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LIST OF ACRONYMS AND ABBREVIATIONS

B&W	Babcock & Wilcox
CDB	Characteristics Data Base
CFR	Code of Federal Regulations
Ci	Curies
cm	centimeters
CRWMS	Civilian Radioactive Waste Management System
DC	Document Control
DBE	Design Basis Event
DIRS	Document Input Reference Sheet
DOE	U.S Department of Energy
DP	Dose Point
DTN	Data Tracking Number
EDA	Enhanced Design Alternative
FA	Fuel Assembly
kW	kilowatts
hr	hours
LADS	License Application Design Selection
m	meters
MeV	Million Electron Volts
mm	millimeters
mrem	millirem
MTU	Metric Tons of Uranium
MWd	Megawatt Days
M&O	Management and Operating Contractor
N/A	Not Applicable
PWR	Pressurized Water Reactor
rem	Roentgen Equivalent in Man
s or sec	seconds
SNF	Spent Nuclear Fuel
STN	Software Tracking Number
TBV	To Be Verified
TCR	Technical Change Request
TDMS	Technical Data Management System
TIC	Technical Information Center
WP	Waste Package
μCi	microcuries

1. PURPOSE

The purpose of this activity is to identify and determine potential radiation hazards in the service exhaust main due to a waste package leakage from an emplacement drift. This work supports the subsurface ventilation system design for the EDA II, which consists of an accessible service exhaust main for personnel, and an exhaust main for hot air flow.

The objective is to provide the necessary radiation exposure calculations to determine if the service exhaust main is accessible following a waste package leak.

This work includes the following items responsive to the stated purpose and objective:

- Calculate the limiting transient radiation exposure of personnel in the service exhaust main due to the passage of airborne radioactive material through the ventilation raise and connecting horizontal raise to the exhaust main in the event of a leaking waste package
- Calculate the potential exposures to maintenance workers in the service exhaust main from residual radioactive material deposited inside of the ventilation raise and connecting horizontal raise

This calculation is limited to external radiation only, since the airborne and contamination sources will be contained in the ventilation raise and connecting horizontal raise.

The technical product development plan for this calculation is provided in *Development Plan for Exhaust Main Personnel Exposure Calculation*, Document Identifier No.: TDP-SVS-NU-000001 REV 00 (MOL.19990811.0293).

2. METHOD

Since the qualified source data are currently unavailable, this calculation uses the isotopic source data directly from the DOE Characteristics Data Base (CDB) (TBV-455) (DIRS 1). The CDB inputs are intended for scoping calculations and parametric study only.

The EDA II design is used for this calculation. The WP thermal design basis is 11.8 kW/WP for the 21 PWR waste package, which is 20% over the average thermal load (DIRS 3, Enclosure 2, p. 3). The fuel parameters (including initial enrichment, burnup and cooling time) used in this calculation are provided in Section 5.1.3. The radionuclide release fractions are based on NUREG-1536 (DIRS 9, p. 7-6), consistent with the previous design basis event (DBE) analysis (DIRS 4, p. 15).

For this calculation, conservative assumptions are made regarding the distributions of the airborne and contamination sources in the ventilation raise and connecting horizontal raise. It should be recognized that this calculation would be subject to refinement or revision, when the airborne and contamination sources are available from the forthcoming detailed subsurface airborne contaminant transport analysis.

Gamma radiation fields in the service exhaust main directly beneath the ventilation raise are calculated with the qualified PATH code (DIRS 5). The calculations include the contributions from the airborne and contamination sources. The results are used to identify and determine the potential radiation hazards in the service exhaust main in the event of a waste package leak.

3. ASSUMPTIONS

The following assumptions are used:

- 3.1 The waste package contains 21 PWR fuel assemblies.

Rationale: This assumption is consistent with the previous shielding analyses as the bounding case. The EDA II design also focuses on the 21 PWR waste package only. Other waste package designs for different waste forms remain to be developed for the license application.

Usage: This assumption is used in Section 5.4 for WP isotopic inventory calculation.

- 3.2 The WP thermal design basis is 11.8 kW/WP, representing the maximum thermal load per waste package which is 20% over the average thermal heat output.

Rationale: This assumption is based on the license application design selection described in DIRS 3 (Enclosure 2, p. 3) for EDA II.

Usage: This assumption is used in Section 5.1.2 for obtaining the heat output per MTU.

- 3.3 A single waste package failure is assumed.

Rationale: This assumption is the same as used in the DBE analysis (DIRS 4, p.10). Concurrent failures of multiple waste packages have not been considered in the DBE analysis.

Usage: This assumption is used in Section 5.4 to calculate the airborne source concentrations.

- 3.4 The radionuclide release fractions specified in NUREG-1536 (DIRS 9, p. 7-6) is assumed.

Rationale: This assumption adopts the NUREG-1536 specifications, consistent with the DBE analysis (DIRS 4, p. 15)

Usage: This assumption is used in Section 5.1.5.

- 3.5 The duration of radionuclide releases following a waste package breach is 2 hours.

Rationale: The duration of radionuclide releases from a leaking WP could be instantaneous, or continue for several hours or days, depending on the breach conditions. Consistent with the non-mechanistic DBE analysis (DIRS 4, p. 21), the 2-hour duration is assumed for this calculation. The assumption is relevant only for the airborne source concentrations and resulting dose rates. This duration period is cancelled out in determination of the time-integrated dose due to the airborne source (Section 5.6) and in

derivation of the contamination source terms (Section 5.5), therefore this assumption does not impact these outputs.

Usage: This assumption is used in Section 5.4 to calculate the airborne source concentrations, and Section 6.1 to calculate the corresponding time-integrated dose.

- 3.6 The airborne source concentrations are assumed to be uniformly present in the ventilation raise and connecting horizontal raise.

Rationale: This assumption is based on uniform mixing of the radionuclide releases with ventilation air supply. Airborne contaminants are then carried along the airflow path from the site of the breach through the emplacement drift, ventilation raise and horizontal raise to the exhaust main.

Usage: This assumption is used in Section 5.6 for modeling the airborne source distribution.

- 3.7 The deposition velocity for the airborne contaminants is assumed to be 0.001 m/s or 0.1 cm/s.

Rationale: This assumption is taken from DIRS 4 (p. 24) for mechanistic dose assessments associated with a repository design basis event.

Usage: This assumption is used in Section 5.5 to calculate the contamination source activity (Ci/cm²).

- 3.8 The contamination source is assumed to occur uniformly on the inside surface of the horizontal raise between the two exhaust mains, based on the ground contamination model.

Rationale: Gravitational deposition is a major contributor to the ground contamination source. Gravitational settling tends to be on the horizontal surface such as the horizontal raise rather than on the vertical surface such as the ventilation raise. To account for potential contamination on the ventilation raise, the entire surface of the horizontal raise (both upper and lower of the cylindrical surface of the duct) is assumed to be contaminated with the same activity level.

Usage: This assumption is used in Section 5.7 to calculate the dose rates due to the contamination source.

- 3.9 The subsurface ventilation rate to an emplacement drift is 5 m³/s.

Rationale: EDA II requires that the ventilation system shall be designed to remove at least 70% of the heat generated by the waste packages during preclosure (DIRS 3, Enclosure 2, p. 3). DIRS 3 refers to the license application design selection (LADS) report for the rationale for this requirement. The LADS report considered three

ventilation rates of 2, 5 and 10 m³/s for EDA II, and determined that the rate of 5 m³/s would meet the repository thermal goals. It should be recognized that the Repository Subsurface Design Department has issued a Technical Change Request (TCR No. T1999-0095) in association with the *Technical Development Plan for Emplacement Ventilation System* (DI: TDP-SVS-HV-000005 REV 00) (MOL.19990810.0473) to validate and update the ventilation design for EDA II, which may result in selection of a different ventilation rate.

Usage: This assumption is used in Section 5.4 to calculate the airborne source concentrations.

- 3.10 The outer diameter of the horizontal raise connecting the two exhaust mains is 2 m.

Rationale: This diameter is the same as for the ventilation raise.

Usage: This assumption is used in Sections 5.6 and 5.7 for the PATH models.

4. USE OF COMPUTER SOFTWARE AND MODELS

4.1 SOFTWARE APPROVED FOR QUALITY ASSURANCE WORK

As stated in Section 2, this calculation uses the PATH code (Version 88A, Software Tracking Number: 30007 V88A). PATH has been fully qualified and baselined on the PC platform (DIRS 6). The computer hardware used in this calculation is a DELL PowerEdge 2200 desktop personal computer (CRWMS-M&O Tag Number 112106). This computer has been qualified to perform execution of the PATH software used in this calculation.

The qualified version of the PATH code was obtained from Software Configuration Management. The PATH computer software used in this calculation was appropriate per the capabilities and applications of the code, and was used within the range of validation in the software qualification report.

The PATH input and output file names from this calculation are listed in Attachment I, along with a complete listing of the input files. All the PATH input and output files are stored on an electronic medium (DIRS 7).

4.2 SOFTWARE ROUTINES

In addition to the software described in Section 4.1, computational support software was used for spreadsheets. The spreadsheets were performed, using Microsoft Excel 97. The user-defined formulas and algorithms for the spreadsheets are described in Sections 5.4 and 5.5. The spreadsheet calculations with Excel 97 give correct results, as verified by example hand calculations illustrated in Sections 5.4 and 5.5.

In addition, the Characteristics Data Base (CDB) software (DIRS 1) was used in this calculation to generate the radiation source terms. As stated in Section 2, the CDB is currently unqualified, and to be verified (TBV-455).

4.3 MODELS

No models validated in accordance with per AP-3.10Q were used in this calculation.

5. CALCULATION

5.1 INPUT PARAMETERS

This calculation uses inputs and references from Technical Data Management System (TDMS), Technical Information Center (TIC) and Document Control (DC) as provided on Document Input Reference Sheets (DIRS) in Attachment II. The calculation contains the TBV inputs including TBV-326, TBV-455, TBV-3243 and TBV-3271.

5.1.1 Fuel Type

Consistent with the previous subsurface shielding analyses for the 21 PWR waste package, the fuel type used in this calculation is the B&W 15x15 Mark B fuel assembly with a heavy metal loading of 0.464 MTU per assembly (DIRS 8, p.16) (TBV-326). This design input (0.464 MTU) is available in the TDMS as DTN: MO98WASTAN00011.000 and MO9905WHODANQ1.000.

5.1.2 Decay Heat

Per Assumption 3.2, the WP thermal design basis is 11.8 kW/WP for EDA II (DIRS 3, Enclosure 2, p. 3). With 0.464 MTU per assembly, this heat output equals 1211 watts/MTU.

5.1.3 Fuel Parameters

Based on the mid-range fuel specifications determined in DIRS 2 (p. 29), the fuel parameters used in this calculation are 3.5% initial enrichment, 35000 MWd/MTU and 10 years cooling time (TBV-3243). The fuel burnup is rounded up to 35000 MWd/MTU from 34400 MWd/MTU in DIRS 2 (p. 29) for added conservatism. These fuel parameters result in a heat output of 1239 watts/MTU, which is slightly greater than the WP thermal design basis of 1211 watts/MTU given in Section 5.1.2. Therefore, the selected fuel parameters are conservative.

5.1.4 Isotopic Inventory

With the fuel parameters of 3.5% initial enrichment, 35000 MWd/MTU and 10 years cooling, the isotopic inventory was obtained from the CDB (DIRS 1) in units of Ci/MTU by isotope for PWR SNF. The Ci/MTU values as presented in Table 5-1 is used in Section 5.4 for conversion to Ci/WP using 0.464 MTU per fuel assembly (Section 5.1.1) and 21 fuel assemblies per waste package (Assumption 3.1). Note that the isotopic data sensitivity level in Table 5-1 is 0.01%; i.e., the list includes all isotopes contributing at least 0.01% of the total inventory in Ci.

5.1.5 Radionuclide Release Fractions

Radionuclide release fractions for a breached waste package under abnormal conditions are consistent with those used in the related Design Basis Event (DBE) analysis (DIRS 4, p. 15). Table 5-2 lists the release fractions, based on the specifications provided in DIRS 9 (p. 7-6) and Assumption 3.4. These parameters are used in Sections 5.3, 5.4 and 5.5 to derive the airborne and surface contamination sources for abnormal conditions.

Table 5-1. PWR SNF Isotopic Inventory from CDB
(Direct Printout from CDB)

LWR Radiological DATABASE

CURIES BY ISOTOPE

REACTOR TYPE & BURNUP: PWR 35000 MWd/MTU

ENRICHMENT: 3.50%

DECAY TIME: 10 YEARS

DATA SENSITIVITY: 0.01%

ISOTOPE	CURIES/MTU	%TOTAL
=====		
H 3	4.701E+02	0.11%
FE 55	2.293E+02	0.06%
CO 60	2.373E+03	0.57%
NI 63	4.038E+02	0.10%
KR 85	5.110E+03	1.23%
SR 90	6.080E+04	14.68%
Y 90	6.082E+04	14.68%
RU106	5.232E+02	0.13%
RH106	5.232E+02	0.13%
SB125	1.295E+03	0.31%
TE125M	3.161E+02	0.08%
CS134	5.869E+03	1.42%
CS137	8.649E+04	20.88%
BA137M	8.184E+04	19.76%
CE144	1.408E+02	0.03%
PR144	1.408E+02	0.03%
PM147	9.229E+03	2.23%
SM151	3.939E+02	0.10%
EU154	4.421E+03	1.07%
EU155	1.619E+03	0.39%
PU238	2.896E+03	0.70%
PU239	3.587E+02	0.09%
PU240	5.105E+02	0.12%
PU241	8.327E+04	20.10%
AM241	1.857E+03	0.45%
CM244	1.661E+03	0.40%
TOTAL	*4.136E+05	99.85%*

*This value was obtained by interpolating TOTALS values from ORIGEN2 runs to the specific burnup/enrichment/decay time combination specified. Percentages have been calculated from this interpolated value and may not add up to 100 percent in all cases.

Table 5-2. Radionuclide Release Fractions

Species	Release Fraction
Tritium	0.30
Noble gas	0.30
Iodine	0.10
Cesium	2.3E-05
Strontium	2.3E-05
Ruthenium	1.5E-05
Particulates	2.3E-05 ^a
Crud (Co-60)	0.15

^a This category is not explicitly listed in NUREG-1536 (DIRS 9, p. 7-6), but adapted herein for consistency with the bounding release fraction for other solid radionuclides.

5.1.6 Other Parameters

Emplacement drift ventilation rate = $5 \text{ m}^3/\text{s}$ (Assumption 3.9)
Release duration = 2 hours (Assumption 3.5)
Radionuclide deposition velocity = 0.001 m/s (Assumption 3.7)
Exhaust main diameter = 7.62 m (DIRS 11, p. 79; TBV-3271)
Ventilation raise diameter = 2 m (DIRS 11, p. 79; TBV-3271)
Ventilation raise length = 10 m (DIRS 11, p. 79)
Horizontal raise diameter = 2 m (Assumption 3.10)
TSw2 (Topopah Spring welded unit) dry bulk density = 2.22 g/cm^3 (DIRS 13, p. 27)
A516 carbon steel density = 7.832 g/cm^3 (DIRS 13, p. 6)
Air density = 0.001225 g/cm^3 (DIRS 13, p. 26)

5.2 RADIONUCLIDE SCREENING

For external radiation dose calculations, only the gamma-emitting radionuclides need to be considered. The radionuclide list in Table 5-1 was first screened to eliminate beta and alpha emitters. Additional screening was then made to delete the gamma emitters, which would be of little consequence, because of weak energy emission or insignificant activity. Table 5-3 describes the rationale for retaining or removing a given radionuclide, based on Kocher's Radioactive Decay Data Tables (DIRS 10).

5.3 CRUD INVENTORY CALCULATION

The crud inventory for the 21 PWR waste package has been calculated and documented in DIRS 12 (p. 48). The calculation is reproduced here for completeness. Note that the half life for Co-60 used in this calculation is 5.271 years for consistency with the data in DIRS 10.

The upper-bound crud activity for PWR fuel is $140 \text{ } \mu\text{Ci/cm}^2$ of Co-60 on fuel rods, based on NUREG-1536 (DIRS 9, p. 7-6). This activity corresponds to the time at fuel discharge. For a cooling or decay time of 10 years, the Co-60 crud activity is $(140 \text{ } \mu\text{Ci/cm}^2)/2^{(10/5.271)} = 37.586 \text{ } \mu\text{Ci/cm}^2$. The factor of $2^{(10/5.271)}$ represents the decay of Co-60 with a half life of 5.271 years (DIRS 10, p. 78) for a period of 10 years. The crud inventory in the 21 PWR waste package is calculated as follows:

Fuel assembly (FA) type:	B&W 15x15 Mark B
No. of fuel rods/FA:	208 (DIRS 1, p. 2A-7)
Fuel rod outer diameter:	10.922 mm (0.43") (DIRS 1, p. 2A-7)
Fuel rod length:	3903.5 mm (153.68") (DIRS 1, p. 2A-7)
Crud surface area/rod:	$\pi(10.922)(3903.5) \text{ mm}^2 = 1.339 \times 10^5 \text{ mm}^2 = 1339 \text{ cm}^2$
Crud surface area/FA:	$(1339 \text{ cm}^2)(208) = 2.785 \times 10^5 \text{ cm}^2$
Crud surface area/WP:	$(2.785 \times 10^5 \text{ cm}^2)(21) = 5.85 \times 10^6 \text{ cm}^2$
Co-60 crud inventory/WP:	$(37.586 \text{ } \mu\text{Ci/cm}^2)(5.85 \times 10^6 \text{ cm}^2) = 220 \times 10^6 \text{ } \mu\text{Ci} = 220 \text{ Ci}$

Table 5-3. Radionuclide Screening

Isotope	Retention	Rationale ^a
H-3	No	Beta emitter
Fe-55	No	Beta emitter
Co-60	Yes	Gamma emitter
Ni-63	No	Beta emitter
Kr-85	Yes	Gamma emitter
Sr-90	No	Beta emitter
Y-90	No	Beta emitter
Ru-106	No	Beta emitter
Rh-106	Yes	Gamma emitter, daughter of Ru-106
Sb-125	Yes	Gamma emitter
Te-125m	No	Weak photons, low activity
Cs-134	Yes	Gamma emitter
Cs-137	No	Beta emitter
Ba-137m	Yes	Gamma emitter, daughter of Cs-137
Ce-144	No	Beta emitter, weak photons
Pr-144	Yes	Gamma emitter, daughter of Ce-144
Pm-147	No	Beta emitter
Sm-151	No	Beta emitter, weak photons, low activity
Eu-154	Yes	Gamma emitter
Eu-155	No	Beta emitter, weak photons, low activity
Pu-238	No	Alpha emitter, weak photons, low activity
Pu-239	No	Alpha emitter, weak photons, low activity
Pu-240	No	Alpha emitter, weak photons, low activity
Pu-241	No	Beta emitter, decay to Am-241
Am-241	No	Alpha emitter, weak photons, low activity
Cm-244	No	Alpha emitter, weak photons, low activity

^a Based on Kocher's Radioactive Decay Data Tables (DIRS 10)

5.4 AIRBORNE SOURCE CALCULATION

The airborne source concentration following a waste package leak in an emplacement drift was calculated as follows:

$$A_i = (C_i \times f_i) / (T_d \times F) \quad (\text{Eq. 5-1})$$

where A_i = airborne source concentration for isotope i (Ci/cm^3)

C_i = inventory in waste package for isotope i (Ci)

f_i = release fraction for isotope i

T_d = duration of release (seconds)

F = emplacement drift ventilation flow rate (cm^3/s)

The duration of release is 2 hours or 7200 seconds, per Assumption 3.5. The subsurface ventilation rate selected for the license application design is $5 \text{ m}^3/\text{s}$ or $5 \times 10^6 \text{ cm}^3/\text{s}$, per Assumption 3.9. The number of PWR fuel assemblies per waste package is 21, as given in Assumption 3.1. A single waste package failure is assumed (Assumption 3.3).

Eq. 5-1 provides an estimate of the airborne source concentration, with no removal of contaminants from the air stream considered. In other words, all the contaminants remain airborne.

The calculation was performed with Microsoft Excel 97 for each isotope selected in Table 5-3. The results are given in Table 5-4. An example calculation is given below for Kr-85:

Kr-85 activity = 5110 Ci/MTU (Table 5-1)

Kr-85 inventory = $(5110 \text{ Ci/MTU})(0.464 \text{ MTU/FA})(21 \text{ FAs}) = 4.979 \times 10^4 \text{ Ci/WP}$

Kr-85 release = $(4.979 \times 10^4 \text{ Ci/WP})(0.3) = 1.494 \times 10^4 \text{ Ci/WP}$

Kr-85 concentration = $(1.494 \times 10^4 \text{ Ci/WP} \times 1 \text{ WP}) / (7200 \text{ sec} \times 5 \times 10^6 \text{ cm}^3/\text{sec})$
 $= 4.149 \times 10^{-7} \text{ Ci}/\text{cm}^3$

5.5 CONTAMINATION SOURCE CALCULATION

Based on Assumption 3.8, the ground surface contamination model was used to calculate the contamination level on the inside surface of the horizontal raise between the two exhaust mains. The vertical ventilation raise is also subject to surface contamination. However, radionuclides tend to deposit on the horizontal (or ground) rather than vertical surface, especially with gravitational settling. Accordingly, surface contamination is most significant on the lower half surface of the horizontal raise between the two exhaust mains.

For this calculation, the upper half surface of the horizontal raise is also assumed to be contaminated with the same level as the lower surface (Assumption 3.8). This assumption is used to account for potential contamination on the surfaces of other areas such as the ventilation raise.

Table 5-4. Airborne and Contamination Source Terms

Isotope	Inventory (Ci/MTU) ^a	Inventory (Ci/WP) ^b	Release Fraction ^c	Release (Ci/WP) ^d	Airborne Source ^e		Contamination Source ^f	
					Ci/cm ³	μCi/cm ³	Ci/cm ²	μCi/cm ²
Fuel								
Co-60 ^g	2.373E+03	2.312E+04	2.3E-05	5.318E-01	1.477E-11	1.477E-05	1.064E-08	1.064E-02
Kr-85	5.110E+03	4.979E+04	3.0E-01	1.494E+04	4.149E-07	4.149E-01	0.000E+00	0.000E+00
Rh-106	5.232E+02	5.098E+03	1.5E-05	7.647E-02	2.124E-12	2.124E-06	1.529E-09	1.529E-03
Sb-125	1.295E+03	1.262E+04	2.3E-05	2.902E-01	8.062E-12	8.062E-06	5.805E-09	5.805E-03
Cs-134	5.869E+03	5.719E+04	2.3E-05	1.315E+00	3.654E-11	3.654E-05	2.631E-08	2.631E-02
Ba-137m	8.184E+04	7.974E+05	2.3E-05	1.834E+01	5.095E-10	5.095E-04	3.668E-07	3.668E-01
Pr-144	1.408E+02	1.372E+03	2.3E-05	3.155E-02	8.765E-13	8.765E-07	6.311E-10	6.311E-04
Eu-154	4.421E+03	4.308E+04	2.3E-05	9.908E-01	2.752E-11	2.752E-05	1.982E-08	1.982E-02
Crud								
Co-60 ^g	N/A	2.200E+02	1.5E-01	3.300E+01	9.167E-10	9.167E-04	6.600E-07	6.600E-01

^a From Table 5-1^b Inventory (Ci/WP) = (Ci/MTU)(0.464 MTU/FA)(21 FAs)^c From Table 5-2^d Release (Ci/WP) = (Inventory Ci/WP)(release fraction)^e Eq. 5-1^f Eq. 5-2^g Combined for input into PATH

Determination of the contamination source due to radioactive material deposits along the flow path requires considerations of various airborne contaminant transport mechanisms. These mechanisms include molecular diffusion, gravitational settling, absorption, resuspension and so forth. A crude approximation was used in this calculation to provide an estimate of the contamination source terms for assessment of personnel accessibility to the service exhaust main. The approximation ignored effects of turbulence and flow geometry factors.

The contamination source term for isotope i is calculated with the following equation:

$$S_i = A_i \times V_d \times T_d \quad (\text{Eq. 5-2})$$

where S_i = surface contamination activity (Ci/cm^2)

A_i = airborne source concentration from Eq. 5-1 in Section 5.4 (Ci/cm^3)

V_d = deposition velocity (cm/sec)

T_d = deposition time interval (seconds)

With A_i from Eq. 5-1, Eq. 5-2 becomes $S_i = (C_i \times f_i \times V_d)/F$, which is independent of T_d as stated in Assumption 3.5.

The deposition velocity is given in Assumption 3.7 as 0.001 m/s or 0.1 cm/s. The deposition time interval is 2 hours or 7200 seconds (Assumption 3.5), consistent with the release duration used in Section 5.4.

Spreadsheet calculations were performed with Microsoft Excel 97 by isotope. The results are provided in Table 5-4. An example calculation is shown below:

$$\begin{aligned} \text{Co-60 crud airborne concentration} &= 9.167 \times 10^{-10} \text{ Ci}/\text{cm}^3 \text{ (Section 5.4, Table 5-4)} \\ \text{Co-60 crud contamination activity} &= (9.167 \times 10^{-10} \text{ Ci}/\text{cm}^3)(0.1 \text{ cm/s})(7200 \text{ s}) \\ &= 6.60 \times 10^{-7} \text{ Ci}/\text{cm}^2 \end{aligned}$$

5.6 DOSE RATE CALCULATION FOR AIRBORNE SOURCE

The dose rates from the airborne source were calculated with the PATH code at two dose points. The PATH model used Assumption 3.10. As shown in Figure 5-1, Dose Point 1 (DP1) is located at the center of the service exhaust main, which is near the worker elevation. Dose Point 2 (DP2) is on the ventilation raise centerline directly beneath the horizontal raise. Since DP2 is on the surface of the horizontal raise, which is close to the source, the accuracy of the calculation at this point is subject to the $(1/R^2)$ effect used in the point-kernel integration method for the PATH code. Note that R is the distance from the source point to the dose point.

The airborne source was modeled in two regions: the ventilation raise between the emplacement drift and service exhaust main, and the horizontal raise between two exhaust mains. The section of the horizontal raise considered in the model was extended to 10 m from the center of the service exhaust main, as shown in Figure 5-1. The contribution beyond this section should be completely negligible, because of the distance factor plus attenuation by the host rock (TSw2).

Figure 5-1. PATH Model for Airborne and Contamination Dose Rate Calculations

The airborne source terms were taken from Table 5-4, and input into the PATH code by isotope in units of Ci/cm³. The source input for Co-60 includes the activity from fuel and crud. Uniform spatial source distribution was assumed in the ventilation raise and horizontal raise (Assumption 3.6).

Parametric calculations were made for three different duct wall thicknesses: 0 mm, 12.7 mm (0.5") and 25.4 mm (1") using A516 carbon steel. The unshielded case (i.e., 0 mm duct wall thickness) used nitrogen (for air) for the dose buildup factors. The shielded cases (12.7 and 25.4 mm duct wall) used the buildup factors for iron.

The PATH input and output file names are listed in Table 5-5. The entire computer files for the PATH calculations are stored on an electronic medium (DIRS 7)

5.7 DOSE RATE CALCULATION FOR CONTAMINATION SOURCE

Per Assumption 3.8, the contamination source was assumed to be present on the cylindrical surface of the horizontal raise only. The contamination surface model extended from the end in the service exhaust main to 10 m from the center of the service exhaust main, as illustrated in Figure 5-1. The section of the horizontal raise used in this model was consistent with that for the airborne source model. The model included Assumption 3.10.

The dose rates from the contamination source were also calculated with the PATH code at DP1 and DP2 as for the airborne source. Again, the results at DP2 are sensitive to the $1/R^2$ factor, or source spatial meshing used in the PATH code, because of close proximity of DP2 to the source. Accuracy at DP2 could be improved with a more sophisticated shielding code such as MCNP.

The contamination source was modeled as a cylindrical shell source on the inside surface of the horizontal raise. Since the PATH code is unable to treat any cutout for a cylindrical surface source, the model included an extra area on the bottom of the ventilation raise. This inclusion would over-predict the results somewhat, but would be within the calculational uncertainties associated with the point-kernel integration technique used in the PATH code.

The contamination source terms were obtained from Table 5-4, and input to the PATH code in units of Ci/cm². The source input for Co-60 includes the activity from fuel and crud. The contamination source was uniformly distributed on the surface of the horizontal raise, according to Assumption 3.8.

The dose rates due to the contamination source was also determined in a parametric manner for the duct wall thicknesses of 0, 12.7 and 25.4 mm, respectively. The medium used for the dose buildup factors was the same as for the airborne source calculation depending on the case (unshielded or shielded).

Table 5-5 lists the PATH input and output file names for the contamination source calculation. The PATH input and output files are stored on an electronic medium (DIRS 7).

Table 5-5. PATH Input and Output Files

Source	Duct Wall Thickness (mm)	Input File	Output File
Airborne Source	0	EXHST1A.INP	EXHST1A.OUT
	12.7	EXHST2A.INP	EXHST2A.OUT
	25.4	EXHST3A.INP	EXHST3A.OUT
Contamination Source	0	EXHST1B.INP	EXHST1B.OUT
	12.7	EXHST2B.INP	EXHST2B.OUT
	25.4	EXHST3B.INP	EXHST3B.OUT

6. RESULTS

The results of this calculation are based on the unqualified data or TBV inputs including TBV-326, TBV-455, TBV-3243, and TBV-3271. Therefore, the calculation contains information and assumptions that must be confirmed prior to the use of the results of the calculation.

6.1 DOSE RESULTS FOR AIRBORNE SOURCE

The PATH-calculated dose rates from the airborne source are presented in Table 6-1 for the three duct wall thicknesses considered. The results at DP1 are also plotted in Figure 6-1 as a function of duct wall thickness. DP1 represents a location for occasional workers standing in the service exhaust main directly beneath the ventilation raise; and DP2 is on the surface of the ventilation duct where work might be performed in contact with the duct.

The dose rate results in Table 6-1 represent the transient exposures to workers in the service exhaust main due to the passage of airborne radioactive material through the ventilation raise and horizontal raise. The workers will be subject to this transient condition over the duration of radionuclide releases.

With the assumption of a 2-hour release duration (Assumption 3.5), the time-integrated dose at the center of the service exhaust main (DP1) would be about 4 mrem ($2.05 \text{ mrem/hr} \times 2 \text{ hr}$) for a duct wall thickness of 25.4 mm. This exposure is small relative to the 10CFR20 annual allowance of 5000 mrem for occupational exposures. Even with zero duct wall thickness, the time-integrated dose at DP1 is only 9 mrem over 2 hours ($4.49 \text{ mrem/hr} \times 2 \text{ hr}$). This integrated exposure is realized only when the worker ignores radiation alarm and remains in this location directly beneath the ventilation raise for the entire release duration. Actual dose to the worker will be greatly reduced by leaving the ventilation ducting area upon detection of waste package leakage and activation of radiation alarm.

It should be noted that the airborne source and resulting transient personnel exposure are sensitive to the radionuclide release fractions, ventilation rate and release duration. Increase in airflow to the emplacement drifts from $5 \text{ m}^3/\text{s}$ to $10 \text{ m}^3/\text{s}$ currently under consideration for the subsurface ventilation system design will provide more dilution of the airborne source concentration, resulting in a reduction in radiation exposure to the worker by a factor of 2.

6.2 DOSE RESULTS FOR CONTAMINATION SOURCE

The PATH-calculated dose rates from the contamination source are presented in Table 6-2 for the three duct wall thicknesses considered. The results at DP1 are also plotted in Figure 6-1 as a function of duct wall thickness.

The results in Table 6-2 represent the potential exposures to maintenance workers in the service exhaust main from residual radioactive material deposited inside of the ventilation raise and horizontal raise. The radiation dose rates in the service exhaust main due to the contamination source are higher than those due to the airborne source. Repository workers could be subject to these exposure rates while working in the service exhaust main directly beneath the ventilation

duct. Workers could avoid excessive or unnecessary exposures by observing local radiation alarm when activated, and leaving the area.

With a moderate duct wall thickness (12.7 mm or 25.4 mm), the dose rate due to the contamination source is less than 100 mrem/hr even at contact with the ventilation duct (see Table 6-2). Therefore, the service exhaust main will be in a "radiation area" as defined in 10CFR20.1003 rather than a "high radiation area".

It needs to be stressed that the dose rates due to the contamination source were calculated with certain assumptions and a simplified approach to provide preliminary estimates only. The results are highly sensitive to the assumptions and input parameters used. The calculation will be subject to revision after completion of the subsurface airborne contaminant transport analysis.

6.3 PRINCIPAL RADIONUCLIDE CONTRIBUTORS

Table 6-3 provides the percent contribution by isotope to the dose rate at the center of the service exhaust main (DP1). The percent contribution by isotope at DP2 is similar to that at DP1, since there is no intervening shielding between the two dose points.

For the airborne source, the principal contributors are Co-60 (from crud) and Kr-85. Co-60 from crud is also a dominant contributor for the contamination source. As specified in Section 5.1.3, the age (or cooling time) of SNF is 10 years. DIRS 3 (Enclosure 2, p. 5) indicates that the average age of commercial SNF will be 26 years. Additional decay of Co-60 from 10 years to 26 years would reduce the resulting dose rates from both airborne and contamination sources considerably.

The percent contribution values are useful for deriving the dose factor on a per-unit-source basis. For example, the dose rate at DP1 due to the airborne source for 0 mm duct wall is 4.49 mrem/hr (Table 6-1) with 28.03% contribution from Kr-85 (Table 6-3). The dose rate from Kr-85 is $(4.49 \text{ mrem/hr})(0.2803) = 1.26 \text{ mrem/hr}$. With $4.149 \times 10^{-7} \text{ Ci/cm}^3$ of Kr-85 in the airborne source (Table 5-4), the dose factor per unit source for Kr-85 is $(1.26 \text{ mrem/hr}) / (4.149 \times 10^{-7} \text{ Ci/cm}^3) = 3.03 \times 10^6 \text{ (mrem/hr)/(Ci/cm}^3\text{)}$ or $3.03 \text{ (mrem/hr)/(\mu Ci/cm}^3\text{)}$.

Table 6-1. Dose Rates from Airborne Source

Duct Wall Thickness	Dose Rate (mrem/hr)		Input File	Output File
	DP1 ^a	DP2 ^b		
0 mm (0")	4.49	21.54	EXHST1A.INP	EXHST1A.OUT
12.7 mm (0.5")	3.19	12.73	EXHST2A.INP	EXHST2A.OUT
25.4 mm (1")	2.05	7.44	EXHST3A.INP	EXHST3A.OUT

^a DP1 (Dose Point 1) is at the center of the service exhaust main

^b DP2 (Dose Point 2) is on the outside surface of the horizontal raise on the ventilation raise centerline

Table 6-2. Dose Rates from Contamination Source

Duct Wall Thickness	Dose Rate (mrem/hr)		Input File	Output File
	DP1	DP2		
0 mm (0")	33.88	316.7	EXHST1B.INP	EXHST1B.OUT
12.7 mm (0.5")	19.44	75.02	EXHST2B.INP	EXHST2B.OUT
25.4 mm (1")	11.43	43.93	EXHST3B.INP	EXHST3B.OUT

Table 6-3. Radionuclide Contributors to Dose Rates (DP1)

Dose Rate/ Isotopic Contribution	Airborne Source			Contamination source		
	0 mm	12.7 mm	25.4 mm	0 mm	12.7 mm	25.4 mm
mrem/hr	4.49	3.19	2.05	33.88	19.44	11.43
% Contribution						
Co-60	61.07	63.10	66.73	84.88	86.53	88.32
Kr-85	28.03	26.55	23.82	0.00	0.00	0.00
Rh-106	0.01	0.01	0.01	0.02	0.02	0.01
Sb-125	0.10	0.09	0.07	0.14	0.11	0.09
Cs-134	1.63	1.58	1.49	2.27	2.08	1.87
Ba-137m	8.25	7.79	6.99	11.45	10.08	8.57
Eu-154	0.90	0.87	0.88	1.25	1.18	1.15

Figure 6-1. Gamma Dose Rate at the Center of the Service Exhaust Main (DP1)

7. ATTACHMENTS

There are two attachments to this calculation as described below:

Attachment I List of PATH Input and Output Files (7 pages)

Attachment II Document Input Reference Sheets (6 pages)

ATTACHMENT I

LIST OF PATH INPUT AND OUTPUT FILES

This attachment lists the input and output file names for the PATH calculations in support of the *Exhaust Main Personnel Exposure Calculation*. In addition, a complete listing of the input files is provided in this attachment. Table 5-5 provides a brief description of these files. DIRS 7 stores all the input and output files on an electronic medium.

I.1 FILE LIST

Volume in drive D is DELLWIN95-2
Volume Serial Number is 1BE3-2E60
Directory of D:\pcpath

<u>File</u>	<u>Size (bytes)</u>	<u>Date</u>	<u>Time</u>	<u>File Name</u>
EXHST2A INP	1,716	09-22-99	10:01a	EXHST2A.INP
EXHST1A INP	1,507	09-22-99	10:01a	EXHST1A.INP
EXHST3A INP	1,716	09-22-99	10:02a	EXHST3A.INP
EXHST1B INP	1,307	09-22-99	10:03a	EXHST1B.INP
EXHST2B INP	1,516	09-22-99	10:03a	EXHST2B.INP
EXHST3B INP	1,516	09-22-99	10:04a	EXHST3B.INP
EXHST1A OUT	21,123	09-22-99	10:05a	EXHST1A.OUT
EXHST2A OUT	22,097	09-22-99	10:05a	EXHST2A.OUT
EXHST3A OUT	22,119	09-22-99	10:06a	EXHST3A.OUT
EXHST1B OUT	15,028	09-22-99	10:06a	EXHST1B.OUT
EXHST2B OUT	15,936	09-22-99	10:07a	EXHST2B.OUT
EXHST3B OUT	15,848	09-22-99	10:07a	EXHST3B.OUT
12 file(s)	121,429 bytes			

I.2 LISTING OF INPUT FILE EXHST1A.INP

GAMMA DOSE RATE IN SERVICE EXHAUST MAIN
 EDA II VENTILATION SYSTEM DESIGN
 SINGLE WP LEAK
 AIRBORNE SOURCE IN VENTILATION RAISE AND HORIZONTAL RAISE
 ZERO INCH (0.0 MM) STEEL DUCT
 S. SU AUGUST 1999

CM	ATTN	BLD	MEV	MFP	PATH	NOSP			
									8.0
1.0		1.0		AIR		0.001225	1.0		
2.0		1.0		FE		7.832	1.0		
3.0		1.0		CONC		2.22	1.0		
1.0	SPH	3.0		10000.0					
2.0	CYL	1.0		381.0	-1000.0	0.0		0.0	
1000.0		0.0		0.0					
3.0	CYL	1.0		100.0	0.0	0.0		270.0	
0.0		0.0		1370.0					
4.0	CYL	1.0		100.0	0.0	-100.0		270.0	
0.0		1000.0		270.0					
1.0	2.0	3.0	4.0						
1.0	RAZ	1000.0		RAD	10.0	HT	99.0	ANG	1.0
3.0	CYL	1.0		100.0		0.0		0.0	270.0
0.0		0.0		1370.0					
1.0	ISO	CO60		9.315E-10	KR85			4.419E-07	
1.0	ISO	RH106		2.124E-12	SB125			8.062E-12	
1.0	ISO	CS134		3.654E-11	BA137M			5.095E-10	
1.0	ISO	PR144		8.765E-13	EU154			2.752E-11	
2.0	RAZ	3000.0		RAD	10.0	HT	30.0	ANG	10.0
4.0	CYL	1.0		100.0		0.0		-100.0	270.0
0.0		1000.0		270.0					
1.0		0.0		0.0		0.0			
1.0		7.0	2.0	ALL					
2.0		0.0		0.0		170.0			
2.0		7.0	2.0	ALL					

GAMMA DOSE RATE IN SERVICE EXHAUST MAIN
EDA II VENTILATION SYSTEM DESIGN
SINGLE WP LEAK
AIRBORNE SOURCE IN VENTILATION RAISE AND HORIZONTAL RAISE
0.5 INCH (1.27 CM) STEEL DUCT
S. SU AUGUST 1999

September 1999

I.4 LISTING OF INPUT FILE EXHST3A.INP

GAMMA DOSE RATE IN SERVICE EXHAUST MAIN
 EDA II VENTILATION SYSTEM DESIGN
 SINGLE WP LEAK
 AIRBORNE SOURCE IN VENTILATION RAISE AND HORIZONTAL RAISE
 1.0 INCH (2.54 CM) STEEL DUCT
 S. SU AUGUST 1999

CM	ATTN	BLD	MEV	MFP	PATH	NOSP				8.0
1.0		1.0		AIR		0.001225	1.0			
2.0		1.0		FE		7.832	1.0			
3.0		1.0		CONC		2.22	1.0			
1.0	SPH	3.0		10000.0						
2.0	CYL	1.0		381.0	-1000.0	0.0	0.0			
1000.0		0.0		0.0						
3.0	CYL	1.0		97.46	0.0	0.0	270.0			
0.0		0.0		1370.0						
4.0	CYL	1.0		97.46	0.0	-100.0	270.0			
0.0		1000.0		270.0						
5.0	CYL	2.0		100.0	0.0	0.0	270.0			
0.0		0.0		1370.0						
6.0	CYL	2.0		100.0	0.0	-100.0	270.0			
0.0		1000.0		270.0						
1.0	2.0	5.0	6.0	3.0	4.0					
1.0	RAZ	1000.0		RAD	10.0	HT	99.0	ANG	1.0	
3.0	CYL	1.0		97.46	0.0		0.0		270.0	
0.0		0.0		1370.0						
1.0	ISO	CO60		9.315E-10	KR85			4.419E-07		
1.0	ISO	RH106		2.124E-12	SB125			8.062E-12		
1.0	ISO	CS134		3.654E-11	BA137M			5.095E-10		
1.0	ISO	PR144		8.765E-13	EU154			2.752E-11		
2.0	RAZ	3000.0		RAD	10.0	HT	30.0	ANG	10.0	
4.0	CYL	1.0		97.46	0.0		-100.0		270.0	
0.0		1000.0		270.0						
1.0		0.0		0.0		0.0				
1.0		26.0	2.0	ALL						
2.0		0.0		0.0		170.0				
2.0		26.0	2.0	ALL						

I.5 LISTING OF INPUT FILE EXHST1B.INP

GAMMA DOSE RATE IN SERVICE EXHAUST MAIN
 EDA II VENTILATION SYSTEM DESIGN
 SINGLE WP LEAK
 CONTAMINATION SOURCE IN HORIZONTAL RAISE ONLY
 ZERO INCH (0.0 MM) STEEL DUCT
 S. SU AUGUST 1999

CM	ATTN	BLD	MEV	MFP	PATH	NOSP	
							8.0
1.0		1.0		AIR		0.001225	1.0
2.0		1.0		FE		7.832	1.0
3.0		1.0		CONC		2.22	1.0
1.0	SPH	3.0		10000.0			
2.0	CYL	1.0		381.0	-1000.0	0.0	0.0
1000.0		0.0		0.0			
3.0	CYL	1.0		100.0	0.0	0.0	270.0
0.0		0.0		1370.0			
4.0	CYL	1.0		100.0	0.0	-100.0	270.0
0.0		1000.0		270.0			
1.0	2.0	3.0	4.0				
1.0	SHEL	4000.0		HT	99.0	ANG	40.0
100.0		100.0		0.0		-100.0	270.0
0.0		1000.0		270.0			
1.0	ISO	CO60		6.706E-07	KR85		0.0
1.0	ISO	RH106		1.529E-09	SB125		5.805E-09
1.0	ISO	CS134		2.631E-08	BA137M		3.668E-07
1.0	ISO	PR144		6.311E-10	EU154		1.982E-08
1.0		0.0		0.0		0.0	
1.0		7.0	2.0	ALL			
2.0		0.0		0.0		170.0	
2.0		7.0	2.0	ALL			

I.6 LISTING OF INPUT FILE EXHST2B.INP

GAMMA DOSE RATE IN SERVICE EXHAUST MAIN
 EDA II VENTILATION SYSTEM DESIGN
 SINGLE WP LEAK
 CONTAMINATION SOURCE IN HORIZONTAL RAISE ONLY
 0.5 INCH (1.27 CM) STEEL DUCT
 S. SU AUGUST 1999

CM	ATTN	BLD	MEV	MFP	PATH	NOSP	
							8.0
1.0		1.0		AIR		0.001225	1.0
2.0		1.0		FE		7.832	1.0
3.0		1.0		CONC		2.22	1.0
1.0	SPH	3.0		10000.0			
2.0	CYL	1.0		381.0	-1000.0	0.0	0.0
1000.0		0.0		0.0			
3.0	CYL	1.0		98.73	0.0	0.0	270.0
0.0		0.0		1370.0			
4.0	CYL	1.0		98.73	0.0	-100.0	270.0
0.0		1000.0		270.0			
5.0	CYL	2.0		100.0	0.0	0.0	270.0
0.0		0.0		1370.0			
6.0	CYL	2.0		100.0	0.0	-100.0	270.0
0.0		1000.0		270.0			
1.0	2.0	5.0	6.0	3.0	4.0		
1.0	SHEL	4000.0		HT	99.0	ANG	40.0
98.73		98.73		0.0		-100.0	270.0
0.0		1000.0		270.0			
1.0	ISO	CO60		6.706E-07	KR85		0.0
1.0	ISO	RH106		1.529E-09	SB125		5.805E-09
1.0	ISO	CS134		2.631E-08	BA137M		3.668E-07
1.0	ISO	PR144		6.311E-10	EU154		1.982E-08
1.0		0.0		0.0		0.0	
1.0		26.0	2.0	ALL			
2.0		0.0		0.0		170.0	
2.0		26.0	2.0	ALL			

I.7 LISTING OF INPUT FILE EXHST3B.INP

GAMMA DOSE RATE IN SERVICE EXHAUST MAIN
 EDA II VENTILATION SYSTEM DESIGN
 SINGLE WP LEAK
 CONTAMINATION SOURCE IN HORIZONTAL RAISE ONLY
 1.0 INCH (2.54 CM) STEEL DUCT
 S. SU AUGUST 1999

CM	ATTN	BLD	MEV	MFP	PATH	NOSP	
							8.0
1.0		1.0		AIR		0.001225	1.0
2.0		1.0		FE		7.832	1.0
3.0		1.0		CONC		2.22	1.0
1.0	SPH	3.0		10000.0			
2.0	CYL	1.0		381.0	-1000.0	0.0	0.0
1000.0		0.0		0.0			
3.0	CYL	1.0		97.46	0.0	0.0	270.0
0.0		0.0		1370.0			
4.0	CYL	1.0		97.46	0.0	-100.0	270.0
0.0		1000.0		270.0			
5.0	CYL	2.0		100.0	0.0	0.0	270.0
0.0		0.0		1370.0			
6.0	CYL	2.0		100.0	0.0	-100.0	270.0
0.0		1000.0		270.0			
1.0	2.0	5.0	6.0	3.0	4.0		
1.0	SHEL	4000.0		HT	99.0	ANG 40.0	
97.46		97.46		0.0		-100.0	270.0
0.0		1000.0		270.0			
1.0	ISO	CO60		6.706E-07	KR85		0.0
1.0	ISO	RH106		1.529E-09	SB125		5.805E-09
1.0	ISO	CS134		2.631E-08	BA137M		3.668E-07
1.0	ISO	PR144		6.311E-10	EU154		1.982E-08
1.0		0.0		0.0		0.0	
1.0		26.0	2.0	ALL			
2.0		0.0		0.0		170.0	
2.0		26.0	2.0	ALL			

ATTACHMENT II
DOCUMENT INPUT REFERENCE SHEETS (DIRS)

This attachment contains the Document Input Reference Sheets (DIRS) for the inputs and references from the following sources:

Technical Data Management System (TDMS): Data sets with DTN
Technical Information Center (TIC): References with TIC catalog numbers
Document Control (DC): Approved project documents with accession numbers.

OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

DOCUMENT INPUT REFERENCE SHEET

1. Document Identifier No./Rev.:		Change:	Title:						
CAL-SVS-NU-000001/00		N/A	Exhaust Main Personnel Exposure Calculation						
			Page II-2 of II-6						
Input Document		4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To			
2. Technical Product Input Source Title and Identifier(s) with Version	3. Section					Unqual.	From Uncontrolled Source	Un-confirmed	
2a	Department of Energy 1992. <i>Characteristics of Potential Repository Wastes</i> . Vol. 1, 2, 3 and 4. DOE/RW-0184-R1. Washington, D.C.: U.S. Department of Energy, Office of Civilian Radioactive Waste management. ACC: HQO.19920827.0001; HQO.19920827.0002; HQO.19920827.0003; HQO.19920827.0004.	2.4	TBV-455	5.1.4	Spent fuel characteristics (CDB)	1	X		
1		App. A	TBV-455	5.3	Spent fuel characteristics (CDB)	1	X		
2	CRWMS M&O 1999. <i>Subsurface Shielding-specific Source Term Evaluation</i> . CAL-WER-NU-000001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990831.0053.	6.5	TBV-3243	5.1.3	PWR spent fuel parameters	1	X		
3	Wilkins, D. R. 1999. "Direction to Transition to Enhanced Design Alternative II." Letter from D. R. Wilkins (CRWMS M&O), June 15, 1999, with enclosure, "Enclosure 2 - Guidelines for Implementation of EDA II, Rev 02, 6/15/99". ACC: MOL.19990622.0126; MOL.19990622.0128.	Entire	N/A (Baselined input)	3.2 & 5.1.2 3.9	WP thermal load Ventilation rate	N/A	N/A		

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1. Document Identifier No./Rev.:		Change:		Title:					
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Input Document		3. Section	4. Input Status	5. Section Used in	6. Input Description	7. TBV/TBD Priority	8. TBV Due To		
2a	2. Technical Product Input Source Title and Identifier(s) with Version						Unqual.	From Uncontrolled Source	Un-confirmed
4	CRWMS M&O 1997. <i>DBE/Scenario Analysis for Preclosure Repository Subsurface Facilities</i> . BCA000000-01717-0200-00017 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980218.0237. Note: DBE analysis input based on NUREG-1536 as cited in DIRS 9.	4.1.4 4.3.3 4.3.12 3.	N/A (Accepted engr. practice)	3.4 & 5.1.5 3.5 3.7 3.3	Release fractions Release duration Deposition velocity Single WP failure	N/A	N/A		
5	Su, S. D.; Baylor, K. J.; and Engholm, B. A. 1987. <i>PATH Gamma Shielding Code User's Manual</i> . GA-A16772 (Rev. 1). San Diego, California: GA Technologies, Inc. TIC: 241215.	Entire	N/A (Reference)	2.	User's manual	N/A	N/A		
6	CRWMS M&O 1996. <i>Software Qualification Report for PATH/V88A - A Gamma Shielding Analysis Code</i> . CSCI:30007 V88A. DI: 30007-2003 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19970708.0143.	Entire	N/A (Reference)	4.1	Qualified engineering software	N/A	N/A		

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2. Technical Product Input Source Title and Identifier(s) with Version		3. Section					Unqual.	From Uncontrolled Source	Un-confirmed	
2a	CRWMS M&O 1999. <i>Computer Files for Exhaust Main Personnel Exposure Calculation, DI: CAL-SVS-NU-000001 REV 00.</i> Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19990922.0376.		Entire	N/A (Reference)	5.6 & 5.7	Computer input and output files	N/A	N/A		
7										
8	CRWMS M&O 1998. <i>Exhaust Drift Shielding Calculations.</i> BCAE00000-01717-0210-00001 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19980731.0057. Subsurface shielding design inputs also available in TDMS: DTN: MO98WASTAN00011.000 DTN: MO9905WHODANQ1.000		5.1.1	TBV-326	5.1.1	Shielding input - fuel type	1	X		
9	U. S. Nuclear Regulatory Commission 1997. <i>Standard Review Plan for Dry Cask Storage Systems.</i> NUREG-1536, Final Report. Washington, D.C.: U.S. Nuclear Regulatory Commission. TIC: 232373.		7.0 7.0	N/A (Accepted engr. practice)	5.1.5	Release fractions PWR crud activity	N/A N/A	N/A N/A		

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2. Technical Product Input Source Title and Identifier(s) with Version	3. Section					Unqual.	From Uncontrolled Source	Un-confirmed	
2a	Kocher, D. C. 1981. <i>Radioactive Decay Data Tables</i> . DOE/TIC-11026. Washington DC: U.S. Department of Energy. TIC: 228074.	Entire	N/A	5.2	Radioactive decay data	N/A	N/A		
10			(Accepted engr. practice)	5.3	Co-60 half life				
11	CRWMS M&O 1997. <i>Repository Subsurface Layout Configuration Analysis</i> . BCA000000-01717-0200-00008 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971201.0879. (TBV-3271: INITIAL USE)	Fig. 7-23	TBV-3271	5.1.6 5.1.6 5.1.6	Exhaust main diameter Ventilation raise diameter Ventilation raise length	1	X		
12	CRWMS M&O 1997. <i>Preliminary Radiological Evaluation of Waste package Retrieval</i> . BCAE00000-01717-0200-00002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19971231.0332.	7.1.2.2	N/A (Reference)	5.3	PWR SNF crud activity	N/A	N/A		

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2. Technical Product Input Source Title and Identifier(s) with Version		3. Section					Unqual.	From Uncontrolled Source	Un-confirmed			
2a	CRWMS M&O 1996. <i>Material Compositions and Number Densities for Neutronics Calculations.</i>		N/A (Accepted engr. practice)	5.1.6	Standard material composition	N/A	N/A					
13	BBA000000-01717-0200-00002 REV 00. Las Vegas, Nevada: CRWMS M&O. ACC: MOL.19960624.0023											