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MONITORING CRITERIA AND METHODS TO CALCULATE OCCUPATIONAL RADIATION DOSES

A. INTRODUCTION

Monitoring of an individual's external radiation exposure is required by 10 CFR 20.1502(a) if the external occupational dose is likely to exceed 10% of the dose limit appropriate for the individual (i.e., adult, minor, or declared pregnant woman). External radiation monitoring is also required by 10 CFR 20.1502(a)(3) for any individual entering a high or very high radiation area.

Monitoring of the intake of radioactive material is required by 10 CFR 20.1502(b) if the intake is likely to exceed 0.1 ALI (annual limit on intake) during the year for an adult worker or the committed effective dose equivalent is likely to exceed 0.05 rem (0.5 mSv) for the occupationally exposed minor or declared pregnant woman.

In the revised 10 CFR Part 20, "Standards for Protection Against Radiation," 10 CFR 20.1201 establishes radiation dose limits for occupationally exposed adults. These limits apply to the sum of the dose received from external exposure and the dose from internally deposited radioactive material. In 10 CFR 20.1201(a)(1), the annual limits for adults are (i) 5 rems (0.05 Sv) total effective dose equivalent or (ii) 50 rems (0.5 Sv) total organ dose equivalent to any single organ or tissue (other than the lens of the eye), whichever is more limiting. The occupational dose limits for minors in 10 CFR 20.1207 are 10% of the dose limit for adults, and 10 CFR 20.1208 establishes a dose limit for the embryo/fetus of 0.5 rem (0.005 Sv) during the entire pregnancy.

The "total effective dose equivalent" is defined as the sum of the "deep-dose equivalent" (for external exposures) and the "committed effective dose equivalent" (for internal exposures). The total organ dose equivalent limit of 50 rems (0.5 Sv) specified in 10 CFR 20.1201(a)(1)(ii) applies to the sum of the "deep-dose equivalent" and the "committed dose equivalent" to any individual organ or tissue. The requirements in 10 CFR 20.1202 are for summing external and internal doses to demonstrate compliance with the dose limits of 10 CFR 20.1201.

The Part 20 requirements for recording individual monitoring results are contained in 10 CFR 20.2106. When monitoring is required under 10 CFR 20.1502, the monitoring results must be recorded on NRC Form 5 or equivalent.

Any information collection activities mentioned in this regulatory guide are contained as requirements in 10 CFR Part 20, which provides the regulatory basis for this guide. The information collection

requirements in 10 CFR Part 20 have been cleared under OMB Clearance No. 3150-0014.

B. DISCUSSION

This guide provides criteria acceptable to the NRC staff that may be used by licensees to determine when monitoring is required, and it describes methods acceptable to the NRC staff for calculating occupational doses when the intake is known. Guidance on calculating doses to the embryo/fetus is contained in Regulatory Guide 8.36, "Radiation Dose to the Embryo/Fetus." Revision 1 to Regulatory Guide 8.9, "Interpretation of Bioassay Measurements," is under development and will provide guidance on determining intakes from bioassay results. Guidance on determining intakes from air sampling measurements is contained in Revision 1 to Regulatory Guide 8.25, "Air Sampling in the Workplace." Guidance on recording the calculated doses onto NRC Forms 4 and 5 is described in Revision 1 to Regulatory Guide 8.7, "Instructions for Recording and Reporting Occupational Radiation Exposure Data."

The appendix to this guide gives examples of the calculations of internal and external doses for entry onto NRC Form 5.

C. REGULATORY POSITIONS

1. MONITORING CRITERIA

The monitoring requirements in 10 CFR Part 20 are summarized in Table 1. For external dose monitoring, 10 CFR 20.1502(a) requires the use of individual monitoring devices. Individual monitoring devices are not required for monitoring the intake of radioactive material.

The monitoring requirements apply separately to each external dose type (i.e., deep-dose equivalent, shallow-dose equivalent to the skin, eye dose equivalent, and shallow-dose equivalent to the extremities).

1.1 Evaluation of Likely Annual Occupational Dose

Evaluation of the likelihood of doses exceeding 10% of the limit should be based on the potential occupational dose to the individual for the year. Doses that may have been received or will be received during the year from employment by another licensee are not included in the determination of monitoring requirements. The requirements in 10 CFR 20.1502 refer to *each* licensee. Each licensee makes the determination independently. It would not be appropriate to base the monitoring requirements at one licensee's facility on exposure conditions at a different licensee's facility. Rather, the need for monitoring at a facility should be based on the exposure conditions at that facility only.

Evaluations of previous dosimetric or bioassay data may be considered in projecting doses. The use of and credit for respiratory protective equipment may be considered in the evaluations, provided use of the equipment is in compliance with the requirements of 10 CFR 20.1703. Surveys of dose rates and estimates of occupancy times may be used to estimate expected external doses. Measurements and predictions of airborne radionuclide concentrations and the expected duration of exposure may be used to predict radionuclide intakes. The potential for unlikely exposures and accident conditions need not be considered because these events, by definition, are not likely.

1.2 Establishing Categories of Workers for Monitoring

If groups or categories of workers are exposed to similar radiological conditions, a single evaluation may be used to determine the need for monitoring. For simplicity, licensees may establish routine operational guidelines for categories of workers who will be monitored. For example, licensees may establish criteria or procedures for monitoring based on anticipated area access or work functions.

1.3 Change in Exposure Conditions

If an individual's radiation exposure conditions change during the year, the need to provide individual monitoring should be reevaluated.

For example, consider an unmonitored individual whose work assignment is changed from periodic delivery of supplies to a restricted area to performing maintenance activities within a radiation area. Under this new job assignment, if the licensee determines that the worker's dose is likely to exceed 10% of the limit, 10 CFR 20.1502 requires that monitoring be provided. When monitoring is required, 10 CFR 20.2106 requires that the monitored doses be recorded.

Similarly, if reevaluation of a monitored individual's anticipated annual occupational dose indicates that the dose is likely to be below 10% of the limits, monitoring may be terminated. Even when the doses are actually below 10% of the limit, the doses measured while monitoring was provided must be recorded pursuant to 10 CFR 20.2106 because the monitoring was provided to meet 10 CFR 20.1502.

1.4 Monitoring Performed But Not Required by 10 CFR 20.1502

Individual monitoring may be conducted for reasons other than those noted in 10 CFR 20.1502. While the results of required monitoring are subject to the dose recording requirements of 10 CFR 20.2106, the results of monitoring provided when not

Table 1

Summary of 10 CFR Part 20 Monitoring Requirements

The use of individual monitoring devices for external dose is required:

For adults who are likely to receive an annual dose in excess of any of the following (each evaluated separately):

- 0.5 rem (0.005 Sv) deep-dose equivalent.
- 1.5 rems (0.015 Sv) eye dose equivalent.
- 5 rems (0.05 Sv) shallow-dose equivalent to the skin.
- 5 rems (0.05 Sv) shallow-dose equivalent to any extremity.

For minors who are likely to receive an annual dose in excess of any of the following (each evaluated separately):

- 0.05 rem (0.5 mSv) deep-dose equivalent.
- 0.15 rem (1.5 mSv) eye dose equivalent.
- 0.5 rem (0.005 Sv) shallow-dose equivalent to the skin.
- 0.5 rem (0.005 Sv) shallow-dose equivalent to any extremity.

For declared pregnant women who are likely to receive an annual dose from occupational exposure in excess of 0.05 rem (0.5 mSv) deep-dose equivalent, although the dose limit applies to the entire gestation period.

Individuals entering a high or a very high radiation area.

Internal exposure monitoring (not necessarily individual monitoring devices) is required:

For adults likely to receive in 1 year an intake in excess of 10% of the applicable ALIs for ingestion and inhalation.

For minors and declared pregnant women likely to receive in 1 year a committed effective dose equivalent in excess of 0.05 rem (0.5 mSv).

required by 10 CFR 20.1502 are not subject to those dose recording requirements.

Surveys and monitoring results that serve as confirmatory measures are not subject to the individual dose recordkeeping requirements of 10 CFR 20.2106(a) provided such results confirm that actual individual doses are less than 10% of the limits. These surveys and monitoring results may be used to meet 10 CFR 20.1501 requirements. An example of confirmatory monitoring is an individual's annual bioassay measurement used as confirmation of the adequacy of airborne control measures. Another example is placing monitoring devices, such as thermoluminescence dosimeters (TLDs), on a sample of workers to provide a confirmation that doses are not above those anticipated.

1.5 Detection Sensitivity

The monitoring criteria contained in 10 CFR 20.1502 do not establish required levels of detection sensitivity, e.g., the lower limit of detection (LLD). For example, it may not be feasible to actually confirm intakes of 10% of the ALI, particularly for bioassay measurements of some alpha-emitting radionuclides. Therefore, monitoring thresholds should not be considered requirements on the sensitivity of a particular measurement. Workplace monitoring and occupancy factors should be considered, as appropriate, in evaluating potential exposures and monitoring requirements.

2. DETERMINATION OF EXTERNAL DOSES

There are three dose limits included in 10 CFR 20.1201 that apply to external exposure: deep dose to the whole body (5 rems or 0.05 Sv), shallow dose to the skin or extremities (50 rems or 0.5 Sv), and dose to the lens of the eye (15 rems or 0.15 Sv). According to the definitions in 10 CFR 20.1003, the deep-dose equivalent to the whole body is considered to be at a tissue depth of 1 cm (1000 mg/cm^2), shallow-dose equivalent to the skin or extremities at 0.007 cm (7 mg/cm^2), and eye dose equivalent at 0.3 cm (300 mg/cm^2). In evaluating the eye dose equivalent, it is acceptable to take credit for the shielding provided by protective lenses.

2.1 Placement of Individual Monitoring Devices

External dose is typically determined by the use of individual monitoring devices, such as film badges and thermoluminescence dosimeters (TLDs). The device for monitoring the whole body dose should be placed near the location expected to receive the highest dose during the year (10 CFR 20.1201(c)). When the whole body is exposed fairly uniformly, the individual monitoring device is typically worn on the front of the upper torso.

If the radiation dose is highly nonuniform, causing a specific part of the whole body (head, trunk, arms above the elbow, or legs above the knees) to receive a substantially higher dose than the rest of the whole body, the individual monitoring device should be placed near that part of the whole body expected to receive the highest dose. For example, if the dose rate to the head of an individual is expected to be higher than the dose rate to the trunk of the body, a monitoring device should be located on or close to the head so as to measure the dose received by the head.

If postexposure evaluations indicate that the maximum dose to a part of the whole body was substantially higher than the dose measured by the individual monitoring device, an evaluation should be conducted to estimate the actual maximum dose.

2.2 Use of More Than One Dosimeter

An acceptable alternative approach for highly nonuniform radiation fields is to use more than one dosimeter to separately track doses to different parts of the whole body. At the end of the year, each of the doses for each location would be summed. The deep- dose equivalent to be recorded would be that of the dosimeter location receiving the highest dose.

2.3 Extremity Monitoring

If the licensee determines that extremity monitoring is required, it may be appropriate to use an extremity dosimeter for some, but not all, radiation exposure. The licensee could supply an extremity dosimeter when exposure is nonuniform. When exposure is uniform, the shallow-dose equivalent measured by a torso dosimeter would be representative of the shallow-dose equivalent to the extremities, and separate extremity monitoring would not be needed.

If protective gloves are used, it is acceptable to place the extremity dosimeter under the gloves.

3. CALCULATION OF COMMITTED EFFECTIVE DOSE EQUIVALENT FROM INHALATION

The internal dose component needed for evaluating the total effective dose equivalent is the committed effective dose equivalent. The committed effective dose equivalent is the 50-year effective dose equivalent that results when radioactive material is taken into the body, whether through inhalation, ingestion, absorption through the skin, accidental injection, or introduction through a wound. The contributions from all occupational intakes for these modes of intake are added over the yearly time period for which the total committed effective dose equivalent is being evaluated. The regulatory requirements for determining the internal dose are in 10 CFR 20.1204.

Some noble gases in Appendix B to §§ 20.1001–20.2401 do not have inhalation ALI values listed and are listed "submersion" class. For these radionuclides, the internal dose is negligible compared to the external dose. These radionuclides may be excluded from the determination of the internal dose.

There are at least five methods acceptable to the NRC staff for calculating committed effective dose equivalent from inhaled radioactive materials. The five methods are described below.

3.1 Use of Federal Guidance Report No. 11

Federal Guidance Report No. 11 (Ref. 1) lists the committed effective dose equivalent per unit intake by inhalation in sieverts per becquerel in its Table 2.1. These values may be used directly after converting the units from sieverts per becquerel to rem per microcurie (Sv/Bq x 3.7 x 10^6 = rem/μCi).

3.2 Use of Stochastic Inhalation ALIs from 10 CFR Part 20

ALI values have been established for individual radionuclides and are presented in Table 1 in Appendix B to §§ 20.1001–20.2401. The ALI values for inhalation, presented in Column 2 in Table 1, correspond to a committed effective dose equivalent of 5 rems (0.05 Sv) or a committed dose equivalent of 50 rems (0.5 Sv) to any individual organ or tissue, whichever is more limiting. If the ALI value presented in Table 1 is limited by the 50-rem committed dose equivalent, the controlling organ is listed directly below the ALI value, and the stochastic ALI value based on the 5-rem committed effective dose equivalent is listed in parentheses directly below the organ name. If a stochastic ALI is listed in parentheses, that value should be used to calculate the committed effective dose equivalent. The committed effective dose equivalent for each radionuclide may be calculated, using the estimated radionuclide intake, by Equation 1.

$$H_{i,E} = \frac{5\ I_i}{ALI_{i,E}} \qquad \text{Equation 1}$$

where

$H_{i,E}$ = Committed effective dose equivalent from radionuclide i (rems)

I_i = Intake of radionuclide i by inhalation during the calendar year (μCi) (If multiple intakes occurred during the year, I_i is the sum of all intakes.)

$ALI_{i,E}$ = Value of the stochastic inhalation ALI (based on the committed effective dose equivalent) from Column 2 of Table 1 in Appendix B to §§ 20.1001–20.2401 (μCi)

5 = Committed effective dose equivalent from intake of 1 ALI (rems)

If intakes of more than one radionuclide occurred, the total committed effective dose equivalent will be the sum of the committed effective dose equivalents for all radionuclides.

The ALIs in Part 20 are based on a particle distribution with a 1-micron activity median aerodynamic diameter. Those ALIs may be used regardless of the actual median diameter. However, the NRC allows adjustment of ALIs to account for particle size, but only with prior approval from the NRC (10 CFR 20.1204(c)).

3.3 Use of DACs from 10 CFR Part 20

Committed effective dose equivalent may also be calculated from exposures expressed in terms of DAC-hours. If the DAC in Appendix B to §§ 20.1001–20.2401 for a radionuclide represents a stochastic value (i.e., the corresponding ALI does not have the name of an organ below it), the DAC may be used directly. If Appendix B to §§ 20.1001–20.2401 does not list a stochastic DAC, which will be the case any time there is a stochastic ALI value in parentheses, it is preferred (but not required) that the licensee calculate and use a stochastic DAC. The stochastic DAC can be calculated from the stochastic ALI (the ALI in parentheses) by the following equation:

$$DAC_{stoc,i} = \frac{ALI_{stoc,i}}{2.4 \times 10^9} \qquad \text{Equation 2}$$

where

$DAC_{stoc,i}$ = The stochastic DAC for radionuclide i (microcuries/ml)

$ALI_{stoc,i}$ = The stochastic ALI for radionuclide i (microcuries)

2.4×10^9 = The volume of air inhaled by a worker in a workyear (ml).

Then

$$H_{i,E} = \frac{5\ C_i t}{2000\ DAC_{stoc,i}} \qquad \text{Equation 3}$$

where

$H_{i,E}$ = Committed effective dose equivalent from radionuclide i (rems)

C_i = The airborne concentration of radionuclide i to which the worker is exposed (microcuries/ml)

t = The duration of the exposure (hours)

2000 = The number of hours in a workyear

5 = Committed effective dose equivalent from annual intake of 1 ALI or 2000 DAC-hours (rems)

If there is a mixture of several radionuclides, it is permissible to disregard certain radionuclides in the mixture that are present in relatively small quantities (10 CFR 20.1204(g)). These radionuclides may be disregarded if the following conditions are met: (1) the concentration of any radionuclide disregarded is less than 10% of its DAC; (2) the sum of these percentages for all of the radionuclides disregarded in the mixture does not exceed 30%; and (3) the licensee uses the total activity of the mixture in demonstrating compliance with the dose limits and monitoring requirements.

3.4 Use of ICRP Publication 30

The supplements to ICRP Publication 30 (Ref. 2) list "weighted committed dose equivalent to target organs or tissues per intake of unit activity" for inhalation in sieverts per becquerel. The sum of the values given is the committed effective dose equivalent. ICRP Publication 30 (Ref. 2) does not give the sum, but the licensee can easily add the values given to calculate the sum. Then it is only necessary to convert from sieverts per becquerel to rems per microcurie (3.7×10^6 x Sv/Bq = rem/μCi).

3.5 Use of Individual or Material-Specific Information

NRC regulations (10 CFR 20.1204(c)) state that "When specific information on the physical and biochemical properties of the radionuclides taken into the body or the behavior of the material in an individual is known, the licensee may...use that information to calculate the committed effective dose equivalent...." No prior NRC approval is required for using this approach, but records must be kept.

This approach requires the licensee to do considerably more work and to have greater technical expertise than the other approaches. Thus, the approach is unlikely to be attractive to most licensees

for small routine intakes. On the other hand, it might be attractive in the case of accidental large exposures if more accurate information would lead to a better estimate of the actual dose.

When this approach is used, the dose to organs not "significantly irradiated" may be excluded from the calculation (10 CFR 20.1202(b)(3)).

4. CALCULATION OF COMMITTED EFFECTIVE DOSE EQUIVALENT DUE TO INGESTION

There are annual limits on intake (ALIs) for occupational ingestion of radioactive material. Only one ingestion ALI is given for each radionuclide, whereas for inhalation a different ALI was given for each solubility class. Solubility classes are not used for ingestion. The ingestion ALI given for each radionuclide is used for all chemical forms of that radionuclide.

If ingestion has occurred, the methods for determining the committed effective dose equivalent are similar to the methods used for estimating inhalation dose. Four acceptable methods are described here.

Some noble gas radionuclides in Appendix B to §§ 20.1001–20.2401 do not have ingestion ALI values listed because the ingestion pathway does not contribute significantly to the dose. These radionuclides may be excluded from the determination of the internal dose from ingestion.

4.1 Use of Federal Guidance Report No. 11

Federal Guidance Report No. 11 (Ref. 1) lists in its Table 2.2 the committed effective dose equivalent per unit of intake by ingestion in sieverts per becquerel. These values may be used directly after converting the units from sieverts per becquerel to rems per microcurie (by multiplying the Sv/Bq value by 3.7×10^6).

4.2 Use of Stochastic Ingestion ALIs from 10 CFR Part 20

If the amount of ingested radioactive material is known, the stochastic ingestion ALIs from Column 1 of Table 1 in Appendix B to §§ 20.1001–20.2401 may be used. Equation 4 may be used for this determination.

$$H_{i,E} = \frac{5\, I_i}{ALI_{i,E,oral}} \qquad \text{Equation 4}$$

where

$H_{i,E}$ = Committed effective dose equivalent from radionuclide i (rems)

I_i = Intake of radionuclide i by ingestion during the calendar year (μCi)

$ALI_{i,E,oral}$ = Value of the stochastic ingestion ALI for the committed effective dose equivalent from Column 1 of Table 1 in Appendix B to §§ 20.1001–20.2401 (μCi)

5 = Committed effective dose equivalent from annual intake of 1 ALI (rems)

4.3 Use of ICRP Publication 30

The supplements to ICRP Publication 30 (Ref. 2) list "weighted committed dose equivalent to target organs or tissues per intake of unit activity" for oral intake in sieverts per becquerel. The sum of the values given is the committed effective dose equivalent. ICRP Publication 30 does not give the sum, but the licensee can easily add the values given to calculate the sum. Then it is only necessary to convert from sieverts per becquerel to rems per microcurie (by multiplying the Sv/Bq value by 3.7×10^6).

4.4 Use of Individual or Material-Specific Information

NRC regulations (10 CFR 20.1204(c)) allow the committed effective dose equivalent to be calculated based on specific information on the physical and biochemical properties of radionuclides taken into the body of a specific worker. The doses due to ingestion can be calculated using the specific information previously described for inhalation.

5. DETERMINATION OF ORGAN-SPECIFIC COMMITTED DOSE EQUIVALENTS

The internal dose component needed for demonstrating compliance with the dose limit specified in 10 CFR 20.1201(a)(1)(ii) is the organ-specific committed dose equivalent. The organ-specific committed dose equivalent is calculated for an individual organ. Tissue weighting factors are not used.

Organ-specific committed dose equivalents need be calculated only if the committed effective dose equivalent exceeds 1 rem or if an overexposure has occurred, because if the committed effective dose equivalent is less than 1 rem and no overexposure has occurred, the 50-rem nonstochastic organ limit cannot be exceeded.

Five acceptable methods to calculate the organ-specific committed dose equivalent are described here.

5.1 Use of Federal Guidance Report No. 11

One method for calculating the organ-specific committed dose equivalent is to use the factors in

Federal Guidance Report No. 11 (Ref. 1). The organ-specific exposure-to-dose conversion factors presented in Table 2.1 (for inhalation) and Table 2.2 (for ingestion) of Federal Guidance Report No. 11 (Ref. 1) provide acceptable data for calculating individual organ doses based on intakes as follows:

$$H_{i,T} = I_i \times DCF_i \times 3.7 \times 10^6 \qquad \text{Equation 5}$$

where

$H_{i,T}$ = Committed dose equivalent to the tissue or organ from radionuclide i (rems)

I_i = Intake of radionuclide i (μCi)

DCF_i = Dose conversion factor for radionuclide i from Table 2.1 or 2.2 in Federal Guidance Report No. 11 (Sv/Bq)

3.7×10^6 = Conversion factor to convert from Sv/Bq to rem/μCi

5.2 Use of Nonstochastic Inhalation ALIs from Part 20

It is possible to calculate organ-specific committed dose equivalents for those radioactive materials for which nonstochastic ALIs are given in 10 CFR Part 20. (Nonstochastic ALIs are those in which the organ is identified underneath the ALI in Appendix B to §§ 20.1001–20.2401.) The equation is:

$$H_{i,T} = \frac{50\ I_i}{ALI_{i,T}} \qquad \text{Equation 6}$$

where

$H_{i,T}$ = Committed dose equivalent to tissue or organ T from radionuclide i (rems)

I_i = Intake of radionuclide i by inhalation during the calendar year (μCi)

$ALI_{i,T}$ = Value of the nonstochastic inhalation ALI for radionuclide i (based on the organ-specific committed dose equivalent) from Column 2 of Table 1 in Appendix B to §§ 20.1001–20.2401 (μCi)

50 = Committed dose equivalent to maximum-exposed organ from inhalation of 2000 DAC-hours (rems)

5.3 Use of DACs from Part 20

If a radionuclide has an ALI based on a nonstochastic dose limit to an organ, the corresponding DAC may be used to calculate the organ-specific committed dose equivalent to the organ with the highest dose using the following equation:

$$H_{i,T} = \frac{50\ C_i t}{2000\ DAC_i} \qquad \text{Equation 7}$$

$H_{i,T}$ = Committed dose equivalent to tissue or organ T from radionuclide i (rems)

C_i = The concentration of the radionuclide i (microcuries/ml)

DAC_i = The nonstochastic DAC for radionuclide i (microcuries/ml)

t = The duration of the exposure (hours)

2000 = The number of hours in the workyear

50 = Committed dose equivalent to maximum-exposed organ from annual intake of 1 ALI or 2000 DAC-hours (rems)

If intakes during the monitoring period are from more than one radionuclide and the organs receiving the highest dose are different from each radionuclide, this method may substantially overestimate the maximum organ dose. In this situation, the licensee may wish to use one of the other methods.

5.4 Use of ICRP Publication 30

The supplements to ICRP Publication 30 (Ref. 2) list "committed dose equivalent in target organs or tissues per intake of unit activity," in sieverts per becquerel, to significantly exposed organs. These values may be used to calculate organ-specific committed dose equivalents after converting the units from Sv/Bq to rem/μCi.

5.5 Use of Individual or Material-Specific Information

NRC regulations (10 CFR 20.1204(c)) state that the committed effective dose equivalent may be calculated based on specific information on the physical and biochemical properties of radionuclides taken into the body. Although not explicitly stated, the organ-specific committed dose equivalent may also be calculated based on specific information.

In general, if specific information is used to calculate the committed effective dose equivalent, it should also be used to calculate the organ-specific dose equivalent so that both dose calculations have the same basis.

6. DOSES FROM INTAKES THROUGH WOUNDS OR ABSORPTION THROUGH SKIN

According to 10 CFR 20.1202(d), the licensee must evaluate and, to the extent practical, account for intakes through wounds or skin absorption. (Dose from tritium absorption through the skin is taken into account in the DAC value in Appendix B to §§ 20.1001–20.2401.) As a practical matter, the intake by skin absorption of airborne radioactive materials usually does not need to be considered because it will be negligible compared to the intake from inhalation. It may be necessary to consider absorption through the skin when solutions containing dissolved radioactive material come in contact with the skin.

7. RECORDING OF INDIVIDUAL MONITORING RESULTS

The requirements for recording individual monitoring results are contained in 10 CFR 20.2106, which requires that the recording be done on NRC Form 5 or equivalent. NRC Form 5 is used to record, on an annual basis, doses received. Thus, for workers who work for the same licensee for the entire year, the monitoring period will normally be January 1 to December 31. The monitoring year may be adjusted as necessary to permit a smooth transition from one monitoring year to another—so long as the year begins and ends within the month of January, the change is made at the beginning of the year, and no day is omitted or duplicated in consecutive years. A copy of NRC Form 5 and instructions for filling it out are contained in Revision 1 to Regulatory Guide 8.7, "Instructions for Recording and Reporting Occupational Exposure Data."

7.1 Summation of External and Internal Doses

Summation of external and internal doses is required in 10 CFR 20.1202 when both external monitoring and internal monitoring of an individual are required to meet 10 CFR 20.1502(a) and (b). The requirement for summation applies to the occupationally exposed adult and minor and to the embryo/fetus of a declared pregnant woman.

The requirements for summation of external and internal doses specified in 10 CFR 20.1202(a) are not applicable to the shallow-dose equivalent to the skin or extremities or to the eye dose equivalent. Only external dose is considered in evaluating the shallow-dose equivalent to the skin and the extremities and the eye dose equivalent.

Total effective dose equivalent is calculated by summing the external component (deep-dose equivalent) and the internal component (committed effective dose equivalent). Likewise, the total organ dose equivalent is calculated by summing the external component (deep-dose equivalent) and the internal component to the organ or tissue (committed dose equivalent to any organ or tissue).

7.2 Preferred Units

The preferred unit for dose is the "rem." The use of "millirems" on NRC Form 5 is permitted but is discouraged. The preferred unit for intakes is the "microcurie." NRC regulations (10 CFR 20.2101(a)) do not permit the use of the units "sieverts" or "becquerels" on Part 20 records.

7.3 Roundoff of Doses

Licensees should avoid entering doses on NRC Form 5 with more significant figures than justified by the precision of the basic measured values. In general, it is appropriate to enter dose values with two significant figures on NRC Form 5 using the standard rules for roundoff. Thus, a computer-generated calculated dose of "1.726931 rems" should be entered on NRC Form 5 as "1.7 rems." However, licensees should generally carry at least three significant figures in calculations to avoid loss of accuracy due to multiple roundoffs.

In addition, licensees should not enter doses smaller than 0.001 rem on NRC Form 5 because smaller values are insignificant relative to the dose limits. Therefore, a calculated committed effective dose equivalent of "0.006192 rem" should be entered as "0.006 rem," and a value of "0.000291 rem" should be entered as "0 rem."

The rounding recommended in this section is illustrated in the appendix to this guide.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this regulatory guide.

Except in those cases in which an applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the methods described in this guide will be used in the evaluation of applications for new licenses, license renewals, and license amendments and for evaluating compliance with 10 CFR 20.1001–20.2401.

REFERENCES

1. K. F. Eckerman, A. B. Wolbarst, and A. C. B. Richardson, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," Environmental Protection Agency, Federal Guidance Report No. 11 (EPA 520/1–8–020), September 1988. This report may be purchased from the National Technical Information Service, Springfield, VA 22161. For information and credit card sales, call (703) 487–4650.

2. International Commission on Radiological Protection, "Limits for Intakes of Radionuclides by Workers," ICRP Publication 30 (7-volume set, including supplements), Pergamon Press Inc., 1982.

APPENDIX
EXAMPLE OF THE CALCULATION OF OCCUPATIONAL DOSES

This example illustrates the calculation of dose information needed for NRC Form 5, "Occupational Exposure Record for a Monitoring Period." An NRC Form 5 with the data and calculations in this example is provided to illustrate how to fill out the form. In this example, it is assumed that the individual was exposed to external radiation and received an intake by inhalation of five airborne radionuclides.

Deep-Dose Equivalent (Whole Body)

The licensee provided individual monitoring for the deep-dose equivalent (1-cm depth) based on the likelihood of exceeding 0.5 rem deep-dose equivalent. In this example, the sum of the dosimeter reading for the year is assumed to be 1.435 rems of low-LET radiation (gamma), which in the licensee's calculations is rounded to 1.44 rems, maintaining three significant figures for calculational purposes, but entered as 1.4 rems on NRC Form 5.

Eye Dose Equivalent

The licensee provided monitoring for eye dose equivalent because the dose to the eye was likely to exceed 1.5 rems. The total annual dose measured at a depth of 0.3 cm by a dosimeter worn on the trunk was 1.720 rems. The rounded value of 1.7 is entered on NRC Form 5.

Shallow-Dose Equivalent

The shallow-dose equivalent to the skin or extremities must be monitored if the shallow-dose equivalent is likely to exceed 5 rems in the year. In this example, the licensee concluded at the start of the year that the shallow-dose equivalent was not likely to exceed 5 rems, and, therefore, monitoring of the shallow-dose equivalent was not required by 10 CFR 20.1502. Nevertheless, the licensee provided shallow-dose equivalent monitoring because the dosimeter supplier automatically provided a shallow-dose equivalent reading on all badges. The annual monitored total of the shallow-dose equivalent was 1.85 rems, confirming that monitoring of the shallow-dose equivalent was not necessary. The licensee could enter "NR," meaning not required, on NRC Form 5 because monitoring the shallow-dose equivalent was not required by 10 CFR 20.1502. However, in this case the licensee decided, for the sake of completeness, to enter the rounded value of 1.9 rems as the shallow-dose equivalent, whole body column, but he entered "NR" under shallow-dose equivalent to the extremities because no extremity monitoring was required or provided. The licensee also could have entered 1.9 rems on the basis that the extremities received about the same dose as the dosimeters located on the trunk. Either of those entries is acceptable. A value of zero should not be entered if no monitoring was provided. Any numerical value, including zero, should signify a measured or estimated dose.

Radionuclide Intakes

The intake of each radionuclide must be entered separately. The solubility class of each radionuclide must be specified. The intake mode, inhalation (H) in this case, must also be entered. Based on air sampling data, worker stay times, and respirator protection factors when applicable, the licensee calculated the intakes from inhalation (H), which are shown in Table A.1 using this equation:

$$I_i = \frac{C_i B t}{APF} \qquad \text{Equation A.1}$$

where

I_i = intake from radionuclide i in microcuries

C_i = the concentration of radionuclide i in microcuries/ml

B = the worker's breathing rate of 20,000 ml/min

t = duration of the worker's exposure in minutes

APF = assigned respiratory protection factor, dimensionless

All the data in Table A.1 must be entered on NRC Form 5.

Committed Effective Dose Equivalent

The committed effective dose equivalent from each radionuclide is calculated by using Equation 1. The data used in Equation 1 are shown in Table A.2.

The sum (1.3 rems) in Table A.2 must be entered on NRC Form 5.

Total Effective Dose Equivalent

The total effective dose equivalent is the sum of the deep-dose equivalent and the sum of the committed effective dose equivalent from all radionuclides. In this case, the total effective dose equivalent is 1.44 + 1.30 rems = 2.74 rems, which is rounded to 2.7 rems for entry onto NRC Form 5.

Organ-Specific Committed Dose Equivalent

The organ-specific committed dose equivalents should be calculated because the committed effective

Table A.1
Worker Intakes

Radionuclide	Solubility Class	Intake Mode	Intake (microcuries)
U-238	D	H	0.022
U-235	D	H	0.0031
U-234	D	H	0.060
Cs-137	D	H	1.87
Ce-144	Y	H	2.07

Table A.2
Calculation of Committed Effective Dose Equivalent

Radionuclide and Class	Intake, I_i (microcuries)	$ALI_{i,E}$ (microcuries)	CEDE (rems)
U-238 (D)	0.022	2	0.055
U-235 (D)	0.0031	2	0.008
U-234 (D)	0.060	2	0.15
Cs-137 (D)	1.87	200	0.047
Ce-144 (Y)	2.07	10	1.04
Sum			1.30

dose equivalent exceeds 1 rem. The organ dose factors in Federal Guidance Report No. 11* may be used. The organ dose factors from Table 2.1 of that report are reproduced in Table A.3. The dose factor for the "remainder" listed in Federal Guidance Report No. 11 is not listed here or used to calculate organ-specific committed dose equivalents because it does not represent a dose to a particular individual organ.

To calculate the organ-specific committed dose equivalent, multiply the intake by the organ dose factor and a conversion factor to convert from Sv/Bq to rem/μCi. The equation is:

$$H_{T,i} = I_i \times DCF_{T,i} \times 3.7 \times 10^6 \qquad \text{Equation A.2}$$

where

$H_{i,T}$ = 50-year committed dose to organ or tissue T from radionuclide i, in rems

I_i = the intake of radionuclide i, in microcuries

$DCF_{T,i}$ = the dose conversion factor for organ or tissue T from radionuclide i, in Sv/Bq

The results are shown in Table A.4.

The doses in Table A.4 were calculated using the rounding method described in this guide.

Organ Dose

The organ dose to the most exposed organ is the sum of the deep-dose equivalent and the committed dose equivalent to the organ with the largest dose. In this case, the deep-dose equivalent is 1.44 rems. The lung is the organ with the highest committed dose equivalent (6.22 rems). The organ dose is the sum, 7.66 rems, which is rounded to 7.7 rems and entered on NRC Form 5.

*K.F. Eckerman, A.B. Wolbarst, and A.C.B. Richardson, "Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion," Environmental Protection Agency, Federal Guidance Report No. 11 (EPA 520/1-88-020), September 1988. This report may be purchased from the National Technical Information Service, Springfield, VA 22161. For information and credit card sales, call (703) 487-4650.

Table A.3
Organ Dose Factors From Federal Guidance Report No. 11

Radionuclide	Dose Per Unit Intake (Sv/Bq)					
	Gonad	Breast	Lung	R Marrow	B Surface	Thyroid
U-238 (D)	2.23E-8	2.23E-8	2.80E-7	6.58E-7	9.78E-6	2.22E-8
U-235 (D)	2.37E-8	2.38E-8	2.95E-7	6.58E-7	1.01E-5	2.37E-8
U-234 (D)	2.50E-8	2.50E-8	3.18E-7	6.98E-7	1.09E-5	2.50E-8
Cs-137 (D)	8.76E-9	7.84E-9	8.82E-9	8.30E-9	7.94E-9	7.93E-9
Ce-144 (Y)	2.39E-10	3.48E-10	7.91E-7	2.88E-9	4.72E-9	2.92E-10

Table A.4
Calculated Organ-Specific Committed Dose Equivalents

Radionuclide	Intake (μCi)	Organ-Specific Committed Dose Equivalent (rems)					
		Gonad	Breast	Lung	R Marrow	B Surface	Thyroid
U-238(D)	0.022	0.002	0.002	0.023	0.054	0.796	0.002
U-235(D)	0.0031	0	0	0.003	0.008	0.116	0
U-234(D)	0.060	0.006	0.006	0.071	0.155	2.42	0.006
Cs-137(D)	1.87	0.061	0.054	0.061	0.057	0.055	0.055
Ce-144(Y)	2.07	0.002	0.003	6.06	0.022	0.036	0.002
Sum		0.071	0.065	6.22	0.296	3.42	0.065

NRC FORM 5
(6-92)
10 CFR PART 20

U.S. NUCLEAR REGULATORY COMMISSION

OCCUPATIONAL EXPOSURE RECORD FOR A MONITORING PERIOD

1. NAME (LAST, FIRST, MIDDLE INITIAL)	2. IDENTIFICATION NUMBER	3. ID TYPE	4. SEX	5. DATE OF BIRTH
McGuire, Stephen A.	[redacted]	SSN	[X] MALE [ ] FEMALE	[redacted]

6. MONITORING PERIOD	7. LICENSEE NAME	8. LICENSE NUMBER(S)	9A	9B
1-1-94 to 12-31-94	XYZ Corp.	SNM-944	[X] RECORD [ ] ESTIMATE	[X] ROUTINE [ ] PSE

INTAKES

10A. RADIONUCLIDE	10B. CLASS	10C. MODE	10D. INTAKE IN μCi
U-238	D	H	0.022
U-235	D	H	0.0031
U-234	D	H	0.060
Cs-137	D	H	1.87
Ce-144	Y	H	2.07

DOSES (in rem)

DEEP DOSE EQUIVALENT	(DDE)	11 1.4
EYE DOSE EQUIVALENT TO THE LENS OF THE EYE	(LDE)	12 1.7
SHALLOW DOSE EQUIVALENT, WHOLE BODY	(SDE,WB)	13 1.9
SHALLOW DOSE EQUIVALENT, MAX EXTREMITY	(SDE,ME)	14 NR
COMMITTED EFFECTIVE DOSE EQUIVALENT	(CEDE)	15 1.3
COMMITTED DOSE EQUIVALENT, MAXIMALLY EXPOSED ORGAN	(CDE)	16 6.2
TOTAL EFFECTIVE DOSE EQUIVALENT *(BLOCKS 11 + 15)*	*(TEDE)*	17 2.7
TOTAL ORGAN DOSE EQUIVALENT, MAX ORGAN *(BLOCKS 11 + 16)*	*(TODE)*	18 7.7

19. COMMENTS

Value in Box 18 is not equal to sum of Box 11 plus Box 16 because rounding to two significant figures was not done until the final step.

20. SIGNATURE - LICENSEE

[signature]

21. DATE PREPARED
1-31-95

REGULATORY ANALYSIS

A separate regulatory analysis was not prepared for this regulatory guide. The regulatory analysis prepared for 10 CFR Part 20, "Standards for Protection Against Radiation" (56 FR 23360), provides the regulatory basis for this guide and examines the costs and benefits of the rule as implemented by the guide. A copy of the "Regulatory Analysis for the Revision of 10 CFR Part 20" (PNL-6712, November 1988) is available for inspection and copying for a fee at the NRC Public Document Room, 2120 L Street NW., Washington, DC, as an enclosure to Part 20 (56 FR 23360).

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