STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION TITLE PAGE

*SEE INSTRUCTIONS ON REVERSE SIDE

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CLIENT & PROJECT	PAGE 1 OF ~~8~~ 13 JRJ
Private Fuel Storage Limited Liability Corp. / Private Fuel Storage Facility	
CALCULATION TITLE (Indicative of the Objective): Postulated Release of Removable Contamination from Canister Outer Surfaces - Dose Consequences	QA CATEGORY (✓) ☑ I - NUCLEAR SAFETY RELATED ☐ II ☐ III ☐ ______ OTHER

CALCULATION IDENTIFICATION NUMBER				
J. O. OR W.O. NO.	DIVISION & GROUP	CURRENT CALC. NO.	OPTIONAL TASK CODE	OPTIONAL WORK PACKAGE NO.
05996.01	Rad Protection	UR-3	N.A.	N.A.

* APPROVALS - SIGNATURE & DATE			REV. NO. OR NEW CALC NO.	SUPERSEDES * CALC. NO. OR REV. NO.	CONFIRMATION *REQUIRED (✓)	
PREPARER(S)/DATE(S)	REVIEWER(S)/DATE(S)	INDEPENDENT REVIEWER(S)/DATE(S)			YES	NO
J.R. Johns JR Johns 6/5/97	W.P. Hennessy WP Hennessy 6/15/97	W.P. Hennessy WP Hennessy 6/15/97	0	N.A.		✓
J.R. Johns JR Johns 5/4/98	J.L. COOPER JL Cooper 5-5-98	J.L. COOPER JL Cooper 5-5-98	1	0		✓
ISSUED	FOR USE ON	JO. NO 05996.02				
J.R. Johns JR Johns ~~3-9-99~~ 5-3-99	E.S. Kirstein ESK 5/4/99	E.S. Kirstein ESK 5/4/99	2	1		✓
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(Revisions, Additions, Deletions, Etc.)

STONE & WEBSTER ENGINEERING

CALCULATION SHEET

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05996.01-UR-3	2	

PREPARER/DATE	REVIEWER/CHECKER/DATE	INDEPENDENT REVIEWER
J.R. Johns 5/3/99		

SUBJECT/TITLE	QA CATEGORY/CODE CLASS
Postulated Release of Removable Contamination from Canister Outer Surfaces - Dose Consequences	I

TABLE OF CONTENTS AND HISTORICAL DATA

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CALCULATION OBJECTIVE

The objective of this calculation is to determine conservative doses at the Private Fuel Storage Facility (PFSF) Owner Controlled Area (OCA) boundary and at 150 meters from the postulated release of contamination from the outer surfaces of a canister. In addition, concentrations inside the Canister Transfer Building resulting from this postulated accident are calculated for comparison with 10 CFR 20 derived air concentration occupational values.

CALCULATION METHOD / ASSUMPTIONS

It is conservatively assumed that the entire outer surface of a canister is covered with removable beta/gamma contamination at a concentration of 22,200 dpm/100 cm^2, slightly above the maximum allowable limit of PFSF Technical Specification 3/4.1, "Canister External Surface Contamination", 22,000 dpm/100 cm^2. It is assumed that all of the surface contamination is Co-60, consistent with the approach used by Sierra Nuclear Corporation in their evaluation of this postulated accident in the TranStor SAR (Reference 1). This particular event is not analyzed in the HI-STORM SAR (Reference 2). It is conservatively assumed that 100% of this external surface contamination is released from the vendor's canister having the greatest external surface area. Internal inhalation doses and external submersion doses are calculated to individuals assumed to be 150 meters and 500 meters away, using the dispersion coefficients (χ/Qs) calculated for these distances in Reference 3. Dose conversion factors are taken from Reference 4 for inhalation and from Reference 5 for submersion. Adding the committed effective dose equivalent (CEDE) from inhalation (an internal committed dose) to the external dose from submersion results in a calculated total effective dose equivalent (TEDE) at these two distances. It is also assumed that the Co-60 postulated to be released from the outer surfaces of a canister into the high bay portion of the Canister Transfer Building remains in the building with uniform mixing. The concentration of Co-60 is calculated in the free volume of the high bay area and compared with 10 CFR 20 permissible derived air concentration values for occupational workers.

REFERENCES

1. Safety Analysis Report for the TranStor Storage Cask System, SNC-96-72SAR, Sierra Nuclear Corporation, Docket 72-1023, Revision B, March 1997.

2. Topical Safety Analysis Report for the Holtec International Storage and Transfer Operation Reinforced Module Cask System (HI-STORM 100 Cask System), Holtec Report HI-951312, Docket 72-1014, Revision 4, May 1998.

3. SWEC Calculation No. 0599601-UR-1, Rev. 1, "Accident χ/Qs for the PFSF", prepared by J.R. Johns, dated October 22, 1997.

4. Federal Guidance Report No. 11, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, EPA 520/1-88-020, U.S. Environmental Protection Agency, September 1988.

5. Federal Guidance Report No. 12, External Exposure to Radionuclides in Air, Water, and Soil, EPA 402-R-93-081, U.S. Environmental Protection Agency, September 1993.

6. 10 CFR 20, Standards for Protection Against Radiation.

7. 10 CFR 72, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste.

CONCLUSIONS

It was determined that the HI-STORM canister has the largest external surface area, of 312,000 cm^2. Assuming that the entire outer surface of a canister is covered with removable contamination at approximately the maximum allowable limit of PFSF Technical Specification 3/4.1 (22,000 dpm/100 cm^2) and that 100% of this activity is released from the outer surface of the canister and becomes airborne results in a source term of 31.2 μCi. Based on a review of the inhalation dose conversion factors in Reference 4 for Co-60, it is determined that the dose conversion factor for lung is higher than that for any other organ. Therefore, the lung is the maximally exposed organ. Committed Effective dose equivalents (CEDE) and committed dose equivalents (CDE) to the lung from inhalation were calculated at 150 m and 500 m distances, with the following results:

CEDE (150 m) = 3.15 E-2 mrem
CDE (lung, 150 m) = 1.84 E-1 mrem

CEDE (500 m) = 4.37 E-3 mrem
CDE (lung, 500 m) = 2.55 E-2 mrem

In addition to these internal committed doses from inhalation, external doses were calculated for submersion in the radioactive plume using the equations from Reference 5, with the following results:

Submersion dose (150 m) = 2.04 E-4 mrem
Submersion dose (500 m) = 2.82 E-5 mrem

The total effective dose equivalent (TEDE) is the sum of the internal CEDE from inhalation and the external dose from submersion, and the total lung dose is the CDE to the lungs plus the external dose from submersion, as follows:

TEDE (150 m) = 3.15 E-2 mrem + 2.04 E-4 mrem = 3.17 E-2 mrem

Total Lung Dose (150 m) = 1.84 E-1 mrem + 2.04 E-4 mrem = 1.84 E-1 mrem

TEDE (500 m) = 4.37 E-3 mrem + 2.82 E-5 mrem = 4.40 E-3 mrem

Total Lung Dose (500 m) = 2.55 E-2 mrem + 2.82 E-5 mrem = 2.55 E-2 mrem

These calculated doses, based on a conservative postulated accident scenario,

are well within the limits of Part 72.106 of 10 CFR 72 (Reference 7) for design basis accidents, which applies to an individual located at or beyond the OCA boundary, and states the following:

> "Any individual located on or beyond the nearest boundary of the controlled area may not receive from any design basis accident the more limiting of a total effective dose equivalent of 0.05 Sv (5 rem), or 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) of 0.5 Sv (50 rem). The lens dose equivalent shall not exceed 0.15 Sv (15 rem) and the shallow dose equivalent to skin or to any extremity shall not exceed 0.5 Sv (50 rem)."

Assuming that the 31.2 μCi of Co-60 were released into the high bay of the Canister Transfer Building from a canister transfer cell, and assuming the activity remains in the building with uniform mixing in the high bay free volume, the calculated airborne concentration of 8.79 E-10 $\mu Ci/cm^3$ of Co-60 is within the 10 CFR 20 (Appendix B, Table 1) derived air concentration value for occupational workers.

CALCULATION

Determine External Surface Area of a Canister

HI-Storm

Dimensions of Holtec International's (Holtec's) HI-STORM canister are given in the following drawings in Section 1 of the HI-STORM SAR (Reference 2) as follows:

O.D. = 68.5 inches, (68.5 inch)(2.540 cm/inch) = 174.0 cm = D

Based on Holtec Drawing No. 1395, sheet 1 of 4, "HI-STAR 100 MPC-24 Construction", Rev. 8 - gives the outer diameter of the canister as 68 3/8 inches ± 3/16 inch. This is identical to the outer diameter of the MPC-68 canister, shown on Holtec Drawing No. 1401, sheet 1 of 4, "HI-STAR 100 MPC-68 Construction", Rev. 9.

Height = 190.5 inches, (190.5 inch)(2.540 cm/inch) = 483.9 cm = H

Based on Holtec Drawing No. 1396, sheet 1 of 6, "HI-STAR 100 MPC-24 Construction", Rev. 8 - gives the outer height of the canister as 190 1/2 inches + 1/16 inch, - 1/8 inch. This is identical to the outer height dimension of the MPC-68 canister, shown on Holtec Drawing No. 1402, sheet 1 of 6, "HI-STAR 100 MPC-68 Construction", Rev. 9.

Surface Area = $\pi DH + 2(\pi D^2)/4$

Surface Area = $\pi(174.0\text{ cm})(483.9\text{ cm}) + 2(\pi)(174.0)^2/4 = 3.12\text{ E5 cm}^2$

TranStor

Dimensions of Sierra Nuclear Corporation's (SNC) TranStor canister (PWR and BWR canister dimensions are identical) are given in SNC Drawing No. TSP-001, sheet 1 of 3, "TranStor PWR Basket Assembly", Rev. 6, and SNC Drawing No. TSB-001, sheet 1 of 6, "TranStor BWR Basket Assembly", Rev. 2, as follows:

O.D. = 66.0 inches, (66.0 inch)(2.540 cm/inch) = 167.6 cm = D

Height = 192.25 inches, (192.25 inch)(2.540 cm/inch) = 488.3 cm = H

Surface Area = $\pi DH + 2(\pi D^2)/4$

Surface Area = $\pi(167.6\text{ cm})(488.3\text{ cm}) + 2(\pi)(167.6)^2/4 = 3.01\text{ E5 cm}^2$

Removable Contamination on Outer Surfaces of a Canister

Since the HI-STORM canister has the largest surface area (3.12 E5 cm^2), this surface area is used to determine the total quantity of removable surface contamination on the outer surface of a canister. It is conservatively assumed that the entire outer surface of a canister is covered with removable beta/gamma contamination at 1.0 E-4 $\mu Ci/cm^2$, equal to 22,200 dpm/100 cm^2, slightly above the maximum allowable beta/gamma limit of PFSF Technical Specification 3/4.1, "Canister External Surface Contamination", 22,000 dpm/100 cm^2.

By definition, 1 Ci = 3.7 E10 disintegrations per second = 2.22 E12 disintegrations per minute (dpm)

1 μCi = 1 E-6 Ci = 2.22 E6 dpm

$$\frac{(22{,}000 \text{ dpm})}{100 \text{ cm}^2} \; \frac{(1\ \mu\text{Ci})}{2.22 \text{ E } 6 \text{ dpm}} = 9.91 \text{ E-5} \frac{\mu\text{Ci}}{\text{cm}^2}$$

Assume the canister is coated with removable contamination at a concentration of 1.0 E-4 $\mu Ci/cm^2$, equal to 22,200 dpm/100 cm^2 (0.9% above the Technical Specification limit):

(312,000 cm^2) (1.0 E-4 $\mu Ci/cm^2$) = 31.2 μCi.

Thus, it is assumed that 31.2 μCi of Co-60 is released from the surfaces of the canister and becomes airborne.

Inhalation Dose Calculation

Doses are calculated assuming that an offsite individual is located at the OCA boundary at its closest point of approach to the Canister Transfer Building, 500 meters east of the Canister Transfer Building. This represents the nearest distance to the OCA boundary from a point where a loaded canister would be staged, stored, or handled at the PFSF. Doses are also calculated to an onsite individual assumed to be located 150 meters from the release point, which is an arbitrarily selected distance inside the OCA boundary.

Doses are calculated in accordance with the following equation:

Dose = (activity released, μCi)(χ/Q, sec/m^3) (breathing rate, m^3/sec)(dose conversion factor, mrem/μCi)

where:

Activity released is 31.2 μCi, as calculated above.
Adult breathing rate is assumed to be 3.3 E-4 m^3/sec, in accordance with Reference 4.

Dispersion factors of 1.40 E-2 sec/m^3 for 150 meters and 1.94 E-3 sec/m^3 for 500 meters were calculated in Reference 3, conservatively assuming an instantaneous release, a 1 meter/sec horizontal wind speed, and Pasquill Stability Class F meteorological conditions.
Dose conversion factors for Co-60 are stated in Reference 4 to be 5.91 E-8 Sv/Bq for Committed Effective Dose Equivalent, and 3.45 E-7 Sv/Bq for Committed Dose Equivalent to the lungs, which is the highest dose conversion factor for any organ. A factor of 3.7 E9 is used to convert from Sv/Bq to mrem/μCi, in accordance with Reference 4, resulting in 218.7 mrem/μCi for CEDE and 1,277 mrem/μCi for CDE to the lungs.

CEDE (150 m) = (31.2 μCi)(1.40 E-2 sec/m^3)(3.3 E-4 m^3/sec)(218.7 mrem/μCi)
= 3.15 E-2 mrem

CDE (lung, 150 m) = (31.2 μCi)(1.40 E-2 sec/m^3)(3.3 E-4 m^3/sec)(1,277 mrem/μCi)
= 1.84 E-1 mrem

CEDE (500 m) = (31.2 μCi)(1.94 E-3 sec/m^3)(3.3 E-4 m^3/sec)(218.7 mrem/μCi)
= 4.37 E-3 mrem

CDE (lung, 500 m) = (31.2 μCi)(1.94 E-3 sec/m^3)(3.3 E-4 m^3/sec)(1,277 mrem/μCi)
= 2.55 E-2 mrem

<u>Submersion Dose Calculation</u>

The submersion dose from this accident can be calculated by means of the following equation:

External Dose = (activity released, μCi)(χ/Q, sec/m^3) (dose conversion factor, mrem per sec / μCi per m^3)

where:

Activity released is 31.2 μCi, as calculated above.
Dispersion factors of 1.40 E-2 sec/m^3 for 150 meters and 1.94 E-3 sec/m^3 for 500 meters were calculated in Reference 3, conservatively assuming an instantaneous release, a 1 meter/sec horizontal wind speed, and Pasquill Stability Class F meteorological conditions.
The effective dose conversion factors for Co-60, submersion, is stated in Reference 5 to be 1.26 E-13 Sv per sec / Bq per m^3). A factor of 3.7 E9 is again used to convert from Sv/Bq to mrem/μCi, resulting in a dose conversion factor of 4.66 E-4 mrem per sec / μCi per m^3.

Using the same χ/Qs values used above for calculation of inhalation doses:

External Dose (150 m) = (31.2μCi) (1.40 E-2 sec/m^3) (4.66 E-4 mrem per sec / μ Ci per m^3) = 2.04 E-4 mrem

External Dose (500 m) = (31.2μCi) (1.94 E-3 sec/m^3) (4.66 E-4 mrem per sec / μ Ci per m^3) = 2.82 E-5 mrem

Total Effective Dose Equivalents and Total Organ Doses

The total effective dose equivalent (TEDE) is the sum of the internal CEDE from inhalation and the external dose from submersion, and the total dose to the lung is the CDE to this organ plus the external dose from submersion, calculated as follows:

TEDE (150 m) = 3.15 E-2 mrem + 2.04 E-4 mrem = 3.17 E-2 mrem

Total Lung Dose = 1.84 E-1 mrem + 2.04 E-4 mrem = 1.84 E-1 mrem

TEDE (500 m) = 4.37 E-3 mrem + 2.82 E-5 mrem = 4.40 E-3 mrem

Total Lung Dose = 2.55 E-2 mrem + 2.82 E-5 mrem = 2.55 E-2 mrem

These calculated doses, based on a conservative postulated accident scenario,

are well within the limits of 10 CFR 72.106(b) for design basis accidents, which applies to an individual located at or beyond the OCA boundary, and states the following:

> "Any individual located on or beyond the nearest boundary of the controlled area may not receive from any design basis accident the more limiting of a total effective dose equivalent of 0.05 Sv (5 rem), or 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) of 0.5 Sv (50 rem). The lens dose equivalent shall not exceed 0.15 Sv (15 rem) and the shallow dose equivalent to skin or to any extremity shall not exceed 0.5 Sv (50 rem)."

<u>Activity Concentration in the Canister Transfer Building, Assuming Uniform Mixing of Co-60 in the Canister Transfer Building Atmosphere</u>

It is assumed that the 31.2 μCi of Co-60 is released from the outer surfaces of a canister into the high bay portion of the Canister Transfer Building, and there is uniform mixing. Taking credit for the total free volume of the high bay area is considered reasonable when evaluating protection of Canister Transfer Building personnel during this radiological event since:

(1) there is a very low probability of more then a few percent of the surface contamination being dislodged, becoming airborne, and available for uptake by personnel in the cell,

(2) most of the airborne activity released into the affected canister transfer cell will be exhausted from the cell by the ventilation system,

(3) a continuous airborne monitor will detect the release and provide an audible alarm,

(4) personnel in the cell will likely evacuate due to the event which caused the release or immediately upon hearing the audible alarm,

(5) other personnel present in the Canister Transfer Building will be directed to move to areas with lower potential for airborne activity or leave the building.

(6) due to the flow of air directed by the ventilation system design, migration of the airborne radioactivity to other areas of the building will be very slow.

The walls of a canister transfer cell are approximately 30 ft. high (based on

discussions with Steve Smith - SWEC). The ceiling of the high bay area is approximately 90 ft above the building floor, at grade level, per SWEC Drawing No. 0599601-EA-9-D, "Canister Transfer Building Elevations -Sh1". Therefore, contamination released from a canister would not be trapped in the canister transfer cell in which the release occurred, but would tend to mix with air in the entire high bay portion of the Canister Transfer Building. The high bay area is approximately 63 ft wide by 260 ft long and includes canister transfer cells No. 1, 2, and 3, the transfer equipment laydown area, the LLW storage room (east of canister transfer cell No. 1), the crane aisle east of the transfer cells, the shipping cask load/unload bays No. 1 and 2, and the impact limiter laydown area (SWEC Drawing No. 0599601-EA-8-D, "Canister Transfer Building Floor Plan"). Based on these dimensions, the inside volume of the high bay area is:

Total Volume = (63 ft) (260 ft) (90 ft) = 1.47 E6 ft^3

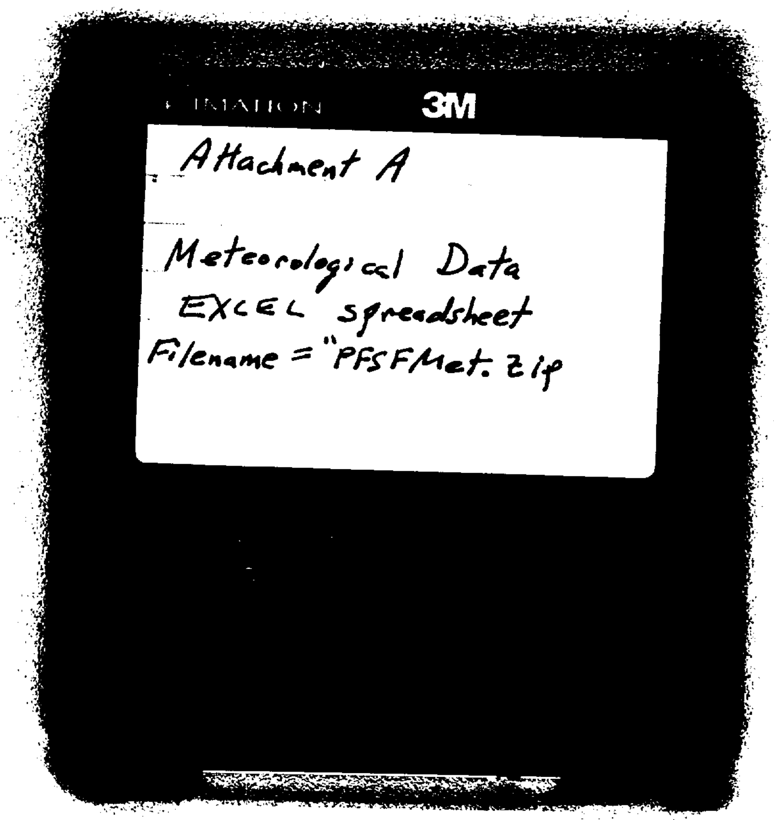
Assume 15 % of this volume is occupied by equipment and walls, then the free volume inside the high bay area is approximately:

Free Volume = (0.85) (1.47 E6 ft^3) (2.832 E4 cm^3 / ft^3) = 3.55 E10 cm^3

Assuming uniform mixing throughout the high bay free volume, the concentration of Co-60 would be:

$$\frac{31.2\ \mu Ci}{3.55\ E10\ cm^3} = 8.79\ E\text{-}10\ \mu Ci/cm^3$$

10 CFR 20 Appendix B, Table 1, specifies derived air concentration values for occupational workers. For Co-60, the limits are 1 E-8 μCi/ml for cobalt oxides, hydroxides, halides, and nitrates and 7 E-8 μCi/ml for all other cobalt compounds. Since a cm^3 is the same volume as a ml, the calculated airborne concentration of 8.79 E-10 μCi/cm^3 of Co-60 is less than the 10 CFR 20 derived air concentration values for occupational workers, and represents an acceptable concentration for occupational workers for this nuclide.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