# 72-1027 TN-68 AMENDMENT 1
# TABLE OF CONTENTS

**SECTION** **PAGE**



## List of Tables



## List of Figures

# CHAPTER 10

# RADIATION PROTECTION

## 10.1 Ensuring that Occupational Radiation Exposures are As Low As Is Reasonably Achievable (ALARA)

### 10.1.1 Policy Considerations

A radiological protection program will be implemented at the ISFSI in accordance with requirements of 10CFR72.126. The program will be based upon the specific policies in existence at the nuclear generating plant, (ISFSI license holder).

Plant personnel are given training in the proper operation of the cask. This training covers operations, inspections, repair and maintenance of the cask. Proper training of the operation personnel helps to minimize exposure to radiation such that the total individual and collective exposure to personnel in all phases of operation and maintenance are kept As Low As Reasonably Achievable.

### 10.1.2 Design Considerations

The TN-68 cask is designed to store BWR fuel assemblies. It is similar in design to the TN-32 and TN-40 in use at Surry and Prairie Island, respectively, which store PWR assemblies. Experience from these sites has shown the TN designs have good operational features that have resulted in occupational exposures being lower than those postulated here.

The TN-68 dry storage cask design takes into account radiation protection considerations, which ensure that occupational radiation exposures are ALARA. The fuel will be stored dry, inside the sealed, heavily-shielded cask. The most significant radiation protection design consideration provides for heavy shielding to minimize personnel exposures. To avoid personnel exposures, the casks will not be opened nor fuel removed from the casks while at the ISFSI. Storage of the fuel in the dry sealed cask eliminates the possibility of leakage of contaminated liquids. Gaseous releases are not considered credible. The exterior of the casks will be decontaminated before leaving the station, thereby minimizing exposure of personnel to surface contamination and the potential spread of contamination outside of the radiologically controlled area. The TN-68 cask contains no active components which require periodic maintenance or surveillance. This method of spent fuel storage minimizes direct radiation exposures and eliminates the potential for personnel contamination.

Regulatory Position 2 of Regulatory Guide 8.8[(1)], is incorporated into the design considerations, as described below:

- ALARA objective 2a on access control will be met by use of a fence with a locked gate that surrounds the ISFSI and prevents unauthorized access.

- Regulatory Position 2b on radiation shielding is met by the heavy shielding of the cask which minimizes personnel exposures.

- Regulatory Position 2c on process instrumentation and controls is met by designing the instrumentation for a long service life and locating readouts in a low dose rate location.

- Regulatory Position 2d on control of airborne contaminants does not apply because no gaseous releases are expected. No significant surface contamination is credible because the exterior of the cask will be decontaminated before it leaves the station.

- Regulatory Position 2e on crud control is not applicable to the ISFSI because there are no systems at the ISFSI that could transport crud.

- Regulatory Position 2f on decontamination is met because the exterior of the cask is designed for decontamination. The cask is decontaminated before it is released from the decontamination areas in the station.

- Regulatory Position 2g on radiation monitoring does not apply because the casks are sealed. There is no need for airborne radioactivity monitoring since no airborne radioactivity is anticipated. Area radiation monitors are not required because the ISFSI will not normally be occupied.

- Regulatory Position 2h on resin treatment systems is not applicable because there will be no radioactive systems containing resins.

- Regulatory Position 2i concerning other miscellaneous ALARA items is not applicable because these items refer to radioactive systems not present at the ISFSI.

### 10.1.3 Operational Considerations

Operational requirements for surveillance are incorporated into the design considerations in Section 10.1.2 in that the casks are stored with adequate spacing to allow ease of on site surveillance. In addition, remote annunciation and/or indication is available outside the ISFSI protected area to minimize surveillance time.

The operational requirements are incorporated into the radiation protection design features described in Section 10.2 since the cask are heavily shielded to minimize occupational exposure.

The TN-68 cask is designed to be essentially maintenance free. It is a passive system without any moving parts. The double metallic O-ring design with periodic surveillance of the over pressure system guarantees that in the unlikely event of a failure of one of the seals, adequate time is available to restore the cask leak tightness.

The only cask repair procedure that could be envisioned is the replacement of a containment seal. For this, the cask would be returned to the spent fuel pool area in order to minimize radiation exposure to personnel.

The only anticipated maintenance procedures are visual inspection, possible paint touch-up, pressure transducer/switch surveillance/maintenance, and overpressure system re-pressurization.

The TN-68 cask/ISFSI contains no systems that process liquids or gases or contain, collect, store, or transport radioactive liquids or solids other than the stored spent fuel.  Therefore, the ISFSI meets ALARA requirements since there are no such systems to be maintained, be repaired, or be a source of leaks.

## 10.2 Radiation Protection Design Features

### 10.2.1 Cask Design Features

The TN-68 dry storage cask has a number of design features which ensure a high degree of integrity for the confinement of radioactive materials and reduction of direct radiation exposures to levels that are as low as practical.

- The casks are loaded, sealed, and decontaminated prior to transfer to the ISFSI.
- The fuel will not be unloaded nor will the casks be opened at the ISFSI.
- The fuel will be stored dry inside the casks, so that no radioactive liquid is available for leakage.
- The casks will be sealed airtight with a helium atmosphere to preclude oxidation of the fuel. The seals are double metallic o-rings to assure leak-tightness.
- The casks will be heavily shielded to reduce external dose rates. The shielding design features are discussed below.
- No radioactive material will be discharged during storage.

Shielding for the TN-68 cask is provided mainly by the thick-walled cask body. For neutron shielding, a borated polyester resin compound surrounds the cask body and a polypropylene disk covers the lid for storage. Additional shielding is provided by the steel shell surrounding the resin layer and by the stainless steel and aluminum/steel structure of the basket. Details of the cask shielding and radioactive sources are provided in Section 5.2.

Geometric attenuation, enhanced by ground and air attenuation, provides additional “shielding” for distant locations at restricted area and site boundaries. Two independent methods are utilized to determine the dose rates (and annual doses) around a 20-cask ISFSI containing design basis fuel.

### 10.2.2 Radiation Dose Rates

Calculated dose rates in the immediate vicinity of the TN-68 cask are presented in Chapter 5, which provides a detailed description of source term configuration, analysis models and bounding dose rates. The dose rate as a function of distance from the ISFSI for a single TN-68 cask is also presented in Chapter 5. Off-site dose rates and annual doses for an ISFSI containing 20 casks are presented in this section. This evaluation determines the neutron and gamma-ray off-site dose rates including skyshine in the vicinity of a generic ISFSI layout containing design-basis contents in the casks.

The generic ISFSI evaluated is a 2x10 array of TN-68 casks loaded with design-basis (described in chapter 5 as DBF-68) fuel. This generic ISFSI layout is shown in Figure 10.2-1. This evaluation provides results for distances ranging from 10 to 600 meters from the front, side and corner of the arrays.

The total annual exposure for this ISFSI layout as a function of distance from each location (front, corner or side) is given in Table 10.2-1 and plotted in Figure 10.6. The total annual exposure estimates assume 100% occupancy for 365 days.

The Monte Carlo computer code MCNP [2] calculates the dose rates at the specified locations around the array of casks. The results of this calculation provide an example of how to demonstrate compliance with the relevant radiological requirements of 10 CFR 20 [5], 10 CFR 72[4], and 40 CFR 190[6] for a specific site. Each site must perform specific site calculations to account for the actual layout of the casks and fuel source. Two independent methods are utilized to evaluate the dose rate as a function of distance from the ISFSI. These are the "Blocking Factor" method and the "MCNP Array" method. These methods and their results are described below.

#### 10.2.2.1 Blocking Factor Method – Methodology and Assumptions

The blocking factor method is a two step method to determine the dose rate as a function of distance from the ISFSI for an array of casks. The first step involves the calculation of the dose rate as a function of distance for a single cask. For the purpose of expanding the single cask results to be applicable for a multi-cask ISFSI, the total dose rate at any given location is a sum of dose rate contribution from two components – *direct* and *skyshine*. The direct dose rate component is basically due to the unobstructed (no shielding from other casks) sources. The skyshine component is due to the scattering of source particles around (and above) the cask. A conservative assumption in the blocking factor approach is that the dose rate contribution from skyshine is not blocked. That is, the blocking factors are applied only to the direct dose rate component. Two different MCNP calculations are performed to determine the total and direct dose rates. In the total dose rate calculation model, the single cask ISFSI geometry is modeled in its entirety. The results of these calculations are shown in Chapter 5. In the direct dose rate calculational model, the top boundary is typically set at 500 cm or any other short distance from the cask top. This ensures that the scattering and particle transport above the cask top is minimized or eliminated, thereby removing the skyshine component. The conservatism in the direct model depends on the distance of the top boundary from the cask top. A typical value for this distance is the inter-cask radial separation distance. The skyshine doses are calculated by subtracting the direct doses from the total doses. Two models are used to determine the dose rates that differ on the source term – a "gamma" model to calculate the gamma dose rates due to the fuel and hardware and a "neutron" model to determine the neutron dose rates from the active fuel. All the doses are determined using volumetric F4 detectors.

In the second step of the methodology, the blocking factors required to scale the single cask direct dose rates as a function of the cask location and distance are calculated. Subsequently, the total dose rates for the ISFSI are calculated as a cumulative sum of the direct and skyshine dose rate components for all the casks in the ISFSI. The QADS module of the SCALE4.4 [3] computer code system is utilized to determine the blocking factors.

The assumptions for the blocking factor methodology are summarized below.

- Because the cask height is not a factor for a radial point kernel calculation, the casks are 10 cm high in the QADS model of the array. The shielding calculations are performed using iron cross sections with a Co60 source and air scattering. The iron cross sections are sufficient since the bulk of the cask shielding materials are steels. The gamma source in the cask is well approximated using the Co60 source.

- The dose rates due to capture gamma sources are not calculated since they are insignificant at large distances in comparison to primary gamma and neutron sources.

- The “ground shine” contribution is not calculated since soil is not modeled explicitly beyond the concrete pad of the ISFSI. The ground shine component is that portion of the dose rate that is due to reflection/scatter from the ground. The ground shine is significant only at the immediate vicinity of the cask (source) and is relatively insignificant at far distances.

- The choice of the F4 annular cylindrical detectors for the single cask MCNP model tallies inherently assumes that there is no effect due to the orientation of the casks on the dose rates especially at far distances.

- The selection of the top boundary for determining the direct doses in the blocking factor MCNP model is conservative and is expected to result in a higher skyshine component.

Blocking Factor Method - MCNP and QADS Results

The *blocking factor* MCNP model consists of a single TN 68 cask that is centered on a 14-foot concrete pad. The problem geometry is extended to include volumetric F4 detectors placed at 10m, 20m, 40m, 60m, 80m, 100m, 200m, 400m and 600m from the edge of the concrete pad. The detectors are modeled as annular cylinders with a thickness of 30cm and an axial height of 30cm. For calculating the total dose rates, the top boundary of the model is extended to 50000 cm which provides adequate room for scattering of particles in air. In the direct dose calculational model, the top boundary is fixed at 500 cm, which is about 6 ft from the top of the cask. This distance is also the approximate distance of separation between casks in the ISFSI. The choice of 500 cm as the top boundary is conservative since a realistic value would be about twice the distance thereby providing for a free air space above the cask that is equal to a single cask height. The implication of a conservative axial boundary is that any particle that crosses the boundary is lost and does not contribute to the direct dose tally. Therefore, this model is expected to result in an overestimation of the skyshine dose rates and an underestimation of the blocking or cask-shielded dose rates.

Table 10.2-1 shows the results of the MCNP farfield (total and direct) dose rate calculations for a single cask. The skyshine dose rate calculations are shown in Table 10.2-2. Skyshine dose rates are obtained by subtracting the direct dose rates from the total dose rates. In order to obtain a smooth fit of the data for use in the subsequent ISFSI dose evaluations, the gamma skyshine dose rates are adjusted conservatively. These adjusted dose rates are shown in column 3 of Table 10.2-2. A blank entry in these columns indicates that the calculated dose rates are utilized to determine the skyshine dose rates (no adjustments are made) as a function of distance. Only the dose rates at 10m and 40m distance are adjusted.

The MCNP results are utilized to determine mathematical equations that express the dose rate as a function of distance for both gamma and neutron sources. Due to the large distances involved, two equations are determined to represent these dose rates – short distance (0 – 80 m) and long distance (80 – 600m). Figure 10.2-2 shows plots of the total dose rates as a function of distance. The plot at the top is based on short distance data and the one at the bottom is based on the long distance data. The mathematical function for gamma dose rates is shown at the top of each plot while that for neutron is shown at the bottom of each plot. The $R^2$ value (included in the plots) of these functions indicates that they represent a very good fit of the dose rates. Figure 10.2-3 shows plots of the direct dose rates as a function of distance and Figure 10.2-4 shows plots of the skyshine dose rates as a function of distance. The mathematical equations developed in the previous sections that fit the MCNP dose rate results as a function of distance for a single cask are summarized in Table 10.2-3.

Due to the layout of the ISFSI, three types of blocking factors are determined – longer side, shorter side and corner. The longer side of the cask array is that side that has 10 casks facing it and is shown in Figure 10.2-1. The dose points are located at 10m, 20m, 40m, 60m, 80m, 100m, 200m, 400m, and 600m from the edge of the ISFSI array between casks 5 and 6. The shorter side of the cask array is that side that has 2 casks facing it and is also shown in Figure 10.2-1. The dose points are located at 10m, 20m, 40m, 60m, 80m, 100m, 200m, 400m, and 600m from the edge of the ISFSI array between casks 1 and 11. The dose calculational methodology is similar to that outlined for the longer array of casks. The corner dose points are located 10m, 20m, 40m, 60m, 80m, 100m, 200m, 400m, and 600m from the corner of cask 1. Due to the symmetry of the ISFSI along the sides, only the blocking factors for casks 11 through 15 were determined along the longer side of the array. Along the shorter side of the array, the blocking factor for cask 15 in the longer direction (same as the blocking factor for cask 11 in the shorter direction) - is conservatively utilized as the blocking factor for casks 2 through 10. The unblocked casks for the longer side of array are casks 1 through 10 while the unblocked casks for the shorter side of array are casks 1 and 11. The unblocked casks for the corner dose points are casks 1 through 11.

The blocking factor calculation concept is pictorially represented in Figure 10.2-5 for Cask 13 at 10m distance (for longer side of the array). To calculate the blocking factor for cask 13, the casks 13, 14, 4 and 5 are represented in QADS with the location of Cask 13 at X=0, Y=0. Basically, all the casks that are likely to “block” cask 13 from the dose point A are modeled in QADS. Dose point A represents the actual location of the detector while the dose point B is a complementary position of the detector without any blocking. The ratio of the dose rates at dose point A and dose point B is what is called the “blocking factor”.

As an example, at 10 m distance, the dose rate at dose point A is 0.514 and the dose rate at dose point B is 0.972. The blocking factor, at 10m for cask 13, is therefore 0.529 (0.514/0.972). All the results shown in this section are based on the same concept of calculating blocking factors with QADS. The blocking factors for the side and corner locations are shown in Table 10.2-4 and Table 10.2-5 respectively.

Blocking Factor Method – Dose Rate as a Function of Distance

Utilizing the mathematical equations and the blocking factors determined in the previous section for direct and skyshine dose rates as a function of distance, the dose rate contribution from each cask in the ISFSI and subsequently, the total dose rate as a function of distance for an array of casks can be determined. First, the direct dose rates and skyshine dose rates (for both gamma and neutron) for the given distance is calculated using the equations determined in Table 10.2-3. Then, the direct dose rates are multiplied (or scaled) using the appropriate blocking factors determined in Table 10.2-4 and Table 10.2-5. Finally, the dose rate contributions are calculated as a summation of the skyshine and the blocked direct dose rates for each blocked cask. These results are shown in Table 10.2-6.

#### 10.2.2.2 MCNP Array Method – Methodology, Model and Assumptions

The ISFSI layout as illustrated in Figure 10.2-1 is explicitly modeled in MCNP using advanced MCNP geometry. The gamma and neutron dose rates are determined as a function of distance from the ISFSI. All the doses are determined using F5 point detectors. The *ISFSI array* MCNP model consists of a 2x10 ISFSI containing TN 68 HB casks. The cask array is modeled using advanced MCNP geometry to represent the ISFSI as shown in Figure 3.2-1. The concrete pad at the bottom is modeled to span the extent of the array (X±2140 cm, Y±428cm). Three sets of point detector tallies are utilized to determine the dose rates. One set is utilized to determine the dose rate as a function of distance from the longer side of the array (between casks 5 and 6), the other is utilized to determine the dose rates from the shorter side of the array (between casks 1 and 11) and the third is utilized to determine the dose rates from the corner of the array (corner of cask 1). These point F5 detectors placed at 10m, 20m, 40m, 60m, 80m, 100m, 200m, 400m and 600m from the edge of the concrete pad at each direction (long, short and corner).

The assumptions for the MCNP methodology are summarized below.

- The doses due to capture gamma sources are not calculated since they are insignificant at large distances in comparison to primary gamma and neutron sources.

- The “ground shine” contribution is not calculated since soil is not modeled explicitly beyond the concrete pad of the ISFSI. The ground shine component is that portion of the dose rate that is due to reflection/scatter from the ground. The ground shine is significant only at the immediate vicinity of the cask (source) and is relatively insignificant at far distances.

- The location of the F5 detectors for the ISFSI array MCNP model inherently assume that there is no effect on the orientation of the casks on the dose rates especially at far distances.

- The “universe” is a cylinder surrounding the ISFSI. To account for skyshine radius of this sphere (r=150,000 cm) is more than 10 mean free paths for neutrons and 50 mean free paths for gammas greater than that of the outermost surface, thus ensuring that the model is of a sufficient size to include all interactions, including skyshine, affecting the dose rate at the detectors.

MCNP Array Method – Dose Rate as a Function of Distance

The MCNP results for each detector provides the dose rate as a function of distance at all the locations (sides and corner) around the ISFSI. These results are shown in Table 10.2-7. Some of the MCNP tally results appear to have very large errors associated with them. An inspection of the MCNP output indicates that there is expected to be no change in the tally value at convergence. However, for conservatism, the tallies with errors greater than 10% but less than 20% (neutron and gamma 600m tally for longer side, neutron 400m and gamma 600m tally for corner) are scaled by a factor of 1.1 and the tallies for errors greater than 20% (neutron 400m and gamma 600m tally for shorter side) are scaled by a factor of 1.2.

#### 10.2.2.3 ISFSI Annual Doses

The ISFSI annual doses (mrem) as a function of distance for both the methods are shown in Table 10.2-8. These doses are obtained by multiplying the dose rates (mrem/hour) with 8760 (total number of hours per year assuming full occupancy). These results are also shown pictorially in Figure 10.2-6 and Figure 10.2-7. The results indicate that the blocking factor methodology results in conservative dose rates. The ratio of the dose rates (blocking factor to MCNP array) is also shown in Table 10.2-8. These results also show that the longer side of the array and corner of array results for the blocking factor methodology are in better agreement to the MCNP array results than the shorter side of the array results. The agreement of blocking factor results with those of the MCNP array results is directly related to the number of blocked casks. The more the number of blocked casks, the higher the conservatism in the skyshine dose and therefore, the larger the ratio of the blocked dose rates to the MCNP array dose rates.

These results demonstrate that both methods result in similar dose rate predictions. The blocking factor methodology can be utilized to quickly determine the site doses even for complicated ISFSI layouts.

The preceding analyses and results are intended to provide high estimates of dose rates for generic ISFSI layouts. The written evaluations performed by a licensee for an actual ISFSI must consider the type and number of casks, layout, characteristics of the irradiated fuel to be stored, site characteristics (e.g., berms, distance to the controlled area boundary, etc.), and reactor operations at the site in order to demonstrate compliance with 10 CFR 72.104.

## 10.3 Estimated Onsite Collective Dose Assessment

Cask Loading Operations

Table 10.3-1 shows the estimated design basis occupational exposures to ISFSI personnel during the loading, transport, and emplacement of the storage casks (time and manpower may vary depending on individual utility practices). The task times, number of personnel required and the average distance from the cask are listed in this table.

This estimate of operational doses is based on 7x7 fuel at 40 GWd/MTU, 10 years cooling, with a total decay heat load of 21.2 kW. It assumes that there is no temporary shielding used. Lead bean bags and temporary plastic neutron shielding can be used to maintain doses ALARA. With the same assumptions, the doses from design basis 8x8 fuel would be about a factor 1.5 higher for gamma and 4 higher for neutrons.

Operations with the TN-68 have yielded much lower doses, as shown in Table 10.3-3, which shows cumulative dose measurements for loads of about 16 kW per cask. For the design basis load of 30 kW, the operational doses would be a factor of 2 to 4 higher.

The average distance for a given operation takes into account the fact that the operator may be momentarily in contact with the cask, but this time will be limited. For example, during bolting, the placement of the bolts in the holes will bring the operator in contact with the cask. While torquing the operator will be further away due to the typical length of a torque wrench handle. Similarly, for draining, vacuum drying, and leak testing, the attachment of fittings will take place closer to the cask than the operation of the pump and vacuum drying system. For decontamination, although operators will be close to the cask to take swipes, other parts of the operation will be done by hosing the cask down from further away.

For this reason, 0.5 or 1.0 meter is an appropriate average distance for these hands-on operations.

The operator’s hands may be in a high dose rate location momentarily, for example when connecting couplings or vacuum fitting at the ports. This does not translate into a whole-body dose, and therefore, these localized streaming effects are not considered here.

For the operations near the lid, typically most of the operation will take place around the perimeter (corner) and a smaller portion will take place directly over the lid. A 33/67 weighted average of axial centerline and above neutron shield radial dose rates is used for these operations as described below.

Dose rates used for the operations dose estimate

All of the following dose rates are in mrem/hr.

Water/lid: Dose rates at the cask top while the cask is still filled with water are low due to the water shielding; they are estimated at

| | |
|---|---|
| 0.5 meter | 7 $\gamma$ / 3 n |
| 2 meter | 2 $\gamma$ / 1 n |

After the cask is drained, and before the neutron shield is installed, dose rates at the cask lid centerline are equivalent to the accident “top” dose rates in Table 5.1-2.

| | |
|---|---|
| Contact | 267 γ / 59n |
| 0.5 meter | 206 γ / 39n |
| 1 meter | 145 γ / 19 n |
| 2 meter | 80 γ / 8.1 n |

The surface radial dose rate above the neutron shield is calculated in Table 5.1-2.  Extrapolation to the points away from the surface is based upon ratios derived from measurements of loaded TN-32 casks.

| | |
|---|---|
| Contact | 357 γ / 40 n |
| 0.5 meter: | 202 γ / 23 n |
| 1 meter | 87 γ / 10 n |
| 2 meter | 55 γ / 6.1 n |

Lid/Corner: (prior to placement of top neutron shield) 33% axial dose rates at the cask lid centerline and 67% radial dose rate above the neutron shield:

| | |
|---|---|
| 0.5 meter: | 203 γ / 28 n |
| 1 meter | 106 γ / 13 n |
| 2 meter | 63 γ / 6.8 n |

Top/Corner (after installation of top neutron shield): use the radial dose rate above the neutron shield (table above).

| | |
|---|---|
| 0.5 meter: | 202 γ / 23 n |
| 1 meter | 87 γ / 10 n |
| 2 meter | 55 γ / 6.1 n |

Radial (midplane dose rates from Table 5.1-2)

| | |
|---|---|
| 0.5 meter | 52 γ / 3.4 n |
| 1 meter: | 36 γ / 2.6 n |
| 2 meter | 23 γ / 1.6 n |
| 3 meter | 14 γ / 1.0 n |

Maintenance Operations

Table 10.3-2 shows the estimated annual person-rem for surveillance and maintenance activities. These estimates take no credit for reduced dose rates due to decay time at the ISFSI. The background dose rate at the ISFSI is estimated at 10γ /0.7n mrem/hr based on a distance of more than 4 meters from the nearest cask, except as noted. Dose rates are based upon the radial midplane dose rates for 21.2 kW cask loads except where noted.

Visual surveillance is based on a walk down among the casks at a distance no closer than 2 meters to a single cask while maintaining a distance of 3 meters from its neighboring cask.

For operability tests and calibration, and for unanticipated instrument repair, the worker was assumed to be located at the plumbing manifold located on the cask exterior about 4 feet from the ground, an average of 1 meter from the cask. Repressurization of the overpressure system may be done at the same time as calibration with little or no additional exposure.

For paint touch up, an average distance is 0.5 meter.

For major repairs to the overpressure system that would require removal of the weather protective cover, the 0.5 meter radial dose rate from the area above the radial neutron shield is used (top/corner dose rate).

## 10.4 References


1. U.S. Nuclear Regulatory Commission, Regulatory Guide 8.8, Information Relevant to Ensuring that Occupational Exposures at Nuclear Power Stations will be As Low As Is Reasonably Achievable, Revision 3, June 1978

2. MCNP4C2, Monte Carlo N-Particle Transport Code System, Oak Ridge National Laboratory, CCC-701, RSICC Computer Code Collection, June 2001

3. SCALE-4.4, Modular Code System for Performing Standardized Computer Analysis for Licensing Evaluation for Workstations and Personal Computers, CCC-545, ORNL

4. Title 10 Code of Federal Regulations Part 72, Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste

5. Title 10 Code of Federal Regulations Part 20, Standards for Protection Against Radiation

6. Title 40 Code of Federal Regulations Part 190, Environmental Radiation Protection Standards for Nuclear Power Operations

TABLE 10.2-1

TOTAL AND DIRECT DOSE RATES AS A FUNCTION OF DISTANCE
FOR A SINGLE TN-68 CASK

| Distance (meters) | Gamma (mrem/hour) | Error | Neutron (mrem/hour) | Error |
|---|---|---|---|---|
| **Total Dose Rate Results** | | | | |
| 10 | 3.67E+00 | 0.0199 | 7.14E-01 | 0.0198 |
| 20 | 1.21E+00 | 0.0272 | 2.23E-01 | 0.0240 |
| 40 | 3.07E-01 | 0.0330 | 5.27E-02 | 0.0279 |
| 60 | 1.34E-01 | 0.0365 | 2.36E-02 | 0.0307 |
| 80 | 7.124E-02 | 0.0398 | 1.16E-02 | 0.0302 |
| 100 | 4.06E-02 | 0.0444 | 6.74E-03 | 0.0323 |
| 200 | 5.30E-03 | 0.0513 | 8.88E-04 | 0.0362 |
| 400 | 4.42E-04 | 0.0547 | 5.62E-05 | 0.0313 |
| 600 | 6.50E-05 | 0.0752 | 6.79E-06 | 0.0460 |

| **Direct Dose Rate Results** | | | | |
|---|---|---|---|---|
| 10 | 3.65E+00 | 0.0197 | 6.61E-01 | 0.0187 |
| 20 | 1.14E+00 | 0.0259 | 1.95E-01 | 0.0242 |
| 40 | 2.91E-01 | 0.0340 | 3.98E-02 | 0.0336 |
| 60 | 1.13E-01 | 0.0409 | 1.50E-02 | 0.0427 |
| 80 | 5.73E-02 | 0.0454 | 6.39E-03 | 0.0503 |
| 100 | 3.18E-02 | 0.0505 | 3.11E-03 | 0.0583 |
| 200 | 3.45E-03 | 0.0780 | 2.84E-04 | 0.1080 |
| 400 | 1.73E-04 | 0.1278 | 8.12E-06 | 0.1834 |
| 600 | 2.41E-05 | 0.1736 | 7.11E-07 | 0.2947 |

TABLE 10.2-2

SKYSHINE DOSE RATES AS A FUNCTION OF DISTANCE FOR A SINGLE TN-68 CASK

| Distance (meters) | Gamma (mrem/hour) | Adjusted Gamma (mrem/hour) | Neutron (mrem/hour) |
|---|---|---|---|
| 10 | 2.12E-02 | 1.20000E-01 | 5.28E-02 |
| 20 | 7.33E-02 | | 2.81E-02 |
| 40 | 1.54E-02 | 3.08809E-02 | 1.29E-02 |
| 60 | 2.12E-02 | | 8.57E-03 |
| 80 | 1.38E-02 | | 5.21E-03 |
| 100 | 8.79E-03 | | 3.63E-03 |
| 200 | 1.85E-03 | | 6.04E-04 |
| 400 | 2.69E-04 | | 4.81E-05 |
| 600 | 4.09E-05 | | 6.08E-06 |

TABLE 10.2-3

MATHEMATICAL FUNCTIONS FOR DOSE RATES AS A FUNCTION OF DISTANCE FOR A SINGLE TN-68 CASK

| Description | Mathematical Function |
|---|---|
| **X=Distance from Edge of PAD, X ≤ 80 m** | |
| Total Dose Rate, Gamma | $323.62*(X)^{(-1.9035)}$ |
| Total Dose Rate, Neutron | $74.803*(X)^{(-1.9789)}$ |
| Direct Dose Rate, Gamma | $405.71*(X)^{(-1.9973)}$ |
| Direct Dose Rate, Neutron | $129.23*(X)^{(-2.2236)}$ |
| Skyshine Dose Rate, Gamma | $1.4694*(X)^{(-1.0462)}$ |
| Skyshine Dose Rate, Neutron | $0.6961*(X)^{(-1.0921)}$ |
| **X=Distance from Edge of PAD, X ≥ 80 m** | |
| Total Dose Rate, Gamma | $2.8474*10^5*(X)^{(-3.4209)}$ |
| Total Dose Rate, Neutron | $1.2938*10^5*(X)^{(-3.6374)}$ |
| Direct Dose Rate, Gamma | $1.5472*10^6*(X)^{(-3.8439)}$ |
| Direct Dose Rate, Neutron | $2.8503*10^6*(X)^{(-4.4683)}$ |
| Skyshine Dose Rate, Gamma | 0.0247*EXP((X)*(-0.011)) |
| Skyshine Dose Rate, Neutron | 0.0116*EXP((X)*(-0.013)) |

TABLE 10.2-4

BLOCKING FACTORS FOR USE IN THE SIDE (SHORTER AND LONGER) DOSE RATE CALCULATIONS

| Distance | Cask 15 | Cask 14 | Cask 13 | Cask 12 | Cask 11 |
|---|---|---|---|---|---|
| 10 m | 0.100 | 0.705 | 0.529 | 0.529 | 0.529 |
| 20 m | 0.015 | 0.448 | 0.706 | 0.623 | 0.331 |
| 40 m | 0.013 | 0.245 | 0.292 | 0.499 | 0.688 |
| 60 m | 0.012 | 0.106 | 0.262 | 0.291 | 0.483 |
| 80 m | 0.011 | 0.099 | 0.218 | 0.269 | 0.291 |
| 100 m | 0.001 | 0.088 | 0.110 | 0.254 | 0.273 |
| 200 m | 0.001 | 0.014 | 0.087 | 0.101 | 0.108 |
| 400 m | 0.001 | 0.012 | 0.014 | 0.015 | 0.087 |
| 600 m | 0.001 | 0.001 | 0.012 | 0.013 | 0.015 |

TABLE 10.2-5

BLOCKING FACTORS FOR USE IN THE CORNER DOSE RATE CALCULATIONS

| Distance | Cask 12 | Cask 13 | Cask 14 | Cask 15 | Casks 16 through 20 |
|---|---|---|---|---|---|
| 10 m | 0.001 | 0.152 | 0.001 | 0.001 | 0.001 |
| 20 m | 0.001 | 0.158 | 0.001 | 0.001 | 0.001 |
| 40 m | 0.001 | 0.047 | 0.002 | 0.001 | 0.001 |
| 60 m | 0.001 | 0.045 | 0.157 | 0.137 | 0.001 |
| 80 m | 0.001 | 0.044 | 0.151 | 0.107 | 0.143 |
| 100 m | 0.001 | 0.041 | 0.049 | 0.157 | 0.017 |
| 200 m | 0.001 | 0.001 | 0.044 | 0.047 | 0.137 |
| 400 m | 0.001 | 0.001 | 0.001 | 0.042 | 0.045 |
| 600 m | 0.001 | 0.001 | 0.001 | 0.001 | 0.042 |

TABLE 10.2-6

DOSE RATE AS A FUNCTION OF DISTANCE FOR THE ISFSI (BLOCKING FACTOR METHOD)

| **Distance (m)** | **Gamma (mrem/hr)** | **Neutron (mrem/hr)** | **Total (mrem/hr)** | **Gamma (mrem/hr)** | **Neutron (mrem/hr)** | **Total (mrem/hr)** |
|---|---|---|---|---|---|---|
| | Longer Side of Array | | | Shorter Side of Array | | |
| 10 | 3.25E+01 | 6.24E+00 | 3.88E+01 | 1.14E+01 | 2.41E+00 | 1.38E+01 |
| 20 | 1.19E+01 | 2.20E+00 | 1.41E+01 | 3.10E+00 | 7.44E-01 | 3.85E+00 |
| 40 | 3.66E+00 | 6.72E-01 | 4.33E+00 | 1.11E+00 | 2.99E-01 | 1.41E+00 |
| 60 | 1.70E+00 | 3.20E-01 | 2.02E+00 | 6.28E-01 | 1.81E-01 | 8.08E-01 |
| 80 | 1.03E+00 | 1.96E-01 | 1.23E+00 | 4.25E-01 | 1.27E-01 | 5.52E-01 |
| 100 | 5.18E-01 | 1.01E-01 | 6.19E-01 | 2.26E-01 | 6.87E-02 | 2.95E-01 |
| 200 | 6.54E-02 | 1.37E-02 | 7.91E-02 | 5.62E-02 | 1.63E-02 | 7.25E-02 |
| 400 | 6.50E-03 | 1.05E-03 | 7.54E-03 | 6.13E-03 | 1.23E-03 | 7.36E-03 |
| 600 | 1.22E-03 | 1.46E-04 | 1.36E-03 | 7.81E-04 | 1.05E-04 | 8.86E-04 |

| **Distance (m)** | **Gamma (mrem/hr)** | **Neutron (mrem/hr)** | **Total (mrem/hr)** |
|---|---|---|---|
| | Corner of Array | | |
| 10 | 1.41E+01 | 2.75E+00 | 1.69E+01 |
| 20 | 5.71E+00 | 1.09E+00 | 6.80E+00 |
| 40 | 2.15E+00 | 4.11E-01 | 2.56E+00 |
| 60 | 1.19E+00 | 2.27E-01 | 1.41E+00 |
| 80 | 7.15E-01 | 1.37E-01 | 8.52E-01 |
| 100 | 3.74E-01 | 7.34E-02 | 4.47E-01 |
| 200 | 5.56E-02 | 1.11E-02 | 6.67E-02 |
| 400 | 5.81E-03 | 8.94E-04 | 6.70E-03 |
| 600 | 1.17E-03 | 1.38E-04 | 1.31E-03 |

TABLE 10.2-7

DOSE RATE AS A FUNCTION OF DISTANCE FOR THE ISFSI (MCNP ARRAY METHOD)

| Distance (meters) | Gamma (mrem/hour) | Error | Neutron (mrem/hour) | Error | Total (mrem/hour) |
|---|---|---|---|---|---|
| **Longer Side Dose Rate Results** | | | | | |
| 10 | 3.08E+01 | 0.0391 | 5.34E+00 | 0.0154 | 3.61E+01 |
| 20 | 1.31E+01 | 0.0350 | 2.31E+00 | 0.0376 | 1.54E+01 |
| 40 | 3.88E+00 | 0.0325 | 6.84E-01 | 0.0160 | 4.56E+00 |
| 60 | 1.57E+00 | 0.0434 | 2.89E-01 | 0.0173 | 1.86E+00 |
| 80 | 8.19E-01 | 0.0599 | 1.57E-01 | 0.0278 | 9.76E-01 |
| 100 | 4.83E-01 | 0.0436 | 8.69E-02 | 0.0240 | 5.70E-01 |
| 200 | 7.68E-02 | 0.0567 | 1.20E-02 | 0.0392 | 8.88E-02 |
| 400 | 5.46E-03 | 0.0995 | 7.45E-04 | 0.0667 | 6.20E-03 |
| 600 | 8.30E-04 | 0.1383 | 1.22E-04 | 0.1967 | 9.52E-04 |

| | | | | | |
|---|---|---|---|---|---|
| **Shorter Side Dose Rate Results** | | | | | |
| 10 | 7.46E+00 | 0.0583 | 2.13E+00 | 0.0243 | 9.59E+00 |
| 20 | 2.50E+00 | 0.0523 | 8.15E-01 | 0.0271 | 3.32E+00 |
| 40 | 7.68E-01 | 0.0461 | 2.89E-01 | 0.0918 | 1.06E+00 |
| 60 | 3.86E-01 | 0.0501 | 1.29E-01 | 0.0229 | 5.15E-01 |
| 80 | 2.28E-01 | 0.0484 | 7.22E-02 | 0.0200 | 3.00E-01 |
| 100 | 1.44E-01 | 0.0455 | 4.78E-02 | 0.0358 | 1.92E-01 |
| 200 | 2.53E-02 | 0.0466 | 7.48E-03 | 0.0333 | 3.28E-02 |
| 400 | 2.10E-03 | 0.0796 | 9.89E-04 | 0.3413 | 3.09E-03 |
| 600 | 5.26E-04 | 0.2952 | 5.51E-05 | 0.0926 | 5.82E-04 |

| | | | | | |
|---|---|---|---|---|---|
| **Corner Dose Rate Results** | | | | | |
| 10 | 1.17E+01 | 0.0747 | 2.40E+00 | 0.0578 | 1.41E+01 |
| 20 | 5.42E+00 | 0.0662 | 1.03E+00 | 0.0285 | 6.45E+00 |
| 40 | 2.02E+00 | 0.0597 | 3.91E-01 | 0.0292 | 2.41E+00 |
| 60 | 9.87E-01 | 0.0534 | 1.91E-01 | 0.0326 | 1.18E+00 |
| 80 | 5.61E-01 | 0.0495 | 1.10E-01 | 0.0459 | 6.71E-01 |
| 100 | 3.54E-01 | 0.0532 | 6.51E-02 | 0.0371 | 4.19E-01 |
| 200 | 5.45E-02 | 0.0550 | 9.59E-03 | 0.0580 | 6.41E-02 |
| 400 | 4.79E-03 | 0.1023 | 7.06E-04 | 0.1296 | 5.49E-03 |
| 600 | 7.73E-04 | 0.1791 | 6.17E-05 | 0.0862 | 8.34E-04 |

TABLE 10.2-8

ISFSI ANNUAL DOSES AS A FUNCTION OF DISTANCE FOR 20 TN-68 CASKS

| Distance (m) | Blocking Total (mrem) | Arrays Total (mrem) | Ratio (Blocking/ Arrays) | Blocking Total (mrem) | Arrays Total (mrem) | Ratio (Blocking/ Arrays) |
|---|---|---|---|---|---|---|
| | Longer Side of Array | | | Shorter Side of Array | | |
| 10 | 3.39E+05 | 3.16E+05 | 1.073 | 1.21E+05 | 8.40E+04 | 1.436 |
| 20 | 1.23E+05 | 1.35E+05 | 0.913 | 3.37E+04 | 2.91E+04 | 1.159 |
| 40 | 3.79E+04 | 4.00E+04 | 0.949 | 1.23E+04 | 9.25E+03 | 1.331 |
| 60 | 1.77E+04 | 1.63E+04 | 1.088 | 7.08E+03 | 4.51E+03 | 1.570 |
| 80 | 1.07E+04 | 8.55E+03 | 1.256 | 4.83E+03 | 2.63E+03 | 1.839 |
| 100 | 5.43E+03 | 4.99E+03 | 1.086 | 2.58E+03 | 1.68E+03 | 1.539 |
| 200 | 6.93E+02 | 7.78E+02 | 0.891 | 6.35E+02 | 2.87E+02 | 2.211 |
| 400 | 6.61E+01 | 5.43E+01 | 1.216 | 6.45E+01 | 2.71E+01 | 2.384 |
| 600 | 1.19E+01 | 8.34E+00 | 1.430 | 7.76E+00 | 5.09E+00 | 1.524 |

| Distance (m) | Blocking Total (mrem) | Arrays Total (mrem) | Ratio (Blocking/ Arrays) |
|---|---|---|---|
| | Corner of Array | | |
| 10 | 1.48E+05 | 1.24E+05 | 1.192 |
| 20 | 5.96E+04 | 5.65E+04 | 1.054 |
| 40 | 2.24E+04 | 2.11E+04 | 1.060 |
| 60 | 1.24E+04 | 1.03E+04 | 1.199 |
| 80 | 7.46E+03 | 5.88E+03 | 1.269 |
| 100 | 3.92E+03 | 3.67E+03 | 1.068 |
| 200 | 5.84E+02 | 5.61E+02 | 1.041 |
| 400 | 5.87E+01 | 4.81E+01 | 1.221 |
| 600 | 1.14E+01 | 7.31E+00 | 1.566 |

TABLE 10.3-1
OCCUPATIONAL EXPOSURES FOR CASK LOADING, TRANSPORT, AND EMPLACEMENT (ONE TIME EXPOSURE, 21.2 kW CONTENTS)

| | | | | | | GAMMA | | NEUTRON | |
|---|---|---|---|---|---|---|---|---|---|
| | | **No of Persons** | **Time (hr)** | **Avg Dist (m)** | **location** | **Dose rate mrem/hr** | **person-rem** | **Dose rate mrem/hr** | **person-rem** |
| A. Cask Receipt | | | | | | | | | |
| 1-12 | Unloading, inspection, etc. | NO EXPOSURE OTHER THAN BACKGROUND | | | | | | | |
| B. Cask Loading Pool | | | | | | | | | |
| 1 | Lower cask into cask loading pool | NO EXPOSURE OTHER THAN BACKGROUND (POOL) | | | | | | | |
| 2 | Load | NO EXPOSURE OTHER THAN BACKGROUND (POOL) | | | | | | | |
| 3 | Verify | NO EXPOSURE OTHER THAN BACKGROUND (POOL) | | | | | | | |
| 4 | Lower lid | NO EXPOSURE OTHER THAN BACKGROUND (POOL) | | | | | | | |
| 5 | Lift cask and install some of the lid bolts hand tight | 1 | 0.25 | 0.5 | water/lid | 7 | 0.0018 | 3 | 0.0008 |
| | | 1 | 0.5 | 2 | water/lid | 2 | 0.0010 | 1 | 0.0005 |
| 6 | Drain (pump) water | 1 | 0.5 | 0.5 | water/lid | 7 | 0.0035 | 3 | 0.0015 |
| | | 1 | 1 | 2 | water/lid | 2 | 0.0020 | 1 | 0.0010 |
| 7 | Disconnect drain line | 1 | 0.25 | 0.5 | lid/corner | 203 | 0.0508 | 28 | 0.0070 |
| 8 | Move to decontamination area | 2 | 1 | 2 | radial | 23 | 0.0460 | 1.6 | 0.0032 |
| C. Decontamination Area | | | | | | | | | |
| 1 | Decontaminate | 2 | 1 | 1 | radial | 36 | 0.0720 | 2.6 | 0.0052 |
| | | 1 | 0.5 | 1 | lid/corner | 106 | 0.0530 | 13 | 0.0065 |
| 2 | Install remaining lid bolts and torque | 2 | 1 | 0.5 | lid/corner | 203 | 0.4060 | 28 | 0.0560 |
| 3 | Remove plug from neutron shield vent, install pressure relief valve. | 1 | 0.25 | 0.5 | lid/corner | 203 | 0.0508 | 28 | 0.0070 |
| 4 | Connect the Vacuum Drying System | 1 | 0.25 | 0.5 | lid/corner | 203 | 0.0508 | 28 | 0.0070 |
| | | 1 | 0.5 | 2 | radial | 23 | 0.0115 | 1.6 | 0.0008 |
| 5 | Continue vacuum drying | 1 | 1 | 1 | radial | 36 | 0.0360 | 2.6 | 0.0026 |
| 6 | Backfill cask with helium and pressurize | 1 | 0.25 | 0.5 | lid/corner | 203 | 0.0508 | 28 | 0.0070 |
| | | 2 | 1 | 2 | radial | 23 | 0.0460 | 1.6 | 0.0032 |
| 7 | Helium leak test all lid and port cover seals | 1 | 1 | 0.5 | lid/corner | 203 | 0.2030 | 28 | 0.0280 |
| | | 2 | 2 | 2 | radial | 23 | 0.0920 | 1.6 | 0.0064 |
| 8 | Install top neutron shield. | 2 | 0.25 | 0.5 | top/corner | 202 | 0.1010 | 23 | 0.0115 |
| 9 | Install overpressure system tank | 2 | 0.5 | 0.5 | top/corner | 202 | 0.2020 | 23 | 0.0230 |
| 10 | Leak test OP system | 2 | 0.5 | 1 | top/corner | 87 | 0.0870 | 10 | 0.0100 |
| 11 | Pressurize OP system | 1 | 0.5 | 1 | top/corner | 87 | 0.0435 | 10 | 0.0050 |
| 12 | Install protective cover | 2 | 1 | 0.5 | top/corner | 202 | 0.4040 | 23 | 0.0460 |
| 13 | Check surface dose rate and contamination levels | 2 | 0.5 | 1 | radial | 36 | 0.0360 | 2.6 | 0.0026 |
| 14 | Install exterior tubing, leak test | 1 | 0.5 | 0.5 | top/corner | 202 | 0.1010 | 23 | 0.0115 |
| | | 1 | 1 | 1 | radial | 36 | 0.0360 | 2.6 | 0.0026 |
| 15 | Backfill exterior tubing | 1 | 0.5 | 1 | radial | 36 | 0.0180 | 2.6 | 0.0013 |
| 16 | Load cask on transporter | 2 | 1 | 2 | radial | 23 | 0.0460 | 1.6 | 0.0032 |
| 17 | Move cask to storage area | 2 | 3 | 3 | radial | 14 | 0.0840 | 1 | 0.0060 |
| D. Storage Area | | | | | | | | | |
| 1 | Lower cask onto storage pad | 2 | 0.5 | 2 | radial | 23 | 0.0230 | 1.6 | 0.0016 |
| 2 | Disconnect cask transporter | 2 | 0.5 | 2 | radial | 23 | 0.0230 | 1.6 | 0.0016 |
| 3 | Connect over pressure system to monitoring panel | 2 | 1 | 1 | radial | 36 | 0.0720 | 2.6 | 0.0052 |
| 4 | Check OP system function. | 1 | 0.5 | 1 | radial | 36 | 0.0180 | 2.6 | 0.0013 |
| | | | | | | | | | |
| | | | | | | Total | 2.47 $\gamma$ | | 0.28 |
| | | | | | | n+gam | | | 2.75 |

TABLE 10.3-2

ISFSI MAINTENANCE OPERATIONS
ANNUAL EXPOSURES FOR 21.2 kW CONTENTS

GAMMA

| Task | Time Req'd (hr) | No of Person | Dist (m) | Dose Rate (mrem/hr) | Backgrnd (mrem/hr) | Operation Dose (rem) | Operation Frequency ( /year) | Annual Dose (rem) |
|---|---|---|---|---|---|---|---|---|
| Visual Surveillance of Casks | 0.25 | 1 | 2 | 23 | 14 | 0.00925 | 12 | 0.111 |
| Instrumentation | | | | | | | | |
| a. Operability & Calibration | 2 | 2 | 1 | 36 | 10 | 0.184 | 1 | 0.184 |
| b. Unanticipated Repairs | 2 | 2 | 1 | 36 | 10 | 0.184 | 0.25 | 0.046 |
| Surface Defect Repair | 1 | 2 | 0.5 | 52 | 10 | 0.124 | 1 | 0.124 |
| Repair under Protective Cover | 8 | 2 | 0.5 | 202 | 10 | 3.392 | 0.05 | 0.170 |

NEUTRON AND TOTAL

| Task | Time Req'd (hr) | No of Person | Dist (m) | Dose Rate (mrem/hr) | Backgrnd (mrem/hr) | Operation Dose (rem) | Operation Frequency ( /year) | Annual Dose (rem) | Total gamma + n (rem) |
|---|---|---|---|---|---|---|---|---|---|
| Visual Surveillance of Casks | 0.25 | 1 | 2 | 1.6 | 1 | 0.00065 | 12 | 0.008 | 0.119 |
| Instrumentation | | | | | | | | | |
| a. Operability & Calibration | 2 | 2 | 1 | 2.6 | 0.7 | 0.0132 | 1 | 0.013 | 0.197 |
| b. Unanticipated Repairs | 2 | 2 | 1 | 2.6 | 0.7 | 0.0132 | 0.25 | 0.003 | 0.049 |
| Surface Defect Repair | 1 | 2 | 0.5 | 3.4 | 0.7 | 0.0082 | 1 | 0.008 | 0.132 |
| Repair under Protective Cover | 8 | 2 | 0.5 | 23 | 0.7 | 0.3792 | 0.05 | 0.019 | 0.189 |

1. All dose rates assume that the TN-68 cask contains design basis fuel. No reduction of dose rate is assumed for decay time.

2. Doses are on a per cask basis.

TABLE 10.3-3

MEASURED OPERATIONAL DOSES FROM TN-68 CASK LOADING

| Year | Cask Number | Cask Heat Load kW | Man-Rem | Man-Hours |
|---|---|---|---|---|
| 2000 | TN-68-01 | 17.2 | 0.375 | 1744 |
| 2000 | TN-68-02 | 17.1 | 0.284 | 1430 |
| 2000 | TN-68-03 | 17.1 | 0.279 | 1272 |
| 2000 | TN-68-04 | 17.1 | 0.168 | 1267 |
| 2001 | TN-68-05 | 17.1 | 0.357 | 1068 |
| 2001 | TN-68-06 | 17.1 | 0.358 | 937 |
| 2001 | TN-68-07 | 17.2 | 0.371 | 1020 |
| 2001 | TN-68-08 | 17.2 | 0.345 | 896 |
| 2001 | TN-68-09 | 17.3 | 0.257 | 787 |
| 2002 | TN-68-10 | 17.2 | 0.238 | 926 |
| 2002 | TN-68-11 | 16.8 | 0.189 | 666 |
| 2002 | TN-68-12 | 16.6 | 0.198 | 680 |
| 2002 | TN-68-13 | 16.6 | 0.184 | 658 |
| 2002 | TN-68-14 | 16.7 | 0.216 | 680 |
| 2002 | TN-68-15 | 16.8 | 0.254 | 726 |
| 2003 | TN-68-16 | 15.7 | 0.336 | 1104 |
| 2003 | TN-68-17 | 16.5 | 0.206 | 559 |
| 2003 | TN-68-18 | 16.5 | 0.254 | 724 |
| 2003 | TN-68-19 | 16.6 | 0.198 | 589 |
| 2003 | TN-68-20 | 16.6 | 0.235 | 592 |
| 2004 | TN-68-21 | 16.8 | 0.226 | 710 |
| 2004 | TN-68-22 | 17.0 | 0.208 | 604 |
| 2004 | TN-68-23 | 16.9 | 0.210 | 575 |
| 2004 | TN-68-24 | 17.0 | 0.183 | 560 |

Data provided by Peach Bottom Atomic Power Station

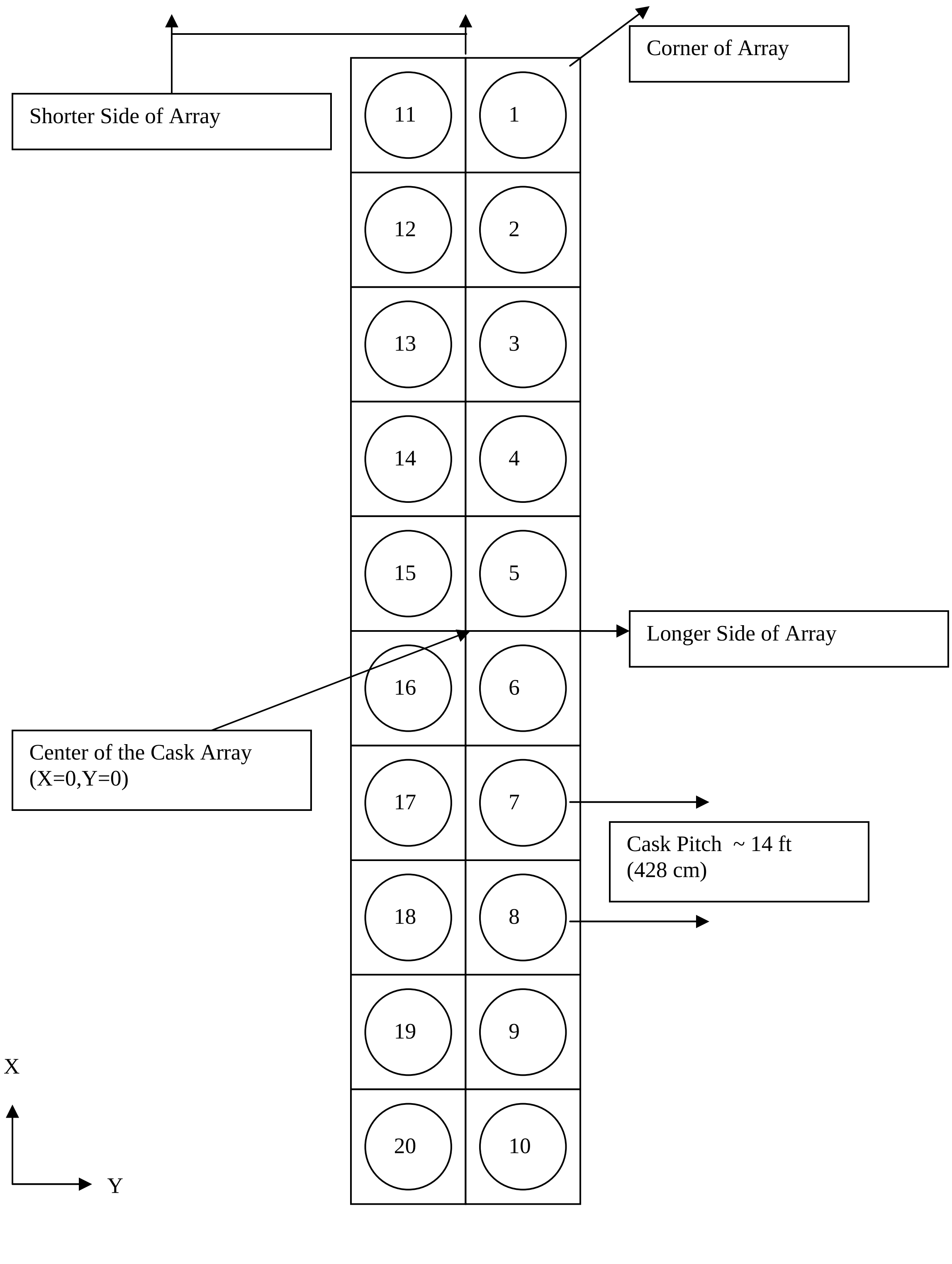
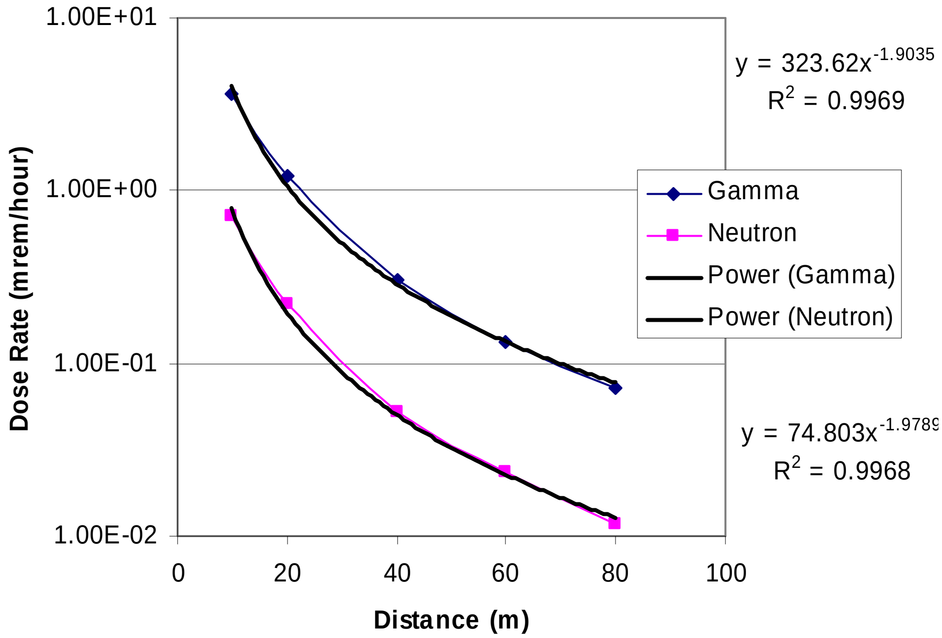



FIGURE 10.2-1

ISFSI LAYOUT WITH A 2X10 ARRAY OF TN-68 CASKS



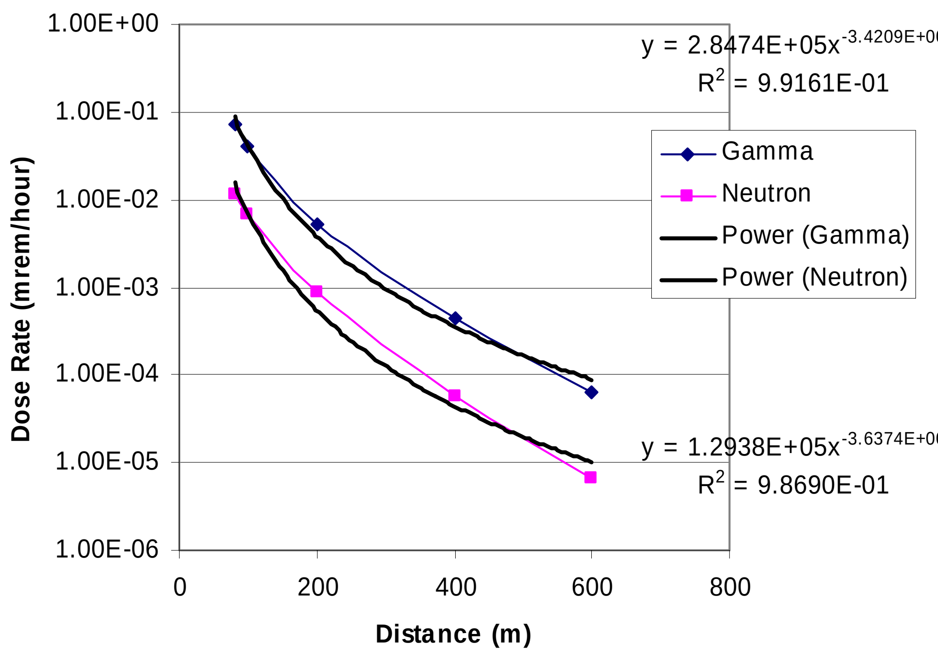




FIGURE 10.2-2

TOTAL DOSE RATE AS A FUNCTION OF DISTANCE FOR A SINGLE TN-68 CASK

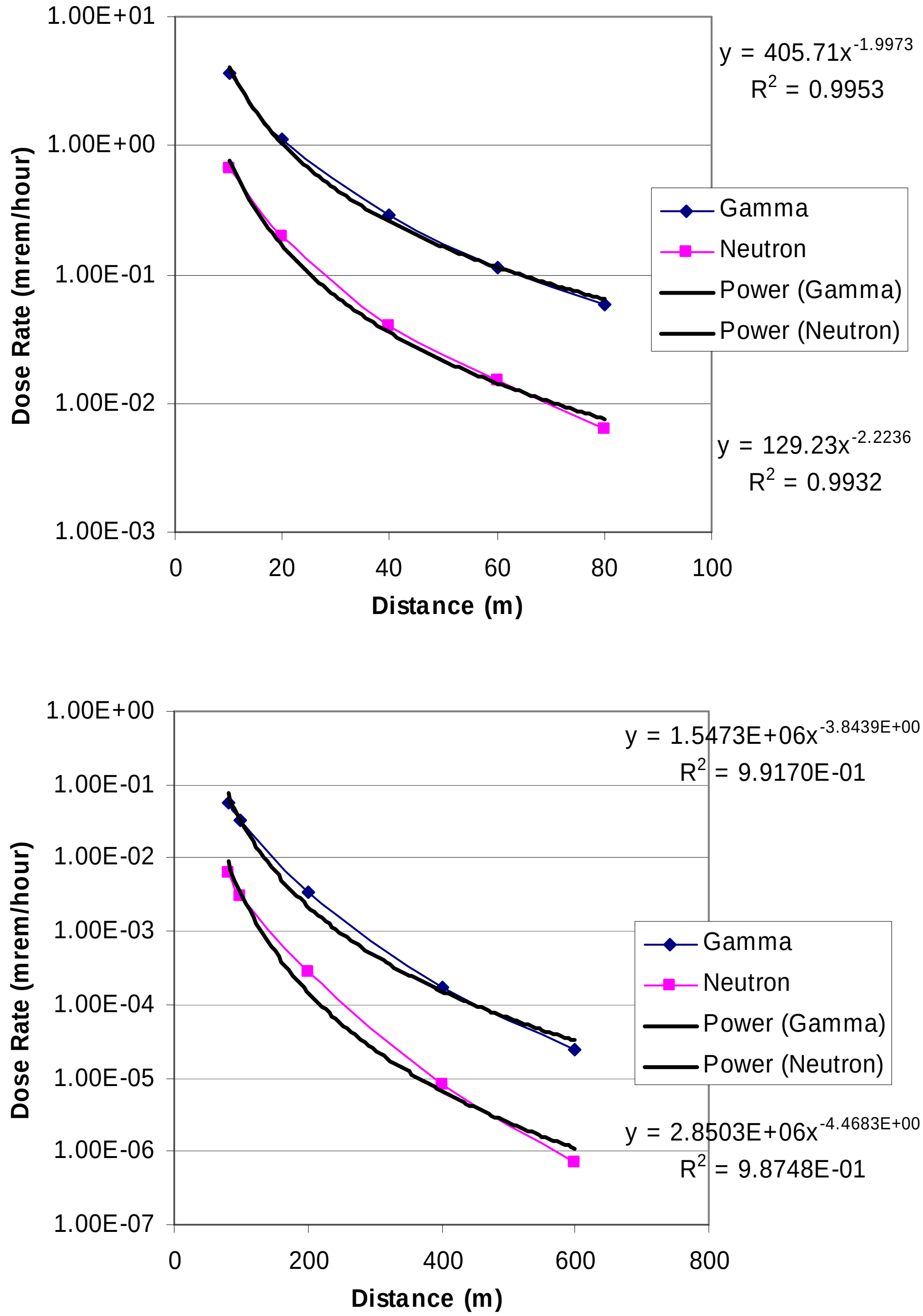



FIGURE 10.2-3

DIRECT DOSE RATE AS A FUNCTION OF DISTANCE FOR A SINGLE TN-68 CASK

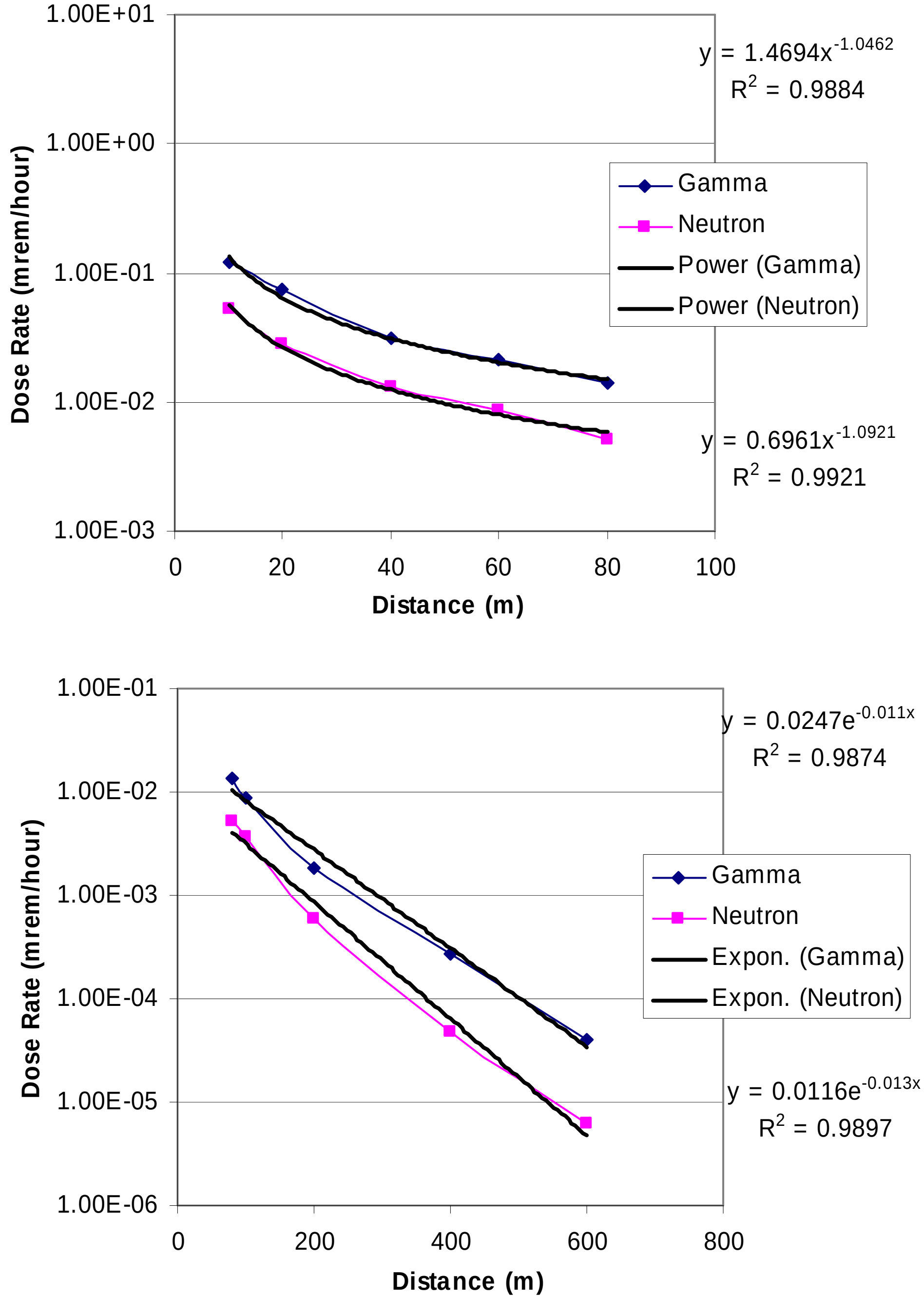



FIGURE 10.2-4

SKYSHINE DOSE RATE AS A FUNCTION OF DISTANCE FOR A SINGLE TN-68 CASK

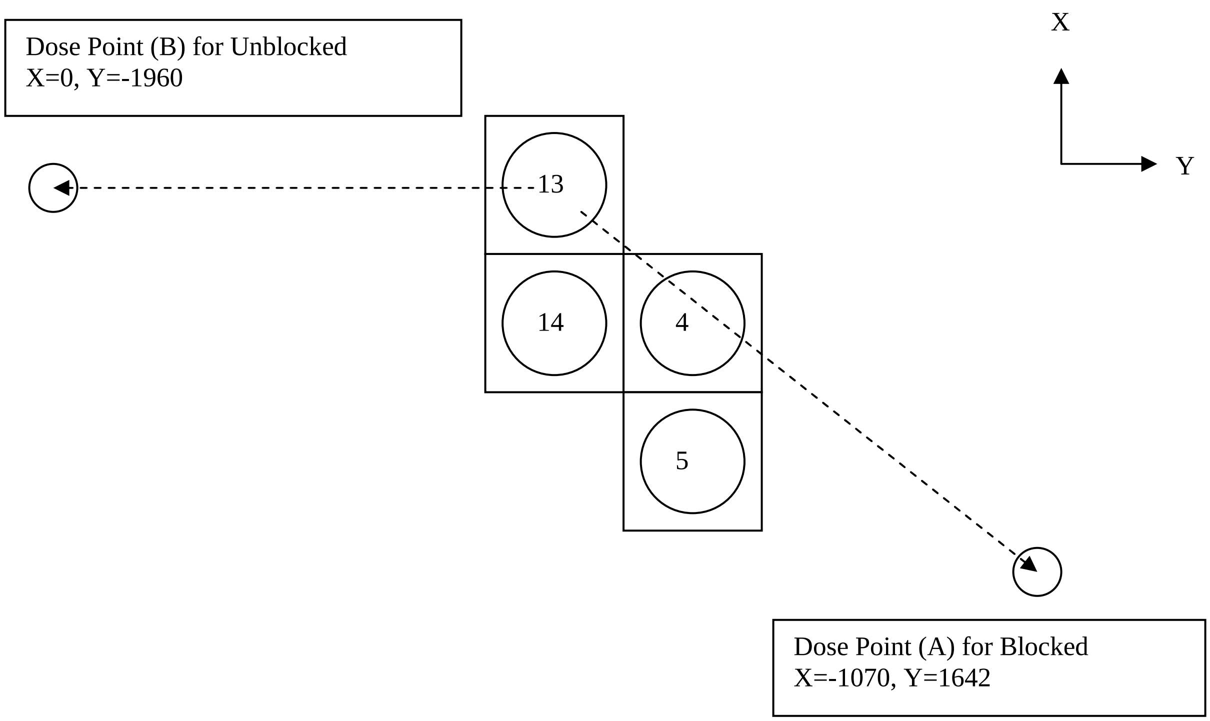



FIGURE 10.2-5

BLOCKING FACTOR CALCULATION ILLUSTRATION WITH QADS

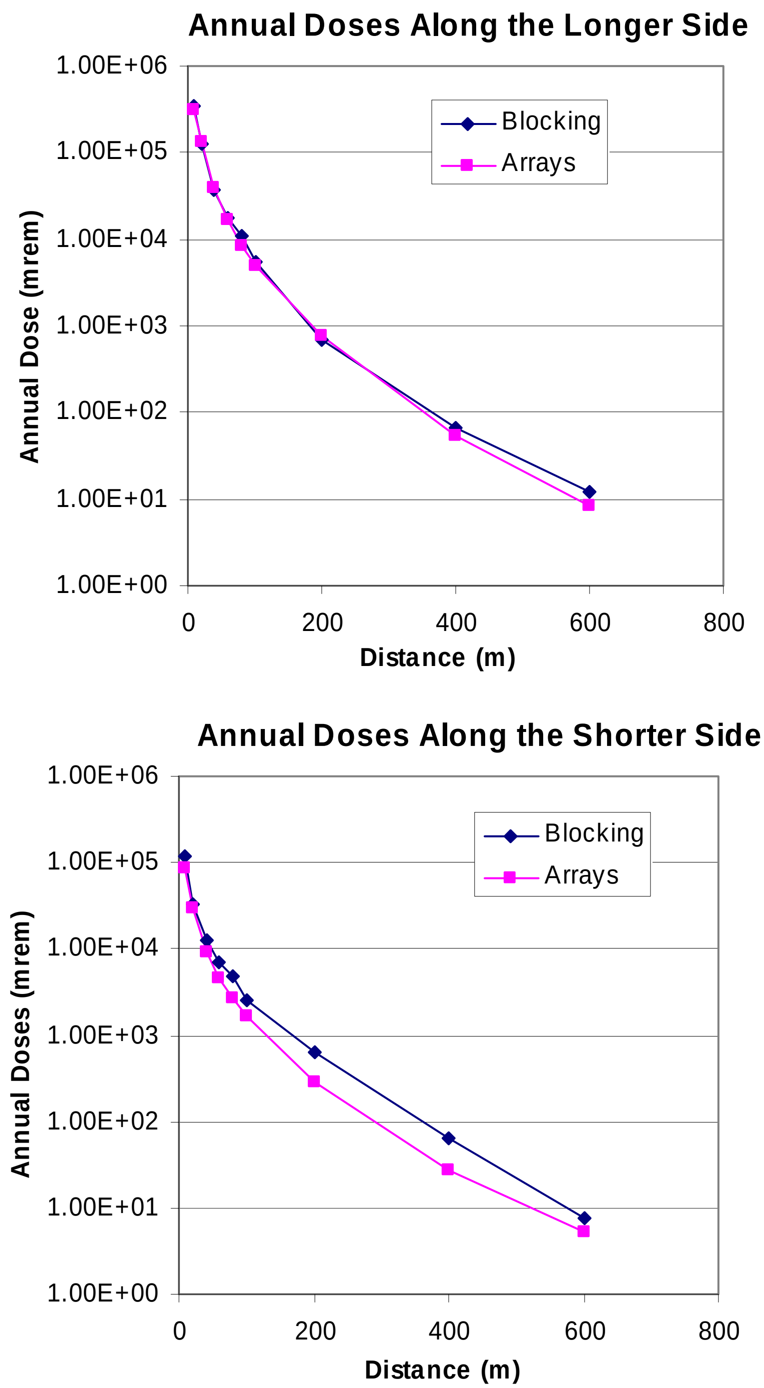



FIGURE 10.2-6

ISFSI SIDE ANNUAL DOSES AS A FUNCTION OF DISTANCE – 20 TN-68 CASKS

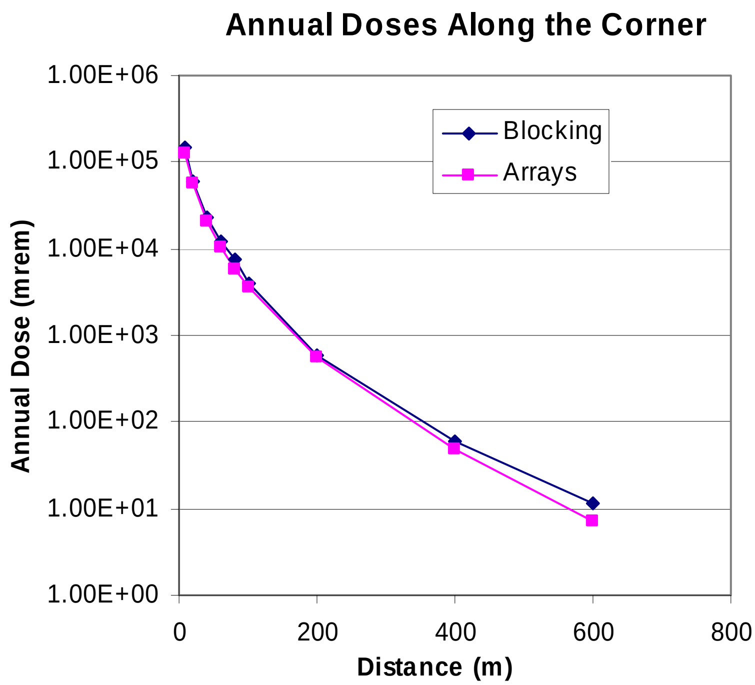



FIGURE 10.2-7

ISFSI CORNER ANNUAL DOSES AS A FUNCTION OF DISTANCE – 20 TN-68 CASKS