Appendix B.

PROCEDURE FOR CALCULATING DEEP DOSE EQUIVALENT (DDE)

[Instructions provided on Pages 2 - 4]

Table 1.	Occupational Worker Dosimetry Data	
☐	DDE (millirem)	Monitoring Period Start Date: __________________ End Date: __________________
		🡐 Enter the highest individual cumulative external dose for the 12 month monitoring period in the space provided to the left. Use this value in Appendix A

Table 2.	Dosimetry Data for the Maximally Exposed Individual MOP	
☐	DDE (millirem)	Monitoring Period Start Date: __________________ End Date: __________________
		☐ Check to indicate that a facility diagram is attached that identifies all restricted areas and adjacent unrestricted areas, and where the monitored MOP's workstation is located
		🡐 Enter the highest cumulative individual dose for the 12 month monitoring period in the space provided to the left. Use this value in Appendix A

Table 3.	Environmental Monitoring Data	
☐	DDE (millirem)	Monitoring Period Start Date: __________________ End Date: __________________
		☐ **A.** Check if calculations are based on continuous year-round occupancy (8766 hours) in unrestricted areas
		OR
		☐ **B.** Check if calculations are adjusted for workplace occupancy factors (e.g., 2000 hours for a work year) in unrestricted areas
		**
		☐ Check to indicate that a facility diagram identifying restricted areas, adjacent unrestricted areas, and the location of posted TLD(s) is attached
		🡐 Enter the TLD highest cumulative dose for the 12 month monitoring period. Use this value in Appendix A

Table 4.	Radiation Level Data	
☐	DDE (millirem)	☐ **A-1.** Check to indicate use of radiation survey instrument measurements and the inverse square law to calculate the DDE
		OR
		☐ **B-1.** Check to indicate use of RAM package Transport Index (TI) values or RAM package surface radiation levels and the inverse square law to calculate DDE
		**
		☐ **A-2.** Check if dose is based on continuous year-round occupancy (8766 hours) in unrestricted areas
		OR
		☐ **B-2.** Check if dose has been adjusted for workplace occupancy factors (e.g., 2000 hours for a work year) in unrestricted areas
		**
		☐ Check to indicate that documentation of all calculations is attached, along with instrument identification, specifications and calibration information
		☐ Check to indicate a facility diagram showing restricted and unrestricted areas is attached
		🡐 Enter the calculated DDE in the space provided to the left; use this value in Appendix A

Appendix B. PROCEDURE FOR CALCULATING DDE

INSTRUCTIONS

If licensed for, or seeking licensure for possession and use of radioactive material (RAM), the external radiation hazard resulting from licensed operations must be evaluated to demonstrate compliance with the public dose limits described section 64E-5.312, Florida Administrative Code (F.A.C.)

Deep Dose Equivalent (DDE) refers to external whole body exposures equivalent to doses received at 1 cm tissue depths [refer to subsection 64E-5.101(33), F.A.C.]. If authorized only for sealed sources, use the calculated DDE value as the **Total Effective Dose Equivalent (TEDE)** value, because only external exposures are likely to result from use of sealed RAM. If authorized for both sealed and unsealed RAM, the DDE value must be added together with the calculated **Committed Effective Dose Equivalent (CEDE)** value (dose resulting from internal exposures) to determine the TEDE value (dose resulting from combined internal and external exposures).

Tables 1 - 4 describe four DDE calculation methodologies. Indicate the method used to calculate the DDE value.

- New licensee applicants: Mark the box indicating the procedure that *will* be used.
- Current licensees: Mark the box indicating the procedure that *was* used.

Following determination of the DDE value, enter it in the appropriate tables provided in Appendices B and A. Attach documentation of all assumptions and calculations used to make the DDE dose determination. Where appropriate, attach an annotated facility diagram to illustrate the radiological conditions present in the workplace.

Method 1. Occupational Worker Dosimetry Data

If the highest annual dose received by the maximally exposed occupational radiation worker is less than 100 millirem (mrem), it can be assumed that no MOP is likely to receive 100 mrem in a year from the same operations.

Assign a personnel monitoring (PM) device (film badge or TLD) to all occupational radiation workers, or at least to those likely to receive the highest exposures. The monitoring period should cover at least 12 continuous months of typical RAM use. In Table 1, record the monitoring period start and end dates, and enter the cumulative dose for the worker receiving the highest dose during the monitoring period.

Method 2. Dosimetry Data for the Maximally Exposed Individual Member of the Public

If the highest annual dose received by the maximally exposed MOP is less than 100 mrem, it can be assumed that no other MOP is likely to receive 100 mrem in a year from the same operations.

Determine which MOP is likely to receive the highest dose from licensed activities. Monitor the MOP's exposures for at least 12 continuous months by assigning a PM device to the individual. In Table 2, record the monitoring period start & end dates. Sum the individual's cumulative dose for the period and enter it in the space provided. Attach an annotated diagram of the facility to illustrate the radiological conditions present in the workplace.

INSTRUCTIONS

(continued)

Method 3. Environmental Monitoring Data

If environmental monitoring demonstrates that continuous exposure to ambient radiation levels in the workplace for a year results in doses < 100 mrem, then no MOP is likely to exceed of the 100 mrem annual public dose limit due to the licensed operations generating the radiation levels. If environmental monitoring indicates that continuous occupancy would exceed the public dose limit, then occupancy factors may be used to demonstrate compliance.

Post one or more environmental TLDs in the unrestricted areas adjacent to restricted areas, or in the restricted area on a wall adjacent to unrestricted areas, for at least 12 months. Post badges where the highest radiation exposure is expected and where exposure to non-regulated sources of radiation (e.g., medical patients injected with radionuclides) will not contribute to the measurements. Record the monitoring period start and end dates in Table 3. If the results for the 12 month monitoring period total < 100 mrem, mark Box A, indicating that continuous occupancy was used for the dose determination (24 hours/day, 365.25 days/year = 8,766 hours), and enter the total value in the DDE box provided in Table 3.

If the results for the 12 month monitoring period total > 100 mrem, it may be possible to demonstrate compliance with the annual dose limit by applying a more realistic (but still very conservative) occupancy factor, such as 2000 hours for a work year (8 hour work day, 40 hours a week, 50 weeks a year = 2,000 hours). Mark Box B if using a normal work week occupancy factor to calculate the DDE.

Example: The total dose measured by the environmental badges = 280 mrem
The dose received by a MOP working 2,000 hours in the area that the badge was posted is

280 mrem/8,766 hrs = .032 mrem/hr x 2,000 hrs = 64 mrem

Using a 2000 hour occupancy factor means that any annual dose from environmental monitoring that totals < 438 mrem will demonstrate compliance

Example: 438 mrem/8,766 hrs = .049 mrem/hr x 2,000 hrs = 99.9 mrem

If the results for the 12 month monitoring period total > 438 mrem, compliance may still be demonstrated by using an even more realistic occupancy factor, provided the number can be legitimized by supporting documentation (e.g., employment records).

Example: Environmental badges total 680 mrem for the 12 month monitoring period; time sheets indicate that a conservative estimate of the most time spent by any MOP in the monitored area is 25 hours a week, 50 weeks a year = 1,250 hours.

680 mrem/8,766 hrs = .078 mrem/hr x 1,250 hrs = 97 mrem

In each case, attach an annotated diagram of the facility to illustrate the radiological conditions present in the workplace and to indicate the location of posted badges.

Notes:

1. Protect posted badges from adverse environmental conditions such as excessive heat and light.
2. Only specifically designed badges are acceptable for environmental monitoring; PM badges are not appropriate. Contact the Bureau of Radiation Control for more information.

INSTRUCTIONS

(continued)

Method 4. Radiation Level Data

Survey measurements and calculations can be used to demonstrate that the radiation levels resulting from licensed operations are not likely to cause any MOP to exceed the annual public dose limit.

Radiation levels generated by RAM present in the workplace can be determined by direct measurement with survey instruments, or from indirect information, such as radioactive material package transport index values (describing radiation levels at 1 meter from a package's exterior surface). The radiation level data can then be used with the inverse square law to calculate the DDE. In Table 4, check to indicate use of either rad. survey instrument measurements (Box A-1) or RAM package Transport Index (TI) values (Box B-1) with the inverse square law to calculate the DDE.

The issue of occupancy factors is addressed by selecting one of two options provided in Table 4. Check off the Box A-2 to indicate use of the most conservative scenario -- assuming a MOP is continuously present in the unrestricted area (24 hours/day, 365.25 days/year = 8766 hours). Check Box B-2 to indicate use of a more realistic (but still very conservative) assumption -- the individual located in the unrestricted area is present during all business hours (8 hours/day x 40 hours/week x 50 weeks/year = 2,000 hours).

Inverse Square Law: $I_2 = \dfrac{I_1 R_1^2}{R_2^2}$

Where: I_1 = intensity (radiation dose rate) at distance R_1
I_2 = intensity (radiation dose rate) at distance R_2.
R_1 = distance from RAM with dose rate I_1
R_2 = distance from RAM where dose rate I_2 is calculated

Notes:

A. This formula has 2 limitations: (a) it only applies to gamma-emitters; and (b) the closest distance should be at least 5 source diameters.

B. If using transport package exterior radiation levels, set R_1 = 1 inch.

Example of an Inverse Square Law Calculation Using Survey Meter Measurements

A lab contains a variety of sealed sources. The sources may be treated as a single point source by positioning them together for the measurement. Assuming a collective source diameter of 12 inches, a radiation measurement (I_1) is taken at a distance equal to at least 5 source diameters from the grouped sources, shielded behind lead brick corral, which serves as R_1 in the inverse square formula. The intensity at 10 feet is the unknown value being sought (the distance to the nearest unrestricted area).

I_1 = 0.1 mR/hr
I_2 = ? mR/hr
R_1 = 60 in. (5 x 12 in.)
R_2 = 120 in. (10 ft.)

$$I_2 = \frac{0.1 \times (60)^2}{(120)^2}$$

I_2 = .025 mR/hr

A 2,000 hour occupancy factor yields:
.025 mR/hr x 2,000 hours
= 50 mrem
= DDE

Example of an Inverse Square Law Calculation Using a Package Transport Index

A shipping case used to store a portable nuclear density gauge bears a Radioactive Yellow II label that shows its TI = 1.2. The nearest MOP workstation is located 24 feet away.

I_1 = 1.2 mR/hr
I_2 = ? mR/hr
R_1 = 3.3 feet (1 meter)
R_2 = 24 feet

$$I_2 = \frac{1.2 \times (3.3)^2}{(24)^2}$$

I_2 = 0.023 mR/hr

A 2,000 hour occupancy factor yields:
0.023 mR/hr x 2,000 hours
= 46 mrem
= DDE