STONE & WEBSTER ENGINEERING CORPORATION

CALCULATION TITLE PAGE

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CALCULATION TITLE **Calculational Basis for PFSF SAR Tables 7.4-1 and 7.4-2, Estimated Personnel Exposures for Canister Transfer Operations**	QA CATEGORY III

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SUBJECT/TITLE Calculational Basis for PFSF SAR Tables 7.4-1 and 7.4-2, Estimated Personnel Exposures for Canister Transfer Operations		QA CATEGORY/CODE CLASS III	

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(Revisions, Additions, Deletions, Etc.)

CALCULATION OBJECTIVE

The objective of this calculation is to provide the calculational bases for the radiation exposure estimates in PFSF SAR (Reference 1) Tables 7.4-1 and 7.4-2, and identify any necessary revisions. Table 7.4-1 is entitled "Estimated Personnel Exposures for HI-STORM Canister Transfer Operations", and Table 7.4-2 is entitled "Estimated Personnel Exposures for TranStor Canister Transfer Operations". The original tables are based on dose rates from the versions of the vendor storage cask and shipping cask SARs in effect when the PFSF SAR was being prepared. Since some of the vendor SARs have been revised since PFSF SAR Tables 7.4-1 and 7.4-2 were developed, the effects of revisions on these tables will be taken into account. The calculation indicates the general worker location assumed for each operation identified in the tables, calculates dose rates at these locations, and identifies the estimated time to perform each operation. Based on the dose rate calculated at the assumed worker location and the time spent in the radiation field, an integrated dose is calculated for each step. For those steps where it was judged that temporary shielding was practical for reducing dose rates, the attenuation effect of temporary shielding is quantified.

CALCULATION METHOD / ASSUMPTIONS

Information regarding dose rates and integrated radiation exposures to workers involved in canister transfer operations is contained in Section 10 of the vendor storage cask SARs. Table 10.3.3 of the HI-STORM SAR (Reference 2) is entitled "HI-STORM 100 System Transfer to Storage Directly from Transport Estimated Operational Exposures". This table addresses operations that will be performed at the PFSF, including shipping cask receipt, transfer of the canister from the shipping cask to the storage cask, and moving the storage cask to the pads. Therefore, this table is considered to be applicable to operations that will be performed at the PFSF. Table 10.3-3 of the TranStor SAR (Reference 3), entitled "Estimated Personnel Exposure Doses", is not directly applicable to PFSF operations since it addresses tasks necessary to load spent fuel from a fuel pool into the canister and then transfer the canister from a transfer cask (rather than from a shipping cask) into a storage cask. Steps in this table that involve loading the canister into the storage cask and moving the storage cask to the pads are considered relevant to the operations that will be performed at the PFSF. However, Table 10.3-3 of the TranStor storage cask SAR does not include the level of detail that was desired for the PFSF SAR, and therefore its usefulness was limited.

Since Holtec had already developed dose rate estimates to operators involved in detailed tasks associated with canister transfer operations, and included these dose rate estimates in Table 10.3.3 of the HI-STORM Storage Cask SAR, these dose rate estimates were used for the same steps in the PFSF SAR. As discussed in following paragraphs, it was necessary to scale down the dose rates given in Table 10.3.3 of the HI-STORM SAR, which apply to design basis fuel, to dose rates representative of typical fuel that will be received at the PFSF. In those cases where Table 7.4-1 of the PFSF SAR contains a step not included in Table

10.3.3 of the HI-STORM Storage Cask SAR and for which dose rate information was not provided, then it was necessary to estimate dose rates based on the dose rate information provided in Section 5 of the HI-STAR Shipping Cask SAR and/or Section 5 of the HI-Storm Storage Cask SAR. Again, dose rates from these vendor SARs are based on the assumption that the canisters contain design basis fuel, and it was necessary to scale down the dose rates provided in the SARs to arrive at dose rates representative of typical fuel that will be received at the PFSF.

Since Table 10.3-3 of the TranStor SAR did not provide information on dose rates that applied to detailed tasks included in Table 7.4-2 of the PFSF SAR, for the most part, it was necessary to estimate dose rates for the individual tasks based on the dose rate information provided in Section 5 of the TranStor Shipping Cask SAR and/or Section 5 of the TranStor Storage Cask SAR. These dose rates, based on the assumption that the TranStor canisters contain design basis fuel, were then scaled down to arrive at dose rates representative of typical fuel that will be received at the PFSF.

As noted above, dose rates and integrated exposures identified in Table 10.3.3 of the HI-STORM SAR and in Table 10.3-3 of the Transtor Storage Cask SAR are both based on the assumption that the canisters involved in these operations are loaded with design basis fuel. It was considered that use of dose rates and personnel exposures from these tables in the PFSF SAR, assuming 200 canister transfer operations per year, would result in extremely high estimates of annual worker integrated dose, since most of the fuel to be handled at the PFSF will have much lower burnup and longer cooling times than the vendors' design basis fuel which served as the basis for their personnel exposure estimates. The design basis fuels considered in these operations for the storage cask are substantially "hotter" (have higher gamma and neutron generation rates) than the design basis fuels permitted in the shipping casks that will be used to transport fuel to the PFSF. For example, a design basis PWR fuel for the HI-STORM storage cask system has a burnup of 45 GWd/MTU and 5 year cooling time, whereas the design basis PWR fuel for the HI-STAR shipping cask has a burnup of 40 GWd/MTU and 10 year cooling time. A design basis PWR fuel for the TranStor storage cask system has a burnup of 45 GWd/MTU and 6 year cooling time, whereas the design basis PWR fuel for the TranStor shipping cask has a burnup of 40 GWd/MTU and 8 year cooling time. Since design basis storage cask fuel is not permitted to be transported to the PFSF in the vendors' shipping casks, it is not reasonable to assume that canisters containing the storage cask design basis fuels are handled at the PFSF.

Even the shipping cask design basis fuels are substantially hotter than fuel that would typically be received at the PFSF, and it was considered that occupational exposure estimates based on the assumption that canisters received at the PFSF are loaded with the vendors' shipping cask design basis fuels would result in estimated worker exposures far in excess of actual exposures. In order for the occupational exposure estimates to be realistic it was necessary to identify spent fuel with characteristics representative of typical fuel expected to be received at the PFSF. PFSF SAR Section 7.4 states the following regarding fuel assumed to be received at the PFSF, which is a key input to dose rates calculated in PFSF SAR Tables 7.4-1 and 7.4-2:

> "Dose rate values include both gamma and neutron flux components, and are based on PWR fuel with 35 GWd/MTU burnup and 20-year cooling time. Fuel with these characteristics is considered to be representative of typical fuel that will be contained in canisters handled at the PFSF and dose estimates based on fuel with these characteristics are considered to be realistic."

DOE's Energy Information Administration's Service Report entitled "Spent Nuclear Fuel Discharges from U.S. Reactors - 1994", published in February 1996 (Reference 9), provides information regarding characteristics of spent fuel in the U.S. This report was reviewed to evaluate average burnups and cooling time associated with the spent fuel inventory at the end of 1994. At this time, the spent fuel inventory from pressurized water reactors (PWRs) was approximately 19,000 metric tons of uranium (MTU), and the inventory from boiling water reactors (BWRs) approximately 11,000 MTU, for a total inventory of approximately 30,000 MTU (Table 5 of DOE report). This spent fuel inventory represents 75% of the capacity of the PFSF. While it is recognized that provisions already exist for storage of some of this spent fuel and the PFSF will not furnish storage for this entire inventory, data associated with this spent fuel is considered representative of fuel that the PFSF could be expected to receive. The weighted average burnup (weighted by MTU) for the BWR spent fuel inventory in the U.S. was calculated from Table 7 of the above referenced DOE Report to be approximately 23.8 GWd/MTU, and the weighted average burnup for the PWR spent fuel inventory in the U.S. was calculated from Table 7 of this report to be approximately 32.4 GWd/MTU. The spreadsheet used to calculate these weighted average burnups is included in Attachment A of this calculation.

Weighted average cooling times were also calculated from the data presented in Table 7 of the DOE Report, conservatively assuming that the PFSF receives 2,000 MTU of spent fuel each year, beginning in the year 2002, until all 30,000 MTU have been received (in year 2016). It was assumed that the older spent fuel, whether BWR or PWR, is received first. Based on these assumptions, the weighted average cooling time for spent fuel assumed to be received at the PFSF was calculated to be 23.0 years. The spreadsheet used to calculate this weighted average cooling time is also included in Attachment A of this calculation.

Because of the large inventory of spent fuel taken into account (approximately 30,000 MTU), this is considered to be a reasonable representation of typical fuel that will be received at the PFSF. Based on this evaluation, the 35 GWd/MTU burnup and 20-year cooling time spent fuel assumed in the PFSF SAR onsite dose assessment is considered to be representative of typical fuel expected to be received at the PFSF and will result in reasonably accurate and realistic occupational exposure estimates.

Dose rates computed by Holtec and TranStor at different points near their shipping casks, transfer casks and storage casks, assumed to contain canisters loaded with design basis fuel, are scaled by the gamma and neutron source strengths to estimate dose rates at the same points based on the "cooler" PFSF typical fuel. Scaling is performed as described in Section 5.4.1 of the TranStor SAR, and as discussed in the calculation below.

Whereas, the vendors provide dose rate information for storage and shipping casks containing PWR and BWR design basis fuels, Tables 7.4-1 and 7.4-2 are based on the assumption that canisters contain PWR fuel.

Time durations are best estimates for operations at the PFSF, with Table 10.3.3 of Ref. 2 considered for input to HI-STORM tasks. Input was also provided by several phone discussions between Jeff Johns (SWEC) and John Broschak (H.P. Supervisor at Palisades Nuclear Power Plant, phone 616-764-2650) and Mike Holdsman (H.P. Supervisor at Point Beach Nuclear Power Plant, phone 414-755-6831) which took place in 1997 when the PFSF SAR was being prepared. Personnel at Palisades and Point Beach nuclear power plants have been involved in cask loading operations for Sierra Nuclear Corporation's (SNC) VSC-24 spent fuel cask storage system, which is the precursor to SNC's TranStor cask storage system.. The two systems, and fuel loading and canister transfer operations, are very similar, and operating experience at these facilities is relevant to PFSF operations involving the TranStor cask storage system. While this system has differences when compared to HI-STORM, some of the operations were judged to be similar, and some of the information regarding times to complete various steps was considered applicable to both the HI-STORM and TranStor cask storage systems.

Credit is taken for temporary shielding, installed by the operators at the direction of HP personnel, for certain steps where it is considered that temporary shielding would be effective in reducing dose rates and its installation and removal would not result in a net increase in integrated doses. In telephone calls between Jeff Johns (SWEC), John Broschak (HP - Palisades) and Mike Holdsman (HP - Point Beach), information was communicated regarding dose rates associated with VSC-24 cask storage system canister transfer operations and the effectiveness of temporary shielding. Some of this information was considered to be applicable to the PFSF canister transfer operations.

The number of operators and health physics (HP) technicians is based on consideration of the tasks involved and best estimate of the minimum personnel necessary to perform these tasks in a manner which maintains integrated personnel exposures as low as is reasonably achievable (ALARA). For most steps it is assumed that the HP technician is stationed in an area with relatively low dose rates some distance from the casks, and spends very little time next to or on top of the casks measuring dose rates in the relatively high dose rate areas where the operators need to perform some of the steps. For this reason, the HP technician dose rates are lower than those for the operators, and it is generally assumed that the HP technician is able to spend most of the time in an area with dose rates of 1 mrem/hr.

REFERENCES

1. Private Fuel Storage Facility Safety Analysis Report, Docket No. 72-22, Revision 0.

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 2, April 1997.

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

4. DOE/RW-0184-R1, Characteristics of Potential Repository Wastes, Office of Civilian Radioactive Waste Management, U.S. Department of Energy, July 1992. Light Water Reactor Radiological Computer Database for Generic PWR Spent Fuel.

5. NRC NUREG-1567, Standard Review Plan for Spent Fuel Dry Storage Facilities (Draft Report for Comment), October 1996.

6. Topical Safety Analysis Report for the Holtec International Storage, Transport, and Repository Cask System, (HI-STAR 100 Cask System), Holtec Report HI-951251, Docket 71-9261, Revision 4, September 1996.

7. Safety Analysis Report for the TranStor Shipping Cask System, SNC-95-71SAR, Sierra Nuclear Corporation, Docket 71-9268, Revision 2, June 1997.

8. The Health Physics and Radiological Health Handbook, edited by Bernard Shleien, Revised Edition, 1992.

9. SR/CNEAF/96-01, Report by the Energy Information Administration of the Department of Energy, “Spent Nuclear Fuel Discharges from U.S. Reactors - 1994”, published February 1996.

CONCLUSION

The bases for PFSF SAR Tables 7.4-1 and 7.4-2 are provided in the calculation which follows. The calculation discusses the assumed general location of workers for each operation identified in the tables, dose rates at these locations, estimated times to perform each operation, and the estimated dose reduction due to temporary shielding for those steps where applicable. Revisions were determined to be necessary to the PFSF SAR Tables 7.4-1 and 7.4-2, as doses estimated in this calculation for some of the steps are different from those identified in these tables in Rev. 0 of the PFSF SAR (Reference 1). There are several primary reasons for these revisions, as follows:

- Whereas it was considered in the original PFSF SAR tables that it would be practical to use temporary shielding to reduce dose rates to workers on top of the canister to levels of approximately 2 mrem/hr, this calculation indicates that gamma reduction would require up to 1.5 inches of lead, which is considered impractical due to the weight of the lead disc required (about 1 ton). Therefore, the dose rates used in the revised tables (Attachment D) reflect the use of temporary neutron shields but not the much heavier gamma shields, and shielded dose rates to workers on top of the canister are above the 2 mrem/hr originally assumed (7.1 mrem/hr for HI-STORM and 4.5 mrem/hr for TranStor).

- Sierra Nuclear Corporation revised the applicable design basis PWR fuel for their TranStor shipping cask in Revision 2 of the TranStor shipping cask SAR (Reference 7 of this calculation), from 45 GWd/MTU burnup and 8 year cooled to 40 GWd/MTU burnup and 8 year cooled. This resulted in different dose rates associated with this shipping cask with design basis fuel, as well as different scaling factors to scale the gamma and neutron source strengths from this fuel to the typical PFSF fuel (35 GWd/MTU burnup and 20 year cooled) assumed in this calculation. The effect of this change was, in general, an increase in dose rates to workers for those tasks involving the TranStor shipping cask.

- General area dose rates associated with the HI-STAR shipping cask for workers involved in receiving and inspecting the shipment, measuring dose rates and removing the personnel barrier, had previously been estimated at 2.5 mrem/hr for typical PFSF fuel, but was recalculated at approximately 4 mrem/hr, used in the revised tables shown in Attachment D.

- Final integrated doses to operators and HP personnel involved in the canister transfer operations, with credit for temporary shielding on top of the shipping casks and canisters, increased from 176.6 mrem for HI-STORM and 182.9 mrem for TranStor (listed in Tables 7.4-1 and 7.4-2 of Rev. 0 in the PFSF SAR) to 198.7 mrem for HI-STORM and 208.9 for TranStor, as shown in Attachment D.

CALCULATION

Determination of Scaling Factors

The canister transfer operation involves dose rates associated with shipping casks, canisters, transfer casks and storage casks for each of the two PFSF cask vendors. Each vendor uses the same design basis fuels for analyses involving their storage cask and transfer cask, but specifies different design basis fuels for their shipping casks.

Following are the characteristics associated with the design basis fuels that serve as the basis for PFSF SAR Tables 7.4-1 and 7.4-2:

HI-STORM Storage & HI-TRAC transfer casks (Tables 5.1-2 and 5.1.8 of Reference 2)	45 GWd/MTU burnup, 5 yr-cooled
HI-STAR Shipping Cask (Table 5.1.5 of Reference 6)	40 GWd/MTU burnup, 10 yr-cooled
TranStor Storage and Transfer Casks (Tables 5.1-1 and 5.1-2 of Reference 3)	45 GWd/MTU burnup, 6 yr-cooled
TranStor Shipping Cask (Table 5.5-11 of Reference 7))	40 GWd/MTU burnup, 8 yr-cooled

Scaling factors are applied to assess dose rates assuming casks contain typical PFSF fuel assumed to have 35 GWd/MTU burnup and 20 year cooling time rather than design basis fuel. These scaling factors are calculated using source data obtained from the OCRWM LWR Database (Reference 4) using the scaling method applied by Sierra Nuclear Corporation and discussed in Section 5.4.1 of the TranStor SAR (Reference 3). Applicable information from the OCRWM LWR Database was transmitted to SWEC by Jim Hopf (formerly with Sierra Nuclear Corporation, vendor for the TranStor cask storage system, and currently with Westinghouse Government and Environmental Services Company, Spent Nuclear Fuel Programs), and is included in Attachment B.

The following table compares a key portion of the gamma source energy spectrum associated with HI-STORM design basis PWR fuel having 45 GWd/MTU burnup and 5 year cooling time with that associated with PFSF typical fuel assumed to have 35 GWd/MTU burnup and 20 year cooling time. Gamma energy spectra are compared, and not simply the total gamma production rate, since the fraction of total energy contributed by each energy bin varies significantly with burnup and cooling time.

Table 1 Determination of Gamma Scaling Factor for 45 GWd/MTU Burnup and 5-Year Cooled Fuel - the Design Basis Fuel for the HI-STORM Storage Cask and HI-TRAC Transfer Cask

Average Energy (MeV)	45 GWd/MTU, 5-yr cooled, 3.7% enrichment (photons/sec per metric ton heavy metal)	35 GWd/MTU, 20-year cooled, 3.43% enrichment (photons/sec per metric ton heavy metal))	Ratio of photons/sec 35 GWd/45 GWd
0.575	7.221 E+15	2.524 E+15	3.495E-1
0.850	1.825 E+15	5.149 E+13	2.821E-2
1.250	7.531 E+14	9.075 E+13	1.205E-1
1.750	1.079 E+13	1.412 E+12	1.309E-1
2.250	4.551 E+12	3.513 E+8	7.719E-5
2.750	1.638 E+11	4.001 E+8	2.443E-3
3.50	2.101 E+10	1.828 E+7	8.701E-4

The highest ratio of the gamma source strengths is 3.495 E-1 photons/sec, associated with the relatively low average energy of 0.575 MeV. Section 9.4.2.1 of NRC NUREG-1567 (Reference 5), states "In general, only gamma sources with energies from approximately 0.8 to 2.5 MeV will contribute significantly to the dose rate through typical types of shielding, however all energy ranges should be included in shielding calculations." Based on this, the highest gamma energy ratio for the energy ranges between 0.8 and 2.5 MeV is conservatively used to scale the total gamma dose rate provided for the design basis fuels. Considering that the 0.575 MeV average energy bin will not contribute significantly to dose rates outside the storage cask or transfer casks, the highest ratio of the 35 GWd/45 GWd sources is associated with the 1.750 MeV energy bin, having a ratio of 1.309 E-1. This ratio (scaling factor) is conservatively applied to the total gamma dose rate to scale dose rates from all gamma energies from those associated with 45 GWd/MTU 5-year cooled fuel to those applying to 35 GWd/MTU 20-year cooled fuel.

In order to assess dose rates associated with neutrons, it is not necessary to compare neutron source energy spectra, since the fraction of total energy contributed from each energy bin does not change significantly with variations in burnup or cooling time (Sections 5.2.2 and 5.4.1 of Reference 3). For this reason, only the total neutron source strengths extracted from the OCRWM LWR Database for fuel having the two different characteristics are compared. The database indicates that PWR fuel having 45 GWd/MTU 5-year cooled fuel emits 8.340 E+8 neutrons/sec per metric ton heavy metal, while the 35 GWd/MTU 20-year cooled fuel emits 1.786 E+8 neutrons/sec per metric ton heavy metal, resulting in a 35 GWd/45 GWd neutron source ratio of 2.141 E-1. This factor is conservatively applied to the total neutron dose rate associated with storage casks containing design basis fuel to scale neutron dose rates from those associated with 45 GWd/MTU 5-year cooled fuel to those applying to 35

GWd/MTU 20-year cooled fuel.

The same methodology was applied to calculate scaling factors for the other design basis fuels, all compared to the 35 GWd/MTU 20-year cooled typical PFSF fuel.

Table 2 Determination of Gamma Scaling Factor for 40 GWd/MTU Burnup and 10-Year Cooled Fuel - the Design Basis Fuel for the HI-STAR Shipping Cask

Average Energy (MeV)	40 GWd/MTU, 10-yr cooled, 3.7% enrichment (photons/sec per metric ton heavy metal)	35 GWd/MTU, 20-year cooled, 3.43% enrichment (photons/sec per metric ton heavy metal))	Ratio of photons/sec 35 GWd/45 GWd
0.575	3.988 E+15	2.524 E+15	6.329 E-1
0.850	3.571 E+14	5.149 E+13	1.442 E-1
1.250	3.227 E+14	9.075 E+13	2.812 E-1
1.750	3.786 E+12	1.412 E+12	3.730 E-1
2.250	7.254 E+10	3.513 E+8	4.843 E-3
2.750	5.216 E+9	4.001 E+8	7.671 E-2
3.50	6.440 E+8	1.828 E+7	2.839 E-2

Considering that the 0.575 MeV average energy bin will not contribute significantly to dose rates outside the shipping cask, the highest gamma ratio of the 35 GWd/40 GWd sources is associated with the 1.750 MeV energy bin, having a ratio of 3.730 E-1. The database indicates that PWR fuel having 40 GWd/MTU 10-year cooled fuel emits 4.181 E+8 neutrons/sec per metric ton heavy metal, while the 35 GWd/MTU 20-year cooled fuel emits 1.786 E+8 neutrons/sec per metric ton heavy metal, resulting in a 35 GWd/45 GWd neutron source ratio of 4.272 E-1.

Table 3 Determination of Gamma Scaling Factor for 45 GWd/MTU Burnup and 6-Year Cooled Fuel - the Design Basis Fuel for the TranStor Storage Cask and Transfer Cask

Average Energy (MeV)	45 GWd/MTU, 6-yr cooled, 3.3% enrichment (photons/sec per metric ton heavy metal)	35 GWd/MTU, 20-year cooled, 3.43% enrichment (photons/sec per metric ton heavy metal))	Ratio of photons/sec 35 GWd/45 GWd
0.575	6.388 E+15	2.524 E+15	3.951 E-1
0.850	1.408 E+15	5.149 E+13	3.657 E-2
1.250	6.810 E+14	9.075 E+13	1.333 E-1
1.750	8.626 E+12	1.412 E+12	1.637 E-1
2.250	2.021 E+12	3.513 E+8	1.738 E-4
2.750	9.095 E+10	4.001 E+8	4.399 E-3
3.50	1.174 E+10	1.828 E+7	1.557 E-3

Considering that the 0.575 MeV average energy bin will not contribute significantly to dose rates outside the storage cask or transfer casks, the highest gamma ratio of the 35 GWd/45 GWd sources is associated with the 1.750 MeV energy bin, having a ratio of 1.637 E-1. The database indicates that PWR fuel having 45 GWd/MTU 6-year cooled fuel emits 1.055 E+9 neutrons/sec per metric ton heavy metal, while the 35 GWd/MTU 20-year cooled fuel emits 1.786 E+8 neutrons/sec per metric ton heavy metal, resulting in a 35 GWd/45 GWd neutron source ratio of 1.693 E-1.

Table 4 Determination of Gamma Scaling Factor for 40 GWd/MTU Burnup and 8-Year Cooled Fuel - the Design Basis Fuel for the TranStor Shipping Cask

Average Energy (MeV)	40 GWd/MTU, 8-yr cooled, 3.02% enrichment (photons/sec per metric ton heavy metal)	35 GWd/MTU, 20-year cooled, 3.43% enrichment (photons/sec per metric ton heavy metal))	Ratio of photons/sec 35 GWd/45 GWd
0.575	4.622 E+15	2.524 E+15	5.461 E-1
0.850	6.729 E+14	5.149 E+13	7.652 E-2
1.250	4.623 E+14	9.075 E+13	1.963 E-1
1.750	5.233 E+12	1.412 E+12	2.698 E-1
2.250	3.984 E+11	3.513 E+8	8.818 E-4
2.750	2.395 E+10	4.001 E+8	1.671 E-2
3.50	3.075 E+9	1.828 E+7	5.945 E-3

Considering that the 0.575 MeV average energy bin will not contribute significantly to dose rates outside the shipping cask, the highest ratio of the 35

GWd/40 GWd sources is associated with the 1.750 MeV energy bin, having a gamma ratio of 2.698 E-1. The database indicates that PWR fuel having 40 GWd/MTU 8-year cooled fuel emits 7.277 E+8 neutrons/sec per metric ton heavy metal, while the 35 GWd/MTU 20-year cooled fuel emits 1.786 E+8 neutrons/sec per metric ton heavy metal, resulting in a 35 GWd/45 GWd neutron source ratio of 2.454 E-1.

The following table summarizes the scaling factors associated with the different design basis fuels, all scaled to the 35 GWd/MTU 20-year cooled fuel.

Table 5 Summary of Scaling Factors for Scaling Dose Rates Associated with Design Basis Fuels to Those Representative of PFSF Typical Fuel

Applicable Cask(s) and Characteristics of Design Basis Fuel	Gamma Scaling Factor	Neutron Scaling Factor
HI-STORM Storage and Transfer Casks 45 GWd/MTU Burnup, 5-yr cooled	0.1309	0.2141
HI-STAR Shipping Cask 40 GWd/MTU Burnup, 10-yr cooled	0.3730	0.4272
TranStor Storage and Transfer Casks 45 GWd/MTU Burnup, 6-yr cooled	0.1637	0.1693
TranStor Shipping Cask 40 GWd/MTU Burnup, 8-yr cooled	0.2698	0.2454

The dose rates to workers during several steps of the canister transfer operation are considered to be relatively high, and could be reduced by the use of temporary shielding. In particular, dose rates to workers assumed to be positioned on top of the shipping cask, on top of the canister within the shipping cask when the shipping cask closure lid has been removed, and on top of the storage cask with the lid in place in the case of the TranStor storage cask. The HI-STORM storage cask lid provides sufficient shielding to workers so that temporary shielding is not warranted. Where practical, it is desirable to reduce dose rates to 2 mrem/hr through the use of temporary shielding. Following is a discussion of shielding thicknesses calculated to reduce both gamma and neutron dose rates.

Temporary Shielding

Relatively high dose rates occur on top of the HI-STORM and TranStor canisters and shipping casks, and the TranStor storage cask with its lid in place. Low dose rates occur on top of the HI-STORM storage cask with its lid in place, due to the design of its massive lid which is over 1 ft thick and consists of steel and concrete. From step 6 in the following exposure estimates for the canister transfer operations of each vendor it is seen that the dose rates on top of the shipping casks consist primarily of neutron radiation. For shipping casks, in the case of HI-STAR, the total dose rate to a worker in the general area above the shipping cask is estimated to be 12.5 mrem/hr, consisting of 12.34 mrem/hr neutron (98.7%) and 0.16 mrem/hr gamma (1.3%). In the case of TranStor, the dose rate above the shipping cask is estimated at 17.64 mrem/hr, with 100% due to neutron and the gamma dose rate a negligible contribution. Therefore, it is considered that a temporary neutron shield placed on top of the shipping cask will suffice to reduce dose rates to desired levels of approximately 2 mrem/hr. This will require an approximately 7 to 8-fold reduction in the neutron dose rates.

Attachment C of this calculation is a curve which shows neutron dose rate reduction factors for Water Extended Polyethylene (WEP), which is an excellent neutron shield material, assuming the neutron source is from plutonium metal. While the neutron energy spectrum from the plutonium metal used to derive this curve differs from that associated with spent fuel assemblies, the curve is used to obtain approximate dose rate reduction factors associated with varying thicknesses of WEP. Based on this figure, 6.0 inches of WEP would provide a neutron dose rate reduction factor of approximately 0.12, approximately an 8-fold reduction. The temporary shield is assumed to be a circular disc, whose diameter would extend to near the shipping cask closure lid bolt ring, but permit access to the bolts by means of a wrench or special tool so operators could untorque and remove the lid bolts while their body is shielded from the underlying canister by the WEP. It is considered that the WEP shield could be designed with dimensions so that it can be used on top of the shipping cask, to remove shipping cask closure bolts, and on top of the canister (after the shipping cask closure lid has been removed). The WEP would need to be encased in a thin steel outer shell so that it will not flake. In the case of HI-STORM, the shield disc would need to have a hole or grooves in the center so that operators could access the area where the canister lifting cleats are bolted and unbolted. This is not necessary for TranStor, where the canister lifting eyes are located near the outside of the canister.

Gamma radiation contributes significantly to dose rates from the top of the canister, as seen in step 9 of the following transfer operations for both vendors. For instance, in the case of the HI-STORM canister, the total dose rate to a worker in the general area above the canister is estimated to be 12.5 mrem/hr, consisting of 6.34 mrem/hr gamma (50.7%) and 6.16 mrem/hr neutron (49.3%). In the case of TranStor, the dose rate above the canister is estimated to be 16.8 mrem/hr, consisting of 2.79 mrem/hr gamma (16.6%) and 14.0 mrem/hr neutron (83.4%).

A 6.0 inch thick WEP circular disc shield placed on top of the HI-STORM <u>canister</u> would be expected to reduce neutron dose rates from 6.16 mrem/hr to: (6.16) (0.12) = 0.74 mrem/hr. In order to obtain gamma dose rates of approximately 2 - 0.74 = 1.26 mrem/hr, it is necessary to install gamma shielding material which would achieve a factor of 1.26 / 6.34 = 0.20 dose rate reduction. It is assumed that the average energy of gamma radiation at the top of the canister is approximately 1.25 MeV (the average gamma emission energy associated with Co-60 decay), since the 1.25 MeV energy line is the predominant contributor of total gamma emission from the fuel in the range of 0.8 to 2.5 MeV that contribute to dose rates outside the thick top canister shielding as seen in Tables 1 through 4 above. Based on Table 6.1.2 of Reference 8, the linear attenuation coefficient (μ) of lead for gamma radiation emitted by Co-60 decay (1.25 MeV average energy) is 0.679 cm^{-1}. The buildup factor for lead where the attenuation coefficient is characterized by a 1.47 cm mean free paths ($1/\mu$) is interpolated from Table 6.4-1 of Reference 8 between 1 and 2 MeV for the 1.25 MeV average gamma energy considered as 1.54. Solving the shielding equation $D_x = D_0Be^{-\mu x}$ for x (where $D_x/D_0 = 0.20$, and B is the buildup factor) a lead thickness of approximately 1.2 inches is required to reduce the gamma dose rate by a factor of 0.20.

In the case of the TranStor canister, a 6.0 inch thick WEP circular disc shield placed on top of the TranStor canister would be expected to reduce neutron dose rates from 14.0 mrem/hr to 1.68 mrem/hr. In order to obtain gamma dose rates of approximately 2 - 1.68 = 0.32 mrem/hr, it is necessary to install gamma shielding material which would achieve a factor of 0.32 / 2.79 = 0.115 dose rate reduction. Solving the shielding equation $D_x = D_0Be^{-\mu x}$ for x (where $D_x/D_0 = 0.115$ and the buildup factor, B, is 1.54) a lead thickness of approximately 1.5 inches is required to reduce the gamma dose rate by a factor of 0.115.

Step 25 of the following transfer operations for both vendors requires installation of storage cask lid bolts. In the case of the HI-STORM storage cask, the massive storage cask lid, with its 10.5 inches thick concrete and 5.25 inches thick steel, greatly attenuates both gamma and neutron radiation. Table 5.1.2 of Reference 2 identifies calculated dose rates of 1.86 mrem/hr one meter above the top of the cask and 14.22 mrem/hr one meter from the side of the cask (assuming design basis fuel). In the case of the TranStor storage cask, with its 0.75 inch thick steel lid, dose rates are higher above the lid than at the side of the cask. Table 5.1-1 of Reference 3 identifies calculated dose rates of 83.0 mrem/hr one meter above the top of the cask, 9.7 mrem/hr one meter from the side of the cask and 7.1 mrem/hr on contact with the air outlet duct near the top of the cask (assuming design basis fuel). Based on these values, it is prudent to station the workers installing the HI-STORM lid bolts on top of the storage cask lid, while workers installing the TranStor storage cask lid should have their bodies positioned to the side of the TranStor storage cask. Scaling dose rates from those associated with design basis fuel to PFSF typical fuel (see step 25 for each vendor), workers involved in installing HI-STORM lid bolts on top of the storage cask would be in a dose field of approximately 2 mrem/hr, while workers positioned along the side of a TranStor storage cask would be in a dose field of approximately 3 mrem/hr. These dose rates are considered acceptable, and temporary shielding is not required on either vendor's storage cask for this step.

While worker dose rates of approximately 2 mrem/hr on top of the shipping casks, canisters and storage casks are desirable, temporary installation of 1.2 to 1.5 inch thick lead shield discs on top of the canister lids (in steps 10 and 24 of the following exposure estimates), weighing up to one ton, is considered to be impractical and unreasonable. Therefore it is assumed that the 6 inch thick WEP neutron shields, which are lighter weight and relatively easy to handle, will be used, but not the much heavier gamma shields. The neutron shields alone will reduce total dose rates to operators working above the <u>shipping cask</u> lids to levels of approximately 2 mrem/hr. While the neutron shields will reduce <u>neutron</u> levels to below 2 mrem/hr for operators working on top of the <u>canister</u>, total dose rates will be somewhat higher due to gamma levels. No credit is taken for reduction of gamma dose rates by WEP to workers on top of the shipping casks or canisters.

Based on the above, total dose rates associated with the HI-STORM canister will be approximately 0.74 mrem/hr (neutron) + 6.34 mrem/hr (gamma) = 7.1 mrem/hr; and total dose rates associated with the TranStor canister will be approximately 1.68 mrem/hr (neutron) + 2.79 mrem/hr (gamma) = 4.5 mrem/hr.

BASIS FOR DOSE ESTIMATES, INCLUDING TIMES TO PERFORM EACH STEP AND DOSE RATE ESTIMATES USED IN PFSF SAR TABLE 7.4-1 - HI-STORM SYSTEM

Estimated Personnel Exposure During Shipping Cask Receipt, Canister Transfer Operation, and Placement of Storage Cask on Pad

The following steps correspond to those in Table 7.4-1 of the PFSF SAR, "Estimated Personnel Exposures for HI-STORM Canister Transfer Operations."

1. Receive and inspect shipment, and measure dose rates. It is estimated that 2 operators can receive the shipment and perform the receipt inspection, while one HP technician measures dose rates, in approximately 30 minutes.

Ref. 2 Table 10.3.3 estimates a dose rate of 10 mrem/hr for this operation, and estimates a completion time of 0.1 hours (6 min). While not stated in Chapter 10 of the HI-STORM SAR, this is assumed to be based on the reference PWR fuel used in the HI-STAR Shipping Cask SAR (Ref. 6), with 40 GWd/MTU burnup and 10 year cooling time. Based on Figure 5.1.1 of Ref. 6 and Table 5.1-5 ("Dose Rates at Two Meters for Normal Conditions MPC-24 Design Basis Fuel at Worst Case Burnup and Cooling Time 40,000 MWd/MTU and 10-Year Cooling") the dose rate at 2 meters from the side of the cask (dose location 2) is 8.68 mrem/hr, comprised of 6.42 mrem/hr gamma (74% of total) and 2.26 mrem/hr neutron radiation (26% of total). Using the Ref. 1 Table 10.3.3 estimated dose rate of 10 mrem/hr and applying scaling factors to consider the 35 GWd/MTU burnup, 20 year cooling time assumed fuel results in:

Gamma dose rate = 7.4 (0.373) = 2.76
Neutron dose rate = 2.6 (0.427) = 1.11
Total dose rate = 10.0; scaled = 3.87 (Use 4 mrem/hr)

2. Move shipment into Canister Transfer Building. It is estimated that 3 operators would be involved in driving and positioning the trailer or rail car in the cask load/unload bay of the Canister Transfer Building, with an HP technician monitoring the operation. This operation is estimated to take 30 minutes.

Personnel should be able to remain well clear of the shipping cask during this operation, and will not be exposed to significant dose rates.

3. Remove personnel barrier, measure dose rates, and perform contamination survey. 1 hr in the dose field is more than adequate time for two operators to remove the personnel barrier and provide the HP technician with any necessary assistance during the radiological survey. 1.6 hr is estimated for one HP technician to perform the radiation and contamination survey.

Table 10.3.3 of Reference 2 estimates an average dose rate of 10 mrem/hr to workers performing this step, the same as for step 1. As determined in step 1, this dose rate scaled from design basis fuel to PFSF typical fuel is 4 mrem/hr. However, dose rates are estimated to be slightly higher to the technician performing the contamination survey and an average dose rate of 6 mrem/hr is assumed.

4. Remove impact limiters and tiedowns. Table 10.3.3 of Ref. 2 estimates 2 hours to remove the impact limiters and 0.5 hours to remove the tiedowns, which seems excessive. It is considered that 1.5 hours provides adequate time for two operators to perform these operations.

Table 10.3.3 of Ref. 2 assumes general area dose rates of 10 mrem/hr for this task, the same as removal of the personnel barrier (which was scaled to approximately 4 mrem/hr considering typical PFSF fuel). However, it is considered that the operators would need to position their bodies somewhat closer to the cask for this step than for removal of the personnel barrier, and the dose rate was assumed to be 5 mrem/hr.

5. Attach lifting yoke to crane and HI-STAR shipping cask. Upright HI-STAR shipping cask and move to transfer cell. While it is estimated that the entire operation takes 1 hr, 30 minutes is adequate time for the operators to perform work needed in the vicinity of the shipping cask.

5 mrem/hr is estimated for average dose rates to operators working in the vicinity of the shipping cask, as discussed in the previous steps.

6. Sample enclosed cask gas and vent (assuming cask internal pressure exceeds atmospheric). It is estimated that 1 operator can perform this task in about 30 minutes.

Table 10.3.3 of Ref. 2 estimates dose rates for this step of 25 mrem/hr. With the impact limiters removed, Ref. 6 dose rates for normal conditions of transport at the ends of the cask are not applicable. Figure 5.1.2 and Table 5.1.8 provide information on cask dose rates under accident conditions with the impact limiters and radial neutron shield removed. The dose rate given 1 meter from the top of the cask for PWR fuel with 40 GWd/MTU burnup and 10-year cooling time is 17.59 mrem/hr comprised of 0.23 mrem/hr (1.3%) gamma and 17.36 mrem/hr (98.7%) neutron radiation. The average radiation field to a worker on top of the shipping cask is estimated in Table 10.3.3 of Ref. 2 to be approximately 25 mrem/hr. This average dose rate is somewhat higher than that calculated at 1 meter above the lid since the worker's body is assumed to be, on average, closer than 1 meter from the top of the lid. The 25 mrem/hr estimate in Table 10.3.3 of Ref. 2 is scaled to be representative of PWR fuel with 35 GWd/MTU burnup and 20 year cooling time as follows:

Gamma dose rate =	(25) (0.013) (0.373)	= 0.12	
Neutron dose rate =	(25) (0.987) (0.427)	= 10.54	
Total dose rate =	25; scaled	= 10.66	Use a dose rate on top of the

canister of 12.5 mrem/hr, or one-half of that estimated by Holtec in Table 10.3.3 of Ref. 2 for the design basis fuel. This is slightly conservative based on the scaled estimate of 10.66 mrem/hr. It is assumed that the 12.5 mrem/hr consists of the same fraction of neutrons and gamma radiation as the 17.59 mrem/hr total dose rate at 1 meter, or 12.34 mrem/hr neutron (98.7%) and 0.16 mrem/hr gamma (1.3%).

The 6 inch thick disc consisting of WEP, that is discussed in the previous section on temporary shielding, would be expected to reduce neutron dose rates by a factor of 0.12 (the gamma dose rates would also be reduced though not as much, but no credit is taken for gamma reduction by WEP, which is primarily a neutron shield material). Dose rates with the temporary shielding in place are calculated to be:

Gamma dose rate = 0.16
Neutron dose rate = (12.34) (0.12) = 1.48
Total dose rate = = 1.64 (Use 2 mrem/hr)

7. Remove HI-STAR closure plate (lid) bolts. There are 54 closure lid bolts for the HI-STAR shipping cask (Figure 7.1.31 of Ref. 6), tightened to relatively high torque values. It is estimated that two operators can remove these bolts in 1 hr, which allows slightly over 2 minutes for removal of each bolt. It is considered that an electric or pneumatic tool can be used to expedite bolt removal once the bolt is initially loosened.

It is estimated that dose rates on top of the shipping cask lid will be approximately one-half the 25 mrem/hr estimated in Ref. 2 Table 10.3.3, since 35 GWd/MTU burnup, 20 year cooling time PWR fuel is assumed instead of the 40 GWd/MTU burnup, 10 year cooling time design basis fuel, as discussed in step 6 above.

Temporary shielding is assumed to be used to reduce dose rates to the workers on top of the shipping cask. The 6 inch thick WEP disc would reduce the total dose rate from 12.5 mrem/hr to less than 2 mrem/hr, and 2 mrem/hr is used in the occupational exposure estimate.

8. Remove HI-STAR closure plate (lid). Operators must spend several minutes on top of the shipping cask installing eyebolts and connecting rigging to lift the shipping cask lid. 12 minutes (0.2 hours) is considered adequate for two operators to perform this operation on top of the shipping cask.

12.5 mrem/hr on average is estimated to operators working on top of the shipping cask with its lid in place, as discussed in step 6, above. The temporary shield is assumed to have been removed from the top of the shipping cask prior to this step.

9. Prep HI-STAR to mate with HI-TRAC transfer cask. This involves installation of the transfer collar on the shipping cask to protect the shipping cask sealing surface and provide a seating surface for the transfer cask. It is estimated that two operators can perform this task on top of the shipping cask in approximately 12 minutes.

Table 10.3.3 of Ref. 2 estimates average dose rates of 25 mrem/hr to an operator working directly on top of the canister. Ref. 2 Figure 5.1.2 and Table 5.1.7 give dose rates on contact with the top of the canister (dose location 4) of 547.62 mrem, assuming PWR fuel with 45 GWd/MTU burnup and 5-years cooling time. This dose rate is comprised of 277.63 mrem/hr (50.7%) gamma and 269.99 mrem/hr (49.3%) neutron. Assuming the operator is in a 25 mrem/hr dose field, on average, and scaling to the 35 GWd/MTU burnup and 20-years cooling time fuel results in:

Gamma dose rate =	(25) (0.507) (0.131)	= 1.66
Neutron dose rate =	(25) (0.493) (0.214)	= 2.64
Total dose rate =	25; scaled	= 4.30

This value seems low for work performed on or in the vicinity of the top of the canister, so rather than use the 4.3 mrem/hr dose rate calculated above by scaling from 25 mrem/hr, the dose rate on top of the canister is assumed to be 12.5 mrem/hr, or one-half of that estimated by Holtec in Table 10.3.3 of Ref. 2 for the design basis fuel.

10. Install canister lift cleat and attach slings. Two large bolts are inserted and torqued onto each side of the lifting cleat (4 bolts total) to fasten the lifting cleat to the top of the canister. It is estimated that it takes two operators 1 hour to perform this operation.

12.5 mrem/hr on average is estimated to operators working on top of the canister, as discussed in step 9, above.

It is assumed that the 12.5 mrem/hr consists of the same fraction of neutrons and gamma radiation as the dose rate on contact with the top of the canister in the above step, 6.34 mrem/hr gamma (50.7%) and 6.16 mrem/hr neutron (49.3%).

The 6 inch thick disc consisting of WEP would be expected to reduce neutron dose rates by a factor of 0.12, and dose rates with the temporary shielding in place are calculated to be:

Gamma dose rate =		6.34
Neutron dose rate =	(6.16) (0.12) =	0.74
Total dose rate =		7.08 mrem/hr

11. Attach lifting yoke to crane and HI-TRAC. It is estimated that two operators can perform this operation in a relatively low dose rate field in approximately 30 minutes.

Operators do not need to be positioned at the level of the top of the transfer cask to help connect the lifting yoke to the transfer cask, and operators can watch this operation from the floor of the transfer facility, maintaining distance to minimize dose rate. It is estimated that with 35 GWd/MTU burnup and 20-year cooling time fuel, both operators and the HP technician would be in relatively low dose rate areas, with the operators assumed to be in a 2 mrem/hr radiation field and the HP technician in a 1 mrem/hr field.

12. Mount HI-TRAC on top of HI-STAR. It is estimated that two operators can perform this operation in a relatively low dose rate field within about 30 minutes.

Same as step 11, above.

13. Open HI-TRAC transfer cask doors. This is a manual operation performed at the bottom of the transfer cask, estimated to take two operators approximately 12 minutes to perform.

Table 10.3.3 of Ref. 2 does not provide a dose rate estimate for this operation. With the canister in the shipping cask, Figure 5.1.1 and Table 5.4.8 of Ref. 6 give dose rates representative of operators working near the top and at the side of the shipping cask to manipulate the transfer cask doors. The contact dose rate at dose location 4 for 40 GWd/MTU burnup and 10 year cooled fuel is given as 37.11 mrem/hr. Since the operators would not be in contact with the cask, but several feet away on average, a dose rate estimate of 12 mrem/hr is considered to be reasonably conservative for this task assuming design basis fuel. While the breakdown of gamma vs. neutron at this dose point on contact is not given, it can be calculated based on the breakdown given for this same dose point at 2 meters in Table 5.1.5, where the total dose rate of 6.99 mrem/hr is comprised of 3.91 mrem/hr gamma (55.9%) and 3.08 mrem/hr neutron (44.1%). Assuming an average dose rate of 12 mrem/hr to perform this task, and scaling to the 35 GWd/MTU burnup and 20-years cooling time fuel results in:

Gamma dose rate = (12) (0.559) (0.373) = 2.50
Neutron dose rate = (12) (0.441) (0.427) = 2.26
Total dose rate = 12; scaled = 4.76 mrem/hr; Use 5 mrem/hr for this task.

14. Attach slings to canister downloader hoist and raise canister. This operation involves two operators located near the top of the transfer cask grappling the slings connected to the canister lid lifting eyebolts, and attaching these to the canister downloader mounted on top of the HI-TRAC transfer cask. 30 minutes is considered adequate for this operation.

Table 10.3.3 of Ref. 2 estimates 10 mrem/hr to the operators performing this task. Per Figure 5.1.2 and Table 5.1.8 of Ref. 2, the dose rate 1 meter above the canister lid is 93.66 mrem/hr (dose location 4), assuming design basis PWR fuel with 45 GWd/MTU burnup and 5-year cooling time, comprised of 67.84 mrem/hr gamma (72.4%) and 25.82 mrem/hr neutron (27.6%) radiation. Assuming an average dose rate of 10 mrem/hr to perform this task, and scaling to the 35 GWd/MTU burnup and 20-years cooling time fuel results in:

Gamma dose rate = (10) (0.724) (0.131) = 0.95
Neutron dose rate = (10) (0.276) (0.214) = 0.59
Total dose rate = 10; scaled = 1.54 mrem/hr

It is conservative to assume 2 mrem/hr for this task, with the operators approximately 5 meters from the top of the canister.

15. Close HI-TRAC doors and install pins. Two operators can accomplish this task in 12 minutes, as in step 13.

With the canister in the transfer cask, dose rates near the side of the transfer cask will be significantly higher for this operation than when the transfer cask doors were opened in step 13. Per Figure 5.1.2 and Table 5.1.8 of Ref. 2, the dose rate 1 meter from the side of the transfer cask is 48.85 mrem/hr (dose location 2), assuming design basis PWR fuel with 45 GWd/MTU burnup and 5-year cooling time, comprised of 37.12 mrem/hr gamma (76.0%) and 11.73 mrem/hr neutron (24.0%) radiation. Assuming that the operators can maintain their bodies an average of 1 meter from the side of the transfer cask during this task, and scaling to the 35 GWd/MTU burnup and 20-years cooling time fuel results in:

Gamma dose rate = (37.12) (0.131) = 4.86
Neutron dose rate = (11.73) (0.214) = 2.51
Total dose rate = 48.85; scaled = 7.37 mrem/hr; Use 10 mrem/hr for this task.

16. Lower canister onto HI-TRAC doors. It is estimated that two operators can perform this step in about 12 minutes.

The operators do not need to be in the vicinity of the transfer cask for this operation, and can station themselves in a relatively low dose rate field, similar to the HP technician. Therefore, assume a dose rate of 1 mrem/hr for the operators and the HP technician for this task.

17. Prep HI-STORM storage cask to mate with HI-TRAC transfer cask (including installation of HI-STORM shielding inserts). It is estimated that 2 operators can perform this step in approximately 12 minutes.

Operators working near the top of the storage cask will be exposed to radiation emanating from the sides of the transfer cask. While operators will not be as close to the transfer cask as in step 15, above, where 10 mrem/hr was estimated, it is possible that the operators could be in a 5 mrem/hr dose rate field if the storage cask is assumed to be in relative close proximity to the shipping/transfer casks.

18. Move HI-TRAC from HI-STAR to HI-STORM. This operation is estimated to take approximately 42 minutes (0.7 hr) to perform, with the two operators and HP technician stationed in a relatively low dose rate area throughout the transfer cask movement.

1.0 mrem/hr is estimated for this operation.

19. Raise canister, and open HI-TRAC doors. It is estimated that two operators positioned alongside the transfer cask are positioned at the bottom of the transfer cask to manually open the transfer cask doors. It is estimated that this step takes 30 minutes to perform, but the two operators can open the transfer cask doors spending 12 minutes in the dose field.

This task requires that operators be alongside of the transfer cask for a short interval. Per step 15 above, 10 mrem/hr is estimated.

20. Lower canister into HI-STORM storage cask. Operators are standing by in the transfer cell, but not close to the storage or transfer casks during this operation, which is estimated to take 30 minutes (lower canister approximately 18 ft at a relatively low crane speed).

Operators do not need to be next to the transfer or storage casks for this canister lowering operation. General area dose rates are assumed to be relatively low, approximately 1 mrem/hr for the operators and the HP technician.

21. Disconnect lifting slings. It is estimated that it takes two operators 12 minutes to disconnect the canister lifting slings from the canister downloader.

Table 10.3.3 of Ref. 2 estimates 15 mrem/hr for this operation with design basis fuel in the canister. It is considered that operators can perform this task with their bodies located at the side and near the top of the transfer cask. A scaling calculation cannot be performed to determine gamma and neutron dose rates since Ref. 2 does not identify calculated dose rates alongside the transfer cask when the canister is in the storage cask under the transfer cask, and the fraction of gamma vs. neutron contribution is unknown. It is assumed that the operators are exposed to dose rates one-half the 15 mrem/hr value that is associated with design basis fuel, or 7.5 mrem/hr. This is conservative since gamma and neutron scaling factors are both less than 0.5, so the total scaled dose rate would be less than 1/2 that estimated with design basis fuel, regardless of the gamma/neutron breakdown.

22. Close transfer cask doors. It is estimated that two operators can manually close the transfer cask doors in 12 minutes.

It is conservative to assume 5 mrem/hr, the dose rate used in Step 13 for opening the transfer cask doors when the canister is in the shipping cask, since the storage cask provides more shielding than the shipping cask.

23. Remove HI-TRAC from HI-STORM. The crane remains connected to the transfer cask, so this is simply a crane operation. Two operators are assumed to be involved in this task, estimated to take 30 minutes.

Operators need not be next to the transfer or storage casks for this transfer cask movement. With the canister in the storage cask, general area dose rates are assumed to be 1 mrem/hr.

24. Remove canister lift cleat and HI-STORM shield inserts. It is estimated that two operators can untorque and remove the four bolts fastening the lifting cleat to the top of the canister, and remove the shield inserts from the air outlet ducts in 30 minutes, about one-half the time estimated for insertion and torquing of the canister lifting cleat bolts in step 10.

Dose rates on top of the canister will be the same as for Step 10, approximately 12.5 mrem/hr.

The same temporary shield disc used in step 10 to install the canister lift cleat is assumed to be used in this step, reducing the general area dose rate to workers on the canister from 12.5 mrem/hr to 7.1 mrem/hr.

25. Install HI-STORM lid and lid bolts. It is estimated that it will take two operators approximately 1 hr to place the storage cask lid, and bolt the lid onto the storage cask (4 bolts per Section 3.4.4.3.2.2 of Ref. 2).

Operators will need to be positioned on top of or near the top of the storage cask to coordinate with the crane operator and install the lid. Table 10.3.3 of Ref. 2 estimates 15 mrem/hr for this operation. This appears to be conservative, since dose rates calculated on top of the HI-STORM storage cask loaded with design basis fuel (45 GWd/IMTU and 5-year cooling time) with the lid in place are 6.69 mrem/hr on contact (Table 5.1.2 of Ref. 2) and 1.86 mrem/hr at 1 meter (Table 5.1.5 of Ref. 2). A dose rate of 2 mrem/hr is assumed for this operation, which accounts for scaling from design basis fuel to the 35 GWd/MTU burnup and 20-years cooling time PWR fuel assumed.

26. Perform dose survey and install HI-STORM lifting eyes. It is estimated that it takes two operators 30 minutes to prepare the HI-STORM storage cask for lifting by the cask transporter vehicle, and 30 minutes for the HP technician to perform a radiation survey of the cask.

As discussed in the above step, dose rates 1 meter above the storage cask with the lid in place are calculated to be 1.86 mrem/hr assuming design basis fuel. Dose rates to the operators are assumed to be 2.0 mrem/hr, which is conservative for the 35 GWd/MTU burnup and 20-years cooling time PWR fuel assumed.

27-30. Drive cask transporter in transfer cell. Connect HI-STORM to cask transporter. Raise HI-STORM storage cask. Transport HI-STORM cask to storage pad. Only one operator is needed to drive the cask transporter into a transfer cell, and this operation (step 27) is estimated to take 18 minutes. Two operators connect the storage cask to the cask transporter (step 28), an operation that is estimated to take 30 minutes. 2 operators are on hand to lift the storage cask by means of the cask transporter (step 29), the driver and one other operator, an operation estimated to take 12 minutes. Two operators are involved in moving the storage cask to the pad (step 30), the driver and another operator, which could possibly take as long as 2 hours, depending on the location of the storage pad and its distance from the Canister Transfer Building.

Personnel will not be in a significant dose field during these operations. The cask transporter is used to lift, move, and lower the storage cask, and (with the exception of step 28) personnel are not required to be adjacent to or on top of the cask during these operations. Assume general area dose rates of approximately 1 mrem/hr.

31. Position and lower HI-STORM cask on pad. It is estimated that two operators are involved in placing the storage cask on the pad, the cask transporter vehicle driver and an operator to function as a spotter to help the driver place the cask in the proper location. This operation is estimated to take 30 minutes in a significant dose rate field, since the operators and HP technician are exposed to radiation from casks already on the pads.

Based on Tables 5.1.2 and 5.1.5 of Ref. 2, dose rates at the side of a HI-STORM storage cask with 45 GWd/MTU, 5 yr-cooled PWR fuel are 28.91 mrem/hr on contact and 14.22 mrem/hr 1 meter from the cask. This 14.22 mrem/hr value is comprised of 13.67 mrem/hr gamma (96.1%) and 0.55 mrem/hr neutron (3.9%) radiation. Scaling to the 35 GWd/MTU burnup and 20-years cooling time typical PFSF fuel results in:

Gamma dose rate = (13.67) (0.131) = 1.79
Neutron dose rate = (0.55) (0.214) = 0.12
Total dose rate = 14.22; scaled = 1.91 mrem/hr at one meter from the side of a cask loaded with the assumed typical PFSF fuel.

Operators can position themselves away from the storage cask being lowered, and reduce exposure from this cask, but the dose rate from storage casks already at the pads could be significant. It is estimated that the total dose rate from the cask being handled, as well as nearby casks, is approximately 10 mrem/hr. The average dose rate to the HP technician, who is not working near a single cask for significant time, is estimated to be approximately 5 mrem/hr.

32. Disconnect HI-STORM cask from transporter and remove cask lifting eyes. It is estimated that two operators spend 1 hour on top of the storage cask disconnecting the cask from the cask transporter vehicle. The HP technician is in a significant dose rate field, since locations near the storage pads receive radiation from storage casks already on the pads.

As discussed in step 26, dose rates on top a HI-STORM storage cask are relatively low (a dose rate field of 2 mrem/hr was estimated to operators installing the cask lifting eyebolts) due to substantial shielding by the storage cask lid. However, it is assumed that operators on top of a HI-STORM storage cask on the pad are in a 10 mrem/hr dose rate field, primarily due to exposure from other nearby storage casks. The average dose rate to the HP technician, who is not working near a single cask for significant time, is estimated to be approximately 5 mrem/hr.

33. Connect cask temperature instrumentation. It is estimated that two operators spend 30 minutes in the vicinity of the storage cask recently placed on the storage pad connecting the temperature monitoring instrumentation. The HP technician is also in a significant dose rate field (though not as high as the operators since this person does not need to work on a cask and stay in the immediate vicinity of a storage cask), since locations near the storage pads receive radiation from storage casks already on the pads.

It is estimated that general area dose rates on the storage pads while working near a single cask, and accruing radiation from adjacent casks, could be approximately 10 mrem/hr, as discussed in step 31 above. The average dose rate to the HP technician, who is not working near a single cask for significant time, is estimated to be approximately 5 mrem/hr.

34. Perform cask operability tests. It is estimated that one operator can perform the cask operability tests required by the PFSF Technical Specifications over a period of about 2 days, spending approximately 1 hour near the storage cask on its storage pad. It is assumed that an HP technician accompanies the operator during the 1 hour involving tasks performed near the cask.

It is estimated that general area dose rates on the storage pads while working near a single cask, and accruing radiation from adjacent casks, could be approximately 10 mrem/hr, as discussed in steps 31, 32 and 33 above. The average dose rate to the HP technician, who is not working near a single cask for significant time, is estimated to be approximately 5 mrem/hr.

BASIS FOR DOSE ESTIMATES, INCLUDING TIMES TO PERFORM EACH STEP AND DOSE RATE ESTIMATES USED IN PFSF SAR TABLE 7.4-2 - TRANSTOR SYSTEM

Estimated Personnel Exposure During Shipping Cask Receipt, Canister Transfer Operation, and Placement of Storage Cask on Pad

The following steps correspond to those in Table 7.4-2 of the PFSF SAR, "Estimated Personnel Exposures for TranStor Canister Transfer Operations."

1. Receive and inspect shipment, and measure dose rates. It is estimated that 2 operators can receive the shipment and perform the receipt inspection, while one HP technician measures dose rates, in approximately 30 minutes.

Based on Figure 5.1-1 of SNC's Shipping Cask SAR (Ref. 7) and Table 5.5-11 ("TranStor Shipping Cask External Dose Rates (mrem/hr) for Normal Conditions of Transport 40,000 MWd - 8 Year Cooled PWR Fuel"), the dose rate at 2 meters from the side of the cask is 8.17 mrem/hr. The personnel barrier is located 19 inches from the side of the cask. Dose rates along the side of the personnel barrier are shown to be 18.72 mrem/hr near the bottom, 23.14 mrem/hr at the center and 18.37 mrem/hr near the top. Dose rates at the top and bottom of the cask with the impact limiter in place, and on contact with the impact limiter, were lower (11.16 mrem/hr at the top and 16.99 mrem/hr at the bottom). An average dose rate of 18.72 mrem/hr (Detector location 9 on Table 5.5-11 - 7.55 mrem/hr gamma and 11.17 mrem/hr neutron) was selected as representative of dose rates that could be seen during the receipt inspection. The gamma and neutron dose rates are scaled from design basis fuel with 40,000 MWd/MTU burnup and 8 year cooled to the typical PFSF fuel with 35,000 MWd/MTU burnup and 20 year cooled by applying the scaling factors from Table 5, above.

Gamma dose rate = 7.55 (0.270) = 2.04
Neutron dose rate = 11.17 (0.245) = 2.74
Total dose rate = 18.72; scaled = 4.78 (Use an average dose rate of 5 mrem/hr)

2. Move shipment into Canister Transfer Building. It is estimated that 3 operators would be involved in driving and positioning the trailer or rail car in the cask load/unload bay of the Canister Transfer Building, with an HP technician monitoring the operation. This operation is estimated to take 30 minutes.

Personnel should be able to remain well clear of the shipping cask during this operation, and will not be exposed to significant dose rates.

3. Remove personnel barrier, measure dose rates, and perform contamination survey. 1 hr in the dose field is more than adequate time for two operators to remove the personnel barrier and provide the HP technician with any necessary assistance during the radiological survey. 1.6 hr is estimated for one

HP technician to perform the radiation and contamination survey.

With the impact limiters still in place, average dose rates are the same as for step 1, approximately 5 mrem/hr.

4. Remove impact limiters and tiedowns and install cask rotation trunnions. Each of the two impact limiters has 24 bolts (Table 7.0-1 of Ref. 7), and it is estimated that two operators can remove both impact limiters in about an hour. It is estimated that two operators can install both cask rotation trunnions (16 bolts each per Table 7.0-1 of Ref. 7) in about 30 minutes.

As stated above, dose rates on contact with the ends of the top and bottom impact limiters are shown to be 11.16 mrem/hr at the top and 16.99 mrem/hr at the bottom. Once the impact limiters are removed, dose rates increase substantially at the top and bottom ends of the shipping cask. However, removal of the saddle tiedown straps would only take several minutes, and most of the 1.5 hours estimated for these tasks would be spent removing the impact limiters. Therefore, a dose rate of 15 mrem/hr is considered to be representative of the dose radiation field operators would be exposed to during these tasks. Assume the same gamma/neutron fractions as in step 1, 40.3% gamma and 59.7% neutron:

Gamma dose rate = 15 (0.403) (0.270) = 1.63
Neutron dose rate = 15 (0.597) (0.245) = 2.19
Total dose rate = 15.0; scaled = 3.82 mrem/hr

5. Attach lifting yoke to crane and TranStor shipping cask. Upright shipping cask and move to transfer cell. While it is estimated that the entire operation takes 1 hr, 30 minutes is adequate time for the operators to perform work needed in the vicinity of the shipping cask.

It is considered that the shipping cask lifting yoke can be attached to the cask in the horizontal position quickly and with minimal exposure. With the shipping cask placed in a vertical position, dose rates 2 meters from the side of the cask near the bottom are shown in Figure 5.1-1 and Table 5.5-11 of Ref. 7 to be 6.04 mrem/hr at 2 meters (detector location 4):

Gamma dose rate = 3.13 (0.270) = 0.845
Neutron dose rate = 2.91 (0.245) = 0.713
Total dose rate = 6.04; scaled = 1.558 (Use an average dose rate of 2 mrem/hr for this operation).

6. Sample enclosed cask gas and vent (assuming cask internal pressure exceeds atmospheric). It is estimated that 1 operator can perform this task in about 30 minutes.

With the impact limiters removed, Ref. 7 dose rates for normal conditions of transport at the ends of the cask are not applicable, since the impact limiters are assumed to be in place under normal conditions. Figure 5.1-2 and Table 5.5-20 provide information on cask dose rates under accident conditions with the impact limiters and the neutron shield removed. Since there is no neutron shield at the bottom or top of the cask, the dose rate given at the top (dose location 1, 72 mrem/hr at 1 meter) is representative. Although the operator's hands would be in a higher dose field when actually working at the vent plug, it is assumed that the operator's body would be, on average, a distance of 1 meter from the top of the shipping cask. Therefore, a dose rate of 72 mrem/hr was assumed, with design basis fuel. Applying scaling factors to revise dose rates consistent with typical PFSF fuel results in:

Gamma dose rate = 0
Neutron dose rate = 72 (0.245) = 17.64
Total dose rate = 72; scaled = 17.64

The 6 inch thick disc consisting of WEP, that is discussed in the temporary shielding section, would be expected to reduce neutron dose rates by a factor of 0.12. Dose rates with the temporary shielding in place are calculated to be:

Gamma dose rate = 0.00
Neutron dose rate = (17.6) (0.12) = 2.11
Total dose rate = = 2.11 (Use 2 mrem/hr)

7. Remove shipping cask closure lid bolts. There are 60 closure lid bolts for the TranStor shipping cask (Table 7.0-1 of Ref. 7), tightened to relatively high torque values. It is estimated that two operators can remove these bolts in 1 hr, which allows 2 minutes for removal of each bolt. It is considered that an electric or pneumatic tool can be used to expedite bolt removal once the bolt is initially loosened.

The general area dose rate to workers on top of the shipping cask, on average, with temporary shielding in place, is estimated to be 2 mrem/hr, the same as in step 6, above.

8. Remove shipping cask closure lid. Operators must spend several minutes on top of the shipping cask installing eyebolts and connecting rigging to lift the shipping cask lid. 12 minutes (0.2 hours) is considered adequate for two operators to perform this operation.

17.6 mrem/hr on average is estimated to operators working on top of the shipping cask with its lid in place and without the benefit of temporary shielding, as discussed in step 6, above. The temporary shield is assumed to have been removed from the top of the shipping cask prior to this step.

9. Prep shipping cask to mate with TranStor transfer cask. This involves installation of the cask adaptor ring on the shipping cask to protect the shipping cask sealing surface and provide a seating surface for the transfer cask. Transfer cask alignment pins are installed in the adapter ring. It is estimated that two operators can install these components on top of the shipping cask in approximately 12 minutes

The closure lid of the shipping cask is solid steel, 6 inches thick. With the closure lid removed, operators would be working directly on top of the canister structural lid. Table 5.1-2 of Ref. 3, "TranStor Transfer Cask Dose Rates" gives the dose rate on top of the canister, on contact with the structural lid, as 135 mrem/hr (dose location 4), for 45 GWd/MTU PWR fuel cooled 6 years. A dose rate 1 meter from the top of the transfer cask is not given. Based on a contact dose rate of 135 mrem/hr at the center of the canister lid, a dose rate of 100 mrem/hr a couple feet above the lid where an operator's torso would be located while positioning the adaptor ring (in conjunction with the crane) seems reasonable. At dose location 4, 17% of the dose rate is gamma and 83% of the dose rate is neutron:

Gamma dose rate = 17.0 (0.164) = 2.79
Neutron dose rate = 83.0 (0.169) = 14.0
Total dose rate = 100.0; scaled = 16.79 mrem/hr

Section 5.3.1 of Ref. 7 states that radiation streaming in the gap between the canister shell and the shipping cask is modeled, and localized gamma dose rates at the top and bottom ends of the gap are roughly 5 rem/hr. "After passing through the thick steel cask top lid (or bottom plate) and the large impact limiters at the cask ends, this streaming dose rate contribution is reduced to approx. 1 mrem/hr..." Since the shipping cask lid and impact limiters have been removed by this step, it is assumed that H.P. personnel instruct operators to keep their body away from this gap at the top of the cask, around the outside of the canister lid. Per discussions with Jim Hopf of SNC and John Broschak of Palisades Nuclear Plant, high dose rates around the top of this gap are a very real concern and it may be prudent to fabricate a shield ring that could be positioned in this gap during steps where operators are working on or near the top of the canister. The above 16.79 mrem/hr dose rate is based on the assumption that operators stay away from this gap, since dose rates directly above the gap would be much higher.

10. Install canister lift eyes and attach slings. There are eight canister lifting eyebolts that must be inserted and torqued. It is estimated that it takes two operators 1 hour to perform this operation.

Dose rates are estimated to be 100 mrem/hr a foot or two above the top of the canister assuming design basis fuel, same as used for step 9 above, scaled to 16.79 mrem/hr. Based on the discussion in step 9, 17% of the dose rate is gamma (2.79 mrem/hr) and 83% of the dose rate is neutron (14.0 mrem/hr).

The 6 inch thick disc consisting of WEP would be expected to reduce neutron dose rates by a factor of 0.12, and dose rates with the temporary shielding in place are calculated to be:

Gamma dose rate = 2.79
Neutron dose rate = (14.0) (0.12) = 1.68
Total dose rate = 4.47 mrem/hr (Use 4.5 mrem/hr)

11. Attach lifting yoke to crane and transfer cask. It is estimated that two operators can perform this operation in a relatively low dose rate field in approximately 30 minutes.

Per conversations with Boris Chechelnitsky (formerly with Sierra Nuclear Corporation - SNC), the crane operator can "hook" and unhook the lifting yoke on the transfer cask trunnions without the help of operators. Boris has seen this done. Therefore, operators do not need to be positioned at the level of the top of the transfer cask to help connect the lifting yoke to the transfer cask, and operators can watch this operation from the floor of the transfer facility, maintaining distance to minimize dose rate. Dose rates of approximately 5 mrem/hr on average for personnel involved with these operations with design basis fuel are estimated, scaled to approximately 2 mrem/hr.

12. Mount transfer cask on top of shipping cask, connect support struts, and disengage crane. It is estimated that two operators can perform this operation in a relatively low dose rate field within about 42 minutes.

Same as step 11, above. The canister is in the shipping cask when the operators connect the support struts to the transfer cask, so dose rates near the side of the transfer cask will be fairly low, and are assumed to be 2 mrem/hr to the operators.

13. Open transfer cask doors. The hydraulic system is already connected to the transfer cask doors, so the operators only need to open the doors by actuating the hydraulic door opener, which can be accomplished in 12 minutes by two operators.

With the canister in the shipping cask, Figure 5.1-1 and Table 5.5-11 of Ref. 7 give representative dose rates for operators working at the side and near the top of the shipping cask to manipulate the transfer cask door hydraulic system at the bottom of the transfer cask. The dose rate 19 inches from the side of the shipping cask near the top is 18.37 mrem/hr (dose location 7). At dose location 7, 26.3% of the dose rate is gamma (4.83 mrem/hr) and 73.7% (13.54 mrem/hr) of the dose rate is neutron:

Gamma dose rate = 4.83 (0.270) = 1.30
Neutron dose rate = 13.54 (0.245) = 3.32
Total dose rate = 18.37; scaled = 4.62 mrem/hr

14. Attach slings to crane and raise canister. This operation involves two operators located near the top of the transfer cask grappling the slings connected to the canister lid lifting eyebolts, and attaching these to the crane hook. 30 minutes is considered to be adequate for this operation.

Per discussions with Boris Chechelnitsky (formerly with Sierra Nuclear Corporation, the TranStor cask vendor), operators will likely use reach rods and work through the top of the transfer cask to grasp the lifting slings attached to the eye bolts bolted into the structural lid of the canister. Per Table 5.1-2 of Ref. 3, the dose rate on contact with the canister structural lid is 135 mrem/hr (dose location 4). At 5 meters above this point, it seems reasonable to assume 10 mrem/hr. Operators will be out of significant dose field while the crane operator lifts the canister. From dose location 4, 17% of the dose rate is gamma (1.7 mrem/hr) and 83% of the dose rate is neutron (8.3 mrem/hr):

Gamma dose rate = 1.7 (0.164) = 0.279
Neutron dose rate = 8.3 (0.169) = 1.40
Total dose rate = 10.0; scaled = 1.679 (Use 2.0 mrem/hr)

15. Close transfer cask doors and install pins. Two operators can accomplish this task in 12 minutes, as in step 13.

Per Table 5.1-2 of Reference 3, the dose rate 1 meter from the side of a loaded transfer cask is 79 mrem/hr (dose location 5). Assume that on average personnel are able to keep their bodies positioned 1 meter away and use 79 mrem when personnel need to be located at the side of a loaded transfer cask. At dose location 5, the gamma dose rate is 48 mrem/hr and the neutron dose rate 31 mrem/hr:

Gamma dose rate = 48 (0.164) = 7.9
Neutron dose rate = 31 (0.169) = 5.2
Total dose rate = 79; scaled = 13.1 mrem/hr

16. Lower canister onto transfer cask doors and disconnect canister slings from crane hook. It is estimated that two operators, working alongside a transfer cask, can disconnect the canister lifting slings from the crane hook in 12 minutes.

Dose rates at the side of a loaded transfer cask are the same as in step 15, 79 mrem/hr for design basis fuel, scaled to 13.1 mrem/hr.

17. Attach lifting yoke to crane hook and engage transfer cask. Disconnect support struts. This step prepares the transfer cask for movement from the shipping cask to the storage cask. While it is assumed that the crane operations involved with attaching the transfer cask lifting yoke to the crane hook may take 30 minutes to complete, it is estimated that 2 operators can assist with this operation, as necessary, and disconnect the support struts from the side of the transfer cask, spending only about 12 minutes in a significant dose rate field.

Per discussions with Boris Chechelnitsky, and based on his personal observations, the crane operator can connect the lifting yoke to the transfer cask trunnions without the aid of operators at the elevation of the trunnions. Therefore, operators will only be exposed to a significant dose field while disconnecting the support struts. The dose rate for this operation is estimated to be the same as for step 16, 13.1 mrem/hr).

18. Move transfer cask from shipping cask to storage cask. Attach support struts to transfer cask and disengage crane. While this entire operation is estimated to take approximately 1 hr to perform, two operators only need to be in a significant dose rate field while attaching the support struts and possibly assisting with disengaging the crane from the transfer cask, estimated to take about 18 minutes (0.3 hours).

This task requires that operators be positioned alongside the transfer cask for a short interval. Per steps 15 and 16 above, use 13.1 mrem/hr.

19. Engage crane to canister lifting slings, raise canister, and open transfer cask doors. It is estimated that two operators positioned alongside the transfer cask connect the canister lifting slings to the crane hook. The operators need not be in a significant dose rate field while the canister is being raised to enable the transfer cask doors to be opened, but are positioned at the bottom of the transfer cask to actuate the hydraulic door openers. It is estimated that two operators are in the dose field for 18 minutes of this 30 minute operation.

This task requires that operators be alongside of the transfer cask for a short interval. Per step 16 above, use 13.1 mrem/hr.

20. Lower canister into TranStor storage cask. Operators are standing by in the transfer cell, but not close to the storage or transfer casks during this operation, which is estimated to take 30 minutes (lower canister approximately 18 ft at a relatively low crane speed).

Operators do not need to be next to the transfer or storage casks for this canister lowering operation. General area dose rates are assumed to be approximately 5 mrem/hr for design basis fuel scaled to approximately 1 mrem/hr.

21. Disconnect canister lifting slings. It is estimated that it takes two operators 12 minutes to disconnect the canister lifting slings from the crane hook.

With the canister in the storage cask, dose rates alongside the empty transfer cask, where operators will disconnect the canister from the crane hook, will be minimal. General area dose rates are assumed to be 1 mrem/hr.

22. Close transfer cask doors. It is estimated that two operators can actuate the hydraulic transfer cask door operating system and close the doors in 12 minutes.

It is conservative to assume 18.37 mrem/hr for this condition with design basis fuel, the same dose rate used in Step 13 for opening the transfer cask doors when the canister is in the shipping cask, since the storage cask provides more shielding than the shipping cask. This value was scaled to 4.6 mrem/hr in step 13 for typical fuel at the PFSF.

23. Attach lifting yoke to crane and engage to transfer cask. Remove transfer cask from storage cask. Two operators assist in this operation, estimated to take 0.8 hours.

With the canister in the storage cask, dose rates alongside the transfer cask, where operators will disconnect the canister from the crane hook, will be minimal. Operators need not be next to the transfer or storage casks for this transfer cask movement. General area dose rates are assumed to be 5 to 10 mrem/hr with design basis fuel, scaled to approximately 2 mrem/hr.

24. Remove the canister lifting eyes. It is estimated that two operators can untorque and remove the eight canister lifting eyebolts in 30 minutes, about one-half the time estimated for insertion and torquing of these bolts in step 10.

Dose rates on top of the canister will be the same as for Steps 9 and 10, 16.8 mrem/hr.

Based on the discussion in step 10, dose rates on top of the canister with the temporary shield disc assumed to be in place are approximately 4.5 mrem/hr.

25. Install storage cask shield ring, lid, and lid bolts. It is estimated that it will take two operators approximately 1 hr to install the shield ring in the gap between the storage cask inner surface and the basket outer surface, emplace the storage cask lid, and bolt the lid onto the storage cask (6 bolts per SNC Drawing No. TCC-002, sht. 1 of 2, Rev. 0).

Operators will need to be positioned high up along the side of the storage cask to coordinate with the crane operator and help install the shield ring. With the storage cask lid (cover plate) in place, dose rates given in Table 5.1-1 of Reference 3 are 98.2 mrem/hr on contact (dose location 3) and 83 mrem/hr at 1 meter from the top of the cover plate (dose location 4), or approximately 90 mrem/hr in the general area working on top of the lid. Dose rates are much lower along the side of the cask, and so it is assumed that operators help the crane operator to place the lid and that they install the lid bolts working on platforms or ladders at the sides of the storage cask. Based on Table 5.1-1 of Reference 3, dose rates are 18.2 mrem/hr on contact with the side of the storage cask near the center, and only 7.1 mrem/hr on contact with the top air outlet vent. Since the operator's bodies will need to be positioned near the cask to reach the lid bolts, dose rates on contact with the sides of the storage casks are assumed. The 18.2 mrem/hr total dose rate on contact with the side of a storage cask containing design basis fuel consists of 17.3 mrem/hr gamma (95.1%) and 0.9 mrem/hr neutron (4.9%).

Gamma dose rate =	17.3 (0.164)	=	2.84	
Neutron dose rate =	0.9 (0.169)	=	0.15	
Total dose rate =	18.2; scaled	=	2.99 mrem/hr	(3.0 mrem/hr is used)

26. Perform dose survey and install storage cask lifting eyes. It is estimated that it takes two operators 30 minutes to prepare the TranStor storage cask for lifting by the cask transporter vehicle, and 30 minutes for the HP technician to perform a radiation survey of the cask.

Operators will install the storage cask lifting eyes working from platforms or ladders with their bodies positioned on the side of the storage cask, near the top. Based on the preceding step, dose rates along the side of the storage cask are calculated to be 3.0 mrem/hr.

27-30. Drive cask transporter in transfer cell. Connect storage cask to cask transporter. Raise storage cask. Transport storage cask to storage pad. Only one operator is needed to drive the cask transporter into a transfer cell, and this operation (step 27) is estimated to take 18 minutes. Two operators connect the storage cask to the cask transporter (step 28), an operation that is estimated to take 30 minutes. 2 operators are on hand to lift the storage cask by means of the cask transporter (step 29), the driver and one other operator, an operation estimated to take 12 minutes. Two operators are involved in moving the storage cask to the pad (step 30), the driver and another operator, which could possibly take as long as 2 hours, depending on the location of the storage pad and its distance from the Canister Transfer Building.

Personnel will not be in a significant dose field during these operations. The cask transporter is used to lift, move, and lower the storage cask, and (with the exception of step 28) personnel are not required to be adjacent to or on top of the cask during these operations. Assume general area dose rates of approximately 1 mrem/hr.

31. Position and lower storage cask on pad. It is estimated that two operators are involved in placing the storage cask on the pad, the cask transporter vehicle driver and an operator to function as a spotter to help the driver place the cask in the proper location. This operation is estimated to take 30 minutes in a significant dose rate field, since the operators and HP technician are exposed to radiation from casks already on the pads.

Based on Table 5.1-1 of Ref.3, dose rates at the side of a TranStor storage cask with 45 GWd/MTU, 6 yr-cooled PWR fuel are 18.2 mrem/hr on contact and 9.7 mrem/hr 1 meter from the cask. This 9.7 mrem/hr value is comprised of 9.2 mrem/hr gamma (94.8%) and 0.5 mrem/hr neutron (5.2%). Scaling to the 35 GWd/MTU burnup and 20-years cooling time typical PFSF fuel results in:

Gamma dose rate = (9.2) (0.164) = 1.51
Neutron dose rate = (0.5) (0.169) = 0.08
Total dose rate = 9.7; scaled = 1.59 mrem/hr at one meter from the side of a cask loaded with the assumed typical PFSF fuel.

Operators can position themselves away from the storage cask being lowered, and reduce exposure from this cask, but the dose rate from storage casks already at the pads could be significant. It is estimated that the total dose rate from the cask being handled, as well as nearby casks, is approximately 10 mrem/hr. The average dose rate to the HP technician, who is not working near a single cask for significant time, is estimated to be approximately 5 mrem/hr.

32. Disconnect storage cask from transporter and remove storage cask lifting eyes. It is estimated that two operators spend 1 hour on ladders positioned at the side and near the top of the storage cask disconnecting the cask from the cask transporter vehicle. The HP technician is in a significant dose rate field, since locations near the storage pads receive radiation from storage casks already on the pads.

Due to the relatively high dose rates estimated to workers on top of the TranStor storage cask (see section on temporary shielding) operators will disconnect the storage cask lifting eyes working from platforms or ladders with their bodies positioned to the side of the storage cask, near the top. Based on step 25, dose rates along the side of the storage cask are calculated to be 3.0 mrem/hr. Radiation from adjacent casks is estimated to increase the total dose rates to approximately 10 mrem/hr for this task. The average dose rate to the HP technician, who is not working near a single cask for significant time, is estimated to be approximately 5 mrem/hr.

33. Connect cask temperature instrumentation. It is estimated that two operators spend 30 minutes in the vicinity of the storage cask recently placed on the storage pad connecting the temperature monitoring instrumentation. The HP technician is also in a significant dose rate field (though not as high as the operators since this person does not need to work on a cask and stay in the immediate vicinity of a storage cask), since locations near the storage pads receive radiation from storage casks already on the pads.

It is estimated that general area dose rates on the storage pads while working near a single cask, and accruing radiation from adjacent casks, could be approximately 10 mrem/hr, as assumed in step 31 above. The average dose rate to the HP technician, who is not working near a single cask for significant time, is estimated to be approximately 10 mrem/hr.

34. Perform cask operability tests. It is estimated that one operator can perform the cask operability tests required by the PFSF Technical Specifications over a period of about 2 days, spending approximately 1 hour near the storage cask on its storage pad. It is assumed that an HP technician accompanies the operator during the 1 hour involving tasks performed near the cask.

It is estimated that general area dose rates on the storage pads while working near a single cask, and accruing radiation from adjacent casks, could be approximately 10 mrem/hr, as assumed in steps 31 and 33 above. The average dose rate to the

HP technician, who is not working near a single cask for significant time, is estimated to be approximately 5 mrem/hr.

Burnup for PWR Spent Fuel

	Total Burnup (GWd/MTU)												
Burnup	0 - 5	5 - 10	10 - 15	15 - 20	20 - 25	25 - 30	30 - 35	35 - 40	40 - 45	45 - 50	50 - 55	55 - 60	
Mean Burnup	2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	
(MTU)	13.4	85.0	582.9	1445.7	1037.9	3010.1	4976.6	4647.0	2560.6	635.3	43.5	4.5	19042.5
	33.5	637.5	7286.25	25299.8	23352.8	82777.8	161740	174263	108826	30176.8	2283.75	258.75	616934

Weighted Average Burnup = 32.3978

Burnup for BWR Spent Fuel

	Total Burnup (GWd/MTU)												
Burnup	0 - 5	5 - 10	10 - 15	15 - 20	20 - 25	25 - 30	30 - 35	35 - 40	40 - 45	45 - 50	50 - 55	55 - 60	
Mean Burnup	2.5	7.5	12.5	17.5	22.5	27.5	32.5	37.5	42.5	47.5	52.5	57.5	
(MTU)	358.6	452.1	712.9	1408	2340	3166.7	1838	502.1	8.9	0.7	0	0	10788
	896.5	3390.75	8911.25	24640	52650	87084.3	59735	18828.8	378.25	33.25	0	0	256548

Weighted Average Burnup = 23.7809

ATTACHMENT A

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ATTACHMENT A

Year Fuel	Year Shipped to PFSF	Cooling Time (yrs)	MTU Shipped		MTU * Cooling
1968	2002	34	0.6		20.4
1969	2002	33	9.8		323.4
1970	2002	32	44.6		1427.2
1971	2002	31	109.2		3385.2
1972	2002	30	245.7		7371
1973	2002	29	160.6		4657.4
1974	2002	28	449.3		12580.4
1975	2002	27	547.6		14785.2
1976	2002	26	432.6	2000	11247.6
1976	2003	27	266.5		7195.5
1977	2003	26	850.1		22102.6
1978	2003	25	883.4	2000	22085
1978	2004	26	198.8		5168.8
1979	2004	25	1121		28025
1980	2004	24	680.2	2000	16324.8
1980	2005	25	557.7		13942.5
1981	2005	24	1134.6		27230.4
1982	2005	23	307.7	2000	7077.1
1982	2006	24	689.9		16557.6
1983	2006	23	1262.6		29039.8
1984	2006	22	47.5	2000	1045
1984	2007	23	1291.7		29709.1
1985	2007	22	708.3	2000	15582.6
1985	2008	23	684.3		15738.9
1986	2008	22	1315.7	2000	28945.4
1986	2009	23	138.8		3192.4
1987	2009	22	1705.9		37529.8
1988	2009	21	155.3	2000	3261.3
1988	2010	22	1497.2		32938.4
1989	2010	21	502.8	2000	10558.8
1989	2011	22	1410.5		31031
1990	2011	21	589.5	2000	12379.5
1990	2012	22	1547.6		34047.2
1991	2012	21	452.4	2000	9500.4
1991	2013	22	1406.6		30945.2
1992	2013	21	593.4	2000	12461.4
1992	2014	22	1697.8		37351.6
1993	2014	21	302.2	2000	6346.2
1993	2015	22	1929.4		42446.8
1994	2015	21	70.6	2000	1482.6
1994	2016	22	1811.9	1811.9	39861.8
			29811.9		686902

Weighted Average Cooling Time = 686,902 / 29811.9
23.0412 yrs

ATTACHMENT B

LWR Radiological DATABASE
PHOTONS REPORT
REACTOR TYPE & BURNUP: PWR 45000
ENRICHMENT: 3.70%
DECAY TIME: 5 YEARS
The data is shown in Photons per second/MTIHM

CALC 05996.02-UR-6
Pg B1 of B10

ENERGY (MeV)	PHO/SEC	% TOTAL
1.000E-02	3.973E+15	21.73%
2.500E-02	9.383E+14	5.13%
3.750E-02	1.026E+15	5.61%
5.750E-02	7.861E+14	4.30%
8.500E-02	5.151E+14	2.82%
1.250E-01	5.314E+14	2.91%
2.250E-01	4.266E+14	2.33%
3.750E-01	2.536E+14	1.39%
5.750E-01	7.221E+15	39.50%
8.500E-01	1.825E+15	9.98%
1.250E+00	7.531E+14	4.12%
1.750E+00	1.079E+13	0.06%
2.250E+00	4.551E+12	0.02%
2.750E+00	1.638E+11	0.00%
3.500E+00	2.101E+10	0.00%
5.000E+00	3.600E+07	0.00%
7.000E+00	4.152E-06	0.00%
9.500E+00	4.770E+05	0.00%
TOTAL	*1.826E+16	99.92%*

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

ATTACHMENT B

LWR Radiological DATABASE
RADIOLOGICAL TOTALS REPORT
REACTOR TYPE & BURNUP: PWR 45000
ENRICHMENT: 3.70%
DECAY TIME: 5 YEARS

CALC 05996.02-UR-6
Pg B2 of B10

CURIES/MTIHM	
ACTIVATION PRODUCTS	8.148E+03
ACTINIDES AND DAUGHTERS	1.441E+05
FISSION PRODUCTS	5.846E+05
TOTAL	7.373E+05

WATTS/MTIHM	
ACTIVATION PRODUCTS	8.810E+01
ACTINIDES AND DAUGHTERS	4.900E+02
FISSION PRODUCTS	2.084E+03
TOTAL	2.667E+03

GRAMS/MTIHM	
ACTIVATION PRODUCTS	4.403E+05
ACTINIDES AND DAUGHTERS	9.534E+05
FISSION PRODUCTS	4.625E+04
TOTAL	1.440E+06

NEUTRONS/MTIHM	
ALPHA,N NEUTRONS	1.463E+07
SPONTANEOUS FISSION NEUTRONS	8.193E+08
TOTAL NEUTRONS	8.340E+08

PHOTONS per Second/MTIHM	
TOTAL PHOTONS/SEC	1.828E+16

*Some of the above values were obtained by interpolating TOTALS values f ORIGEN2 runs to the specific burnup/enrichment/decay time combination yo specified. □

ATTACHMENT B

LWR Radiological DATABASE
PHOTONS REPORT
REACTOR TYPE & BURNUP: PWR 40000
ENRICHMENT: 3.70%
DECAY TIME: 10 YEARS
The data is shown in Photons per second/MTIHM

ENERGY (MeV)	PHO/SEC	% TOTAL
1.000E-02	2.277E+15	24.39%
2.500E-02	4.880E+14	5.23%
3.750E-02	5.921E+14	6.34%
5.750E-02	4.552E+14	4.88%
8.500E-02	2.685E+14	2.88%
1.250E-01	2.547E+14	2.73%
2.250E-01	2.202E+14	2.36%
3.750E-01	1.066E+14	1.14%
5.750E-01	3.988E+15	42.72%
8.500E-01	3.571E+14	3.83%
1.250E+00	3.227E+14	3.46%
1.750E+00	3.786E+12	0.04%
2.250E+00	7.254E+10	0.00%
2.750E+00	5.216E+09	0.00%
3.500E+00	6.440E+08	0.00%
5.000E+00	1.795E+07	0.00%
7.000E+00	2.069E+06	0.00%
9.500E+00	2.377E+05	0.00%
TOTAL	*9.334E+15	99.99%*

CALC 0599602-UR-6
Pg B3 of B10

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

ATTACHMENT B

LWR Radiological DATABASE
RADIOLOGICAL TOTALS REPORT
REACTOR TYPE & BURNUP: PWR 40000
ENRICHMENT: 3.70%
DECAY TIME: 10 YEARS

CALC 0599.602-UR-6
Pg B4 of B10

CURIES/MTIHM	
ACTIVATION PRODUCTS	3.601E+03
ACTINIDES AND DAUGHTERS	1.064E+05
FISSION PRODUCTS	3.604E+05
TOTAL	4.704E+05
WATTS/MTIHM	
ACTIVATION PRODUCTS	4.027E+01
ACTINIDES AND DAUGHTERS	3.498E+02
FISSION PRODUCTS	1.078E+03
TOTAL	1.469E+03
GRAMS/MTIHM	
ACTIVATION PRODUCTS	4.403E+05
ACTINIDES AND DAUGHTERS	9.588E+05
FISSION PRODUCTS	4.116E+04
TOTAL	1.440E+06
NEUTRONS/MTIHM	
ALPHA,N NEUTRONS	1.023E+07
SPONTANEOUS FISSION NEUTRONS	4.078E+08
TOTAL NEUTRONS	4.181E+08
PHOTONS per Second/MTIHM	
TOTAL PHOTONS/SEC	9.335E+15

*Some of the above values were obtained by interpolating TOTALS values f ORIGEN2 runs to the specific burnup/enrichment/decay time combination yo specified. □

PHOTONS REPORT
REACTOR TYPE & BURNUP: PWR 45000
ENRICHMENT: 3.30%
DECAY TIME: 6 YEARS
The data is shown in Photons per second/MTIHM

ATTACHMENT B

CALC 059960.2-UR-6

Pg B5 of B10

ENERGY (MeV)	PHO/SEC	% TOTAL
1.000E-02	3.274E+15	21.31%
2.500E-02	7.599E+14	4.95%
3.750E-02	8.748E+14	5.69%
5.750E-02	6.440E+14	4.19%
8.500E-02	4.144E+14	2.70%
1.250E-01	4.327E+14	2.82%
2.250E-01	3.385E+14	2.20%
3.750E-01	1.964E+14	1.28%
5.750E-01	6.388E+15	41.58%
8.500E-01	1.408E+15	9.16%
1.250E+00	6.810E+14	4.43%
1.750E+00	8.626E+12	0.06%
2.250E+00	2.021E+12	0.01%
2.750E+00	9.095E+10	0.00%
3.500E+00	1.174E+10	0.00%
5.000E+00	4.561E+07	0.00%
7.000E+00	5.260E+06	0.00%
9.500E+00	6.042E+05	0.00%
TOTAL	*1.542E+16	100.38%*

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

RADIOLOGICAL TOTALS REPORT
REACTOR TYPE & BURNUP: PWR 45000
ENRICHMENT: 3.30%
DECAY TIME: 6 YEARS

ATTACHMENT B

CALC 05996.02-UR-6

Pg B6 of B10

CURIES/MTIHM	
ACTIVATION PRODUCTS	7.440E+03
ACTINIDES AND DAUGHTERS	1.463E+05
FISSION PRODUCTS	5.095E+05
TOTAL	6.634E+05
WATTS/MTIHM	
ACTIVATION PRODUCTS	8.184E+01
ACTINIDES AND DAUGHTERS	5.601E+02
FISSION PRODUCTS	1.740E+03
TOTAL	2.383E+03
GRAMS/MTIHM	
ACTIVATION PRODUCTS	4.403E+05
ACTINIDES AND DAUGHTERS	9.535E+05
FISSION PRODUCTS	4.621E+04
TOTAL	1.440E+06
NEUTRONS/MTIHM	
ALPHA,N NEUTRONS	1.682E+07
SPONTANEOUS FISSION NEUTRONS	1.039E+09
TOTAL NEUTRONS	1.055E+09
PHOTONS per Second/MTIHM	
TOTAL PHOTONS/SEC	1.536E+16

*Some of the above values were obtained by interpolating TOTALS values from ORIGEN2 runs to the specific burnup/enrichment/decay time combination you specified.

ATTACHMENT B

LWR Radiological DATABASE
PHOTONS REPORT
REACTOR TYPE & BURNUP: PWR 40000
ENRICHMENT: 3.02%
DECAY TIME: 8 YEARS
The data is shown in Photons per second/MTIHM

ENERGY (MeV)	PHO/SEC	% TOTAL
1.000E-02	2.406E+15	22.41%
2.500E-02	5.363E+14	5.00%
3.750E-02	6.499E+14	6.05%
5.750E-02	4.772E+14	4.45%
8.500E-02	2.921E+14	2.72%
1.250E-01	2.971E+14	2.77%
2.250E-01	2.375E+14	2.21%
3.750E-01	1.270E+14	1.18%
5.750E-01	4.622E+15	43.06%
8.500E-01	6.729E+14	6.27%
1.250E+00	4.623E+14	4.31%
1.750E+00	5.233E+12	0.05%
2.250E+00	3.984E+11	0.00%
2.750E+00	2.395E+10	0.00%
3.500E+00	3.075E+09	0.00%
5.000E+00	3.141E+07	0.00%
7.000E+00	3.622E+06	0.00%
9.500E+00	4.161E+05	0.00%
TOTAL	*1.079E+16	100.48%*

CALC 05996.02-UR-6
Pg B7 of B10

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

ATTACHMENT B

LWR Radiological DATABASE
RADIOLOGICAL TOTALS REPORT
REACTOR TYPE & BURNUP: PWR 40000
ENRICHMENT: 3.02%
DECAY TIME: 8 YEARS

CALC 05996.02-UR-6
Pg B8 of B10

CURIES/MTIHM

ACTIVATION PRODUCTS	5.230E+03
ACTINIDES AND DAUGHTERS	1.287E+05
FISSION PRODUCTS	3.887E+05
TOTAL	5.225E+05

WATTS/MTIHM

ACTIVATION PRODUCTS	5.843E+01
ACTINIDES AND DAUGHTERS	4.407E+02
FISSION PRODUCTS	1.219E+03
TOTAL	1.717E+03

GRAMS/MTIHM

ACTIVATION PRODUCTS	4.403E+05
ACTINIDES AND DAUGHTERS	9.589E+05
FISSION PRODUCTS	4.111E+04
TOTAL	1.440E+06

NEUTRONS/MTIHM

ALPHA,N NEUTRONS	1.310E+07
SPONTANEOUS FISSION NEUTRONS	7.146E+08
TOTAL NEUTRONS	7.277E+08

PHOTONS per Second/MTIHM

TOTAL PHOTONS/SEC	1.073E+16

*Some of the above values were obtained by interpolating TOTALS values f ORIGEN2 runs to the specific burnup/enrichment/decay time combination yo specified.

LWR Radiological DATABASE
RADIOLOGICAL TOTALS REPORT
REACTOR TYPE & BURNUP: PWR 40000
ENRICHMENT: 3.02%
DECAY TIME: 8 YEARS

CURIES/MTIHM

PHOTONS REPORT
REACTOR TYPE & BURNUP: PWR 35000
ENRICHMENT: 3.43%
DECAY TIME: 20 YEARS
The data is shown in Photons per second/MTIHM

ATTACHMENT B

CALC 05996.02-UR-6

Pg B9 of B10

ENERGY (MeV)	PHO/SEC	% TOTAL
1.000E-02	1.541E+15	26.88%
2.500E-02	3.098E+14	5.40%
3.750E-02	3.752E+14	6.55%
5.750E-02	3.239E+14	5.65%
8.500E-02	1.709E+14	2.98%
1.250E-01	1.388E+14	2.42%
2.250E-01	1.435E+14	2.50%
3.750E-01	6.044E+13	1.05%
5.750E-01	2.524E+15	44.03%
8.500E-01	5.149E+13	0.90%
1.250E+00	9.075E+13	1.58%
1.750E+00	1.412E+12	0.02%
2.250E+00	3.513E+08	0.00%
2.750E+00	4.001E+08	0.00%
3.500E+00	1.828E+07	0.00%
5.000E+00	7.547E+06	0.00%
7.000E+00	8.698E+05	0.00%
9.500E+00	9.989E+04	0.00%
TOTAL	*5.731E+15	99.99%*

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

RADIOLOGICAL TOTALS REPORT
REACTOR TYPE & BURNUP: PWR 35000
ENRICHMENT: 3.43%
DECAY TIME: 20 YEARS

ATTACHMENT B

CALC 05996.02-UR-6
Pg B10 of B10

CURIES/MTIHM	
ACTIVATION PRODUCTS	1.146E+03
ACTINIDES AND DAUGHTERS	6.022E+04
FISSION PRODUCTS	2.355E+05
TOTAL	2.968E+05
WATTS/MTIHM	
ACTIVATION PRODUCTS	1.005E+01
ACTINIDES AND DAUGHTERS	2.632E+02
FISSION PRODUCTS	6.752E+02
TOTAL	9.505E+02
GRAMS/MTIHM	
ACTIVATION PRODUCTS	4.403E+05
ACTINIDES AND DAUGHTERS	9.636E+05
FISSION PRODUCTS	3.604E+04
TOTAL	1.440E+06
NEUTRONS/MTIHM	
ALPHA,N NEUTRONS	7.570E+06
SPONTANEOUS FISSION NEUTRONS	1.708E+08
TOTAL NEUTRONS	1.786E+08
PHOTONS per Second/MTIHM	
TOTAL PHOTONS/SEC	5.732E+15

*Some of the above values were obtained by interpolating TOTALS values from ORIGEN2 runs to the specific burnup/enrichment/decay time combination you specified. □

ATTACHMENT C

CALC 05996.02-UR-6

Pg C1 of C1

Neutron Dose Reduction Factor for WEP as a Function of Shield Thickness

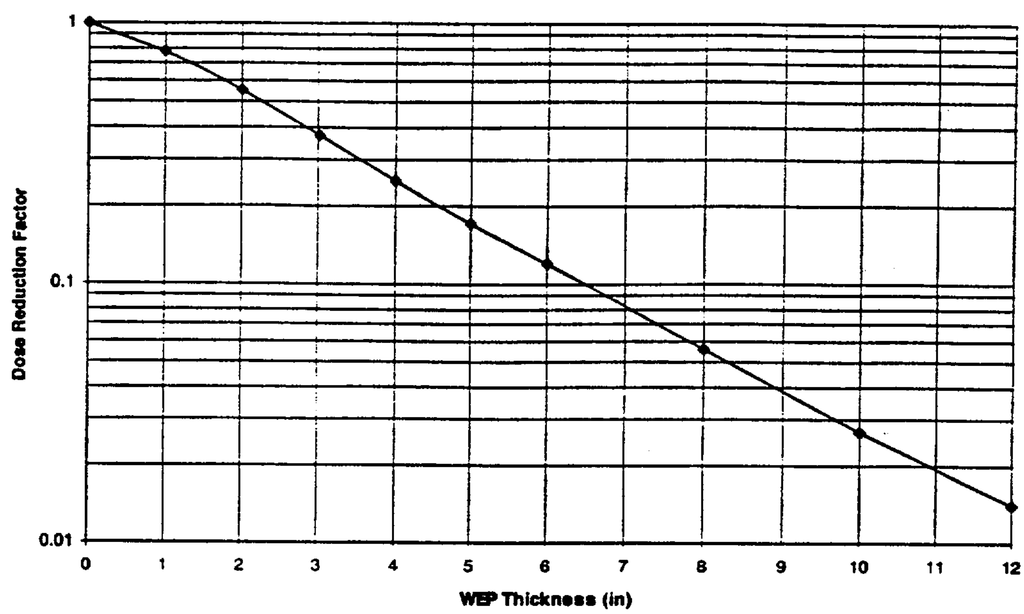

TABLE 7.4-1
(Page 1 of 4)
ESTIMATED PERSONNEL EXPOSURES FOR HI-STORM CANISTER TRANSFER OPERATIONS

Operation	No. of Personnel [1]	Task Duration[2] (hours)	Time in Dose Area[3] (hours)	Dose Rate in Area[4] (mrem/hr)	Dose[5] (person-mrem)
1. Receive and inspect shipment, and measure dose rates.	2 Ops 1 HP	0.5	0.5 0.5	4.0 4.0	4.0 2.0
2. Move shipment into Canister Transfer Building.	3 Ops 1 HP	0.5	0.5 0.5	0 0	0 0
3. Remove personnel barrier, measure dose rates, and perform contamination survey.	2 Ops 1 HP	1.6	1.0 1.6	4.0 6.0	8.0 9.6
4. Remove impact limiters and tiedowns.	2 Ops 1 HP	1.5	1.5 1.5	5.0 1.0	15.0 1.5
5. Attach lifting yoke to crane and HI-STAR shipping cask. Upright HI-STAR cask and move to transfer cell.	2 Ops 1 HP	1.0	0.5 1.0	5.0 1.0	5.0 1.0
6. Sample enclosed cask gas and vent.	1 Op 1 HP	0.5	0.5 0.5	12.5 / 2.0 1.0	6.3 /1.0 0.5
7. Remove HI-STAR closure plate (lid) bolts.	2 Ops 1 HP	1.0	1.0 1.0	12.5 / 2.0 1.0	25.0 / 4.0 1.0
8. Remove HI-STAR closure plate (lid).	2 Ops 1 HP	0.2	0.2 0.2	12.5 1.0	5.0 0.2
9. Prep HI-STAR to mate with HI-TRAC transfer cask.	2 Ops 1 HP	0.2	0.2 0.2	12.5 1.0	5.0 0.2
10. Install canister lift cleats and attach slings.	2 Ops 1 HP	1.0	1.0 1.0	12.5 / 7.1 1.0	25.0 / 14.2 1.0

TABLE 7.4-1 (Page 2 of 4)

Operation	No. of Personnel[1]	Task Duration[2] (hours)	Time in Dose Area[3] (hours)	Dose Rate in Area[4] (mrem/hr)	Dose[5] (person-mrem)
11. Attach lifting yoke to crane and HI-TRAC.	2 Ops 1 HP	0.5	0.5 0.5	2.0 1.0	2.0 0.5
12. Mount HI-TRAC on top of HI-STAR.	2 Ops 1 HP	0.5	0.5 0.5	2.0 1.0	2.0 0.5
13. Open HI-TRAC transfer cask doors.	2 Ops 1 HP	0.2	0.2 0.2	5.0 1.0	2.0 0.2
14. Attach slings to canister downloader hoist and raise canister.	2 Ops 1 HP	0.5	0.5 0.5	2.0 1.0	2.0 0.5
15. Close HI-TRAC doors and install pins.	2 Ops 1 HP	0.2	0.2 0.2	10.0 1.0	4.0 0.2
16. Lower canister onto HI-TRAC doors.	2 Ops 1 HP	0.2	0.2 0.2	1.0 1.0	0.4 0.2
17. Prep HI-STORM storage cask to mate with HI-TRAC transfer cask (including installation of HI-STORM shielding inserts).	2 Ops 1 HP	0.2	0.2 0.2	5.0 1.0	2.0 0.2
18. Move HI-TRAC from HI-STAR to HI-STORM.	2 Ops 1 HP	0.7	0.7 0.7	1.0 1.0	1.4 0.7
19. Raise canister and open HI-TRAC doors.	2 Ops 1 HP	0.5	0.2 0.5	10.0 1.0	4.0 0.5
20. Lower canister into HI-STORM storage cask.	2 Ops 1 HP	0.5	0.5 0.5	1.0 1.0	1.0 0.5
21. Disconnect lifting slings.	2 Ops 1 HP	0.2	0.2 0.2	7.5 1.0	3.0 0.2

TABLE 7.4-1 (Page 3 of 4)

Operation	No. of Personnel[1]	Task Duration[2] (hours)	Time in Dose Area[3] (hours)	Dose Rate in Area[4] (mrem/hr)	Dose[5] (person-mrem)
22. Close transfer cask doors.	2 Ops	0.2	0.2	5.0	2.0
	1 HP		0.2	1.0	0.2
23. Remove HI-TRAC from HI-STORM.	2 Ops	0.5	0.5	1.0	1.0
	1 HP		0.5	1.0	0.5
24. Remove canister lift cleats and HI-STORM shield inserts.	2 Ops	0.5	0.5	12.5 / 7.1	12.5 / 7.1
	1 HP		0.5	1.0	0.5
25. Install HI-STORM lid and lid bolts.	2 Ops	1.0	1.0	2.0	4.0
	1 HP		1.0	1.0	1.0
26. Perform dose survey and install HI-STORM lifting eyes.	2 Ops	0.5	0.5	2.0	2.0
	1 HP		0.5	1.0	0.5
27. Drive cask transporter in transfer cell.	1 Op	0.3	0.3	1.0	0.3
	1 HP		0.3	1.0	0.3
28. Connect HI-STORM to cask transporter.	2 Ops	0.5	0.5	1.0	1.0
	1 HP		0.5	1.0	0.5
29. Raise HI-STORM storage cask.	2 Ops	0.2	0.2	1.0	0.4
	1 HP		0.2	1.0	0.2
30. Transport HI-STORM cask to storage pad.	2 Ops	2.0	2.0	1.0	4.0
	1 HP		2.0	1.0	2.0
31. Position and lower HI-STORM cask on pad.	2 Ops	0.5	0.5	10.0	10.0
	1 HP		0.5	5.0	2.5
32. Disconnect HI-STORM cask from transporter and remove cask lifting eyes.	2 Ops	1.0	1.0	10.0	20.0
	1 HP		1.0	5.0	5.0

TABLE 7.4-1 (Page 4 of 4)

Operation	No. of Personnel[1]	Task Duration[2] (hours)	Time in Dose Area[3] (hours)	Dose Rate in Area[4] (mrem/hr)	Dose[5] (person-mrem)
33. Connect cask temperature instrumentation.	2 Ops 1 HP	0.5	0.5 0.5	10.0 5.0	10.0 2.5
34. Perform cask operability tests.	1 Op 1 HP	48	1.0 1.0	10.0 5.0	10.0 5.0
TOTAL					241.2 / 198.7 [5]

1. Number of personnel typically includes 2 to 4 operators and 1 HP technician.
2. Task duration includes total estimated time required to perform task.
3. Time in dose area includes only that time personnel are in a significant dose field.
4. The values in this column represent estimated average dose rates in the area where personnel will be working to perform the associated task. For operations where it is considered that temporary shielding will be effective in keeping dose rates ALARA, two values are presented (e.g., 50 / 5). The first value (50 mrem/hr) is the projected dose rate assuming no credit for temporary shielding. The second value (5 mrem/hr) takes credit for radiation attenuation by the use of temporary shielding.
5. Doses are calculated for times in dose fields without temporary shielding and with temporary shielding, such as 50 / 5, where the first value (50 mrem) is calculated based on the time spent in an area with the dose rate in the preceding column without temporary shielding, and the second value (5 mrem) is calculated based on the dose rate in the preceding column that takes credit for temporary shielding.

TABLE 7.4-2
(Page 1 of 4)

ESTIMATED PERSONNEL EXPOSURES FOR TRANSTOR CANISTER TRANSFER OPERATIONS

Operation	No. of Personnel[1]	Task Duration[2] (hours)	Time in Dose Area[3] (hours)	Dose Rate in Area[4] (mrem/hr)	Dose[5] (person-mrem)
1. Receive and inspect shipment, and measure dose rates.	2 Ops 1 HP	0.5	0.5 0.5	5.0 5.0	5.0 2.5
2. Move shipment into Canister Transfer Building.	3 Ops 1 HP	0.5	0.5 0.5	0 0	0 0
3. Remove personnel barrier, measure dose rates, and perform contamination survey.	2 Ops 1 HP	1.6	1.0 1.6	5.0 5.0	10.0 8.0
4. Remove impact limiters and tiedowns and install cask rotation trunnions.	2 Ops 1 HP	1.5	1.5 1.5	3.8 1.0	11.4 1.5
5. Attach lifting yoke to crane and TranStor shipping cask. Upright shipping cask and move to transfer cell.	2 Ops 1 HP	1.0	0.5 1.0	2.0 1.0	2.0 1.0
6. Sample enclosed cask gas and vent.	1 Op 1 HP	0.5	0.5 0.5	17.6 / 2.0 1.0	8.8 / 1.0 0.5
7. Remove shipping cask closure lid bolts.	2 Ops 1 HP	1.0	1.0 1.0	17.6 / 2.0 1.0	35.2 / 4.0 1.0
8. Remove shipping cask closure lid.	2 Ops 1 HP	0.2	0.2 0.2	17.6 1.0	7.0 0.2
9. Prep shipping cask to mate with TranStor transfer cask.	2 Ops 1 HP	0.2	0.2 0.2	16.8 1.0	6.7 0.2

TABLE 7.4-2 (Page 2 of 4)

Operation	No. of Personnel[1]	Task Duration[2] (hours)	Time in Dose Area[3] (hours)	Dose Rate in Area[4] (mrem/hr)	Dose[5] (person-mrem)
10. Install canister lift eyes and attach slings.	2 Ops 1 HP	1.0	1.0 1.0	16.8 / 4.5 1.0	33.6 / 9.0 1.0
11. Attach lifting yoke to crane and transfer cask.	2 Ops 1 HP	0.5	0.5 0.5	2.0 1.0	2.0 0.5
12. Mount transfer cask on top of shipping cask, connect support struts, and disengage crane.	2 Ops 1 HP	0.7	0.7 0.7	2.0 1.0	2.8 0.7
13. Open transfer cask doors.	2 Ops 1 HP	0.2	0.2 0.2	4.6 1.0	1.8 0.2
14. Attach slings to crane and raise canister.	2 Ops 1 HP	0.5	0.5 0.5	2.0 1.0	2.0 0.5
15. Close transfer cask doors and install pins.	2 Ops 1 HP	0.2	0.2 0.2	13.1 1.0	5.2 0.2
16. Lower canister onto transfer cask doors and disconnect canister slings from crane hook.	2 Ops 1 HP	0.2	0.2 0.2	13.1 1.0	5.2 0.2
17. Attach lifting yoke to crane hook and engage transfer cask. Disconnect support struts.	2 Ops 1 HP	0.5	0.2 0.5	13.1 1.0	5.2 0.5
18. Move transfer cask from shipping cask to storage cask. Attach support struts to transfer cask and disengage crane.	2 Ops 1 HP	1.0	0.3 1.0	13.1 1.0	7.9 1.0
19. Engage crane to canister lifting slings, raise canister, and open transfer cask doors.	1 Op 1 HP	0.5	0.3 0.5	13.1 1.0	3.9 0.5

TABLE 7.4-2 (Page 3 of 4)

Operation	No. of Personnel [1]	Task Duration[2] (hours)	Time in Dose Area[3] (hours)	Dose Rate in Area[4] (mrem/hr)	Dose[5] (person-mrem)
20. Lower canister into TranStor storage cask.	2 Ops	0.5	0.5	1.0	1.0
	1 HP		0.5	1.0	0.5
21. Disconnect canister lifting slings.	2 Ops	0.2	0.2	1.0	0.4
	1 HP		0.2	1.0	0.2
22. Close transfer cask doors.	1 Op	0.2	0.2	4.6	0.9
	1 HP		0.2	1.0	0.2
23. Attach lifting yoke to crane and engage to transfer cask. Remove transfer cask from storage cask.	2 Ops	0.8	0.8	2.0	3.2
	1 HP		0.8	1.0	0.8
24. Remove canister lifting eyes.	2 Ops	0.5	0.5	16.8 / 4.5	16.8 / 4.5
	1 HP		0.5	1.0	0.5
25. Install storage cask shield ring, lid, and lid bolts.	2 Ops	1.0	1.0	3.0	6.0
	1 HP		1.0	1.0	1.0
26. Perform dose survey and install storage cask lifting eyes.	2 Ops	0.5	0.5	3.0	3.0
	1 HP		0.5	1.0	0.5
27. Drive cask transporter in transfer cell.	1 Op	0.3	0.3	1.0	0.3
	1 HP		0.3	1.0	0.3
28. Connect storage cask to cask transporter.	2 Ops	0.5	0.5	1.0	1.0
	1 HP		0.5	1.0	0.5
29. Raise storage cask.	2 Ops	0.2	0.2	1.0	0.4
	1 HP		0.2	1.0	0.2
30. Transport storage cask to storage pad.	2 Ops	2.0	2.0	1.0	4.0
	1 HP		2.0	1.0	2.0

TABLE 7.4-2 (Page 4 of 4)

Operation	No. of Personnel[1]	Task Duration[2] (hours)	Time in Dose Area[3] (hours)	Dose Rate in Area[4] (mrem/hr)	Dose[5] (person-mrem)
31. Position and lower storage cask on pad.	2 Ops 1 HP	0.5	0.5 0.5	10.0 5.0	10.0 2.5
32. Disconnect storage cask from transporter and remove storage cask lifting eyes.	2 Ops 1 HP	1.0	1.0 1.0	10.0 5.0	20.0 5.0
33. Connect cask temperature instrumentation.	2 Ops 1 HP	0.5	0.5 0.5	10.0 5.0	10.0 2.5
34. Perform cask operability tests.	1 Op 1 HP	48	1.0 1.0	10.0 5.0	10.0 5.0
TOTAL					284.8 / 208.9[5]

1. Number of personnel typically includes 2 operators and 1 HP technician.
2. Task duration includes total estimated time required to perform task.
3. Time in dose area includes only that time personnel are in a significant dose field.
4. The values in this column represent estimated average dose rates in the area where personnel will be working to perform the associated task. For operations where it is considered that temporary shielding will be effective in keeping dose rates ALARA, two values are presented (e.g., 50 / 5). The first value (50 mrem/hr) is the projected dose rate assuming no credit for temporary shielding. The second value (5 mrem/hr) takes credit for radiation attenuation by the use of temporary shielding.
5. Doses are calculated for times in dose fields without temporary shielding and with temporary shielding, such as 50 / 5, where the first value (50 mrem) is calculated based on the time spent in an area with the dose rate in the preceding column without temporary shielding, and the second value (5 mrem) is calculated based on the dose rate in the preceding column that takes credit for temporary shielding.