BSC

Design Calculation or Analysis Cover Sheet

Complete only applicable items.

1. QA: QA
2. Page 1

3. System	4. Document Identifier
Wet Handling Facility	050-00C-WH00-00200-000-00A

5. Title
Wet Handling Facility and Low Level Waste Facility Worker Dose Assessment

6. Group
Nuclear and Radiological Engineering

7. Document Status Designation
☐ Preliminary ☒ Committed ☐ Confirmed ☐ Cancelled/Superseded

8. Notes/Comments

NOTICE OF OPEN CHANGE DOCUMENTS - THIS DOCUMENT IS IMPACTED BY THE LISTED CHANGE DOCUMENTS AND CANNOT BE USED WITHOUT THEM.

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1) CACN-001, DATED 02/12/2009

Attachments	Total Number of Pages
Attachment 1: Annual Inhalation and Submersion Doses	7
Attachment 2: Annual Collective Doses per Cask Type	2
Attachment 3: List of Files on Attached CD	1
Attachment 4: Attached CD	N/A

RECORD OF REVISIONS

9. No.	10. Reason For Revision	11. Total # of Pgs.	12. Last Pg. #	13. Originator (Print/Sign/Date)	14. Checker (Print/Sign/Date)	15. EGS (Print/Sign/Date)	16. Approved/Accepted (Print/Sign/Date)
00A	Initial issue	78	78	Tom Karl 10-15-07	Edward Salisbury CHP 10-15-07	Norman Kahler 10/15/07	David B. Darling 10/15/07

DISCLAIMER

The calculations contained in this document were developed by Bechtel SAIC Company, LLC (BSC), and are intended solely for the use of BSC in its work for the Yucca Mountain Project.

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ACRONYMS AND ABBREVIATIONS

ACRONYMS

ALARA	as low as is reasonably achievable
AO	aging overpack
BSC	Bechtel SAIC Company, LLC
CHC	Cask Handling Crane
CRCF	Cask Receipt and Closure Facility
DAW	dry active waste
DCF	dose conversion factor
DOE	U.S. Department of Energy
DPC	dual-purpose canister
FGR	Federal Guidance Report
GROA	Geologic Repository Operations Area
HEPA	high-efficiency particulate air (filter)
HIC	high integrity container
HLW	high-level waste
HPT	Health Physics Technician
HVAC	heating, ventilation, and air-conditioning
ICRP	International Commission on Radiological Protection
MTHM	metric tons of heavy metal
MTU	metric tons uranium
LLW	Low-Level Waste
LLWF	Low Level Waste Facility
NDO	No Dose Operation
R	Remote
RF	Receipt Facility
TAD	transportation, aging, and disposal (canister)
TC	Transportation Cask
TEDE	total effective dose equivalent
SFP	spent fuel pool
SNF	spent nuclear fuel
STC	shielded transfer cask

WHF	Wet Handling Facility
YMP	Yucca Mountain Project

ABBREVIATIONS

Bq	becquerel
Ci	curie
cm	centimeter
dpm	disintegrations per minute
ft	feet
hr	hour
inches	in
m	meter
min	minute
ml	milliliter
mrem	millirem
s	second
Sv	sievert
yr	year

1. PURPOSE

The purpose of this calculation is to estimate radiation doses received by personnel working in the Wet Handling Facility (WHF) who perform operations to receive transportation casks (TCs) containing Dual Purpose Canisters (DPCs) and commercial Spent Nuclear Fuel (SNF); who transfer the bare fuel contained in the TCs and DPCs into Transportation, Aging, and Disposal (TAD) canisters; and who export the TAD canisters in an Aging Overpack (AO). This calculation also estimates radiation doses received by personnel working in the Low Level Waste Facility (LLWF) who collect, package, and ship low-level radioactive waste (LLW) to a licensed LLW processing or disposal facility.

The WHF is designed to receive TCs containing DPC and commercial SNF. The mechanical handling systems in the WHF provide the capability to receive, inspect, complete radiological surveys on incoming TCs, remove the TC from the carrier, prepare the TC for unloading, transfer the contents of the TC into a TAD within a Shielded Transfer Cask (STC), move the loaded STC to an unloading room, transfer the TAD to an AO, and transfer the loaded AO to the Aging Facility or Cask Receipt and Closure Facility (CRCF), as applicable (Ref. 2.2.29 Section 5.1.1). The unloaded/empty TC (truck or rail) is prepared for return to the national transportation system in the WHF Cask Preparation Area, and exits through the Entrance Vestibule. The specific scope of work contained in this calculation covers both collective doses and individual worker doses on an annual basis, and includes contributions from external and internal radiation from normal operations since there are no Category 1 event sequences identified in the current Categorization of Event Sequences for License Application (Ref. 2.2.28, Section 7.2).

The LLWF is designed for the collection, packaging, and shipment of low-level radioactive waste (LLW) streams generated during the handling of high-level radioactive waste (HLW) and SNF. The building is also capable of storing limited quantities of packaged LLW for short periods of time, if necessary. Dry active waste (DAW) is typically received at the LLWF in bags or drums, sorted, and repacked for disposal. DPC carcasses are received, decontaminated if necessary, and packaged for disposal. Spent HEPA filters may be brought to the LLWF for packaging and disposal. Spent liquid waste filter media and resins may be transferred to the LLWF for storage prior to shipment at a later date.

Per Reference 2.1.1 Sections 2.3 and 3.2.2, “Assumptions that will be met by operational control of activities such as worker dose assessments, do not require verification”. “Results and conclusions from preliminary or committed calculations or analyses may be used in other preliminary or committed calculations or analyses as design input”. “Engineering sketches and studies may be used as design input in preliminary calculations and in committed calculations provided the calculations are not used for procurement, fabrication or construction purposes”.

The calculations contained in this document were developed by Nuclear and Radiological Engineering of the Repository Project Management organization and are intended solely for the use of the Repository Project Management in its work regarding facility design and operation. Yucca Mountain Project (YMP) personnel from Nuclear and Radiological Engineering should be consulted before use of these calculations for purposes other than those stated herein, or use by individuals other than personnel in Nuclear and Radiological Engineering.

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2.4 DESIGN OUTPUTS

This calculation is performed to support information in the license application and further design refinement to incorporate ALARA dose reductions.

3. ASSUMPTIONS

3.1 ASSUMPTIONS REQUIRING VERIFICATION

3.1.1 Air Changes (WHF)

Assumption: The air change rate in the WHF Cask Preparation Area and the Pool Room (one open room) during normal operations is assumed to be one air change per hour, with 10% of the air exchange comprised of outside air makeup. The area around personnel performing SNF operations is 4,594 m^3.

Rationale: Currently the WHF is being designed for 100% make up air from outside. A typical nuclear heating, ventilation and air-conditioning (HVAC) system for a nuclear facility has a room air turnover rate greater than one air change per hour and makeup from outside air of 10% or more. Using one air change per hour with 10% of the air exchange comprised of outside air makeup is conservative. The volume of the Cask Preparation Area and the Pool Room is estimated from Ref. 2.2.1, 2.2.2 and 2.2.3, and is considered conservative because it only considers the open volume of the two adjacent rooms where the actual cask handling operations take place. Measurements are based on interior wall surfaces. 10% of the total available volume 4,594 m^3 will be used to better represent the area around personnel who are performing SNF processing operations in the WHF. The room volume is derived as follows:

Cask Preparation Area and Pool Room:

Length = 212 feet (ft) center wall to center wall. Minus, 4 ft for walls = 208 ft.
Width = 104 ft center wall to center wall. Minus, 4 ft for walls = 100 ft
Height = 80 ft minus 2 ft for ceiling = 78 ft
208 ft x 100 ft x 78 ft = 1,622,400 ft^3

Total volume: 1,622,400 ft^3/(35.315 ft^3/meters $(m)^3$) = 45,941 m^3

Available volume: 4,594 m^3

Usage: This assumption is used in Attachment #1.

3.1.2 Work Platform Shielding to Reduce Dose Rate (WHF)

Assumption: Shielding and/or tooling will be provided on work platforms to reduce worker dose by a minimum of a factor of four.

Rationale: See Ref. 2.2.19 which requires cask platform designs to incorporate shielding and/or tooling to reduce worker dose by a minimum factor of four.

Usage: This assumption is used in Table 4 and noted by an asterisk (*) by those steps.

3.1.3 SFP Filters (WHF)

Assumption: There will be 208 spent fuel pool (SFP) support filters and 312 in-pool filters changed on an annual basis.

Rationale: This number of filters is consistent with the Low Level Waste Management Plan (Ref. 2.2.21 Section 6.1.4, which establish the process frequencies and manpower demands for the LLWF and are suitable for their intended use in this calculation). This number is considered large enough to prevent the SFP from exceeding Class B LLW limits.

Usage: This assumption is used in Tables 4 and 5.

3.1.4 HVAC Filters Volume (WHF)

Assumption: There will be 108 HVAC filters that will need to be changed every 10 months.

Rationale: There will be 36 pre-filters, 36 stage I filters, and 36 stage II HVAC filters (Ref. 2.2.21 Table 4.3) changed out every 10 months. The WHF is a unique YMP surface nuclear facility compared to other surface nuclear facility in that it has C3 contamination zones, potential for airborne contamination (Ref. 2.2.16 Figure I-4.5). The other facilities do not anticipate having any airborne contamination. See Ref. 2.2.16 for explanation of contamination classification.

Usage: This assumption is used in Table 5.

3.1.5 Transported HIC Dose Rate

Assumption: The dose rate from high integrity containers (HICs) when transporting SFP filters and spent resin from the WHF to the LLWF and while handled at the LLWF will be the same as Ref. 2.2.27, Table 7.5, of 20.12 mrem/hr (rounded to 20) at 1 m, 12.99 mrem/hr (rounded to 13) at 2 m, 9.06 mrem/hr (rounded to 9) at 3 m, and 4.95 mrem/hr (rounded to 5) at 5 m.

Rationale: This dose rate is consistent with the allowable AO dose rates (Ref. 2.2.17, Section 3.3.4), thus, using the dose rates from Ref. 2.2.27, Table 7.5 as follows for the HIC is conservative and will not create a high radiation area.

Usage: This assumption is used in Table 4, 5, and 6.

3.1.6 SFP Spent Fuel Transfer Machine Work Dose Rate (WHF)

Assumption: The average dose rate for an occupant working on the Spent Fuel Transfer Machine area is 2 mrem/hr.

Rationale: During refueling operations which are similar to the area above the SFP where the Spent Fuel Transfer Machine will be used is zoned as a R2 (Ref. 2.2.16, Figure I-4.2), because 9'-2" to 10'-6" of water will be maintained to keep the dose rate less than 2.5 mrem/hr (Ref. 2.2.20, Section 5.4.3), so on average 2 mrem/hr in the general work area is considered appropriate and is typical of the dose rates encountered in nuclear power plants during refueling operations.

Usage: This assumption is used in Table 5.

3.1.7 HVAC Filters Dose (WHF)

Assumption: It is assumed it will take 10 minutes to change each filter in an average dose rate of 1 mrem/hr.

Rationale: The radiation criteria for a HEPA filter housing is set at the maximum allowable level for a R2 of 2.5 mrem/hr (Ref. 2.2.16, Figure I-4.2). This is because most areas of the nuclear facilities are zoned as having a potential for contamination and the HEPA filter rooms have low occupancy. It is recognized that the HEPA filters will likely be changed out due to high differential pressure from non-contaminated dust loading rather than from the radiation levels resulting from radioactivity buildup. Thus, it is conservative to assume that the average dose rate of 1 mrem/hr is present during filter changeouts.

Usage: This assumption is used in Table 5.

3.1.8 Air Changes (LLWF)

Assumption: The air change rate in the LLWF packaging area and adjacent open areas during normal operations is assumed to be one air change per hour, with 10% of the air exchange comprised of outside air makeup. The volume of the LLWF packaging area and adjacent open areas is 24,314 m^3.

Rationale: A typical nuclear HVAC system for a nuclear facility has a room air turnover rate greater than 1 air change per hour and makeup from outside air of 10% or more. Using one air change per hour with 10% of the air exchange comprised of outside air makeup is conservative. The volume of the LLWF packaging area and adjacent open areas is estimated from the LLWF general arrangements, and is considered conservative because it only considers the open volume of the adjacent rooms where the actual material handling operations take place. Measurements are based on interior wall surfaces from the general arrangement drawings (Ref. 2.2.22, 2.2.23, 2.2.24, 2.2.25, and 2.2.26, which establish the dimensions of these areas and are suitable for their intended use in this calculation). The room volume is derived as follows:

LLWF packaging area and adjacent open areas:

Length = 262 ft 6 inches (in) center wall to center wall. Minus, 4 ft 6 in to wall center = 258 ft.
Width = 88 ft center wall to center wall. Minus, 4 ft for walls = 84 ft
Height = 66 ft 3 in minus 25 ft for height of highest room = 41 ft 3 in
258 ft x 84 ft x 41.25 ft = 893,970 ft^3

Total volume: 893,970 ft^3/(35.315 ft^3/m^3) = 25,314 m^3

Usage: This assumption is used in Attachment #1.

3.1.9 Low Activity DAW Processed (LLWF)

Assumption There will be an expected weekly throughput of 61 drums of bagged DAW. (Ref. 2.2.21 Table 6.7).

Rationale: This equates to 12.2 drums a day that will need to be processed. Processing these drums involves sorting the contents and repackaging for shipment.

Usage: This assumption is used in Table 6.

3.1.10 Radiologically Contaminated Waste Water (LLWF)

Assumption: All radiologically contaminated waste water low-level waste (LLW) received at the LLWF will be processed by a contractor-supplied liquid waste clean up system that is remotely operated. The processed water will be appropriately reused within the Geologic Repository Operations Area (GROA).

Rationale: The LLWF will receive 1,480 gallons/week (Ref. 2.2.21 Table 6.7) of radiologically contaminated waste water and this work will be processed by a contractor-supplied system that is remotely operated. Since LLW processing systems in the nuclear industry are typically designed to be remotely operated this assumption is considered appropriate.

Usage: This assumption is used in Section 6.3.2.

3.1.11 High Activity DAW Processed (LLWF)

Assumption: Work crews at the LLWF will process high activity DAW once a week.

Rationale: A portion of the low activity DAW received at the LLWF, will need to be treated as high activity DAW and processed on average, once a week.

Usage: This assumption is used in Table 6.

3.1.12 DAW Loading and Shipping Frequency (LLWF)

Assumption: The Operators at the LLWF will load and ship DAW two times a week.

Rationale: With the amount of DAW processed weekly at the LLWF, it will generate enough DAW to load and ship one to two waste loads a week on average. The use of two waste loads per week is conservative.

Usage: This assumption is used in Table 6.

3.1.13 Prepare, Package, and Ship empty DPCs (LLWF)

Assumption: The Operators at the LLWF will process 6 empty DPCs per year for shipping and disposal.

Rationale: Per Ref. 2.2.21, Table 6.7, the LLWF will process up to 6 empty DPCs per year for shipping and disposal. Note that the WHF could generate up to 32 empty DPCs (Ref. 2.2.4, Table 6) average maximum per year, but, the LLWF would still only process 6 empty DPCs per year in order to support processing all other waste streams. See Assumption 3.1.20.

Usage: This assumption is used in Attachments #1 and Table 6.

3.1.14 Package and Ship HEPA Filters (LLWF)

Assumption: The Operators at the LLWF will ship 12 shipments per year of spent HEPA filters. There are 12 filters per shipping container, and there are 10 containers per shipment.

Rationale: This number of HEPA filters processed for waste shipment per year is consistent with Ref. 2.2.21, Table 4.3, of 1,457 HEPA spent filters generated per year.

Usage: This assumption is used in Section 6.3.2.

3.1.15 Spent Resin and SFP Cartridge Filters Within HICS (LLWF)

Assumption: The Operators at the LLWF will process SFP Spent Resin once a year and used filter cartridges three times a year.

Rationale: This frequency of resin and SFP filter cartridge change out should prevent the facility from generating greater than Class B radioactive waste from these waste streams.

Usage: This assumption is used in Table 6.

3.1.16 Load and Ship Shielded Transport Casks with HIC (LLWF)

Assumption: The Operators at the LLWF will load and ship a shielded transport cask two times annually.

Rationale: The LLWF has the capability to store enough material so that only two shielded transport casks will be required per year.

Usage: This assumption is used in Table 6.

3.1.17 Airborne Radioactivity (LLWF)

Assumption: The most significant operation in the LLWF that will have a potential of generating airborne radioactivity will be processing an empty DPC.

Rationale: The LLWF will be receiving various forms and containers of radioactive waste, all released from other facilities. Low activity bagged waste will be sorted and disposed of. High activity bagged waste will be sorted in a glove box. The exterior of all HICs and drums received will be within facility release limits. The most significant potential for airborne radioactivity will happen when the DPC is removed from the STC in the LLWF.

Usage: This assumption is used in Attachment #1.

3.1.18 Exposures from SFP Filter change outs (WHF)

Assumption: The worker doses to remotely change out and dispose of the 208 SFP support filters will be minimal to operations personnel and the HPT and is assumed to be 10 mrem/filter per crew member and 4 mrem/filter per HPT. The dose to change the 312 in-pool filters is assumed to be negligible.

Rationale: Typical filter skids designed to perform this process at current operating nuclear facilities are performed remotely and minimal doses are picked up from operations personnel performing this process and are considered to be conservative. The in-pool filters are changed out remotely (under water) with little dose consequence.

Usage: This assumption is used in Table 5.

3.1.19 Number of HICs to process spent fuel filters

Assumption: Three HICs will be required to dispose of the 520 SFP filters on an annual basis.

Rationale: The filter is approximately 6 in in diameter and 2 ft in length (typically), and will occupy a rectangular volume of 6 in by 6 in by 2 ft. The size of a typical HIC is approximately 6 ft high with a 5 ft diameter.

Filter volume = Width X Height X Length = 0.5 ft X 0.5 ft X 2 ft = 0.5 ft^3

HIC Volume = π X r^2 X Height = $\pi(2.5\text{ ft.})^2$ X 6 ft = 118 $ft^3 \approx$ 100 ft^3 usable volume.

Number of filters per HIC = HIC volume/Filter volume = 100 ft^3/0.5 ft^3 = 200 filters/HIC

Number of HICs required = Total number of filters/Number of filters per HIC

= 520 filters/200 filters per HIC = 2.6 HICs ≈ 3 HICs

Usage: This assumption is used in Tables 5 and 6.

3.1.20 Annual Throughput of TCs (WHF)

Assumption: The total number of TCs to be processed annually in the WHF is 50 rail, bare SNF based TCs. (Ref. 2.2.4, section 5.1, table 6), that contain 21 PWR assembles per TC.

Rationale: The exact number of TCs processed in the WHF will vary from year to year based on what is being processed (DPCs, CSNF). Using the truck based TCs would result in an exposure 4 times higher than the rail based TC and would not be ALARA. (See attachment #2). The use of the DPC only model would fill 40 TADs per year with on average only 32 DPCs being processed. The number of DPCs to be processed in the facility is low when compared to the rail, bare-fuel based canister. Also the average number of waste stream casks processed from Ref. 2.2.4, Table 6, columns 8 and 9, the mix model, and columns 11 and 12, for the medium and large rail based bare-fuel model, is approximately 50 TCs processed to fill 50 TADs. This would allow for approximately 1 TC and 1 TAD to be processed per week. Use of the medium and large rail casks will meet the required 300 MTHM and would maximize the total MTHM processed annually in the WHF. Therefore, an average of 50 TCs is considered an appropriate number of TCs processed per year.

Usage: This assumption is used in Sections 6.2, and 6.3.

3.2 ASSUMPTIONS NOT REQUIRING VERIFICATION

3.2.1 Dose Rates from TC (WHF)

Assumption: The radiation dose rate distribution around a TS125 cask (see Table 1) is used to estimate dose rates received by workers while processing a rail transportation cask in the WHF. It is assumed that this calculated data is representative of the conditions of the cask process in the WHF and can be used to estimate dose rates received by workers at various distances from the exterior surfaces of a rail TC.

Rationale: The dose rates from the TS125 are considered representative of a loaded TC. Dose rates in the vicinity of a TS125 rail cask have been determined in Ref. 2.2.5 Figure 6.2-2. All TCs received at the WHF are required to meet the requirements in Ref. 2.3.1 for packaging, preparation for shipment, and transportation of licensed materials. For the purpose of these dose calculations, it is expected that the TC will not exceed 200 mrem/hr at any point on the package external surface and 10 mrem/hr at 2 m from the surface of the package which is consistent with the radiation dose rates of the TS125 TC (Ref. 2.2.5). The use of this dose rate profile is representative of a typical rail cask containing spent fuel handled in the WHF.

Usage: This assumption is used in Sections 6.2 and 6.3.

Table1. Dose Map for One Horizontal Cask (without Impact Limiters)

	center	2 m	5 m	10 m	15 m	20 m	30 m	40 m	50 m
40 m	0.091	0.130	0.108	0.103	0.092	0.081	0.062	0.046	0.033
30 m	0.150	0.217	0.205	0.179	0.151	0.128	0.092	0.064	0.043
20 m	0.317	0.396	0.370	0.295	0.235	0.187	0.121	0.081	0.053
15 m	0.513	0.713	0.594	0.430	0.324	0.244	0.148	0.093	0.058
10 m	1.115	1.541	1.092	0.679	0.452	0.320	0.174	0.104	0.063
5 m	3.397	3.370	1.967	1.000	0.591	0.381	0.191	0.109	0.065
2 m	11.192	5.577	2.747	1.192	0.639	0.406	0.194	0.112	0.066
1 m	19.641	7.631	3.159	1.256	0.680	0.413	0.197	0.111	0.066
Top axial	**cask**	9.097	3.435	1.313	0.677	0.412	0.200	0.113	0.067
	cask	7.015	2.801	1.112	0.597	0.375	0.183	0.104	0.062
mid-plane radial	**cask**	7.495	2.912	1.071	0.566	0.351	0.173	0.100	0.060
	cask	6.723	2.763	1.067	0.557	0.342	0.166	0.095	0.057
Bottom axial	**cask**	5.622	2.408	1.011	0.534	0.331	0.164	0.093	0.056
-1m	2.943	4.225	2.054	0.944	0.529	0.326	0.162	0.093	0.055
-2 m	1.611	2.761	1.669	0.830	0.495	0.318	0.157	0.092	0.055
-5 m	0.669	1.459	1.095	0.667	0.421	0.291	0.152	0.088	0.053
-10 m	0.269	0.483	0.520	0.401	0.304	0.226	0.131	0.082	0.049
-15 m	0.164	0.208	0.235	0.136	0.194	0.161	0.108	0.070	0.045
-20 m	0.104	0.128	0.140	0.141	0.135	0.115	0.084	0.059	0.039
-30 m	0.064	0.111	0.081	0.080	0.079	0.076	0.059	0.044	0.031
-40 m	0.034	0.040	0.044	0.046	0.045	0.043	0.038	0.030	0.022

The dose rates are given in mrem/hr. The displayed distances are from the surface of the cask to the dose points.

(Ref 2.2.5, Figure 6.2-2)

LEGEND:
Top Axial, upper impact limiter and lid work.
Top Axial, trunnion work.
Mid Plane Radial.
Bottom Axial, lower impact limiter work.

3.2.2 Time and Motion Study (WHF)

Assumption: Process task definitions for rail transportation cask operations within the WHF, and their corresponding task duration times, average worker distance, and number of needed personnel are provided in Ref. 2.2.6.

Rationale: The operation process steps, time durations, average worker distances, and numbers of personnel are necessary information for the determination of WHF workers' external and internal doses. The time and motion information of Ref. 2.2.6 represents reasonable estimates of the average times to perform the process operations and is suitable for performing worker dose estimate calculations at this stage of design of the WHF. Note that these times are based on average times to perform tasks and not optimum throughput minimum times.

The following worker average distance locations for axial work from a TS125 are defined as:

1 m = 1 m away from the center axial plane of the cask surface and 2 m away vertical (radial)
2 m = 2 m away from the center axial plane of the cask surface and 2 m away vertical (radial)
5 m = 2 m away from the center axial plane of the cask surface and 5 m away vertical (radial)

The radial dose rates used are from the mid-plane and are 7.495 (rounded to 7.50) mrem/hr at 2 m average distance, 2.912 (rounded to 2.90) mrem/hr at 5 m average distance, and 1.071 (rounded to 1.10) mrem/hr at 10 m average distance, (Ref 2.2.5, Figure 6.2-2).

The top radial dose rates are used for installation of both the upper and lower trunnions is 9.097 (rounded to 9.1) mrem/hr at 2 m average distance (From Table 1).

The top axial dose rates are 7.631 (rounded to 7.60) mrem/hr at 1 m average distance, 5.577 (rounded to 5.60) mrem/hr at 2 m average distance and 2.747 (rounded to 2.70) mrem/hr at 5 m average distance (Ref. 2.2.5, Figure 6.2-2).

The bottom axial dose rates are 4.225 (rounded to 4.2) mrem/hr at 1 m average distance, 2.761 (rounded to 2.8) mrem/hr at 2 m average distance, and 1.669 (rounded to 1.7) mrem/hr at 5 m average distance (Ref. 2.2.5, Figure 6.2-2).

Usage: This assumption is used in Section 4.3, 6.2, and 6.3.

3.2.3 Average Distances (WHF)

Assumption: Worker locations for cask preparation operations in the WHF are defined in terms of average distances from the TC. The distances are estimated from averaged worker locations to perform each specific task for cask preparation operations. In general, for hands-on activities (e.g., smears for surface contamination sampling), the worker is assumed to be at 1 m average distance from the cask. For processing tasks that are non hands-on, but require the worker's presence in the area, the worker is assumed to be standing a reasonable distance away from the cask. In addition to the general as low as is reasonably achievable (ALARA) concept of workers minimizing their time and maximizing their distance from the source, permanent engineering controls (shielding) would be expected to be designed/installed to protect personnel not required to perform tasks that are in the immediate proximity of the cask.

Rationale: Based on standard ALARA principles, it is expected that workers will use distance as much as possible to reduce their radiation dose. Workers are expected to move to low dose areas when not specifically required by a job function to be proximate to the cask. The approximate worker locations for the required cask preparation operations in the WHF are used from Ref. 2.2.6. Appropriate length tools (e.g., long-reach tools) will be used to facilitate the distances used.

Usage: This assumption is used in Section 4.3, 6.2, and 6.3.

3.2.4 Staffing (WHF)

Assumption: It is assumed that there will need to be 6 work crews to support the WHF operating 24 hours per day, 7 days a week (24/7). Staffing requirements and worker group categories include the following personnel to support 24/7 operations:

- Operators (includes crane Operator, riggers, laborers)
- Health Physics Technicians (HPTs)

The following make up a complete work crew:

- Five Operators
- One HPT

Total work crews for WHF operations:

- Six complete work crews

Rationale: At least three crews are needed to support 24/7 operations. However, three crews would not allow for training, weekend days off, holidays, vacation or sick leave. Five crews, each working 2,000 hours per year, would provide 10,000 hours per year coverage, which covers the number of hours per year required (8,760 hours in a year). The WHF is a unique YMP surface nuclear facility in that it has a SFP with a large amount of added maintenance and support work. Due to this extra anticipated support work, at least one additional crew will be needed, making the total number of crews for supporting the facility six. This assumption is also consistent with shift coverage practices at facilities operating under 24/7 schedules. Five Operators and One HPT meet the minimum number of personnel per crew to support cask operations (Ref. 2.2.6).

Usage: This assumption is used in Sections 6.1, 6.2, 6.3, and Attachments #1.

3.2.5 HPTs

Assumption: An HPT is assumed to be present whenever WHF or LLWF workers are performing operations involving exposure to radiation.

Rationale: The Ref. 2.2.6 has an HPT listed during material handling activities to support personnel on the day-to-day operation and processing activities. HPTs are within close proximity to Operators with whom they work side-by-side. Every activity is surveyed and analyzed for

radiological conditions. HPTs are in a support role, and do not typically perform hands-on operations for cask processing. An HPT is assumed to be present whenever WHF and LLWF personnel are performing operations involving exposure to radiation. The HPT support personnel will use remote radiation monitoring (i.e., long-handle detector) whenever possible to support cask operations to maintain doses ALARA.

Usage: This assumption is used in Sections 6.2, 6.3, and Attachment #1.

3.2.6 Operations Support Personnel

Assumption: Doses to other WHF and LLWF operations support personnel are not calculated.

Rationale: The WHF and LLWF will have support personnel that are "Non Hands-On" workers (i.e., they do not handle loaded casks or waste). These personnel will generally be located in low dose areas that are well shielded from the radiation sources (i.e., the loaded casks). This is consistent with standard ALARA practices of minimizing the number of individuals who can receive dose.

Usage: This is a general assumption for the WHF and LLWF.

3.2.7 Annual Throughput of TADs (WHF)

Assumption: The total number of TADs to be processed annually in the WHF is 50.

Rationale: Per the Preliminary Wet Handling Facility Throughput Study (Ref. 2.2.4, section 2.1, table 1), the maximum number of TADs to be processed annually in the WHF is 50. This maximum number of TADs is based on receipt of rail, bare SNF only waste.

Usage: This assumption is used in Sections 4.3.2, 6.1, 6.2, 6.3, and Attachments #1.

3.2.8 Contamination Levels of Incoming TCs

Assumption: It is assumed that the non-fixed (removable) radioactive contamination on the external surface of a rail transportation cask is 10^{-4} μCi/cm^2 for beta and gamma emitters and low-toxicity alpha emitters, and 10^{-5} μCi/cm^2 for all other alpha emitters.

Rationale: The surface contamination levels used in this assumption are the regulatory limits for packages offered for transportation (Ref. 2.3.2, Article 173.443(a), Table 9). Rail transportation casks accepted at the WHF are expected to meet the surface contamination limits of Ref 2.3.2, Article 173.443(a), which states, in part:

> "The level of non-fixed (removable) radioactive contamination on the external surfaces of each package offered for transport must be kept as low as reasonably achievable. The level of non-fixed radioactive contamination may not exceed the limits set forth in Table 9…"

Therefore, this assumption is conservative for the purpose of calculating inhalation and submersion doses to workers due to the resuspension of non-fixed radioactive contamination from the cask's surface. Ref. 2.3.2, Article 173.443(a), Table 9 is reproduced in Table 2.

Table 2. Non-fixed External Radioactive Contamination Limits for Packages.

Contaminant	Maximum permissible limits		
	Bq/cm^2	**µCi/cm^2**	**dpm/cm^2**
Beta and gamma emitters and low toxicity alpha emitters	4	10^{-4}	220
All other alpha emitting radionuclides	0.4	10^{-5}	22

Usage: This assumption is used in Section 6.7, and Attachment #1.

3.2.9 Resuspension of Contamination

Assumption: It is assumed that the resuspension rate of surface contamination from the rail TC is 4×10^{-5}/hr.

Rationale: This resuspension factor is the bounding value recommended for aerodynamic entrainment of powder lying on a heterogeneous surface (indoors or outdoors) exposed to ambient conditions following an event (Ref. 2.2.7, Section 5, p. 5-7, and Section 5.2.4, p. 5-21).

Usage: This assumption is used in Section 6.7, and Attachment #1.

3.2.10 Respirability of Airborne Radioactivity

Assumption: It is assumed that all released or suspended radioactive particles are respirable with a respirable fraction of 1.

Rationale: This assumption is appropriate because it yields the maximum inhalation dose values. Furthermore, the Department of Energy (DOE) handbook for estimating airborne release fractions/rates and respirable fractions recommends a respirable fraction of one (1) for aerodynamic entrainment of powder lying on a heterogeneous surface (indoors or outdoors) exposed to ambient conditions following an event (Ref. 2.2.7, Section 4.3.5).

Usage: This assumption is used in Section 6.7, and Attachment #1.

3.2.11 Radionuclides

Assumption: The radioactive surface contamination on the rail TC is assumed to be evenly distributed cobalt-60 (^{60}Co), strontium-90 (^{90}Sr), plutonium-239 (^{239}Pu), and americium-241 (^{241}Am).

Rationale: It is assumed that any contamination on the exterior surface of the rail TC containing commercial spent nuclear fuel SNF is likely to come from radioactive particulates suspended in the spent fuel pool water at the originating nuclear facility. At the time of cask loading, most of the particulates in the pool are the long half-life corrosion products from commercial SNF surfaces that might dislodge during commercial SNF movement. The most prominent particulates are ^{60}Co, ^{58}Co, ^{55}Fe, ^{59}Fe, ^{54}Mn, ^{51}Cr, and ^{65}Zn (Ref. 2.2.9, p. 4-51). Of these products, ^{60}Co has the highest inhalation dose conversion factor (DCF) for a corrosion product (Ref. 2.2.10, Table 2.1) and half-life (5.27 years) (Ref. 2.2.11, p. 78).

The remaining isotopes are chosen because they are the most dose-significant, long-lived isotopes likely to be present. Table 3 lists the half-lives, and the effective inhalation dose conversion factor (DCF^{inh}) and submersion dose conversion factor (DCF^{sub}) for the significant isotopes considered. A comparison of DCFs is also shown in Table 3.

Table 3. Half-Lives and DCFs for Selected Isotopes

		FGR 11	FGR 12	ICRP 68	FGR 13
Isotope [A]	**Half-Life (yr) [B]**	***DCF^{inh}* (Sv/Bq) [C]**	***DCF^{sub}* (Sv-m^3/Bq-s) [D]**	***DCF^{inh}* (Sv/Bq) [E]**	***DCF^{sub}* (Sv-m^3/Bq-s) [F]**
^{60}Co	5.271	5.91E-08	1.26E-13	2.90E-08	1.19E-13
^{90}Sr	28.6	3.51E-07	7.53E-18	1.50E-07	9.83E-17
^{239}Pu	24,131	1.16E-04	4.24E-18	4.70E-05	3.49E-18
^{241}Am	432.2	1.20E-04	8.18E-16	3.90E-05	6.77E-16

Sources: [A] Isotopes, Ref. 2.2.9, p. 4-51.

[B] Half-Lives, Ref. 2.2.11, pp. 78, 99, 209, and 211.

[C] FGR11, Ref. 2.2.10 Table 2.1.

[D] FGR12, 2.2.12, Table III.1.

[E] ICRP68, Ref. 2.2.13, Table B.1

[F] FGR13, Ref. 2.2.14, Table F12TIII1.

Usage: This assumption is used in Section 6.7.

3.2.12 Surface Contamination Area

Assumption: Surface contamination is assumed to cover the entire external surface of a rail cask which is 51 m^2. This is also assumed to be equivalent to the surface area of an STC loaded with an empty DPC.

Rationale: The maximum dimensions of a rail cask is 100 inches in diameter and 200 inches in length which bounds that of all currently designed rail casks (Ref. 2.2.8, Section 2.2.1, Table 2-4, Figures 2-5 through 2-10, which establish the dimensions of a typical rail cask and are suitable for their intended use in this calculation). The amount of surface contamination assumed to be available for release to the atmosphere is 100%, which is significantly higher than is anticipated for the rail TCs handled at the WHF and STC/DPCs at the LLWF. This is because only a small portion, if any, of the cask's exterior surface would have any removable contamination due to preventive decontamination measures used during loading at the originating nuclear facility. Therefore, the amount of removable contamination hypothetically available to become airborne under normal and off-normal conditions would be significantly less than the amount assumed here. This is expected to be the case even if only portions (i.e., hot spots) of a TC exceed the

removable surface contamination limits upon arrival at the Yucca Mountain Repository. The use of this assumed value will yield conservative dose values.

Usage: This assumption is used in Section 6.7, and Attachment #1.

3.2.13 Worker Breathing Rate

Assumption: The WHF worker is assumed to be breathing at a rate of 20,000 ml/min, which is equivalent to 3.33×10^{-4} m^3/s.

Rationale: This is the breathing rate recommended to be used in calculating occupational doses due to inhalation intake (Ref. 2.2.15, p. 8.34-10, Equation A-1).

Usage: This assumption is used in Section 6.7, and Attachment #1.

3.2.14 Non Hands-on Work

Assumption: It is assumed that all WHF and LLWF workers will be in a work environment with an average external dose rate of 0.05 mrem/hr for non-cask processing times (i.e., non hands-on work or SFP work).

Rationale: When not performing work involved with processing casks that will be loaded into AOs or STCs or processing LLW, WHF and LLWF work crews will be in either an unlimited occupancy area (R1) or a routine occupancy area (R2) less than 2000 hrs/yr, (Ref. 2.2.16, Figure I-1.1). It is considered reasonable based on the area classification that the workers are on average residing in an environment where the dose rate is 0.05 mrem/hr when not involved in an operation, this includes LLWF workers in non hands-on work (Ref. 2.2.16, Figure I-5.1).

Usage: This assumption is used in Sections 6.2, 6.3, and 6.5.

3.2.15 Dose Rate of Loaded AO/STC (WHF)

Assumption: It is assumed that the STCs handled in the WHF will have the same radiation levels as the AO handled in the WHF.

Rationale: AOs will be designed to be less than or equal to 40 mrem/hr at contact when loaded with any DPC or TAD (Ref. 2.2.17, section 3.3.4). It is reasonable to assume that the STC will have dose rates comparable to these levels (Ref. 2.2.27, Table 7.5) as follows: 20.12 mrem/hr (rounded to 20) at 1 m, 12.99 mrem/hr (rounded to 13) at 2 m, 9.06 mrem/hr (rounded to 9) at 3 m, and 4.95 mrem/hr (rounded to 5) at 5 m. STCs will typically only be used for cutting open DPCs and closing TADs. Loaded TADs will be placed in AOs and sent to the CRCF for placement into a WP. Since, the TADs handled in the WHF will typically be configured for placement into a WP it is appropriate to assume a lower dose rate on the STC surface.

Usage: This assumption is used in Section 4.3.1, Table 4, and Attachment #2.

3.2.16 Throughput with a TC for External Dose (WHF)

Assumption: All TCs considered in the throughput will be loaded with commercial SNF.

Rationale: Processing a TC loaded with commercial SNF is considered conservative when evaluating external exposures. The WHF will handle far more TCs containing bare commercial SNF and therefore it is more representative of the TCs to be processed.

Usage: This assumption is used in Sections 6.2, and 6.3.

3.2.17 Staffing (LLWF)

Assumption: It is assumed that there will need to be 2 work crews to support the LLWF operating on a standard work week of 5 days per week and one shift each day:

- Operators (includes crane Operator, riggers, laborers)
- Health Physics Technicians (HPTs)

The following make up a complete work crew:

- Five Operators
- One HPT

Total work crews for LLWF operations:

- Two complete work crews

Rationale: Two crews are needed to support a standard work week, since a single crew would not allow for training, days off, vacation or sick leave. Also there will need to be two crews to handle the expected weekly throughput of 61 drums of bagged DAW (Ref. 2.2.21, Table 6.7). This assumption is also consistent with shift coverage practices at facilities operating under a standard work week of 5 days per week with one shift each day. Five Operators and one HPT meet the minimum number of personnel per crew to support LLWF operations.

Usage: This assumption is used in Table 6, and Sections 6.2, and 6.3.

4. METHODOLOGY

This dose assessment involves the calculation of annual individual worker exposures and annual collective worker exposures resulting from the processing of loaded casks in the WHF and processing waste in the LLWF. The calculated doses include the contributions from external radiation and from inhalation of and submersion in airborne radioactivity. The methodology for calculating direct external radiation doses is described in Section 4.3. The methodology for calculating inhalation and submersion doses is described in Section 6.7. The total TEDE is calculated by summing the component doses from inhalation, submersion, and direct external radiation dose.

4.1 QUALITY ASSURANCE

This calculation was prepared in accordance with EG-PRO-3DP-G04B-00037, *Calculations and Analyses* (Ref. 2.1.1). Although the WHF and LLWF have not yet been classified on *Q-List* (Ref. 2.1.2), results of this calculation provide worker dose assessments that identify radiological hazards for facilities important to safety or important to waste isolation; therefore, this approved version is designated as QA: QA.

4.2 USE OF SOFTWARE

Microsoft® Excel® 2003 SR-2, a spreadsheet program, is used in this calculation. This software is installed on a personnel computer running Microsoft® XP Professional (Central Processing number 001859). Excel® was used to generate tables listing the receipt, processing, and loading tasks for each operation; the dose rates at the worker locations; and the time spent by the workers in the radiation field at each location. User-defined formulas (derived in Section 4.3), design inputs and assumptions (discussed in Sections 2.2 and 3.2), and results are documented in sufficient detail in Section 6 to allow hand checking for independent duplication of the various computations without recourse to the originator per Ref. 2.1.1. Microsoft® Excel® 2003 is listed on the Controlled Software Report and is identified in the Repository Project Management Automation Plan Ref. 2.2.30 and the use of Excel constitutes level 2 software usage per Ref. 2.1.3 and does not require qualification. All calculation results generated from Excel were verified by hand calculation.

4.3 EXTERNAL DOSE CALCULATION

This dose assessment for the WHF uses data from a time and motion study Ref. 2.2.6 and dose rates calculated for worker locations from Table 1 and Ref. 2.2.27. For the LLWF data from Table 4 Sections 4-8A through 12 is used. Dose calculations are made on a per unit operation, i.e., per TC/TAD processed or per waste process, and then multiplied by the annual number of loaded cask transfers or waste processes to determine the total annual worker dose. The calculated total individual dose is compared with the ALARA design goal as specified in Ref. 2.2.18, Section 4.10.3.3 in accordance with Ref. 2.1.4. Different worker tasks are involved in the WHF operations from receiving the loaded TC through loading a TAD into the AO which then exits the facility (see assumption 3.2.2). All tasks to process, store, and export all waste forms in the LLWF are included in this calculation (see Table 6).

4.3.1 Exposure Rates for Specific WHF and LLWF Processing Operations

Per Assumptions 3.2.1, 3.2.2, and 3.2.3, the dose rates at various distances from a loaded TS125 cask are from the calculations in Ref. 2.2.5, Figure 6.2-2 as reproduced in Table 1; and per Assumption 3.2.15, the dose rates at various distances from a loaded AO, STC, or HIC are from Ref. 2.2.27.

4.3.2 Annual Number of Cask Operations

Based on the design capacity of the WHF, the expected TCs and TADs that will require processing is 50 each per year (Assumption 3.2.7). Annual Number of Casks Processed per Work Crew (WHF). The average number of casks processed annually by each work crew is the

total number of casks that will be handled annually in the WHF (50 TCs and 50 TADs) divided by the number of work crews (6) supporting those operations. This equates to 8.333 rounded to 8.4 TCs and 8.4 TADs. A single work crew will not be present 24/7 to process casks. Work crew assignments will be adjusted as necessary to balance accumulated doses among workers.

4.3.3 Process Tasks and Durations

Process tasks, durations, number of personnel and distances for the WHF are obtained from Ref. 2.2.6. (See Assumption 3.2.2.); and those for the LLWF, are shown in Table 4 Tasks 4-8A through 12 and are based on the types of waste to be processed as listed in Ref. 2.2.21.

4.3.4 Staffing

The staffing requirements and worker group categories for the WHF are presented in Assumption 3.2.4. The staffing requirements and worker group categories support 24 hours per day for 7 days (24/7) operations.

The staffing requirements and worker group categories for the LLWF are presented in Assumption 3.2.17. The staffing requirements and worker group categories support a standard 5 day per week 2 crew operation.

4.3.5 Calculation of External Dose

For an operation such as cask or waste processing, the external dose, ED_k, received by a worker for a task k is calculated as follows. The dose rates are at the locations of each operation task due to external radiation from the contained radiation sources.

$$ED_k = \frac{t_k}{60} \times EDR_{dist} \qquad \text{Equation 1}$$

Where:

ED_k = external dose to a worker per task k (mrem/task)
t_k = duration of exposure per task k (minutes)
EDR_{dist} = external dose rate at the worker's distance *dist* from the source (mrem/hr)
60 = units conversion (minutes/hr)

The total external dose, ED_o, to a worker for a series of N different tasks per operation (e.g., cask handling) is calculated as follows:

$$ED_o = \sum_{k=1}^{N} ED_k \qquad \text{Equation 2}$$

Where:

ED_o = external dose to a worker per operation consisting of N different tasks (mrem/operation)

When not performing manual operations on a cask, the individual in a work crew is assumed to remain inside the WHF and LLWF doing support activities in intermittent access lower radiation

areas. This support-only time, T_n, is determined from the time available, i.e. 40 hrs/week x 50 weeks/year = 2000 hrs, minus the time performing cask operations, T_o.

$$T_o = \sum_{k=1}^{N_C} \frac{t_k}{60} \times NP_C$$

and Equation 3

$$T_n = 2000\left(\frac{hrs}{yr}\right) - T_o$$

Where:

T_o	=	Time performing cask or cask operations for worker (hrs/year)
T_n	=	Support-only time for worker (hrs/year)
NP_C	=	Annual number of casks processed per crew (casks/crew-year) = $OP_C / crews_g$
OP_C	=	Number of casks processed per year (casks/year)
$crews_g$	=	Number of work crews
60	=	Units conversion (minutes/hr)

The total annual external dose, ED_g, to a worker for all cask operations including support-only time is calculated as:

$$ED_g = ED_C \times OP_C + T_n \times DR$$ Equation 4

Where:

ED_g	=	external dose to a worker (mrem/year)
ED_C	=	external dose to a worker per cask during cask processing operations (mrem/cask)
OP_C	=	number of casks processed per year (casks/year)
DR	=	dose rate in areas of lower radiation (mrem/hr)

4.4 INHALATION AND SUBMERSION DOSE CALCULATION

All operations conducted within the WHF and LLWF will involve DPCs and commercial SNF contained within TCs and the LLWF with empty STC/DPCs and packaged waste, with very low levels of surface contamination.

The following methodology is used to calculate the airborne concentrations and resultant doses from potential resuspension of surface contamination on a rail transportation cask.

Without taking credit for radioactive decay, the airborne radioactivity buildup in a room while the cask is present is given by:

$$\frac{dA_i}{dt} = \lambda_R S_i - \lambda_H A_i$$

$$\textit{and solving}$$

$$A_i(t) = \frac{\lambda_R S_i}{\lambda_H}\left(1 - e^{-\lambda_H t}\right)$$

Equation 5

Where:

A_i	=	airborne activity of isotope *i* at time *t* (μCi)
S_i	=	cask surface contamination activity of isotope *i* (μCi)
λ_R	=	surface contamination resuspension rate (hr^{-1})
λ_H	=	room HVAC turn over rate (hr^{-1})
t	=	duration of cask presence in the room (hr)

The airborne radioactivity will decrease after the cask is removed from the area, and due to the ventilation system recirculation and cleanup operation. Therefore, the maximum airborne radioactivity concentration occurs at the time of cask removal *t* and is determined by:

$$C_i(t) = \frac{\lambda_R S_i}{\lambda_H V_B}\left(1 - e^{-\lambda_H t_B}\right)$$

Equation 6

Where:

C_i	=	airborne concentration of isotope *i* at time *t* (μCi/m^3)
V_B	=	room air volume (m^3)

The inhalation and submersion doses to a worker for task, *k*, due to resuspension is given by:

$$H_k^{inh} = \sum_i C_i(t) \times DCF_i^{inh} \times 3.7 \times 10^9 \times RF \times BR \times t_k \times 60$$

$$H_k^{sub} = \sum_i C_i(t) \times DCF_i^{sub} \times 3.7 \times 10^9 \times t_k \times 60$$

Equation 7

Where:

H_k^{inh}	=	inhalation dose (mrem)
H_k^{sub}	=	submersion dose (mrem)
DCF_i^{inh}	=	inhalation dose conversion factor for isotope *i* (Sv/Bq)
RF	=	respirable fraction (= 1 per Assumption 3.2.10)
BR	=	occupational breathing rate (m^3/s)
DCF_i^{sub}	=	submersion DCF for isotope *i* (Sv-m^3/Bq-s)
t_k	=	duration of exposure per operation task *k* (minutes) (i.e., residence time in airborne radioactivity)

60 = units conversion (s/min)
3.7×10^9 = units conversion (mrem Bq/Sv μCi)

The total inhalation and submersion dose, ID_o, to a worker for a series of N different tasks per cask handling operation in the WHF and LLWF in the presence of airborne radioactivity is calculated as follows:

$$ID_o = \sum_{k=1}^{N} \left(H_k^{inh} + H_k^{sub} \right) \qquad \text{Equation 8}$$

Where:

ID_o = inhalation and submersion dose to a worker per operation consisting of N different tasks (mrem/operation)

The total annual inhalation and submersion dose, ID_g, to a worker in a work crew for all operations is calculated as:

$$ID_g = \sum_{o} ID_o \times \frac{OP}{crews_g} \qquad \text{Equation 9}$$

Where:

ID_g = inhalation and submersion dose to a worker (mrem/year)
$crews_g$ = number of workers in a work crew performing this operation
OP = total number of these operations, o, per year

The annual maximum inhalation and submersion doses to a WHF and LLWF worker due to resuspension of surface contamination on a cask are much lower than the contribution from the direct external dose for all worker categories and are therefore considered to be an insignificant contributor to the totals presented in Section 6.8. (See Attachment 1: Annual Inhalation and Submersion Doses.)

4.5 TEDE DOSE CALCULATION

The annual TEDE, $TEDE_g$, to a worker in a work crew is calculated by summing the component doses from inhalation, submersion and direct external radiation doses.

$$TEDE_g = ID_g + ED_g \qquad \text{Equation 10}$$

Where:

$TEDE_g$ = annual TEDE to a worker (mrem/year)

5. LIST OF ATTACHMENTS

	Number of Pages
Attachment 1 Annual Inhalation and Submersion Doses	7
Attachment 2 Annual Collective Doses per Cask Type	2

Attachment 3 List of Files on Attached CD 1
Attachment 4 Attached CD NA

6. BODY OF CALCULATION

6.1 PROCESSING TASK PER WORKER

The average number of TCs and TADs processed annually by each work crew is the total number of TCs that will be handled annually in the WHF and the total number of TADs that will be handled annually in the WHF divided by the number of work crews performing those operations. Per Assumption 3.2.7, the WHF throughput is 50 TCs and 50 TADs. The annual number of TCs and TADs processed per work crew is OP_C divided by the number of work crews (six crews per Assumptions 3.2.4). Thus, a work crew will process an estimated annual average of 8.4 (8.333 rounded to 8.4) TCs and 8.4 TADs (i.e., 50/6 rounded up). The total hands-on time expected to process a single TC to a TAD exiting the WHF is equal to 6,784 minutes which can be derived from Table 4 by summing Tasks 4-1, 4-3 and 4-4.

The average number of bags/drums of DAW to process, number of SFP spent resin HICs and SFP filter HICs to store and process, of DPC carcasses to store and process, of HEPA filters to process, of shielded transport casks with HICs to process, and loading and shipping of these waste forms, determines the total hands-on time to process elevated dose rate material in the LLWF. The total hands-on time expected to process waste forms out of the LLWF is 40,020 mins, which can be derived from Table 4 Tasks 4-8A, B, and C, 4-9, 4-10 A and B, 4-11, and 4-12 .

6.2 EXTERNAL RADIATION DOSES PER CASK PER WORKER TYPE

The total dose incurred per operation by workers involved in cask/waste processing operations at the WHF and LLWF (HPTs or Operators), and the WHF and LLWF total annual exposure for all workers, are calculated and listed in Table 4, using:

$$ED_k = \frac{t_k}{60} \times EDR_{dist} \qquad \text{Equation 1}$$

Where:

ED_k = external dose to a worker per task k (mrem/task)
t_k = duration of exposure per task k (min)
EDR_{dist} = dose rate at the worker's distance (*dist*) from the source (mrem/hr)
60 = units conversion (min/hr)

The total external dose, ED_o, to a worker for a series of N different tasks per operation (e.g., TC/TAD/waste handling) is calculated as follows:

$$ED_o = \sum_{k=1}^{N} ED_k \qquad \text{Equation 2}$$

Where:

ED_o = external dose to a worker per operation consisting of N different tasks (mrem/operation)

In the LLWF, this is the total annual dose to process all waste forms, which is divided by 2 work crews to obtain the total annual exposure to a worker to process all waste forms. See Table 6.

In the WHF, the total annual dose, ED_{anl}, to a worker to process 8.4 TC/TADs/yr (per section 6.1) divided by 1000 mrem/rem and calculated as follows:

$$ED_{anl} = ED_o \times 8.4 \frac{TC/TAD}{yr} / 1000 \frac{mrem}{rem} \qquad \text{Equation 11}$$

Where:

ED_{anl} = total annual external dose to a worker to process 8.4 TC/TADs/yr (person-rem/yr)

ED_o = external dose to a worker per operation (processing 1 TC/TAD) consisting of N different tasks (mrem/operation, processing 1 TC/TAD)

In the WHF, the total annual dose to a work crew, ED_{crew}, to process 8.4 TC/TADs/yr (per section 6.1) is calculated, using 5 Operators and 1 HPT per work crew, assumption 3.2.4, and 6 work crews working annually in the WHF, as follows:

$$ED_{crew} = (ED_{anl}\ (Operator) \times 5 + ED_{anl}(HPT)) \times 6 \qquad \text{Equation 12}$$

Where:

ED_{crew} = total annual external dose to a work crew to process 8.4 TC/TADs/yr (person-rem/yr)

HPT = HPT total exposure

Table 4 (which is attached on CD attachment #4, file Table4-1.xls through Table4-7.xls, and Table4-8-12.xls) is separated into 7 Tasks for the WHF and 8 Tasks for the LLWF. Each section breaks down separate hands-on processes that occur in the facility to process commercial SNF into a TAD, perform SFP support, and to process waste out of the LLWF. Section 4.5 (process SFP filters) is presented only for information and it is assumed (Assumption 3.1.3) all SFP filter change outs will be performed remotely. The installation of four trunnions is included in Task 4.1 (receive and upend a TC). A summarization of this data is presented in Tables 5 and 6.

Table 4. WHF and LLWF Hands-On Operations

Outline

Task	WHF Process	Time min	Op Dose mrem	HPT Dose mrem
4-1	Receive and upend a TC	880	29.0	24.6
4-2	Process a TC with commercial SNF	372	6.3	2.3
4-3	Process a TC with a DPC	1932	19.2	3.9
4-4	Process and export a TAD	3972	13.8	4.5
4-5	Process SFP filters	210	66.7	53.4
4-6	Process SFP spent resin	2164	28.9	13.9
4-7	Trunnion Installation (4 total)	370	6.2	5.6
Task	**LLWF Process**	Time min	Op Dose mrem	HPT Dose mrem
4-8A	Sort and Package Low Activity Dry Active Waste	180	6.9	4.6
4-8B	Sort and Package High Activity Dry Active Waste	120	7.5	1.3
4-8C	Load and Ship Dry Active Waste	90	1.9	1.3
4-9	Prepare, Package, and Ship DPC Carcasses	435	12.7	9.7
4-10A	Package HEPA Filters	100	2.9	5.3
4-10B	Load and Ship HEPA Filters	120	1.3	2.6
4-11	Store Spent Resin and Cartridge Filter HICs	165	3.4	13.4
4-12	Load and Ship Shielded Transport Casks with HICs	435	30.3	25.3

Task 4-1 Receive and upend a TC								
			Operator			HPT		
WHF Process Step [A]	Time (min) [B]	Time (hr) [C]	Distance (m) [D]	Dose Rate (mrem/hr) [E]	Single Operator Dose (mrem) [F]	Distance (m) [G]	Dose Rate (mrem/hr) [H]	Single HPT Dose (mrem) [I]
Open TC Entrance Vestibule exterior door	10	**0.17**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Move Loaded TC into TC Vestibule Entrance Vestibule	10	**0.17**	2	7.5	**1.25**	5	2.9	**0.48**
Close TC Vestibule Entrance Vestibule exterior door, and open WHF Interior Entrance Vestibule door	10	**0.17**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Move Loaded TC into Cask Prep Area & close WHF interior entrance vestibule door	15	**0.25**	2	7.5	**1.88**	5	2.9	**0.73**
Set brakes and chock rail car	25	**0.42**	2	7.5	**3.13**	2	7.5	**3.13**
Disconnect Prime Mover from parked rail car	18	**0.30**	2	7.5	**2.25**	2	7.5	**2.25**
Perform inspection and radiological survey of the loaded, incoming TC	30	**0.50**	R	0.05	**0.03**	2	7.5	**3.75**
Set up Mobile Access Platform	15	**0.25**	R	0.05	**0.01**	R	0.05	**0.01**
Partially unbolt first impact limiter	20	**0.33**	1	7.6	**2.53**	5	2.8	**0.93**
Move Cask Handling Crane (CHC) to impact limiter lifting device storage area	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**
Attach the impact limiter lifting device to CHC	15	**0.25**	R	0.05	**0.01**	R	0.05	**0.01**
Move crane to first impact limiter	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**
Attach the impact limiter lifting device to the first impact limiter	6	**0.10**	1	7.6	**0.76**	5	2.8	**0.28**
Finish unbolting first impact limiter	10	**0.17**	1	7.6	**1.27**	5	2.8	**0.47**
Clear Mobile Access Platform	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**
Lift first impact limiter and move to storage area	10	**0.17**	R	0.05	**0.01**	R	0.05	**0.01**
Lower and detach impact limiter lifting device from first impact limiter	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**

			Operator			HPT		
WHF Process Step [A]	**Time (min) [B]**	**Time (hr) [C]**	**Distance (m) [D]**	**Dose Rate (mrem/hr) [E]**	**Single Operator Dose (mrem) [F]**	**Distance (m) [G]**	**Dose Rate (mrem/hr) [H]**	**Single HPT Dose (mrem) [I]**
Move CHC back to get second impact limiter	15	**0.25**	R	0.05	**0.01**	R	0.05	**0.01**
Position Mobile Access Platform	10	**0.17**	R	0.05	**0.01**	R	0.05	**0.01**
Partially unbolt second impact limiter	20	**0.33**	1	4.3	**1.43**	5	1.7	**0.57**
Attach impact limiter lifting device to second impact limiter	6	**0.10**	1	4.3	**0.43**	5	1.7	**0.17**
Finish unbolting second impact limiter	10	**0.17**	1	4.3	**0.72**	5	1.7	**0.28**
Clear Mobile Access Platform	5	**0.08**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
Lift second impact limiter and move to storage area	10	**0.17**	R	0.05	**0.01**	R	0.05	**0.01**
Lower and detach impact limiter lifting device from second impact limiter	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**
Move CHC to impact limiter lifting device storage area	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**
Detach impact limiter lifting device from CHC	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**
Complete radiological survey of TC without impact limiters	30	**0.50**	R	0.05	**0.03**	2	7.6	**3.80**
Install cask lifting trunnions, if required	370	**6.20**	****	****	**6.2**	****	****	**5.60**
Remove Mobile Access Platform and store	20	**0.33**	R	0.05	**0.02**	R	0.05	**0.02**
Complete The radiological survey of the two impact limiters being stored	15	**0.25**	R	0.05	**0.01**	R	0.05	**0.01**
Move CHC to the cask handling yoke storage area	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**
Attach cask handling yoke to CHC	15	**0.25**	R	0.05	**0.01**	R	0.05	**0.01**
Move CHC to the upper lifting trunnions of the TC	5	**0.08**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
Engage cask handling yoke with the upper lifting trunnions of the TC	15	**0.25**	2	7.5	**1.88**	NDO	0.05	**0.01**
Move Mobile Lift to front of TC	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**

			Operator			HPT		
WHF Process Step [A]	**Time (min) [B]**	**Time (hr) [C]**	**Distance (m) [D]**	**Dose Rate (mrem/hr) [E]**	**Single Operator Dose (mrem) [F]**	**Distance (m) [G]**	**Dose Rate (mrem/hr) [H]**	**Single HPT Dose (mrem) [I]**
Remove front TC tie downs and stabilizers	20	**0.33**	2	7.5	**2.50**	5	2.9	**0.97**
Move Mobile Lift to rear of TC	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**
Remove rear TC tie downs and stabilizers	20	**0.33**	2	7.5	**2.50**	5	2.9	**0.97**
Return Mobile Lift to secure location	15	**0.25**	R	0.05	**0.01**	R	0.05	**0.01**
Upend TC on Transportation Skid	30	**0.50**	NDO	0.05	**0.03**	NDO	0.05	**0.03**
Lift TC from the carrier	5	**0.08**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
TOTALS	**880**	**14.70**			**28.98**			**24.59**

Task 4-2 Process a TC with commercial SNF								
			Operator			HPT		
WHF Process Step [A]	Time (min) [B]	Time (hr) [C]	Distance (m) [D]	Dose Rate (mrem/hr) [E]	Single Operator Dose (mrem) [F]	Distance (m) [G]	Dose Rate (mrem/hr) [H]	Single HPT Dose (mrem) [I]
Move the TC to the preparation station #1 or #2	5	**0.08**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
Cool cask interior as required *	60	**1.00**	5	0.75	**0.75**	NDO	0.05	**0.05**
Vent TC and fill with borated water *	120	**2.00**	5	0.75	**1.50**	NDO	0.05	**0.10**
Remove TC lid bolts leaving at least 4 in place*	162	**2.70**	2	1.4	**3.78**	5	0.75	**2.03**
Attach lid lifting device on TC lid	5	**0.08**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
Move the TC to the wash down area *	5	**0.08**	2	1.4	**0.12**	5	0.75	**0.06**
Wash exterior of TC	10	**0.17**	R	0.05	**0.01**	R	0.05	**0.01**
Move TC to staging shelf in pool	5	**0.08**	2	1.4	**0.12**	NDO	0.05	**0.00**
TOTALS	**372**	**6.20**			**6.28**			**2.26**

Task 4-3 Process a TC with a DPC								
			Operator			HPT		
WHF Process Step [A]	Time (min) [B]	Time (hr) [C]	Distance (m) [D]	Dose Rate (mrem/hr) [E]	Single Operator Dose (mrem) [F]	Distance (m) [G]	Dose Rate (mrem/hr) [H]	Single HPT Dose (mrem) [I]
Move cask transfer trolley to prep station #1	10	**0.17**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Move TC to the cask transfer trolley position	15	**0.25**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Secure TC into cask transfer trolley *	15	**0.25**	5	0.75	**0.19**	NDO	0.05	**0.01**
Disengage cask handling yoke from the TC trunnions *	15	**0.25**	5	0.75	**0.19**	NDO	0.05	**0.01**
Raise CHC with Cask Handling Yoke	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**
Move CHC to the cask handling yoke stand	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**
Detach the cask handling yoke from the CHC, secure in its stand	15	**0.25**	R	0.05	**0.01**	R	0.05	**0.01**
Move CHC to its secure location	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**
Move CHC to snubber block storage area	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**
Attach sling between CHC and snubber block #1	10	**0.17**	R	0.05	**0.01**	R	0.05	**0.01**
Move CHC to transfer trolley and position snubber block #1 in the transfer trolley *	15	**0.25**	2	1.4	**0.35**	NDO	0.05	**0.01**
Install and torque bolts of snubber block #1 in the transfer trolley *	20	**0.33**	2	1.4	**0.47**	NDO	0.05	**0.02**
Complete snubber block installation for remaining 3 each snubber blocks *	150	**2.50**	2	1.4	**3.50**	NDO	0.05	**0.13**
Move CHC to its secure location	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**
Perform TC gas sampling, and venting if required *	60	**1.00**	3	1.4	**1.40**	3	1.4	**1.40**
Remove up to 54 lid bolts from TC *	162	**2.70**	1	1.4	**3.78**	NDO	0.05	**0.14**
Prepare Auxiliary Crane	25	**0.42**	NDO	0.05	**0.02**	NDO	0.05	**0.02**
Set adapter on TC lid and align bolt hole pattern *	15	**0.25**	2	1.4	**0.35**	NDO	0.05	**0.01**

			Operator			HPT		
WHF Process Step [A]	**Time (min) [B]**	**Time (hr) [C]**	**Distance (m) [D]**	**Dose Rate (mrem/hr) [E]**	**Single Operator Dose (mrem) [F]**	**Distance (m) [G]**	**Dose Rate (mrem/hr) [H]**	**Single HPT Dose (mrem) [I]**
Install and torque 8 lid adapter bolts *	40	**0.67**	2	1.4	**0.93**	NDO	0.05	**0.03**
Remove TC lid and place onto lid rack	15	**0.25**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Disengage grapple adapter lifting fixture from lid grapple adapter *	5	**0.08**	2	1.4	**0.12**	NDO	0.05	**0.00**
Move auxiliary Crane to lid grapple adapter lifting fixture stand	5	**0.08**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
Disconnect grapple adapter lifting fixture from auxiliary Crane	15	**0.25**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Install shield ring	20	**0.33**	2	1.4	**0.47**	3	1.4	**0.47**
Install DPC STC lid adapter onto DPC	15	**0.25**	2	1.4	**0.35**	NDO	0.05	**0.01**
Remove shield ring	20	**0.33**	2	1.4	**0.47**	3	1.4	**0.47**
Move auxiliary Crane to secure location	5	**0.08**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
Remove upper platform	20	**0.33**	NDO	0.05	**0.02**	NDO	0.05	**0.02**
Open shield door to Cask Unloading Room	5	**0.08**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
Move transfer trolley with TC into Cask Unloading Room	30	**0.50**	5	0.75	**0.38**	NDO	0.05	**0.03**
Close shield door to Cask Unloading Room	5	**0.08**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
Move DPC STC to DPC cutting station	15	**0.25**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Fill DPC STC annulus with water	120	**2.00**	5	0.75	**1.50**	NDO	0.05	**0.10**
Remove DPC STC lid bolts	20	**0.33**	2	1.4	**0.47**	NDO	0.05	**0.02**
Remove lid from DPC STC and place on STC lid rack	15	**0.25**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Remove DPC lid adapter	15	**0.25**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Move DPC cutting machine to the DPC adapter plate stand	10	**0.17**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Attach DPC cutting machine to the DPC adapter plate	10	**0.17**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Position the DPC cutting equipment on the DPC	10	**0.17**	2	1.4	**0.23**	NDO	0.05	**0.01**
Cut DPC lid	240	**4.00**	NDO	0.05	**0.20**	NDO	0.05	**0.20**

			Operator			HPT		
WHF Process Step [A]	**Time (min) [B]**	**Time (hr) [C]**	**Distance (m) [D]**	**Dose Rate (mrem/hr) [E]**	**Single Operator Dose (mrem) [F]**	**Distance (m) [G]**	**Dose Rate (mrem/hr) [H]**	**Single HPT Dose (mrem) [I]**
Remove DPC cutting equipment and outer lid to LLW box	15	**0.25**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Detach DPC cutting machine from DPC outer lid	10	**0.17**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Position the DPC cutting machine onto the DPC inner lid/shield plug	10	**0.17**	2	1.4	**0.23**	NDO	0.05	**0.01**
Attach DPC cutting machine to DPC inner lid/shield plug and cut port covers	30	**0.50**	NDO	0.05	**0.03**	NDO	0.05	**0.03**
Remove DPC port covers and attach siphon and vent hoses to DPC ports	30	**0.50**	NDO	0.05	**0.03**	NDO	0.05	**0.03**
Cool DPC interior as required	60	**1.00**	NDO	0.05	**0.05**	NDO	0.05	**0.05**
Vent DPC and fill with borated water	120	**2.00**	5	0.75	**1.50**	NDO	0.05	**0.10**
Detach siphon and vent hoses from DPC ports	15	**0.25**	2	1.4	**0.35**	NDO	0.05	**0.01**
Cut DPC inner lid	240	**4.00**	NDO	0.05	**0.20**	NDO	0.05	**0.20**
Remove DPC cutting machine and inner lid and move to LLW box	15	**0.25**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Detach DPC cutting machine from DPC inner lid	10	**0.17**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Move DPC cutting machine to the DPC adapter plate stand	10	**0.17**	R	0.05	**0.01**	R	0.05	**0.01**
Detach DPC adapter plate from DPC cutting machine	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**
Park DPC cutting machine on DPC cutting machine stand	10	**0.17**	R	0.05	**0.01**	R	0.05	**0.01**
Position the shield plug lift adapter on the DPC shield plug	10	**0.17**	2	1.4	**0.23**	R	0.05	**0.01**
Attach the shield plug lift adapter to the DPC shield plug	10	**0.17**	2	1.4	**0.23**	NDO	0.05	**0.01**
Install DPC STC lid with a minimum of four bolts	15	**0.25**	2	1.4	**0.35**	NDO	0.05	**0.01**
Open DPC STC fill/vent port and fill remainder of STC with borated water	30	**0.50**	5	0.75	**0.38**	NDO	0.05	**0.03**

			Operator			HPT		
WHF Process Step [A]	**Time (min) [B]**	**Time (hr) [C]**	**Distance (m) [D]**	**Dose Rate (mrem/hr) [E]**	**Single Operator Dose (mrem) [F]**	**Distance (m) [G]**	**Dose Rate (mrem/hr) [H]**	**Single HPT Dose (mrem) [I]**
Move and lower DPC STC to staging shelf in pool	15	**0.25**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Wash cask handling yoke over pool and place onto stand	15	**0.25**	R	0.05	**0.01**	R	0.05	**0.01**
Attach long reach adapter and pool cask handling yoke to cask handling crane	15	**0.25**	R	0.05	**0.01**	R	0.05	**0.01**
Remove DPC STC lid bolts	20	**0.33**	R	0.05	**0.02**	R	0.05	**0.02**
Lower DPC STC to DPC station in bottom of pool	15	**0.25**	R	0.05	**0.01**	R	0.05	**0.01**
TOTALS	**1932**	**32.20**			**19.23**			**3.86**

Task 4-4 Process and export a TAD								
			Operator			HPT		
WHF Process Step [A]	**Time (min) [B]**	**Time (hr) [C]**	**Distance (m) [D]**	**Dose Rate (mrem/hr) [E]**	**Single Operator Dose (mrem) [F]**	**Distance (m) [G]**	**Dose Rate (mrem/hr) [H]**	**Single HPT Dose (mrem) [I]**
Lift TAD STC out of pool	15	**0.25**	5	0.75	**0.19**	5	0.75	**0.19**
Wash cask pool handling yoke and exterior of TAD STC over pool	10	**0.17**	3	1.4	**0.23**	NDO	0.05	**0.01**
Move TAD STC to TAD closure station	15	**0.25**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Clean up 200T crane	20	**0.33**	R	0.05	**0.02**	R	0.05	**0.02**
Open STC drain port	10	**0.17**	3	1.4	**0.23**	NDO	0.05	**0.01**
Drain STC partially	10	**0.17**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Remove TAD STC lid bolts	20	**0.33**	2	1.4	**0.47**	NDO	0.05	**0.02**
Remove TAD STC lid and place in lid rack	15	**0.25**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Attach hoses to TAD siphon and vent ports	10	**0.17**	3	1.4	**0.23**	NDO	0.05	**0.01**
Drain TAD partially and remove siphon and vent hoses	40	**0.67**	NDO	0.05	**0.03**	NDO	0.05	**0.03**
Move TAD canister welding machine to the TAD canister	15	**0.25**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Position the TAD canister welding machine on the TAD lid	10	**0.17**	2	1.4	**0.23**	NDO	0.05	**0.01**
Weld TAD inner lid	240	**4.00**	NDO	0.05	**0.20**	NDO	0.05	**0.20**
Remove TAD canister welding machine from the TAD	15	**0.25**	2	1.4	**0.35**	NDO	0.05	**0.01**
Inspect weld	100	**1.67**	NDO	0.05	**0.08**	NDO	0.05	**0.08**
Connect hoses to TAD siphon and vent ports	10	**0.17**	3	1.4	**0.23**	3	1.4	**0.23**
Drain TAD fully and remove siphon and vent hoses	40	**0.67**	3	1.4	**0.93**	NDO	0.05	**0.03**
Vacuum dry, Helium fill, Leak test TAD weld	2280	**38.00**	NDO	0.05	**1.90**	NDO	0.05	**1.90**
Move TAD canister welding machine to the TAD	15	**0.25**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Position the TAD canister welding machine on the TAD lid	10	**0.17**	2	1.4	**0.23**	NDO	0.05	**0.01**
Weld TAD siphon and vent port covers	60	**1.00**	NDO	0.05	**0.05**	NDO	0.05	**0.05**

			Operator			HPT		
WHF Process Step [A]	**Time (min) [B]**	**Time (hr) [C]**	**Distance (m) [D]**	**Dose Rate (mrem/hr) [E]**	**Single Operator Dose (mrem) [F]**	**Distance (m) [G]**	**Dose Rate (mrem/hr) [H]**	**Single HPT Dose (mrem) [I]**
Remove TAD canister welding machine from the TAD	10	**0.17**	2	1.4	**0.23**	NDO	0.05	**0.01**
Inspect TAD	40	**0.67**	NDO	0.05	**0.03**	NDO	0.05	**0.03**
Place outer lid on TAD	15	**0.25**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Move the TAD canister welding machine to the TAD and position on the TAD lid	10	**0.17**	2	1.4	**0.23**	NDO	0.05	**0.01**
Weld TAD outer lid	240	**4.00**	NDO	0.05	**0.20**	NDO	0.05	**0.20**
Remove TAD canister welding machine from the TAD	10	**0.17**	2	1.4	**0.23**	NDO	0.05	**0.01**
Inspect weld	100	**1.67**	NDO	0.05	**0.08**	NDO	0.05	**0.08**
Prepare 20T crane	20	**0.33**	R	0.05	**0.02**	R	0.05	**0.02**
Install STC lid	40	**0.67**	NDO	0.05	**0.03**	NDO	0.05	**0.03**
Bolt on STC lid with at least 4 bolts	20	**0.33**	2	1.4	**0.47**	NDO	0.05	**0.02**
Open STC drain port	5	**0.08**	3	1.4	**0.12**	3	1.4	**0.12**
Drain annulus between STC and TAD	40	**0.67**	NDO	0.05	**0.03**	NDO	0.05	**0.03**
Dry interior of TAD STC	115	**1.92**	NDO	0.05	**0.10**	NDO	0.05	**0.10**
Connect/disconnect hose	5	**0.08**	2	1.4	**0.12**	NDO	0.05	**0.00**
Close STC drain port	15	**0.25**	3	1.4	**0.35**	NDO	0.05	**0.01**
Prepare 200T crane	25	**0.42**	R	0.05	**0.02**	R	0.05	**0.02**
Move cask transfer trolley into cask preparation area	15	**0.25**	R	0.05	**0.01**	R	0.05	**0.01**
Move STC to cask transfer trolley	15	**0.25**	3	1.4	**0.35**	NDO	0.05	**0.01**
Secure STC to cask transfer trolley	15	**0.25**	3	1.4	**0.35**	NDO	0.05	**0.01**
Remove TAD STC lid bolts	20	**0.33**	2	1.4	**0.47**	NDO	0.05	**0.02**
Move STC into cask unloading room	15	**0.25**	5	0.75	**0.19**	NDO	0.05	**0.01**
Move site transporter with loaded AO out of the loading room	15	**0.25**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Perform radiological survey and inspections	30	**0.50**	3	1.4	**0.70**	3	1.4	**0.70**
Bolt on AO lid	162	**2.70**	2	1.4	**3.78**	NDO	0.05	**0.14**
Remove AO from WHF	15	**0.25**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
TOTALS	**3972**	**66.20**			**13.83**			**4.50**

Task 4-5 Process SFP filters								
			Operator			HPT		
WHF Process Step [A]	Time (min) [B]	Time (hr) [C]	Distance (m) [D]	Dose Rate (mrem/hr) [E]	Single Operator Dose (mrem) [F]	Distance (m) [G]	Dose Rate (mrem/hr) [H]	Single HPT Dose (mrem) [I]
Isolate filter train	5	**0.08**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
Prep filter train for transfer (plastic, drain, loosen top slide gate)	15	**0.25**	1	20	**5.00**	NDO	0.05	**0.01**
Move filter transfer container to above roughing filter	5	**0.08**	2	20	**1.67**	2	20	**1.67**
Position filter transfer container on top of roughing filter housing	5	**0.08**	2		**0.00**	2	20	**1.67**
Open lower filter transfer container slide gate	1	**0.02**	2	20	**0.33**	2	20	**0.33**
Open roughing filter housing slide gate	1	**0.02**	2	20	**0.33**	2	20	**0.33**
Release roughing filter	1	**0.02**	2	20	**0.33**	2	20	**0.33**
Pull filter into filter transfer container	5	**0.08**	2	20	**1.67**	2	20	**1.67**
Close lower filter transfer container slide gate	2	**0.03**	2	20	**0.67**	2	20	**0.67**
Move filter transfer container to lay down area	10	**0.17**	2	20	**3.33**	2	20	**3.33**
Place filter transfer container over HIC	5	**0.08**	2	20	**1.67**	2	20	**1.67**
Position filter transfer container on top of HIC	5	**0.08**	2	20	**1.67**	2	20	**1.67**
Open lower filter transfer container slide gate	2	**0.03**	2	20	**0.67**	2	20	**0.67**
Lower roughing filter in HIC	5	**0.08**	2	20	**1.67**	2	20	**1.67**
Replace remote tool into filter transfer container	5	**0.08**	2	20	**1.67**	2	20	**1.67**
Close lower filter transfer container slide gate	2	**0.03**	2	20	**0.67**	2	20	**0.67**
Place new roughing filter inside roughing filter housing, obtain sample	10	**0.17**	2	20	**3.33**	2	20	**3.33**
Re-seal roughing filter	1	**0.02**	2	20	**0.33**	2	20	**0.33**
Close roughing filter housing slide gate	1	**0.02**	2	20	**0.33**	2	20	**0.33**

			Operator			HPT		
WHF Process Step [A]	**Time (min) [B]**	**Time (hr) [C]**	**Distance (m) [D]**	**Dose Rate (mrem/hr) [E]**	**Single Operator Dose (mrem) [F]**	**Distance (m) [G]**	**Dose Rate (mrem/hr) [H]**	**Single HPT Dose (mrem) [I]**
Decontaminate filter transfer container	15	**0.25**	2	20	**5.00**	2	20	**5.00**
Move filter transfer container to polishing filter housing	5	**0.08**	2	20	**1.67**	2	20	**1.67**
Position filter transfer container on top of polishing filter housing	5	**0.08**	2	20	**1.67**	2	20	**1.67**
Open lower filter container slide gate	1	**0.02**	2	20	**0.33**	2	20	**0.33**
Release polishing filter	1	**0.02**	2	20	**0.33**	2	20	**0.33**
Pull filter into filter transfer container	5	**0.08**	2	20	**1.67**	2	20	**1.67**
Close lower filter transfer container slide gate	2	**0.03**	2	20	**0.67**	2	20	**0.67**
Move filter transfer container to lay down area	10	**0.17**	2	20	**3.33**	2	20	**3.33**
Place filter transfer container over HIC	5	**0.08**	2	20	**1.67**	2	20	**1.67**
Position filter transfer container on top of HIC	5	**0.08**	2	20	**1.67**	2	20	**1.67**
Open lower filter transfer container slide gate	1	**0.02**	2	20	**0.33**	2	20	**0.33**
Lower polishing filter in HIC	5	**0.08**	2	20	**1.67**	2	20	**1.67**
Replace remote tool into filter transfer container	5	**0.08**	2	20	**1.67**	2	20	**1.67**
Close lower filter transfer container slide gate	2	**0.03**	2	20	**0.67**	2	20	**0.67**
Place new polishing filter inside roughing filter housing , obtain sample	10	**0.17**	2	20	**3.33**	2	20	**3.33**
Re-seal polishing filter	1	**0.02**	2	20	**0.33**	2	20	**0.33**
Close polishing filter housing slide gate	1	**0.02**	2	20	**0.33**	2	20	**0.33**
Decontaminate filter transfer container	15	**0.25**	2	20	**5.00**	2	20	**5.00**
Test new filters	30	**0.50**	3	20	**10.00**	NDO	0.05	**0.03**
TOTALS	**210**	**3.50**			**66.67**			**53.38**

Task 4-6 Process SFP spent resin ***								
			Operator			HPT		
WHF Process Step [A]	Time (min) [B]	Time (hr) [C]	Distance (m) [D]	Dose Rate (mrem/hr) [E]	Single Operator Dose (mrem) [F]	Distance (m) [G]	Dose Rate (mrem/hr) [H]	Single HPT Dose (mrem) [I]
Receive resin cask trailer	10	**0.17**	R	0.05	**0.01**	R	0.05	**0.01**
Remove primary cask lid bolts	30	**0.50**	R	0.05	**0.03**	R	0.05	**0.03**
Remove primary cask lid and place on trailer	20	**0.33**	R	0.05	**0.02**	R	0.05	**0.02**
Remove lid from HIC and place on trailer	10	**0.17**	R	0.05	**0.01**	R	0.05	**0.01**
Install fill head	15	**0.25**	R	0.05	**0.01**	R	0.05	**0.01**
Install flex line between discharge line of fill head and dewatering pump	10	**0.17**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Install discharge line from dewatering pump and liquid waste system (or nearest liquid waste system sump).	10	**0.17**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Open discharge line valve from fill head to pump	1	**0.02**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
Start pump	2	**0.03**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
Start flow of clean service water to resin vessel	1	**0.02**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
Open discharge resin discharge valve	1	**0.02**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
Allow resin to fill HIC/Sluice as it fills/Dewater HIC as it fills with resin	60	**1.00**	NDO	0.05	**0.05**	NDO	0.05	**0.05**
Close the resin vessel discharge when resin reaches high level indicator	1	**0.02**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
Establish a by-pass of the resin vessel and use service water to rinse the resin line and fill head	30	**0.50**	NDO	0.05	**0.03**	NDO	0.05	**0.03**
When only clear water is running through resin line, allow to run until resin line is rinsed	30	**0.50**	NDO	0.05	**0.03**	NDO	0.05	**0.03**
Discontinue service water flow	1	**0.02**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
Dewater HIC per procedure	1800	**30.00**	NDO	0.05	**1.50**	NDO	0.05	**1.50**
Close dewatering discharge valve	1	**0.02**	NDO	0.05	**0.00**	NDO	0.05	**0.00**

			Operator			HPT		
WHF Process Step [A]	**Time (min) [B]**	**Time (hr) [C]**	**Distance (m) [D]**	**Dose Rate (mrem/hr) [E]**	**Single Operator Dose (mrem) [F]**	**Distance (m) [G]**	**Dose Rate (mrem/hr) [H]**	**Single HPT Dose (mrem) [I]**
Turn off pump	1	**0.02**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
Drain all lines to liquid waste systems	10	**0.17**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Disconnect all flex lines	10	**0.17**	3	9	**1.50**	3	9	**1.50**
Remove fill head	15	**0.25**	2	13	**3.25**	2	13	**3.25**
Obtain grab sample of resin (from fill head trap)	5	**0.08**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
Replace lid on HIC	10	**0.17**	2	13	**2.17**	2	13	**2.17**
Torque HIC (Remotely)	5	**0.08**	3	9	**0.75**	3	9	**0.75**
Replace primary cask lid	30	**0.50**	3	9	**4.50**	3	9	**4.50**
Replace lid bolts	30	**0.50**	1	20	**10.00**	NDO	0.05	**0.03**
Torque to specified settings	15	**0.25**	1	20	**5.00**	NDO	0.05	**0.01**
TOTALS	**2164**	**36.07**			**28.87**			**13.91**

Task 4-7 Trunnion Installation								
			Operator			HPT		
WHF Process Step [A]	**Time (min) [B]**	**Time (hr) [C]**	**Distance (m) [D]**	**Dose Rate (mrem/hr) [E]**	**Single Operat or Dose (mrem) [F]**	**Distance (m) [G]**	**Dose Rate (mrem/hr) [H]**	**Single HPT Dose (mrem) [I]**
Move CHC to Trunnions Stand	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**
Engage sling lifting device with 1st trunnion	10	**0.17**	R	0.05	**0.01**	R	0.05	**0.01**
Move CHC to TC	5	**0.08**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
Move Mobile Elevating Platform	15	**0.25**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Adjust CHC to 1st trunnion *	5	**0.08**	2	2.28	**0.19**	2	2.28	**0.19**
Bolt 1st trunnion *	30	**0.50**	2	2.28	**1.14**	2	2.28	**1.14**
Disengage sling lifting device from 1st trunnion *	5	**0.08**	2	2.28	**0.19**	NDO	0.05	**0.00**
Reposition Mobile Elevating Platform	15	**0.25**	NDO	0.05	**0.01**	NDO	0.05	**0.01**
Move CHC to Trunnions Stand	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**
Engage sling lifting device with 2nd trunnion	10	**0.17**	R	0.05	**0.01**	R	0.05	**0.01**
Move CHC to TC	5	**0.08**	NDO	0.05	**0.00**	NDO	0.05	**0.00**
Adjust CHC to 2nd trunnion *	5	**0.08**	2	2.28	**0.19**	2	2.28	**0.19**
Bolt 2nd trunnion *	30	**0.50**	2	2.28	**1.14**	2	2.28	**1.14**
Disengage sling lifting device from 2nd trunnion *	5	**0.08**	2	2.28	**0.19**	NDO	0.05	**0.00**
Move Mobile Elevating Platform to storage location	15	**0.25**	R	0.05	**0.01**	R	0.05	**0.01**
Move CHC to sling lifting device stand	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**

			Operator			HPT		
WHF Process Step [A]	**Time (min) [B]**	**Time (hr) [C]**	**Distance (m) [D]**	**Dose Rate (mrem/hr) [E]**	**Single Operat or Dose (mrem) [F]**	**Distance (m) [G]**	**Dose Rate (mrem/hr) [H]**	**Single HPT Dose (mrem) [I]**
Disengage CHC from sling lifting device	10	**0.17**	R	0.05	**0.01**	R	0.05	**0.01**
Move CHC to its storage location	5	**0.08**	R	0.05	**0.00**	R	0.05	**0.00**
TOTALS 2 Trunnions	**185**	**3.1**			**3.1**			**2.8**
TOTALS 4 Trunnions	**370**	**6.2**			**6.2**			**5.6**

Task 4-8A Sort and Package Low Activity Dry Active Waste								
			Operator			HPT		
LLWF Process Step [A]	**Time (min) [B]**	**Time (hr) [C]**	**Distance (m) [D]**	**Dose Rate (mrem/hr) [E]**	**Single Operator Dose (mrem) [F]**	**Distance (m) [G]**	**Dose Rate (mrem/hr) [H]**	**Single HPT Dose (mrem) [I]**
Receive and survey incoming bags of contaminated trash at C-Van Load Area	30	**0.50**	2	2.5	**1.25**	1	5	**2.50**
Segregate bags into high/low activity	15	**0.25**	2	2.5	**0.63**	2	2.5	**0.63**
Transfer high activity bags to Sorting Room B	15	**0.25**	2	2.5	**0.63**	5	0.5	**0.13**
Open and sort low activity bags in Sorting Room A	60	**1.00**	1	2.5	**2.50**	NDO	0.05	**0.05**
Re-bag and survey low activity trash	30	**0.50**	1	2.5	**1.25**	1	2.5	**1.25**
Load low activity trash in C-Van at C-Van Load Area	30	**0.50**	2	1.25	**0.63**	NDO	0.05	**0.03**
TOTALS	**180**	**3.00**			**6.88**			**4.58**

Frequency: Daily

Task 4-8B Sort and Package High Activity Dry Active Waste								
			Operator			HPT		
LLWF Process Step [A]	Time (min) [B]	Time (hr) [C]	Distance (m) [D]	Dose Rate (mrem/hr) [E]	Single Operator Dose (mrem) [F]	Distance (m) [G]	Dose Rate (mrem/hr) [H]	Single HPT Dose (mrem) [I]
Open and sort high activity bags in glove box	60	**1.00**	1	5	**5.00**	NDO	0.05	**0.05**
Package high activity trash as appropriate (Drum, Box, etc.) and survey	30	**0.50**	2	2.5	**1.25**	2	2.5	**1.25**
Load high activity trash in C-Van or move to a Staging Area if necessary	30	**0.50**	2	2.5	**1.25**	NDO	0.05	**0.03**
TOTALS	**120**	**2.00**			**7.50**			**1.33**

Frequency: Weekly

Task 4-8C Load and Ship Dry Active Waste								
			Operator			HPT		
LLWF Process Step [A]	Time (min) [B]	Time (hr) [C]	Distance (m) [D]	Dose Rate (mrem/hr) [E]	Single Operator Dose (mrem) [F]	Distance (m) [G]	Dose Rate (mrem/hr) [H]	Single HPT Dose (mrem) [I]
Load C-Van onto conveyance at C-Van Load Area	30	**0.50**	2	2.5	**1.25**	NDO	0.05	**0.03**
Secure load to conveyance	30	**0.50**	3	1.25	**0.63**	NDO	0.05	**0.03**
Survey conveyance	30	**0.50**	NDO	0.05	**0.03**	2	2.5	**1.25**
TOTALS	**90**	**1.50**			**1.90**			**1.30**

Frequency: 2 x Weekly

Task 4-9 Prepare, Package, and Ship DPC Carcasses								
			Operator			HPT		
LLWF Process Step [A]	Time (min) [B]	Time (hr) [C]	Distance (m) [D]	Dose Rate (mrem/hr) [E]	Single Operator Dose (mrem) [F]	Distance (m) [G]	Dose Rate (mrem/hr) [H]	Single HPT Dose (mrem) [I]
Receive and survey DPC in STC in Truck Bay	30	**0.50**	2	2.5	**1.25**	1	5	**2.50**
Use STC platform to attach DPC lid	60	**1.00**	2	2.5	**2.50**	5	0.5	**0.50**
Use overhead crane to remove Truck Bay hatch	15	**0.25**	Remote	0.05	**0.01**	Remote	0.05	**0.01**
Use crane to move DPC to Decon Room	15	**0.25**	Remote	0.05	**0.01**	NDO	0.05	**0.01**
Decon outer surfaces by most appropriate method	60	**1.00**	1	5	**5.00**	3	1.25	**1.25**
Move DPC to Packaging Area or to Staging Area as appropriate	30	**0.50**	Remote	0.05	**0.03**	NDO	0.05	**0.03**
To ship for disposal, re-align DPC to horizontal	30	**0.50**	Remote	0.05	**0.03**	NDO	0.05	**0.03**
Survey DPC for transportation	30	**0.50**	NDO	0.05	**0.03**	1	5	**2.50**
Use crane to move DPC to Truck Bay	15	**0.25**	Remote	0.05	**0.01**	NDO	0.05	**0.01**
Place DPC in open-topped C-Van	15	**0.25**	Remote	0.05	**0.01**	NDO	0.05	**0.01**
Secure DPC in C-Van	30	**0.50**	1	2.5	**1.25**	NDO	0.05	**0.03**
Use crane to load C-Van onto conveyance	30	**0.50**	2	2.5	**1.25**	NDO	0.05	**0.03**
Secure load to conveyance	30	**0.50**	2	2.5	**1.25**	5	0.5	**0.25**
Use crane to replace Truck Bay hatch	15	**0.25**	Remote	0.05	**0.01**	Remote	0.05	**0.01**
Survey conveyance	30	**0.50**	NDO	0.05	**0.03**	1	5	**2.50**
TOTALS	**435**	**7.25**			**12.66**			**9.66**

Frequency: 6 x Annually

Task 4-10A Package HEPA Filters								
			Operator			HPT		
LLWF Process Step [A]	Time (min) [B]	Time (hr) [C]	Distance (m) [D]	Dose Rate (mrem/hr) [E]	Single Operator Dose (mrem) [F]	Distance (m) [G]	Dose Rate (mrem/hr) [H]	Single HPT Dose (mrem) [I]
Receive and survey incoming bagged HEPA filters	30	**0.50**	2	2.5	**1.25**	1	5	**2.50**
Place filters into trans-portation/disposal containers (e.g., B-25 steel boxes)	30	**0.50**	2	2.5	**1.25**	5	0.5	**0.25**
Attach container lid	10	**0.17**	1	2.5	**0.42**	5	0.5	**0.08**
Survey container	30	**0.50**	NDO	0.05	**0.03**	1	5	**2.50**
TOTALS	**100**	**1.67**			**2.94**			**5.33**

Frequency: 120 x Annually

Task 4-10B Load and Ship HEPA Filters								
			Operator			HPT		
LLWF Process Step [A]	Time (min) [B]	Time (hr) [C]	Distance (m) [D]	Dose Rate (mrem/hr) [E]	Single Operat or Dose (mrem) [F]	Distance (m) [G]	Dose Rate (mrem/hr) [H]	Single HPT Dose (mrem) [I]
Move containers to Truck Bay or to Staging Area as appropriate	30	**0.50**	Remote	0.05	**0.03**	NDO	0.05	**0.03**
Load containers onto conveyance	30	**0.50**	Remote	0.05	**0.03**	NDO	0.05	**0.03**
Secure load to conveyance	30	**0.50**	2	2.5	**1.25**	NDO	0.05	**0.03**
Survey conveyance	30	**0.50**	NDO	0.05	**0.03**	1	5	**2.50**
TOTALS	**120**	**2.00**			**1.33**			**2.58**

Frequency: 12 x Annually

Task 4-11 Store Spent Resin and Cartridge Filter HICs ***								
			Operator			HPT		
LLWF Process Step [A]	Time (min) [B]	Time (hr) [C]	Distance (m) [D]	Dose Rate (mrem/hr) [E]	Single Operator Dose (mrem) [F]	Distance (m) [G]	Dose Rate (mrem/hr) [H]	Single HPT Dose (mrem) [I]
Receive shielded HIC in Truck Bay.	15	**0.25**	2	13	**3.25**	2	13	**3.25**
Survey incoming transport shield	30	**0.50**	NDO	0.05	**0.03**	1	20	**10.00**
Use overhead crane to remove Truck Bay hatch	15	**0.25**	Remote	0.05	**0.01**	NDO	0.05	**0.01**
Use crane to move shielded HIC to Packaging Area	15	**0.25**	Remote	0.05	**0.01**	NDO	0.05	**0.01**
Use crane to remove HIC from transport shield	15	**0.25**	Remote	0.05	**0.01**	NDO	0.05	**0.01**
Survey HIC	30	**0.50**	NDO	0.05	**0.03**	NDO	0.05	**0.03**
Use crane to place HIC in available Staging Room	15	**0.25**	Remote	0.05	**0.01**	NDO	0.05	**0.01**
Use crane to return transport shield to Truck Bay	15	**0.25**	Remote	0.05	**0.01**	NDO	0.05	**0.01**
Use crane to replace Truck Bay hatch	15	**0.25**	Remote	0.05	**0.01**	NDO	0.05	**0.01**
TOTALS	**165**	**2.75**			**3.38**			**13.35**

Frequency: 3 to 4 x Annually

Task 4-12 Load and Ship Shielded Transport Casks with HIC***								
			Operator			HPT		
LLWF Process Step [A]	Time (min) [B]	Time (hr) [C]	Distance (m) [D]	Dose Rate (mrem/hr) [E]	Single Operator Dose (mrem) [F]	Distance (m) [G]	Dose Rate (mrem/hr) [H]	Single HPT Dose (mrem) [I]
Receive and survey incoming empty cask in Truck Bay	30	**0.50**	NDO	0.05	**0.03**	NDO	0.05	**0.03**
Decon outer surface of cask if necessary	30	**0.50**	NDO	0.05	**0.03**	NDO	0.05	**0.03**
Remove cask tie-down cables	30	**0.50**	NDO	0.05	**0.03**	NDO	0.05	**0.03**
Use overhead crane to remove Truck Bay hatch	15	**0.25**	Remote	0.05	**0.01**	Remote	0.05	**0.01**
Use crane to move cask to Packaging Area	15	**0.25**	Remote	0.05	**0.01**	Remote	0.05	**0.01**
Unbolt cask lid	60	**1.00**	NDO	0.05	**0.05**	NDO	0.05	**0.05**
Use crane to remove cask lid	15	**0.25**	Remote	0.05	**0.01**	Remote	0.05	**0.01**
Use crane to move HIC from Staging Area	15	**0.25**	Remote	0.05	**0.01**	Remote	0.05	**0.01**
Survey HIC	30	**0.50**	NDO	0.05	**0.03**	1	20	**10.00**
Place HIC in cask	15	**0.25**	Remote	0.05	**0.01**	Remote	0.05	**0.01**
Use crane to replace cask lid	15	**0.25**	Remote	0.05	**0.01**	Remote	0.05	**0.01**
Bolt lid to cask	60	**1.00**	1	20	**20.00**	5	5	**5.00**
Use crane to move cask to Truck Bay	15	**0.25**	Remote	0.05	**0.01**	Remote	0.05	**0.01**
Load cask on conveyance	15	**0.25**	Remote	0.05	**0.01**	Remote	0.05	**0.01**
Re-attach cask tie-down cables	30	**0.50**	1	20	**10.00**	NDO	0.05	**0.03**
Use crane to replace Truck Bay hatch	15	**0.25**	Remote	0.05	**0.01**	Remote	0.05	**0.01**
Survey conveyance	30	**0.50**	NDO	0.05	**0.03**	1	20	**10.00**
TOTALS	**435**	**7.25**			**30.29**			**25.26**

Frequency: 1 to 2 x Annually

NOTES: R in columns D and G corresponds to a remote operation in 0.05 mrem/hr background (Assumption 3.2.14).

NDO in columns D and G corresponds to a no dose operation in 0.05 mrem/hr background (Assumption 3.2.14).

** Values have been rounded in the table.

*** Values from Ref. 2.2.27, Table 7.5 are used when working with an AO/STC/HIC (See Assumptions 3.1.5, and 3.2.15).

**** Total for trunnion installation, Table 4, Task 4-7 (times 2 for 4 total trunnions).

Column [A] : From Ref 2.2.6 Table 1

Column [B] : From Ref 2.2.6 Table, except for trunnion installation, Table 4, Task 4-7 (times 2 for 4 total trunnions).

Column [C] : Column [B]/60

Column [D] : From Ref 2.2.6 Table 1

Column [E] : From Table 1 (Assumption 3.2.2 and Assumption 3.2.14).

Column [F] : [C] x [E]

Column [G] : From Ref 2.2.6 Table 1

Column [H] : From Table 1 (Assumption 3.2.2 and Assumption 3.2.14).

Column [I] : [C] x [H]

Equation 1 used for [F] and [I]:

$$ED_k = \frac{t_k}{60} \times EDR_{dist}$$

Equation 2 used for the total of [F] and [I]:

$$ED_o = \sum_{k=1}^{N} ED_k$$

6.3 ANNUAL EXTERNAL EXPOSURE PER ALL OPERATIONS PER WORKER TYPE

6.3.1 WHF Annual External Exposure

The total annual external dose to a worker in the WHF for all hands-on waste processing operations is given by taking the individual doses to each worker for each set of steps and multiplying those steps total exposure by their frequency and then summing all the totals for each process. See Table 5 which follows and is contained in attachment #4, file Table-5.xls.

The HPT and WHF Operator are calculated separately. The following table illustrates the exposures to workers in the WHF performing different tasks. Per Assumption 3.2.4 the crew makeup will be 5 Operators, 1 HPT, and there will be a total of 6 crews. Per Section 4.3.2 there will be 8.4 TCs and 8.4 TADs processed annually per crew in the WHF. Per Assumption 3.1.3 there will be 34.7 SFP canister filters processed annually per crew in the WHF. Per Assumption 3.1.15 there will be 1 SFP resin change out annually. Per Assumptions 3.1.4 and 3.1.19 there will be 18 HVAC filter change outs annually per crew. Sections 6.4.2 and 6.5.2 derive the Non hands on times and exposures.

The total WHF worker dose is the sum of all hands-on operations divided by the number of crews (6, per Assumption 3.2.4) plus the total time in areas of low dose times 0.05 mrem/hr. The following table shows that an Operator in the WHF will receive a maximum annual exposure of 1.06 rem/yr and a HPT 0.687 rem/yr. The collective dose for the facility will be 36 person-rem for 6 crews of 6 people.

Table 5. WHF Yearly Worker Dose Summaries

Activity	Worker Dose per Event (mrem)		Number of events per Year	Number of workers per Event		Total Dose for Activity (person-rem)	
	Op	HPT		Op	HPT	Op	HPT
Receive and upend TC	29.0 (1)	24.6 (1)	8.4 (2)	5 (3)	1 (3)	1.218	0.207
Process a TC with SNF	6.3 (4)	2.3 (4)	8.4 (2)	5 (3)	1 (3)	0.265	0.019
Process and export TAD	13.8 (5)	4.5 (5)	8.4 (2)	5 (3)	1 (3)	0.580	0.038
Process SFP filters	10 (6)	4 (6)	34.7 (7)	5 (3)	1 (3)	1.735	0.139
Process SFP resin	28.9 (8)	13.9 (8)	1 (9)	5 (3)	1 (3)	0.145	0.014
Pool support work	26.2 (10)	26.2 (10)	8.4 (2)	5 (3)	1 (3)	1.100	0.220
HVAC filter change outs	0.17 (11)	0.17 (11)	18 (12)	5 (3)	1(3)	0.015	0.003
Non hands on work	47 (13)	47 (13)	N/A	5 (3)	1 (3)	0.235	0.047
Total Dose per Crew for Operator Type (14)						5.292	0.687
Total Dose per Crew (16)						5.98	
Total for Facility (6 Work Groups) (17)						35.9	

Notes:

(1) Table 4, Task 4-1
(2) Section 4.3.2 – 50 TADS and TCs/6 Work Crews = 8.4
(3) Assumption 3.2.4
(4) Table 4, Task 4-2.
(5) Table 4, Task 4-4.
(6) Assumption 3.1.18.
(7) Assumption 3.1.3 – 208 Filters/6 Crews = 34.7
(8) Table 4, Task 4-6.
(9) Assumption 3.1.15.
(10) Assumption 3.1.6, and Section 6.3.1 - (2 mr/hr X 110 hrs)/8.4 TADs = 26.2
(11) Assumption 3.1.7
(12) Assumption 3.1.4 and 3.1.19
(13) Sections 6.4.2 (hours derived) and 6.5.2 (dose derived)
(14) Sum of all activity doses
(15) Sum of operator doses/5operators
(16) Sum of 5 operators and 1 HPT
(17) 1 Work group times 6 total work groups.

Maximum Individual dose:

Op = (Operator total dose per crew)/(number of operators per crew) = 5.297/5 = 1.06 rem.
HPT = (HPT total dose per crew)/(number of HPT per crew) = 0.687/1 = 0.687 rem.

6.3.2 LLWF Annual External Exposure

The total annual external dose to a worker in the LLWF for all hands-on waste processing operations is given by taking the individual doses to each worker for each set of steps and multiplying those steps total exposure by their frequency and then summing all the totals for each process. See Table 6 which is contained in attachment #4, file Table-6.xls.

The following table illustrates the exposures to workers in the LLWF performing different tasks. Per Assumption 3.1.9, work crews will process low activity DAW daily in the LLWF, which is 260 work days in a year. (365 days/per/yr divided by 7 days/week or 52 weeks/yr times 5 work days/week, is 260 work days/year.) Per Assumption 3.1.11, work crews in the LLWF will process high activity DAW once a week, 52 weeks in a year, or 52 times per year. Per Assumption 3.1.12, work crews in the LLWF will load and ship DAW 2 times a week, or 52 weeks/yr times 2 times per week which is 104 times/yr. Per Assumption 3.1.13, work crews in the LLWF will process 6 empty DPCs per year for shipping and disposal. Per Assumption 3.1.14, work crews in the LLWF will process 1,457 HEPA filters per year, with 12 filters per shipping container, which equals 121 shipping containers per year going out of the LLWF in 10 containers per shipment, or 12 shipments per year. Per Assumption 3.1.15, spent resin from the WHF will be handled once a year, and per Assumption 3.1.19, 3 HICs with a minimum of 200 SFP cartridge filters will be handled in the LLWF. Per Assumption 3.1.16, work crews in the LLWF will load and export 2 shielded transport casks per year. Per Assumption 3.1.10, all liquid low-level waste (LLW) received at the LLWF will be remotely processed by a contractor-supplied liquid waste clean up system and will be appropriately reused within the Geologic Repository Operations Area (GROA).

The total LLWF worker dose is the sum of all hands-on operations divided by the number of crews (2, per Assumption 3.2.17) plus the total time in areas of low dose times 0.05 mrem/hr. The following table shows that an Operator in the LLWF will receive a maximum annual exposure of 1.52 rem/yr and a HPT 1.18 rem/yr. The collective dose for the facility will be 18 person-rem for 2 crews of 6 people.

Table 6 LLW Yearly Worker Dose Summaries

Activity	Worker Dose per Event (mrem)		Number of events per Year	Number of workers per Event		Total Dose for Activity (person-rem)	
	Op	HPT		Op	HPT	Op	HPT
Sort and package low activity dry active waste	6.9 (1)	4.6 (1)	130 (2)	5 (3)	1 (3)	4.485	0.598
Sort and package high activity dry active waste	7.5 (4)	1.3 (4)	26 (5)	5 (3)	1 (3)	0.975	0.034
Load and ship dry active waste	1.9 (6)	1.3 (6)	52 (8)	5 (3)	1 (3)	0.494	0.068
Prepare, package and ship DPC carcasses	12.7 (7)	9.7 (7)	3 (10)	5 (3)	1 (3)	0.191	0.029
Package HEPA filters	2.9 (9)	5.3 (9)	60 (11)	5 (3)	1 (3)	0.870	0.318
Load and ship HEPA filters	1.3 (12)	2.6 (12)	6 (11)	5 (3)	1 (3)	0.039	0.016
Store spent resin and cartridge filters	3.4 (13)	13.4 (13)	2 (14)	5 (3)	1 (3)	0.034	0.027
Load and ship shielded transport cask	30.3(15)	25.3(15)	1 (16)	5 (3)	1 (3)	0.152	0.025
Non hands on work	67.0(17)	67.0(17)	N/A	5 (3)	1 (3)	0.335	0.067
Total Dose per crew for Operator Type (18)						7.575	1.182
Total dose per crew (19)						8.757	
Total Dose for facility (20)						17.514	

Notes:
(1) Task 4-8A – Dose to package waste per day.
(2) Assumption 3.1.9 – (52 wks/yr X 5 days/wk)/2crews = 130 events/yr
(3) Assumption 3.2.17
(4) Task 4-8B
(5) Assumption 3.1.11 – (52 events/year)/2 crews = 26 events/yr
(6) Task 4-8C
(7) Task 4-9
(8) Assumption 3.1.12 - (2 events/wk X 52 wks/yr)/2 crews = 52 events/yr
(9) Task 4-10A
(10) Assumption 3.1.13 – (6 DPC carcass/yr)/2 crews = 3 events/yr
(11) Assumption 3.1.14, and Section 6.3.2 – (120 HEPAs/yr)/2 crews = 60 events/yr
(12) Task 4-10B
(13) Task 4-11
(14) Assumption 3.1.15 – (Process 4 times/yr)/2 crews = 2 events/yr
(15) Task 4-12
(16) Assumption 3.1.16 – (Ship 2 transport cask/yr)/2 crews = 1 event/yr
(17) Sections 6.4.2 (hours derived) and 6.5.2 (dose derived)
(18) Sum of activity doses per operator type.
(19) Sum of total doses per operator type.
(20) Total dose per crew times 2 crews.

Maximum Individual dose:

Op = (Operator total dose per crew)/(number of operators per crew) = 7.575/5 = 1.515 rem.
HPT = (HPT total dose per crew)/(number of HPT per crew) = 1.182/1 = 1.182 rem.

6.4 WORKER TIME IN CONTINUOUS ACCESS AREAS OF LOW RADIATION

6.4.1 WHF Time in Continuous Access Low Radiation Areas

The time in continuous access low radiation areas, (T_n), is equal to the annual time available (i.e., 40 hr/week × 50 weeks/year = 2,000 hr) minus the time performing manual cask/waste operations, T_o (from Table 4):

In the WHF, the total hours for occupancy above the pool bridge crane to process 1 TC/TAD is equal to the total time to perform Task 3 (862 min) Ref. 2.2.6 minus the out of water time of (372 min) or (490 min) plus the total time to perform Task 5 (4,267 min) Ref. 2.2.6 minus the out of water time of (3,972 min) or (295 min). The total in water time for 1 TC/TAD is (490 min plus 295 min or 785 min). The outside of pool hands-on time T_{oo} and in pool times T_{oi} as determined from Equation 3:

$$T_o = \sum_{k=1}^{N_C} \frac{t_k}{60} \times NP_C$$

$$T_{oo} = \frac{6{,}784 \left(\frac{\min}{TC\ /\ TAD}\right)}{60 \left(\frac{\min}{hr}\right)} \times 8.4 \left(\frac{TC\ /\ TAD}{crew\ -\ yr}\right)$$

$$= 950 \left(\frac{hrs}{yr}\right) / TC\ /\ TAD$$

and

$$T_{oi} = \frac{785\left(\frac{\min}{TC/TAD}\right)}{60\left(\frac{\min}{hr}\right)} \times 8.4\left(\frac{TC/TAD}{crew-yr}\right)$$

$$= 110\left(\frac{hrs}{yr}\right) / TC/TAD$$

and

$$T_n = 2000\left(\frac{hrs}{yr}\right) - T_o = 2000\left(\frac{hrs}{yr}\right) - 950\left(\frac{hrs}{yr}\right) - 110\left(\frac{hrs}{yr}\right) = 940\left(\frac{hrs}{yr}\right)$$

6.4.2 LLWF Time in Continuous Access Low Radiation Areas

The time in continuous access low radiation areas, (T_n), is equal to the annual time available (i.e., 40 hr/week × 50 weeks/year = 2,000 hr) minus the time performing manual cask/waste operations, T_o (from Table 4):

(From Section 6.1) For the LLWF this is equal to the total hands-on time expected to process waste, the total of Table 4 Tasks 4-8A, B, C, 5-9, 4-10A, B, 4-11, and 4.12, this total is then multiplied by those operational frequencies and is then divided by 2 crews or (667 hrs/yr see Table 6) and subtracting the total hands-on time from the annual time available (2,000 hrs/yr) calculated from Equation 3.

$$T_n = 2000\left(\frac{hrs}{yr}\right) - T_o = 2000\left(\frac{hrs}{yr}\right) - 667\left(\frac{hrs}{yr}\right) = 1334\left(\frac{hrs}{yr}\right)$$

6.5 ANNUAL EXTERNAL DOSE PER WORK CREW WORKER

6.5.1 WHF Annual External Per Worker

In the WHF, the total annual external dose, ED_g, to a worker in a work crew for all TC/TAD hands-on operations, plus spent fuel transfer machine work, SFP support work and support-only time (Assumption 3.2.14) is calculated from Equation 4:

For WHF Operator (See Table 5):

Hands on:

$$ED_g = [(49.1\frac{\text{mrem}}{\text{TC/TAD}} \times 8.4\frac{\text{TC/TAD}}{\text{yr}}) + (220 mrem/yr) + (10\frac{mrem}{filter} x 34.7\frac{filters}{yr})$$
$$+ 28.9\frac{mrem}{re\sin} + 3\frac{mrem}{HEPAs})]/1000\frac{\text{mrem}}{\text{rem}} = 1.011 person - rem$$

Non hands on:

$$ED_g = [(0.05\frac{\text{mrem}}{\text{hr}} \times 940\frac{\text{hrs}}{\text{yr}})]/1000\frac{\text{mrem}}{\text{rem}} = 0.047 person - rem$$

Total: 1.011 person-rem + 0.047 person-rem = 1.06 person-rem

For WHF HPT (See Table 5):

Hands on:

$$ED_g = [(31.4\frac{\text{mrem}}{\text{TC/TAD}} \times 8.4\frac{\text{TC/TAD}}{\text{yr}}) + (220 mrem/yr) + (4\frac{mrem}{filter} x 34.7\frac{filters}{yr})$$
$$+ 13.9\frac{mrem}{res\sin} + 3\frac{mrem}{HEPAs})]/1000\frac{\text{mrem}}{\text{rem}} = 0.640 person - rem$$

Non hands on:

$$ED_g = [(0.05 \frac{\text{mrem}}{\text{hr}} \times 940 \frac{\text{hrs}}{\text{yr}})] / 1000 \frac{\text{mrem}}{\text{rem}} = 0.047\ person - rem$$

Total: 0.639 person-rem + 0.047 person-rem = 0.687 person-rem

6.5.2 LLWF Annual External Per Worker

In the LLWF, the total annual external dose, ED_g, to a worker in a work crew for processing all waste hands-on operations and support-only time (Assumption 3.2.14) is calculated from Equation 4:

For an LLWF Operator (See Table 6):

Hands on:

$$ED_g = [(6.9 \frac{\text{mrem}}{\text{Op 4 - 8A}} \times 260 \frac{\text{Ops}}{\text{yr}}) + (7.5 \frac{\text{mrem}}{\text{Op 4 - 8B}} x52 \frac{Ops}{yr}) + (1.9 \frac{mrem}{Op\ 4-8C} x104 \frac{Ops}{yr})$$
$$+ (12.7 \frac{mrem}{Op\ 4-9} + 6 \frac{Ops}{yr}) + (2.9 \frac{mrem}{Op\ 4-10\ A} x120 \frac{Ops}{yr}) + (1.3 \frac{mrem}{Op\ 4-10\ B} x12 \frac{Ops}{yr})$$
$$+ (3.4 \frac{mrem}{Op\ 4-11} x4 \frac{Ops}{yr}) + (30.3 \frac{mrem}{Op\ 4-12} x2 \frac{Ops}{yr})] / 1000 \frac{mrem}{rem}$$
$$/ 10\ operators / crew / 2\ crews = 1.448\ person - rem$$

Non hands on:

$$ED_g = [(0.05 \frac{mrem}{hr} x1334 \frac{hrs}{yr})] / 1000 \frac{mrem}{rem} = 0.0667\ person - rem$$

Total: 1.448 person-rem + 0.0667 person-rem = 1.52 person-rem

For an LLWF HPT (See Table 6):

Hands on:

$$ED_g = [(4.6 \frac{\text{mrem}}{\text{Op 4 - 8A}} \times 260 \frac{\text{Ops}}{\text{yr}}) + (1.3 \frac{\text{mrem}}{\text{Op 4 - 8B}} x52 \frac{Ops}{yr}) + (1.3 \frac{mrem}{Op\ 4-8C} x104 \frac{Ops}{yr})$$
$$+ (9.7 \frac{mrem}{Op\ 4-9} + 6 \frac{Ops}{yr}) + (5.3 \frac{mrem}{Op\ 4-10\ A} x120 \frac{Ops}{yr}) + (2.6 \frac{mrem}{Op\ 4-10\ B} x12 \frac{Ops}{yr})$$
$$+ (13.4 \frac{mrem}{Op\ 4-11} x4 \frac{Ops}{yr}) + (25.3 \frac{mrem}{Op\ 4-12} x2 \frac{Ops}{yr})] / 1000 \frac{mrem}{rem}$$
$$10\ operators\ / 2\ crews = 1.114\ person - rem$$

Non hands on:

$$ED_g = [(0.05 \frac{mrem}{hr} x1334 \frac{hrs}{yr})] / 1000 \frac{mrem}{rem} = 0.067\ person - rem$$

Total: 1.114 person-rem + 0.067 person-rem = 1.18 person-rem

6.6 ANNUAL EXTERNAL RADIATION DOSES

6.6.1 WHF External Radiation Doses

In the WHF, the maximum estimated dose to an individual Operator is 1.06 rem per year and to an individual HPT is 0.687 rem per year. (Both numbers rounded).

In the WHF, the total annual facility external radiation dose to all workers is equal to the annual dose to a single work crew (1.06 rem/Operator/yr x 5 Operators/crew) plus the dose to 1 HPT (0.687 rem/yr), which results in (6.0 rem/crew) and then multiplied by the total number of work crews expected to be working throughout a year in the facility, 6, to obtain 36 person-rem.

6.6.2 LLWF External Radiation Doses

In the LLWF, the maximum estimated dose to an individual Operator is 1.52 rem per year and to an individual HPT is 1.18 rem per year.

In the LLWF, the total annual facility external radiation dose to all workers is equal to the annual dose to a single work crew (1.52 rem/Operator/yr x 5 Operators/crew) plus the dose to 1 HPT (1.18 rem/yr), which results in (8.78 rem/crew) and then multiplied by the total number of work crews expected to be working throughout a year in the facility, 2, to obtain 18 person-rem.

6.7 ANNUAL INHALATION AND SUBMERSION DOSES

Airborne radioactivity concentrations, and inhalation and submersion doses, are determined based on the methodology in Section 4.4. The airborne radioactivity concentration of radioactive contamination from a release of surface contamination from a rail TC is determined as a time-dependent buildup. The concentration builds up while the cask is present in the work room resulting from resuspension off the cask surface and eventually decreases after the cask leaves the work room because of the air exchange provided by the HVAC system.

All operations conducted within the WHF will involve sealed canisters contained in TCs with very low levels of surface contamination. All operations conducted within the LLWF will involve receiving various waste containers which meet other nuclear surface facilities release criteria for external surface contamination levels. The annual maximum internal and external doses to a WHF and LLWF worker due to resuspension of surface contamination on a cask are much lower than the contribution from the direct external dose for all worker categories and are therefore considered to be an insignificant contributor to the totals presented in Section 6.8 (See Attachment 1).

6.8 TEDE DOSE CALCULATION

The annual total TEDE for each worker category is calculated by summing the component doses from inhalation, submersion, and direct external radiation exposure over all isotopes considered, using Equation 10. All operations conducted within the WHF will involve sealed casks with very low levels of surface contamination. The annual maximum internal and external doses to a WHF worker due to resuspension of surface contamination on a cask are much lower than the contribution from the direct external dose for all worker categories and are therefore considered to be an insignificant contributor to the totals presented in Table 7. The annual TEDE doses by worker category are presented in Table 7 below:

Table 7. Annual TEDE Doses by Worker Category (rem/yr)

Doses from WHF Operations	**Symbol**	**Units**	**Operator**	**HPT**
External Dose	ED_g	rem/yr	1.06	0.687
Inhalation Dose (CEDE) + Submersion (DDE)	ID_g	rem/yr	2E-03	2E-03
WHF Total Annual TEDE Doses by Worker Group		rem/yr	**1.06**	**0.687**
Doses from LLWF Operations	**Symbol**	**Units**	**Operator**	**HPT**
External Dose	ED_g	rem/yr	1.52	1.18
Inhalation Dose (CEDE) + Submersion (DDE)	ID_g	rem/yr	7E-06	7E-06
LLWF Total Annual TEDE Doses by Worker Group		rem/yr	**1.52**	**1.18**

NOTES: CEDE = committed effective dose equivalent; DDE = deep dose equivalent.

7. RESULTS AND CONCLUSIONS

The results of this dose assessment calculation are summarized in Sections 6.6 and 6.8. The parameters used in the dose calculations are supported by appropriate and conservative input

data and assumptions. The calculated worker doses in Section 6.8 represent reasonable maximum results compared with the input used to derive them. The results are therefore suitable for the intended use. The uncertainties in the results are identified primarily by the worker locations and the dose rates that workers will receive, and by the duration of operations. However, the selected inputs are judged to be representative of the operating conditions.

7.0.1 From Section 6.8, the maximum estimated dose to an individual WHF worker is **1.06 rem/yr** and to an individual HPT is **0.687 rem/yr**. The WHF collective dose is **36 person-rem.**

7.0.2 From Section 6.8, the maximum estimated dose to an individual LLWF worker is **1.52 rem/yr** and to an individual HPT is **1.18 rem/yr**. The LLWF collective dose is **18 person-rem.**

These doses are in compliance with the requirements of the limit of 5 rem/yr for occupational workers (Ref. 2.3.3, Article 1201(a)(1)(i)). These estimated annual doses to WHF Operators and HPTs do not contribute to the ALARA design goal of minimizing the number of workers exposed to more than 0.5 rem/yr (Ref. 2.1.4).

7.1 REGULATIONS

The regulation applicable to worker doses is provided in 10 CFR 20, Article 1201, Ref. 2.3.3 (as specified in Ref. 2.2.18, Section 4.10.1.2):

"The licensee shall control the occupational dose to individual adults...to the following dose limits:

(1) An annual limit, which is the more limiting of:

(i) The total effective dose equivalent being equal to 5 rems (0.05 Sv); or

(ii) The sum of the deep-dose equivalent and the committed dose equivalent to any individual organ or tissue other than the lens of the eye being equal to 50 rems (0.5 Sv).

(2) The annual limits to the lens of the eye, to the skin, and to the extremities, which are:

(i) A lens dose equivalent of 15 rems (0.15 Sv); and

(ii) a shallow-dose equivalent of 50 rems (0.5 Sv)to the skin or to any extremity.

7.2 ALARA DESIGN GOALS

The ALARA design goals (Ref. 2.2.18, Section 4.10.3.3.1) for occupational workers are to ensure that individual and collective doses shall be maintained at ALARA levels during normal operations and as a result of Category 1 event sequences. Category 1 event sequences shall be included in worker dose assessments. The specific scope of work contained in this calculation covers both collective doses and individual worker doses on an annual basis, and includes

contributions from external and internal radiation from normal operations since there are no Category 1 event sequences identified in the current Categorization of Event Sequences for License Application (Ref. 2.2.28, Section 7.2) The design process shall meet the following ALARA design goals:

(1) Individual Dose:

"The ALARA design goal for individual radiation worker doses is to minimize the number of individuals that have the potential of receiving more than 500 mrem/yr TEDE. That goal is 10 % of the annual TEDE limit in 10 CFR 20.1201, and includes internal and external doses."

(2) Collective Dose:

"The ALARA design process is to ensure that the collective dose is maintained ALARA."

7.3 DISCUSSION

This worker dose estimate is based on best available estimates or projections of annual WHF and LLWF processing rates with the current throughput model and Low-Level Waste Management Plan (Ref. 2.2.21). Dose rates are based on representative cask configurations based on the WHF time and motion study.

One of the secondary uses of the dose assessment is to identify and prioritize WHF and LLWF design areas that should consider additional ALARA design features to reduce individual worker doses to achieve the ALARA goals. In this respect, attention should be focused on means by which doses to workers involved with WHF and LLWF operations can be reduced.

7.4 RECOMMENDATIONS

The results of the dose assessment presented in this document lead to the following conclusions and recommendations:

The principal contributor to the worker dose is external radiation from cask handling operations in the WHF and SFP SNF transfers. The contribution from the airborne radioactivity resuspension source is negligible. The WHF Operators and HPTs will receive the highest dose during commercial SNF movement in the SFP. The doses to the WHF and LLWF workers does not fulfill the ALARA design goal of minimizing the number of workers exposed to more than 0.5 rem per year. It is recommended that further ALARA design considerations be included in the final design to achieve the ALARA design goal.

Opportunities for external radiation dose reduction could include:

- Engineering design of additional permanent or portable shielding for higher dose operations (e.g., shielding on all of the work platforms and when transferring spent fuel)
- Using more automation (e.g., remote, mechanical equipment to remove and install lid bolts)

- Standardizing the cask/canister lid lifting fixtures on incoming canisters (e.g., TADs and DPCs) and making provisions that the lifting fixture can be kept in place and need not be removed for subsequent processing operations

- Standardizing the lifting devices (i.e., grapples, yokes, slings, etc.) so that they do not need to be manually changed out for various processing operations

- Engineering the lifting devices (i.e., grapples, yokes, slings, etc.) so they automatically, remotely and mechanically engage the lifting mechanism of any of the bridge cranes, mobile cranes, or auxiliary cranes

- Using remote radiation monitoring/surveillance techniques (e.g., radiation detector portal, long-handle detector, mechanical swiping, vacuum swipe collection, etc.)

- There are currently several locations in the country that weld shield plug lids onto containers loaded with SNF prior to being sent to an aging/storage facility. These processes are accomplished remotely and with long reach tools. Current operations at operating nuclear facilities need to be reviewed and their processes incorporated into the WHF when performing similar processes.

ATTACHMENT 1 ANNUAL INHALATION AND SUBMERSION DOSES

Airborne concentrations, and inhalation and submersion doses, are determined based on the methodology in Section 4.4. The airborne concentration of radioactive contamination from a release of surface contamination from a TC is determined as a time-dependent buildup. The concentration builds up while the cask is present in the facility resulting from resuspension off the cask surface and eventually decreases after the cask leaves the facility because of the air exchanges provided by the HVAC system.

Surface Contamination Available for Resuspension

The amount of radioactive contamination on the surface of a cask is a function of the assumed contamination level, the radioisotopes present, and the surface area covered by contamination.

Per Assumption 3.2.12, surface contamination is assumed to cover the entire external surface of the TC, and is assumed to be removable and releasable to the room's atmosphere.

Surface Area = $2\pi r^2 + 2\pi rh$ or $(2 \times 3.1416 \times 50^2) + (2 \times 3.1416 \times 50 \times 200) = 78{,}540\ in^2$

$78{,}540\ in^2 \times 0.0254^2\ (cm^2) = 50.67\ m^2$ rounded to $51\ m^2$.

The external surface area of a cask is $51\ m^2$ per Assumption 3.2.12.

Per Assumption 3.2.8, the non-fixed (removable) radioactive contamination on the external surface of a TC is $10^{-4}\ \mu Ci/cm^2$ for beta and gamma emitters, and low-toxicity alpha emitters, and $10^{-5}\ \mu Ci/cm^2$ for all other alpha emitters. Therefore, the amount of activity available to be released from the cask surface is:

$$S_{\beta\gamma} = 10^{-4}\left(\mu Ci/cm^2\right) \times 5.1\times10^5\ \left(cm^2\right) = 51\ \mu Ci$$

and

$$S_{\alpha} = 10^{-5}\left(\mu Ci/cm^2\right) \times\ 5.1\times10^5\ \left(cm^2\right) = 5.1\ \mu Ci$$

Per Assumption 3.2.11, four radioisotopes are considered to dominate the doses resulting from airborne contamination: ^{60}Co, ^{90}Sr, ^{239}Pu, and ^{241}Am. ^{60}Co and ^{90}Sr are beta/gamma emitters, and ^{239}Pu and ^{241}Am are primarily alpha emitters.

Airborne Concentration Buildup

While in the WHF, the radioactive contamination resuspended off the TC surface would be dispersed within the free air volume of the Cask Preparation Area and Pool Room. The maximum time the cask could be present would be equal to the total cask processing time prior to going into the SFP, a comparison of a TC loaded with commercial SNF and a TC loaded with a DPC follows. Table 4 Tasks 4.1 (880 min) plus 4.2 (372 min) resulting in a total time of 1252 minutes for a TC loaded with commercial SNF, and for a TC loaded with a DPC the time is equal to the total of Table 4 Tasks 4.1 (880 min) plus 4.3 (1932 min) resulting in a total time of 2812 minutes.

While in the LLWF, the radioactive contamination resuspended off a STC/DPC surface would be dispersed within the free air volume of the packaging area and adjacent open areas. The maximum time the STC/DPC could be present would be equal to the total STC/DPC processing time prior to going into decontamination (180 minutes). From Table 4 Task 4-9.

The WHF and LLWF ventilation fresh air intake rate, λ_H, is the product of the HVAC air exchange rate, 1 hr^{-1}, and the outside air fraction, 10% per Assumptions 3.1.1 and 3.1.8. Thus,

$$\lambda_H = 1\ hr^{-1} \times 10\% = 0.1\ hr^{-1}$$

In the WHF, the buildup of airborne radioactivity concentration in the cask handling area is determined from Equation 6 with t_B equal to infinity and λ_R, the surface contamination resuspension rate, equal to 4×10^{-5} hr^{-1} per Assumption 3.2.9. 10% of the volume of the Cask Preparation Area and Pool Room is 4,594 m^3 per Assumption 3.1.1.

The calculation for airborne concentration at equilibrium is:

$$C_i(\infty) = \frac{\lambda_R S_i}{\lambda_H V_B}\left(1 - e^{-\lambda_H \infty}\right) = \frac{\lambda_R S_i}{\lambda_H V_B} = \frac{4\times10^{-5}\left(hr^{-1}\right) S_i\ (\mu Ci)}{0.1\left(hr^{-1}\right) \times\ 4{,}594\left(m^3\right)} = 8.7\times10^{-8}\left(m^{-3}\right) \times\ S_i\ (\mu Ci)$$

Therefore, airborne concentration at equilibrium for beta and gamma emitters and low-toxicity alpha emitters and for all other alpha emitters based on the surface activity is:

$$C_{\beta\gamma}(\infty) = 8.7\times10^{-8}\left(m^{-3}\right)\times S_{\beta\gamma}\ (\mu Ci) = \ 8.7\times10^{-8}\ \left(m^{-3}\right)\times\ 51\ \mu Ci = 4.4\times10^{-6}\left(\mu Ci/m^3\right)$$

and

$$C_{\alpha}(\infty) = 8.7\times10^{-8}\left(m^{-3}\right)\times S_{\alpha}\ (\mu Ci) = \ 8.7\times10^{-8}\left(m^{-3}\right)\times\ 5.1\ \mu Ci = 4.4\times10^{-7}\left(\mu Ci/m^3\right)$$

In the LLWF, the buildup of airborne radioactivity concentration in the packaging and adjacent areas is determined from Equation 6 with t_B equal to infinity and λ_R, the surface contamination resuspension rate, equal to 4×10^{-5} hr^{-1} per Assumption 3.2.9. The volume of the packaging and adjacent areas is 25,314 m^3 per Assumption 3.1.8.

The calculation for airborne concentration at equilibrium is:

$$C_i(\infty) = \frac{\lambda_R S_i}{\lambda_H V_B}\left(1 - e^{-\lambda_H \infty}\right) = \frac{\lambda_R S_i}{\lambda_H V_B} = \frac{4\times10^{-5}\left(hr^{-1}\right) S_i\ (\mu Ci)}{0.1\left(hr^{-1}\right) \times\ 25{,}314\left(m^3\right)} = 1.6\times10^{-8}\left(m^{-3}\right) \times\ S_i\ (\mu Ci)$$

Therefore, airborne concentration at equilibrium for beta and gamma emitters and low-toxicity alpha emitters and for all other alpha emitters based on the surface activity is:

$$C_{\beta\gamma}(\infty) = 8.7\times10^{-9}\left(m^{-3}\right)\times S_{\beta\gamma}\ (\mu Ci) = 1.6\times10^{-8}\ \left(m^{-3}\right)\times\ 51\ \mu Ci = 8.2\times10^{-7}\left(\mu Ci/m^3\right)$$

and

$$C_{\alpha}(\infty) = 8.7\times10^{-9}\left(m^{-3}\right)\times S_{\alpha}\ (\mu Ci) = 1.6\times10^{-8}\left(m^{-3}\right)\times\ 5.1\ \mu Ci = 8.2\times10^{-8}\left(\mu Ci/m^3\right)$$

Worker Inhalation and Submersion Doses per Cask

The inhalation and submersion doses to a worker resulting from resuspension of contamination from a single cask for a duration of t_k minutes is determined from Equation 7:

$$H_k^{inh} = \sum_i C_i\left(t\ \right)\times DCF_i^{inh}\times 3.7\times10^9\times RF\times BR\times t_k\times 60$$

$$H_k^{sub} = \sum_i C_i\left(t\ \right)\times DCF_i^{sub}\times 3.7\times10^9\times t_k\times 60$$

WHF: For the WHF, The total time expected to process a single rail TC in the WHF Cask Preparation Area with either commercial SNF or a DPC follows:

Process time for 1 TC loaded with commercial SNF into the facility and into the SFP is 1252 min, total from airborne concentration buildup p.69.

Process time for 1 TC loaded with a DPC into the facility and into the SFP is 2812 min, total from airborne concentration buildup p.69.

The exposure duration t_k is conservatively taken as the total cask processing time from entering the WHF to being placed in the SFP. Per Assumption 3.2.10, the respirable fraction, WHF, is 1. The breathing rate, BR, is 3.33×10^{-4} m^3/s per Assumption 3.2.13.

The total inhalation and submersion dose, ID_o, to a worker for all cask processing tasks resulting from the presence of airborne activity is determined from Equation 8 with $N = 1$ because the exposure duration t_k is conservatively taken as the total cask processing time and includes all tasks:

$$ID_o = \left(H_k^{inh} + H_k^{sub}\right)$$

The results of applying Equations 7 and 8 to determine ID_o (mrem/cask) are given in the following tables below which are contained in attachment #4, files Inhalation8-9.xls, Inhalation10-11.xls, and Inhalation12-13.xls). Per Assumption 3.2.11, the dominant beta/gamma-emitting isotopes are ^{60}Co and ^{90}Sr, and the dominant alpha-emitting isotopes are ^{239}Pu and ^{241}Am. The effective inhalation and submersion DCFs for these isotopes are given in Assumption 3.2.11. The dose per cask due to inhalation and submersion is conservatively taken as the sum of the calculated ^{60}Co, ^{90}Sr, ^{239}Pu, and ^{241}Am doses. The doses are then summed to estimate the total inhalation and submersion dose, ID_o, to a worker in group g for all the cask processing tasks. The following calculations evenly distribute the total activity present between the two dominant beta/gamma-emitting isotopes and two dominant alpha-emitting isotopes.

When multiple solubility classes where available, the most restrictive value was used in the calculation.

Table 8. TC with commercial SNF Inhalation and Submersion Doses FGR 11 and FGR 12.

	$C_{\beta-\gamma}$ or C_α	DCF^{inh}	H^{inh}	DCF^{sub}	H^{sub}	ID_o
Isotope	**(μCi/m^3)**	**(Sv/Bq)**	**(mrem/cask)**	**(Sv/Bq-s-m^{-3})**	**(mrem/cask)**	**(mrem/cask)**
^{60}Co	2.20E-06	5.91E-08	2.01E-04	1.26E-13	1.29E-06	2.02E-04
^{90}Sr	2.20E-06	3.51E-07	1.19E-03	7.53E-18	7.69E-11	1.19E-03
^{239}Pu	2.20E-07	1.16E-04	3.94E-02	4.24E-18	4.33E-12	3.94E-02
^{241}Am	2.20E-07	1.20E-04	4.08E-02	8.18E-16	8.35E-10	4.08E-02
			Max ID_o $(\beta-\gamma)$ +Max ID_o (α) =			8.16E-02

Sources: Refs. 2.2.10 and 2.2.12

Table 9. TC with commercial SNF Inhalation and Submersion Doses ICRP-68 and FGR 13.

	$C_{\beta-\gamma}$ or C_α	DCF^{inh}	H^{inh}	DCF^{sub}	H^{sub}	ID_o
Isotope	**(μCi/m^3)**	**(Sv/Bq)**	**(mrem/cask)**	**(Sv/Bq-s-m^{-3})**	**(mrem/cask)**	**(mrem/cask)**
^{60}Co	2.20E-06	2.90E-08	9.86E-05	1.19E-13	1.21E-06	9.98E-05
^{90}Sr	2.20E-06	1.50E-07	5.10E-04	9.83E-17	1.00E-09	5.10E-04
^{239}Pu	2.20E-07	4.70E-05	1.60E-02	3.49E-18	3.56E-12	1.60E-02
^{241}Am	2.20E-07	3.90E-05	1.33E-02	6.77E-16	6.91E-10	1.33E-02
			Max ID_o $(\beta-\gamma)$ +Max ID_o (α) =			2.98E-02

Sources: Refs. 2.2.13 and 2.2.14

Table 10. TC with DPC Inhalation and Submersion Doses FGR 11 and FGR 12.

	$C_{\beta-\gamma}$ or C_α	DCF^{inh}	H^{inh}	DCF^{sub}	H^{sub}	ID_o
Isotope	**(μCi/m^3)**	**(Sv/Bq)**	**(mrem/cask)**	**(Sv/Bq-s-m^{-3})**	**(mrem/cask)**	**(mrem/cask)**
^{60}Co	2.20E-06	5.91E-08	4.51E-04	1.26E-13	2.89E-06	4.54E-04
^{90}Sr	2.20E-06	3.51E-07	2.68E-03	7.53E-18	1.72E-10	2.68E-03
^{239}Pu	2.20E-07	1.16E-04	8.85E-02	4.24E-18	9.71E-12	8.85E-02
^{241}Am	2.20E-07	1.20E-04	9.15E-02	8.18E-16	1.87E-09	9.15E-02
			Max ID_o $(\beta-\gamma)$ +Max ID_o (α) =			1.83E-01

Sources: Refs. 2.2.10 and 2.2.12

Table 11. TC with DPC Inhalation and Submersion Doses ICRP-68 and FGR 13.

	$C_{\beta-\gamma}$ or C_α	DCF^{inh}	H^{inh}	DCF^{sub}	H^{sub}	ID_o
Isotope	**(μCi/m^3)**	**(Sv/Bq)**	**(mrem/cask)**	**(Sv/Bq-s-m^{-3})**	**(mrem/cask)**	**(mrem/cask)**
^{60}Co	2.20E-06	2.90E-08	2.21E-04	1.19E-13	2.73E-06	2.24E-04
^{90}Sr	2.20E-06	1.50E-07	1.14E-03	9.83E-17	2.25E-09	1.14E-03
^{239}Pu	2.20E-07	4.70E-05	3.59E-02	3.49E-18	7.99E-12	3.59E-02
^{241}Am	2.20E-07	3.90E-05	2.97E-02	6.77E-16	1.55E-09	2.97E-02
			Max ID_o $(\beta-\gamma)$ +Max ID_o (α) =			6.70E-02

Sources: Refs. 2.2.13 and 2.2.14

Although many of the biokinetic and dosimetric models used in FGR 13 are updates of models used in FGR 11, the present report does not replace either that document or FGR 12 or affect their use for radiation protection purposes. The dose coefficients given in FGR 11 and FGR 12 continue to be recommended for determining conformance with radiation protection guidance to Federal agencies. The values cited for submersion from FGR 13 are the submersion values from FGR 12 with the ICRP 60 weighting factors applied to them and can be found in the FGR 13 (Ref. 2.2.14) supplement CD Table F12TIII1.

Using FGR 11 (Ref. 2.2.10) and FGR 12 (Ref. 2.2.12) with the TC loaded with a DPC values result in a higher and more conservative exposure estimate of 1.83E-01 mrem/cask, and will be used to calculate the total annual inhalation and submersion doses in the WHF.

The total annual inhalation and submersion dose, ID_g, to a worker in a work crew for all operations is determined from Equation 9 with the total number of operations, OP, equal to the number of casks processed per year of 50 TC/TADs (Assumption 3.2.7) and the number of work crews, $crews_g$, in the cask operations group of 6 work crews (Assumption 3.2.4).

$$ID_g = \sum_o ID_o \times \frac{OP}{crews_g} = 1.83\times10^{-1}\left(\frac{mrem}{cask}\right)\times\frac{50\left(\frac{casks}{yr}\right)}{6} = 1.5\left(\frac{mrem}{yr}\right)$$

This dose of 1.5 mrem/yr is applied to both the Operator and the HPT because they are present in the Cask Preparation Area during cask processing.

The total annual inhalation and submersion dose (1.5 mrem/yr) is shown to be insignificant compared to the overall TEDE of 1.06 rem/yr (in Table 7 of section 6.8).

LLWF: For the LLWF, the total time expected to process a single DPC in the LLWF packaging area and adjacent areas is as follows:

Process time for one STC loaded with an empty DPC into the facility and into the decontamination area is 180 min. From Table 5 Section 5-9.

The exposure duration, t_k, is conservatively taken as the total STC/DPC processing time from entering the LLWF to being decontaminated. Per Assumption 3.2.10, the respirable fraction, is 1. The breathing rate, BR, is 3.33×10^{-4} m^3/s, per Assumption 3.2.13.

The total inhalation and submersion dose, ID_o, to a worker for all STC/DPC processing tasks resulting from the presence of airborne activity is determined from Equation 8 with $N = 1$ because the exposure duration t_k is conservatively taken as the total STC/DPC processing time and includes all tasks:

$$ID_o = \left(H_k^{inh} + H_k^{sub}\right)$$

The results of applying Equations 7 and 8 to determine ID_o (mrem/cask) are given in the following tables. Per Assumption 3.2.11, the dominant beta/gamma-emitting isotopes are ^{60}Co and ^{90}Sr, and the dominant alpha-emitting isotopes are ^{239}Pu and ^{241}Am. The effective inhalation and submersion DCFs for these isotopes are given in Assumption 3.2.11. The dose per cask due to inhalation and submersion is conservatively taken as the sum of the calculated ^{60}Co, ^{90}Sr,

^{239}Pu, and ^{241}Am doses. The doses are then summed to estimate the total inhalation and submersion dose, ID_o, to a worker in group g for all the cask processing tasks. The following calculations evenly distribute the total activity present between the two dominant beta/gamma-emitting isotopes and two dominant alpha-emitting isotopes. When multiple solubility classes where available, the most restrictive value was used in the calculation.

Table 12. STC/DPC Inhalation and Submersion Doses FGR 11 and FGR 12.

	$C_{\beta-\gamma}$ or C_α	DCF^{inh}	H^{inh}	DCF^{sub}	H^{sub}	ID_o
Isotope	**(μCi/m^3)**	**(Sv/Bq)**	**(mrem/cask)**	**(Sv/Bq-s-m^{-3})**	**(mrem/cask)**	**(mrem/cask)**
^{60}Co	4.10E-07	5.91E-08	5.37E-06	1.26E-13	3.44E-08	5.41E-06
^{90}Sr	4.10E-07	3.51E-07	3.19E-05	7.53E-18	2.06E-12	3.19E-05
^{239}Pu	4.10E-08	1.16E-04	1.05E-03	4.24E-18	1.16E-13	1.05E-03
^{241}Am	4.10E-08	1.20E-04	1.09E-03	8.18E-16	2.23E-11	1.09E-03
			Max ID_o $(\beta-\gamma)$ +Max ID_o (α) =			2.18E-03

Sources: Refs. 2.2.10 and 2.2.12

Table 13. STC/DPC Inhalation and Submersion Doses ICRP-68 and FGR 13.

	$C_{\beta-\gamma}$ or C_α	DCF^{inh}	H^{inh}	DCF^{sub}	H^{sub}	ID_o
Isotope	**(μCi/m^3)**	**(Sv/Bq)**	**(mrem/cask)**	**(Sv/Bq-s-m^{-3})**	**(mrem/cask)**	**(mrem/cask)**
^{60}Co	4.10E-07	2.90E-08	2.64E-06	1.19E-13	3.25E-08	2.67E-06
^{90}Sr	4.10E-07	1.50E-07	1.36E-05	9.83E-17	2.68E-11	1.36E-05
^{239}Pu	4.10E-08	4.70E-05	4.27E-04	3.49E-18	9.53E-14	4.27E-04
^{241}Am	4.10E-08	3.90E-05	3.55E-04	6.77E-16	1.85E-11	3.55E-04
			Max ID_o $(\beta-\gamma)$ +Max ID_o (α) =			7.98E-04

Sources: Refs. 2.2.13 and 2.2.14

Although many of the biokinetic and dosimetric models used in FGR 13 are updates of models used in FGR 11, the present report does not replace either that document or FGR 12 or affect their use for radiation protection purposes. The dose coefficients given in FGR 11 and FGR 12 continue to be recommended for determining conformance with radiation protection guidance to Federal agencies. The values cited for submersion from FGR 13 are the submersion values from FGR 12 with the ICRP 60 weighting factors applied to them and can be found in the FGR 13 (Ref. 2.2.14) supplement CD Table F12TIII1.

Using FGR 11 (Ref. 2.2.10) and FGR 12 (Ref. 2.2.12) values result in a higher and more conservative exposure estimate of 2.18E-03 mrem/STC/DPC, and will be used to calculate the total annual inhalation and submersion doses in the LLWF.

The total annual inhalation and submersion dose, ID_g, to a worker in a work crew for all operations is determined from Equation 9 with the total number of Operations, *OP*, equal to the number of casks processed per year of 6 STC/DPCs (Assumption 3.1.13) and the number of work crews, $crews_g$, in the LLWF is 2 work crews (Assumption 3.2.20).

$$ID_g = \sum_o ID_o \times \frac{OP}{crews_g} = 2.18\times10^{-3}\left(\frac{mrem}{cask}\right)\times\frac{6\left(\frac{casks}{yr}\right)}{2} = 6.5E-03\left(\frac{mrem}{yr}\right)$$

This dose of 0.007 mrem/yr is applied to both the Operator and the HPT because they are present in the Cask Preparation Area during cask processing.

The total annual inhalation and submersion dose (0.007 mrem/yr) is shown to be insignificant compared to the overall TEDE of 1.52 rem/yr (in Table 7 of section 6.8).

ATTACHMENT 2 ANNUAL COLLECTIVE DOSES PER CASK TYPE

The following tables, 14, 15, and 16 were prepared to illustrate the variation of dose resulting from processing different type casks. Per assumption 3.2.15 it is assumed that there will be 50 TC/TAD processed annually in the WHF, or 8.4 TC/TAD per work crew. The rail based TC loaded with commercial SNF is the model used for the total worker dose and annual facility dose. It can be noted that the use of a TC loaded with a DPC is a slightly higher dose per TC, but, the frequency of processing this configuration of TC is very small compared to the rail, bare SNF model. Use of the truck based TC is a primary purpose of the WHF (Ref 2.2.29 Section 5.1), but resulted in an exposure 5.25 times higher on front end operations (A TAD holds 21 PWR SNF assemblies, a rail, bare SNF TC has on average 21 assemblies in it, a truck TC has 4 PWR assemblies. It will take 21/4, or, 5.25 truck TCs to fill 1 TAD), and 4 times higher overall and would not be able to make the 50 TAD output for the WHF (Ref. 2.2.4, Table 4), (The total dose per crew to process 8.4 full TADs per year by receiving truck TCs, 8.346 rem, divided by the total dose per crew to process 8.4 full TADs per year by receiving rail, bare SNF, of 2,062, or, 4). Any additional TCs processed with a DPC would decrease the overall throughput of the facility and therefore decrease the overall exposure. An all DPC throughput of 33 DPCs (Ref. 2.2.4, Table 6, maximum annual) would generate only 40 TADs (Ref. 2.2.4, Table 4, maximum annual). The use of the truck based TC would not be ALARA compared to the rail based TC processing.

Table 14 Process Rail TC with bare SNF

Activity	Worker Dose per Event (mrem)		Number of events per Year	Number of workers per Event		Total Dose for Activity (person-rem)	
	Op	HPT		Op	HPT	Op	HPT
Receive and upend TC	29.0 (1)	24.6 (1)	8.4 (2)	5 (3)	1 (3)	1.218	0.207
Process a TC with SNF	6.3 (4)	2.3 (4)	8.4 (2)	5 (3)	1 (3)	0.265	0.019
Process and export TAD	13.8 (5)	4.5 (5)	8.4 (2)	5 (3)	1 (3)	0.580	0.038
Total Dose per Crew for Operator Type (sum of activity dose per worker type)						**2.062**	**0.264**
Total Dose per Crew (sum of OP and HPT collective dose)						**2.326**	
Total Facility collective dose (6 Work Groups)						**13.956**	

Table 15 Process Rail TC with DPC

Activity	Worker Dose per Event (mrem)		Number of events per Year	Number of workers per Event		Total Dose for Activity (person-rem)	
	Op	HPT		Op	HPT	Op	HPT
Receive and upend TC	29.0 (1)	24.6 (1)	8.4 (2)	5 (3)	1 (3)	1.218	0.207
Process TC with DPC	19.2 (6)	3.9 (6)	8.4 (2)	5 (3)	1 (3)	0.806	0.033
Process and export TAD	13.8 (5)	4.5 (5)	8.4 (2)	5 (3)	1 (3)	0.580	0.038
Total Dose per Crew for Operator Type (sum of activity dose per worker type)						**2.604**	**0.277**
Total Dose per Crew (sum of OP and HPT collective dose)						**2.881**	
Total Facility collective dose (6 Work Groups)						**17.287**	

Table 16 Process Truck TC with bare SNF

Activity	Worker Dose per Event (mrem)		Number of events per Year	Number of workers per Event		Total Dose for Activity (person-rem)	
	Op	HPT		Op	HPT	Op	HPT
Receive and upend TC	29.0 (1)	24.6 (1)	44 (7)	5 (3)	1 (3)	6.38	1.082
Process TC with SNF	6.3 (4)	2.3 (4)	44 (7)	5 (3)	1 (3)	1.386	0.101
Process and export TAD	13.8 (5)	4.5 (5)	8.4 (2)	5 (3)	1 (3)	0.580	0.038
Total Dose per Crew for Operator Type (sum of activity dose per worker type)						**8.346**	**1.221**
Total Dose per Crew (sum of OP and HPT collective dose)						**9.567**	
Total Facility collective dose (6 Work Groups)						**57.402**	

Notes:

(1) Table 4, Task 4-1
(2) Assumption 3.2.7 – 50 TADS/6 Work Crews = 8.4
(3) Assumption 3.2.4
(4) Table 4, Task 4-2.
(5) Table 4, Task 4-4.
(6) Table 4, Task 4-3.
(7) A truck TC with SNF can only carry 4 fuel bundles compared to a rail TC that can carry 21 fuel bundles. Therefore, it will take 5.25 more shipments of truck TCs to deliver the same amount of fuel as a rail TC (5.25 X 8.4 = 44)
(8) These totals do not include pool support work or non hands on time.

ATTACHMENT 3 LIST OF FILES ON ATTACHED CD (ATTACHMENT 4)

All Microsoft® Excel spreadsheets used to calculate input values or to display the results in graphical or tabular form are included on the CD Attachment 4, Volume Attachment4.

Directory: CD\Excel, Attachment 4

Date	Time	File Size (bytes)	File Name
10/13/2007	2:10 pm	18,000	Inhalation8-9.xls
10/13/2007	2:13 pm	18,000	Inhalation10-11.xls
10/03/2007	10:58 am	18,000	Inhalation12-13.xls
10/09/2007	09:17 am	24,000	Table4-1.xls
10/03/2007	11:05 am	18,000	Table4-2.xls
10/03/2007	11:05 am	31,000	Table4-3.xls
10/03/2007	11:05 am	26,000	Table4-4.xls
08/21/2007	1:53 pm	24,000	Table4-5.xls
10/03/2007	3:32 pm	22,000	Table4-6.xls
10/11/2007	12:11 pm	18,000	Table4-7.xls
10/03/2007	3:25 pm	68,000	Table4-8-12.xls
10/10/2007	1:32 pm	16,000	Table-5.xls
10/10/2007	1:57 pm	17,000	Table-6.xls
10/11/2007	8:09 am	19,000	Attachment 2.xls

BSC	Calculation/Analysis Change Notice *Complete only applicable items.*	1. QA: QA 2. Page 1 of 19

3. Document Identifier:	4. Rev.:	5. CACN:
050-00C-WH00-00200-000	00A	001

6. Title:
Wet Handling Facility and Low Level Waste Facility Worker Dose Assessment

7. Reason for Change:
This CACN is being issued to resolve CR# 13047

- As shown in the following unit analysis, in order for the units of t_k to cancel out they have to be in minutes.

$$H_k^{inh} = \sum C_i\left(\frac{\mu Ci}{m^3}\right) \times DCF_i\left(\frac{Sv}{Bq}\right) \times 3.7\times10^9\left(\frac{mrem-Bq}{Sv-\mu Ci}\right) \times 1\times3.33\times10^{-4}\left(\frac{m^3}{\sec}\right) \times t_k \times \left(\frac{60\sec}{\min}\right)$$

$$H_k^{sub} = \sum C_i\left(\frac{\mu Ci}{m^3}\right) \times DCF_i\left(\frac{Sv-m^3}{Bq-\sec}\right) \times 3.7\times10^9\left(\frac{mrem-Bq}{Sv-\mu Ci}\right) \times t_k \times \left(\frac{60\sec}{\min}\right)$$

  In the worker inhalation and submersion dose calculation the cask process time (t_k) was calculated in hours which resulted in inhalation and submersion dose values being reported a factor of 60 lower.

- In the Max ID_o calculation, an even distribution of the isotopic mix was assumed. By definition, Max ID_o refers to the largest single dose contributor for the isotopes of concern in each group (i.e., beta or alpha emitters). Assuming an even distribution of the isotopic mix will underestimate the inhalation and submersion dose.

- The instantaneous fraction removed (λ_H) was revised from 0.1 to 1. This value is still conservative, and more consistent with nuclear facility HVAC designs. The previous value only took into account a 10% infiltration of outside air with no consideration of total air exhausted from the cask preparation room resulting in infiltration of air from other spaces. Adjusting λ_H from 0.1 to 1 results in a peak airborne activity concentration a factor of 10 lower.

- An additional calculation was added to show the facility dose consequence of the inhalation and submersion dose for ICRP68 and FGR 13 on an annual basis so it can be used for comparative purposes when summing internal and external doses. The previous calculation only calculated this dose on a per cask basis.

There was no impact from these changes on the previously reported individual or collective facility doses for the WHF and LLWF.

8. Supersedes Change Notice: ☐ Yes If, Yes, CACN No.: _____ ☒ No

9. Change Impact:

Inputs Changed:	☐ Yes	☒ No	Results Impacted:	☐ Yes	☒ No
Assumptions Changed:	☒ Yes	☐ No	Design Impacted:	☐ Yes	☒ No

10. Description of Change:
Replacement pages for the affected calculation are provided with this CACN in order to more clearly show the changes made by this CACN. Changes were made on the following pages:

Page 12

- Changed Assumption 3.1.1 and the first paragraph of the rationale to read:

3.1.1 WHF - Instantaneous Fraction Removed (λ_H) and Airborne Activity Volume

Assumption: λ_H is assumed to be equal to 1.

Rationale: λ_H is calculated by taking the sum of all infiltration sources into the space and dividing by the space volume which is defined as the instantaneous room turn over rate. A typical nuclear heating, ventilation and air-conditioning (HVAC) system for a nuclear facility has a room turnover rate greater than 1. Therefore, using a value of 1 for λ_H is conservative and appropriate for this level of design.

The room volume of the Cask Preparation Area and the Pool Room is estimated from Ref. 2.2.1, 2.2.2 and 2.2.3. The airborne activity volume used to calculate the airborne activity concentration is conservatively chosen to be 10% of the room volume because it conservatively estimates the airborne concentration in the vicinity of the cask. 10% of the room volume equates to 4,594 m^3. The room volume is calculated as follows:

Pages 14 and 15

- Changed Assumption 3.1.8 and first two sentences of the rationale to read:

  3.1.8 LLWF - Instantaneous Fraction Removed (λ_H)

  Assumption - λ_H is assumed to be equal to 1.

  Rationale - λ_H is calculated by taking the sum of all infiltration sources into the space and dividing by the space volume which is defined as the instantaneous room turn over rate. A typical nuclear heating, ventilation and air-conditioning (HVAC) system for a nuclear facility has a room turnover rate greater than 1. Therefore, using a value of 1 for λ_H is conservative and appropriate for this level of design.

Page 31

- Changed definition of $crews_g$ in Equation 9 from "number of workers in a work crew performing this operation" to "number of work crews performing this operation, 6 crews"
  Note: This definition was used correctly in the body of the calculation.

Page 65

- Revised the sum of the inhalation and submersion dose values in Table 7 to 0.009 rem/yr for the WHF, and 4E-05 rem/yr for the LLWF.
- Revised total annual doses by worker group in Table 7 for WHF operator to 1.1 rem/yr and HPT to 0.7 rem/yr , and for the LLWF operator to 1.5 rem/yr and HPT to 1.2 rem/yr.

Page 66

- Revised Section 7.0.1 to read "From Section 6.8, the maximum estimated dose to an individual WHF worker is 1.1 rem/yr and to an individual HPT is 0.7 rem/yr. The WHF collective dose is 36 person-rem."
- Revised Section 7.0.2 to read "From Section 6.8, the maximum estimated dose to an individual LLWF worker is 1.5 rem/yr and to an individual HPT is 1.2 rem/yr. The LLWF collective dose is 18 person-rem."

Page 69

- Changed paragraph at the top of page to read: "Airborne concentrations, and inhalation and submersion doses, are determined based on the methodology in Section 4.4. The airborne concentration of radioactive contamination from a release of surface contamination from a cask is determined using a constant release which is proportional to the resuspension factor and the surface contamination available for resuspension. The peak activity concentration is arrived at by setting the airborne release rate equal to the airborne removal rate. This peak activity concentration is present during all cask dismantling operations and hence is a worst case scenario."

Page 70

- Revised 2nd paragraph to read "The WHF and LLWF ventilation fresh air intake rate, λ_H, is the total infiltration rate divided by the space volume per Assumptions 3.1.1 and 3.1.8. Thus, $\lambda_H = 1\ hr^{-1}$"
- Due to the change in λ_H to 1 for the WHF, the airborne concentration at equilibrium (C_i) is revised to $8.7\times10^{-9}\,(m^{-3}) \times S_i\,(\mu Ci)$ resulting in an equilibrium concentration for $C_{\beta\gamma}$ equal to 4.4×10^{-7} ($\mu Ci/m^3$) and C_α equal to 4.4×10^{-8} ($\mu Ci/m^3$).

Pages 70 and 71

- Due to the change in λ_H to 1 for the LLWF, the airborne concentration at equilibrium (C_i) is revised to $1.6\times10^{-9}\,(m^{-3}) \times S_i\,(\mu Ci)$ resulting in an equilibrium concentration for $C_{\beta\gamma}$ equal to 8.2×10^{-8} ($\mu Ci/m^3$) and C_α equal to 8.2×10^{-9} ($\mu Ci/m^3$).

Page 71

- Replaced the last two sentences with "The Max ID_o is then calculated by summing the largest single dose contributor for the isotopes of concern in each group (i.e., beta or alpha emitters) as highlighted in Tables 8 through Tables 11."

Page 72

- The values for $C_{\beta\text{-}\gamma}$ *or* C_α, H^{inh}, H^{sub}, ID_o, and Max ID_o (β-γ) + Max ID_o (α) highlighted below were revised in the following tables:

Table 8

Revised values	$C_{\beta\text{-}\gamma}$ *or* C_α	DCF^{inh}	H^{inh}	DCF^{sub}	H^{sub}	ID_o
Isotope	**(μCi/m³)**	**(Sv/Bq)**	**(mrem/cask)**	**(Sv/Bq-s-m⁻³)**	**(mrem/cask)**	**(mrem/cask)**
^{60}Co	4.4E-07	5.91E-08	2.41E-03	1.26E-13	1.54E-05	2.42E-03
^{90}Sr	4.4E-07	3.51E-07	1.43E-02	7.53E-18	9.21E-10	1.43E-02
^{239}Pu	4.4E-08	1.16E-04	4.72E-01	4.24E-18	5.19E-11	4.72E-01
^{241}Am	4.4E-08	1.20E-04	4.89E-01	8.18E-16	1.00E-08	4.89E-01
					Max ID_o (β-γ) +Max ID_o (α) =	5.0E-01

Table 9

	$C_{\beta\text{-}\gamma}$ *or* C_α	DCF^{inh}	H^{inh}	DCF^{sub}	H^{sub}	ID_o
Isotope	**(μCi/m³)**	**(Sv/Bq)**	**(mrem/cask)**	**(Sv/Bq-s-m⁻³)**	**(mrem/cask)**	**(mrem/cask)**
^{60}Co	4.4E-07	2.90E-08	1.18E-03	1.19E-13	1.46E-05	1.20E-03
^{90}Sr	4.4E-07	1.50E-07	6.11E-03	9.83E-17	1.20E-08	6.11E-03
^{239}Pu	4.4E-08	4.70E-05	1.91E-01	3.49E-18	4.27E-11	1.91E-01
^{241}Am	4.4E-08	3.90E-05	1.59E-01	6.77E-16	8.28E-09	1.59E-01
					Max ID_o (β-γ) +Max ID_o (α) =	2.0E-01

Table 10

	$C_{\beta\text{-}\gamma}$ *or* C_α	DCF^{inh}	H^{inh}	DCF^{sub}	H^{sub}	ID_o
Isotope	**(μCi/m³)**	**(Sv/Bq)**	**(mrem/cask)**	**(Sv/Bq-s-m⁻³)**	**(mrem/cask)**	**(mrem/cask)**
^{60}Co	4.4E-07	5.91E-08	5.41E-03	1.26E-13	3.46E-05	5.44E-03
^{90}Sr	4.4E-07	3.51E-07	3.21E-02	7.53E-18	2.07E-09	3.21E-02
^{239}Pu	4.4E-08	1.16E-04	1.06E+00	4.24E-18	1.16E-10	1.06E+00
^{241}Am	4.4E-08	1.20E-04	1.10E+00	8.18E-16	2.25E-08	1.10E+00
					Max ID_o (β-γ) +Max ID_o (α) =	1.1E+00

Table 11

	$C_{\beta\text{-}\gamma}$ *or* C_α	DCF^{inh}	H^{inh}	DCF^{sub}	H^{sub}	ID_o
Isotope	**(μCi/m³)**	**(Sv/Bq)**	**(mrem/cask)**	**(Sv/Bq-s-m⁻³)**	**(mrem/cask)**	**(mrem/cask)**
^{60}Co	4.4E-07	2.90E-08	2.65E-03	1.19E-13	3.27E-05	2.69E-03
^{90}Sr	4.4E-07	1.50E-07	1.37E-02	9.83E-17	2.70E-08	1.37E-02
^{239}Pu	4.4E-08	4.70E-05	4.30E-01	3.49E-18	9.59E-11	4.30E-01
^{241}Am	4.4E-08	3.90E-05	3.57E-01	6.77E-16	1.86E-08	3.57E-01
					Max ID_o (β-γ) +Max ID_o (α) =	4.4E-01

Page 73

- Deleted 2nd paragraph.
- Revised 3rd, 4th and 5th paragraphs to read :

The total annual inhalation and submersion dose, ID_g, to a worker in a work crew for all operations is determined from Equation 9 with the total number of operations, *OP*, equal to the number of casks processed per year of 50 TC/TADs (Assumption 3.2.7) and the number of work crews, $crews_g$, in the cask operations group of 6 work crews (Assumption 3.2.4). The maximum annual inhalation and submersion dose in Tables 10 and 11 for the TC loaded with a DPC are used because they will result in a more conservative exposure estimate.

Annual Inhalation and Submersion Dose FGR 11 & FGR 12

$$ID_g = \sum_o ID_o \times \frac{OP}{crews_g} = 1.1\left(\frac{mrem}{cask}\right) \times \frac{50\left(\frac{casks}{yr}\right)}{6} = 9\left(\frac{mrem}{yr}\right)$$

Annual Inhalation and Submersion Dose ICRP 68 & FGR 13

$$ID_g = \sum_o ID_o \times \frac{OP}{crews_g} = 0.44\left(\frac{mrem}{cask}\right) \times \frac{50\left(\frac{casks}{yr}\right)}{6} = 4\left(\frac{mrem}{yr}\right)$$

Using FGR 11 (Ref. 2.2.10) and FGR 12 (Ref. 2.2.12), values shown above, result in a higher and more conservative exposure estimate of 9 mrem/yr. This result will be used in Table 7 to calculate the annual TEDE doses by worker category.

The dose of 9 mrem/yr is applied to both the operator and the HPT because they are present in the cask preparation room during cask processing and as shown in Table 7 is an insignificant contributor to the total individual doses.

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- Revised first sentences to read "The Max ID_o is then calculated by summing the largest single dose contributor for the isotopes of concern in each group (i.e., beta or alpha emitters) as highlighted in Table 12 and Table 13."

- The values for $C_{\beta\text{-}\gamma}$ *or* C_α, H^{inh}, H^{sub}, ID_o, and Max ID_o (β-γ) + Max ID_o (α) highlighted below were revised in the following tables:

Table 12

Isotope	$C_{\beta\text{-}\gamma}$ or C_α (μCi/m^3)	DCF^{inh} (Sv/Bq)	H^{inh} (mrem/cask)	DCF^{sub} (Sv/Bq-s-m^{-3})	H^{sub} (mrem/cask)	ID_o (mrem/cask)
^{60}Co	8.2E-08	5.91E-08	6.45E-05	1.26E-13	4.13E-07	6.49E-05
^{90}Sr	8.2E-08	3.51E-07	3.83E-04	7.53E-18	2.47E-11	3.83E-04
^{239}Pu	8.2E-09	1.16E-04	1.27E-02	4.24E-18	1.39E-12	1.27E-02
^{241}Am	8.2E-09	1.20E-04	1.31E-02	8.18E-16	2.68E-10	1.31E-02
					Max ID_o (β-γ) +Max ID_o (α) =	1.4E-02

Table 13

Isotope	$C_{\beta\text{-}\gamma}$ or C_α (μCi/m^3)	DCF^{inh} (Sv/Bq)	H^{inh} (mrem/cask)	DCF^{sub} (Sv/Bq-s-m^{-3})	H^{sub} (mrem/cask)	ID_o (mrem/cask)
^{60}Co	8.2E-08	2.90E-08	3.16E-05	1.19E-13	3.90E-07	3.20E-05
^{90}Sr	8.2E-08	1.50E-07	1.64E-04	9.83E-17	3.22E-10	1.64E-04
^{239}Pu	8.2E-09	4.70E-05	5.13E-03	3.49E-18	1.14E-12	5.13E-03
^{241}Am	8.2E-09	3.90E-05	4.26E-03	6.77E-16	2.22E-10	4.26E-03
					Max ID_o (β-γ) +Max ID_o (α) =	5.3E-03

- Deleted last paragraph.

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- Replaced everything following the first paragraph with:

Annual Inhalation and Submersion Dose FGR 11 & FGR 12

$$ID_g = \sum_o ID_o \times \frac{OP}{crews_g} = 0.014\left(\frac{mrem}{cask}\right) \times \frac{6\left(\frac{casks}{yr}\right)}{2} = 0.04\left(\frac{mrem}{yr}\right)$$

Annual Inhalation and Submersion Dose ICRP 68 & FGR 13

$$ID_g = \sum_o ID_o \times \frac{OP}{crews_g} = 0.0053\left(\frac{mrem}{cask}\right) \times \frac{6\left(\frac{casks}{yr}\right)}{2} = 0.02\left(\frac{mrem}{yr}\right)$$

Using FGR 11 (Ref. 2.2.10) and FGR 12 (Ref. 2.2.12), values shown above, result in a higher and more conservative exposure estimate of 0.04 mrem/yr. This result will be used in Table 7 to calculate the annual TEDE doses by worker category.

The dose of 0.04 mrem/yr is applied to both the operator and the HPT because they are present in the cask preparation room during cask processing and as shown in Table 7 is an insignificant contributor to the total individual doses.

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- Attachment 3 – The date, time, and file size under file names; Inhalation8-9.xls, Inhalation10-11.xls, Inhalation12-13.xls, will need to be updated when a new CD is generated to incorporate these changes in the next revision of this document.

11.	REVIEWS AND APPROVAL	
Printed Name	**Signature**	**Date**
11a. Originator: Ed Salisbury	Edward J. Salisbury	12/12/08
11b. Checker: Scott Manley	Scott Manley	12/12/08
11c. EGS: Norman Kahler	Norman Kahler	12/12/08
11d. DEM: Dave Darling	Dave Darling	2/2/09
11e. Design Authority: Barbara Rusinko	B Rusinko	2/12/09

2.2.28 SC (Bechtel SAIC Company) 2005. *Categorization of Event Sequences for License Application.* 000-00C-MGR0-00800-000-00C. Las Vegas, Nevada: Bechtel SAIC Company. ACC: ENG.20050808.0003.

2.2.29 SC 2007. *Basis of Design for the TAD Canister-Based Repository Design Concept.* 000-3DR-MGR0-00300-000-001. ACC: ENG.20071002.0042.

2.2.30 BSC 2007. *Repository Project Management Automation Plan.* 000-PLN-MGR0-00200-000-00E. Las Vegas, Nevada. Bechtel SAIC Company. ACC: ENG. 20070326.0019

2.3 DESIGN CONSTRAINTS

2.3.1 10 CFR 71. 2006 Energy: *Packaging and Transportation of Radioactive Material.* Internet Accessible. (DIRS 176575).

2.3.2 49 CFR 173. 2005 Transportation: *Shippers-- General Requirements for Shipments and Packagings.* Internet Accessible. ACC: MOL.20060116.0146. (DIRS 176026).

2.3.3 10 CFR 20. 2006 Energy: *Standards for Protection Against Radiation.* Internet Accessible. (DIRS 176618).

2.4 DESIGN OUTPUTS

This calculation is performed to support information in the license application and further design refinement to incorporate ALARA dose reductions.

3. ASSUMPTIONS

3.1 ASSUMPTIONS REQUIRING VERIFICATION

3.1.1 WHF - Instantaneous Fraction Removed (λ_H) and Airborne Activity Volume

Assumption - λ_H is assumed to be equal to 1.

Rationale - λ_H is calculated by taking the sum of all infiltration sources into the space and dividing by the space volume which is defined as the instantaneous room turn over rate. A typical nuclear heating, ventilation and air-conditioning (HVAC) system for a nuclear facility has a room turnover rate greater than 1. Therefore, using a value of 1 for λ_H is conservative and appropriate for this level of design.

The room volume of the Cask Preparation Area and the Pool Room is estimated from Ref. 2.2.1, 2.2.2 and 2.2.3. The airborne activity volume used to calculate the airborne activity concentration is conservatively chosen to be 10% of the room volume because it conservatively estimates the airborne concentration in the vicinity of the cask. 10% of the room volume equates to 4,594 m^3. The room volume is calculated as follows:

3.1.5 Transported HIC Dose Rate

Assumption: The dose rate from high integrity containers (HICs) when transporting SFP filters and spent resin from the WHF to the LLWF and while handled at the LLWF will be the same as Ref. 2.2.27, Table 7.5, of 20.12 mrem/hr (rounded to 20) at 1 m, 12.99 mrem/hr (rounded to 13) at 2 m, 9.06 mrem/hr (rounded to 9) at 3 m, and 4.95 mrem/hr (rounded to 5) at 5 m.

Rationale: This dose rate is consistent with the allowable AO dose rates (Ref. 2.2.17, Section 3.3.4), thus, using the dose rates from Ref. 2.2.27, Table 7.5 as follows for the HIC is conservative and will not create a high radiation area.

Usage: This assumption is used in Table 4, 5, and 6.

3.1.6 SFP Spent Fuel Transfer Machine Work Dose Rate (WHF)

Assumption: The average dose rate for an occupant working on the Spent Fuel Transfer Machine area is 2 mrem/hr.

Rationale: During refueling operations which are similar to the area above the SFP where the Spent Fuel Transfer Machine will be used is zoned as a R2 (Ref. 2.2.16, Figure I-4.2), because 9'-2" to 10'-6" of water will be maintained to keep the dose rate less than 2.5 mrem/hr (Ref. 2.2.20, Section 5.4.3), so on average 2 mrem/hr in the general work area is considered appropriate and is typical of the dose rates encountered in nuclear power plants during refueling operations.

Usage: This assumption is used in Table 5.

3.1.7 HVAC Filters Dose (WHF)

Assumption: It is assumed it will take 10 minutes to change each filter in an average dose rate of 1 mrem/hr.

Rationale: The radiation criteria for a HEPA filter housing is set at the maximum allowable level for a R2 of 2.5 mrem/hr (Ref. 2.2.16, Figure I-4.2). This is because most areas of the nuclear facilities are zoned as having a potential for contamination and the HEPA filter rooms have low occupancy. It is recognized that the HEPA filters will likely be changed out due to high differential pressure from non-contaminated dust loading rather than from the radiation levels resulting from radioactivity buildup. Thus, it is conservative to assume that the average dose rate of 1 mrem/hr is present during filter changeouts.

Usage: This assumption is used in Table 5.

3.1.8 LLWF - Instantaneous Fraction Removed (λ_H)

Assumption - λ_H is assumed to be equal to 1.

Rationale - λ_H is calculated by taking the sum of all infiltration sources into the space and dividing by the space volume which is defined as the instantaneous room turn over rate. A typical nuclear heating, ventilation and air-conditioning (HVAC) system for a nuclear facility has a room turnover rate greater than 1. Therefore, using a value of 1 for λ_H is conservative and appropriate for this level of design

The volume of the LLWF packaging area and adjacent open areas is estimated from the LLWF general arrangements, and is considered conservative because it only considers the open volume of the adjacent rooms where the actual material handling operations take place. Measurements are based on interior wall surfaces from the general arrangement drawings (Ref. 2.2.22, 2.2.23, 2.2.24, 2.2.25, and 2.2.26, which establish the dimensions of these areas and are suitable for their intended use in this calculation). The room volume is derived as follows:

LLWF packaging area and adjacent open areas:

Length = 262 ft 6 inches (in) center wall to center wall. Minus, 4 ft 6 in to wall center = 258 ft.

Width = 88 ft center wall to center wall. Minus, 4 ft for walls = 84 ft

Height = 66 ft 3 in minus 25 ft for height of highest room = 41 ft 3 in

258 ft x 84 ft x 41.25 ft = 893,970 ft^3

Total volume: 893,970 ft^3/(35.315 ft^3/m^3) = 25,314 m^3

Usage: This assumption is used in Attachment #1.

3.1.9 Low Activity DAW Processed (LLWF)

Assumption There will be an expected weekly throughput of 61 drums of bagged DAW. (Ref. 2.2.21 Table 6.7).

Rationale: This equates to 12.2 drums a day that will need to be processed. Processing these drums involves sorting the contents and repackaging for shipment.

Usage: This assumption is used in Table 6.

3.1.10 Radiologically Contaminated Waste Water (LLWF)

Assumption: All radiologically contaminated waste water low-level waste (LLW) received at the LLWF will be processed by a contractor-supplied liquid waste clean up system that is remotely operated. The processed water will be appropriately reused within the Geologic Repository Operations Area (GROA).

Rationale: The LLWF will receive 1,480 gallons/week (Ref. 2.2.21 Table 6.7) of radiologically contaminated waste water and this work will be processed by a contractor-supplied system that is remotely operated. Since LLW processing systems in the nuclear industry are typically designed to be remotely operated this assumption is considered appropriate.

Usage: This assumption is used in Section 6.3.2.

3.1.11 High Activity DAW Processed (LLWF)

60 = units conversion (s/min)
3.7×10^9 = units conversion (mrem Bq/Sv μCi)

The total inhalation and submersion dose, ID_o, to a worker for a series of N different tasks per cask handling operation in the WHF and LLWF in the presence of airborne radioactivity is calculated as follows:

$$ID_o = \sum_{k=1}^{N} \left(H_k^{inh} + H_k^{sub} \right) \qquad \text{Equation 8}$$

Where:

ID_o = inhalation and submersion dose to a worker per operation consisting of N different tasks (mrem/operation)

The total annual inhalation and submersion dose, ID_g, to a worker in a work crew for all operations is calculated as:

$$ID_g = \sum_{o} ID_o \times \frac{OP}{crews_g} \qquad \text{Equation 9}$$

Where:

ID_g = inhalation and submersion dose to a worker (mrem/year)
$crews_g$ = number of work crews performing this operation, 6 crews
OP = total number of these operations, o, per year

The annual maximum inhalation and submersion doses to a WHF and LLWF worker due to resuspension of surface contamination on a cask are much lower than the contribution from the direct external dose for all worker categories and are therefore considered to be an insignificant contributor to the totals presented in Section 6.8. (See Attachment 1: Annual Inhalation and Submersion Doses.)

4.5 TEDE DOSE CALCULATION

The annual TEDE, $TEDE_g$, to a worker in a work crew is calculated by summing the component doses from inhalation, submersion and direct external radiation doses.

$$TEDE_g = ID_g + ED_g \qquad \text{Equation 10}$$

Where:

$TEDE_g$ = annual TEDE to a worker (mrem/year)

5. LIST OF ATTACHMENTS

	Number of Pages
Attachment 1 Annual Inhalation and Submersion Doses	7
Attachment 2 Annual Collective Doses per Cask Type	2

6.7 ANNUAL INHALATION AND SUBMERSION DOSES

Airborne radioactivity concentrations, and inhalation and submersion doses, are determined based on the methodology in Section 4.4. The airborne radioactivity concentration of radioactive contamination from a release of surface contamination from a rail TC is determined as a time-dependent buildup. The concentration builds up while the cask is present in the work room resulting from resuspension off the cask surface and eventually decreases after the cask leaves the work room because of the air exchange provided by the HVAC system.

All operations conducted within the WHF will involve sealed canisters contained in TCs with very low levels of surface contamination. All operations conducted within the LLWF will involve receiving various waste containers which meet other nuclear surface facilities release criteria for external surface contamination levels. The annual maximum internal and external doses to a WHF and LLWF worker due to resuspension of surface contamination on a cask are much lower than the contribution from the direct external dose for all worker categories and are therefore considered to be an insignificant contributor to the totals presented in Section 6.8 (See Attachment 1).

6.8 TEDE DOSE CALCULATION

The annual total TEDE for each worker category is calculated by summing the component doses from inhalation, submersion, and direct external radiation exposure over all isotopes considered, using Equation 10. All operations conducted within the WHF will involve sealed casks with very low levels of surface contamination. The annual maximum internal and external doses to a WHF worker due to resuspension of surface contamination on a cask are much lower than the contribution from the direct external dose for all worker categories and are therefore considered to be an insignificant contributor to the totals presented in Table 7. The annual TEDE doses by worker category are presented in Table 7 below:

Table 7. Annual TEDE Doses by Worker Category (rem/yr)

Doses from WHF Operations	**Symbol**	**Units**	**Operator**	**HPT**
External Dose	ED_g	rem/yr	1.06	0.687
Inhalation Dose (CEDE) + Submersion (DDE)	ID_g	rem/yr	0.009	0.009
WHF				
Total Annual TEDE Doses by Worker Group		rem/yr	**1.1**	**0.7**
Doses from LLWF Operations	**Symbol**	**Units**	**Operator**	**HPT**
External Dose	ED_g	rem/yr	1.52	1.18
Inhalation Dose (CEDE) + Submersion (DDE)	ID_g	rem/yr	4E-05	4E-05
LLWF				
Total Annual TEDE Doses by Worker Group		rem/yr	**1.5**	**1.2**

NOTES: CEDE = committed effective dose equivalent; DDE = deep dose equivalent.

7. RESULTS AND CONCLUSIONS

The results of this dose assessment calculation are summarized in Sections 6.6 and 6.8. The parameters used in the dose calculations are supported by appropriate and conservative input

data and assumptions. The calculated worker doses in Section 6.8 represent reasonable maximum results compared with the input used to derive them. The results are therefore suitable for the intended use. The uncertainties in the results are identified primarily by the worker locations and the dose rates that workers will receive, and by the duration of operations. However, the selected inputs are judged to be representative of the operating conditions.

7.0.1 From Section 6.8, the maximum estimated dose to an individual WHF worker is **1.1 rem/yr** and to an individual HPT is **0.7 rem/yr**. The WHF collective dose is **36 person-rem**.

7.0.2 From Section 6.8, the maximum estimated dose to an individual LLWF worker is **1.5 rem/yr** and to an individual HPT is **1.2 rem/yr**. The LLWF collective dose is **18 person-rem.**

These doses are in compliance with the requirements of the limit of 5 rem/yr for occupational workers (Ref. 2.3.3, Article 1201(a)(1)(i)). These estimated annual doses to WHF Operators and HPTs do not contribute to the ALARA design goal of minimizing the number of workers exposed to more than 0.5 rem/yr (Ref. 2.1.4).

7.1 REGULATIONS

The regulation applicable to worker doses is provided in 10 CFR 20, Article 1201, Ref. 2.3.3 (as specified in Ref. 2.2.18, Section 4.10.1.2):

"The licensee shall control the occupational dose to individual adults...to the following dose limits:

(1) An annual limit, which is the more limiting of:

(i) The total effective dose equivalent being equal to 5 rems (0.05 Sv); or

(ii) The sum of the deep-dose equivalent and the committed dose equivalent to any individual organ or tissue other than the lens of the eye being equal to 50 rems (0.5 Sv).

(2) The annual limits to the lens of the eye, to the skin, and to the extremities, which are:

(i) A lens dose equivalent of 15 rems (0.15 Sv); and

(ii) a shallow-dose equivalent of 50 rems (0.5 Sv)to the skin or to any extremity.

7.2 ALARA DESIGN GOALS

The ALARA design goals (Ref. 2.2.18, Section 4.10.3.3.1) for occupational workers are to ensure that individual and collective doses shall be maintained at ALARA levels during normal operations and as a result of Category 1 event sequences. Category 1 event sequences shall be included in worker dose assessments. The specific scope of work contained in this calculation covers both collective doses and individual worker doses on an annual basis, and includes

ATTACHMENT 1 ANNUAL INHALATION AND SUBMERSION DOSES

Airborne concentrations, and inhalation and submersion doses, are determined based on the methodology in Section 4.4. The airborne concentration of radioactive contamination from a release of surface contamination from a cask is determined using a constant release which is proportional to the resuspension factor and the surface contamination available for resuspension. The peak activity concentration is arrived at by setting the airborne release rate equal to the airborne removal rate. This peak activity concentration is present during all cask dismantling operations and hence is a worst case scenario.

Contamination Available for Resuspension

The amount of radioactive contamination on the surface of a cask is a function of the assumed contamination level, the radioisotopes present, and the surface area covered by contamination.

Per Assumption 3.2.12, surface contamination is assumed to cover the entire external surface of the TC, and is assumed to be removable and releasable to the room's atmosphere.

Surface Area = $2\pi r^2 + 2\pi rh$ or $(2 \times 3.1416 \times 50^2) + (2 \times 3.1416 \times 50 \times 200) = 78{,}540\ in^2$

$78{,}540\ in^2 \times 0.0254^2\ (cm^2) = 50.67\ m^2$ rounded to $51\ m^2$.

The external surface area of a cask is $51\ m^2$ per Assumption 3.2.12.

Per Assumption 3.2.8, the non-fixed (removable) radioactive contamination on the external surface of a TC is $10^{-4}\ \mu Ci/cm^2$ for beta and gamma emitters, and low-toxicity alpha emitters, and $10^{-5}\ \mu Ci/cm^2$ for all other alpha emitters. Therefore, the amount of activity available to be released from the cask surface is:

$$S_{\beta\gamma} = 10^{-4}\left(\mu Ci/cm^2\right) \times 5.1\times10^5\left(cm^2\right) = 51\ \mu Ci$$

and

$$S_{\alpha} = 10^{-5}\left(\mu Ci/cm^2\right) \times 5.1\times10^5\left(cm^2\right) = 5.1\ \mu Ci$$

Per Assumption 3.2.11, four radioisotopes are considered to dominate the doses resulting from airborne contamination: ^{60}Co, ^{90}Sr, ^{239}Pu, and ^{241}Am. ^{60}Co and ^{90}Sr are beta/gamma emitters, and ^{239}Pu and ^{241}Am are primarily alpha emitters.

Airborne Concentration Buildup

While in the WHF, the radioactive contamination resuspended off the TC surface would be dispersed within the free air volume of the Cask Preparation Area and Pool Room. The maximum time the cask could be present would be equal to the total cask processing time prior to going into the SFP, a comparison of a TC loaded with commercial SNF and a TC loaded with a DPC follows. Table 4 Tasks 4.1 (880 min) plus 4.2 (372 min) resulting in a total time of 1252 minutes for a TC loaded with commercial SNF, and for a TC loaded with a DPC the time is equal to the total of Table 4 Tasks 4.1 (880 min) plus 4.3 (1932 min) resulting in a total time of 2812 minutes.

While in the LLWF, the radioactive contamination resuspended off a STC/DPC surface would be dispersed within the free air volume of the packaging area and adjacent open areas. The maximum time the STC/DPC could be present would be equal to the total STC/DPC processing time prior to going into decontamination (180 minutes). From Table 4 Task 4-9.

The WHF and LLWF ventilation fresh air intake rate, is the total infiltration rate divided by the space volume, λ_H, per Assumptions 3.1.1 and 3.1.8. Thus,

$$\lambda_H = 1\ hr^{-1}$$

In the WHF, the buildup of airborne radioactivity concentration in the cask handling area is determined from Equation 6 with t_B equal to infinity and λ_R, the surface contamination resuspension rate, equal to 4×10^{-5} hr^{-1} per Assumption 3.2.9. 10% of the volume of the Cask Preparation Area and Pool Room is 4,594 m^3 per Assumption 3.1.1.

The calculation for airborne concentration at equilibrium is:

$$C_i(\infty) = \frac{\lambda_R S_i}{\lambda_H V_B}\left(1 - e^{-\lambda_H \infty}\right) = \frac{\lambda_R S_i}{\lambda_H V_B} = \frac{4\times10^{-5}\left(hr^{-1}\right) S_i\left(\mu Ci\right)}{1\left(hr^{-1}\right) \times 4{,}594\left(m^3\right)} = 8.7\times10^{-9}\left(m^{-3}\right) \times S_i\ (\mu Ci)$$

Therefore, airborne concentration at equilibrium for beta and gamma emitters and low-toxicity alpha emitters and for all other alpha emitters based on the surface activity is:

$$C_{\beta\gamma}(\infty) = 8.7\times10^{-9}\left(m^{-3}\right)\times S_{\beta\gamma}\ (\mu Ci) = 8.7\times10^{-9}\ \left(m^{-3}\right)\times\ 51\ \mu Ci = 4.4\times10^{-7}\left(\mu Ci/m^3\right)$$

and

$$C_\alpha(\infty) = 8.7\times10^{-9}\left(m^{-3}\right)\times S_\alpha\ (\mu Ci) = 8.7\times10^{-9}\left(m^{-3}\right)\times\ 5.1\ \mu Ci = 4.4\times10^{-8}\left(\mu Ci/m^3\right)$$

In the LLWF, the buildup of airborne radioactivity concentration in the packaging and adjacent areas is determined from Equation 6 with t_B equal to infinity and λ_R, the surface contamination resuspension rate, equal to 4×10^{-5} hr^{-1} per Assumption 3.2.9. The volume of the packaging and adjacent areas is 25,314 m^3 per Assumption 3.1.8.

The calculation for airborne concentration at equilibrium is:

$$C_i(\infty) = \frac{\lambda_R S_i}{\lambda_H V_B}\left(1 - e^{-\lambda_H \infty}\right) = \frac{\lambda_R S_i}{\lambda_H V_B} = \frac{4\times10^{-5}\left(hr^{-1}\right) S_i\left(\mu Ci\right)}{1\left(hr^{-1}\right) \times 25{,}314\left(m^3\right)} = 1.6\times10^{-9}\left(m^{-3}\right) \times S_i\ (\mu Ci)$$

Therefore, airborne concentration at equilibrium for beta and gamma emitters and low-toxicity alpha emitters and for all other alpha emitters based on the surface activity is:

$$C_{\beta\gamma}(\infty) = 1.6\times10^{-9}\left(m^{-3}\right)\times S_{\beta\gamma}\ (\mu Ci) = 1.6\times10^{-9}\ \left(m^{-3}\right)\times\ 51\ \mu Ci = 8.2\times10^{-8}\left(\mu Ci/m^3\right)$$

and

$$C_{\alpha}(\infty) = 1.6\times10^{-9}\left(m^{-3}\right)\times S_{\alpha}\ (\mu Ci) = 1.6\times10^{-9}\left(m^{-3}\right)\times\ 5.1\ \mu Ci = 8.2\times10^{-9}\left(\mu Ci/m^3\right)$$

Worker Inhalation and Submersion Doses per Cask

The inhalation and submersion doses to a worker resulting from resuspension of contamination from a single cask for a duration of t_k minutes is determined from Equation 7:

$$H_k^{inh} = \sum_i C_i\left(t\ \right)\times DCF_i^{inh}\times 3.7\times10^9\times RF\times BR\times t_k\times 60$$

$$H_k^{sub} = \sum_i C_i\left(t\ \right)\times DCF_i^{sub}\times 3.7\times10^9\times t_k\times 60$$

WHF: For the WHF, The total time expected to process a single rail TC in the WHF Cask Preparation Area with either commercial SNF or a DPC follows:

Process time for 1 TC loaded with commercial SNF into the facility and into the SFP is 1252 min, total from airborne concentration buildup p.69.

Process time for 1 TC loaded with a DPC into the cask unloading room is 2812 min, total from airborne concentration buildup p.69.

The exposure duration t_k is conservatively taken as the total cask processing time from entering the WHF to being placed in the SFP. Per Assumption 3.2.10, the respirable fraction, WHF, is 1. The breathing rate, BR, is 3.33×10^{-4} m^3/s per Assumption 3.2.13.

The total inhalation and submersion dose, ID_o, to a worker for all cask processing tasks resulting from the presence of airborne activity is determined from Equation 8 with $N = 1$ because the exposure duration t_k is conservatively taken as the total cask processing time and includes all tasks:

$$ID_o = \left(H_k^{inh} + H_k^{sub}\right)$$

The results of applying Equations 7 and 8 to determine ID_o (mrem/cask) are given in the following tables below which are contained in attachment #4, files Inhalation8-9.xls, Inhalation10-11.xls, and Inhalation12-13.xls). Per Assumption 3.2.11, the dominant beta/gamma-emitting isotopes are ^{60}Co and ^{90}Sr, and the dominant alpha-emitting isotopes are ^{239}Pu and ^{241}Am. The effective inhalation and submersion DCFs for these isotopes are given in Assumption 3.2.11. The dose per cask due to inhalation and submersion is conservatively taken as the sum of the calculated ^{60}Co, ^{90}Sr, ^{239}Pu, and ^{241}Am doses. The Max ID_o is then calculated by summing the largest single dose contributor for the isotopes of concern in each group (i.e., beta or alpha emitters) as highlighted in Tables 8 through Tables 11.

When multiple solubility classes where available, the most restrictive value was used in the calculation.

Table 8. TC with commercial SNF Inhalation and Submersion Doses FGR 11 and FGR 12.

Isotope	$C_{\beta\text{-}\gamma}$ or C_α (µCi/m^3)	DCF^{inh} (Sv/Bq)	H^{inh} (mrem/cask)	DCF^{sub} (Sv/Bq-s-m^{-3})	H^{sub} (mrem/cask)	ID_o (mrem/cask)
^{60}Co	4.4E-07	5.91E-08	2.41E-03	1.26E-13	1.54E-05	2.42E-03
^{90}Sr	4.4E-07	3.51E-07	1.43E-02	7.53E-18	9.21E-10	1.43E-02
^{239}Pu	4.4E-08	1.16E-04	4.72E-01	4.24E-18	5.19E-11	4.72E-01
^{241}Am	4.4E-08	1.20E-04	4.89E-01	8.18E-16	1.00E-08	4.89E-01
					Max ID_o (β-γ) +Max ID_o (α) =	5.0E-01

Sources: Refs. 2.2.10 and 2.2.12

Table 9. TC with commercial SNF Inhalation and Submersion Doses ICRP-68 and FGR 13.

Isotope	$C_{\beta\text{-}\gamma}$ or C_α (µCi/m^3)	DCF^{inh} (Sv/Bq)	H^{inh} (mrem/cask)	DCF^{sub} (Sv/Bq-s-m^{-3})	H^{sub} (mrem/cask)	ID_o (mrem/cask)
^{60}Co	4.4E-07	2.90E-08	1.18E-03	1.19E-13	1.46E-05	1.20E-03
^{90}Sr	4.4E-07	1.50E-07	6.11E-03	9.83E-17	1.20E-08	6.11E-03
^{239}Pu	4.4E-08	4.70E-05	1.91E-01	3.49E-18	4.27E-11	1.91E-01
^{241}Am	4.4E-08	3.90E-05	1.59E-01	6.77E-16	8.28E-09	1.59E-01
					Max ID_o (β-γ) +Max ID_o (α) =	2.0E-01

Sources: Refs. 2.2.13 and 2.2.14

Table 10. TC with DPC Inhalation and Submersion Doses FGR 11 and FGR 12.

Isotope	$C_{\beta\text{-}\gamma}$ or C_α (µCi/m^3)	DCF^{inh} (Sv/Bq)	H^{inh} (mrem/cask)	DCF^{sub} (Sv/Bq-s-m^{-3})	H^{sub} (mrem/cask)	ID_o (mrem/cask)
^{60}Co	4.4E-07	5.91E-08	5.41E-03	1.26E-13	3.46E-05	5.44E-03
^{90}Sr	4.4E-07	3.51E-07	3.21E-02	7.53E-18	2.07E-09	3.21E-02
^{239}Pu	4.4E-08	1.16E-04	1.06E+00	4.24E-18	1.16E-10	1.06E+00
^{241}Am	4.4E-08	1.20E-04	1.10E+00	8.18E-16	2.25E-08	1.10E+00
					Max ID_o (β-γ) +Max ID_o (α) =	1.1E+00

Sources: Refs. 2.2.10 and 2.2.12

Table 11. TC with DPC Inhalation and Submersion Doses ICRP-68 and FGR 13.

Isotope	$C_{\beta\text{-}\gamma}$ or C_α (µCi/m^3)	DCF^{inh} (Sv/Bq)	H^{inh} (mrem/cask)	DCF^{sub} (Sv/Bq-s-m^{-3})	H^{sub} (mrem/cask)	ID_o (mrem/cask)
^{60}Co	4.4E-07	2.90E-08	2.65E-03	1.19E-13	3.27E-05	2.69E-03
^{90}Sr	4.4E-07	1.50E-07	1.37E-02	9.83E-17	2.70E-08	1.37E-02
^{239}Pu	4.4E-08	4.70E-05	4.30E-01	3.49E-18	9.59E-11	4.30E-01
^{241}Am	4.4E-08	3.90E-05	3.57E-01	6.77E-16	1.86E-08	3.57E-01
					Max ID_o (β-γ) +Max ID_o (α) =	4.4E-01

Sources: Refs. 2.2.13 and 2.2.14

Although many of the biokinetic and dosimetric models used in FGR 13 are updates of models used in FGR 11, the present report does not replace either that document or FGR 12 or affect their use for radiation protection purposes. The dose coefficients given in FGR 11 and FGR 12 continue to be recommended for determining conformance with radiation protection guidance to Federal agencies. The values cited for submersion from FGR 13 are the submersion values from FGR 12 with the ICRP 60 weighting factors applied to them and can be found in the FGR 13 (Ref. 2.2.14) supplement CD Table F12TIII1.

The total annual inhalation and submersion dose, ID_g, to a worker in a work crew for all operations is determined from Equation 9 with the total number of operations, OP, equal to the number of casks processed per year of 50 TC/TADs (Assumption 3.2.7) and the number of work crews, $crews_g$, in the cask operations group of 6 work crews (Assumption 3.2.4). The maximum annual inhalation and submersion dose in Tables 10 and 11 for the TC loaded with a DPC are used because they will result in a more conservative exposure estimate.

Annual Inhalation and Submersion Dose FGR 11 & FGR 12

$$ID_g = \sum_o ID_o \times \frac{OP}{crews_g} = 1.1\left(\frac{mrem}{cask}\right) \times \frac{50\left(\frac{casks}{yr}\right)}{6} = 9\left(\frac{mrem}{yr}\right)$$

Annual Inhalation and Submersion Dose ICRP 68 & FGR 13

$$ID_g = \sum_o ID_o \times \frac{OP}{crews_g} = 0.44\left(\frac{mrem}{cask}\right) \times \frac{50\left(\frac{casks}{yr}\right)}{6} = 4\left(\frac{mrem}{yr}\right)$$

Using FGR 11 (Ref. 2.2.10) and FGR 12 (Ref. 2.2.12), values shown above, result in a higher and more conservative exposure estimate of 9 mrem/yr. This result will be used in Table 7 to calculate the annual TEDE doses by worker category.

The dose of 9 mrem/yr is applied to both the operator and the HPT because they are present in the cask preparation room during cask processing and as shown in Table 7 is an insignificant contributor to the total individual doses.

LLWF: For the LLWF, the total time expected to process a single DPC in the LLWF packaging area and adjacent areas is as follows:

Process time for one STC loaded with an empty DPC into the facility and into the decontamination area is 180 min. From Table 5 Section 5-9.

The exposure duration, t_k, is conservatively taken as the total STC/DPC processing time from entering the LLWF to being decontaminated. Per Assumption 3.2.10, the respirable fraction, is 1. The breathing rate, BR, is 3.33×10^{-4} m^3/s, per Assumption 3.2.13.

The total inhalation and submersion dose, ID_o, to a worker for all STC/DPC processing tasks resulting from the presence of airborne activity is determined from Equation 8 with $N = 1$ because the exposure duration t_k is conservatively taken as the total STC/DPC processing time and includes all tasks:

$$ID_o = \left(H_k^{inh} + H_k^{sub}\right)$$

The results of applying Equations 7 and 8 to determine ID_o (mrem/cask) are given in the following tables. Per Assumption 3.2.11, the dominant beta/gamma-emitting isotopes are ^{60}Co and ^{90}Sr, and the dominant alpha-emitting isotopes are ^{239}Pu and ^{241}Am. The effective inhalation and submersion DCFs for these isotopes are given in Assumption 3.2.11. The dose per cask due to inhalation and submersion is conservatively taken as the sum of the calculated ^{60}Co, ^{90}Sr,

^{239}Pu, and ^{241}Am doses. The Max ID_o is then calculated by summing the largest single dose contributor for the isotopes of concern in each group (i.e., beta or alpha emitters) as highlighted in Table 12 and Table 13.

Table 12. STC/DPC Inhalation and Submersion Doses FGR 11 and FGR 12.

Isotope	$C_{\beta\text{-}\gamma}$ or C_α (μCi/m^3)	DCF^{inh} (Sv/Bq)	H^{inh} (mrem/cask)	DCF^{sub} (Sv/Bq-s-m^{-3})	H^{sub} (mrem/cask)	ID_o (mrem/cask)
^{60}Co	8.2E-08	5.91E-08	6.45E-05	1.26E-13	4.13E-07	6.49E-05
^{90}Sr	8.2E-08	3.51E-07	3.83E-04	7.53E-18	2.47E-11	3.83E-04
^{239}Pu	8.2E-09	1.16E-04	1.27E-02	4.24E-18	1.39E-12	1.27E-02
^{241}Am	8.2E-09	1.20E-04	1.31E-02	8.18E-16	2.68E-10	1.31E-02
					Max ID_o (β-γ) +Max ID_o (α) =	1.4E-02

Sources: Refs. 2.2.10 and 2.2.12

Table 13. STC/DPC Inhalation and Submersion Doses ICRP-68 and FGR 13.

Isotope	$C_{\beta\text{-}\gamma}$ or C_α (μCi/m^3)	DCF^{inh} (Sv/Bq)	H^{inh} (mrem/cask)	DCF^{sub} (Sv/Bq-s-m^{-3})	H^{sub} (mrem/cask)	ID_o (mrem/cask)
^{60}Co	8.2E-08	2.90E-08	3.16E-05	1.19E-13	3.90E-07	3.20E-05
^{90}Sr	8.2E-08	1.50E-07	1.64E-04	9.83E-17	3.22E-10	1.64E-04
^{239}Pu	8.2E-09	4.70E-05	5.13E-03	3.49E-18	1.14E-12	5.13E-03
^{241}Am	8.2E-09	3.90E-05	4.26E-03	6.77E-16	2.22E-10	4.26E-03
					Max ID_o (β-γ) +Max ID_o (α) =	5.3E-03

Sources: Refs. 2.2.13 and 2.2.14

Although many of the biokinetic and dosimetric models used in FGR 13 are updates of models used in FGR 11, the present report does not replace either that document or FGR 12 or affect their use for radiation protection purposes. The dose coefficients given in FGR 11 and FGR 12 continue to be recommended for determining conformance with radiation protection guidance to Federal agencies. The values cited for submersion from FGR 13 are the submersion values from FGR 12 with the ICRP 60 weighting factors applied to them and can be found in the FGR 13 (Ref. 2.2.14) supplement CD Table F12TIII1.

The total annual inhalation and submersion dose, ID_g, to a worker in a work crew for all operations is determined from Equation 9 with the total number of Operations, *OP*, equal to the number of casks processed per year of 6 STC/DPCs (Assumption 3.1.13) and the number of work crews, $crews_g$, in the LLWF is 2 work crews (Assumption 3.2.20).

Annual Inhalation and Submersion Dose FGR 11 & FGR 12

$$ID_g = \sum_o ID_o \times \frac{OP}{crews_g} = 0.014\left(\frac{mrem}{cask}\right) \times \frac{6\left(\frac{casks}{yr}\right)}{2} = 0.04\left(\frac{mrem}{yr}\right)$$

Annual Inhalation and Submersion Dose ICRP 68 & FGR 13

$$ID_g = \sum_o ID_o \times \frac{OP}{crews_g} = 0.0053\left(\frac{mrem}{cask}\right) \times \frac{6\left(\frac{casks}{yr}\right)}{2} = 0.02\left(\frac{mrem}{yr}\right)$$

Using FGR 11 (Ref. 2.2.10) and FGR 12 (Ref. 2.2.12), values shown above, result in a higher and more conservative exposure estimate of 0.04 mrem/yr. This result will be used in Table 7 to calculate the annual TEDE doses by worker category.

The dose of 0.04 mrem/yr is applied to both the operator and the HPT because they are present in the cask preparation area during processing.