-151	196.5125	C-899	194.7562
C-530	198.7878	C-152	196.4492	C-1006	194.7433
C-1181	198.7425	C-1126	196.432	C-993	194.6699
C-242	198.6937	C-1100	196.4144	C-1376	194.6246
C-1048	198.6546	C-1034	196.4098	C-1240	194.6184
C-659	198.6191	C-1154	196.3975	C-1427	194.6055
C-870	198.4355	C-988	196.2415	C-1460	194.5315
C-1533	198.3744	C-1086	196.2147	C-832	194.5309
C-85	198.3373	C-188	196.1369	C-1560	194.5137
C-852	198.3329	C-95	196.1276	C-934	194.4761
C-256	198.3098	C-1207	196.1058	C-997	194.4678
C-1030	198.2892	C-32	196.0225	C-905	194.4247
C-1068	198.2859	C-230	196.0078	C-267	194.4133
C-1000	198.2452	C-1075	196.0002	C-1432	194.3871
C-1026	198.2177	C-376	195.991	C-457	194.3707
C-387	198.1921	C-800	195.9515	C-283	194.3534
C-1170	198.19	C-1399	195.9476	C-999	194.2431
C-1078	198.0871	C-1296	195.8273	C-725	194.1978
C-932	197.9953	C-1634	195.7629	C-1335	194.15
C-1111	197.8164	C-1732	195.7549	C-1551	194.1212
C-380	197.7952	C-440	195.74	C-460	194.0969
C-1249	197.7462	C-1698	195.6564	C-447	194.0561
C-1740	197.7316	C-1772	195.6151	C-1162	194.0221
C-202	197.692	C-280	195.5938	C-416	194.0075
C-320	197.691	C-1227	195.509	C-908	193.9976
C-732	197.6801	C-742	195.4787	C-1070	193.9956
C-1121	197.6485	C-762	195.4748	C-826	193.9223
C-1326	197.5997	C-1288	195.4645	C-1405	193.9118
C-838	197.5559	C-1251	195.4491	C-970	193.8909
C-48	197.4812	C-174	195.398	C-232	193.8766
C-377	197.3817	C-167	195.3799	C-324	193.8748
C-401	197.3773	C-1118	195.3796	C-1049	193.8513
C-547	197.3633	C-1047	195.3568	C-1165	193.8224
C-1231	197.2965	C-737	195.3389	C-1081	193.7948
C-1751	197.2534	C-1009	195.3374	C-1028	193.7111
C-430	197.2495	C-144	195.3101	C-183	193.6862
C-1205	197.2469	C-793	195.301	C-154	193.6599
C-739	197.2265	C-1140	195.2708	C-1297	193.5873
C-414	197.1813	C-185	195.2328	C-1155	193.5817
C-403	197.1707	C-1088	195.2114	C-854	193.4833
C-1097	197.1294	C-892	195.1955	C-276	193.4809
C-682	197.1161	C-1279	195.1727	C-155	193.4698
C-1401	197.1109	C-1778	195.1122	C-663	193.4565
C-1027	196.9177	C-272	195.0418	C-1646	193.3683
C-181	196.8736	C-153	194.9912	C-175	193.362
C-1640	196.8359	C-214	194.9745	C-637	193.3598
C-1325	196.8012	C-273	194.974	C-904	193.3568
C-186	196.7978	C-1169	194.9292	C-741	193.2293
C-1807	196.7948	C-537	194.8787	C-1758	193.1331
C-1244	196.6513	C-802	194.8322	C-1036	193.1307
C-166	196.6486	C-1426	194.824	C-869	193.1285
C-1120	196.6055	C-913	194.8052	C-769	193.0986

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Capsule #	Watts	Capsule #	Watts	Capsule #	Watts
C-243	193.0538				
C-247	192.989				
C-900	192.9766				
C-1403	192.9666				
C-1398	192.918				
C-1136	192.9124				
C-1252	192.9115				
C-1003	192.8852				
C-990	192.8839				
C-1273	192.8576				
C-691	192.8437				
C-231	192.8432				
C-813	192.8302				
C-1490	192.8088				
C-287	192.8014				
C-1323	192.724				
C-580	192.7146				
C-427	192.7028				
C-1455	192.6916				
C-1143	192.6911				
C-525	192.6907				
C-1625	192.6705				
C-733	192.5256				

TABLE IV. Areas of a Standard Normal Distribution

An entry in the table is the proportion under the entire curve which is between z = 0 and a positive value of z. Areas for negative values of z are obtained by symmetry.

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.0000	.0040	.0080	.0120	.0160	.0199	.0239	.0279	.0319	.0359
0.1	.0398	.0438	.0478	.0517	.0557	.0596	.0636	.0675	.0714	.0753
0.2	.0793	.0832	.0871	.0910	.0948	.0987	.1026	.1064	.1103	.1141
0.3	.1179	.1217	.1255	.1293	.1331	.1368	.1406	.1443	.1480	.1517
0.4	.1554	.1591	.1628	.1664	.1700	.1736	.1772	.1808	.1844	.1879
0.5	.1915	.1950	.1985	.2019	.2054	.2088	.2123	.2157	.2190	.2224
0.6	.2257	.2291	.2324	.2357	.2389	.2422	.2454	.2486	.2517	.2549
0.7	.2580	.2611	.2642	.2673	.2703	.2734	.2764	.2794	.2823	.2852
0.8	.2881	.2910	.2939	.2967	.2995	.3023	.3051	.3078	.3106	.3133
0.9	.3159	.3186	.3212	.3238	.3264	.3289	.3315	.3340	.3365	.3389
1.0	.3413	.3438	.3461	.3485	.3508	.3531	.3554	.3577	.3599	.3621
1.1	.3643	.3665	.3686	.3708	.3729	.3749	.3770	.3790	.3810	.3830
1.2	.3849	.3869	.3888	.3907	.3925	.3944	.3962	.3980	.3997	.4015
1.3	.4032	.4049	.4066	.4082	.4099	.4115	.4131	.4147	.4162	.4177
1.4	.4192	.4207	.4222	.4236	.4251	.4265	.4279	.4292	.4306	.4319
1.5	.4332	.4345	.4357	.4370	.4382	.4394	.4406	.4418	.4429	.4441
1.6	.4452	.4463	.4474	.4484	.4495	.4505	.4515	.4525	.4535	.4545
1.7	.4554	.4564	.4573	.4582	.4591	.4599	.4608	.4616	.4625	.4633
1.8	.4641	.4649	.4656	.4664	.4671	.4678	.4686	.4693	.4699	.4706
1.9	.4713	.4719	.4726	.4732	.4738	.4744	.4750	.4756	.4761	.4767
2.0	.4772	.4778	.4783	.4788	.4793	.4798	.4803	.4808	.4812	.4817
2.1	.4821	.4826	.4830	.4834	.4838	.4842	.4846	.4850	.4854	.4857
2.2	.4861	.4864	.4868	.4871	.4875	.4878	.4881	.4884	.4887	.4890
2.3	.4893	.4896	.4898	.4901	.4904	.4906	.4909	.4911	.4913	.4916
2.4	.4918	.4920	.4922	.4925	.4927	.4929	.4931	.4932	.4934	.4936
2.5	.4938	.4940	.4941	.4943	.4945	.4946	.4948	.4949	.4951	.4952
2.6	.4953	.4955	.4956	.4957	.4959	.4960	.4961	.4962	.4963	.4964
2.7	.4965	.4966	.4967	.4968	.4969	.4970	.4971	.4972	.4973	.4974
2.8	.4974	.4975	.4976	.4977	.4977	.4978	.4979	.4979	.4980	.4981
2.9	.4981	.4982	.4982	.4983	.4984	.4984	.4985	.4985	.4986	.4986
3.0	.4987	.4987	.4987	.4988	.4988	.4989	.4989	.4989	.4990	.4990

From: Basic Statistics For Business And Economics,
Paul G. Hoel and Raymond J. Jessen,
John Wiley & Sons, Inc
New York, 1971

Figure 1
Sr Wattage

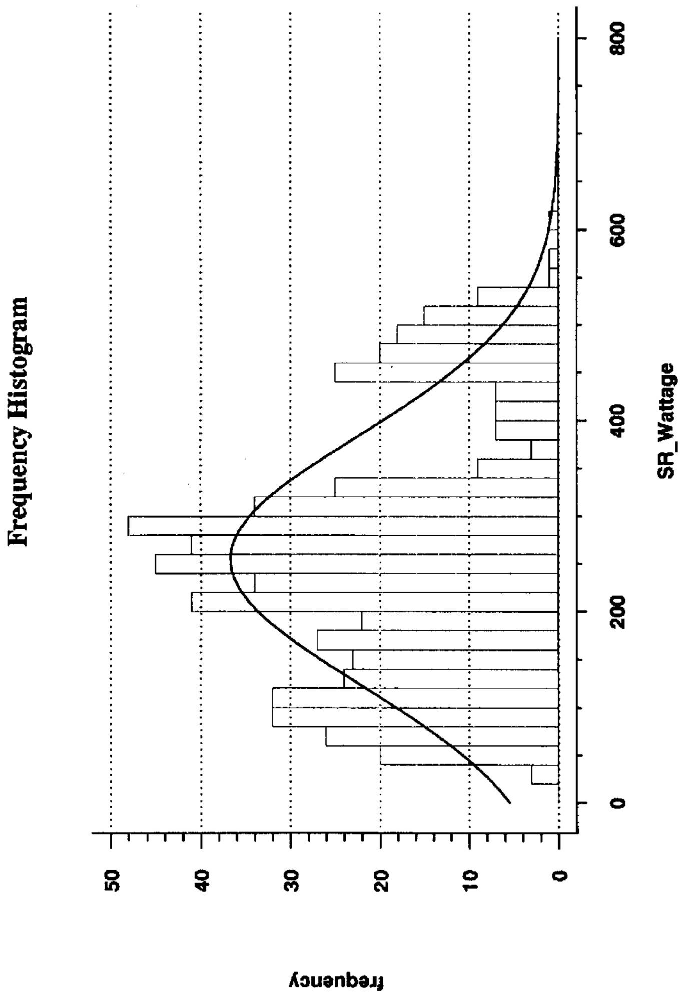
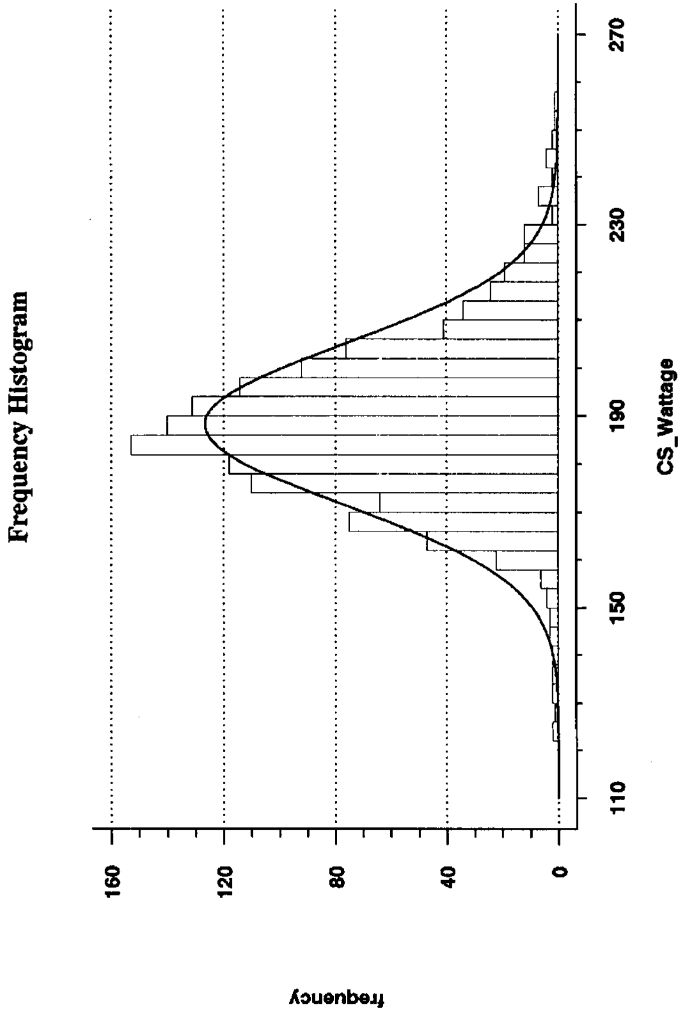


Figure 1
Cs Wattage



PEER REVIEW CHECKLIST

Document Reviewed: Statistical Analysis of Strontium and Cesium Capsule Power Data in Support of Hypothetical Pool Drain Analysis
Author: Milton Shultz
Date: March 19, 1996
Scope of Review: Content and Technical Adequacy

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

COMMENTS:

JOHN E KELLY John E Kelly 3/19/96
Reviewer (Printed Name and Signature) Date

APPENDIX J - Hanford Site Boundary Definitions and Guidance

This appendix contains:

1. DOE Letter from Walter B. Scott to Contractors, Richland, Washington dated September 26, 1995, "Clarification of Hanford Site Boundaries for Current and Future Use in Safety Analyses."

2. DOE Letter from P. W. Kruger to Contractors, Richland, Washington dated March 5, 1996, "Further Discussion on Previous Site Boundary Memorandum."

3. CC:mail message from Brad Evans to L. E. Johnson w/r to site boundary.

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Department of Energy
Richland Operations Office
P.O. Box 550
Richland, Washington 99352

SEP. 26 1995

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SEP 27 1995
A.L. RAMBLE

Contractors, Richland, Washington

Director
Pacific Northwest Laboratory

President
Westinghouse Hanford Company

Gentlemen:

CLARIFICATION OF HANFORD SITE BOUNDARIES FOR CURRENT AND FUTURE USE IN SAFETY ANALYSES

As a result of recent activity in updating facility safety analyses, the location of the site boundary has become an issue. This memorandum is intended to discuss and clarify the current location of the site boundary, application of that information in performing safety analyses, and considerations for future changes to the site boundary.

The Hanford Site boundary has changed without recognition and, therefore, has not been incorporated into all facility safety analyses. Historically, the Hanford Site boundary was recognized as the "fence line" which surrounded the site inclusive of the East side of Rattlesnake Mountain and land North of the Columbia River. This was intersected by Highway 240 and the Columbia River. RL controlled river access along the 100 Area, and Highway 240 was limited to transient use. As a result, these locations were considered onsite locations for safety analyses purposes. There has been no change in the status of Highway 240; however, RL no longer controls access to any portion of the river. The result is a de facto change in the site boundary.

The rationale for consideration of these two boundary issues, highway 240 and the river, differ. Since RL controls the land on either side of the highway it would be considered a throughway, with public usage considered transient, and part of the site for safety analysis purposes. This is consistent with the Department of Transportation (DOT) interpretation of similar situations. This also holds true for Route 4 South up to the Wye Barricade. The river, although a transportation route, also serves as a recreational area similar to the Richland City Park. Usage is not controlled by DOE, nor does it fit the DOT view of the highway as strictly being a throughway. Therefore, the river must be viewed as a location of the public for safety analysis purposes.

<u>What are the implications for current facility safety analyses?</u> It requires an Unreviewed Safety Question (USQ) determination for facilities whose accident scenario risks to the public may increase due to this change. This does not mean facilities must automatically be upgraded to limit a newly recognized risk. The USQ process allows any newly identified risk to be

Contractors SEP. 26 1995

either controlled to within the current authorization basis, or RL may approve the new risk. When making these decisions, consideration should be given to the fact that this is not an inhabited population center, and usage is variable and transient. Decisions should also take into consideration public use of the Hanford Site North of the river, resulting from land management agreements between RL, Federal, and State Wildlife agencies. The State agency allows virtual unlimited public access, while the Federal agency allows no access, thus presenting two completely different levels of concern.

What are the implications for future land use? As consideration is given to releasing portions of the Hanford Site for public use, the impact to current facility authorization and safety bases must be a major factor. The USQ process provides a method for facilities to identify increased risk from proposed activities. The cost impact, as incremental shrinking of the site involving multiple facilities occurs, may be considerable. However, if increased risks ensue, and are not identified prior to boundary changes, after the fact controls may be untenable. Additionally, future facility cleanup activities, many of which are currently unknown, may temporarily increase risks to any nearby public and may not be feasible if those risks are unacceptable. The Emergency Preparedness Program may also be challenged as previously relied upon buffer zones shrink. The land use identified for the released areas will impact the density of the population that could be affected, and the type of environmental concerns that will exist.

In summary, there may be weaknesses in current facility authorization bases that need to be addressed, and future land use planning needs to consider safety and cost impacts to both the public and DOE. If you have any questions on this subject, please contact Mark Jackson, of my staff, on 376-3246.

Sincerely,

WBScott

Walter B. Scott, Director
Quality, Safety, and Health
Programs Division

QSH:MJW

cc: A. L. Ramble, WHC
P. J. Pelto, PNL

1. XC - JCM
SCV
DGH
2. Rout to DBC

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Author	Addressee	Correspondence No.
P. W. Kruger/RL	President/WHC	Incoming: 9600588 WHC CC Recd: 03/08/96 pm

Subject: FURTHER DISCUSSION ON PREVIOUS SITE BOUNDARY MEMORANDUM

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Director
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President
Westinghouse Hanford Company

Gentlemen:

FURTHER DISCUSSION ON PREVIOUS SITE BOUNDARY MEMORANDUM

This memorandum is intended to address three points of confusion stemming from the previous correspondence, dated September 26, 1995, titled "Clarification of Hanford Site Boundaries for Current and Future Use in Safety Analysis," which presented a discussion on site boundary as it applies to nuclear safety documents.

First the intent was not to create new policy, but rather point out existing requirements. The definition presented was based on DOE-STD-3009-94, Preparation Guide for U.S. DOE Nonreactor Nuclear Facility Safety Analysis Reports (SARs), which defines site boundary as:

> "A well-marked boundary of the property over which the owner and operator can exercise strict control without the aid of outside authorities. [DOE 6430.1A]
>
> For the purpose of implementing this Standard, the DOE site boundary is a geographic boundary within which public access is controlled and activities are governed by DOE and its contractors, and not by local authorities. A public road traversing a DOE site is considered to be within the DOE site boundary if, when necessary, DOE or the site contractor has the capability to control the road during accident or emergency conditions."

The memorandum was distributed to enable line organizations to identify possible Unreviewed Safety Questions (USQ) situations they may have overlooked, based upon this additional information. This should be accomplished as a coordinated effort involving both contractor and RL line organization personnel. It should be noted that RL does not have the jurisdiction to physically clear the Columbia River. Remember, if a USQ is identified, it does not automatically mean facilities must be upgraded to limit a newly recognized risk. Instead, when a determination is positive, the USQ process allows RL to fulfill its responsibility by either requiring the contractor to control the risk to within the current authorization basis, or approve the new risk.

Contractors

Secondly, it has come to our attention there may be some confusion over the examples used. The intent of comparing Route 240 and the Columbia River Was to show they represent two different situations and, as such, should not be viewed the same. Consideration for public use of Route 240 cannot be neglected in safety analyses and, in fact, has already been addressed. It, therefore, does not pose the same potential USQ concern as does the river.

Finally, this discussion, and use of the site boundary, is intended only for the purposes of nuclear safety documentation, and may not be applicable to other uses such as legal or environmental regulations and restrictions.

If you have any questions concerning this matter, please contact Mr. Mark Jackson, of the Quality, Safety, and Health Programs Division, at 376-3246.

P. W. Kruger, Director
Office of Environment, Safety
and Health

[94] From: C B (Brad) Evans at ~WHC166 3/28/96 12:15PM (2654 bytes: 1 ln)
To: L E (Safety Analysis) Johnson at ~BCS78
cc: Gary R Franz at ~WHC89, Emil J Krejci at ~WHC186, Alan L Ramble at ~WHC85, Donna M Busche at ~WHC161
Subject: Re: Site Boundary

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

Larry,

This letter is information from RL clarifying that public access in the Columbia River is no longer within the jurisdiction of RL. Any assumptions made in the existing authorization basis (AB) documents, either explicit or implicit, of such jurisdiction in the event of an accident, are invalid as of September 1995. New analyses should consider the near bank of the river as the eastern boundary of unrestricted public access.

AB documents that were initially screened for this change are unaffected. Otherwise, the memo should initiate a determination of a reportable discovery of a condition that represents a potential USQ per WHC-CM-1-5, Section 7.1 and a subsequent USQ evaluation per Section 7.3.

There has been no such change of jurisdiction with respect to Hwy 240. The letter states that this public access route is adequately addressed in the existing AB documents and no action in this regard is required. I confirmed this interpretation with Mark Jackson of QSH.

Brad Evans
Nuclear Safety Programs

______________________________ Reply Separator ______________________________

Subject: Site Boundary
Author: L E (Safety Analysis) Johnson at ~BCS78
Date: 3/28/96 10:54 AM

Brad,

I assume you are aware of the recent site boundary memo issued by Kruger at RL. Can I assume that this is clear direction from RL to treat the Columbia river as the site boundary? Also, my interpretation is that we should consider consequences to the public along route 240, but not consider it to be the site boundary. It sounds to me like we could limit the duration of exposure based on our ability to remove the public within certain period of time. I'm looking to you for some clarification and direction on this matter. How soon can we get something? The WESF ISB needs to resolve this quickly.

Thanks,

Larry

APPENDIX K - Fluid Hydraulics Calculations for WESF Emergency Makeup Water

This appendix contains:

1. Engineering Analysis calculation from David W. Mertz dated 10/1/96.

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ENGINEERING ANALYSIS

Document Number: WHC-SD-WM-TI-733

Document Title: Supporting Calculations and Assumptions for use in Waste Encapsulation and Storage Facility (WESF) Basis for Interim Operation (BIO)

Originator: David W. Mertz David W. Mertz Date 10/1/96

Checker: R. D. Brown R.D. Brown Date 10/1/96

Subject: Hydraulic Flow Analysis for Backup Cooling Water Supply Sources to the WESF Pool Cells

INTRODUCTION

The purpose of this analysis is to determine the approximate flowrate that can be expected from three separate water sources which could be used to supply backup cooling water to WESF the pool cells. Each source would be used individually to supply water at a given supply pressure, and discharge the water at atmospheric pressure through a single fixed emergency cooling water supply pipe located on the North side of the WESF capsule storage area. A standard 2-1/2" fire hose will be used to route the water from the source to the supply pipe. The supply pipe is a 2-1/2" schedule 40 pipe which is fitted with a 2-1/2" fire hose connection. The supply pipe will route the backup cooling water to pool cell #12.

DISCUSSION

The three separate water sources mentioned above are as follows:

1. Raw Water - connection will be made by fire hose to fire hydrant R3-B, located to the South of building 225B. Supply pressure at this hydrant is approximately 100 psi.

2. Sanitary Water - connection will be made by fire hose to fire hydrant 8-B, located to the Northeast of building 225B. Supply pressure at this hydrant is approximately 80 psi.

3. Deep Well Pumps - connection will be made by fire hose to the Emergency Deep Well Pump discharge piping located in building 282-BA. Supply pressure from the deep well pumps is approximately 30 psi.

REFERENCES

a. Flow of Fluids through valves, fittings and pipe, Crane, Technical Paper No. 410, 23rd printing - 1986

b. Hydraulic Handbook, Fairbanks Morse Pump Corp. 12th edition

ASSUMPTIONS

a. The given supply pressures are the static pressures. Flowrate will be calculated based on the pressure differential between the given pressure and atmospheric pressure.
b. Pipe internal diameter is the same as hose internal diameter
c. Based on flowrate data from previous flow testing on the raw water system, the flowrate can be estimated to be at least 250 gallons per minute (GPM). Assume this number for all three water sources, initially.
d. Water temperature is 60^{0}F.
e. Hose couplings will not be considered when determining friction loss.

SOLUTION

Governing equation is as follows:

$$\Delta P = 1.799 \times 10^{-5} \frac{K \rho Q^2}{d^4}$$ Crane, page 3-4, Equation 3-14

where K = resistance coefficient
ρ = density of water at 60^{0}F (lb/ft^3)
Q = flowrate (GPM)
d = internal diameter of the piping components (in.)
ΔP = differential pressure between initial supply pressure and final pressure (psi)

STEP 1: Determine Reynolds Number (R_e) using the estimated flowrate in assumption c, above.

$$R_e = 50.6 \frac{Q \rho}{d \mu}$$

where μ = viscosity of water at 60^{0}F (centipoise, cp)

$$R_e = 50.6 \frac{250(62.37)}{2.5(1.1)}$$

$$R_e = 2.869 \times 10^5$$

STEP 2: Determine friction factor (f)

From Crane, page A-25, the friction factor is approximately 0.0195 based on the Reynolds Number which was calculated using an estimated flowrate of 250 GPM.

STEP 3: Determine the value of the resistance coefficient (K) for each component of the piping system

A. 2-1/2" diameter supply pipe (5 FEET TOTAL)

$$K = f\frac{L}{D}$$ Crane, page 3-4, equation 3-15

where L = pipe or hose length (ft)
D = internal pipe or hose diameter (ft)

$$K = 0.0195\ \frac{5}{0.208}$$ $\underline{K = 0.47}$

B. 2-1/2" diameter 90^0 elbows (3 total)

$K = 30f_t$ Crane, page A-29, where f_t = the friction factor in the fully turbulent region of the diagram. From Crane, page A-25, the friction factor for completely turbulent flow in a 2-1/2 diameter pipe is approximately 0.0183.
Note: Although flow through the pipe is not completely turbulent, flow through the elbow will be.

$$K = (3)30(0.0183)$$ $\underline{K = 1.65}$

C. Exit loss

K = 1.00 Crane, page A-29 $\underline{K = 1.00}$

D. 2-1/2" diameter rubber lined fire hose

From Hydraulic Handbook, a multiplier is used to convert the friction factor of standard carbon steel pipe found to other various piping materials. The multiplier for rubber lined hose is 0.72 as shown on page 62. From Crane, page A-25, the friction factor was found to be 0.0195.

Hose lengths will be 300 feet and 600 feet. Calculate the K value for a 300 foot length of hose and a 600 foot length of hose.

1. 300 feet

$$K = 0.0195(0.72)\ \frac{300}{0.208}$$ $\underline{K = 20.25}$

2. 600 feet

$$K = 0.0195(0.72)\frac{600}{0.208} \qquad \underline{K = 40.50}$$

STEP 3: Find K_{total} for each of the three water sources

Raw Water, $K_{total} = K_{3A} + K_{3B} + K_{3C} + K_{3D2}$

$$K_{TOT} = 0.47 + 1.65 + 1.00 + 40.50 \qquad \underline{K_{TOT} = 43.62}$$

Sanitary Water, $K_{total} = K_{3A} + K_{3B} + K_{3C} + K_{3D1}$

$$K_{TOT} = 0.47 + 1.65 + 1.00 + 20.25 \qquad \underline{K_{TOT} = 23.37}$$

Deep well Pumps, $K_{total} = K_{3A} + K_{3B} + K_{3C} + K_{3D1}$

$$K_{TOT} = 0.47 + 1.65 + 1.00 + 20.25 \qquad \underline{K_{TOT} = 23.37}$$

STEP 4: Calculate the estimated flowrates from each source.

A. Raw Water

$$\Delta P = 1.799 \times 10^{-5} \frac{K \rho Q^2}{d^4}, \text{ SOLVING FOR } Q \text{ GIVES}$$

$$Q = \sqrt{\frac{\Delta P(d^4)}{K(\rho)1.799 \times 10^{-5}}} = \sqrt{\frac{100(2.5)^4}{43.62(62.37)1.799 \times 10^{-5}}}$$

$$\boxed{Q = 283 \text{ GPM}}$$

B. Sanitary Water

$$Q = \sqrt{\frac{80(2.5)^4}{23.37(62.37)1.799 \times 10^{-5}}}$$

$$\boxed{Q = 345 \text{ GPM}}$$

C. Deep Well Pumps

$$Q = \sqrt{\frac{30(2.5)^4}{23.37(62.37)1.799 \times 10^{-5}}}$$

$$\boxed{Q = 211 \text{ GPM}}$$

CONCLUSION

From Crane, page A-25, a higher Reynolds Number corresponds to a lower friction factor until the flow is completely turbulent. Since the raw water and sanitary water calculated flowrates are greater than the estimated flowrate used in the Reynolds Number calculation, this means that the friction factor would be lower and would result in a higher calculated flowrate. The deep well pump calculated flowrate is less than the estimated flowrate, therefore, the friction factor will be higher, which will result in less flowrate. However, the difference between the friction factor obtained by using an estimated flowrate versus the friction factor using the calculated flowrate is minimal, and will not significantly affect the deep well pump flowrate results.

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APPENDIX L - Peer Review Checklists

This appendix contains:

1. Peer review checklists.

2. HEDOP review checklists.

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PEER REVIEW CHECKLIST

Document Reviewed: WHC-SD-WM-TI-733 Rev. 0 " Supporting Calculations and Assumptions for Use in WESF ISB"
Author: Brit E. Hey
Date: January 1996
Scope of Review: Sections ~~2.1.2, 2.1.3, 2.1.6, 2.1.8~~ section numbers changed 10/16/96. Now section 2.2

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

D.A. Himes [signature] 3/21/96
Reviewer (Printed Name and Signature) Date

HEDOP REVIEW CHECKLIST

Document Reviewed: WHC-SD-WM-TI-733 Rev. 0 " Supporting Calculations and Assumptions for Use in WESF ISB"
Author: Brit E. Hey
Date: January 1996
Scope of Review: Sections ~~2.1.2, 2.1.3, 2.1.6, 2.1.8~~ Section numbers changed 10/16/96. Now section 2.2

YES	NO*	N/A		
[X]	[ ]	[ ]	1.	A detailed technical review and approval of the environmental transport and dose calculation portion of the analysis has been performed and documented.
[ ]	[ ]	[X]	2.	Detailed technical review(s) and approval(s) of scenario and release determinations have been performed and documented.
[ ]	[ ]	[X]	3.	HEDOP-approved code(s) were used.
[ ]	[ ]	[X]	4.	Receptor locations were selected according to HEDOP recommendations.
[X]	[ ]	[ ]	5.	All applicable environmental pathways and code options were included and are appropriate for the calculations.
[X]	[ ]	[ ]	6.	Hanford site data were used.
[ ]	[ ]	[X]	7.	Model adjustments external to the computer program were justified and performed correctly.
[X]	[ ]	[ ]	8.	The analysis is consistent with HEDOP recommendations.
[ ]		[X]	9.	Supporting notes, calculations, comments, comment resolutions, or other information is attached. (Use the "Page 1 of X" page numbering format and sign and date each added page.)
[X]	[ ]		10.	**Approval is granted on behalf of the Hanford Environmental Dose Overview Panel.**

* All "NO" responses must be explained and use of nonstandard methods justified.

D.A. Himes [signature] 3/21/96
HEDOP-Approved Reviewer (Printed Name and Signature) Date

COMMENTS (add additional signed and dated pages if necessary):

PEER REVIEW CHECKLIST

Document Reviewed: Supporting Calculations and Assumptions for Use in WESF ISB, WHC-SD-WM-TI-733, 2/6/96 DRAFT
Author: Brit E. Hey
Date: February 14, 1996
Scope of Review: The review consisted of checking calculations related to Section ~~2.2.3 (CsCl Load Factor) and Section 2.2.4 (Capsule Failure Criteria)~~ 7.7.1 through 7.7.8. Section numbers changed 10/16/96. BEH DLS

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

David L. Scott — D L Scott — 2/21/96
Reviewer (Printed Name and Signature) — Date

Author: David L. Scott

Date: February 29, 1996

Filename: CsClLoad

CHECK CALCULATIONS ON WESF CESIUM CHLORIDE CAPSULES--LOAD FACTORS

To perform these calculations version 4.0 of Mathcad for windows was used.

The load factor of a cesium chloride inner capsule is defined as the mass of CsCl salt (plus impurities) in grams divided by the internal volume of the inner capsule.

In *Supporting Calculations and Assumptions for Use in WESF ISB*, WHC-SD-WM-TI-733, Table 8, load factors are listed along with "number of capsules exceeding."

Calculations for inner capsules (dimensions are from Table 7 of WHC-SD-WM-733)

$D_o := 2.250 \cdot in$ nominal outer diameter of inner capsule (this value is from type 3 capsule drawing)

$t_w := 0.136 \cdot in$ nominal wall thickness of inner capsule

$h := 19.725 \cdot in$ height of inner capsule

$t_c := 0.4 \cdot in$ cap thickness of inner capsule

$$V_{inner25C} := \frac{\pi \cdot (D_o - 2 \cdot t_w)^2}{4} \cdot (h - 2 \cdot t_c)$$

$V_{inner25C} = 58.154 \cdot in^3$ inside volume of inner capsule at 25 °C

$V_{inner25C} = 952.971 \cdot cm^3$

Temperature vector in °C and CsCl density vector in gm/cm^3 are

$$T_c := \begin{bmatrix} 430 \\ 482 \\ 538 \\ 593 \\ 649 \\ 704 \\ 760 \\ 816 \\ 871 \\ 927 \\ 982 \\ 1038 \\ 1093 \\ 1149 \\ 1204 \end{bmatrix} \qquad \rho_{CsClT} := \begin{bmatrix} 2.89 \\ 2.88 \\ 2.87 \\ 2.84 \\ 2.82 \\ 2.76 \\ 2.69 \\ 2.64 \\ 2.56 \\ 2.51 \\ 2.46 \\ 2.40 \\ 2.35 \\ 2.30 \\ 2.25 \end{bmatrix} \cdot \frac{gm}{cm^3} \qquad \Delta T := \overrightarrow{(T_c - 25)} \qquad \Delta T = \begin{bmatrix} 405 \\ 457 \\ 513 \\ 568 \\ 624 \\ 679 \\ 735 \\ 791 \\ 846 \\ 902 \\ 957 \\ 1.013 \cdot 10^3 \\ 1.068 \cdot 10^3 \\ 1.124 \cdot 10^3 \\ 1.179 \cdot 10^3 \end{bmatrix}$$

$\alpha_{sst} := 1.921 \cdot 10^{-5}$ the mean coefficient of thermal expansion of 316 stainless steel provided in WHC-SD-WM-TI-733

$$V_{innerT} := V_{inner25C} \cdot \left(1 + 3 \cdot \alpha_{sst} \cdot \Delta T\right)$$

$$V_{innerT} = \begin{bmatrix} 975.213 \\ 978.069 \\ 981.144 \\ 984.165 \\ 987.24 \\ 990.261 \\ 993.337 \\ 996.412 \\ 999.433 \\ 1.003 \cdot 10^3 \\ 1.006 \cdot 10^3 \\ 1.009 \cdot 10^3 \\ 1.012 \cdot 10^3 \\ 1.015 \cdot 10^3 \\ 1.018 \cdot 10^3 \end{bmatrix} \cdot cm^3$$

$$\rho_{LFinner} := \overrightarrow{\left(\frac{V_{innerT} \cdot \rho_{CsClT}}{V_{inner25C}}\right)}$$

$$\rho_{LFinner} = \begin{bmatrix} 2.957 \\ 2.956 \\ 2.955 \\ 2.933 \\ 2.921 \\ 2.868 \\ 2.804 \\ 2.76 \\ 2.685 \\ 2.64 \\ 2.596 \\ 2.54 \\ 2.495 \\ 2.449 \\ 2.403 \end{bmatrix} \cdot \frac{gm}{cm^3}$$

These values of load factor for inner capsules are identical to those shown in Table 8 of WHC-SD-WM-TI-733.

Data was keyed into ASCII files named LOAD.dat for load factor data; PERCENT.dat for "percent exceeding" data; and NUMBER.dat for "number of capsules exceeding" data. These data files must be in the Mathcad directory; eg., C:\winmcad\PERCENT.dat. The data files were then read into MathCad as shown on Page 3. The data was obtained from Table 6 of WHC-SD-WM-TI-733.

$i := 0..23$

$L_i := \mathrm{READ}(\mathrm{LOAD})$ $\quad P_i := \mathrm{READ}(\mathrm{PERCENT})$ $\quad NO_i := \mathrm{READ}(\mathrm{NUMBER})$

$$L = \begin{bmatrix} 1 \\ 2 \\ 2.4 \\ 2.5 \\ 2.55 \\ 2.6 \\ 2.65 \\ 2.7 \\ 2.75 \\ 2.8 \\ 2.85 \\ 2.9 \\ 2.95 \\ 3 \\ 3.05 \\ 3.1 \\ 3.15 \\ 3.2 \\ 3.25 \\ 3.3 \\ 3.4 \\ 3.5 \\ 3.6 \\ 3.7 \end{bmatrix} \quad P = \begin{bmatrix} 99.9 \\ 99.5 \\ 97.4 \\ 95.1 \\ 92.3 \\ 88.8 \\ 85.3 \\ 80.2 \\ 75.2 \\ 68.2 \\ 56 \\ 42.4 \\ 27 \\ 13.7 \\ 8.8 \\ 5 \\ 3.1 \\ 1.7 \\ 0.6 \\ 0.4 \\ 0.3 \\ 0.2 \\ 0.2 \\ 0.1 \end{bmatrix} \quad NO = \begin{bmatrix} 1.327\cdot10^3 \\ 1.321\cdot10^3 \\ 1.293\cdot10^3 \\ 1.263\cdot10^3 \\ 1.226\cdot10^3 \\ 1.179\cdot10^3 \\ 1.133\cdot10^3 \\ 1.065\cdot10^3 \\ 999 \\ 906 \\ 744 \\ 563 \\ 359 \\ 182 \\ 117 \\ 66 \\ 41 \\ 23 \\ 8 \\ 5 \\ 4 \\ 3 \\ 3 \\ 1 \end{bmatrix}$$

Cubic spline interpolation methods were used to obtain "in between" values of P. The MathCad interp function uses only scalar values so these were calculated one at a time for each load factor shown above in the $\mathrm{rho}_{\mathrm{LFinner}}$ vector.

$vs := \mathrm{cspline}(L, P)$

$\mathrm{interp}(vs, L, P, 2.957) = 24.816$

$\mathrm{interp}(vs, L, P, 2.956) = 25.126$

$\mathrm{interp}(vs, L, P, 2.955) = 25.436$

$\mathrm{interp}(vs, L, P, 2.933) = 32.347$

$\mathrm{interp}(vs, L, P, 2.921) = 36.088$

$\mathrm{interp}(vs, L, P, 2.868) = 51.226$

$\mathrm{interp}(vs, L, P, 2.804) = 67.395$

$\mathrm{interp}(vs, L, P, 2.760) = 74.111$

$\mathrm{interp}(vs, L, P, 2.685) = 81.79$

$\mathrm{interp}(vs, L, P, 2.640) = 86.111$

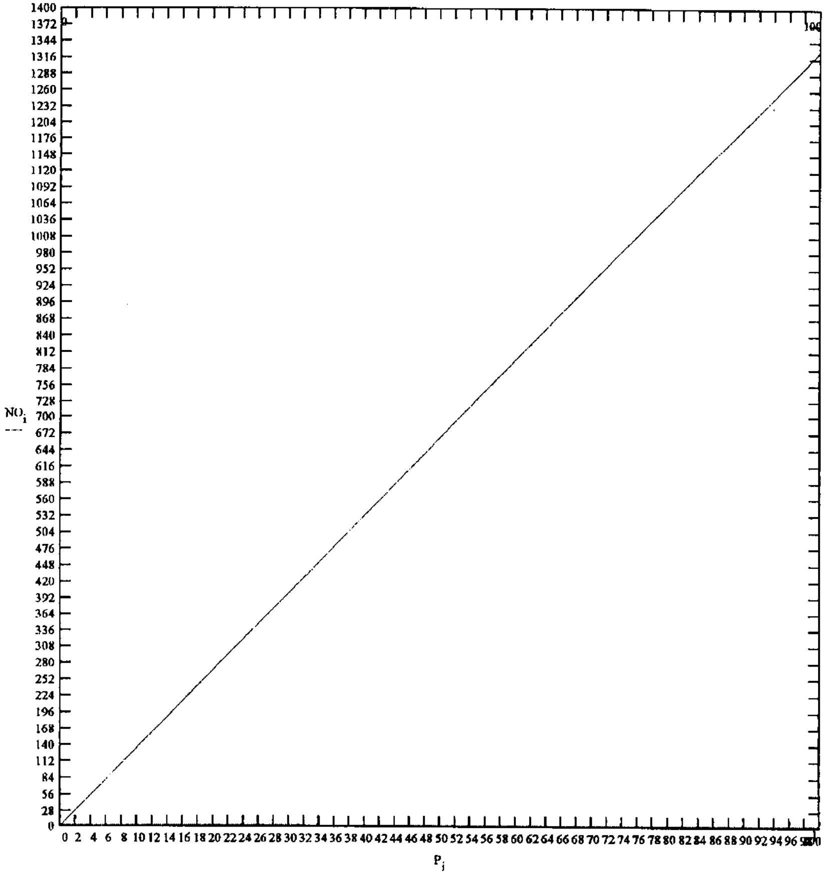
$\mathrm{interp}(vs, L, P, 2.596) = 89.069$

$\mathrm{interp}(vs, L, P, 2.540) = 92.951$

$\mathrm{interp}(vs, L, P, 2.495) = 95.309$

$\mathrm{interp}(vs, L, P, 2.449) = 96.661$

$\mathrm{interp}(vs, L, P, 2.403) = 97.364$



A plot of percent P vs number NO shows that a linear relationship exists between the two variables. The slope and intercept of the line are then calculated along with the correlation coefficient.

$m := \mathrm{slope}(P, NO)$	$b := \mathrm{intercept}(P, NO)$	$c := \mathrm{corr}(P, NO)$
$m = 13.28$	$b = 0.058$	$c = 1$

To facilitate subsequent calcualtions the equation of the line is written in function form as

$$NO(P) := m \cdot P + b$$

Now the interpolated values of P (calculated on page 3) will be used to calculate NO (rounded of to the nearest whole number) as follows:

$NO(24.816) = 330$

$NO(25.126) = 334$

$NO(25.436) = 338$

$NO(32.347) = 430$

$NO(36.088) = 479$

$NO(51.226) = 680$

$NO(67.395) = 895$

$NO(74.111) = 984$

$NO(81.79) = 1.086 \cdot 10^3$

$NO(86.111) = 1.144 \cdot 10^3$

$NO(89.069) = 1.183 \cdot 10^3$

$NO(92.951) = 1.234 \cdot 10^3$

$NO(95.309) = 1.266 \cdot 10^3$

$NO(96.661) = 1.284 \cdot 10^3$

$NO(97.364) = 1.293 \cdot 10^3$

The calculated values of NO are very close (not more than a difference of 3) to the values shown in Table 8 of WHC-SD-WM-TI-733.

Calculations for outer capsules (dimensions are from Table 7 of WHC-SD-WM-TI-733)

$D_{oo} := 2.625 \cdot in$ nominal outer diameter of outer capsule

$t_w := 0.136 \cdot in$ nominal wall thickness of outer capsule

$h_o := 20.775 \cdot in$ height of outer capsule

$t_c := 0.4 \cdot in$ cap thickness of outer capsule

$$V_{outer25C} := \left[\pi \cdot \frac{(D_{oo} - 2 \cdot t_w)^2}{4} \cdot (h_o - 2 \cdot t_c)\right]$$ inside volume of outer capsule at 25 C

$$V_{outer25C} = 86.86 \cdot in^3$$

$$V_{outer25C} = 1.423 \cdot 10^3 \cdot cm^3$$

$$V_{outerT} := \overrightarrow{\left[V_{outer25C} \cdot (1 + 3 \cdot \alpha_{sst} \cdot \Delta T)\right]}$$

$$V_{outerT} = \begin{bmatrix} 1.457 \cdot 10^3 \\ 1.461 \cdot 10^3 \\ 1.465 \cdot 10^3 \\ 1.47 \cdot 10^3 \\ 1.475 \cdot 10^3 \\ 1.479 \cdot 10^3 \\ 1.484 \cdot 10^3 \\ 1.488 \cdot 10^3 \\ 1.493 \cdot 10^3 \\ 1.497 \cdot 10^3 \\ 1.502 \cdot 10^3 \\ 1.506 \cdot 10^3 \\ 1.511 \cdot 10^3 \\ 1.516 \cdot 10^3 \\ 1.52 \cdot 10^3 \end{bmatrix} \cdot cm^3$$

$V_{inn25C} := \frac{\pi \cdot D_o^2}{4} \cdot h$ volume occupied by inner capsule at 25 C

$V_{inn25C} = 78.428 \cdot in^3$

$V_{inn25C} = 1.285 \cdot 10^3 \cdot cm^3$

$V_{innT} := \overrightarrow{\left[V_{inn25C} \cdot \left(1 + 3 \cdot \alpha_{sst} \cdot \Delta T\right)\right]}$

$$V_{innT} = \begin{bmatrix} 1.315 \cdot 10^3 \\ 1.319 \cdot 10^3 \\ 1.323 \cdot 10^3 \\ 1.327 \cdot 10^3 \\ 1.331 \cdot 10^3 \\ 1.335 \cdot 10^3 \\ 1.34 \cdot 10^3 \\ 1.344 \cdot 10^3 \\ 1.348 \cdot 10^3 \\ 1.352 \cdot 10^3 \\ 1.356 \cdot 10^3 \\ 1.36 \cdot 10^3 \\ 1.364 \cdot 10^3 \\ 1.368 \cdot 10^3 \\ 1.373 \cdot 10^3 \end{bmatrix} \cdot cm^3$$

$V_{annulusT} := \overrightarrow{\left(V_{outerT} - V_{innT}\right)}$

$$V_{annulusT} = \begin{bmatrix} 141.401 \\ 141.815 \\ 142.261 \\ 142.699 \\ 143.145 \\ 143.583 \\ 144.029 \\ 144.474 \\ 144.912 \\ 145.358 \\ 145.796 \\ 146.242 \\ 146.68 \\ 147.126 \\ 147.564 \end{bmatrix} \cdot cm^3$$

volume of annular space between inner capsule and outer capsule including space between end caps

$$\rho_{LFouter} := \frac{\overrightarrow{\rho_{CsClT} \cdot (V_{innerT} + V_{annulusT})}}{V_{inner25C}}$$

In WHC-SD-WM-TI-733, page 12, change equation 2 to read as shown at left; i.e., $V_{inner25C}$ not $V_{outer25C}$.

$$\rho_{LFouter} = \begin{bmatrix} 3.386 \\ 3.384 \\ 3.383 \\ 3.358 \\ 3.345 \\ 3.284 \\ 3.211 \\ 3.161 \\ 3.074 \\ 3.023 \\ 2.972 \\ 2.908 \\ 2.856 \\ 2.804 \\ 2.751 \end{bmatrix} \cdot \frac{gm}{cm^3}$$

<--------

Spot check calculation at 430 C:

$$\rho_{LFouter430C} := \frac{2.89 \cdot (975.213 + 141.404)}{952.971}$$

$$\rho_{LFouter430C} = 3.386$$

which identical to value shown in $\mathrm{rho}_{LFouter}$ vector shown at left

These values of outer capsule load factor are lower than those in Table 8 of WHC-SD-WM-TI-733 by a difference of about 0.02 gm/cc as shown by a check of the first three values:

$3.406 - 3.386 = 0.02$

$3.404 - 3.384 = 0.02$

$3.403 - 3.383 = 0.02$

and the last two values $2.820 - 2.804 = 0.016$

$2.767 - 2.751 = 0.016$

Cubic spline interpolation methods were than used to obtain "in between" values of P. The MathCad interp function uses only scalar values so these were calculated one at a time for each load factor shown above in the $\mathrm{rho}_{LFouter}$ vector.

$vs := \mathrm{cspline}(L, P)$

$\mathrm{interp}(vs, L, P, 3.386) = 0.32$

$\mathrm{interp}(vs, L, P, 3.384) = 0.322$

$\mathrm{interp}(vs, L, P, 3.383) = 0.324$

$\mathrm{interp}(vs, L, P, 3.358) = 0.357$

$\mathrm{interp}(vs, L, P, 3.345) = 0.372$

$\mathrm{interp}(vs, L, P, 3.284) = 0.405$

$\mathrm{interp}(vs, L, P, 3.211) = 1.403$

$\mathrm{interp}(vs, L, P, 3.161) = 2.795$

$\mathrm{interp}(vs, L, P, 3.074) = 6.917$

$\mathrm{interp}(vs, L, P, 3.023) = 10.764$

$\mathrm{interp}(vs, L, P, 2.972) = 20.335$

$\mathrm{interp}(vs, L, P, 2.908) = 40.043$

$\mathrm{interp}(vs, L, P, 2.856) = 54.409$

$\mathrm{interp}(vs, L, P, 2.804) = 67.395$

$\mathrm{interp}(vs, L, P, 2.751) = 75.094$

Now the interpolated values of P (calculated above on page 7) are used to calculate NO (rounded of to the nearest whole number) as follows:

$NO(0.320) = 4$	$NO(6.917) = 92$
$NO(0.322) = 4$	$NO(10.764) = 143$
$NO(0.324) = 4$	$NO(20.335) = 270$
$NO(0.357) = 5$	$NO(40.043) = 532$
$NO(0.372) = 5$	$NO(54.409) = 723$
$NO(0.405) = 5$	$NO(67.395) = 895$
$NO(1.403) = 19$	$NO(75.094) = 997$
$NO(2.795) = 37$	

Most of these values for NO are slightly higher than those reported in WHC-SD-WM-TI-733, Table 8.

<u>**Calculation of Mass of CsCl Spilled**</u>

A good estimate of the mass spilled, M_T, at any temperature T is given by the equation

$$M_T := V_{inner25C} \cdot N \cdot \rho_{avgLF} - N \cdot \rho_{CsClT} \cdot \left(V_{innerT} + V_{annulusT}\right)$$

where N is the "number of capsules exceeding",

ρ_{avgLF} is the average load factor of failed outer capsules,

ρ_{CsClT} is the density of CsCl plus impurities at temperature T, and

the other variables are as described previously.

The values for ρ_{avgLF} were not calculated here but the author was satisfied that they were calculated correctly. The author is also satisfied that the values of M_T were also calculated correctly.

PEER REVIEW CHECKLIST

Document Reviewed: WHC-SD-WM-TI-733 Rev. 0 "Supporing Calculations and Assumptions for Use in WESF Safety Analysis,"
Author: Brit E. Hey
Date: November 8, 1996
Scope of Review: Sections 2.3, 2.4, 2.5, 2.6, 2.8

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

Hussein Y. Fouad
Reviewer (Printed Name and Signature)

11/12/96
Date

PEER REVIEW CHECKLIST

Document Reviewed: WHC-SD-WM-TI-733 Rev. 1 "Supporting Calculations and Assumptions for Use in WESF Safety Analysis"
Author: Brit E. Hey
Date: January 17, 1997
Scope of Review: Section 2.2.4.2

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

Paul Rittmann — Jan 17, 1997

Reviewer (Printed Name and Signature) — Date

Note: reviewed again for minor change in GXQ runs on Feb 14, 1997
All of the above is still valid.
Approved by Paul Rittmann 2-14-97

HEDOP REVIEW CHECKLIST

Document Reviewed: WHC-SD-WM-TI-733 Rev. 1 "Supporting Calculations and Assumptions for Use in WESF Safety Analysis"
Author: Brit E. Hey
Date: January 17, 1997
Scope of Review: Section 2.2.4.2

YES	NO*	N/A		
[X]	[ ]	[ ]	1.	A detailed technical review and approval of the environmental transport and dose calculation portion of the analysis has been performed and documented.
[X]	[ ]	[ ]	2.	Detailed technical review(s) and approval(s) of scenario and release determinations have been performed and documented.
[ ]	[X]	[ ]	3.	HEDOP-approved code(s) were used.
[ ]	[ ]	[X]	4.	Receptor locations were selected according to HEDOP recommendations.
[X]	[ ]	[ ]	5.	All applicable environmental pathways and code options were included and are appropriate for the calculations.
[X]	[ ]	[ ]	6.	Hanford site data were used.
[X]	[ ]	[ ]	7.	Model adjustments external to the computer program were justified and performed correctly.
[X]	[ ]	[ ]	8.	The analysis is consistent with HEDOP recommendations.
[ ]		[X]	9.	Supporting notes, calculations, comments, comment resolutions, or other information is attached. (Use the "Page 1 of X" page numbering format and sign and date each added page.)
[X]	[ ]		10.	**Approval is granted on behalf of the Hanford Environmental Dose Overview Panel.**

* All "NO" responses must be explained and use of nonstandard methods justified.

Paul Rittmann — Jan 17, 1997

HEDOP-Approved Reviewer (Printed Name and Signature) Date

COMMENTS (add additional signed and dated pages if necessary):

GXQ was used since GENII's dispersion model is too simple.

Note: reviewed again on 2-14-97
Approved by Paul Rittmann 2-14-97

Peer Reviewer Notes by Paul D. Rittmann, PhD CHP January 17, 1997

The ISCST3 program (EPA-454/B-95-003a, "User's Guide for the Industrial Source Complex (ISC3) Dispersion Models", September 1995) was used to compute time-integrated air concentrations near the 296-B stack.

The ISCST3 building downwash model requires input of the building height and width in 36 wind directions. The values used are listed in the table below.

Building Height and Width in 36 Wind Transport Directions

Wind Vector	Height, m	Width, m	Wind Vector	Height, m	Width, m
10°	12.2	20	190°	2.0	20
20°	12.2	20	200°	2.0	20
30°	12.2	20	210°	2.0	20
40°	12.2	20	220°	2.0	20
50°	16.0	20	230°	2.0	20
60°	16.0	20	240°	2.0	20
70°	16.0	20	250°	2.0	20
80°	7.6	20	260°	2.0	20
90°	7.6	20	270°	2.0	20
100°	7.6	20	280°	2.0	20
110°	12.2	20	290°	2.0	20
120°	12.2	20	300°	2.0	20
130°	12.2	20	310°	2.0	20
140°	12.2	20	320°	12.2	20
150°	12.2	20	330°	12.2	20
160°	12.2	20	340°	12.2	20
170°	2.0	20	350°	12.2	20
180°	2.0	20	360°	12.2	20
"Wind Vector" directions are measured clockwise from north, so that 90° is east and 180° is south.					

Hourly data collected in the 200 East Area during 1992, 1993, 1994, and 1995 was used. Results are summarized in the table below. These are the worst-case values for ground level releases from each area. The ISCST3 input file is also listed below. The results are comparable to those shown in the document.

P.D.R

Time-Integrated Air Concentrations

Compass Zone	X/Q' (sec/m³)
I	8.03×10^{-5}
II	1.00×10^{-4}
III	5.99×10^{-5}
IV	8.03×10^{-5}
V	5.68×10^{-5}
Note: These are based on 1 hour averages. ISCST3 looks through the data to find the worst hour.	

ISCST3 Input Data File

```
CO STARTING
   TITLEONE  Emissions from 296-B-10 Stack Near WESF
   MODELOPT  MSGPRO  CONC  RURAL  GRDRIS
   AVERTIME  1
   POLLUTID  Unknown
   FLAGPOLE  2.0
   RUNORNOT  RUN
CO FINISHED

SO STARTING
   LOCATION  Exhaust1  POINT   0.0  0.0  0.0
**          22000 cfm  g/sec   ht,m    temp°K   m/sec   diam,m
   SRCPARAM  Exhaust1   1.0    22.86    273.0   11.62    1.067
   BUILDHGT  Exhaust1  4*12.2  3*16.0  3*7.6  6*12.2  15*2.0  5*12.2
   BUILDWID  Exhaust1  36*20.0
   SRCGROUP ALL
SO FINISHED

RE STARTING
   GRIDPOLR  Polar1  STA
                     DIST    100.0  200.0  300.0  1000.0
                     GDIR    36     10.0   10.0
   GRIDPOLR  Polar1  END
RE FINISHED

ME STARTING
   INPUTFIL  EPA92-95.2E
   ANEMHGHT  10.0
   SURFDATA  67656  1992   Hanford-200
   UAIRDATA  67656  1992   Hanford-200
ME FINISHED

OU STARTING
   RECTABLE  ALLAVE FIRST
   MAXTABLE  ALLAVE 36
OU FINISHED
```

PDR

CHECKLIST FOR INDEPENDENT TECHNICAL REVIEW

DOCUMENT REVIEWED
NUMBER: WHC-SD-WM-TI-733, Rev 1
TITLE: Supporting Calculations and Assumptions for Use in WESF Safety Analysis (Only revision to Sections 2.2.4.2.2, 2.2.4.2.3, & 2.2.4.2.5 reviewed herein)
AUTHOR(s): B. E. Hey / P. D. Rittmann

I. Method(s) of Review

(NA) Input data checked for accuracy
(X) Independent calculation performed
  (X) Hand calculation
  ( ) Alternate computer code: ____
(X) Comparison to experiment or previous results
(X) Alternate method (define) Methodology of Wilson & Lamb 1989

II. Checklist (either check or enter NA if not applied)

(X) Task completely defined
(X) Activity consistent with task specification
(X) Necessary assumptions explicitly stated and supported
(X) Resources properly identified and referenced
(X) Resource documentation appropriate for this application
(X) Input data explicitly stated
(X) Input data verified to be consistent with original source
(X) Geometric model adequate representation of actual geometry
(NA) Material properties appropriate and reasonable
(NA) Mathematical derivations checked including dimensional consistency
(X) Hand calculations checked for errors
(X) Assumptions explicitly stated and justified
(NA) Computer software appropriate for task and used within range of validity
(X) Use of resource outside range of established validity is justified
(NA) Software runstreams correct and consistent with results
(NA) Software output consistent with input
(X) Results consistent with applicable previous experimental or analytical findings
(X) Results and conclusions address all points and are consistent with task requirements and/or established limits or criteria
(X) Conclusions consistent with analytical results and established limits
(NA) Uncertainty assesment appropriate and reasonable
( ) Other (define) ____

III. Comments: The model was originally developed and checked against experimental data for release from the top op a building. This was a stack release at a height commensurate with the adjacent buildings. Any effect that this difference would have would tend to decrease the integrated concentration and thus this extention of the range of validity of the model will lead to conservative results.

When slight differences arose between my hand calculations and the results in the document were always more conservative. These differences were small enough that I felt that they were probably due to roundoff and it would not be worth the effort to pursue their resolution.

IV. REVIEWER: Harvey Goldberg DATE: 12 February 1997

Pacific Northwest National Laboratory

Operated by Battelle for the U.S. Department of Energy

February 18, 1997

Ms. Kathleen Jennings-Mills
Babcock & Wilcox Hanford Co.
Senior Principal Engineer
WESF Baseline Control
200 East/MO-029/MS# S6-51
Richland, WA 99352

Dear Ms. Jennings-Mills:

Subject: Technical Review of the Waste Encapsulation and Storage Facility Stack Release Analysis

Attached is the completed Review and Comment Record (RCR) for the technical review of the waste encapsulation and storage facility stack release analysis document, WHC-SD-WM-TI-733, Revision 1, *Supporting Calculations and Assumptions for Use in WESF Safety Analysis.*

PNNL's review was limited to the analysis methodology and assumptions used to model a stack release from the WESF. The GXQ computer code revision 4C and the results of the GXQ revision 4C analysis were not validated.

Please call me if you have any questions or if I can be of further assistance.

Sincerely,

Jay C. Lavender

JCL/sm

Attachment

cc: LI Covey, B&W
JR Brehm, FDNW
BE Hey, FDNW

Battelle Boulevard ■ P.O. Box 999 ■ Richland, WA 99352
Telephone 509/372-4241 ■ Email jc_lavender@pnl.gov ■ Fax 509/375-2370

REVIEW COMMENT RECORD (RCR)

1. Date	2. Review No.
3. Project No.	4. Page 1 of 5

5. Document Number(s)/Title(s)	6. Program/Project/ Building Number	7. Reviewer	8. Organization/Group	9. Location/Phone
WHC-SD-WM-TI-733, Rev.1, WESF BIO Dispersion Analysis	WESF	Christian Fosmire	PNNL/Multimedia Exposure Assessment	ETB/372-6314

17. Comment Submittal Approval:

Organization Manager (Optional)

10. Agreement with indicated comment disposition(s)

2/18/97
Date

Reviewer/Point of Contact

Author/Originator

11. CLOSED

2/18/97
Date

Reviewer/Point of Contact

Author/Originator

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/ resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
General	PNNL's review of this document is limited to the methodology and assumptions used to characterize plume travel from the WESF stack. The GXQ computer code revision 4C or the results of the GXQ analysis were not validated.		No response required.	
1.	<u>Section 2.2.4.2.1 - Page 2-9, 2nd Paragraph from Bottom</u> Was Stack-Tip Downwash accounted for in calculating plume rise for higher wind speeds? Paragraph is unclear if you used it or if you did not use it based on the assumption that the maximum concentration would occur at wind speeds below the 7.7 m/s.		Stack downwash was considered, but not in the verification test cases (see zone GXQ output files where iwash=1). This was done in order to keep the verification test cases simple and focused on the Huber equations which were new to the code and the subject of the test. It turns out that the low wind speeds produced the highest X/Qs anyway, even with stack downwash accounted for.	C
2.	<u>Section 2.2.4.2.1 - Page 2-11, Equation 10</u> You did not explain what Fb is and how it is calculated. I know that Fb only occurs for buoyant plumes, so you may want to only show the first equation in Equation 10 without referring to Fb.		You are right. I will take your advice and delete the other portions of Equation 10.	C

REVIEW COMMENT RECORD (RCR)

1. Date	2. Review No.
3. Project No.	4. Page 2 of 5

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/ resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
3.	<u>Section 2.2.4.2.1 - Page 2-12, First Paragraph</u> Your discussion here is a bit confusing. First, the equation you need to solve to get the virtual sources are $\sigma_z(x_{lee} + x_{z0}) = 1.2H$ where $x_{lee} = 10H$, and a similar equation for sigma y. The other way to say it is that Equation 13 and Equation 12 must be equal at $x_{lee} = 10H$. You also have to take into account that for certain stability classes and building dimensions, the virtual source term can be less than zero (i.e., for the 225-B building and stability class A, x_{z0} would be negative). You need to explain what you are doing in these cases. In the EPA's ISC3 model if the virtual source term is less than zero, the virtual source term is set to zero.		I agree that it is somewhat confusing and in fact, I was confused and this required a revision to the method for calculating virtual distances. The X/Q values are as a result, slightly lower where the far field model was used. As for the possibility of virtual distances less than zero, I have taken the same approach as that used in EPA's ISC3 model and put a floor of zero on those values. The section in question has been revised accordingly.	C
4.	<u>Section 2.2.4.2.1 - Page 2-12, 2nd Paragraph from the Top</u> Uncertain why this paragraph is here as you do not use these equations for Zone V, which is the only case when you have a source downwind of the buildings. This paragraph seems to conflict with what you state in Section 2.2.4.2.6 as you use a different set of equations.		I am just trying to be complete. This was the only discussion I could find with respect to the use of Huber's model for sources downwind of buildings, as in the case with Zone V. That rounded out the discussion of the Huber model. I also said that its use was marginal in this application. That's why I chose to use Brigg's suggested method for Zone V. I will make this more clear in Section 2.2.4.2.6.	C
5.	<u>Section 2.2.4.2.1 - Page 2-12, 3rd Paragraph from the Top - 2nd Sentence</u> This is an ambiguous reference as there are many Symposiums on Atmospheric Turbulence. I'm not sure this sentence means anything; just because a model was presented at a symposium does not mean it's a valid model.		The complete reference was provided in the Reference section. I agree that the presentation of a model at a symposium does not validate the model. I also agree that the sentence is misleading and I delete it.	C

A-6400-090.1 (03/92) WEF011

ID# PNNLO.RCR

REVIEW COMMENT RECORD (RCR)	1. Date	2. Review No.
	3. Project No.	4. Page 3 of 5

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/ resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
6.	<u>Section 2.2.4.2.1 - Page 2-13, Last Paragraph</u> You do not test the sigma y equations in Equations 12 or 13, as 1.2H is below the stack height, so they have not really been validated. You may want to state that sigma y in Equations 12 and 13 are never applied during your modeling calculations.		You are right. None of the buildings are high enough to cause the Huber sigma-y to be calculated. I will so state. However, I have performed a line-by-line check of this small code addition. As it is a simple change I think this should suffice as verification of this code piece. But you are correct in that I did not explicitly verify it in this test case documented here.	C
7.	<u>Section 2.2.4.2.1 - Page 2-14, Last Paragraph - Last Sentence</u> This sentence is missing something. You say the distance is the full 100 m between the stack (and what?)		I meant to say "between the stack and the receptor." I will correct.	C
8.	<u>Section 2.2.4.2.1 - Page 2-16, Table 4</u> In the calculated parameters, you have too many significant figures. Should only have one decimal place to be consistent with the Input Constants.		True. I will correct.	C

REVIEW COMMENT RECORD (RCR)	1. Date	2. Review No.
	3. Project No.	4. Page 4 of 5

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/ resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
9.	<u>Section 2.2.4.2.1 - Page 2-17, Table 5</u> What is Pasquill sigma z based on distance x (range 2)? Why do you give the non-Huber spread sigma z values as they are not applied? What they point out is that for Stability Class A and B, your Huber sigma z is less than the non-spread sigma z, which does not make physical sense (a problem with the Huber equations).		The "Pasquill sigma z based on distance x (range 2)" refers to the "GENII like" sigma z calculated for distance range 2 (i.e., 100-1000 m). Actually, these values are used if they are larger than the Huber modified sigma z. In the GXQ code I calculate both an uncorrected and a Huber modified sigma-y and sigma-z. Only sigma-z applies here for the reasons given above. I use the larger of the two. Since, as you note, the uncorrected sigma-z is larger for stability class A and B, I use that value in the X/Q equation instead. In this case, the X/Q is larger as a result. The reason Huber's sigma is less than the PG sigma is that Huber's sigma is based on a building lee face to receptor distance of 62 m whereas the uncorrected PG sigma is based on a source to receptor distance of 100 m.	C
10.	<u>Section 2.2.4.2.3 - Page 2-21, 2nd Paragraph from the Bottom</u> You assume the building in the ENE direction is 70 m from the stack. This would put the 100 meter receptor within 3 building heights of the lee side of the building. The Huber equations are not valid inside 3 building heights. How are you handling this?		The analysis has been revised and now uses the method proposed by Wilson and Lamb 1994. This model is not restricted to the greater than three building heights limitation. One of the advantages of this model is that it includes the effect of the volume of air exhausted by the stack along with the contaminants. An additional advantage is that the Wilson and Lamb approach gives bounding values for air concentrations based on field data. These are not average values, but worst-case.	C

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12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/ resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
11.	Section 2.2.4.2.3 - Page 2-21, Last Paragraph The conclusion you draw here is not really valid and may be incorrect. In Huber (1986) and Huber (1989), it was determined that the maximum concentration due to a building wakes with the wind at an oblique angle could be larger than at a normal angle. The larger concentration is due to a greater deflection of the streamlines towards the ground (Huber 1986). References: Huber, Alan H. 1986. A Look at the Influence of Building Orientation on Plume Dispersion in the wake of buildings. Preprints of the Fifth Joint Conference on Applications of Air Pollution Meteorology, November 18-21, 1986, Chapel Hill, North Carolina. Huber, Alan H. 1989. The influence of building width and orientation on plume dispersion in the wake of a building. Atmospheric Environment, Vol. 23 No. 10, pp 2109-2116.		Huber (1989) presents wind-tunnel data for stacks on the lee face of various buildings showing an increase in air concentrations as the wind incidence angle changes from normal. He also shows cases where obliquely incident winds decrease the air concentration. Thus it is difficult to generalize on what the exact effect of off-normal winds on the 221-B estimates for X/Q' would be. The near source X/Q' were computed using a bounding dilution factor model from Wilson and Lamb (1994). The conservatism inherent in this model should compensate for any nonconservatism which results from off-normal winds. These words replace the conclusion originally provided in the text	C
12.	Section 2.2.4.2.5 - Page 2-22, Last Paragraph As leading edge of the building in the ESE direction is assumed to be 80 m and the depth of the building is 20 m, the 100 meter receptor would be at the lee edge of the building. How are you handling this?		Please see response to Comment No. 10.	C
13.	Section 2.2.4.2.6 - Page 2-23, Last Paragraph How does the maximum X/Q with this adjustment compare to the case where building wake is ignored?		If building wake is ignored and the release treated as an elevated release, then the X/Q is slightly lower, by about 20%. This comparison has been added to the text.	C

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1. Date	2. Review No.
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12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/ resolve the discrepancy/problem indicated.)	14. Hold Point	15. Disposition (Provide justification if NOT accepted.)	16. Status
14.	Section 2.2.4.2.7 - Page 2-23 Are you assuming that the maximum value that occurs for receptors in the South bounds all the receptors in zone V as shown in Table 9? For example, the receptor in the West would not be affected by building wakes as the 212-B building is not high enough and in the WSW and WNW, the stack is too far away from your modeled buildings.		The X/Q calculated for Zone V is based on Equation 19 and is both independent of direction and building dimensions in this case. It would have been directionally dependent if I had gone to the trouble of coding it and calculating a 99.5 percentile. But, since the maximum value was bounded by values calculated for other zones, I saw no need.	C

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