DOE/EA-1086

# Environmental Assessment

# for

# Amendments to 10 CFR Part 835

## DISCLAIMER

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## 1. Background

On December 14, 1993, the Department of Energy (DOE) published a final rule, 10 CFR Part 835, "Occupational Radiation Protection," [1] which applies to normal operations at all DOE and DOE contractor facilities where individuals could be occupationally exposed to ionizing radiation. The rule codified certain requirement previously promulgated in DOE Order 5480.11, "Radiation Protection for Occupational Workers," [2] which implemented the President's "Radiation Protection Guidance to Federal Agencies for Occupational Exposure," [3] and implemented guidance issued by authoritative organizations, including the National Council on Radiation Protection and Measurements and the International Commission on Radiological Protection. In addition, 10 CFR Part 835 codified the "as low as reasonably achievable" (ALARA) process as the primary means of maintaining occupational exposures below the regulatory exposure limits. The proposed amendments to 10 CFR Part 835 are the culmination of a systematic analysis to consolidate the elements of DOE's comprehensive radiation protection program and to identify those portions of this program which should be codified in 10 CFR Part 835. As a result of this analysis, DOE proposes amendments to all of the subparts of 10 CFR Part 835. These proposed amendments range from minor technical or language clarifications to the restructuring of entire subparts. The analysis included a review of the requirements in DOE Notice 441.1, "Radiological Protection for DOE Activities," [4] and resulted in the proposed codification of certain provisions of that Notice, including those for posting of areas where radioactive material is present and for control of sealed radioactive sources. In addition, the proposed amendments would clarify the scope of 10 CFR Part 835 to explicitly exclude both transportation of radioactive materials conducted in compliance with applicable DOE Orders [5] and DOE activities performed on foreign soil when those activities are performed in accordance with occupational radiation protection requirements agreed to by both the United States and the cognizant foreign government. DOE also proposes to add a removable tritium surface radioactivity value to appendix D. The value would be used to determine the need for posting of areas to warn individuals of the presence of radioactive contamination and the need for implementing other radiological controls.

Several additional changes are proposed to ensure continuity in DOE's system of occupational radiation protection standards now that the DOE Radiological Control Manual [6] is no longer a mandatory standard. These proposed changes are based on articles in the manual and primarily address area access control, radioactive material labeling, and radiation safety

training. These changes are proposed to codify requirements previously imposed through DOE's system of contractually-implemented standards and to minimize the occurrence of radiological events at DOE facilities as reported under DOE Order 231.1, "Environment, Safety, and Health Reporting" [7]. DOE has also identified and proposes revision or deletion of certain requirements that may be viewed as unduly burdensome or unenforceable, including standards related to workplace monitoring, recordkeeping, and facility design. Numerous minor changes are proposed to clarify and/or correct the existing language in the current rule. To facilitate understanding of this Environmental Assessment, appendix A defines many of the technical terms used.

These requirements are being promulgated in accordance with the Secretary's practice of codifying nuclear safety directives. These amendments provide nuclear safety requirements that, if violated, establish a basis for DOE to assess civil and criminal penalties under the Price-Anderson Amendments Act of 1988 (PAAA), Pub. L. 100-408 (August 20, 1988) 42 U.S.C.A. § 2282a (1994) [8].

There are three general categories of proposed changes: Additional Requirements; Clarifications to Existing Requirements; and Exceptions to Requirements. These are discussed in the following sections.

## 1.A. Additional Requirements

### 1.A.1. Sealed Radioactive Source Control

Currently, DOE's interim requirements for sealed radioactive source control are provided in DOE Notice 441.1. DOE proposes to codify sealed radioactive source control requirements for storage, transfer, and control of sealed radioactive sources at DOE facilities. DOE previously indicated in the preamble to final rule 10 CFR Part 835 [9] its intention to codify sealed radioactive source control requirements. These requirements will be published in the **Federal Register** in a notice of proposed rulemaking.

### 1.A.2. Tritium Surface Radioactivity Values

In the original proposed rule (10 CFR Part 835), DOE reserved the surface radioactivity contamination values for tritium. During the public comment period of the original proposed rulemaking, DOE identified appropriate values for inclusion in appendix D. However,

these values were not included in the final rule and, when promulgating the final rule, DOE committed to propose these values in subsequent rulemaking. This addition would provide a value needed to evaluate surfaces contaminated by any compound of tritium (e.g., HT, HTO and metal tritide aerosols) for removable contamination that may be present on materials or equipment being transferred from a radiological to a controlled area. A total surface contamination value, consisting of fixed plus removable tritium, was determined to be not applicable. However, a value of 10,000 dpm/100 $cm^2$ for removable tritium alone was determined to be appropriate and would be included in the existing appendix D to 10 CFR Part 835. This value will be published in the **Federal Register** in a notice of proposed rulemaking.

1.A.3. Posting and Labeling

DOE established posting and labeling requirements in 10 CFR Part 835 to provide warning to individuals of the presence or potential presence of radiation and/or radioactive materials. As a result of comments received from contractors on the implementation of posting and labeling requirements of 10 CFR Part 835 and the DOE Radiological Control Manual, DOE subsequently identified a need to provide additional posting requirements for Radioactive Material Areas and labeling requirements for radioactive items and containers of radioactive materials. These additions will be published in the **Federal Register** in a notice of proposed rulemaking.

1.A.4. Bioassay Program Accreditation

10 CFR Part 835 establishes both external and internal radiation dose limits and monitoring thresholds for occupationally exposed individuals. In promulgating the exposure monitoring requirements for external radiation, DOE required external dosimetry programs to be operated in conformance with the DOE Laboratory Accreditation Program (DOELAP) for Personnel Dosimetry [10]. No equivalent program existed at the time for internal dosimetry radiobioassay programs. This addition would require DOE internal dosimetry radiobioassay programs to be accredited. The new DOELAP for Radiobioassay Programs will establish the applicable standards for program accreditation. This amendment will be published in the **Federal Register** in a notice of proposed rulemaking. The DOELAP radiobioassay programs are under development and are expected to be published when the amendment is published.

1.A.5. Monitoring Received Packages

Transportation of radioactive materials to and from DOE facilities is conducted in compliance with applicable DOE Orders. After implementation of 10 CFR Part 835, it was recognized that individuals could be unintentionally exposed to radiation from damaged or unattended packages containing radioactive materials if the packages were not appropriately surveyed upon receipt. The original proposed rulemaking of 10 CFR Part 835 did not address such surveys. The proposed addition would not duplicate requirements found in existing DOE Orders, but would fill a gap in the current regulations, and is similar to the regulatory requirements implemented in non-DOE facilities handling radioactive materials. These requirements will be published in the **Federal Register** in a notice of proposed rulemaking.

1.B. Clarifications to Existing Requirements

The proposed amendments would incorporate several clarifications to existing requirements. It was recognized during the initial implementation of 10 CFR Part 835 that a number of changes were needed to correct minor typographical, grammatical, and technical errors. These clarifications will be published in the **Federal Register** in a notice of proposed rulemaking. The areas that are being amended to clarify existing requirements are as follows:

- § 835.1002(b) regarding design objectives for external radiation would be deleted because the objectives may not be practical and are redundant with § 835.1001 which adequately addresses DOE facility design objectives.
- § 835.1002(c) regarding design objectives for airborne radioactive material would be deleted because the objectives may not be practical and are redundant with § 835.1001 which adequately addresses DOE facility design objectives.
- § 835.1003(a) would be reworded to reference the actual dose limits as appropriate, rather than reiterate them numerically in this subsection.
- § 835.403(a) would be reworded to clarify existing requirements for monitoring of workplace airborne radioactivity.
- § 835.203(a) would be modified to clarify when external and internal radiation dose values need to be added to demonstrate compliance with the exposure limits in §§ 835.202, 835.207, and 835.208.

- § 835.902 and § 835.903 would be deleted, and § 835.901 would be reworded to incorporate the appropriate requirements for radiation safety training and radiation safety training course content at DOE sites.
- Appendix B of 10 CFR Part 835 would be deleted because DOE has determined that 10 CFR Part 835 establishes no substantive requirements for use of the data presented in appendix B.

1.C. Exclusions to Requirements

The need to exclude certain activities from the provisions in 10 CFR Part 835 arose during implementation to prevent duplication of regulatory requirements and minimize burdensome requirements that do not enhance occupational radiation protection. These exclusions will be published in the **Federal Register** in a notice of proposed rulemaking. The areas that would be proposed for exclusion are as follows:

- Transportation of radioactive material performed in accordance with applicable DOE Orders.
- Activities related to preventing the accidental or unauthorized detonation of nuclear weapons when compliance with 10 CFR Part 835 may compromise the effectiveness of those activities.
- DOE activities conducted outside of the United States under the sovereignty and jurisdiction of other governments.

2. Purpose and Need for Agency Action

In September 1995, DOE cancelled DOE Order 5480.11"Radiation Protection for Occupational Workers," and DOE Notice 5400.13, "Sealed Radioactive Source Accountability," and eliminated the DOE Radiological Control Manual as a mandatory standard. These actions were taken consistent with DOE initiatives to reduce the overall burden of prescriptive and redundant requirements imposed through DOE's system of contractually-implemented directives. At that time, DOE indicated its intent to evaluate the importance of these elements to achievement of DOE's radiological protection objectives and, based upon that evaluation, to propose codification of these elements. DOE has conducted a critical examination of its objectives for occupational radiation protection programs, including a structured analysis of existing standards for similar programs, of operational occurrences within the DOE complex and of the provisions in the current rule. In order to better meet its objectives for occupational radiation protection programs and to avoid

duplication of regulatory requirements, DOE needs to amend 10 CFR Part 835, "Occupational Radiation Protection." These amendments provide nuclear safety requirements that, if violated, provide DOE a basis for assessment of civil and criminal penalties under the Price-Anderson Amendments Act of 1988.

## 3. Description of Proposed Actions and Alternatives

### 3.A. Proposed Actions

DOE proposes to amend 10 CFR Part 835, "Occupational Radiation Protection." As previously discussed, there are three general categories of proposed changes: additional requirements, clarifications to existing requirements, and exceptions to requirements. All but two of the proposed changes have no potential for environmental impact. However, DOE has determined that proposed requirements for sealed radioactive source control and tritium surface radioactivity values need to be analyzed for potential environmental impacts, as follows:

#### 3.A.1. Sealed Radioactive Source Requirements

The proposed amended regulations would incorporate requirements for control of sealed radioactive sources that are consistent with those initially issued in December 1991 under DOE Notice 5400.9, "Sealed Radioactive Source Accountability," [11] and subsequently extended by DOE Notices 5400.10 [12], 5400.11 [13], 5400.12 [14], 5400.13 [15], and 441.1. The proposed amendment, for addition of Subpart M, "Sealed Radioactive Source Control," and other sections of 10 CFR Part 835, would provide requirements as follows:

- Definitions: § 835.2 (a) defines "accountable sealed radioactive source," "sealed radioactive source," and "source leak test."
- Control: § 835.1201(a) requires procedures for control of accountable sealed radioactive sources.
- Inventory and leak tests: § 835.1202 requires the conduct of inventories every six months which establish physical location for accountable sealed radioactive sources, adequacy of posting and labels, and adequacy of storage location, containers, and devices; and requires the conduct of leak testing upon receipt and every six months.

- Labeling: § 835.1201(b) requires labeling for accountable sealed radioactive sources in accordance with § 835.605, except that the specifications of § 835.601(c) are excepted.
- Recordkeeping: § 835.704(f) requires records necessary to demonstrate compliance.
- Exempt values for sealed radioactive source accountability and control requirements: appendix E, "Values for Exemption From Sealed Radioactive Sources Accountability and Posting and Labeling Requirements," provides the activity values, by nuclide, for exception of sealed radioactive sources from certain requirements.

Appendix B of this document contains the proposed sealed radioactive source control requirements and accountability values.

3.A.2. Tritium Surface Radioactivity Values

The proposed tritium removable surface radioactivity value of 10,000 disintegrations per minute (dpm) per 100 square centimeters ($cm^2$) would be used to replace the "[Reserved]" notation for "Removable." Tritium in appendix D to 10 CFR Part 835 - "Surface Radioactivity Values." DOE has determined that a total surface radioactivity value, consisting of fixed plus removable tritium, is not applicable and will so indicate in appendix D to 10 CFR Part 835. The proposed surface radioactivity value for removable tritium contamination is consistent with the value specified in the DOE Radiological Control Manual.

Appendix C of this document contains the proposed tritium surface radioactivity values.

3.B. Alternatives to Promulgating the Proposed Regulations for Sealed Radioactive Sources

The range of potential alternatives to the sealed radioactive source control requirements contained in the proposed amendment includes not proposing the amendment (no action), establishing more restrictive requirements, or establishing less restrictive requirements.

Actions that encompass the range of potential alternatives were considered as discussed below:

3.B.1. No Action Alternative

Under the no action alternative, DOE would not fulfill its commitment made in promulgating 10 CFR Part 835, "Occupational Radiation Protection," to codify requirements for control of sealed radioactive sources. This commitment is based on the Secretary's practice of codifying nuclear safety requirements. Also, DOE would not receive the benefit of public comments on these issues afforded in the rulemaking process. Under the no action alternative, DOE would have no means for imposing nuclear safety requirements for accountable sealed radioactive sources that, if violated, would provide a basis for assessment by DOE of civil and criminal penalties under the PAAA.

Requirements for control of sealed radioactive sources at DOE facilities are currently contained in DOE Notice 441.1, but were originally promulgated by DOE Notice 5400.9 developed in 1991 and subsequently extended by DOE Notices 5400.10, 5400.11, 5400.12, and 5400.13. DOE could issue these requirements as a DOE Order; however, DOE has decided to promulgate nuclear safety requirements through rulemaking.

3.B.2. Establish Different Requirements

The proposed amendment codifies standards that are comprehensive, reasonably achievable, and consistent with those used throughout the DOE complex since 1991. The proposed amendment is consistent with DOE Notice 5400.9, which was originally issued in December 1991 and applied to DOE and contractors performing work for DOE. Each facility that possessed or used sealed radioactive sources was directed to establish sealed radioactive source control procedures consistent with the provisions of the Notice. The Notice has been extended each year since 1991 up through the latest extension via DOE Notice 441.1. The DOE Radiological Control Manual, at sites where it is contractually incorporated, requires continued compliance with the provisions of DOE Notice 5400.9.

More restrictive requirements do not appear to be warranted. Since the issuance of DOE Notice 5400.9, control of sealed radioactive sources has improved and there have been no reports of overexposure or significant environmental impact due to lack of control over sealed radioactive sources. Problems reported regarding sealed radioactive source control involved deviations from the requirements of DOE

Notice 5400.9. When the requirements are properly implemented, health and safety concerns are adequately addressed. More restrictive requirements would have the effect of increasing cost without any apparent commensurate benefit.

Less restrictive requirements could conceivably provide adequate protection, but the proposed amendment is consistent with existing technical guidance. However, DOE will consider arguments for less restrictive, as well as more restrictive, requirements based on comments received from the public on the proposed rulemaking.

The proposed amendment would codify a program which is currently in effect throughout the DOE complex. This program has successfully protected workers and the public since 1991 and should not be significantly changed unless new information establishes that modifications are sufficiently beneficial.

3.C. Alternatives to Promulgating the Proposed Regulations for Tritium Surface Radioactivity Values

The range of potential alternatives to the tritium surface radioactivity values contained in the proposed amendment includes not proposing the amendment (no action), establishing more restrictive requirements, or establishing less restrictive requirements.

Actions that encompass the range of potential alternatives were considered as discussed below:

3.C.1. No Action Alternative

Under the no action alternative, DOE would not fulfill its commitment made in promulgating 10 CFR Part 835, "Occupational Radiation Protection," to provide surface radioactivity values for surfaces contaminated by tritium organic compounds, tritiated hydrogen gas (HT), tritiated water (HTO), and metal tritide aerosols. DOE promulgated surface radioactivity values for tritium in the DOE Radiological Control Manual in 1992, but this requirement is contractually based. Surface radioactivity values were "Reserved" when DOE originally promulgated 10 CFR Part 835. Also, DOE would not receive the benefit of public comments on these issues afforded in the rulemaking process. Under the no action alternative, DOE would have no means for imposing nuclear safety requirements for tritium

surface radioactivity values that, if violated, would provide a basis for assessment by DOE of civil and criminal penalties under the PAAA. If the proposed surface radioactivity values for tritium are not promulgated, these values would be regulated by the generic beta/gamma emitting radionuclide surface radioactivity values contained in 10 CFR Part 835, appendix D. DOE believes that the generic beta-gamma surface radioactivity values are overly restrictive for tritium and cannot be justified based on the very small risk to an individual exposed to tritium contamination at the proposed values (see section 5.B.2.). Using these overly restrictive generic surface radioactivity values for tritium results in significant costs without a commensurate benefit, which is inconsistent with the ALARA philosophy embraced by DOE. Unnecessary expenditures include replacement or decontamination costs for equipment and materials that have low tritium surface radioactivity levels. Additionally, slightly contaminated equipment and materials may have to be disposed of as radioactive waste when, under the proposed regulations, they could be released for use in controlled areas.

Under the no action alternative, the inconsistency between the tritium surface radioactivity values contained in the DOE Radiological Control Manual and 10 CFR Part 835 would continue to cause confusion in implementing radiation protection programs at DOE facilities working with tritium.

3.C.2. Establish Different Requirements

The removable tritium surface radioactivity values are consistent with those provided in the DOE Radiological Control Manual. As previously discussed in the no action alternative, DOE considers surface radioactivity values lower than those proposed to be overly restrictive.

Although it may be possible to establish higher levels based on the low risk estimate for adverse health effects discussed in section 5.B.2., higher levels do not currently appear to be required by operational needs. If public comments provide convincing technical, economic, or operational justifications for higher limits, DOE will consider modifying the proposed rule accordingly.

## 4. The Affected Environment

The environment most affected by the proposed actions and alternatives would be confined within designated controlled areas at sites where DOE radiological activities are conducted. These proposed amendments would have a direct impact on the occupational radiological environment of general employees at DOE and DOE contractor sites and facilities.

The proposed actions set levels of radioactivity for sealed radioactive sources below which specific controls would not be required. In the event of a lost sealed radioactive source, the environment beyond controlled areas at DOE or DOE contractor facilities could be affected. The levels established for the control of sealed radioactive sources included consideration of this potential situation.

The proposed tritium surface radioactivity values define the radioactive contamination levels below which materials and equipment may be released for use in controlled areas at a DOE or DOE contractor facility. 10 CFR Part 835 does not address release of equipment and materials beyond the controlled area. Unrestricted release to the environment is governed by other DOE standards and requirements.

Promulgation of these amendments would not cause either an increase or decrease to normal operational or accidental effluent discharges of radioactivity or hazardous materials to the air or water, and therefore, it is unforeseeable that they could affect any environmentally sensitive resources.

## 5. Environmental Impacts of Proposed and Alternative Actions

The following section discusses the potential health effects of the proposed action and alternatives.

### 5.A. Current Dose Limit System

DOE Order 5400.5, "Radiation Protection of the Public and the Environment," [16] and 10 CFR Part 835 contain a dose limitation system that consists of primary dose limits for exposure of members of the public and general employees to ionizing radiation. They also provide the method for determining these doses and require a formal process for maintaining radiation doses as low as is reasonably achievable (ALARA) below the primary dose limits.

As specified in subpart C of 10 CFR Part 835, dose limits for members of the public entering a controlled area and general employees are as follows:

Table 1 - Dose Limits Based on Limiting Stochastic Health Effects:

| Population | Type of Exposure | Annual Limit |
|---|---|---|
| General Employees | Total Effective Dose Equivalent | 5 rem (50 mSv) |
| Members of the Public | Total Effective Dose Equivalent | 100 mrem (1 mSv) |
| Minors | Total Effective Dose Equivalent | 100 mrem (1 mSv) |

Table 2 - Dose Limits Based on Preventing Nonstochastic Health Effects:

| Population | Type of Exposure | Annual Limit |
|---|---|---|
| General Employees | Dose equivalent to the lens of the eye | 15 rem (150 mSv) |
| General Employees | Shallow dose equivalent to the extremity (hands and arms below the elbow; feet and legs below the knees) and skin | 50 rem (500 mSv) |
| General Employees | Any organ or tissue (other than the lens of the eye) | 50 rem (500 mSv) |

5.A.1. Relationship Between Dose and Risk

DOE controls the risk of stochastic health effects from occupational exposure to ionizing radiation by primary dose limits as discussed in the previous section and by keeping doses as far below those limits as is reasonably achievable or ALARA. For radiation protection purposes, and in lieu of any data that demonstrates the occurrence of health effects at dose levels permitted for radiological workers, DOE assumes that the health effects observed at very high doses delivered at high dose rates are linearly proportional to the dose for all dose levels and that no threshold exists before health effects occur. There is considerable uncertainty in the presumed risk values for low doses, and the risk could be zero. However, for the general public, the estimated potential risk of excess fatal cancers is approximately 0.0005 deaths (or 1 in 2000) per person-rem [17]. The corresponding estimate for radiological workers is approximately 0.0004 deaths (or 1 in 2500) per person-rem.

"Risk" is used in discussions of health effects with wide variation in meaning. Although "risk" sometimes indicates a general statement of concern or danger, in this document "risk" is used to denote the chance or probability of an effect. This probability has a numerical value that is the statistical chance that an event (radiation exposure) will have a specific outcome (fatal cancer).

The National Research Council [18] estimates that the normal expectation in the United States of cancer deaths is about 20%. This means that 1 in 5 people are expected to die from cancer. It is conservatively estimated that there is a potential risk of approximately 1 in 2000 that an individual receiving an exposure of 1 rem (10 mSv) total effective dose equivalent (TEDE) would suffer a radiation-induced fatal cancer. This risk is in addition to the 1 in 5 chance (400 in 2000) of fatal cancer in the United States. Therefore, the total risk of fatal cancer to an individual who received 1 rem is estimated to be 401 in 2000. The risk estimates discussed in the remainder of this document are reported as potential cancer fatalities in excess of the normal expectation, (i.e., in the previous example, the 1 in 2000 above the expected 400 in 2000).

A significant feature of the dose limitation system is that meeting the specific dose limit does not, by itself, constitute satisfactory compliance with the regulation. The risk of health effects to workers

and to members of the public is further reduced by restricting doses to levels that are ALARA. Through these efforts, the average annual dose received by DOE radiological workers was less than 0.1 rem for each of the years 1990 through 1994 (1/50 of the annual dose limit).

The National Council on Radiation Protection and Measurements recommends that the risk to an individual of a fatal cancer from exposure to radiation should be no greater than that of fatal accidents in safe industries. The average annual risk of fatalities in safe industries is 1 in 10,000 [17]. The annual average exposure for DOE radiological workers corresponds to an average estimated potential risk of fatal cancer that is less than 1 in 20,000. The risk estimate of a potential fatal cancer induced by an exposure of 0.1 rem to a member of the public (the annual limit to which a member of the public could be exposed under the regulations) is 0.00005 (1 in 20,000). Both levels of risk are less than the risk of accidental death in safe industries. It is also important to note that radiation exposure is one of the risks a DOE radiological worker faces in an industrial setting.

Notably, these risk estimates may overestimate the number of potential cancers in the low dose range discussed above. The National Research Council's Committee on the Biological Effects of Ionizing Radiations Report (BEIR V) [18] provides an important perspective on this subject:

> "Finally, it must be recognized that derivation of risk estimates for low doses and dose rates through the use of any type of risk model involves assumptions that remain to be validated. At low doses, a model dependent interpolation is involved between the spontaneous incidence and the incidence at the lowest doses for which data are available. Since the committee's preferred risk models are a linear function of dose, little uncertainty should be introduced on this account, but departure from linearity cannot be excluded at low doses below the range of observation. Such departures could be in the direction of either increased or decreased risk. Moreover, epidemiologic data cannot rigorously exclude the existence of a threshold in the millisievert dose range. Thus the possibility that there may be no risks from exposures comparable to external natural background radiation cannot be ruled out. At such low doses

and dose rates, it must be acknowledged that the lower limit of the range of uncertainty in the risk estimates extends to zero."

## 5.B. Human Health Effects of Proposed Actions

### 5.B.1. Proposed Sealed Radioactive Source Requirements

The sealed radioactive source amendment being proposed requires the development and implementation of procedures for control of sealed radioactive sources. These procedures, if properly followed, prevent the loss of sealed radioactive sources and minimize contamination from leaking sealed radioactive sources.

DOE proposes to include the values for exception of sealed radioactive sources from certain control requirements as appendix E of 10 CFR Part 835. These values were selected based on a potential committed effective dose equivalent (CEDE) or deep dose equivalent (DDE) of 10 mrem or less for a credible incident to a member of the public. Based on the risk estimates discussed in section 5.A., this level of exposure, should it occur, would present less than 1 chance in 200,000 of contracting fatal cancer.

The proposed action would serve to reduce exposures to radiological workers through control of sealed radioactive sources and prevent inadvertent exposure to others and, therefore, represents a positive impact on the human environment.

### 5.B.2. Proposed Tritium Surface Radioactivity Values

Proposed values for removable tritium surface radioactivity would be included in appendix D of 10 CFR Part 835. A value of 10,000 disintegrations per second (dpm) per 100 square centimeters ($cm^2$) has been proposed for the removable tritium surface radioactivity value. Appendix D of this document presents a summary of the methodology used for establishing recommended tritium surface radioactivity values using derived shallow dose equivalent (SDE) or CEDE factors for a single contact with surfaces contaminated with removable tritium. The appendix also explains why promulgation of a total (fixed plus removable radioactivity) tritium surface radioactivity value is inappropriate.

As discussed in appendix A, the dose equivalent factors are expressed in dose (mrem) per incident at the proposed surface radioactivity value for the three predominant pathways of exposure to HTO and HT, namely inhalation, skin uptake, and skin retention. The HTO inhalation pathway gives the largest CEDE per unit tritium surface contamination. The largest CEDE to an individual from release of an item having tritium surface contamination at the proposed levels is calculated to be approximately 0.0025 mrem (see appendix D, section 4, Table 1). Based on the risk estimates discussed in section 5.A. above, this exposure presents a chance of contracting fatal cancer of 1 in 800,000,000. In view of the small number of individuals who may be so exposed, the possibility of adverse human health effects is very remote.

## 5.C. Human Health Effects of Alternative Actions

### 5.C.1. Sealed Radioactive Source Requirements

#### 5.C.1.1. No Action Alternative

If the no action alternative is selected, the standards provided in DOE Notice 441.1 would continue to be imposed through contractual mechanisms. This approach provides DOE with less assurance that these standards will be consistently applied. Failure to comply with the proposed sealed radioactive source requirements could lead to increased personnel exposures and human health effects.

#### 5.C.1.2. Establish Different Requirements

The range of potential alternatives to establishing the sealed radioactive source control requirements different from those contained in the proposed amendment includes establishing more restrictive or less restrictive requirements. As discussed in section 5.B.1., the potential health effects from the proposed sealed radioactive source requirements are very low. The sealed radioactive source exception levels have been established such that the risk estimate of fatal cancer for an individual from exposure to an uncontrolled source (exempted from certain control requirements) is less than 1 in 200,000. This level of risk is well below the risk associated with safe industries as previously described. DOE believes that

establishing more restrictive requirements would not lower human health risks commensurate with the increased costs. However, DOE will consider arguments for more restrictive requirements during the public comment period on the proposed rulemaking.

Less restrictive requirements might provide adequate protection while maintaining the risk of serious health effects low. DOE will consider arguments for less restrictive, as well as more restrictive, requirements during the public comment period on the proposed rulemaking.

5.C.2. Tritium Surface Radioactivity Values

5.C.2.1. No Action Alternative

If DOE selects the no action alternative, the generic beta-gamma values specified in the current appendix D to 10 CFR Part 835 will continue to be applied to tritium. As discussed above in section 5.B.2., the risk estimate of potential serious health effects from exposure to the proposed tritium surface radioactivity values are extremely small (1 in 800,000,000). Continued imposition of more restrictive levels resulting from the no action alternative is not necessary or useful to protect health.

5.C.2.2. Establish Different Requirements

The range of potential alternatives to establishing tritium surface radioactivity values, other than those proposed for appendix D to 10 CFR Part 835, includes establishing more restrictive or less restrictive levels. The proposed values are consistent with those provided in the DOE Radiological Control Manual. Levels lower than those proposed would provide no appreciable lowering of the potential human health risks.

Although it may be possible to establish higher levels in view of the low risk estimate for serious health effects discussed in section 5.B.2., higher levels do not currently appear to be required by operational needs. The current proposal appears to be prudent, is compatible with operational needs and provides commensurate economic benefit. However, DOE will consider

arguments for higher levels, as well as lower levels if new information is presented during the public comment period on the proposed rulemaking.

5.D. Adverse Environmental Impacts on Sensitive Resources

Sensitive resources, such as floodplains, wetlands, threatened or endangered species, and unique agricultural lands, in the environs of DOE sites would not be affected by these proposed actions because the actions concern only occupational radiation protection. 10 CFR Part 835 does not regulate the release of radioactive material to the environment. Such releases are controlled by other DOE standards and regulations. However, the potential radiological impact of accidental release of sealed radioactive sources and objects with tritium surface contamination has been addressed by this environmental assessment. These potential accidental releases would have no impact on sensitive resources.

6. Compliance with Other Regulations

To the best knowledge of DOE, the proposed amendments to 10 CFR Part 835 are in compliance with other applicable regulations.

7. References

[1] 10 CFR Part 835. 1993. U.S. Department of Energy, "Occupational Radiation Protection." U.S. Code of Federal Regulations.

[2] DOE Order 5480.11. 1992. "Radiation Protection for Occupational Workers." U.S. Department of Energy.

[3] Federal Register, Vol. 52. No. 17, pg. 2822; 1/27/87, Presidential Documents, "Radiation Protection Guidance to Federal Agencies for Occupational Exposure."

[4] DOE Notice 441.1. 1995. "Radiological Protection for DOE Activities." U.S. Department of Energy.

[5] DOE Order 460.1. 1995. "Packaging and Transportation Safety." U.S. Department of Energy; DOE Order 460.2. 1995. "Departmental Materials Transportation and Packaging Management." U.S.

Department of Energy; DOE Order 5610.12. 1994. "Packaging and Offsite Transportation of Nuclear Components and Special Assemblies Associated with the Nuclear Explosive and Weapons Safety Program." U.S. Department of Energy; and DOE Order 5610.14. 1993. "Transportation Safeguards System Program Operations." U.S. Department of Energy.

[6] DOE/EH-0256T. Revision 1. 1994. DOE Radiological Control Manual. U.S. Department of Energy

[7] DOE Order 231.1. "Environment, Safety, and Health Reporting." 1995. U.S. Department of Energy.

[8] Price-Anderson Amendments Act of 1988, Public Law No. 100-408, August 20, 1988, 42 U.S.C.A. § 2282a (1994).

[9] Federal Register, Vol. 58. No. 238, pg. 65466; 12/14/93.

[10] DOE/EH-0026. 1986. Handbook for the Department Of Energy Laboratory Accreditation Program for Personnel Dosimetry Systems. U.S. Department of Energy, and DOE/EH-0027. 1986. Department Of Energy Standard for the Performance Testing of Personnel Dosimetry Systems. U.S. Department of Energy.

[11] DOE Notice 5400.9. 1991. "Sealed Radioactive Source Accountability." U.S. Department of Energy.

[12] DOE Notice 5400.10. 1992. "Sealed Radioactive Source Accountability." U.S. Department of Energy.

[13] DOE Notice 5400.11. 1993. "Sealed Radioactive Source Accountability." U.S. Department of Energy.

[14] DOE Notice 5400.12. 1994. "Sealed Radioactive Source Accountability." U.S. Department of Energy.

[15] DOE Notice 5400.13. 1994. "Sealed Radioactive Source Accountability." U.S. Department of Energy.

[16] DOE Order 5400.5. 1990. "Radiation Protection of the Public and the Environment." U.S. Department of Energy.

[17] National Council on Radiation Protection and Measurements, March 1993. Limitation of Exposure to Ionizing Radiation. NCRP Report No. 116. Bethesda, MD.

[18] National Research Council, Committee on the Radiological Effects of Ionizing Radiation (BEIR V). 1990. Health Effects of Exposure to Low Levels of Ionizing Radiation. National Academy Press, Washington D.C.

## 8. Appendices

8.A. Definitions
8.B. Proposed Sealed Radioactive Source Control Requirements and Accountability Values
8.C. Proposed Tritium Surface Radioactivity Values
8.D. Calculations for Tritium Dose Estimates

# APPENDIX A

# DEFINITIONS

Definitions - These terms, as used in this Environmental Assessment, are defined as follows:

***Absorbed dose*** (D) means the energy absorbed by matter from ionizing radiation per unit mass of irradiated material at the place of interest in that material. The absorbed dose is expressed in units of rad (or gray)(1 rad = 0.01 gray).

***Collective dose*** means the sum of the total effective dose equivalent values for all individuals in a specified population. Collective dose is expressed in units of person-rem (or person-sievert).

***Committed dose equivalent*** (CDE) means the dose equivalent calculated to be received by a tissue or organ over a 50-year period after the intake of a radionuclide into the body. It does not include contributions from radiation sources external to the body. Committed dose equivalent is expressed in units of rem (or sievert).

***Committed effective dose equivalent*** (CEDE) means the sum of the committed dose equivalents to various tissues in the body (CDE), each multiplied by the appropriate weighting factor ($w_t$) - that is CEDE = $\Sigma w_t$CDE. CEDE is expressed in units of rem (or sievert).

***Controlled area*** means any area to which access is managed in order to protect individuals from exposure to radiation and/or radioactive material. Individuals who enter only the controlled area without entering radiological areas are not expected to receive a total effective dose equivalent of more than 100 mrem (0.001 sievert) in a year.

***Cumulative total effective dose equivalent*** means the sum of the total effective dose equivalents recorded for an individual each year of employment at a DOE or DOE contractor site or facility, effective January 1, 1989.

***Deep dose equivalent*** (DDE) means the dose equivalent derived from external radiation at a depth of 1 cm in tissue.

***Dose equivalent*** (H) means the product of absorbed dose (D) in rad (or gray) in tissue, a quality factor (Q), and other modifying factors (N). Dose equivalent is expressed in units of rem (or sievert) (1 rem = 0.01 sievert).

***Effective dose equivalent*** ($H_E$) means the summation of the products of the dose equivalent received by specified tissues of the body ($H_T$) and the appropriate weighting factor ($w_T$) - that is $H_E = \Sigma w_T H_T$. It includes the dose from radiation

sources internal and/or external to the body. The effective dose equivalent is expressed in units of rem (or sievert).

***External dose or exposure*** means that portion of the dose equivalent received from radiation sources (e.g., "external sources") outside the body.

***Extremity*** means hands and arms below the elbow or feet and legs below the knee.

***General employee*** means an individual who is either a DOE or DOE contractor employee; an employee of a subcontractor to a DOE contractor; or a visitor who performs work for or in conjunction with DOE or utilizes DOE facilities.

***Internal dose or exposure*** means that portion of the dose equivalent received from radioactive materials taken into the body (e.g., "internal sources").

***Lens of the eye dose equivalent*** means the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 cm.

***Quality factor*** (Q) means the principal modifying factor used to calculate the dose equivalent from the absorbed dose; the absorbed dose (expressed in rad or gray) is multiplied by the appropriate quality factor. The quality factors used for determining dose equivalent in rem are provided in 10 CFR Part 835, "Occupational Radiation Protection."

***Shallow dose equivalent*** means the dose equivalent deriving from external radiation at a depth of 0.007 cm in tissue.

***Total effective dose equivalent*** (TEDE) means the sum of the effective dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures). For the purposes of determining compliance with 10 CFR Part 835, deep dose equivalent to the whole body may be used as effective dose equivalent for external exposures.

***Weighting factor*** ($w_T$) means the fraction of the overall health risk, resulting from uniform, whole body irradiation, attributable to specific tissue (T). The dose equivalent to tissue, T, is multiplied by the appropriate weighting factor to obtain the effective dose equivalent contribution from that tissue. The weighting factors are provided in 10 CFR Part 835.

***Whole body*** means, for the purposes of external exposure, head, trunk (including male gonads), arms above and including the elbow, or legs above and including the knee.

# APPENDIX B

## PROPOSED SEALED RADIOACTIVE SOURCE CONTROL REQUIREMENTS AND ACCOUNTABILITY VALUES

## Proposed Requirements for Sealed Radioactive Source Control

§ 835.2 Definitions.

(a) As used in this part:

*Accountable sealed radioactive source* means a sealed radioactive source having a half-life equal to or greater than 30 days and an isotopic activity equal to or greater than the corresponding value provided in appendix E of this part.

*Sealed radioactive source* means a radioactive source manufactured, obtained, or retained for the purpose of utilizing the emitted radiation. The sealed radioactive source consists of a known or estimated quantity of radioactive material contained within a sealed capsule, sealed between layer(s) of non-radioactive material, or firmly fixed to a non-radioactive surface by electroplating or other means intended to prevent leakage or escape of the radioactive material.

*Source leak test* means a test to determine if a sealed radioactive source is leaking radioactive material.

§ 835.704 Administrative records.

(f) Records shall be maintained as necessary to evaluate compliance with the requirements of §§ 835.1201 and 835.1202 for sealed radioactive source written procedures, inventory, and leak testing.

Subpart M-- Sealed Radioactive Source Control

§ 835.1201 General provisions.

(a) Written procedures shall be established and implemented to establish measures used for control of accountable sealed radioactive sources.
(b) Accountable sealed radioactive sources, or their storage containers or devices, shall be labeled in accordance with § 835.605. Such labels are exempt from the design and color specifications of § 835.601(c).

§ 835.1202 Inventories and leak tests.

(a) Each accountable sealed radioactive source shall be inventoried at intervals not to exceed six months. This inventory shall:
(1) Establish the physical location of each accountable sealed radioactive source;

(2) Verify the presence and adequacy of associated postings and labels; and

(3) Establish the adequacy of storage locations, containers, and devices.

(b) Except for sealed sources consisting solely of gaseous radioactive material or tritium, each accountable sealed radioactive source having an activity in excess of 0.005 $\mu$Ci shall be subject to a source leak test upon receipt, when damage is suspected, and at intervals not to exceed six months. Source leak tests shall be capable of detecting radioactive material leakage equal to or exceeding 0.005 $\mu$Ci.

(c) Notwithstanding the requirements of paragraph (b) of this section, an accountable sealed radioactive source is not subject to periodic source leak testing if that source has been removed from service. Such sources shall be stored in a controlled location, subject to periodic inventory as required by paragraph (a) of this section, and subject to source leak testing prior to being returned to service.

(d) Notwithstanding the requirements of paragraph (b) of this section, an accountable sealed radioactive source is not subject to periodic inventory and source leak testing if that source is located in an area that is unsafe for human entry.

(e) An accountable sealed radioactive source found to be leaking radioactive material shall be controlled in a manner that prevents the escape of radioactive material to the workplace.

## Appendix E to Part 835--Values for Exception From Sealed Radioactive Source Accountability and Posting and Labeling Requirements

Less than 300 $\mu$Ci (10 MBq)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| H-3 | Be-7 | C-14 | S-35 | Ca-41 | Ca-45 | V-49 | Mn-53 |
| Fe-55 | Ni-59 | Ni-63 | As-73 | Se-79 | Rb-87 | Tc-99 | Pd-107 |
| Cd-113 | In-115 | Te-123 | Cs-135 | Ce-141 | Gd-152 | Tb-157 | Tm-171 |
| Ta-180 | W-181 | W-185 | W-188 | Re-187 | Tl-204 | | |

Less than 30 $\mu$Ci (1 MBq)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Cl-36 | K-40 | Fe-59 | Co-57 | Se-75 | Rb-84 | Sr-85 | Sr-89 |
| Y-91 | Zr-95 | Nb-93m | Nb-95 | Tc-97m | Ru-103 | Ag-105 | In-114m |
| Sn-113 | Sn-119m | Sn-121m | Sn-123 | Te-123m | Te-125m | Te-127m | Te-129m |
| I-125 | La-137 | Ce-139 | Pm-143 | Pm-145 | Pm-147 | Sm-145 | Sm-151 |
| Eu-149 | Eu-155 | Gd-151 | Gd-153 | Dy-159 | Tm-170 | Yb-169 | Lu-173 |
| Lu-174 | Lu-174m | Hf-175 | Hf-181 | Ta-179 | Re-184 | Re-186m | Ir-192 |
| Pt-193 | Au-195 | Hg-203 | Pb-205 | Np-235 | Pu-237 | | |

Less than 3 $\mu$Ci (100 kBq)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Be-10 | Na-22 | Al-26 | Si-32 | Sc-46 | Ti-44 | Mn-54 | Fe-60 |
| Co-56 | Co-58 | Co-60 | Zn-65 | Ge-68 | Rb-83 | Y-88 | Zr-88 |
| Zr-93 | Nb-94 | Mo-93 | Tc-95m | Tc-97 | Tc-98 | Ru-106 | Rh-101 |
| Rh-102 | Rh-102m | Ag-108m | Ag-110m | Cd-109 | Sn-126 | Sb-124 | Sb-125 |
| Te-121m | I-129 | Cs-134 | Cs-137 | Ba-133 | Ce-144 | Pm-144 | Pm-146 |
| Pm-148m | Eu-148 | Eu-150 | Eu-152 | Eu-154 | Gd-146 | Tb-158 | Tb-160 |
| Ho-166m | Lu-176 | Lu-177m | Hf-172 | Ta-182 | Re-184m | Os-185 | Os-194 |
| Ir-192m | Ir-194m | Hg-194 | Pb-202 | Bi-207 | Bi-210m | Cm-241 | |

Less than 0.3 $\mu$Ci (10 kBq)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sr-90 | Cd-113m | La-138 | Hf-178m | Hf-182 | Po-210 | Ra-226 | Ra-228 |
| Pu-241 | Bk-249 | Es-254 | | | | | |

Less than 0.03 $\mu$Ci (1 kBq)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sm-146 | Sm-147 | Pb-210 | Np-236 | Cm-242 | Cf-248 | Fm-257 | Md-258 |

Less than 0.003 $\mu$Ci (100 Bq)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Gd-148 | Th-228 | Th-230 | U-232 | U-233 | U-234 | U-235 | U-236 |
| U-238 | Np-237 | Pu-236 | Pu-238 | Pu-239 | Pu-240 | Pu-242 | Pu-244 |
| Am-241 | Am-242m | Am-243 | Cm-243 | Cm-244 | Cm-245 | Cm-246 | Cm-247 |
| Bk-247 | Cf-249 | Cf-250 | Cf-251 | Cf-252 | Cf-254 | | |

Less than 0.0003 $\mu$Ci (10 Bq)

| | | | | | |
|---|---|---|---|---|---|
| Ac-227 | Th-229 | Pa-231 | Th-232 | Cm-248 | Cm-250 |

Any alpha emitting radionuclide not listed above and mixtures of alpha emitters of unknown composition having a value of less than 0.001 $\mu$Ci.

Any radionuclide other than alpha emitting radionuclides not listed above and mixtures of beta emitters of unknown composition having a value of less than 0.01 $\mu$Ci.

Note: Where there is involved a combination of radionuclides in known amounts, derive the value for the combination as follows: determine, for each radionuclide in the combination, the ratio between the quantity present in the combination and the value otherwise established for the specific radionuclide when not in combination. If the sum of such ratios for all radionuclides in the combination exceeds unity, then the accountability criterion has been exceeded.

# APPENDIX C

## Proposed Tritium Surface Radioactivity Values

## Appendix D to Part 835--Surface Radioactivity Values

### Surface Radioactivity Values;[1] in dpm/100 $cm^2$

| Radionuclide | Removable [2,4] | Total (Fixed + Removable)[2,3] |
|---|---|---|
| U-nat, U-235, U-238, and associated decay products | 1,000 (alpha) | 5,000 (alpha) |
| Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129 | 20 | 500 |
| Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133 | 200 | 1,000 |
| Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.[5] | 1,000 | 5,000 |
| Tritium and tritiated compounds[6] | 10,000 | N/A |

[1] The values in this appendix, with the exception noted in footnote 6 below, apply to radioactive contamination deposited on, but not incorporated into the interior of, the contaminated item. Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides apply independently.

[2] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute observed by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[3] The levels may be averaged over one square meter provided the maximum surface activity in any area of 100 $cm^2$ is less than three times the value specified. For purposes of averaging, any square meter of surface shall be considered to be above the surface radioactivity value if: (1) from measurements of a representative number of sections it is determined that the average contamination level exceeds the applicable value; or (2) it is determined that the sum of the activity of all isolated spots or particles in any 100 $cm^2$ area exceeds three times the applicable value.

[4] The amount of removable radioactive material per 100 $cm^2$ of surface area should be determined by swiping the area with dry filter or soft absorbent paper, applying moderate pressure, and then assessing the amount of radioactive material on the swipe with an appropriate instrument of known efficiency. (Note - The use of dry material may not be appropriate for tritium.) When removable contamination on objects of surface area less than 100 $cm^2$ is determined, the activity per unit area shall be based on the actual area and the entire surface shall be wiped. It is not necessary to use swiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.

[5] This category of radionuclides includes mixed fission products, including the Sr-90 which is present in them. It does not apply to Sr-90 which has been separated from the other fission products or mixtures where the Sr-90 has been enriched.

[6] Tritium contamination may diffuse into the volume or matrix of materials. Evaluation of surface contamination shall consider the extent to which such contamination may migrate to the surface in order to ensure the surface radioactivity value provided in this appendix is not exceeded. Once this contamination migrates to the surface, it may be removable, not fixed, therefore a "Total" value does not apply.

# APPENDIX D

# CALCULATIONS FOR TRITIUM DOSE ESTIMATES

1. Introduction

Tritium is a low-energy, pure beta-emitting radionuclide with a half-life of 12.43 years [1]. The low beta decay energy of tritium (maximum energy 18.6 kiloelectronvolts [keV; 1 keV = $10^3$ eV], mean energy 5.685 keV) [2] generally requires that tritium be taken into the body before any damage to living tissue can occur. Tritium does not present an external radiation hazard. When tritium is taken into the body as tritiated water or as tritiated hydrogen gas, it tends to be dispersed throughout the whole body in the water of body tissues. Because of its low beta energy, its dilution throughout all of the soft tissues (as opposed to concentration in selected organs), and its relatively short biological half-life (about 10 days [3]), tritium has an extremely low radiological toxicity when compared to other pure-beta emitters, such as phosphorus-32 or strontium-90, or to common beta-gamma emitters, such as iodine-131 or cesium-137 (barium-137).

Despite its physical and biological characteristics, tritium is occasionally grouped with other beta emitters and/or beta-gamma emitters, as is the case for the surface radioactivity values currently in 10 CFR Part 835, "Occupational Radiation Protection" [4]. 10 CFR Part 835, Subpart L, "Release of Materials and Equipment From Radiological Areas", provides requirements for the release of materials and equipment from radiological areas for conditional use in controlled areas and references 10 CFR Part 835 appendix D for the permissible surface radioactivity values. The surface radioactivity values for tritium are currently "Reserved" in 10 CFR Part 835, but have been published in the DOE Radiological Control Manual. Following further consideration by DOE, a removable surface radioactivity value of 10,000 dpm per 100 $cm^2$ is being proposed for incorporation into appendix D of 10 CFR Part 835.

The purpose of this calculation is to verify that the proposed removable tritium surface radioactivity value of 10,000 dpm per 100 $cm^2$ does not pose an undue risk to individuals.

2. Definitions

For the purposes of this calculation, the following definitions apply:

2.1 Protium - The physical name for the hydrogen isotope of atomic mass 1. In common usage, the chemical symbol for protium is H.

2.2 Deuterium - The physical name for the hydrogen isotope of atomic mass 2. In common usage, the chemical symbol for deuterium is D.

2.3 Tritium - The physical name for the hydrogen isotope of atomic mass 3. In common usage, the chemical symbol for tritium is T.

2.4 HT - In this calculation, unless otherwise noted, the chemical notation for tritium (T) in combination with other hydrogen isotopes (H, D, T) to form elemental tritium gas. It will be used here to represent HT, DT and $T_2$.

2.5 HTO - In this calculation, the chemical notation for tritiated water in combination with other hydrogen isotopes. It will be used here to represent HTO, DTO, and $T_2O$.

2.6 Removable Contamination - The portion of the total tritium surface contamination (see section 2.8 of this appendix) which is removable or transferable under normal working conditions. The removable tritium surface contamination is assumed to be identical to that which can be measured directly through the use of smear survey measurements and liquid scintillation counting techniques. This definition applies to the removable "Surface Radioactivity Value" given in appendix D to 10 CFR Part 835.

2.7 Total Tritium Surface Contamination - The total tritium activity adsorbed upon, and/or absorbed into, the surface of the material.

2.8 Removal Fraction ($F_r$) - The fraction of the total surface contamination (see section 2.7 of this appendix) that is readily removable (see section 2.6 of this appendix) or readily transferable to skin under normal working conditions. A value of 0.1 can be assumed for $F_r$ [5], or alternatively, it can be determined experimentally if the items being considered for release are of a routine and consistent nature, so that the experimentally determined value of one item can be applied to another.

2.9 Tritium Decay Induced Bremsstrahlung - The production of a continuous spectrum of low energy X-rays, caused by Beta particles emitted during tritium decay, which may indirectly result in an external radiation hazard [6]. The amount of tritium induced bremsstrahlung will depend on the material and the total amount of tritium that has been dissolved into or otherwise incorporated into the material. Tritium induced

bremsstrahlung has been measured in a variety of materials. Examples include vacuum pump oils, paper products, and various metals [7].

2.10 Outgassing - The generic term for the evolution of tritium gas into the atmosphere from materials that have been exposed to that gas. Tritium outgassing can be expected from any material that has been exposed to tritium gas, which will continue until the tritium in the material has reached background levels.

3. Assumptions

3.1 Exposure Pathways - Tritium contamination in or on surfaces can result in doses to individuals in four different ways: external radiation, inhalation, ingestion, and skin absorption.

3.1.1 External Radiation - At low levels of tritium surface contamination, where releases of materials and equipment would be allowed, significant emission of low energy bremsstrahlung will not occur (see section 2.9 of this appendix). The maximum energy of the tritium beta particle is only 18.6 keV. The maximum range of these particles in tissue is only about 6 micrometers ($\mu$m; 1 $\mu$m = $10^{-6}$ meter). The beta radiation from tritium does not represent an external radiation hazard because the depth of cells in the skin is greater than 30 $\mu$m [8] and the radio-sensitive tissue of the eye is at a depth of 3 millimeter (mm; 1 mm = $10^{-3}$ meter) [9].

The detection of induced bremsstrahlung typically requires tritium amounts ranging upward from tens of millicuries per 100 $cm^2$. Induced bremsstrahlung will not be detectable in materials with removable surface contamination in the range proposed (10,000 dpm/100 $cm^2$ or approximately $4.5 \times 10^{-6}$ millicurie/100 $cm^2$) [5]. Materials that produce measurable amounts of tritium-induced bremsstrahlung should not be considered for release to controlled areas except as contaminated waste. In the absence of bremsstrahlung, the fixed tritium contamination is of no consequence because it presents no external radiation hazard.

3.1.2 Inhalation - The inhalation pathway needs to be considered if tritiated gases and/or particles become airborne. Usually, airborne tritium can be expected to be present as HT and/or

HTO vapor. Inhalation of HTO and HT compounds has been extensively studied [10,11,12]. Exposures to airborne tritiated organic compounds, airborne tritiated particles and tritides, and other tritiated gases have been seen in the workplace [5]. However, less is known about these compounds, and dosimetry models do not generally exist for specific compounds. (Note: Real-time monitoring may be used to detect relatively high tritium outgassing levels. This will depend on the material and its exposure history, but in general, if tritium outgassing can be detected in real time, the material should not be considered for release to controlled areas except as contaminated waste.)

3.1.3 Ingestion - This route of uptake of tritium should only be expected from the ingestion of food or liquids that have been contaminated by handling tritium contaminated items. Since it is conservatively assumed (see section 3.1.4) that all tritium that gets into the hands will be absorbed into and/or through the skin, the ingestion pathway of exposure can be disregarded for the purposes of this calculation as it will not be the most limiting.

3.1.4 Skin Absorption - By the late 1950's, Pinson and Langham [10], and DeLong, Thompson and Kornberg [13], had independently shown that HTO can be readily absorbed through the skin in both the liquid and vapor phases. Osborne [14] showed that the intake of HTO vapor in air by this route was approximately equal to one half the intake via inhalation, assuming a breathing rate of 20 liters per minute (1.2 $m^3$ per hr) during light work.

The International Commission on Radiological Protection (ICRP) [3] recommends that the inhalation rate be increased by a factor of 1.5 to account for skin absorption from tritiated water vapor.

No significant skin absorption of HT in air occurs. However, studies by Vaughan and Davis [15] found that high concentrations of tritiated gas on various metals and glass can be transferred to the skin by contact. Further studies by Hutchin and Vaughan [16], Eakins et al. [17,18], and Johnson et al. [19,20], have shown that if skin comes into

contact with surfaces that have been exposed to high concentrations of HT gas, significant uptake and retention of tritium occurs in the skin, as well as in other organs. The processes by which this occurs are not fully understood.

As described above, inhalation and skin absorption will be the limiting routes of tritium intake that need to be considered for tritium surface radioactivity values. While ingestion may also occur, it will not be limiting for surface radioactivity values because of the assumptions used. External exposure to radiation from tritium does not present a hazard, and thus need not be considered.

3.2 Dose Estimate Considerations - The uptake and retention, and hence the dose conversion factors, for tritium will depend on the chemical and physical form of the tritium under consideration. While HTO and HT are the principal tritium forms present at DOE facilities, different forms could be present and are discussed below.

3.2.1 Tritiated Water (HTO) - Intakes can occur from skin contact with contaminated surfaces and from the inhalation of air contaminated by HTO evaporating or outgassing from surfaces. The committed effective dose equivalent is $1.7 \times 10^{-11}$ Sv per Bq intake [3].

3.2.2 Tritiated Hydrogen Gas (HT) - Current knowledge of HT interaction with surfaces is incomplete. It is known that stainless steel surfaces will retain HT [21]. Skin contamination can result from contacting such a contaminated surface. Dosimetric experiments involving HT contamination of animal skin have estimated the skin dose conversion factor at the point of contact to be $3 \times 10^{-9}$ Sv per Bq/cm$^2$ [20,22]. This dose is assumed to result only from the skin absorption of tritium, with no contribution from external radiation and should be considered a shallow dose equivalent.

Experiments have been conducted to clarify the extent and magnitude of doses to other tissues that may result from tritium transmitted through the skin in this manner. However, based on this understanding [19,20,22], it is thought that the skin dose will be more than 10 times the committed effective dose equivalent, making the skin the limiting factor.

3.2.3 Metal Tritides - Some metal tritides are known to spontaneously oxidize in air at respirable[1] sizes (<100 $\mu$m Activity Median Aerodynamic Diameter) depending on the metal, with either HT or HTO being produced. Others may not spontaneously oxidize. No dose assessment methodology exists by which the dose from inhalation of small particles of metal trioxides can be evaluated. As a first approximation, they could be treated as a Class Y compound [3]. However, if the organically bound tritium seen by Eakins et al. [17,18] and others [20,22] is also produced in the lungs from the tritide particles in contact with tissues in the lung, the estimation of doses from tritide particles will need reevaluation.

Despite these difficulties, metal tritide particles should not pose a concern outside radiological areas. Metal tritides will not diffuse into the matrix of materials and will only be a concern if present as removable surface contamination. If metal tritides exceed the surface radioactivity values of 10 CFR 835, they are readily decontaminated.

3.2.4 Low Molecular Weight Organic Compounds - Low molecular weight organic compounds will be catabolized quickly in the human body, resulting in HTO production, or will be excreted directly. Since there is no generally accepted dosimetry model for these compounds, it will be conservatively assumed that the intakes, and the dose per microcurie intake is the same for these compounds as for HTO. These compounds should not pose a concern outside radiological areas since they are readily removed from surfaces during routine decontamination procedures.

3.2.5 High Molecular Weight Organic Compounds, such as DNA Precursors - In general, these compounds are not volatile and should not result in airborne tritium from surface contamination. Since high molecular weight compounds are not as easily absorbed through the skin as HTO, it is unlikely that these compounds would be more limiting than HTO.

---

1 Particles up to a size of 100 $\mu$m can get into and impact in the nose, and thus can be termed "respirable."

Therefore, skin uptake should not be a factor. Following the recommendation of the ICRP [3], the dose per microcurie intake can be taken to be 10 times that of HTO. These compounds should not pose a concern outside radiological areas since they are readily removed from surfaces during routine decontamination procedures.

As discussed in the preceding sections, HTO and HT contaminated surfaces will result in the largest doses per unit of tritium surface contamination and hence only these two compounds need to be considered for the environmental assessment. Low molecular weight compounds can be conservatively treated as HTO. Surfaces contaminated by high molecular weight organic compounds can also be treated as HTO since the combination of low uptake through the skin and low volatility will make this a conservative assumption. Decontamination of surfaces contaminated with both types of organic compounds should lead to very low levels of residual tritium contamination. Surfaces contaminated by metal tritides are also easily decontaminated to very low levels.

## 4. Doses From a Single Contact with Tritium Contaminated Surfaces

Of the exposure pathways and the chemical and physical forms considered above, the limiting combinations are:

Inhalation or skin uptake of HTO - The committed effective dose equivalent (CEDE) is the applicable dose for this pathway, and the dose conversion factor is $1.7 \times 10^{-11}$ Sv per Bq intake [3].

Skin contamination from HT contaminated surfaces - Skin dose is the applicable dose from this pathway and the estimated skin dose conversion factor is $3 \times 10^{-9}$ Sv per Bq/cm$^2$ [20,22].

Scenarios that involve exposure to HTO or HT contaminated surfaces are evaluated below.

### 4.1 Skin Uptake of HTO

Assumptions:

- The dose conversion factor for skin uptake of HTO is $1.7 \times 10^{-11}$ Sv per Bq.

- The surface contamination level is 1 Bq per $cm^2$.
- The surface area contacted by hands is generally estimated to be 200 $cm^2$.
- The fraction of tritium removed by contact with hands, $F_r$, is 0.1 (see section 2.8 of this appendix).
- All HTO on the hands is assumed to be taken into the body.
- The contamination is uniformly distributed (i.e. 10,000 dpm per 100 $cm^2$ can be represented by 100 dpm per $cm^2$).

In this example, the individual contacts the contaminated object with his hands. When all the removable tritium is transferred to the hands, they will be contaminated with 20 Bq of tritium:

200 $cm^2$ x 0.1 x 1 Bq/$cm^2$ = 20 Bq.

The derived dose conversion factor for one skin contamination for this example is: 20 Bq x 1.7 x $10^{-11}$ Sv/Bq = 3.4 x $10^{-10}$ Sv (per Bq/$cm^2$ of contamination)

The dose due to one exposure at the proposed removable tritium surface radioactivity value (10,000 dpm per 100 $cm^2$ represented as uniform contamination at 100 dpm per $cm^2$) is as follows:

$$3.4 \times 10^{-10} \frac{Sv\ cm^2}{Bq} \times \frac{100\ dpm}{cm^2} \times \frac{1\ Bq}{60\ dpm} \times \frac{100\ rem}{Sv} \times \frac{1000\ mrem}{rem} = 5.7 \times 10^{-5}\ mrem\ per\ event$$

It should be noted that if all the available tritium were removable, i.e., $F_r$ = 1.0, the dose would increase by a factor of 10 or if an individual were subjected to multiple exposures, the dose may increase by as much as a factor of 10. In either case, the resulting dose would still be very small.

4.2 Inhalation of HTO

Assumptions:

- The dose conversion factor for inhalation of HTO is 1.7 x $10^{-11}$ Sv per Bq.
- An individual is in a small room (20 $m^3$) with an object contaminated with tritium for 1 hour.
- The object has a surface area of 1 $m^2$ (approximately an open 1-foot-square box, considering all 12 surfaces).

- Ventilation in the room is not considered.
- All the tritium contamination is assumed to leave the surface via exchange with water vapor and be airborne for the duration of the worker's stay.
- The tritium vapor is uniformly distributed.
- The worker's breathing rate is 1.2 $m^3$ per hour, resulting in an effective breathing rate of 1.8 $m^3$ per hour due to skin uptake (see section 3.1.4 of this appendix).
- The contamination level is 1 Bq per $cm^2$.

In this example, the fraction of tritium taken in by the worker is conservatively estimated to be 9% of the available tritium ([1.8 $m^3$ /hr ÷ 20 $m^3$] x 1 hour = 0.09. For the assumed surface contamination, an intake of 9.0 x $10^2$ Bq is estimated.

The derived dose conversion factor due to inhalation for this example is:

900 Bq x 1.7 x $10^{-11}$ Sv/Bq = 1.5 x $10^{-8}$ Sv (per Bq/$cm^2$ of contamination).

The dose due to one exposure at the proposed removable tritium surface radioactivity value (10,000 dpm per 100 $cm^2$ represented as uniform contamination at 100 dpm per $cm^2$) is as follows:

$$1.5 \times 10^{-8} \frac{Sv\ cm^2}{Bq} \times \frac{100\ dpm}{cm^2} \times \frac{1\ Bq}{60\ dpm} \times \frac{100\ rem}{Sv} \times \frac{1000\ mrem}{rem} = 2.5 \times 10^{-3}\ mrem\ per\ event$$

This fraction of intake is independent of the rate that tritium evolves from the surface, and only depends on the relative magnitude of the breathing rate (plus skin uptake). However, if the worker inhaled all the available tritium, the dose would be increased by about a factor of 10 and the resulting dose would still be very small. It should also be noted that the combination of a 20 $m^3$ volume room, a 1 $m^2$ contaminated surface, no ventilation, and continuous occupancy is conservative. As an example, equipment with larger surfaces could be assumed in the calculation, but it is unlikely that it would be put into such a small room with no ventilation, and that someone would occupy that room continuously for one hour.

4.3 Skin Retention of HT

The shallow dose equivalent conversion factor, based on dosimetric experiments for skin retention is $3 \times 10^{-9}$ Sv per Bq per $cm^2$ of surface contamination [20,22]. The same hand contamination modeled in section 4.1 of this appendix is assumed. The dose is a skin dose only, or shallow dose equivalent.

The dose due to one exposure event at the proposed removable tritium surface radioactivity value (10,000 dpm per 100 $cm^2$ represented as uniform contamination at 100 dpm per $cm^2$) is as follows:

$$3 \times 10^{-9} \frac{Sv\ cm^2}{Bq} \times \frac{1\ Bq}{60\ dpm} \times \frac{100\ rem}{Sv} \times \frac{1000\ mrem}{rem} = 5 \times 10^{-4}\ mrem\ per\ event$$

It should be noted that if all the available tritium were removable, i.e., $F_r = 1.0$, the dose would only increase by a factor of 10 or if an individual were subjected to multiple exposures the total dose may increase by as much as a factor of 10. In either case, the resulting dose would still be very small.

**Table 1. Summary of Dose Estimates from Exposure at the Proposed Removable Tritium Surface Radioactivity Value (in mrem)**

| | Inhalation | Skin Uptake | Skin Retention |
|---|---|---|---|
| **HTO** | $2.5 \times 10^{-3}$ | $5.7 \times 10^{-5}$ | -- |
| **HT**[2] | -- | -- | $5 \times 10^{-4}$ |

[2] This is the shallow dose equivalent for skin, which can be multiplied by a factor of 0.1 for comparison to the committed effective dose equivalent given for inhalation and skin uptake.

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