APPENDIX F-2

DOSE LIMIT FOR MEMBERS OF THE PUBLIC

ANNUAL DOSE DETERMINATION COMPLIANCE STUDY

Introduction

The Rules and Regulations for Control of Sources of Ionizing Radiation, Paragraph RH-1208, requires that portable gauge operations be conducted so that the following limits are met:

- Radiation doses in unrestricted areas do not exceed **2 millirem in any one hour**
- Doses to members of the public do not exceed **100 millirem in a year**

Paragraph RH-1209 requires that appropriate surveys, calculations and/or environmental monitoring be used to demonstrate compliance with the dose limits. Satisfactory completion of this dose study provides the necessary documentation of compliance with both regulatory limits.

The below marked box indicates how this procedure is being utilized:

☐ **New license applicant**: the procedure describes the methodology that will be used to conduct the dose study after licensed activities begin.

☐ **Renewal application**: the procedure describes the methodology and results of the completed dose study of existing operations.

Radioactive Material Licensees must insure that:

- The radiation dose received by individual members of the public resulting from the licensees possession and/or use of licensed materials does not exceed 100 mrem (1 mSv) in one calendar year.

NOTE:	**Members of the public include persons who live work, or may be near locations where industrial radiography devices are used or stored and employees whose assigned duties do not include the use of radioactive material and who work in the vicinity where radiographic devices are stored.**

- The radiation dose in unrestricted areas does not exceed 2 mrem (0.02 mSv) in any one hour.

- Typical unrestricted areas may include offices, shops, laboratories, areas outside buildings, property, and nonradioactive equipment storage areas. The licensee does

not control access to these areas for purposes of controlling exposure to radiation or radioactive materials. However, the licensee may control access to these areas for other reasons such as security.

- Licensees must show compliance with both portions of the regulation. Radiographic operations at temporary jobsites must be demonstrated to have doses to the public in unrestricted areas that do not exceed 2 mrem (0.02 mSv) in any one hour. For storage areas and permanent radiographic facilities, calculations or a combination of calculations and measurements (e.g., using an environmental TLD) are often used to prove compliance with levels of 2 mrem (0.02 mSv) in any one hour and 100 mrem (1 mSv) in a calendar year.

Calculational Method

For ease of use by most industrial radiography licensees, the examples in this Appendix use conventional units. The conversions to SI units are as follows: 1 foot (ft) = 0.305 meter (m); 1 mrem = 0.01 mSv.

The calculational method takes a tiered approach, going through a three-part process starting with a "worst-case" situation and moving toward more realistic situations. It makes the following simplifications:

1. Each device is a point source,

2. Typical radiation levels encountered when the source is in the shielded position are taken from either the Sealed Source & Device (SSD) Registration Sheet, the maximum dose levels allowed for a transport package (exposure device) labeled YELLOW III, or the manufacturer's literature, and

3. No credit is taken for any shielding found between the devices and the unrestricted areas.

Part 1 of the calculational method is simple but conservative. It assumes that a member of the public is present 24 hours a day, and it uses only the inverse square law to determine if the distance between the device and the affected member of the public is sufficient to show compliance with the public dose limits.

Part 2 considers not only distance, but also the time that a member of the public is actually in the area under consideration.

Part 3 considers distance and the portion of time that both the device and the affected member of the public are present.

Part 4 considers the distance, the portion of time that both the device and the affected member of the public are present and the shielding provided by the structural materials or shielding materials specifically added by the licensee.

Using this approach, licensees make only those calculations that are needed to demonstrate compliance. In many cases, licensees will need to use the calculational method through Part 1 or Part 2. These calculations typically result in higher radiation levels than would exist at typical facilities, but provide a method for estimating conservative doses which could be received.

Example 1

To better understand the calculational method, Mo-Rad, Inc., a hypothetical radiography licensee, is demonstrated. Yesterday, the company's president noted that the new device storage area is close to his secretary's desk and he asked Joe, the Radiation Safety Officer (RSO), to determine if the company is complying with Department's regulations.

The secretary's desk is near the wall separating the reception area from the designated, locked device storage area, where the company is storing its two devices. Joe measures the distances from each device to the wall and assumes that each device would have the maximum dose rate allowed under Department or DOT regulations: 200 mrem/hr (2 mSv/hr) on the surface and 10 mrem/hr (0.1 mSv/hr) at one meter. Figure F-2.1 is Joe's sketch of the areas in question, and Table F-2.1 summarizes the information Joe has on each device.

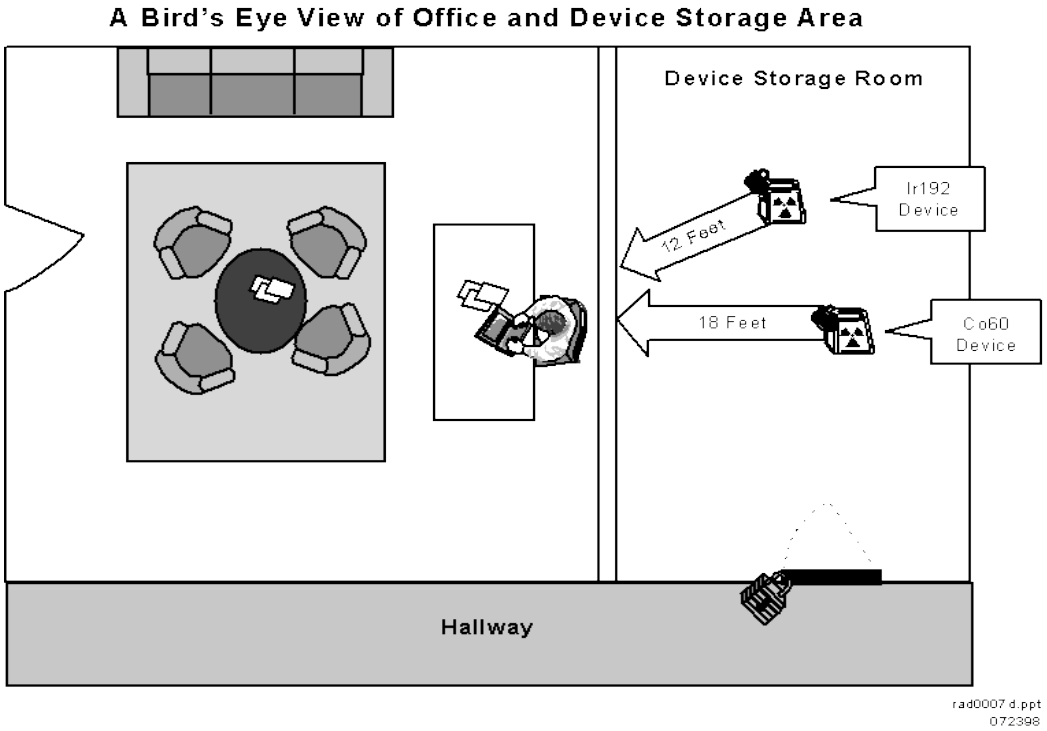

Figure F-2.1. Diagram of Office and Radiographic Device Storage Area

Table F-2.1 Information Known About Each Radiographic Device

Description of Known Information	Device 1	Device 2
How device is stored	Ir-192 exposure device (Type B container)	Co-60 exposure device (Type B container)
Dose rate in mrem/hr encountered at specified distance from the device	10 millirem/hr at 1 meter (3.3 ft)	10 millirem/hr at 1 meter (3.3 ft)
Distance in ft to secretary's chair	12 ft	18 ft

Example 1: Part 1

Joe's first thought is that the distance between the devices and the secretary's chair may be sufficient to show compliance with the regulation in RH-1208. So, taking a worst-case approach, he assumes: 1) the devices are constantly present (i.e., 24 hr/d), 2) both devices remain in storage with no other use, and 3) the secretary is constantly sitting in the desk chair (i.e., 24 hr/d). Joe proceeds to calculate the dose she might receive hourly and yearly from each device, as shown in Tables F-2.2 and F-2...3, below.

Table F-2.2 Calculational Method, Part 1: Hourly and Annual Dose Received from Device 1

Step No.	Description	Device 1 Input Data	Results
1	Dose received in an hour at known distance from device (e.g., from manufacturers data), in millirem/hr	10	10
2	Square of the distance (ft) at which the Step 1 rate was measured, in ft2	(3.3) 2	10.9
3	Square of the distance (ft) from the device the secretary's desk in an unrestricted area, in ft2	(12) 2	144
4	Multiply the results of Step 1 by the results of Step 2 (this is an intermediate result)	10 x 10.9 = 109	
5	Divide the result of Step 4 by the result of Step 3 to calculate the dose received by an individual at the secretary's desk**, HOURLY DOSE RECEIVED FROM DEVICE 1**, in millirem in an hour.	109/144 = **0.76**	
6	Multiply the result of Step 5 by 24 hr/d x 365 d/yr = **MAXIMUM ANNUAL DOSE RECEIVED FROM DEVICE 1**, in millirem in a year.	0.76 x 24 x 365 = 0.76 x 8760 = **6,630**	

Table F-2.3 Calculational Method, Part 1: Hourly and Annual Dose Received from Device 2

Step No.	Description	Device 2 Input Data	Results
1	Dose received in an hour at known distance from device (e.g., from manufacturers data), in millirem/hr	10	10
2	Square of the distance (ft) at which the Step 1 rate was measured, in ft2	(3.3) 2	10.9
3	Square of the distance (ft) from the device to the secretary's desk in an unrestricted area, in ft2	(18) 2	324
4	Multiply the results of Step 1 by the results of Step 2 (this is an intermediate result)	10 x 10.9 = 109	
5	Divide the result of Step 4 by the result of Step 3 to calculate dose received in an hour by an individual at the secretary's desk**, HOURLY DOSE RECEIVED FROM DEVICE 2**, in millirem in an hour	109/324 = **0.34**	
6	Multiply the result of Step 5 by 24 hr/d x 365 d/yr = **MAXIMUM ANNUAL DOSE RECEIVED FROM DEVICE 2**, in millirem in a year	0.34 x 24 x 365 = 0.34 x 8760 = **2950**	

To determine the total hourly and total annual dose received, Joe adds the pertinent data from the preceding tables.

Table F-2.4 Calculational Method, Part 1: Total Hourly and Annual Dose Received from Devices 1 and 2

Step No.	Description	Device 1	Device 2	Sum
7	**TOTAL HOURLY DOSE RECEIVED** from Step 5 of Tables F-2.2, and F-2.3, in millirem in an hour	0.76	0.34	0.76 + 0.34 = **1.1**
8	**TOTAL ANNUAL DOSE RECEIVED** from Step 6 of Tables F-2.2, and F-2.3, in millirem in a year	6630	2950	6630 + 2950 = **9580**

The Sum in Step 7 demonstrates compliance with the limit of 2 mrem in any one hour. Reevaluate if assumptions change. If the Sum in Step 8 exceeds 100 mrem/yr, proceed to Part 2 of the calculational method.

At this point, Joe is pleased to see that the total dose that an individual could receive in any one hour is only 1.1 mrem in an hour, but notes that an individual could receive a dose of **9,580 millirem in a year, much higher than the 100 millirem limit.**

Example 1: Part 2

Joe reviews his assumptions and recognizes that the secretary is not at the desk 24 hr/d. He decides to make a realistic estimate of the number of hours the secretary sits in the chair at the desk, keeping his other assumptions constant (i.e., the devices are constantly present (i.e., 24 hr/d), both devices remain in storage with no other use). He then recalculates the annual dose received.

Table F-2.5 Calculational Method, Part 2: Annual Dose Received from Devices 1 and 2

Step No.	Description	Results	
9	A. Average number of hours per day that individual spends in area of concern (e.g., secretary sits at desk 5 hr/day; the remainder of the day the secretary is away from the desk area copying, filing, etc.)	5	
		B. Average number of days per week in area (e.g., secretary is part time and works 3 days/week)	3
		C. Average number of weeks per year in area (e.g., secretary works all year)	52
10	Multiply the results of Step 9.A. by the results of Step 9.B. by the results of Step 9.C. = **AVERAGE NUMBER OF HOURS IN AREA OF CONCERN PER YEAR**	5 x 3 x 52 = **780**	
11	Multiply the sum in Step 7 by the results of Step 10 = **ANNUAL DOSE RECEIVED FROM DEVICES CONSIDERING REALISTIC ESTIMATE OF TIME SPENT IN AREA OF CONCERN**, in millirem in a year	1.1 x 780 = **860**	

Note: If Step 11 exceeds 100 millirem in a year, proceed to Part 3 of the calculational method.

Although Joe is pleased to note that the calculated annual dose received is significantly lower, he realizes it still exceeds the 100 mrem in a year limit.

Example 1, Part 3

Again, Joe reviews his assumptions and recognizes that the devices are not always in storage when the secretary is seated at the desk. As he examines the situation, he realizes he must consider each device individually.

Table F-2.6 Calculational Method, Part 3: Summary of Information

Summary
Information on When Devices Are Present in the Storage Area: **Device 1:** An Ir-192 Radiographic Device located in the Storage Area overnight; it is used every day at temporary jobsites all year and returned to the storage location at the end of each day. The device is usually present during the Secretary's first and last hours of work each day. **Device 2:** A Co-60 Radiographic Device located in the Storage Area continuously (24 Hr/d) for 8 months of the year; for the remaining 4 months of the year, it is at temporary jobsites
Information from Example 1, Part 2 on When the Secretary Is Sitting at the Desk: 5 Days per Week 3 Days per Week 52 Weeks per Year

Table L.F-2.7 Calculational Method, Part 3: Annual Dose Received from Devices 1 and 2

Step No.	Description	Device 1	Device 2
12	Average number of **hours per day** device is in storage while secretary is present	**2**	**5**
13	Average number of **days per week** device is in storage while secretary is present	**3**	**3**
14	Average number of **weeks per year** device is in storage while secretary is present	**52**	**32**
15	Multiply the results of Step 12 by the results of Step 13 by the results of Step 14 = **TOTAL HOURS EACH DEVICE IS STORED PER YEAR WHILE SECRETARY IS PRESENT**	2 x 3 x 52 = **312**	5 x 3 x 32 = **480**
16	Multiply the results of Step 15 by the results of Step 7 = **ANNUAL DOSE RECEIVED FROM EACH DEVICE**, in millirem in a year	312 x 0.76 = **237**	480 x 0.34 = **163**

17	Sum the results of Step 16 for each device = **TOTAL ANNUAL DOSE RECEIVED CONSIDERING REALISTIC ESTIMATE OF TIME SPENT IN AREA OF CONCERN AND TIME DEVICE IS IN STORAGE**, in millirem in a year	237+ 163 = **400**	

If the result in Step 17 is greater than 100 millirem/yr, the licensee must take corrective actions.

Joe notes that the result in Step 17 does not show compliance with the 100 mrem/yr limit. Since the result in Step 17 is higher than 100 millirem/yr, then Joe has to consider one or more of the following:

Consider whether the assumptions used to determine occupancy and the time each device is in storage are accurate, revise the assumptions as needed, and recalculate using the new assumptions.

Calculate the effect of any shielding located between the device storage area and the secretarial workstation. Listed below are typical half-value layers (HVL) for Ir-192 and Co-60.

Table F-2.8 Half Value Layers (HVL) for Typical Shielding Materials

	Steel	**HVL (inches)** **Lead**	**Concrete**
Ir-192	0.5	0.25	1.7
Co-60	0.8	0.5	2.1

Take corrective action (e.g., move devices within storage area, move the storage area, move the secretarial workstation) and perform new calculations to demonstrate compliance

Designate the area outside the storage area as a restricted area and the secretary as an occupationally exposed individual. This would require controlling access to the area for purposes of radiation protection and training the secretary as required by the Rules and Regulations.

Example 1, Part 4

Joe decides to take into account the amount of shielding provided by the wall between the secretary's desk and the storage area where the two devices are located. The wall between the secretary's office and the storage area is a 4-inch thick concrete firewall.

Table F-2.9 Calculational Method, Part 4: Annual Dose Received from Devices 1 and 2

Step No.	Description	Device 1	Device 2
18	Annual dose received from each device from Step 15	**237**	**163**
19	Number of HVLs (Thickness of shielding material/Thickness for one HVL); If more than one shielding material, need to evaluate each shielding material separately by *type of radionuclide.*	**4.0/1.7 = 2.35**	**4.0/2.1 = 1.9**
20	Fraction of radiation dose transmitted through shield: 0.5 (Total Number of HVLs); If more than one shielding material, then sum the number results from Step 19 *by radionuclide.*	**0.5(2.35) = 0.2**	**0.5(1.9) = 0.27**
21	Multiply the results of Step 20 by the results of Step 18 = **ANNUAL DOSE RECEIVED FROM EACH DEVICE**, in millirem in a year	0.2 x 237 = **47**	0.27 x 163 = **44**
22	Sum the results of Step 21 for each device = **TOTAL ANNUAL DOSE RECEIVED CONSIDERING REALISTIC ESTIMATE OF TIME SPENT IN AREA OF CONCERN, TIME DEVICE IS IN STORAGE AND SHIELDING OF STRUCTURAL MATERIALS**, in millirem in a year	47 + 44 = **91**	

Note: If the result in Step 22 is greater than 100 mrem/yr, the licensee must take corrective actions.

Joe is glad to see that the results in Step 22 show compliance with the **100 mrem in a calendar year limit.**

Note that in the example, Joe evaluated the unrestricted area outside only one wall of the device storage area. Licensees also need to make similar evaluations for other unrestricted areas and to keep in mind the ALARA principle, taking reasonable steps to keep radiation dose received below regulatory requirements. In addition, licensees need to be alert to changes in situations (e.g., moving any of the devices closer to the secretarial workstation, adding a device to the storage area, changing the secretary to a full-time worker, or changing the estimate of the portion of time spent at the desk) and to perform additional evaluations, as needed.

Combination Measurement - Calculational Method

This method, which allows the licensee to take credit for shielding between the device and the area in question, begins by measuring radiation levels in the areas, as opposed to using manufacturer-supplied rates at a specified distance from each device. These measurements must be made with calibrated survey meters sufficiently sensitive to measure background levels of radiation. However, licensees must exercise caution when making measurements with currently calibrated radiation survey instruments. A maximum dose of 100 mrem (1 mSv) received by an individual over an interval of 2080 hours (i.e., a work year of 40 hr/wk for 52 wk/yr) is equal to less than 0.05 mrem (0.5 microsievert) per hour. **This dose rate is well below the minimum sensitivity of most commonly available G-M Survey instruments**.

Instruments used to make measurements for calculations must be sufficiently sensitive. An instrument equipped with a scintillation-type detector (e.g., NaI(Tl)) or a micro-R meter used in making very low gamma radiation measurements should be adequate.

Licensees may also choose to use environmental TLDs. TLDs used for personnel monitoring may not have sufficient sensitivity for this purpose. Generally, the minimum reportable dose received is 10 millirem (0.1 mSv). Suppose a TLD monitors dose received and is changed once a month. If the measurements are at the minimum reportable level, the annual dose received could have been about 120 millirem (1.2 mSv), a value in excess of the 100 mrem/yr (1 mSv/yr) limit. If licensees use TLDs to evaluate compliance with the public dose limits, they should consult with their TLD supplier and choose more sensitive TLDs, such as those containing CaF2 that are used for environmental monitoring. in unrestricted areas next to the device storage area for monitoring. This direct measurement method would provide a definitive measurement of actual radiation levels in unrestricted areas without any restrictive assumptions. Records of these measurements can then be evaluated to ensure that rates in unrestricted areas do not exceed the 100 mrem/yr (1 mSv/yr) limit.

Example 2

As in Example 1, Joe is the RSO for Mo-Rad, Inc., a radiography licensee. The company has two devices stored in a designated, locked storage area that adjoins an unrestricted area where a secretarial work station is located. See Figure F-2.1 and Table F-2.1 for information. Joe wants to see if the company complies with the public dose limits at the secretarial station.

During the winter while all the devices were in storage, Joe placed an environmental TLD badge in the secretarial work space for 30 days. Joe chose a winter month so he did not have to keep track of the number of hours that each device was in the storage area. The TLD processor sent Joe a report indicating the TLD received 100 mrem.

Parts 2 and 3 are the calculated the same as Example 1.

Table F-2.10 Combination Measurement - Calculational Method

Step No.	Description	Input Data and Results
	Part 1	
1	**Dose** received by TLD, in millirem	**100**
2	**Total hours** TLD exposed	24 hr/d x 30 d/month = **720**
3	Divide the results of Step 1 by the results of Step 2 to determine **HOURLY DOSE RECEIVED**, in millirem in an hour	**0.14**
4	Multiply the results of Step 3 by 365 d/yr x 24 hr/d = 8760 hours in one year = **MAXIMUM ANNUAL DOSE RECEIVED FROM DEVICES**, in millirem in a year	365 x 24 x 0.14 = 8760 x 0.14 = **1226**

Parts 2 and 3		
	Calculated Same as Example 1	

For conditions described above, Step 3 indicates that the dose received in any one hour is less than the 2 mrem in any one hour limit. However, if there are any changes, then the licensee would need to reevaluate the potential doses which could be received in any one hour. Step 4 indicates that the annual dose received would be much greater than the 100 millirem in a year allowed by the regulations.

In Step 2, Joe can adjust for a realistic estimate of the time the secretary spends in the area as he did in Part 2 of Example 1.

If the results of Joe's evaluation in Part 2 show that the annual dose received in a year exceeds 100 millirem, then he can make adjustments for realistic estimates of the time spent in the area of concern while the devices are actually in storage as in Part 3 of Example 1. (Recall that the TLD measurement was made while all the devices were in storage -- i.e., 24 hr/d for the 30 days that the TLD was in place.)