# RMI-L-60

# RMIEP HEALTH PHYSICS MANUAL

RMI Titanium Company
Extrusion Plant
P.O. Box 579
Ashtabula, Ohio 44004

11/91 Date Revised

Health Physics

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## TABLE OF ACRONYMS

| ACRONYM | DESCRIPTION |
|---|---|
| ALARA | As Low As Reasonably Achievable |
| ANSI | American National Standards Institute |
| BZ | Breathing Zone |
| CAM | Constant Air Monitor |
| CFR | Code of Federal Regulations |
| DAC | Derived Air Concentrations |
| D&I | Dosimetry and Instrumentation |
| DOE | Department of Energy |
| DOT | Department of Transportation |
| EOC | Emergency Operations Center |
| EPA | Environmental Protection Agency |
| ERT | Emergency Response Team |
| HEPA | High Efficiency Particulate Air Filter |
| HP | Health Physicist |
| HPD | Health Physics Department |
| HPT | Health Physics Technologist |
| ICRP | International Commission on Radiological Protection |
| LSA | Low Specific Activity |
| MPLB | Maximum Permissible Lung Burden |
| NCRP | National Council on Radiation Protection and Measurements |
| NRC | Nuclear Regulatory Commission |
| OSHA | Occupational Safety and Health Administration |
| PF | Protection Factor |
| RDA | Radiation Detection Alarm |
| RMIEP | RMI Titanium Company Extrusion Plant |
| RWP | Radiation Work Permit |
| SCBA | Self-Contained Breathing Apparatus |
| SOP | Standard Operating Procedure |
| TLD | Thermoluminescent Dosimeter |

# SECTION 1

## INTRODUCTION AND PURPOSE

1.0 INTRODUCTION AND PURPOSE

1.1 General - Scope

1.1.1 This manual presents the specific radiological control responsibilities and protective measures that are employed by RMI Titanium Company (RMI) in the operation of the Extrusion Plant (RMIEP), as well as some of the underlying information that forms the basis for those radiological controls.

1.1.2 The radiological control requirements in this manual are based on the recommendations and requirements of the Department of Energy, the Environmental Protection Agency (which has incorporated the functions of the Federal Radiation Council), the National Council on Radiation Protection and Measurements, the International Commission on Radiological Protection, the Department of Transportation, the U.S. Nuclear Regulatory Commission, the State of Ohio, and on standards which have been reviewed and accepted by the U.S. Public Health Service and U.S. Department of Labor (Occupational Safety and Health Administration). Thus, they compare with radiological health standards used throughout the United States and the rest of the world. Compliance with the requirements in this manual is mandatory.

1.1.3 The presence of potential hazards from radiation exposure and radioactive contamination in otherwise normal jobs requires the establishment of protective controls. The primary purpose of this manual is to establish requirements that will ensure satisfactory control is exercised over exposure of personnel to radiation and radioactive contamination.

1.1.4 It must be clearly understood that in emergencies where personnel health and safety are involved, good judgement concerning life saving actions of personnel take precedence over the radiological controls specified in this manual.

1.2 Summary - Policy and Responsibilities

1.2.1 Requirements are specified throughout this manual. The word "should" indicates a recommendation. The word "shall" indicates a requirement and compliance is mandatory. Failure to follow the requirements of this manual may result in disciplinary action under the RMIEP Rules of Conduct.

1.2.2 Maintaining radiological controls is the shared responsibility of every individual working on site. Individual responsibilities include being aware that radiological conditions may exist and alert to potential radiological problems.

1.2.1 Management Responsibilities for Radiation Control

1.2.1.1 Overall responsibility for administration of health and safety programs relative to RMIEP operations and its surrounding environment rests with the Manager of the Environmental, Safety and Health (E,S&H) Department and the Medical Department of the RMI Titanium Company.

1.2.1.2 Management responsibilities addressed in this manual include:

- Providing necessary equipment to safely control radiological conditions.
- Providing appropriate training in methods and procedures for keeping exposures as low as reasonably achievable (ALARA) and for minimizing or limiting the spread of contamination.
- Maintaining records of occupational radiation doses and, upon written request, providing employees with a copy of their recorded occupational radiation dose history.
- Providing each employee with an annual summary of their recorded occupational radiation doses.
- Notifying each affected employee promptly after the determination has been made of any radiation dose which exceeds the DOE occupational dose limits.
- Providing each employee, upon termination of employment, with a copy of their recorded occupational radiation dose history during employment at the RMIEP.
- Notifying employees of the above responsibilities by posting Occupational Safety and Health

Protection for DOE Contractor Employees at Government-Owned Contractor-Operated Facility notice DOE-F-5480.5 (9-83).

- Controlling the use of radioactive material to keep radiation exposures as low as reasonably achievable (ALARA).

1.2.1.3 On-site radiological protection functions are centralized in the Health Physics Department. A summary of tasks performed by this department are as follows:

- Conduct routine radiological monitoring of personnel areas, buildings, equipment, materials, vehicles, and trash.
- Provide radiological monitoring of plant operations, receipts and shipments of radioactive materials and renovation and construction project sites.
- Determine dosimetry and bioassay (both in vitro and in vivo) requirements. Determine results of dosimetry and in vivo monitoring. Evaluate results of all dosimetry and bioassay measurements.
- Evaluate work conditions and practices for adequacy of radiological protection.
- Plan, initiate, and evaluate programs for air monitoring, contamination control, and radiation exposure reduction.
- Provide technical support for assessing radiological impact of new or modified facilities and procedures.
- Approve content of radiation worker training.
- Operate a site-wide radiation source control program.

1.3 Applicable Terms

The following terms are necessary for understanding radiological controls at DOE facilities. Other terms commonly used in the nuclear industry are listed in Appendix A. (Appendix A is a copy of the U. S. Nuclear Regulatory Commission document, NUREG-0770, "Glossary of Terms: Nuclear Power and Radiation," June 1981.)

1.3.1 Airborne Radioactivity Area[(1)] - Any area where airborne radioactive material concentrations greater the 1/10 of the derived air concentrations specified in DOE Order 5480.11, Attachment 1 ($2.0 \times 10^{-11}$ μCi/ml).

1.3.2 Contamination Area[(2)] - Any area within the boundaries of the controlled area where surface contamination levels are grater than 10 times those specified in the Radiological Area, (See 1.3.17 of this document).

1.3.3 Controlled Area[(3)] - Any area within the boundaries of the RMIEP site to which access is controlled in order to protect individuals from exposure to radiation and radioactive materials.

1.3.4 DAC (Derived Airborne Concentration) - the average concentration of a radionuclide suspended in air that if inhaled or ingested for a 2000-hour working year, would irradiate a person to the limiting radiation dose value for control of the work place. Exposure to airborne radioactivity is measured in DAC-hours, that is the time (hours) at the DAC value.

1.3.5 External Radiation Exposure - The dose of radiation received by an individual from a source of ionizing radiation outside the body. Measurements of external radiation doses are made for penetrating and nonpenetrating radiation.

1.3.6 Internal Radiation Exposure - The dose of radiation received to the internal organs of the body from radionuclides ingested, inhaled or absorbed into the body.

1.3.7 Ionizing Radiation - Any radiation capable of displacing electrons either directly or indirectly from atoms or molecules, thereby producing ions. Examples: alpha, beta, gamma, X rays, and neutrons.

1.3.8 Medical Department - The RMI Titanium Company physician and nursing staff located in a dispensary facility at the RMI Company Sodium Plant at State Road and East 6th Street, Ashtabula, Ohio 44004.

1.3.9 Nonpenetrating Dose - The radiation dose to the skin at a depth of 0.007 cm.

1.3.10 Nonradiological Area - Any area within a Controlled Area which does not exceed radiological conditions which would require posting as a Radiological Area as defined below.

1.3.11 Penetrating Dose - The radiation dose penetrating all tissue beyond the skin surface at a depth of 0.007 cm.

1.3.12 Radiation - Energy emitted in the form of alpha, beta, gamma, neutron or X-ray during the process of radioactive decay of an unstable atom, or by the operation of a radiation generating device.

1.3.13 Radiation Dose Terms and Units

1.3.13.1 Dose - the amount of energy deposited in tissue (unit = rad).

1.3.13.2 Dose Equivalent - the dose multiplied by a quality factor (QF). QF for Beta and Gamma is one; for alpha, it is twenty. (units = rem).

1.3.13.3 Effective Dose Equivalent - the summation of organ dose equivalents multiplied by organ-specific weighting factor ($W_T$). (unit = rem).

| Organ/Tissue (T) | Weight ($W_T$) |
|---|---|
| Gonads | 0.25 |
| Breast | 0.15 |
| Red Marrow | 0.12 |
| Lung | 0.12 |
| Thyroid | 0.03 |
| Bone Surfaces | 0.03 |
| Remainder | 0.30 |

(A weighting factor of 0.01 has been suggested for skin.)[5]

1.3.13.4 Committed Effective Dose Equivalent - The effective dose equivalent that would be received over a fifty-year period by an individual with internally deposited radionuclides. (unit = rem).

1.3.14 Radiation Source - A discrete quantity of a radionuclide or a machine which produces ionizing radiation.

1.3.15 Radiation Worker - An occupational worker whose job assignment requires work on, with, or in the proximity of radiation producing machines or radioactive materials, and/or who has the potential of being routinely exposed to 0.1 rem per year, which is the sum of the annual effective dose equivalent from external irradiation and the effective dose equivalent from internal irradiation.

1.3.16 Radiation Work Permit - A permit to administratively control either nonroutine tasks or routine tasks which involve the potential for significant radiation exposures.

1.3.17 Radiological Area(4) - Any area within the boundaries of the controlled area where surface contamination levels exceed the RMIEP administrative limits of 1000 dpm/100cm$^2$ fixed plus removable alpha, beta-gamma contamination.

1.3.18 Radioactive Contamination - A deposit of uncontained or unwanted radioactive material on the surface of structures, areas, objects or personnel (surface contamination) or embedded or contained in other materials (e.g. air, water, etc.).

1.3.19 Radioactivity - The spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays or X-rays, from the nucleus of an unstable atom.

1.3.20 Radioactivity Quantities and Units - Curie is the basic unit used to describe the amount of radioactivity in a sample of material. It is based upon the approximate decay rate of 1 gram of radium which is 37 billion disintegrations per second.

Conversion Factors:

$3.7 \times 10^{-5}$ μC/... 1 Curie (Ci) = $3.7 \times 10^{10}$ disintegrations per second = $2.22 \times 10^{12}$ disintegrations per minute.

1 Millicurie (mCi) = 3.7 x $10^7$ disintegrations per second = 2.22 x $10^9$ disintegrations per minute (dpm).

1 Microcurie (µCi) = 3.7 x $10^4$ disintegrations per second = 2.22 x $10^6$ dpm.

1 x $10^{-11}$ µCi/cc = 22 disintegrations per minute per cubic meter.

1.3.21 Respirator Area - Any area within a Radiological Area where actual airborne radioactivity concentrations exceed 2.0 DAC-hours per shift when averaged over one calendar quarter or 8.0 DAC-hours during any single shift.

## 1.4 References

1. Title 10 Code of Federal Regulations Part 20, paragraph 20.203 (e)(2). (Standards for the Protection Against Radiation).
2. U.S. Department of Energy Order 5480.11, page 22, paragraph 9 k(2)(c).
3. U.S. Department of Energy Order 5480.11, page 7, paragraph 8 c(1).
4. U.S. Department of Energy Order 5480.11, page 7, paragraph 8 c(2).
5. ICRP 60.

# SECTION 2

# RADIATION DOSE LIMITS

# 2.0 RADIATION DOSE LIMITS

## 2.1 General

The radiation dose limits and administrative dose controls identified in this manual are used for controlling personnel occupational radiation exposure. Radiation that is received as a result of medical or dental exams or radiotherapy is not included in occupational radiation exposure. The limits and controls in this section are for exposure to ionizing radiation associated with operation of the RMIEP.

## 2.2 Basis for Limits

2.2.1 These limits are such that no significant biological effects are expected, even if exposures extend for a lifetime at these levels. Nevertheless, personnel exposure shall be maintained as low as reasonably achievable (ALARA) below these limits. RMIEP has established administrative action limits at levels below the DOE limits in order to identify and investigate exposures before they approach ~~DOE~~ limits. AND NRC

2.2.2 The radiation exposure limits identified in this manual have been promulgated by the Department of Energy and are consistent with the requirements of Federal agencies such as the Environmental Protection Agency, Nuclear Regulatory Commission and Occupational Safety and Health Administration, and recommendations of scientific organizations such as the National Council on Radiation Protection. The limits as established by DOE Order 5480.11 are listed in Table 2.1 (on page 2-2) along with the RMIEP administrative action levels.

2.2.3 The limit for exposure to the whole body pertains to penetrating exposure plus internal exposure, combined into a quantity called "effective dose equivalent." Methods for calculating internal exposures shall be selected in accordance with recommendations of widely accepted, published methods.

2.2.4 The limit for all other organs includes exposure to the skin, extremities or the total radiation dose received by internal organs whether from external or internal radiation. Extremities include hands, forearms, feet and legs below the knee. This category includes the least sensitive areas of the body.

TABLE 2.1

RADIATION DOSE EQUIVALENT LIMITS

| Exposure Category | Annual Limit (rem) | | |
|---|---|---|---|
| Occupational | RMIEP[2] | DOE[1] | NRC[3] (Quarterly) |
| Whole body (effective dose equivalent) | 0.5 | 5.0 | 1.25 |
| Lens of eye | 0.5 | 15.0 | 1.25 |
| Skin and all other organs | 3.0 | 50.0 | 7.5 |
| Extremities | 5.0 | 50.0 | 18.75 |
| Embryo and fetus (entire gestation period) | 0.1 | 0.5 | 0.5 |
| Minors (Committed effective dose equivalent) | 0.1 | 0.1 | 0.125 |
| **General Public** | | | |
| All Pathways | | | |
| Whole body, prolonged period of exposure offsite or in a Controlled Area | 0.1 | 0.1 | 0.5 |
| Airborne Emissions Only | | | |
| Whole body (Effective dose equivalent; contribution from radon not included) | 0.01 | 0.01 | 0.5 |
| Drinking Water Only | 0.004 | 0.004 | (Not) (defined) |

(1) Occupational radiation exposure limits per DOE Order 5480.5; radiation exposure limits to the general public per DOE Order 5400.5.

(2) Administrative action levels established by RMIEP.

(3) 10 CFR 20.101; 20.104; 20.104; 20.105; 20.106.

2.3 Exceptions to Limits

2.3.1 The limit for occupational whole body dose may only be exceeded in the event of an emergency situation. During emergency situations personnel may volunteer to exceed normal exposure limits for life saving rescue and other emergency situations. The potential exposures due to the emergency are subject to limits approved by the Plant Manager.

2.3.2 Planned special exposures (non-emergency) may be allowed in unusual situations where alternatives which would avoid higher exposures are unavailable or impractical. The annual occupational dose received or anticipated to be received in that year, shall not exceed 2 times the annual effective dose equivalent limit. Planned special exposures require the approval of the Head of the DOE Field Organization. Documentation of planned special exposures must be maintained in the individual's occupational exposure history.

2.4 Dosimetry Records

2.4.1 A permanent record of exposures received at the RMIEP is maintained for all personnel.

2.5 The Unborn Child

2.5.1 The limiting value of annual dose equivalent received by the unborn child from the period of conception to birth (entire gestation period) as a result of occupational exposure of a female occupational worker, who has notified her employer in writing that she is pregnant, is 0.5 rem. Efforts should be made to avoid substantial variation above the uniform monthly exposure rate that would satisfy this limiting value.

2.5.2 If the dose to the unborn child is determined to have already exceeded 0.5 rem by the time a worker notifies her employer in writing of her pregnancy, the worker shall not be assigned to tasks where additional occupational exposure is likely.

2.5.3 The limiting value of dose equivalent to the unborn and the assignment of female workers (who have declared pregnancy in writing to their employer) to task where additional occupational exposure is not likely does not create a basis for discrimination and should be achieved in conformance with the provisions of Title VII of the Civil Rights Act of 1964 [See Environmental Protection Agency (1) - pages 2829 and 2832 of Federal Register, Vol.52, No.17, 1987].

2.6 Minors

2.6.1 Individuals under age 18 shall not be allowed to exceed 0.1 rem per year.

2.7 General Public

2.7.1 The dose limits to the general public are established by DOE Order 5400.5. The calculation of dose to members of the general public are based upon ICRP (International Commission on Radiological Protection) Publication 30 models and parameters used by DOE environmental programs.

# SECTION 3

# DOSIMETRY

# 3.0 DOSIMETRY

## 3.1 External Dosimetry Requirements

### 3.1.1 General

3.1.1.1 The Health Physics Department provides dosimeters for all personnel requiring them at the RMIEP. They also record and report dosimetry results.

3.1.1.2 All employee and contractor personnel entering the RMIEP site are responsible for wearing dosimeters whenever they are required in accordance with the usage rules listed below for each type of dosimeter. On occasion, individuals may be required to participate in special studies which involve the wearing of special dosimeters in addition to their personal TLD.

3.1.1.3 Visitors to the RMIEP site are required to wear dosimeters in accordance with the same requirements as RMIEP employees whenever they will be entering a Radiological Area.

### 3.1.2 Dosimetry for Measuring Whole Body Exposure

3.1.2.1 Thermoluminescent dosimeters (TLDs) are utilized to measure personnel radiation exposure from radiation penetrating to depths which give a dose to the skin, the lens of the eye, and to the whole body.

3.1.2.2 A multi-element dosimeter measures the radiation exposure, as well as the type and penetrating power of the radiation. The TLDs are obtained from an outside vendor. After exposure the TLDs are returned to the vendor for analysis and reporting of dose assessment.

3.1.2.3 The depth of penetration corresponds to radiation doses to human skin, lens of the eye and whole body. Depth of penetration is dependent on density; therefore, the unit "density thickness" is used for various "depths" of penetration as follows:

| Dose assigned to | Density Thickness |
|---|---|
| Skin | 7 $mg/cm^2$ |
| Lens of eye | 300 $mg/cm^2$ |
| Whole body | 1000 $mg/cm^2$ |

3.1.2.4 The Health Physics Department is responsible for maintaining radiation dose reports and records.

3.1.2.5 The whole body external dosimetry program is subject to the requirements of the Department of Energy Laboratory Accreditation Program (DOELAP) for dosimetry processing, which are contained in DOE Order 5480.15 and the various documents referenced therein.

3.1.3 Dosimetry Wearer's Responsibilities

3.1.3.1 Requirements for issuing dosimeters, processing dosimeters (including frequency of processing), storing dosimeters, and reporting of dosimetry results are established by the Health Physics Department. All individuals who enter the RMIEP are responsible for compliance with the requirements listed below for whole body dosimeter usage.

- Dosimeters shall be worn at all times while on site.
- Dosimeters shall be worn on the outermost garment on the front of the body proximal to the heart of the wearer with the identification number of the badge facing away from the wearer unless directed otherwise by the Health Physics Department.
- Dosimeters shall be worn only by the individuals assigned to them.

- Dosimeters shall be stored in designated storage racks in the Guard house when not being worn.

- Lost or damaged dosimeters shall be immediately reported to Health Physics Department.

3.1.4 Extremity Dosimetry

3.1.4.1 The RMIEP extremity monitoring program utilizes single-element thermoluminescent dosimeters mounted in ring badges. On occasion, wrist dosimeters may be used for special studies. Extremity dosimeters are processed and calibrated in order to determine the radiation dose to the skin of the extremity, i.e., at a density thickness of 7 mg/cm$^2$. These exposures are recorded as extremity doses, not skin doses.

3.1.4.2 Health Physics Department identifies personnel who are required to wear extremity dosimetry and establishes requirements for issuing, processing (including frequency of processing), and storing dosimeters, and reporting results. All personnel issued extremity dosimeters are responsible for compliance with the following requirements:

- Extremity dosimeters shall be worn by personnel designated by Health Physics Department as requiring extremity dosimetry.

- Ring dosimeters shall be worn with the element facing the radiation source, under gloves, unless directed otherwise by Health Physics Department.

- Personnel shall wear only the dosimeters that have been assigned to them.

- Dosimeters shall be stored in designated storage areas when not being worn.

- Personnel shall immediately report lost or damaged dosimeters to Health Physics Department.

3.1.5 Direct Reading Dosimeters

3.1.5.1 Direct reading dosimeters (DRDs) are utilized to allow real time indication of worker exposure to penetrating radiation. The DRD has a single ion chamber which measures gamma exposure. Visual indication is provided by a viewing window in the chamber with a scale marked in milli Roentgen.

3.1.5.2 DRDs will be issued by the Health Physics Department Section to those personnel that may require them. Comparisons are performed between the DRD and TLD results to verify accuracy within allowable limits.

3.1.6 Personnel Accident Dosimeters

3.1.6.1 Inside of each assigned personnel dosimeter badge, is a packet containing the personnel accident dosimeter. These dosimeters contain a sulfur pellet, and three different types of metal foils which are activated by the neutron flux associated with a criticality accident. Analysis of the radioactivity in the pellet and foils will provide indication of an individual's absorbed neutron dose.

3.1.7 Nuclear Criticality Accident Dosimetry

3.1.7.1 Permanently mounted dosimeter units shall be located by Health Physics Department throughout each work area where enriched nuclear material is handled. These dosimeters contain eight metal foils and three pellets of various materials each of which are activated by a neutron flux such as occurs in a criticality accident. By analyzing the radioactivity in these foils and pellets, the amount of absorbed neutron dose in each location can be determined.

3.1.8 Radiation Exposure Investigations

3.1.8.1 Health Physics Department establishes external exposure action levels for investigation, change of work assignments, and restriction of personnel from additional radiation exposure, performs exposure investigations, and informs management of work restrictions.

3.1.8.2 All RMIEP departments shall provide information on work assignments as requested by Health Physics Department to enable evaluations of required participation in the dosimetry program, or evaluations to determine which personnel should be issued permanent dosimeters.

3.2 Internal Radiation

3.2.1 General

3.2.1.1 Internal radiation monitoring at the RMIEP is routinely accomplished by performing in vitro and in vivo bioassay measurements. Health Physics Department defines the internal radiation monitoring program for all personnel at the RMIEP.

3.2.1.2 Health Physics Department is responsible for:

- Identifying personnel for whom internal monitoring is required;
- Determining what type of bioassay measurements will be performed;
- Setting the frequency of measurements;
- Interpreting bioassay results;
- Establishing internal monitoring action levels for investigation;
- Restricting work assignments;
- Restricting personnel from additional radiation exposure;
- Performing exposure investigations;
- Informing managers and supervisors of work restrictions.

3.2.1.3 Internal radiation monitoring is required for all radiation workers exposed to surface or airborne radioactive contamination where the worker could receive 100 mrem annual effective dose equivalent from all intakes of all radionuclides from occupational sources, or if any organ or tissue dose equivalent could exceed 5 rem annual dose equivalent.

3.2.1.4 Managers and supervisors shall provide information on work assignments to Health Physics Department on request to enable evaluation of required participation in an internal monitoring program. Managers and supervisors shall also identify individuals whose work assignments meet criteria provided by Health Physics Department as requiring internal monitoring.

3.2.1.5 All personnel are responsible for reporting for in vivo examinations when scheduled, and for leaving excreta samples for in vitro analysis when requested. Failure to comply is considered a serious offense under the RMIEP Rules of Conduct and may result in disciplinary action or restriction from radiological areas.

3.2.2 Urinalysis

3.2.2.1 Routine uranium urinalysis samples are analyzed for total uranium. The results are reported as concentration of uranium in the sample (mg U/L). These samples are screening samples, intended to identify potential intakes of uranium which can then be further evaluated by additional bioassay measurements. The schedule for collecting routine samples and the criteria for collecting non-routine (i.e., incident or special samples) are established by Health Physics Department.

3.2.2.2 Reasons for collecting special samples include, but are not limited to, analysis for uranium isotopes, analysis for radionuclides other than uranium, evaluation of daily excretion of radioactive material without relying on standard models for relating urinary concentration to daily output, and special studies.

3.2.3 Fecal Monitoring

3.2.3.1 Fecal monitoring is not performed routinely, but may be required when urine sampling is not adequate or appropriate for the radionuclide and chemical form of interest, or when it would be helpful in determining the magnitude and nature of a suspected intake of radioactive material.

3.2.4 In Vivo Monitoring

3.2.4.1 In vivo monitoring is the detection and quantification of radioactive materials in the body by means of measuring the photons emitted from organs within the body. The In Vivo monitoring at the RMIEP is conducted annually.

3.2.5 Internal Dose Assessments

3.2.5.1 Internal dose assessments are performed to determine intakes of radioactive material that are dosimetrically significant. Dose assessments are generally performed according to ICRP 30 methodology. Health Physics Department may modify the approach if recent publications or actual bioassay data indicate that this would be appropriate.

3.2.5.2 In general, dose assessments are based on bioassay data, rather than air sampling results. However, in circumstances when bioassay data are not available or not appropriate, air sampling results may be used to estimate internal exposure.

3.2.5.3 Results of dose assessments shall be included in personnel exposure records. The information that is retained in these records includes the following:

- For each intake of radioactive material, the year the intake occurred;
- Radionuclide(s) involved in each intake;
- Annual effective dose equivalent received in each calendar year;
- Annual dose equivalent to organs or tissues of interest in each calendar year;
- Committed effective dose equivalent from ir.akes occurring during each calendar year;

- Committed dose equivalent to organs or tissues of interest from intakes occurring during each calendar year.

3.2.6 Reports to Employees

3.2.6.1 Health Physics Department shall provide to each radiation worker a summary of annual, cumulative, and committed effective dose equivalent each calendar year. These results, along with more detailed information concerning a worker's exposure, shall also be provided to monitored individuals at any time upon their request.

3.3 Therapeutic Radioisotopes

3.3.1 The employee is responsible for notifying Health Physics anytime they have undergone any medical procedure involving radioisotopes other than x-rays. Some examples are: Stress test, Lower GI scan, Thyroid therapy, etc.

3.3.2 Exposure due to any medical procedure will not be added to a person's occupational exposure records.

# SECTION 4

## ENGINEERING AND ADMINISTRATIVE CONTROLS FOR RADIOLOGICAL SAFETY

SECTION 4 (Cont'd)

ENGINEERING AND ADMINISTRATIVE CONTROLS
FOR
RADIOLOGICAL SAFETY

# 4.0 ENGINEERING AND ADMINISTRATIVE CONTROLS FOR RADIOLOGICAL SAFETY

## 4.1 RMIEP ALARA Program

### 4.1.1 Statement of Policy

It is the policy of RMIEP that:

- No practice involving radiation exposure shall be adopted unless its introduction produces a positive net benefit;

- All exposures shall be kept as low as reasonably achievable (ALARA), with economic and social factors taken into account;

- The dose limits identified in Section 2 of this manual shall not be exceeded.

### 4.1.2 Responsibilities

#### 4.1.2.1 All Managers and Supervisors Shall:

- Enforce all radiation protection rules and limits.

- Identify locations, operations, and conditions that have the potential for causing exposure or environmental releases that are not ALARA.

- Specify and accomplish goals and objectives for RMIEP operations which incorporate the ALARA philosophy and objectives.

- Review all plans for modification or installation of equipment or facilities under their cognizance to ensure that radiation exposures and environmental releases are ALARA.

#### 4.1.2.2 Manager of Environmental, Safety and Health (ES&H)

The Manager of ES&H is responsible for implementation of the radiation protection program and to this end, shall:

- Ensure that all operations involving work with radioactive materials is supported by adequate radiation protection coverage, both in field support and engineering support.

- Review and recommend changes in operating procedures to maintain occupational exposures ALARA.
- Promote the development of training programs related to work performed in radiation areas or with radioactive materials.
- Support the collection, analysis, and evaluation of radiological data and information as it pertains to the Radiation Protection/ALARA Program.

4.1.2.3 Health Physics Department (HP)

The HP Department is responsible for the technical development and adequacy of the radiation protection program. The HP Department also has the ongoing responsibility for surveillance and supervisory action in the implementation of the program. The HP Department also has the responsibility to:

- Identify locations, operations, and conditions which have the potential for causing significant personnel exposures to radiation.
- Maintain a routine surveillance program including air sampling and surface contamination measurements in all nominally occupied areas.
- Review and recommend changes in standard operating procedures to maintain exposures ALARA.
- Participate in the development and implementation of training programs related to work in radiation areas or involving radioactive materials.
- Conduct investigations of radiation exposures which are near or exceed established administrative and regulatory guidelines or are outside of the expected norms.

- Review all process equipment and facility designs to ensure that the potential for significant radiation exposures and environmental releases are minimized.

- Review all modifications of current equipment or facilities to ensure that radiation exposures and environmental releases are ALARA.

- Ensure ALARA considerations are engineered and incorporated into designs, installations, and retrofitting of equipment.

4.1.2.4 The RMIEP ALARA Committee

The ALARA Committee membership and responsibilities, are identified in "ALARA Program-RMIEP."

4.1.2.5 All Individuals at the RMIEP

The ALARA program is only as effective as each individual's performance, therefore all individuals at the RMIEP shall:

- Comply with all rules for radiation protection.

- Comply with requirements identified in Radiation Work Permits.

- Use time, distance and shielding to minimize exposure. Avoid any unnecessary exposure.

- Report to their supervisor, the HP Department and/or the ALARA Committee any process malfunctions or violations of rules or procedures which could result in increased radiation exposure to an individual or to the environment.

- Suggest improvements for the Radiation Protection/ALARA Program and for the radiologically safe operation of work place processes and equipment.

4.1.3 The Radiation Protection/ALARA Program Considerations

4.1.3.1 The HP and the ALARA Committee jointly provide for a Radiation Protection Program that maintains radiation exposure ALARA.

4.1.3.2 The following must be considered for an effective program:

- Special radiological projects with exposure potential greater than one man-rem effective dose equivalent shall require radiation dose budgets and the incorporation of ALARA principles and concepts into work procedures prior to the initiation of the work.

- Job preplanning, work procedures, and worker briefings shall be conducted prior to nonroutine radiological work. Rehearsals of work to be performed in radiation areas shall be performed in low background areas prior to entry into the specific radiation work area when such rehearsals are ALARA based on cost-benefit analyses.

- Radiological surveys and monitoring shall be conducted to obtain information with respect to radiation levels, contamination levels, and airborne radioactivity concentrations before, during and after work as appropriate. These surveys and monitoring will provide the data necessary to establish the radiation safety requirement to be incorporated into the radiological work procedure to keep exposure ALARA.

- Radiation exposure rates shall be reduced either by decontamination, shielding or by removing radiation sources from the work areas as appropriate to keep radiation doses ALARA.

- The ALARA concepts of minimizing time in a radiation area, maximizing distance from sources, and use of shielding shall be applied to all aspects of radiation work in order to keep exposures ALARA.

- Radiation Work Permits shall be used for specific jobs to identify and document job requirements and to control radiation exposures. Supervisors and individuals performing the work shall review the required protective features before the start of work.

- High efficiency (HEPA) filtered exhaust ventilation systems shall be used where practical in order to keep radioactive air concentrations ALARA.

- Protective equipment such as anti-contamination clothing, respirators, dosimetry devices, and monitoring equipment shall be used in the work place as required by the Health Physics Department to minimize skin contamination, monitor exposure, and maintain radiation exposures ALARA.

4.2 Engineering Controls for Facility Design/Modification

4.2.1 The concept of maintaining radiation exposures ALARA shall be incorporated into the design of all facilities at RMIEP.

4.2.2 The design of facilities, processes, and equipment necessary for the performance of work involved with radioactive materials provides one of the earliest and best opportunities for ensuring radiation exposures are kept ALARA.

4.2.3 When designing or modifying radiological facilities, processes, and equipment the following factors shall be considered:

- Radiation Shielding
- Access Control of Radiation Areas
- Control of Airborne Contaminants (Ventilation)
- Contamination Control (Isolation and Decontamination)
- Need for Local Change Rooms
- Radiation Monitoring Systems

- Design shall limit exposure to one-fifth of the applicable RMI dose limits (i.e., 1 rem/year whole body).

- Environmental Protection Systems:

  - Gaseous - HEPA filtration, dust collectors, scrubbers, demisters, etc.

  - Liquid - Water treatment systems.

- Primary means for assuring personnel protection shall be through engineered safeguards, e.g., remote handling equipment, shielding, ventilation, etc.

- Interior surfaces of components and facilities as well as layout of ducts and pipes, shall be designed to minimize buildup of contamination.

- Equipment and components requiring frequent servicing shall be located in areas with the lowest practicable radiation fields and outside process enclosures whenever possible.

- Ventilation systems shall be designed to assure proper control of airborne contaminants. The systems should permit easy and safe access for servicing.

- Decommissioning requirements shall be considered in the design of facilities and equipment.

- New equipment or modifications to existing equipment shall be designed in such a manner that a minimum of "hands on" contact with radioactive material is required. Remote handling tools, robotics, etc., should be considered.

- Enclosures shall be designed with a negative pressure with respect to the surrounding environment. The exhaust from these enclosures shall be routed through a filtration media before being vented to the atmosphere.

- All facility or process design/modification involving a radiological environment shall be reviewed and approved by the HP.

4.2.4 Ventilation Systems

4.2.4.1 Plant ventilation equipment shall be designed and used to remove contamination from the work area. The optimal ventilation design should cause contaminated air to be moved away from workers and be equipped with a filtering system to prevent significant amounts of contamination from reaching the environment.

4.2.4.2 The Industrial Ventilation Manual published by the American Conference of Governmental Industrial Hygienists shall be used as a design guide for ventilation systems for both new and old systems.

4.2.5 Storage of Radioactive Material

4.2.5.1 Design Criteria Requirements

- Dose rates at the warehouse exterior shall not exceed 5 mrem/hr.
- Radioactive materials shall be stored in such a manner as to facilitate access (where access is necessary) and minimize exposure during storage, access, and retrieval.
- Storage facilities with penetrating radiation levels in excess of 100 mrem/hour must be locked and shall require an RWP for entry.

4.3 Radiological Engineering Evaluation

4.3.1 HP evaluations are required on all projects involving changes in plant equipment and any activity that significantly increases personnel to external or internal radiation exposure. This will be accomplished by HP review of the applicable design, SOP or Health and Safety Plan.

4.3.2 To ensure that ALARA is practiced in the work place the following guidelines shall be considered:

4.3.2.1 Plan in Advance: Many of the methods for reducing exposure to radiation require considerable planning, construction, and training prior to the start of work.

4.3.2.2 Delete Unnecessary Work: Determine exactly what is to be accomplished. If secondary work requiring additional exposure can be accomplished in conjunction with the primary task without additional exposure, it should be planned and scheduled. An example would be to remove waste material either during or immediately after the task is completed. Do not allow the material to remain until a later time and require another work group to re-enter the area for material removal.

4.3.2.3 Monitor and Evaluate Radiation Levels: Radiation surveys shall be performed periodically in any facility utilizing radioactive materials. Reports of these surveys provide information on the general radiation levels encountered in most work. Radiation surveys in conjunction with inspections or other activities can define the nature of the radiation fields and identify favorable locations where personnel may take advantage of available shielding, distance, geometry, and other factors that affect the magnitude of the exposure rate or the portions of the body exposed to radiation.

When sufficient advance notification of work is provided, it is possible to obtain more detailed surveys. Interpretation of surveys can be improved if requests for detailed surveys are accompanied by photographs, drawings, or sketches on which the Health Physics Junior Engineer (HPJE) can record or indicate the location of the radiation levels measured. In addition, a survey of work areas prior to starting the work will be necessary to determine any changes from earlier survey data.

4.3.2.4 Consider Design Changes: If existing equipment needs to be replaced or facilities require modification, consideration shall be given to design changes which could be made to reduce exposure to radiation.

4.4 Administrative Controls: Work Procedures

4.4.1 Detailed written work procedures shall be used for routine work with radioactive materials. Procedures shall be written to minimize exposure to radiation and limiting the spread of contamination. Each of the following items shall be incorporated, as applicable, into the work procedures:

4.4.1.1 Plan Access To and Exit From Work Area. In plans for access to and exit from the work area, include a convenient and large enough area for donning and removing anti-C clothing, for briefing personnel before entry and for surveying personnel for radioactive contamination. Where considerable work is to be done in a highly contaminated area, provide direct access from the work area to a change area. Plan the entrance and exit to radiological work areas to avoid having personnel waiting in areas where significant radiation levels exist; for example, locate the personnel monitoring station so that when several people are leaving a work area they do not have to wait inside a radiation area while the people ahead are self-monitoring.

4.4.1.2 Provide for Service Lines. Plan in advance for service lines, including lines for air, welding and ventilation, and specify, in the work procedure, methods to minimize exposure to radiation associated with their installation, maintenance and removal, and to control their interference with personnel access. Minimize the number of lines going into and inside a contaminated area. Minimize unnecessary accumulation of equipment. Use types of lines that can be readily decontaminated or use covers for the lines to prevent their being contaminated.

4.4.1.3 Provide Communication. Communication between workers inside areas with significant levels of radiation or contamination, and supervision and HPJEs outside the area. Provision for communication devices, headsets, or speaker systems can reduce radiation exposure by reducing the time required to make decisions on matters not foreseen in work procedures. Avoid the condition where headsets become contaminated and then have the potential of causing contamination of subsequent users. Use of a communication system also allows supervising personnel to maintain effective control of a job even though continuous visual observation is impractical because of high radiation levels.

4.4.1.4 Remove Sources of Radiation. Significant reductions in radiation exposure can be obtained by eliminating some sources of radiation.

4.4.1.5 Perform as Much Work as Practicable Outside Radiological Areas. Prefabrication shall be considered to minimize the work done in radiation posted areas; for example, prefabrication of temporary shielding to reduce installation time.

4.4.1.6 State Requirements for Standard Tools. By requiring supervisors to determine standard tools known to be needed for the job and requiring that they be available near the job location, radiation exposure of working personnel waiting for tools can be minimized.

4.4.1.7 Consider Special Tools. For certain jobs, special tools or rigs may reduce in radiation exposure through simplification, reduction in time, or reduction of mistakes. These tools should be designed, built, and tested on full-scale models prior to their use in radiation areas if previous usage experience does not exist. In addition, individuals using these tools for the first time should be trained in the proper use, handling, and restrictions of the tool prior to use in the radiation area.

4.4.1.8 Estimate Radiation Exposure. After planning the details of the work procedure where exposure to significant radiation levels will be experienced and prior to performing the work, an estimate of the radiation exposure to personnel on the job should be made. This estimate should be based upon radiation levels measured at the work location, and the estimated time it will take in radiation fields to complete each phase of the job. The estimate should reflect experience gained by others who have performed similar work.

Exposure estimates should be considered for enhancement in the work procedure. For example, special tools might be developed to reduce working time.

4.4.1.9 Review Exposure. During and after the work, the actual dose received shall be compared with the estimates. Determining the reasons for discrepancies promptly and correcting them can reduce radiation dose.

4.4.1.10 Consider Accident Situations. Potential accident situations and unusual occurrences (such as gross contamination, leakage, pressure surges, fires, personnel injury) shall be considered during the preparation of the work plans. Contingency planning can reduce the potential for such occurrences and enhance the capability for rapid mitigation of an accident.

4.4.1.11 Provide Inspection Requirements for Radiological Controls. Radiological coverage may be enhanced if steps requiring radiological control inspections are included in work procedures. HP Department should be contacted whenever operations could cause the need for increased protection and/or posting of radiological conditions.

## 4.5 Administrative Controls: Radiation Work Permit (RWP)

### 4.5.1 General

4.5.1.1 Exposure to radioactive material for which there is no approved work procedure (SOP), shall be controlled by an RWP. In addition, an RWP shall be issued, when work performed under approved work procedures involves working in High Radiation Areas, areas where radiation fields are variable or unknown, or the work procedure requires that an RWP be obtained.

4.5.1.2 The primary purpose of the RWP is to control non-routine or periodic routine tasks that involve the potential for significant radiation exposures. The RWP identifies the work activity, the associated radiological conditions and protective measures required to accomplish the work.

4.5.1.3 The work permit shall remain in force for the duration of the job or as long as conditions remain the same, i.e., all materials, equipment, shielding and structures that were present when the survey was performed have not been adjusted or moved during the performance of work in such a way as to modify the conditions of the original permit.

4.5.1.4 When applicable (as directed by the H.P.), the Requesting Supervisor shall notify an HPJE at the completion of the job so a post-work surface contamination survey can be performed.

4.5.1.5 When a post-work contamination survey is required, the work under the RWP shall not be considered complete until the area surface contamination is less than 1,000 dpm/100cm$^{2}$(1) removable alpha or 5,000 dpm/100cm$^{2}$(1) removable beta/gamma radiation as verified by the HP.

4.6 <u>Administrative Controls for Work in the Administrative Areas of the RMIEP</u>

4.6.1 Radiation Work Permits must be obtained for the following types of work performed in the Control Area (that is, the buildings and grounds between the RMIEP parking lot and the Radiological Area).

4.6.2 Movement of walls or permanently installed equipment.

4.6.3 Breaching of ventilation systems.

# SECTION 5

# GENERAL REQUIREMENTS FOR CONTROLLED AREAS

# 5.0 GENERAL REQUIREMENTS FOR CONTROLLED AREAS

## 5.1 Controlled Area Access Requirements

### 5.1.1 Dosimetry

Dosimetry requirements are specified in Section 3.1.2.

### 5.1.2 Radiation Safety Training

5.1.2.1 Individuals entering Radiological Areas must successfully complete the Radiation Worker Training Program before any unsupervised work assignment is made, in accordance with Section 13, unless directed otherwise by the Manager of ES&H. All other individuals must successfully complete Radiation Safety Training commensurate with their job assignments. This training shall be successfully completed every two years.

5.1.2.2 Vendors and personnel providing short-term repairs on nonradiological equipment shall be provided a brief orientation of the RMIEP operations and safety programs. All visitors entering the Radiological Areas of the RMIEP shall be escorted by a qualified radiation worker unless the visitor has satisfactorily completed Radiation Worker Training.

5.1.2.3 Short-term visitors, such as drivers of delivery vehicles, who do not enter Radiological Areas need not attend Radiation Safety Training.

5.1.2.4 Other training may be required to meet OSHA and EPA standards as determined by ES&H.

### 5.1.3 Open Wounds, Medical Tests with Radionuclides

5.1.3.1 The existence of open wounds shall be reported to the Medical Department prior to work in Radiological Areas. To minimize the potential for internal contamination the Medical Department shall provide guidance on restriction options. Health Physics will confer with Medical Department, then provide requirements for any appropriate restrictions. Restrictions may include additional clothing requirements, bandage requirements or complete restriction from controlled and/or Radiological Areas.

5.1.3.2 Personnel who are returning to work following tests or therapy with radioisotopes shall report to Medical Department. Generally, workers will be excluded from the Radiological area until the radioactive material is eliminated from the body. This is because radiation from medical radioisotopes cannot be distinguished from contamination by radioactive materials in the Radiological Area, making personnel contamination monitoring inaccurate.

5.2 Radiological Area Postings

5.2.1 General

RMIEP posting is done according to the most restrictive of Title 10 CFR Part 20, paragraph 20.203 and DOE Order 5480.11, paragraph 9, section K.

5.2.2 Area Posting

5.2.2.1 Controlled Area

The Controlled area shall be posted in the following manner:

- Controlled Area

5.2.2.2 Radiological Area

The Radiological area shall be posted in the following manner:

- Radiation Symbol
- Radiological Area
- Radiological Area Clothing Required
- Eating, Drinking and Smoking Prohibited

5.2.2.3 Contamination Area

The Contamination area shall be posted in the following manner:

- Radiation Symbol
- Contamination Area
- Contamination Area Clothing Required
- Beta-Gamma Dose Rate _____ mR/hr
- Eating, Drinking and Smoking Prohibited

5.2.2.4 Airborne Radioactive Material

The Airborne Radioactivity areas shall be posted in the following manner:

- Radiation Symbol
- Airborne Radioactivity Area
- Contamination Area
- Contamination Area Clothing Required
- Respiratory Protection Required

5.2.2.5 Radioactive Materials Area

The Radioactive Materials Areas shall be posted in the following manner:

- Radiation Symbol
- Radiological Area
- Radiological Material Area
- Radiation Area
- Beta-Gamma Dose Rate _____ mR/hr
- Eating, Drinking, and Smoking Prohibited

5.2.2.6 Radiation Area

The Radiation Areas shall be posted in the following manner:

- Radiation Symbol
- Radiological Area
- Radiation Area
- Beta-Gamma Dose Rate _____ mR/hr
- Eating, Drinking, and Smoking Prohibited

5.2.2.7 High Radiation Area

The High radiation areas shall be posted in the following manner:

- Radiation Symbol
- Radiological Area
- High Radiation Area
- Beta-Gamma Dose Rate _____ mR/hr
- Eating, Drinking, and Smoking Prohibited

5.2.2.8 Very High Radiation Area

The Very High radiation areas shall be posted in the following manner:

- Radiation Symbol
- Radiological Area
- Very High Radiation Area
- Beta-Gamma Dose Rate _____ mR/hr
- Eating, Drinking, and Smoking Prohibited

5.3 Protective Clothing

5.3.1 Controlled Area Clothing

5.3.1.1 Personal clothing is permitted in Controlled areas. The following RMIEP-provided clothing is provided for use in the Controlled areas for activities that may cause soiling of personal clothing:

- Green protective coveralls
- Green protective smocks
- Dedicated clean safety footwear
- Appropriate safety headgear and eye protection

5.3.1.2 The use of dedicated green coveralls, and smocks will be permitted for tasks in the Controlled area, after the wearer has completed a whole body contamination frisk.

5.3.2 Radiological Area

5.3.2.1 To prevent the contamination of personnel or their clothing, the RMIEP will provide the following special Radiological area clothing to be donned before entry.

- White protective coveralls (cotton or tyvek)
- White protective smocks
- Dedicated safety footwear
- Appropriate safety headgear and eye protection

5.3.3 Contamination Area

5.3.3.1 To prevent the contamination of Radiological area clothing, the RMIEP shall provide the following special Contamination area clothing to be donned before entry.

- Blue disposable coveralls (tyvek)
- Dedicated pull over boots
- Dedicated Radiological area safety footwear
- Additional control clothing as indicated by HP

5.3.3.2 Personnel shall properly dress for entry into the Contamination area with the designated protective clothing listed above over the Radiological area clothing. Contamination area clothing shall be used in Contamination areas only.

5.3.4 <u>Laundry Operations</u>

5.3.4.1 Laundry at RMIEP shall be segregated by area color at all times.

5.3.4.2 Controlled area and Radiological area clothing shall be shipped to WMCO for laundering.

5.3.4.3 RMIEP laundry stored and washed at WMCO shall be segregated by color at all times.

5.3.4.4 Monitoring shall be performed at WMCO to assure the laundered items comply with RMIEP contamination limits as specified.

5.3.4.5 Radiological area laundered clothing shall not have fixed contamination in excess of 15,000 DPM/100cm$^2$, alpha/beta.

5.3.4.6 Controlled area laundered clothing shall not have fixed contamination in excess of 3,750 DPM/100cm$^2$, alpha/beta.

5.3.4.7 RMIEP shall be notified of laundered clothing exceeding specified limits.

5.4 Food, Beverages, Tobacco

5.4.1 Radiological Areas

5.4.1.1 Vending machines for tobacco and food shall be prohibited in Radiological Areas.

5.4.1.2 Food, tobacco products, and beverages shall be prohibited in Radiological Areas.

5.5 General Rules for Work in Controlled Areas

5.5.1 Radiological controls at the RMIEP are necessary in areas where radioactive materials are handled and in areas where potentially contaminated materials and personnel may be located. Radioactive contamination and elevated radiation levels exist in the production areas and waste storage areas of the site. The following rules shall be followed by all individuals to control or minimize radiological hazards:

- Obey promptly, "stop work" and "evacuate" orders of Health Physics and/or Quality Assurance personnel.
- Obey posted, written and verbal radiological control instructions.
- Wear personal dosimetry devices and air samplers as required by this manual, signs, procedures, labels, or by Health Physics personnel.
- Maintain an awareness of personal radiation dose status to avoid exceeding limits. Report prior or concurrent occupational radiation dose to the Health physics Department.
- Remain in as low a radiation exposure area as practicable.
- Do not loiter in radiation areas.
- Eat, drink, chew, or smoke only in designated areas.
- Wear Anti-C clothing and respiratory protection equipment properly.

- Monitor for contamination with personnel contamination monitors, hand and foot monitors or friskers as indicated by postings when entering a break area or leaving any Radiological Area or Controlled Area that requires the use of personnel monitors.

- Follow good "housekeeping" practices to minimize the spread of contamination and the amount of material that has to be decontaminated or disposed of as radioactive waste. Work areas should be returned to "as found" or better radiological conditions to the maximum extent practicable.

- Avoid contact with contaminated surfaces and prevent clothing, tools, or other equipment from doing so.

- For a known or possible spill of radioactive material, minimize its spread and immediately notify supervision and ES&H.

- Report the presence of open wounds to the Medical Department and Health Physics personnel prior to work in areas where radioactive contamination exists. If a wound occurs while in the work area, report immediately to HP personnel and Medical Department.

- Know the emergency alarm signals and the required work area response actions.

5.5.2 Contamination Control

5.5.2.1 An ongoing program of contamination control shall be part of the commitment to quality at the RMIEP.

5.5.2.2 General administrative and engineering controls and their importance in reducing and maintaining contamination at a low level are identified in Section 4. Section 7 identifies survey frequencies, limits and decontamination methods.

5.6 Exiting from Controlled Areas and Radiological Areas

5.6.1 All anti-contamination clothing shall be removed and left for laundering or disposal at the exit point from Contamination

Areas. Dosimeters shall be stored in storage rack in the Guard House.

5.6.2 All personnel exiting from the Controlled Area must monitor for contamination, using the hand and foot monitors or personnel contamination monitors and friskers provided. All personal articles carried from the Controlled Area must be monitored.

5.6.3 If an alarm is received and verified during monitoring, follow the posted procedure for decontaminating and obtaining HPT assistance.

5.6.4 After any alarm, a whole body frisk is required. If elevated levels of contamination are found on any areas of skin or personal clothes, contact an HPJE. Do not leave the area, if possible.

5.6.5 Vehicles, equipment, and materials being removed from the Controlled Area are subject to contamination monitoring. A pass card will be issued to the vehicle operator as evidence of a contamination survey. Items with contamination greater than approved limits will not be permitted to leave the Controlled Area unless a conditional release under controlled conditions is authorized by the ES&H manager.

# SECTION 6

## REQUIREMENTS FOR WORKING IN RADIATION AREAS

# 6.0 REQUIREMENTS FOR WORKING IN RADIATION AREAS

## 6.1 Controlling Exposure in Radiation Areas

6.1.1 Radiation Exposure Control shall be maintained through the use of physical barriers, operating procedures, Radiation Work Permits, surveillance, training and engineered modifications to equipment. Work areas that produce high personnel exposures shall be identified and changes should be engineered to lower exposures. Functions that result in elevated exposures to personnel shall also be evaluated and appropriate changes made. These changes may include, but are not limited to, remote handling equipment, robotics, total enclosures, improved ventilation, and shielding.

6.1.2 All personnel have the responsibility of working in a safe manner and identifying potential hazards to supervision who shall investigate and recommend appropriate remedial actions. RMIEP has the responsibility to provide a safe work environment and to investigate and resolve radiological safety concerns in a conscientious manner.

## 6.2 Exposure Limits for Radiation Areas

6.2.1 External exposure control is accomplished by identifying areas containing sources of radiation and controlling personnel access into these areas or by removing the radiation source.

6.2.1.1 Radiation Areas are accessible areas where a major portion of the body could receive a dose equivalent greater than 5.0 mrem, but less than 100 mrem, in one hour.

6.2.1.2 High Radiation Areas are areas where a major portion of the body could receive a dose equivalent of 100 mrem but less than 5 rem in one hour.

## 6.3 Requirements for Working in Radiation Areas

6.3.1 Posting Requirements

6.3.1.1 Radiation and High Radiation Areas are defined by the following exposure rates:

| Area | Effective Dose Rate Equivalent at 30 cm |
|---|---|
| Radiation Area | >5.0 <100 mrem/hr. |
| High Radiation Area | >100 <5000 mrem/hr. |

6.3.1.2 Radiation Areas shall be conspicuously posted by the HPJE with the standard magenta radiation symbol on a yellow background and the words "Radiation Area". The posting should display any additional information which may be appropriate in aiding individuals to minimize exposure to radiation.

6.3.1.3 The boundaries of a Radiation Area or a High Radiation Area that are not formed by permanent structures (walls, doors, fences, etc.), shall be barricaded by radiation rope/ribbon installed at approximately waist height. Radiation posting signs must be attached.

6.3.1.4 High Radiation Areas shall be conspicuously posted by the HPJEs with the standard magenta radiation symbol on a yellow background and the words "HIGH RADIATION AREA." The posting should include the maximum radiation level and location within the area. The information may be on the High Radiation Area sign or on a separate plant view or sketch. The posting at the entry shall contain special instructions and requirements which may be appropriate in minimizing exposure to radiation.

6.3.1.5 High Radiation Areas that have posted survey dates more than 90 days old must be resurveyed by the HPJEs prior to allowing work in the area. If the conditions producing high radiation in an area are inherent to the facility or operation, and are relatively stable and not subject to change, permanent signs may be posted with the radiation symbol "HIGH RADIATION AREA" and appropriate information and instructions. The use of permanent signs shall be approved by the Manager of ES&H or his designate.

6.3.2 Access to High Radiation Areas

6.3.2.1 The boundaries of a High Radiation Area shall be evaluated by Health Physics personnel for all possible means of access and those not formed by solid physical structures (walls, doors, fences, etc.), shall be barricaded to preclude unauthorized entry.

6.3.2.2 Access(es) to the High Radiation Area shall be locked or maintained under continuous surveillance. When locking systems are used, a key control system shall be established, the number of keys shall be minimized and the personnel authorized to sign out the keys shall be specifically designated in writing.

6.3.2.3 Positive controls shall be established for each individual entry such that no individual is prevented from leaving the area. Prior to locking an area, the area shall be inspected to ensure that no personnel remain inside.

6.3.2.4 No loitering or entry by unauthorized personnel shall be allowed in these areas.

6.3.2.5 Instances in which High Radiation Areas are not controlled as required by this paragraph shall be reported as Unusual Occurrences. These instances include the following:

- Locking personnel in a High Radiation Area.
- Failing to post a High Radiation Area or failing to lock or guard a High Radiation Area. The Unusual Occurrence Report is not required if the area is properly controlled after its initial identification.

6.3.3 <u>Authorization for Work in Radiation and High Radiation Areas</u>

6.3.3.1 Radiation Work Permits are required for tasks performed under approved work procedures if those tasks involve work in high radiation fields or in areas where radiation fields are unknown or where large significant variations are possible in the radiation field. The RWP identifies the work activity, the associated radiological conditions and protective measures required to accomplish the work (See Section 4.4.2).

6.3.4 Shielding

6.3.4.1 Permanent shielding shall be designed and installed as part of construction of new facilities and during modifications to existing facilities where routine operations, materials or equipment produce or involve high radiation levels or where an unusual occurrence could result at such levels.

6.3.4.2 Changes in the use or operation of facilities which could affect radiation levels outside the shielding in excess of design levels, and changes in use of areas surrounding the shielding shall require prior review and approval by ES&H Management. Removal of permanent shielding shall not be permitted unless approval has been obtained from the Manager of ES&H. Radiation surveys are required any time shielding configurations are altered.

6.3.4.3 Temporary shielding shall be used in areas where its use is reasonably beneficial. Incorrect installation, unauthorized movement, or removal of temporary shielding can result in significant changes in work area radiation levels, therefore, control of temporary shielding is essential. Radiological Safety shall specify the locations where temporary shielding is required.

6.3.4.4 Rubber matting shall be routinely used on individual items such as an ingot. The rubber matting is very effective in reducing the beta exposure rate on individual components. The practice of covering the product will significantly reduce skin exposures.

6.3.4.5 Beta radiation can also be shielded with light metals, plywood, or heavy plastic. Aluminum and plywood are very good shielding materials. Heavy plastic shall not be used inside any building without approval of RMIEP Safety Department. Materials with a high atomic number (Z), i.e., lead, steel, should not be used as the primary shield against beta radiation since the X-ray generated by beta absorption can contribute significantly to the penetrating radiation dose.

## 6.4 Radiation Surveys

6.4.1 The primary objective of radiation surveys is to identify existing and potential radiation levels. This is to assure that exposures are maintained as low as reasonably achievable (ALARA). Survey results are utilized to:

- Evaluate jobs for ALARA considerations.
- Set up procedures.
- Provide a baseline for trend analysis, investigation and correction of unusual conditions.
- Detect departures from operating procedures or failure of radiation controls.
- Identify the origin of radiation exposures in the plant by location, system or component.

### 6.4.2 Requirements

6.4.2.1 Radiation surveys shall be performed by HPJEs to preclude the possibility of personnel being exposed to elevated levels of radiation and exceeding established radiation dose limits. They shall be used to meet the requirements for posting Radiation and High Radiation Areas. The surveys shall be performed to determine the magnitude and extent of radiation levels.

6.4.2.2 Radiation surveys are typically divided into routine and nonroutine classifications.

### 6.4.3 Routine Surveys

6.4.3.1 Routine surveys shall be performed by HPJEs on a regular basis (e.g., daily, weekly, monthly, etc.), while nonroutine surveys are performed as necessary to support plant processing modifications, work activities, and any nonroutine conditions.

6.4.3.2 Routine and nonroutine radiation surveys shall be performed for alpha, beta, and gamma radiation.

6.4.3.3 Surveys shall be performed with instruments calibrated for the type and energy range of radiation being monitored. The instrument range should be high enough to read the highest exposure rate expected. The instrument used shall have a current calibration label and its operability verified through performance evaluation.

6.4.3.4 A sufficient number of survey points shall be taken in order to adequately assess the radiological status of the area being surveyed.

6.4.3.5 Surveys shall be accurately and legibly documented in ink on a standard form. These survey records shall be filed and maintained by area in chronological order so that previous radiological conditions can be readily reconstructed and background data for radiological engineering evaluation is readily available.

- The data shall be in sufficient detail so that the meaning and intent of the record is clear.
- Ditto marks and continuation lines are unacceptable for repeated data.
- Any corrections to a survey record shall be made by drawing a single line through the incorrect entry (incorrect entry shall remain legible) and recording the correct entry. The person making the correction shall initial and date the entry. The use of erasures or correction tape/fluid is prohibited. Correction of each copy of a survey record shall be completed in the same manner.

6.4.4 <u>Nonroutine Surveys</u>

6.4.4.1 Nonroutine surveys shall be performed by HPJEs as necessary to support plant operations, maintenance and modification efforts. Examples of nonroutine surveys are as follows:

- An initial radiation survey shall be performed before and after a new facility using radioactive materials becomes operational. The survey shall also be required after completion of any modifications or changes in existing facilities that the HP determines might lead to a substantial change in the radiation hazards associated with operation of the facility. The survey shall be thorough with specific requirements determined by the HP.

- Radiation surveys to verify the effectiveness of permanent or temporary shielding.

- During removal of shielding so that personnel are not unexpectedly exposed to radiation.

- After changes in use of operation of a shielded facility (may be part of the survey required by the first example above).

- After modifications to the shield or changes in shield materials.

6.4.4.2 Radiation surveys shall be performed at predetermined points in active work areas and adjacent areas whenever operations are performed that have the potential for significantly changing radiation levels. Examples of these are movement of permanent or temporary shielding, radioactive waste processing, and relocation of highly radioactive materials. The survey may be done as part of a radiological inspection.

6.4.4.3 Radiation surveys shall be performed upon initial entry into tanks or enclosures that contain radioactive piping or components or high levels of loose contaminated material. Surveys shall be conducted when performing operations which could result in personnel being exposed to small intense beams of radiation. Examples of such operations include removing shielding at the boundaries of a High Radiation Area and opening containers of high activity radiation sources such as radiography sources.

6.4.5 <u>Survey Techniques</u>

6.4.5.1 When surveying areas or equipment where intense small beams of radiation can be present, the radiation detection instrument shall be used with audible response. An audible response is necessary due to the lag time in meter response. The probe shall be moved slowly enough so that the instrument has a chance to give an audible increase for a large radiation level increase. Particular attention shall be given to thoroughly scanning suspected areas, such as portable shield sections and areas which are or are likely to be occupied. Small intense beams have occurred in places such as outside shields surrounding sources containing many curies. For equipment with complex shield design, surveyors shall obtain briefings on the equipment design so that areas most likely to have small beams can be given special attention.

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# SECTION 7

# RADIOACTIVE CONTAMINATION

# 7.0 RADIOACTIVE CONTAMINATION

## 7.1 General

7.1.1 Surface contamination is radioactive dust or finely divided radioactive particles lying loosely or fixed rigidly to surfaces which are otherwise non-radioactive.

7.1.2 Surface contamination is controlled to:

- minimize the potential for ingestion of radioactivity;
- minimize the potential for inhalation of radioactivity which could arise from surface contamination becoming airborne;
- to minimize the potential for skin contamination which could result in ingestion or absorption of radionuclides or irradiation of the skin and body;
- minimize the potential for release of radioactivity to the environment.

7.1.3 Requirements for entry and exit from Regulated and Contaminated Areas are identified in Section 5 of this manual.

## 7.2 Contamination Limits and Posting Requirements

7.2.1 Posting of Controlled, Radiological, Contaminated and RWP/SOP Areas shall be done in accordance with RMI-L-148, RMI Entry Control Program. Limits and entry requirements for these areas are described in detail within this document.

## 7.3 Posting Responsibilities

7.3.1 HP Department shall identify all areas where posting is required, specify sign requirements, and post all temporary or portable signs and barriers.

7.3.2 Operations Department shall install and maintain all permanent signs and barriers.

## 7.4 Barriers

7.4.1 Where loose surface contamination exceeds ten times the limits of Appendix D, or at lower levels specified by HP Department to prevent the spread of contamination, Contamination Areas shall be isolated by barriers consisting of walls, fences, or yellow and magenta rope. Where necessary for the movement of material, Contamination Areas may be identified at material transfer points by conspicuously marking the surface of the transfer point. Signs shall be posted conspicuously for any approach to the area.

7.4.2 Step-off pads, friskers, and receptacles for laundry, waste, and respirators (as needed) shall be provided at exits from Contamination Areas.

7.5 Clothing Requirements

7.5.1 RMI-L-148, RMI Entry Control Program, specifies the clothing requirements for the various areas that comprise the RMI site.

7.6 Survey Requirements

Surveys for contamination shall be performed on a routine basis by Health Physics. Frequency requirements shall be promulgated by the Health Physicist and shall be sufficient to maintain correct posting of areas.

7.7 Cleaning in the Controlled Area

Cleaning methods must be selected to minimize the spread of contamination and to minimize airborne radioactivity. HEPA-filtered vacuum cleaning is preferred for removing dust from floors and other surfaces. Wet wiping is also acceptable.

7.7.1 Decontamination Methods

When cleaning is performed to remove contamination, care must be taken to not spread the contamination. This is accomplished by starting at areas of low contamination and working toward areas of higher contamination. Cleaning material shall be placed in radioactive material receptacles as soon as its usefulness is expired.

7.7.2 Sweeping

7.7.2.1 Dry sweeping is the least recommended cleaning method. It is prohibited in Contamination Areas unless specifically allowed by a radiation work permit.

7.7.2.2 Dry sweeping in Radiological Areas shall be performed only with the following precautions:

- The sweeper (and helper, if any) shall wear a half-face air purifying respirator when a potential for airborne contamination is present,

- Sweeping compound shall be used to limit the potential for dust becoming airborne.

7.7.3 Portable Vacuum Cleaners

7.7.3.1 The spread of airborne radioactivity can be minimized by portable vacuums with a high efficiency particulate air (HEPA) filter. All proposed Controlled Area vacuum systems must be reviewed by HP Department prior to use.

7.7.3.2 Portable vacuum units used for vacuuming radioactive materials or inside of Controlled Area buildings shall be equipped with a HEPA filter or the exhaust must be routed to the building's filtered exhaust system. HEPA vacuums shall be maintained by Restoration Operations personnel.

# SECTION 8

## REQUIREMENTS FOR WORKING IN AIRBORNE RADIOACTIVE AREAS

# 8.0 REQUIREMENTS FOR WORKING IN AIRBORNE RADIOACTIVITY AREAS

## 8.1 Controlling Airborne Radioactivity

8.1.1 Radioactivity can become airborne through such operations as burning, welding or grinding a contaminated component, decontamination, formation of particles from the products of process reactions, or disturbing deposited radioactivity on contaminated floors or other surfaces.

8.1.2 Control of airborne radioactivity by the application of engineered controls is the primary means for minimizing inhalation of airborne radioactivity. In situations where engineered controls are not practicable such as in dust collector enclosures, respiratory protection shall be used.

8.1.3 Air samples shall be taken where significant concentrations of airborne radioactivity are probable or suspected within the work environment. Continuous air monitors (CAM's) are used to monitor selected nominally occupied areas. Continuous fixed-filter air samplers are used for monitoring the air exhausted in the plant stacks.

## 8.2 Limits for Airborne Radioactivity

8.2.1 Limits for airborne radioactivity in occupied areas are listed in Appendix B to this manual. These limits are designated by the DOE as derived air concentrations (DAC) for airborne radioactivity and are limits for average concentrations of radionuclides of various solubility classes over a working year. The use of respiratory protection is prescribed on the basis of airborne concentrations present compared to the listed values. Measurement of air concentration is routinely reported at RMIEP in units of uCi/mL.

## 8.3 Requirements for Working in Airborne Radioactive Areas

### 8.3.1 Posting of Areas

8.3.1.1 Any area within a Radiological Area where the airborne radioactivity concentrations *are* greater than 0.1 DAC or exposed to greater than in one week shall be posted by HP personnel as "CAUTION AIRBORNE RADIOACTIVITY AREA" and "RESPIRATOR REQUIRED."

8.3.2 Respiratory Protection

8.3.2.1 If the sources of airborne contamination cannot be eliminated, respiratory protection shall be required. Respirators shall be used in accordance with the RMIEP Respiratory Protection Manual (RMI-L-140).

8.3.2.2 Air supplied respiratory protection may be required if greater than 1.0 DAC of radioactive material are airborne in the work area at the start of work or if there is a potential for the creation of greater than 1.0 DAC airborne contaminants due to the nature of the work. Examples would be: welding on a contaminated surface, cleaning up spills of dry material, and changing dust collector bags.

8.3.2.3 Respiratory protection shall be considered whenever burning, grinding, or welding takes place on a contaminated surface or when air monitoring indicates air concentration levels exceed 25% DAC.

A. Respirator Selection

Different brands of respiratory protective equipment are available at the RMIEP. These respirators have been chosen to facilitate proper fitting and optimal user protection and comfort.

Several factors govern respirator selection. These include:

1. The nature and extent of the hazard.
2. Work requirements and conditions.
3. Respiratory equipment protection limits.
4. Availability of approved equipment.
5. Facial characteristics (size, shape, etc.).
6. Skin reactions to the material from which the respirator is made.

B. Respirator Types

The types of respirators available for use are: Half-mask air-purifying respirators, full-face air-purifying respirators, air-supplied respirators with full-face mask or hood and self-contained breathing apparatus (SCBAs). They are described in RMI-L-140.

C. Protection Factors

The overall protection provided by a respirator is defined as its protection factor (PF). Table 8.1 shows the protection factors for each type of respirator as listed in NRC Regulatory Guide 8.15.

The PF is defined as the ratio of the concentration of contaminants outside the respirator to that inside the respirator under conditions of use. For example, if the contaminant concentration inside a half mask respirator is less than 10 percent of that outside the respirator, it may be used for respiratory protection in atmospheres with a contaminant concentration up to 10 times the permissible exposure limit. When calculating the exposure of individuals wearing respiratory protection equipment from radioactive materials, the concentration of airborne radioactive contaminants is divided by the protection factor to determine actual intake. The PF is the lowest acceptable fit test factor (FTF) defined in RMI-l-140.

TABLE 8.1[e]

RESPIRATORY PROTECTIVE EQUIPMENT

| Type of Equipment | Condition Inside of Headpiece | Protection Factor [a] |
|---|---|---|
| 1. Air-Purifying[b] | | |
| (a) Half-Face | negative pressure | 10 |
| (b) Full-face Facepiece | negative pressure | 50 |
| 2. Airline Respirator (Type "C" supplied air respirator)[c] | | |
| (a) Half-mask | continuous air flow | 1000 |
| (b) Full-face facepiece with emergency supply of compressed air | continuous air flow | 2000[d] |
| (c) Hood headpiece | continuous flow | 2000 |
| (d) Helmet headpiece | continuous flow | 2000 |
| 3. Self-Contained Breathing Apparatus (SCBA) | | |
| (a) Full-face facepiece - open circuit | pressure-demand | 10,000[d] |

NOTES:

a Protection factor is the multiplication constant used to determine the degree of protection from a properly used respirator (for example, the airborne limit for U-238 is $2 \times 10^{-11}$ uCi/ml. A protection factor of 10 allows entrance into an environment with a concentration of $2 \times 10^{-10}$ uCi/ml).

b An appropriate high efficiency radionuclide cartridge must be used in all cases.

c The equipment supplying breathing air and the air supplied shall meet the requirements in Compressed Gas Association (CGA) Standard G-7.1-1973 for Grade D air. The air in any breathing supply shall be tested initially and at least annually thereafter by the Health Physics Department.

d Approved for use in environments that are immediately dangerous to life and health.

e 10 CFR Part 20 Appendix A.

8.3.3 Authorization for Work in Airborne Radioactivity Areas

8.3.3.1 A Radiation Work Permit shall be required for the performance of any task that involves exposure to radioactive material for which there is not an approved work procedure. The RWP identifies the work activity, the associated radiological conditions and protective measures required to accomplish the work (See Section 4).

8.3.4 Containment of Airborne Radioactivity

8.3.4.1 The spread of airborne contamination should be minimized by employing a localized enclosure equipped with a high velocity, high efficiency particulate air (HEPA) filtered exhaust at the worksite. HEPA filtered vacuum cleaners or portable air movers fitted with ducting and HEPA filters may be used for this application. Personnel are still required to use respiratory protection when the potential for airborne contamination exists. This requirement is not relaxed by the use of a localized HEPA filtered exhaust. Proposed worksite HEPA filtered exhaust systems shall be reviewed by the Operations Department prior to their use.

8.3.4.2 To prevent cross contamination, designated vacuums shall be used in work areas. Hoses of vacuums used in contaminated work areas shall have the ends taped and tagged as radioactively contaminated after use.

8.3.4.3 Contamination containments shall be used to the maximum extent practicable to prevent personnel exposure to airborne radioactivity above the listed limits. This containment is required during radioactive work which has been known to cause or is expected to cause airborne radioactivity.

a. The exhaust from radiologically controlled containments shall be HEPA filtered whenever work is in progress in these containments to prevent the release of airborne contamination to the surrounding environment.

b. HEPA filters shall be installed in the exhaust from contamination containments to prevent personnel from being exposed to significant airborne radioactivity.

c. HEPA filters shall be installed and certified acceptable by the Operations Department in vacuum cleaners used for removing surface contamination.

## 8.4 Monitoring for Airborne Radioactivity

8.4.1 Air particulate surveys shall be performed by HP personnel. Records of the results of these surveys shall be reviewed by the Health Physicist. The following air samples shall be the minimum performed:

a. During radioactive work which has been known to cause or is expected to cause airborne radioactivity, and in occupied surface contamination areas.

b. When opening a process system to the atmosphere for operation or maintenance. Air samples are not required during normal liquid sampling operations or when opening the system in a containment enclosure equipped with a high efficiency filter.

c. When initially entering tanks containing potential radioactive piping or material.

d. Whenever airborne radioactivity levels above the acceptable limit are suspected.

8.4.2 The precise location for air samples cannot be specified for all situations. The primary objective is to obtain "breathing zone" (BZ) air samples or general area air samples. BZ air samples are collected using a portable, battery powered air pump with a small filter located as close to the worker's immediate breathing zone as possible. General area sampling shall be performed continuously in normal work or process areas. The locations for air samples shall be based on the following: 1) the breathing zone of the worker, 2) the position of the sampler relative to the work zone and other operations which might contribute to elevated levels of radioactivity in the breathing zone, 3) the type of work being performed (for example, grinding), and 4) the containment enclosure arrangement used. The volume of air sampled depends on the equipment used and the radionuclides of concern.

8.4.3 When it is determined by the Health Physics Department that an employee has been in an environment where the air concentration is equal to or greater than 40 DAC-hours, with out a respirator, he/she will provide a "special urine sample." This is based on requirements of DOE Order 5480.11, 9.g.2.

# SECTION 9

## RESPONDING TO RADIATION INCIDENTS

# 9.0 RESPONDING TO RADIATION INCIDENTS

## 9.1 Incident Response

9.1.1 An incident is a sudden unexpected event requiring immediate response to limit the impact on people, property or the environment. Specific guidance for various types of emergencies are outlined in the RMI Emergency Procedures Manual, RMI-L-51. When radioactive material is involved, the HP Department plays a major role in evaluating, controlling, and recovering from the event. Examples of incidents involving radioactive materials are:

- Nuclear criticality
- Fire or explosion involving radioactive material
- Spill of radioactive material

9.1.2 HPJE personnel shall respond to all radiological emergency incidents. The ability to assess and evaluate the situation and the immediate steps to minimize the effects of the event are crucial for controlling the emergency.

9.1.3 An emergency response may be initiated by personnel observing the event or by alarm systems.

9.1.4 The type of emergency determines the level of planning for response. For example, a small radioactive spill requires little planning for the initial response. However, when and emergency causes a plant evacuation, preplanning for stay time, route of re-entry, decontamination methods, etc. and the approval of the ES&H Department are necessary for re-entry.

9.1.5 Basic Guidelines

9.1.5.1 The basic guidelines for emergency response include the following:

- Radiation exposure consideration - Total dosages greater than 25 REM for rescue of personnel, may be authorized by to Plant Manager only.

- Rendering first aid to injured employees - This may be administered by members of the Emergency Response Team, Medical Department, or other trained personnel.

- Attempt to stop the cause - Undue risks shall be avoided.

- Warn other personnel - Keep unnecessary personnel away from the event.

- Isolate the area - Install barriers as quickly as possible to establish a controlled area separating the affected area from the unaffected areas. In determining the size of the controlled area, the following should be considered: Gamma (penetrating) dose rates, possible spread of contamination, weather conditions, chemical hazards, non-radiological hazards, and security. Normal operation outside of the controlled area may continue.

- Minimize Exposure - For initial response, unnecessary radiation exposure shall be avoided.

- Survey - Define and assess the radiological problem and conditions. Interview people at the scene regarding the nature and extent of the incident. Perform radiological surveys; the type of survey is based on the event. Types of surveys include: personnel surveys, property and equipment surveys, dose rate estimates, air sampling, perimeter surveys, and re-entry surveys.

9.1.6 Follow-up Action

9.1.6.1 This includes, but is not limited to, decontamination, providing monitoring coverage, formal evaluations, restoration, and documentation. A planned operation is necessary of assure personnel exposures are minimized. Any planed exposure above the occupational dose limits requires the permission of the RMIEP Plant Manager and the personnel who will be expected to receive the extra exposure.

9.1.6.2 Any employee involved in an incident which could have resulted in an intake of radioactive materials by inhalation, ingestion or absorption shall submit a urine sample at the end of the employee's shift and again at the start of the next shift or as directed by the HP.

9.1.7 HP Department response to Incidents

9.1.7.1 The primary function of the HP Department is to provide the radiological data necessary to confirm and control the incident, determine the magnitude of the incident, minimize exposure to personnel, minimize contamination spread, and assist in the recovery actions. Radiological data is provided through surveys performed by the HP Department and by air sample monitors in or near the event area. Radiological surveys include radiation dose rate, radioactive contamination levels and air activity levels.

9.1.7.2 The primary purpose of all surveys is to assure personnel protection, to maintain exposure ALARA, and to minimize contamination of the area and personnel.

9.1.8 General Responsibilities of HP Department Personnel

9.1.8.1 Respond to any potential emergency involving radioactive material.

9.1.8.2 Perform radiological surveys of personnel and the affected area.

9.1.8.3 Document survey results.

9.1.8.4 Establish boundaries and access control.

9.1.9 Communication

9.1.9.1 The primary method of communication with the HPJEs is by telephone. However, the interplant page system and/or two-way radio can be used.

9.1.10 Preparation

9.1.10.1 Availability of First Aid kits and Radiation instruments.

9.1.10.2 Availability of equipment and supplies.

9.1.10.3 Protective clothing.

9.1.10.4 Respiratory protection.

9.1.10.5 Dosimetry.

9.1.10.6 Two-way radio.

9.1.11 <u>Area Survey and Access Control</u>

9.1.11.1 Don protective clothing as necessary.

9.1.11.2 Approach the affected area cautiously, with instrument operating.

9.1.11.3 Survey area to determine incident size.

9.1.11.4 Determine and establish boundaries based on dose rate, contamination spread, and air sampling.

9.1.11.5 Establish entry/exit point of control.

9.1.11.6 Determine radiation background in staging area.

9.1.11.7 Survey personnel who have evacuated for contamination.

9.1.11.8 If applicable, segregate personnel in protective clothing.

9.1.11.9 Set priority of survey.

- Injured personnel should be given first priority.
- Personnel in protective clothing, personnel who evacuated surface contamination area, second priority.
- Remaining personnel last priority.

9.1.11.10 Start air sampling.

9.1.11.11 Report survey results.

9.1.11.12 Survey all personnel and equipment leaving affected incident area.

9.1.12 Information to be obtained

9.1.12.1 Time of incident.

9.1.12.2 Location of the incident.

9.1.12.3 Nature of the incident.

9.1.12.4 What radiological information is known.

- Contamination (property & personnel).
- Dose rate.
- Isotopes involved and their solubility classes.
- Air sampling data.

9.1.12.5 Availability of other personnel to support emergency activities.

9.1.12.6 Are non-radiological hazards involved (i.e., chemicals, explosive devices, fire, etc.)?

9.1.12.7 Plume tracking (if necessary).

9.1.12.8 Status of environmental protective actions (i.e., diverting storm drains, securing dust collectors, etc.).

9.2 Criticality Alarm (See Criticality section of RMI-L-51)

Notification of a Criticality alarm will occur by means of the Criticality Alarm system and/or announcement over the public address system.

9.2.1 Immediate Action for Criticality Alarm

9.2.1.1 Stop any work.

9.2.1.2 Evacuate all personnel to the Emergency Assembly Area (ES&H Building).

9.2.1.3 Assure that all personnel are accounted for and are surveyed for contamination.

9.2.1.4 Obtain information from evacuated personnel on the possible cause of alarm and location of missing personnel.

9.2.1.5 Establish boundaries as necessary to control access until the source of the high dose rates have been identified and eliminated or reduced to normal conditions.

9.3 <u>Radioactive Material Spills</u> (See Spill section of RMI-L-51)

9.3.1 Response actions are needed to minimize the spread of contamination if radioactive material is spilled. These apply to spilled radioactive material in dry or liquid form within or outside a building.

<u>CAUTION</u>: If unfamiliar with the material or system, wait for qualified help. Do not move damaged containers. Evaluate potential for life threatening situations, such as toxic chemical fumes or criticality.

9.3.2 <u>Immediate Actions for Radioactive Material Spill</u>

9.3.2.1 Evacuate all unnecessary personnel in or near the spill area to a safe, central location. (Consider personal contamination surveys and nasal smears.)

9.3.2.2 Warn approaching personnel to remain outside of spill area.

9.3.2.3 Evaluate the need for backup equipment and personnel.

9.3.2.4 Notify the Health Physicist.

9.3.2.5 Notify the Manager of ES&H if the spill is considered to contain more then one pound of Uranium or if there is a chemical release.

9.4 <u>Radioactive Material Fires</u> (See Fire section of RMI-L-51)

9.4.1 Uranium in any pyrophoric form shall be collected and stored under water in a non-sealed drum.

9.4.2 <u>Immediate Action for Radioactive Material Fires</u>

9.4.2.1 Summon the Emergency Response team via the public address system.

9.4.2.2 Notify the guard on duty to call the Ashtabula Township Fire Department if deemed necessary.

9.4.2.3 Evacuate all unnecessary personnel to a safe central location (consider personal contamination surveys and nasal smears).

9.4.2.4 SCBAs shall be worn by all personnel fighting the fire. Full-face respirators with HEPA filters may be worn by personnel required to enter and uncleared area for short duration support of fire fighting personnel.

9.4.2.5 Warn approaching personnel to stay clear of area, and away from smoke or fumes.

<u>NOTE</u>: The primary radiological danger during a radioactive fire is due to ingestion of radioactive smoke, dust, vapors, or fumes. It is very important to keep personnel far enough away from the site of the fire and smoke to prevent the inadvertent inhalation of possible airborne radioactivity. Whether inside or outside a building, personnel should remain upstream of air flow or plume.

9.4.2.6 Notify the Health Physicist.

9.4.2.7 Notify the Manager of Operations.

9.4.2.8 Notify the Safety Supervisor.

9.5 <u>Reporting Radiation Incidents</u>

9.5.1 The Unusual Occurrence Reporting Procedure, RMI-L-117, shall be used to report any unusual or unplanned event having programmatic significance such that it adversely affects or potentially affects the performance, reliability or safety of the facility.

# SECTION 10

# RADIOACTIVE SOURCE CONTROL

# 10.0 RADIATION STANDARD CONTROL

## 10.1 Purpose

10.1.1 The radiation standard controls identified in this manual are intended to ensure that radiation standards received, possessed, used or transferred during routine operations at the RMIEP are accounted for, controlled, and used properly such that exposures to these materials are kept As Low As Reasonably Achievable. This manual provides guidance for radiation standards accountability.

## 10.2 Scope

10.2.1 This section of this manual shall apply to all RMIEP radiation standards and personnel using radiation standards.

## 10.3 Requirements

10.3.1 Sealed Radiation Standards shall be leak tested at least every six months.

10.3.2 Licensed Radiation Standards shall be leak tested every six months using a commercial laboratory to verify leak test results.

10.3.3 All use of Radiation Standards shall be documented using a Radiation Standard Use Log.

10.3.4 Radiation Standards are to be maintained in a locked storage cabinet when not in use.

10.3.5 Licensed Radiation Standards shall be issued for use by the RMIEP Radiation Safety Officer, or his designee, only.

10.3.6 Licensed Radiation Standards shall be used only under the authorization of a RWP or approved procedure.

## 10.4 Responsibilities

10.4.1 The Manager of ES&H shall appoint a member of the HP department staff to act as the Site Radiation Standard Controller.

10.4.2 The Site Radiation Standard Controller is responsible for:

10.4.2.1 Maintaining a master inventory of Radiation Standards.

10.4.2.2 Ensuring Radiation Standard Custodians understand and comply with the requirements of this manual.

10.4.2.3 Reporting to the Radiation Safety Officer all discrepancies with Radiation Standards.

10.4.2.4 Assigning Radiation Standard Custodian responsibilities to individuals (usually an area supervisor).

10.4.3 Radiation Standard Custodians are responsible for:

10.4.3.1 Performing semi annual inventories of the radiation standards for which he/she is responsible. Loss of or damage to sources shall be reported to the Site Radiation Standard Controller immediately.

10.4.3.2 Coordinating with Health Physicist to have leak tests and other functional test performed.

**Note:** Consumable liquid radiation standards are exempt from the leak testing portions of this manual.

10.4.3.3 Reporting the results of these inspections to the Site Radiation Standard Controller.

10.4.3.4 Maintaining an accurate and current log of the Radiation Standards he/she is responsible for.

10.4.3.5 Removing from service any radiation standard found to be within thirty days of its recertification date.

10.4.3.6 Reporting any changes in the radiation standard storage location to the Site Radiation Standard Controller.

10.4.3.7 Ensuring knowledge of procedures pertaining to radiation standard control is maintained, for his or her self and any user of the radiation standards for which he/she is responsible for.

10.4.3.8 Maintaining the Radiation Standard Use Log for the radiation standards assigned to his/her custodianship.

10.4.4 The Health Physics Department is responsible for:

10.4.4.1 Leak testing radiation standards.

10.4.4.2 Support inventory audits.

10.4.4.3 Review work permits and procedures concerning transport and use of radiation standards.

10.4.4.4 Prompt notification to DOE and NRC of lost, damaged, leaking, or stolen radiation standards.

10.4.4.5 Support acquisition/disposal/use of all radiation standards.

10.4.4.6 Ensuring the safe handling of radiation standards.

10.4.5 Any RMIEP employee, subcontractor or visitor bringing radiation standard materials on the RMIEP site shall notify the HP Department and Site Radiation Standard Controller of this intent prior to bringing the materials on site.

10.5 Accountability and Control

10.5.1 A master inventory of all radiation standards shall be maintained and confirmed, with the assistance of the Radiation Standard Custodians.

10.5.2 Radiation standards shall be stored in locked containers or other storage approved by the HP Department.

10.5.3 Radiation standards shall not be permanently moved from their designated storage area without written permission from the Site Radiation Standard Controller.

10.5.4 Appropriate dosimetry shall be used when handling radiation standards.

10.5.5 At no time shall any radiation standard be left un attended when not in its approved storage location.

10.5.6 Leaking or damaged radiation standards shall be removed from service per Health Physics Procedures.

10.6 Records

10.6.1 Records of radiation standard use shall be maintained at the storage locations.

10.6.2 A radiation standard inventory log shall be maintained in each storage area that shall contain the following information: radiation standard serial number, material type (isotope(s), physical form), radiation type, activity and date of activity, Custodian's name, and date of inventory.

10.6.3 A copy of NIST Traceability Certificates, for each NIST traceable radiation standard, shall be maintained at each storage area with the original certificate being filed with the Site Radiation Standard Controller.

10.7 Labeling

10.7.1 All radiation standards shall be permanently marked to permit individual radiation standard identification as follows:

10.7.1.1 The label shall bear the radiation caution symbol and the words "Caution Radioactive Material."

10.7.1.2 If the radiation standard is capable of delivering a whole body dose of 1000 mR/hr or more the label shall bear the radiation caution symbol and the words "Danger Radioactive Materials."

10.7.1.3 The label should include the following information: identification number, isotopic identification, radiation type, dose rate at surface contact, activity, date of activity, and half life.

10.8 Training

10.8.1 All Radiation Standard Custodians shall have source control training commensurate with risk and their responsibilities.

10.8.2 Any user of a radiation standard shall receive radiation standard control training commensurate with risk and their responsibilities as a user of radiation standards.

10.8.3 Health Physics shall review and concur with all training material with regard to radiation standard control.

## SECTION 11

## RADIOACTIVE MATERIAL SHIPPING AND RECEIVING

## 11.0 RADIOACTIVE MATERIAL SHIPPING AND RECEIVING

### 11.1 General Requirements

11.1.1 Radioactive materials received by or shipped from the RMIEP shall conform to U.S. Department of Transportation (DOT), U.S. Department of Energy (DOE), and Nuclear Regulatory Commission (NRC) rules and regulations. These rules and regulations apply to vehicles and packages used for the shipments as well as the materials themselves.

11.1.2 These rules and regulations shall apply to all radioactive materials received or shipped, to vehicles used to ship exclusive use shipments, and to vehicles which deliver exclusive use shipments, regardless of intent to reuse for an exclusive use shipment. It does not apply to materials transported exclusively on site.

11.1.3 Personnel responsible for shipping radioactive material are responsible for packaging it in compliance with applicable rules and regulations.

11.1.4 The Traffic Department shall notify the HPJEs when vehicles carrying radioactive material arrive on site, are empty, are loaded and ready for dispatch, and for preparation of required shipping papers.

11.1.5 The HPJEs shall survey packages, vehicles, etc., maintain records, and make required reports and notifications.

### 11.2 Transportation Standards

11.2.1 The Federal DOT, through Title 49 of the Code of Federal Regulations (49 CFR), sets standards for shipping radioactive materials. These regulations specify how the material is to be packaged, how it is loaded, exposure rates, removable surface contamination levels, and in some cases, how it is routed.

11.2.2 The U.S. Nuclear Regulatory Commission, through Title 10, Part 71 of the Code of Federal Regulations (10 CFR 71), supplements the DOT regulations for large quantities or high levels of byproduct materials and significant quantities of fissile materials.

11.2.3 The types of radioactive material shipments generally made to or from RMIEP are; Low Specific Activity, Limited Quantity, and Fissile Material.

11.3 <u>Surveying of Radioactive Shipments</u>

11.3.1 Surveys of packages and vehicles shall be performed by HPJEs within the following time frames:

11.3.1.1 Incoming packages nonexclusive use vehicle - as soon as practical but not more than three (3) hours after receipt during normal working hours.

11.3.1.2 Incoming exclusive use vehicle - prior to opening.

11.3.1.3 All Vehicles - after unloading.

11.3.1.4 Vehicle to be used for exclusive use - within 48 hours of loading.

11.3.1.5 Outgoing package nonexclusive use vehicle - within 48 hours of leaving.

11.3.1.6 Outgoing exclusive use vehicles - within three (3) hours of leaving.

11.3.2 Removable contamination "Swipe" surveys are conducted using dry filter paper. Four 100 square centimeter ($cm^2$) areas of each package are to be swiped. Large smooth surfaces may be rough checked by swiping a large area with a tissue/towelette (e.g., Kimwipe). If there is detectable activity on the tissue/towelette, four 100 $cm^2$ swipe will be required. Exclusive use vehicles shall be surveyed prior to being loaded.

11.3.3 Packages shall be surveyed for exposure rate at the surface and at one (1) meter. Record the maximum reading found.

11.3.4 Vehicles shall be surveyed for exposure rate at the surface and at two (2) meters. Record the maximum reading found.

11.3.5 If the surface dose equivalent rate is 1.5 mrem/hour or less, packages separated by eight (8) feet or more may be considered in low background. Higher surface dose rates, larger packages --- or arrays of packages, or closer spacing shall use the "<"

(less than) symbol when measured exposure rates are recorded due to unknown contributions from other packages.

NOTE: Because definitions of limited quantity and the requirements for Radioactive I, II, III labels are based on dose rate measurements, the errors resulting from packages being too close together could adversely affect shipping requirements, even though otherwise legal and proper.

11.4 Radiation and Contamination Limits

11.4.1 Limits for: Limited quantity packages:

11.4.1.1 Surface Dose Rate = 0.5 mrem/hr for non-exclusive shipments 2.0 mrem/hr for exclusive shipment.

11.4.1.2 Removable Contamination = 22 dpm/cm$^2$ averaged over at least four 100 cm$^2$ areas (2.2 dpm/cm$^2$ if alpha emitters other than uranium or thorium are present).

11.4.2 Package for non-exclusive use of vehicle shipment:

11.4.2.1 Surface Dose Rate: 200 mrem/hr

11.4.2.2 The Transport Index, i.e., the maximum radiation level in mrem/hr at one meter is limited to not more than 10 units per package and not more than 50 units per shipment.

11.4.3 Exclusive use of vehicle package:

11.4.3.1 Surface Dose Rate: 200 mrem/hr

11.4.3.2 Any "Surface" of Vehicle: 200 mrem/hr

11.4.3.3 2 Meters (6.6 ft): 10 mrem/hr

11.4.3.4 Any normally occupied position in vehicle (truck cab): 2 mrem/hr

11.4.3.5 Contamination Limits: Same as limited quantity packages.

11.4.4 Enclosed Exclusive use Vehicle:

11.4.4.1 Surface Dose Rate: 1000 mrem/hr

11.4.4.2 Surface of Vehicle: 200 mrem/hr

11.4.4.3 2 meters from surface of vehicle: 10 mrem/hr

11.4.4.4 Any normally occupied position in vehicle: 2 mrem/hr

11.4.4.5 Removable Contamination: Same as limited quantity packages.

11.4.5 Empty exclusive use vehicles not marked "For Radioactive Materials Use Only," shall have an interior surface dose rate of 0.5 mrem/hour or less and the removable contamination must be less than 22 dpm/cm$^2$ (or 2.2 dpm/cm$^2$ if transuranic materials are present) averaged over 300 square centimeters.

11.5 Marking, Labeling and Placarding

11.5.1 Radioactive materials received onto, or shipped from, the RMIEP shall conform to the marking, labeling, and placarding requirements of the DOT and DOE rules and regulations as they apply to packages and vehicles.

11.5.2 Personnel responsible for shipping radioactive material are responsible for properly packaging, marking and labeling in compliance with applicable rules and regulations.

11.5.3 The RMIEP Transportation and Materials Management shall verify the labeling, marking and placarding of incoming materials, prior to acceptance, and to verify marking and labeling of outgoing packages or vehicles, and to placard when placards are required on outgoing shipments.

11.5.4 The U.S. Department of Trarsportation (DOT) through Title 49 of the Code of Federal Regulations (49 CFR) establishes rules and regulations for labeling and placarding radioactive materials for shipment. The U.S. Department of Energy (DOE) establishes criteria for packaging and shipping radioactive materials through DOE Order 5480.3.

11.5.5 **Marking**: All packages except those shipped as either limited quantity or LSA/exclusive use of vehicle shall be specification containers and shall be marked in accordance with the following sections of 49 CFR 172:

300 Applicability (what must be marked).

301 General requirements (information required in the marking).

304 Marking requirements, characteristics and location(s) of markings.

310 Radioactive materials - additional markings required for radioactive materials packages.

312 Liquid hazardous materials - "This side up" and prohibition on use of other arrows.

178 Specifies the requirements for the construction of specification containers and the required markings.

11.5.6 **Labels:** Packages of radioactive material shall be labeled in accordance with the following sections of 49 CFR unless they are LSA exclusive use or limited quantity shipments.

11.5.7 **Placards:** Any vehicles carrying a package which has a "Radioactive Yellow III" label and exclusive use vehicles carrying LSA must be placarded. The following sections of 49 CFR pertain to placarding.

11.5.8 **Miscellaneous:** Transportation indexes for fissile material are given in Table 2 of 49 CFR 173.417.

11.5.8.1 Limited quantities of radioactive materials are defined by 49 CFR 173.421, 173.421-1, and 173.423.

11.5.8.2 LSA exemptions and marking, labeling, and placarding requirements are given in 49 CFR 173.425.

11.5.8.3 49 CFR 173.444 lists the sections which proved <u>exceptions</u> to labeling requirements.

# SECTION 12

# RECORDKEEPING

12.1 Radiological Monitoring Records

12.2 Work Place Monitoring

12.3 Personnel Exposure

## 12.0 RECORDKEEPING

### 12.1 Radiological Monitoring Records

12.1.1 All original radiological sampling data including maps, surveys and original sample worksheets shall be filed by Health Physics and kept indefinitely.

12.1.2 Laboratories (including offsite laboratories) shall maintain records of instrument serial numbers, calibration, calibration source identification along with documentation of a complete quality control program in accordance with NRC Regulatory Guide 4.15. This information shall also be maintained indefinitely.

### 12.2 Work Place Monitoring

12.2.1 Records of surveys, data sheets, maps, radiation work permits, health physics calculations, investigations, air sample results, worksheets and any other documentation directly related to work place monitoring shall be filed by Health Physics according to location (i.e., plant, building, project or location) and maintained for an indefinite length of time.

12.2.2 Data compiled on computer disks shall be trackable to original survey results and shall be controlled through the use of backup tapes.

12.2.3 Documentation of work conditions affecting the results of work area monitoring shall be listed on the appropriate record with sufficient detail to allow understanding at an undefined future date. Data stored on disk shall not be construed as sufficient reason to destroy original information.

### 12.3 Personnel Exposure

12.3.1 Completed quarterly dosimetry reports shall be retained. Each plant supervisor and the subcontractor shall receive a copy of his/her personnel's annual dose.

12.3.2 A summary of annual, cumulative and committed effective dose equivalent shall be provided to each employee and subcontractor radiation worker on an annual basis. Dose records shall be kept indefinitely by Health Physics.

12.3.3 All raw data, corrected data and employee external radiation reports shall be retained in a folder labeled with the particular quarter.

12.3.4 When extremity dosimetry is used, an extremity dosimetry report is generated monthly by Health Physics with extremity dose totals for each month.

# SECTION 13

## RADIATION SAFETY TRAINING AND AUDITS

# 13.0 RADIATION SAFETY TRAINING

## 13.1 Radiation Safety Training

Radiation safety training shall be provided to all RMIEP employees through the Health Physics Department by the Safety Engineer/Trainer. The scope and depth of training is a function of the employee's work assignment.

### 13.1.1 Employee Orientation

All employees shall receive an orientation in radiation safety within one month of their initial employment. Retraining shall be provided when there are significant changes to radiation protection policies and procedures which effect general plant employees, but at a sufficient frequency not to exceed two years. The initial orientation should include, but is not limited to:

- the risk of low-level occupational radiation exposure, including cancer and genetic effects
- the risk of prenatal radiation exposure
- basic radiation protection concepts
- DOE and RMIEP radiation protection policies and procedures
- employee and management responsibilities for radiation safety
- emergency procedures

### 13.1.2 Radiation Worker Training

Radiation worker training programs shall be established and conducted annually to familiarize the worker with the fundamentals of radiation protection and the proper procedures for maintaining exposures ALARA. Training should include both classroom and applied training. Training shall precede or be concurrent with assignment as a radiation worker while under the supervision of a trained individual. The knowledge of radiation safety fundamentals possessed by radiation workers shall be certified by examination prior to an unsupervised assignment. The level of training in the following topics shall be commensurate with each worker's assignment:

- radioactivity and radioactive decay
- characteristics of ionizing radiation
- man-made radiation sources
- acute effects of exposure to radiation
- risks associated with occupational radiation exposures
- special considerations in the exposure of women of reproductive age
- dose equivalent limits
- mode of exposure--internal and external
- dose equivalent determinations
- basic protective measures--time, distance, shielding
- specific plant procedures for maintaining exposure as low as reasonable achievable (ALARA)
- radiation survey instrumentation--calibration and limitations
- radiation monitoring programs and procedures
- contamination control, including protective clothing and equipment and workplace design
- self-monitoring instruments for detection of contamination
- bioassay and in vivo measurements
- personnel decontamination
- emergency procedures
- warning signs and alarms

- responsibilities of employees and management

- interaction with radiation protection staff

13.1.3 HPJE Technician Training

Radiation protection technician training programs shall be established and conducted at a sufficient frequency, not to exceed two years, to familiarize technicians with the fundamentals of radiation protection and the proper procedures for maintaining exposures ALARA. This program shall include both classroom and applied training and shall precede or be concurrent with assignment as a radiation protection technician while under the supervision of a trained individual. The knowledge of radiation safety fundamentals possessed by radiation protection technicians should be certified by examination prior to an unsupervised work assignment. The training program should include the topics listed in the paragraph above and should emphasize procedures specific to the facility where the technician is assigned. The level of training in each topic shall be commensurate with the technician's assignment.

13.2 Training Records

Training records of plant employees, radiation workers, and radiation safety personnel shall be retained by Safety Engineer/Trainer to document the level of understanding and proficiency of personnel who work with radioactive materials. Certification of successful completion of training programs and performance records shall also be retained.

# APPENDIX A

## Radiation Safety Terminology

These are terms commonly used in the nuclear industry.

# RADIATION SAFETY TERMINOLOGY

| TERM | DEFINITIONS |
|---|---|
| absorber | Any material that absorbs or lessens the intensity of ionizing radiation. A thin sheet of paper will absorb alpha particles and a thin piece of aluminum will absorb all except the most energetic beta particles. Concrete and steel absorb gamma rays. Neutron absorbers (like boron, hafnium, and cadmium) are used in control rods for reactors. (See shielding.) |
| absorption | The process by which the number of particles or photons entering a body of matter is reduced or attenuated by interaction with the matter. (See neutron capture. |
| activation | The process of making a material radioactive by bombardment with neutrons, protons, or other nuclear radiation. (See induced radioactivity.) |
| air sampling | The collection and analysis of samples of air to measure its radioactivity or to detect the presence of radioactive substances, particulate matter or chemical pollutants. |
| ALARA | Acronym for "As Low As Reasonably Achievable," a basic concept of radiation protection that specifies that radioactive discharges from nuclear plants and radiation exposure to personnel be kept as far below regulatory limits as practical. |
| alpha particle | A positively charged particle ejected spontaneously from the nuclei of some radioactive elements. It is identical to a helium nucleus that has a mass number of 4 and an electrostatic charge of +2. It has low-penetrating power and short range. The most energetic alpha particle will generally fail to penetrate the skin. Alphas are hazardous when an alpha-emitting radioisotope is introduced into the body. |
| anion | Negatively charged ion. (See ionization) |
| atom | The smallest particle of an element that cannot be divided or broken up by chemical means. It consists of a central core called the nucleus, which contains protons and neutrons. Electrons orbit in the region surrounding the nucleus. |
| atomic number | The number of positively charged protons in the nucleus of an atom and the number of electrons on an electrically neutral atom. |

**atomic weight** — See mass number.

**attenuation** — The process by which a beam of radiation is reduced in intensity when passing through some material. It is a combination of absorption and scattering processes.

**background radiation** — The natural radiation in man's environment, including cosmic rays and radiation from the naturally occurring radioactive elements, both outside and inside the bodies of humans and animals. An average individual exposure from background radiation is 125 millirem per year in mid latitudes at sea level.

**beta particle** — A charged particle emitted from a nucleus during radioactive decay, with a mass equal to 1/1837 that of a proton. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron. Large amounts of beta radiation may cause skin burns, and beta emitters are harmful if they enter the body. Beta particles are easily stopped by a thin sheet of metal or plastic.

**becquerel** — A unit, in the International System of Units (SI), for the measurement of radioactivity equal to one transformation or atomic disintegration per second.

**bioassay** — The collection and analysis of human hair, tissue, nasal smears, urine or fecal samples to determine the amount of radioactive material that might have been deposited in the body. Routes of possible entry are inhalation, ingestion or injection.

**biological half-life** — The time required for a biological system, such as that of a human, to eliminate by natural processes half the amount of a substance (such as a radioactive material) that is present within it.

**biological shield** — A mass of absorbing material placed around a reactor or radioactive source to reduce the radiation to a level safe for humans.

**body burden** — The amount of radioactive material which if deposited in the total body will produce the maximum permissible dose rate to the body organ considered the critical organ.

**bone seeker** — A radioisotope that tends to accumulate in the bones when it is introduced into the body. An example is strontium-90, which behaves chemically like calcium.

**Bremsstrahlung** — Secondary photon radiation produced by deceleration of charged particles passing through matter.

**calibration** — The check or correction of the accuracy of a measuring instrument to assure proper operational characteristics. (See counter.)

| | |
|---|---|
| cask | A heavily shielded container used to store and/or ship radioactive materials. Lead and steel are common materials used in the manufacture of casks. |
| charged particle | An ion. An elementary particle carrying a positive or negative electric charge. |
| chronic exposure | See exposure. |
| committed dose equivalent | Predicted total dose equivalent to a given organ or tissue over a 50 year period after an intake of a radionuclide into the body. |
| compound | A chemical combination of two or more elements combined in a fixed and definite proportion by weight. |
| contamination, radioactive | The deposition of uncontained or unwanted radioactive material on the surfaces of structure, areas, objects, or personnel. |
| controlled area | A defined area in which the occupational exposure of personnel to radiation or radioactive material is under the control of an individual in charge of radiation protection. |
| control room (building) | An area in a plant from which most of the plant power production and emergency safety equipment can be operated by remote control. |
| cosmic radiation | Penetrating ionizing radiation, both particulate and electromagnetic, originating in space. Secondary cosmic rays, formed by interactions in the earth's atmosphere, account for about 45 to 50 millirem of the 125 millirem background radiation that an average individual receives a year. |
| counter | A general designation applied to radiation detection instruments or survey meters that detect and measure radiation. The signal that announces an ionization event is called a count. (See Geiger-Mueller counter.) |
| critical organ | The body organ receiving a radionuclide or radiation dose that results in the greatest overall risk. |
| criticality | A term used in radiation physics to describe the state when the number of neutrons released by fission is exactly balanced by the neutrons being absorbed (by the fuel and poisons) and escaping the pile. A reaction is said to be "critical" when it achieves a self-sustaining nuclear chain reaction. |
| crud | A colloquial term for corrosion and wear products (rust particles, etc.) that become radioactive under a radiation flux. (See induced radioactivity.) |

| | |
|---|---|
| cumulative dose | The total dose resulting from repeated exposures of radiation to the same region, or to the whole body, over a period of time. |
| curie (Ci) | The basic unit used to describe the quantity of radioactivity in a sample of material. The curie is equal to 37 billion disintegrations per second, which is the rate of decay of 1 gram of radium. A curie is also a quanitity of any radionuclide that decays at a rate of 37 billion disintegrations per second. Named for Marie and Pierre Curie, who discovered radium in 1898. |
| daughter products | Isotopes that are formed by the radioactive decay of some other radioisotope. In the case of radium-226, for example, there are 10 successive daughter products, ending in the stable isotope lead-206. |
| decay, radioactive | The decrease in the amount of any radioactive material with the passage of time, due to the spontaneous emission from the atomic nuclei of either alpha or beta particles, often accompanied by gamma radiation. (See half-life; radioactive.) |
| decontamination | The reduction or removal of contaminating radioactive material from a structure, area, object, or person. Decontamination may be accomplished by (1) treating the surface to remove or decrease the contamination; (2) letting the material stand so that the radioactivity is decreased as a result of natural decay. |
| depleted uranium | Uranium having a percentage of uranium-235 smaller than the 0.72 percent found in natural uranium. (See mill tailings.) |
| design-basis phenomena | Earthquakes, tornados, hurricanes, floods, etc., that a nuclear facility must be designed and built to withstand without loss to the systems, structures, and components necessary to assure public health and safety. |
| detector | A material or device that is sensitive to radiation and can produce a response signal suitable for measurement or analysis. A radiation detection instrument. (See counter.) |
| differential pressure (DP) | The difference in pressure between two points of a system, such as between the inlet and outlet of a pump. |
| disintegration | See decay, radioactive. |
| dose | A quantity (total or accumulated) of ionizing radiation received. The term "dose" is often used in the sense of the exposure, expressed in roentgens, |

which is a measure of the total amount of ionization that the quantity of X ray or gamma radiation could produce in air. This should be distinguished from the absorbed dose, given in rads, that represents the energy absorbed from any radiation in a gram of any material. Furthermore, the biological dose, given in rem, is a measure of the biological damage to living tissue from the radiation exposure.

**dose equivalent** — A term used to express the amount of biologically effective radiation when modifying factors have been considered. The product of absorbed dose multiplied by a quality factor multiplied by a distribution factor. It is expressed numerically in rem.

**dosimeter** — A portable instrument for measuring and registering the total accumulated exposure to ionizing radiation. (See dosimetry.)

**dosimetry** — The theory and application of the principles and techniques involved in the measurement and recording of radiation doses. Its practical aspect is concerned with the use of various types of radiation instruments with which measurements are made. (See film badge; survey meter.)

**dose rate** — The radiation dose delivered per unit of time. Measured, for example, in rem per hour.

**effective half-life** — The time required for the amount of a radioactive element present in a living organism to be diminished 50 percent as a result of the combined action of radioactive decay and biological elimination. (See biological half-life.)

**electromagnetic (radiation)** — A traveling wave motion resulting from changing electric and magnetic fields. Familiar electromagnetic radiations range from X rays (and gamma rays) of short wavelength, through the ultra-violet, visible, and infrared regions, to radar and radio waves of relatively long wavelength. All electromagnetic radiations travel in a vacuum with the velocity of light (See photon.)

**electron** — An elementary particle with a unit negative charge and a mass 1/1837 that of the proton. Electrons surround the positively charged nucleus and determine the chemical properties of the atom. (See beta particle.)

**element** — One of the 103 known chemical substances that cannot be broken down further without changing its chemical properties. Some examples include hydrogen, nitrogen, gold, lead, and uranium.

**enrichment** — See isotopic enrichment.

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|---|---|
| erythema | An abnormal redness of the skin due to distension of the capillaries with blood. It can be caused by many different agents -- heat, drugs, ultraviolet rays and ionizing radiation. |
| exposure | The act or condition of being subject to the effect or risk of a field of radiation or dispersion of radioactive material. Acute exposure is generally accepted to be a large exposure received over a short period of time. Chronic exposure is exposure received during a lifetime. (See dose.) |
| external radiation | Exposure to ionizing radiation when the radiation source is located outside the body. |
| extremities | The hands and forearms and the feet and ankles. (Permissible radiation exposures in these regions are generally greater than for the whole body because they contain less blood-forming material.) |
| fissile material | Although sometimes used as a synonym for fissionable material, this term has acquired a more restricted meaning; namely, any material fissionable by thermal (slow) neutrons. The three primarily fissile materials are uranium-233, uranium-235 and plutonium-239. |
| fission | The splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy. Two or three neutrons are usually released during this type of transformation. |
| gamma ray (gamma radiation) | High-energy, short wavelength electromagnetic radiation emitted from the nucleus. Gamma radiation frequently accompanies alpha and beta emissions and always accompanies fission. Gamma rays are very penetrating and are best stopped or shielded against by dense materials, such as lead or uranium. Gamma rays are identical to X rays of the same energy. |
| gases | Normally formless fluids that completely fill the space and take the shape of their container. |
| gaseous diffusion (plant) | A method of isotopic separation based on the fact that gas atoms or molecules with different masses will diffuse through a porous barrier (or membrane) at different rates. This method is used to separate uranium-235 from uranium-238; it requires large gaseous diffusion plants and enormous amounts of electric power. |

**Geiger-Mueller counter** — A radiation detection and measuring instrument. It consists of a gas-filled chamber, such as a tube containing electrodes, between which there is an electrical voltage but no current flowing. When ionizing radiation interacts in the chamber, a short, intense pulse of current passes from the negative electrode to the positive electrode and is measured or counted. The number of pulses per second measures the intensity of radiation. It was named for Hans Geiger and W. Mueller who invented it in the 1920s. It is sometimes called simply a Geiger counter, or a G-M counter.

**graphite** — A form of carbon, similar to the lead used in pencils, used as a moderator in some nuclear reactors also for molds in high temperature furnaces.

**gray (Gy)** — A unit, in the International System of Units (SI), of absorbed dose which is equal to 1 joule per kilogram.

1 Gy = 100 rad

**half-life** — The time in which half the atoms of a particular radioactive substance disintegrates to another nuclear form. Measured half-lives vary from millionths of a second to billions of years. Also called physical half-life.

**half-life, biological** — The time required for the body to eliminate by physiologic processes half of the material present in it.

**half-life, effective** — The time required for a radionuclide present in a biological system to be reduced by half as a combined result of radioactive decay and biological elimination.

**half-thickness** — The thickness of any given absorber that will reduce the intensity of a beam of radiation to one-half its initial value. This value varies with radiation energy and beam size and location of shielding. (See attenuation; shielding.)

**health physics** — The science concerned with recognition, evaluation and control of health hazards from ionizing and non-ionizing radiation.

**heat exchanger** — Any device that transfers heat from one fluid (liquid or gas) to another fluid or to the environment.

**heat sink** — Anything that absorbs heat; usually part of the environment, such as the air, a river or outer space.

**high radiation area** — Any area accessible to personnel, in which a major portion of the body could receive a radiation dose of 100 millirem (0.1 rem) in one hour. These areas must be posted as "high radiation areas" and access into these areas is maintained under strict control.

**hot** — A colloquial term meaning highly radioactive.

**hot spot** — The region in a radiation/contamination area in which the level of radiation/contamination is noticeably greater than in neighboring regions in the area.

**induced radioactivity** — See activation.

**ion** — An atom or group of atoms that carries a positive or negative charge as a result of having lost or gained electrons; an electron that is not associated with a nucleus. (See ionization.)

**ionization** — The process of adding one or more electrons to or removing one or more electrons from atoms or molecules, thereby creating ions. High temperatures, electrical discharges, or ionizing radiations can cause ionization.

**ionization chamber** — An instrument that detects and measures ionizing radiation by measuring the electrical current that flows when radiation ionizes gas in a chamber, making the gas a conductor of electricity. (See counter.)

**ionizing radiation** — Any radiation with sufficient energy to displace electrons from atoms or molecules, thereby producing ions. Examples: alpha, beta, gamma, X rays, neutrons and ultraviolet light. High doses of ionizing radiation may produce severe skin or tissue damage.

**irradiation** — Exposure to radiation.

**isotope** — One of two or more atoms with the same number of protons, but different number of neutrons in their nuclei. Thus, carbon-12, carbon-13 and carbon-14 are isotopes of the element carbon, the numbers denoting the approximate atomic weights. Isotopes have the same chemical properties, but often different physical properties (for example, carbon-12 and carbon-13 are stable, carbon-14 is radioactive.

**isotope separation** — The process of separating isotopes from one another, or changing their relative abundances, as by gaseous diffusion or electromagnetic separation. Isotope separation is a step in the isotopic enrichment process.

**isotopic enrichment** — A process by which the relative abundances of the isotopes of a given element are altered, thus producing a form of the element that has been enriched in one particular isotope and depleted in its other isotopic forms.

| | |
|---|---|
| kilo- | A prefix that multiplies a basic unit by 1000. Example: 1 kilometer = 1000 meters. |
| kilovolt (kV) | The unit of electrical potential equal to 1000 volts. |
| LD 50/30 | The acute <u>dose</u> of <u>radiation</u> expected to cause death within 30 days to 50 percent of those exposed without medical intervention. Generally accepted to range from 400 to 450 <u>rem</u> for humans when received over a short period of <u>time</u>. |
| low population zone (LPZ) | An area of low population density often required around a nuclear installation. The number and density of residents is of concern in emergency planning so that certain protective measures (such as notification and instructions to residents) can be accomplished in a timely manner. |
| lung counter | An instrument system used to identify and measure radioactivity in the lungs of human begins; it uses heavy shielding to keep background radiation interference low and ultra sensitive radiation detectors and electronic counting equipment. |
| mass-energy equation | The equation developed by Albert Einstein which is usually given as $E = mc^2$, showing that, the energy of a body, E (no matter what form the energy takes), varies with the product of the mass, m, of the body and a factor, $c^2$. The factor $c^2$, the square of the speed of light in a vacuum, may be regarded as the conversion factor relating units of mass and energy. The equation predicted the possibility of releasing enormous amounts of energy by the conversion of mass to energy. It is also called the Einstein equation. |
| mass number | The number of <u>nucleons</u> (<u>neutrons</u> and <u>protons</u>) in the <u>nucleus</u> of an <u>atom</u>. Also known as the <u>atomic weight</u> of an atom. |
| mega- (M) | A prefix that multiplies a basic unit by 1,000,000. |
| megacurie (MCi) | One million curies. (See <u>curie</u>.) |
| micro- | A prefix that divides a basic unit into one million parts. |
| microcurie ($\mu Ci$) | A one-millionth part of a curie. (See <u>curie</u>.) |
| microsecond ($\mu s$) | A one-millionth part of a second. |
| mill tailings | Naturally <u>radioactive</u> residue from the processing of <u>uranium</u> ore into <u>yellowcake</u> in a mill. Although the milling process recovers about 93 percent of the uranium, the residues, or tailings, contain several radioactive elements, including <u>uranium</u>, thorium, <u>radium</u>, polonium and <u>radon</u>. |

| | |
|---|---|
| milli- (m) | A prefix that divides a basic unit by 1000. |
| millirem (mrem) | A one-thousandth part of a rem. (See rem.) |
| milliroentgen (mR) | A one-thousandth part of a roentgen. (See roentgen.) |
| molecule | A group of atoms held together by valence (electron) forces. A molecule is the smallest unit of a compound that can exist by itself and retain all its chemical properties. |
| monitoring | Periodic or continuous determination of the amount of ionizing radiation or radioactive contamination present in an occupied region, as a safety measure, for purposes of health protection or contamination control. (See radiological survey.) |
| nano- (n) | A prefix that divides a basic unit by one billion. |
| nanocurie (nCi) | One billionth part of a curie. |
| natural radiation | See background radiation. |
| natural uranium | Uranium as found in nature. It contains 0.7 percent uranium-235, 99.3 percent uranium-238 and a trace of uranium-234. |
| neutron | An uncharged elementary particle with a mass slightly greater than that of the proton, and found in the nucleus of every atom heavier than hydrogen and in two isotopes of hydrogen. |
| neutron capture | The process in which an atomic nucleus absorbs a neutron. |
| neutron chain reaction | A process in which some of the neutrons released in one fission event cause other fissions to occur. There are three types of chain reactions:<br>(1) Nonsustaining chain reaction - An average of less than one fission is produced by the neutrons released by each previous fission (reactor subcriticality.)<br>(2) Sustaining chain reaction - An average of exactly one fission is produced by the neutrons released by each previous fission (reactor criticality.)<br>(3) Multiplying chain reaction - An average of more than one fission is produced by the neutrons released by previous fission (reactor supercriticality.) |
| noble gas | A gaseous chemical element that does not readily enter into chemical combination with other elements. An inert gas. (See fission gases.) |

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| nuclear disintegration | See decay, radioactive. |
| nuclear energy | The energy liberated by a nuclear reaction (fission or fusion) or by radioactive decay. |
| nuclear fission | See fission. |
| nuclear force | A powerful short-ranged attractive force that holds together the particles inside an atomic nucleus. |
| nuclear radiation | See radiation, nuclear. |
| nuclear reaction | The process of inducing a disintegration of the nucleus of an atom. |
| nucleon | Common name for a constituent particle of the atomic nucleus. At present, applied to protons and neutrons but may include any other particles found to exist in the nucleus. |
| nucleus (or atomic nucleus); nuclei (plural) | The small, central, positively charged region of an atom that carries essentially all the mass. Except for the nucleus of ordinary (light) hydrogen, which has a single proton, all atomic nuclei contain both protons and neutrons. The number of protons determines the total positive charge, or atomic number; this is the same for all the atomic nuclei of a given chemical element. The total number of neutrons and protons is called the mass number. (See isotope.) |
| nuclide | A general term referring to all known isotopes, both stable (279) and unstable (about 5000), of the chemical elements. |
| occasional radiation worker | An individual who does not routinely work with or in the proximity of radiation generating devices or radioactive materials but whose duties may occasionally bring him/her into areas where radiation exposure may occur. |
| parent | A radionuclide that upon radioactive decay or disintegration yields a specific nuclide (the daughter). |
| parts per million (ppm) | Parts (molecules) of a substance contained in a million parts of air (or water) by volume. |

periodic table
: An arrangement of chemical elements in order of increasing atomic number. Elements of similar properties are placed one under the other, yielding groups or families of elements. Within each group, there is a variation of chemical and physical properties, but in general there is a similarity of chemical behavior within each group.

personnel monitoring
: The determination of the degree of radioactive contamination on individuals using survey meters, or the determination of radiation exposure received by means of dosimetry devices.

photon
: A quantum (or packet) of energy emitted in the form of electromagnetic radiation. Gamma rays and X rays are examples of photons.

pico- (p)
: A prefix that divides a basic unit by one trillion.

picocurie (pCi)
: One trillionth part of a curie.

pig
: A container (usually lead) used to ship or store radioactive materials. The thick walls protect the person handling the container from radiation. Large containers are commonly called casks.

plutonium (Pu)
: A heavy, radioactive, manmade metallic element with atomic number 94. Its most important isotope is fissile plutonium-239, which is produced by neutron irradiation of uranium-238.

pocket dosimeter
: A small ionization detection instrument that indicates radiation exposure directly or indirectly. An auxiliary charging device is usually necessary.

positron
: Particle equal in mass, but opposite in charge, to the electron; a positive electron.

proportional counter
: An instrument in which an electronic detection system receives pulses that are proportional to the number of ions formed in a gas-filled chamber by ionizing radiation.

protection factor
: The degree of protection provided by the proper fit and use of respiratory protective equipment.

proton
: An elementary nuclear particle with a positive electric charge located in the nucleus of an atom. (See atomic number.)

quality factor — The principal factor by which the absorbed dose is to be multiplied to obtain a quantity that expresses, on a common scale for all ionizing radiations, the biological damage to exposed persons. It is used because some types of radiation, such as alpha particles, are more biologically damaging than other types.

rad — Acronym for radiation absorbed dose. The basic unit of absorbed dose of radiation. A dose of one rad means the absorption of 100 ergs (a small but measurable amount of energy) per gram of absorbing material.

radiac — An acronym derived from "radioactivity detection indication and computation," a generic term applying to radiological instruments or equipment.

radiation area — Any area, accessible to personnel, in which the level of radiation is such that a major portion of an individual's body could receive in any one hour a dose in excess of 5 millirem, or in any five consecutive days a dose in excess of 100 millirem.

radiation detection instrument — A device that detects and registers the characteristics of ionizing radiation. (See counter.)

radiation monitoring — See monitoring.

radiation, nuclear — Particles (alpha, beta, neutrons) or photons (gamma) emitted from the nucleus of an unstable (radioactive) atom as a result of radioactive decay.

radiation shielding — Reduction of radiation field by interposing a shield of absorbing material between any radiation source and a person's work area or radiation-sensitive device.

radiation source — Usually a man-made sealed source of radioactive material used in teletherapy, radiography, as a power source for batteries, or in various types of industrial gauges. Machines such as accelerators, X-ray units and radioisotope generators and natural radionuclides may be considered sources.

radiation standards — Exposure standards, radioactivity concentration guide, rules for safe handling, regulations for transportation, regulations for industrial control of radiation and control of radioactive material by legislative means.

radiation syndrome — See radiation sickness (syndrome).

radiation warning symbol — An officially prescribed symbol (a magenta trefoil) on a yellow background that must be displayed where certain quantities of radioactive materials are

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| | present or where certain doses of radiation could be received. Its uses are prescribed by law. |
| radioactive | Exhibiting radioactivity or pertaining to radioactivity. |
| radioactive contamination | Deposition of radioactive material in any place where it is not contained or wanted. |
| radioactive isotope | A radioisotope. |
| radioactive series | A succession of nuclides, each of which tranforms by radioactive disintegration into the next until a stable nuclide results. The first member is called the parent, the intermediate members are called daughters, and the final stable member is called the end product. |
| radioactive waste | See waste, radioactive. |
| radioactivity | The spontaneous emission of radiation, generally alpha or beta particles, often accompanied by gamma rays, from the nucleus of an unstable isotope. |
| radiobiology | The study of the effects of ionizing radiations upon living tissue or organisms. |
| radiography | The making of shadow images on photographic film by the action of ionizing radiation. |
| radioisotope | An unstable isotope of an element that decays or disintegrates spontaneously, emitting radiation. Approximately 5000 natural and artificial radioisotopes have been identified. |
| radiological survey | The evaluation of the radiation hazards accompanying the production, use, or existence of radioactive materials under a specific set of conditions. Such evaluation customarily includes a physical survey of the disposition of materials and equipment, measurements or estimates of the levels of radiation that my be involved, and a sufficient knowledge or processes affecting these materials to predict hazards resulting from expected or possible changes in materials or equipment. |
| radiology | That branch of medicine dealing with the diagnostic and therapeutic applications of radiant energy, including X rays and radioisotopes. |
| radionuclide | A radioisotope. |
| radiosensitivity | The relative susceptability of cells, tissues, organs, organisms, or other substances to the injurious action of ionizing radiation. |

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| radium (Ra) | A radioactive metallic element with atomic number 88. As found in nature, the most common isotope has a mass number of 226. It occurs in minute quantities associated with uranium in pitchblend, carnotite and other minerals. |
| radon (Rn) | A radioactive element that is one of the heaviest gases known. Its atomic number is 86, and its mass number is 222. It is a daughter of radium. |
| reaction | Any process involving a chemical or nuclear change. |
| recycling | The reuse of fissionable material after it has been recovered by chemical processing from spent or depleted reactor fuel, re-enriched and refabricated into new fuel elements. |
| rem | Acronym of roentgen equivalent man. The unit of dose of any ionizing radiation that produces the same biological effect as a unit of absorbed dose of ordinary X rays. (See quality factor.) |
| restricted area | Any area to which access is controlled for the protection of individuals from exposure to radiation and radioactive materials. |
| roentgen (R) | A unit of exposure to ionizing radiation. It is that amount of gamma or X rays required to produce ions carrying 1 electrostatic unit of electrical charge in 1 cubic centimeter of dry air under standard conditions. Named after Wilhelm Roentgen, a German scientist who discovered X rays in 1895. |
| roentgen equivalent man (or mammal) | See rem. |
| scattered radiation | Radiation that, during its interaction with a substance, has been changed in direction. It may also have been modified by a decrease in energy. It is one form of secondary radiation. |
| scintillation detector or counter | The combination of phosphor, photomultiplier tube, and associated electronic circuits for counting light emissions produced in the phosphor by ionizing radiation. (See counter.) |
| secondary radiation | Radiation originating as the result of absorption of other radiation in matter. It may be either electromagnetic or particulate in nature. |
| shielding | Any material or obstruction that absorbs radiation and thus tends to protect personnel or material from the effects of ionizing radiation. |
| sievert (Sv) | A unit, in the International system of Units (SI), of dose equivalent. 1 Sv = 100 rem |

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| soluble | Readily dissolved in body fluids. |
| somatic effects of radiation | Effects of radiation limited to the exposed individual, as distinguished from genetic effects, which may also affect subsequent unexposed generations. |
| special nuclear material | Includes plutonium, uranium-233, or uranium enriched in the isotopes uranium-233 or uranium-235. |
| spent (depleted) fuel | Nuclear reactor fuel that has been used to the extent that it can no longer effectively sustain a chain reaction. |
| source material | Any physical or chemical form of uranium or thorium or ores which contain by weight 0.05% or more of uranium or thorium. |
| stable isotope | An isotope that does not undergo radioactive decay. |
| stay time | The period during which personnel may remain in a restricted area before accumulating some permissible exposure. |
| subcritical mass | An amount of fissionable material insufficient in quantity or of improper geometry to sustain a fission chain reaction. |
| survey | A study to (1) find the radiation or contamination level of specific objects or locations within an area of interest; (2) locate regions of higher-than-average intensity; i.e., hot spots. (See personnel monitoring.) |
| survey meter | Any portable radiation detection instrument especially adapted to establish the existence and amount of ionizing radiation present. (See counter.) |
| tailings, tails | See mill tailings. |
| tenth thickness | The thickness of a given material that will decrease the amount (or dose) of radiation to one-tenth of the amount incident upon it. Two-tenth thicknesses will reduce the dose received by a factor of 10 x 10; i.e., 100, and so on. (See shielding.) |
| terrestrial radiation | The portion of natural radiation (background that is emitted by naturally occurring radioactive materials in the earth. |
| thermalization | The process undergone by high-energy (fast) neutrons as they lose energy by collision. (See neutron, thermal.) |
| toxicology | Is the study of the adverse effects of chemicals on living organisms. |

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| tritium ($^3H$) | A radioactive isotope of hydrogen (one proton, two neutrons). Because it is chemically identical to natural hydrogen, tritium can easily be taken into the body by any inhalation, ingestion or absorption path. Decays by beta emission. Its radioactive half-life is about 12 1/2 years. |
| ultraviolet | Electromagnetic radiation of a wavelength between the shortest visible violet and low-energy X rays. |
| unrestricted area | The area outside the owner-controlled portion of a nuclear facility (usually the site boundary). |
| unstable isotope | A radioisotope. |
| uranium (U) | A radioactive element with the atomic number 92, and as found in natural ores, has an atomic weight of approximately 238. The two principal natural isotopes are uranium-235 (0.7 percent of natural uranium), which is fissle, and uranium-238 (99.3 percent of natural uranium), which is fissionable by fast neutrons and is fertile. Natural uranium also includes a minute amount of uranium-234. |
| uranium enrichment | See isotopic enrichment. |
| uranium millings (tails) | See mill tailings. |
| vapor | The gaseous form of substances that are normally in liquid or solid form. |
| waste, radioactive | Solid, liquid and gaseous materials from nuclear operations that are radioactive or become radioactive and for which there is no further use. Wastes are generally classified as high level (having radioactivity concentrations of hundreds of thousands of curies per gallon or cubic foot), low level (in the range of less than 1 microcurie per gallon or cubic foot), or intermediate level (between these extremes). |
| whole-body counter | A device used to identify and measure the radiation in the body (body burden) of human beings and animals; it uses heavy shielding to minimize the interference of background radiation on ultrasensitive radiation detectors and electronic counting equipment. |
| whole-body exposure | An exposure of the body to radiation, in which the entire body, rather than an isolated part, is irradiated. Where a radioisotope is uniformly distributed throughout the body tissues, rather than being concentrated in certain parts, the irradiation can be considered as a whole-body exposure. |
| wipe sample (swipe or smear) | A sample made for the purpose of determining the presence of removable radioactive contamination on a |

surface. It is done by wiping, with slight pressure, a piece of soft filter paper over a representative type of surface area. It is also known as a "swipe sample." May also be called "smears" at some facilities.

X rays — Penetrating electromagnetic radiation (photon) having a wavelength that is much shorter than that of visible light. These rays are usually produced by excitation of the electron field around certain nuclei. In nuclear reactions, it is customary to refer to photons originating in the nucleus as gamma rays, and to those originating in the electron field of the atom as X rays. These rays are sometimes called roentgen rays after their discoverer, W. K. Roentgen.

yellowcake — A product of the uranium milling process, yellowcake is a solid uranium compound that takes its name from the color and texture. Yellowcake is the initial feed material to the fuel cycle.

# APPENDIX B

## Derived Air Concentrations (DAC)

## for

## Controlling Radiation Exposure to Workers at DOE Facilities

[From DOE Order 5480.11, Radiation Protection for Occupational Workers, (11/30/88), U.S. Department of Energy.]

## DERIVED AIR CONCENTRATIONS FOR CONTROLLING RADIATION EXPOSURE TO WORKERS AT DOE FACILITIES

The derived air concentrations (DAC) for limiting radiation exposures through inhalation of radionuclides by workers are listed in Table 1, Page B-3. The values are based on either a stochastic (committed effective dose equivalent) dose limit of 5 rem (0.05 Sv) or a nonstochastic (organ) dose limit of 50 rem (0.5 Sv) per year, whichever is more limiting. (Note: the 15 rem [0.15 Sv] dose limit for the lens of the eye does not appear as a critical organ dose limit.)

Table 1 contains five columns of information: (1) radionuclide; (2) inhaled air DAC for lung retention class D (uCi/mL); (3) inhaled air DAC for lung retention class W (uCi/mL); (4) inhaled air DAC for lung retention class Y (uC/mL); and (5) an indication of whether or not the DAC for each class is controlled by the stochastic (effective dose equivalent) or nonstochastic (tissue) dose. The classes D, W, and Y have been established by the International Commission on Radiological Protection (ICRP) to describe the clearance of inhaled radionuclides from the lung. This classification refers to the approximate length of retention in the pulmonary region. Thus, the range of half-times is less than 10 days for class D (days), from 10 to 100 days for class W (weeks), and greater than 100 days for class Y (years). The DACs in Table 1 are listed by radionuclide, in order of increasing atomic mass, and are based on the assumption that the particle size distribution of the inhaled material is unknown. For this situation, the ICRP recommends that an assumed particle size distribution of 1 um be used. For situations where the particle size distribution is known to differ significantly from 1 um, appropriate corrections (as described in the DOE report Internal Dose Conversion Factors for Calculation of Dose to the Public)[1/] can be made to both the estimated dose to workers and the DACs.

The following assumptions and procedures were used in calculating these DAC values for inhalation by workers:

(1) The worker is assumed to inhale 2,400 $m^3$ of air during a 2000-hour work year, as defined by the ICRP in its Publication No. 23.[2/]

(2) The internal dose factors used in calculating the DAC values were taken from the report Internal Dose Conversion Factors for Calculation of Dose to the Public.[1/] These factors are based on the metabolic data and dosimetry models recommended by the ICRP in its Publication No. 30.[3/]

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1/ U.S. Department of Energy (DOE). 1988. Internal Dose Conversion Factors for Calculation of Dose to the Public. Washington, D.C.

2/ International Commission on Radiological Protection (ICRP). 1975. ICRP Publication 23: Report of the Task Group on Reference Man. Pergamon Press, New York, New York.

3/ International Commission on Radiological Protection (ICRP). 1979-1982. ICRP Publication 30: Limits for Intakes of Radionuclides by Workers. Parts 1 to 3 and Supplements 2(3/4) through 8(4), Pergamon Press, New York, New York.

The DAC values are given for individual radionuclides. For known mixtures of radionuclides, the sum of the ratio of the observed concentration of a particular radionuclide and its corresponding DAC for all radionuclides in the mixture must not exceed 1.0.

Table 1

Derived Air Concentrations (DAC) for Controlling Radiation Exposures to Workers at DOE Facilities

| Radionuclide | Inhaled Air - Lung Retention Class D (µCi/mL) | W (µCi/mL) | Y (µCi/mL) | Stochastic or Organ1/ (D / W / Y) |
|---|---|---|---|---|
| H-3 (Water)2/ | 2.E-05 | 2.E-05 | 2.E-05 | St/St/St |
| H-3 (Elemental)2/ | 5.E-01 | 5.E-01 | 5.E-01 | St/St/St |
| Be-7 | -3/ | 9.E-06 | 8.E-06 | /St/St |
| Be-10 | - | 6.E-08 | 6.E-09 | /St/St |
| C-11 (Org)2/ | 2.E-04 | 2.E-04 | 2.E-04 | St/St/St |
| C-11 (CO)2/ | 5.E-04 | 5.E-04 | 5.E-04 | St/St/St |
| C-11 ($CO_2$)2/ | 3.E-04 | 3.E-04 | 3.E-04 | St/St/St |
| C-14 (Org)2/ | 1.E-06 | 1.E-06 | 1.E-06 | St/St/St |
| C-14 (CO)2/ | 7.E-04 | 7.E-04 | 7.E-04 | St/St/St |
| C-14 ($CO_2$)2/ | 9.E-05 | 9.E-05 | 9.E-05 | St/St/St |
| F-18 | 3.E-05 | 4.E-05 | 3.E-05 | St/St/St |
| Na-22 | 3.E-07 | - | - | St/ / |
| Na-24 | 2.E-06 | - | - | St/ / |
| Mg-28 | 7.E-07 | 5.E-07 | - | St/St/ |
| Al-26 | 3.E-08 | 3.E-08 | - | St/St/ |
| Si-31 | 1.E-05 | 1.E-05 | 1.E-05 | St/St/St |
| Si-32 | 1.E-07 | 5.E-08 | 2.E-09 | St/St/St |
| P-32 | 4.E-07 | 2.E-07 | - | St/St/ |
| P-33 | 3.E-06 | 1.E-06 | - | St/St/ |
| S-35 | 7.E-06 | 9.E-07 | - | St/St/ |
| S-35 (Gas) | - | 6.E-06 | - | /St/ |
| Cl-36 | 1.E-06 | 1.E-07 | - | St/St/ |
| Cl-38 | 2.E-05 | 2.E-05 | - | St/St/ |
| Cl-39 | 2.E-05 | 2.E-05 | - | St/St/ |
| K-40 | 2.E-07 | - | - | St/ / |
| K-42 | 2.E-06 | - | - | St/ / |
| K-43 | 4.E-06 | - | - | St/ / |
| K-44 | 3.E-05 | - | - | St/ / |
| K-45 | 5.E-05 | - | - | St/ / |

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| Radionuclide | Inhaled Air - Lung Retention Class D (μCi/mL) | W (μCi/mL) | Y (μCi/mL) | Stochastic or Organ1/ (D / W / Y) |
|---|---|---|---|---|
| Ca-41 | - | 2.E-06 | - | /E / |
| Ca-45 | - | 3.E-07 | - | /St/ |
| Ca-47 | - | 4.E-07 | - | /St/ |
| Sc-43 | - | - | 1.E-05 | / /St |
| Sc-44m | - | - | 3.E-07 | / /St |
| Sc-44 | - | - | 5.E-06 | / /St |
| Sc-46 | - | - | 1.E-07 | / /St |
| Sc-47 | - | - | 1.E-06 | / /St |
| Sc-48 | - | - | 6.E-07 | / /St |
| Sc-49 | - | - | 2.E-05 | / /St |
| Ti-44 | 5.E-09 | 1.E-08 | 2.E-09 | St/St/St |
| Ti-45 | 1.E-05 | 1.E-05 | 1.E-05 | St/St/St |
| V-47 | 4.E-05 | 4.E-05 | - | St/St/ |
| V-48 | 4.E-07 | 3.E-07 | - | St/St/ |
| V-49 | 1.E-05 | 7.E-06 | - | BS/St/ |
| Cr-48 | 5.E-06 | 3.E-06 | 3.E-06 | St/St/St |
| Cr-49 | 3.E-05 | 4.E-05 | 4.E-05 | St/St/St |
| Cr-51 | 2.E-05 | 1.E-05 | 8.E-06 | St/St/St |
| Mn-51 | 2.E-05 | 2.E-05 | - | St/St/ |
| Mn-52m | 4.E-05 | 4.E-05 | - | St/St/ |
| Mn-52 | 5.E-07 | 4.E-07 | - | St/St/ |
| Mn-53 | 5.E-06 | 5.E-06 | - | BS/St/ |
| Mn-54 | 4.E-07 | 3.E-07 | - | St/St/ |
| Mn-56 | 6.E-06 | 9.E-06 | - | St/St/ |
| Fe-52 | 1.E-06 | 1.E-06 | - | St/St/ |
| Fe-55 | 8.E-07 | 2.E-06 | - | St/St/ |
| Fe-59 | 1.E-07 | 2.E-07 | - | St/St/ |
| Fe-60 | 3.E-09 | 8.E-09 | - | St/St/ |
| Co-55 | - | 1.E-06 | 1.E-06 | /St/St |
| Co-56 | - | 1.E-07 | 8.E-08 | /St/St |
| Co-57 | - | 1.E-06 | 3.E-07 | /St/St |
| Co-58m | - | 4.E-05 | 3.E-05 | /St/St |
| Co-58 | - | 5.E-07 | 3.E-07 | /St/St |
| Co-60m | - | 2.E-03 | 1.E-03 | /St/St |
| Co-60 | - | 7.E-08 | 1.E-08 | /St/St |
| Co-61 | - | 3.E-05 | 2.E-05 | /St/St |
| Co-62m | - | 7.E-05 | 7.E-05 | /St/St |

| Radionuclide | Inhaled Air - Lung Retention Class D (µCi/mL) | W (µCi/mL) | Y (µCi/mL) | Stochastic or Organ1/ (D / W / Y) |
|---|---|---|---|---|
| Ni-56 (Inorg) | 8.E-07 | 5.E-07 | - | St/St/ |
| Ni-56 (Vapor) | - | 5.E-07 | - | /St/ |
| Ni-57 (Inorg) | 2.E-06 | 1.E-06 | - | St/St/ |
| Ni-57 (Vapor) | - | 3.E-06 | - | /St/ |
| Ni-59 (Inorg) | 2.E-06 | 3.E-06 | - | St/St/ |
| Ni-59 (Vapor) | - | 8.E-07 | - | /St/ |
| Ni-63 (Inorg) | 7.E-07 | 1.E-06 | - | St/St/ |
| Ni-63 (Vapor) | - | 3.E-07 | - | /St/ |
| Ni-65 (Inorg) | 1.E-05 | 1.E-05 | - | St/St/ |
| Ni-65 (Vapor) | - | 7.E-06 | - | /St/ |
| Ni-66 (Inorg) | 7.E-07 | 3.E-07 | - | St/St/ |
| Ni-66 (Vapor) | - | 1.E-06 | - | /St/ |
| Cu-60 | 4.E-05 | 5.E-05 | 4.E-05 | St/St/St |
| Cu-61 | 1.E-05 | 2.E-05 | 1.E-05 | St/St/St |
| Cu-64 | 1.E-05 | 1.E-05 | 9.E-06 | St/St/St |
| Cu-67 | 3.E-06 | 2.E-06 | 2.E-06 | St/St/St |
| Zn-62 | - | - | 1.E-06 | / /St |
| Zn-63 | - | - | 3.E-05 | / /St |
| Zn-65 | - | - | 1.E-07 | / /St |
| Zn-69m | - | - | 3.E-06 | / /St |
| Zn-69 | - | - | 6.E-05 | / /St |
| Zn-71m | - | - | 7.E-06 | / /St |
| Zn-72 | - | - | 5.E-07 | / /St |
| Ga-65 | 7.E-05 | 8.E-05 | - | St/St/ |
| Ga-66 | 1.E-06 | - | 1.E-06 | St/ /St |
| Ga-67 | 6.E-06 | 4.E-06 | - | St/St/ |
| Ga-68 | 2.E-05 | 2.E-05 | - | St/St/ |
| Ga-70 | 7.E-05 | 8.E-05 | - | St/St/ |
| Ga-72 | 2.E-06 | 1.E-06 | - | St/St/ |
| Ga-73 | 6.E-06 | 6.E-06 | - | St/St/ |
| Ge-66 | 1.E-05 | 8.E-06 | - | St/St/ |
| Ge-67 | 4.E-05 | 4.E-05 | - | St/St/ |
| Ge-68 | 2.E-06 | 4.E-08 | - | St/St/ |
| Ge-69 | 6.E-06 | 3.E-06 | - | St/St/ |
| Ge-71 | 2.E-04 | 2.E-05 | - | St/St/ |
| Ge-75 | 3.E-05 | 3.E-05 | - | St/St/ |
| Ge-77 | 4.E-06 | 2.E-06 | - | St/St/ |
| Ge-78 | 9.E-06 | 9.E-06 | - | St/St/ |
| As-69 | - | 5.E-05 | - | /St/ |

| Radionuclide | Inhaled Air - Lung Retention Class D (µCi/mL) | W (µCi/mL) | Y (µCi/mL) | Stochastic or Organ1/ (D / W / Y) |
|---|---|---|---|---|
| As-70 | - | 2.E-05 | - | /St/ |
| As-71 | - | 2.E-06 | - | /St/ |
| As-72 | - | 6.E-07 | - | /St/ |
| As-73 | - | 7.E-07 | - | /St/ |
| As-74 | - | 3.E-07 | - | /St/ |
| As-76 | - | 6.E-07 | - | /St/ |
| As-77 | - | 2.E-06 | - | /St/ |
| As-78 | - | 9.E-06 | - | /St/ |
| Se-70 | 1.E-05 | 2.E-05 | - | St/St/ |
| Se-73m | 6.E-05 | 6.E-05 | - | St/St/ |
| Se-73 | 6.E-06 | 7.E-06 | - | St/St/ |
| Se-75 | 3.E-07 | 3.E-07 | - | St/St/ |
| Se-79 | 3.E-07 | 2.E-07 | - | St/St/ |
| Se-81m | 3.E-05 | 3.E-05 | - | St/St/ |
| Se-81 | 9.E-05 | 1.E-04 | - | St/St/ |
| Se-83 | 5.E-05 | 5.E-05 | - | St/St/ |
| Br-74m | 1.E-05 | 2.E-05 | - | St/St/ |
| Br-74 | 3.E-05 | 3.E-05 | - | St/St/ |
| Br-75 | 2.E-05 | 2.E-05 | - | St/St/ |
| Br-76 | 2.E-06 | 2.E-06 | - | St/St/ |
| Br-77 | 1.E-05 | 8.E-06 | - | St/St/ |
| Br-80m | 7.E-06 | 6.E-06 | - | St/St/ |
| Br-80 | 8.E-05 | 9.E-05 | - | St/St/ |
| Br-82 | 2.E-06 | 2.E-06 | - | St/St/ |
| Br-83 | 3.E-05 | 3.E-05 | - | St/St/ |
| Br-84 | 2.E-05 | 3.E-05 | - | St/St/ |
| Rb-79 | 5.E-05 | - | - | St/ / |
| Rb-81m | 1.E-04 | - | - | St/ / |
| Rb-81 | 2.E-05 | - | - | St/ / |
| Rb-82m | 7.E-06 | - | - | St/ / |
| Rb-83 | 4.E-07 | - | - | St/ / |
| Rb-84 | 3.E-07 | - | - | St/ / |
| Rb-86 | 3.E-07 | - | - | St/ / |
| Rb-87 | 6.E-07 | - | - | St/ / |
| Rb-88 | 3.E-05 | - | - | St/ / |
| Rb-89 | 6.E-05 | - | - | St/ / |
| Sr-80 | 9.E-04 | - | 1.E-03 | St/ /St |
| Sr-81 | 3.E-05 | - | 3.E-05 | St/ /St |
| Sr-83 | 3.E-06 | - | 2.E-06 | St/ /St |
| Sr-85m | 3.E-04 | - | 3.E-04 | St/ /St |

| Radionuclide | Inhaled Air - Lung Retention Class D (µCi/mL) | W (µCi/mL) | Y (µCi/mL) | Stochastic or Organ1/ (D / W / Y) |
|---|---|---|---|---|
| Sr-85 | 1.E-06 | - | 7.E-07 | St/ /St |
| Sr-87m | 5.E-05 | - | 6.E-05 | St/ /St |
| Sr-89 | 3.E-07 | - | 6.E-08 | St/ /St |
| Sr-90 | 8.E-09 | - | 2.E-09 | BS/ /St |
| Sr-91 | 2.E-06 | - | 1.E-06 | St/ /St |
| Sr-92 | 4.E-06 | - | 3.E-06 | St/ /St |
| Y-86m | - | 2.E-05 | 2.E-05 | /St/St |
| Y-86 | - | 1.E-06 | 1.E-06 | /St/St |
| Y-87 | - | 1.E-06 | 1.E-06 | /St/St |
| Y-88 | - | 1.E-07 | 1.E-07 | /St/St |
| Y-90m | - | 5.E-06 | 5.E-06 | /St/St |
| Y-90 | - | 3.E-07 | 3.E-07 | /St/St |
| Y-91m | - | 1.E-04 | 7.E-05 | /St/St |
| Y-91 | - | 7.E-08 | 5.E-08 | /St/St |
| Y-92 | - | 3.E-06 | 3.E-06 | /St/St |
| Y-93 | - | 1.E-06 | 1.E-06 | /St/St |
| Y-94 | - | 3.E-05 | 3.E-05 | /St/St |
| Y-95 | - | 6.E-05 | 6.E-05 | /St/St |
| Zr-86 | 2.E-06 | 1.E-06 | 1.E-06 | St/St/St |
| Zr-88 | 9.E-08 | 2.E-07 | 1.E-07 | St/St/St |
| Zr-89 | 2.E-06 | 1.E-06 | 1.E-06 | St/St/St |
| Zr-93 | 3.E-09 | 1.E-08 | 2.E-08 | BS/BS/BS |
| Zr-95 | 6.E-08 | 2.E-07 | 1.E-07 | BS/St/St |
| Zr-97 | 8.E-07 | 6.E-07 | 5.E-07 | St/St/St |
| Nb-88 | - | 1.E-04 | 9.E-05 | /St/St |
| Nb-89 (66 min) | - | 2.E-05 | 2.E-05 | /St/St |
| Nb-89 (122 min) | - | 8.E-06 | 7.E-06 | /St/St |
| Nb-90 | - | 1.E-06 | 1.E-06 | /St/St |
| Nb-93m | - | 5.E-07 | 7.E-08 | /St/St |
| Nb-94 | - | 8.E-08 | 6.E-09 | /St/St |
| Nb-95m | - | 1.E-06 | 9.E-07 | /St/St |
| Nb-95 | - | 5.E-07 | 5.E-07 | /St/St |
| Nb-96 | - | 1.E-06 | 1.E-06 | /St/St |
| Nb-97 | - | 3.E-05 | 3.E-05 | /St/St |
| Nb-98 | - | 2.E-05 | 2.E-05 | /St/St |
| Mo-90 | 3.E-06 | - | 2.E-06 | St/ /St |
| Mo-93m | 7.E-06 | - | 6.E-06 | St/ /St |
| Mo-93 | 2.E-08 | - | 7.E-08 | St/ /St |
| Mo-99 | 1.E-06 | - | 6.E-07 | St/ /St |
| Mo-101 | 6.E-05 | - | 6.E-05 | St/ /St |

| Radionuclide | Inhaled Air - Lung Retention Class D (µCi/mL) | W (µCi/mL) | Y (µCi/mL) | Stochastic or Organ1/ (D / W / Y) |
|---|---|---|---|---|
| Tc-93m | 7.E-05 | 1.E-04 | - | St/St/ |
| Tc-93 | 3.E-05 | 4.E-05 | - | St/St/ |
| Tc-94m | 2.E-05 | 2.E-05 | - | St/St/ |
| Tc-94 | 8.E-06 | 1.E-05 | - | St/St/ |
| Tc-96m | 1.E-04 | 1.E-04 | - | St/St/ |
| Tc-96 | 1.E-06 | 9.E-07 | - | St/St/ |
| Tc-97m | 3.E-06 | 5.E-07 | - | SW/St/ |
| Tc-97 | 2.E-05 | 2.E-06 | - | St/St/ |
| Tc-98 | 7.E-07 | 1.E-07 | - | St/St/ |
| Tc-99m | 6.E-05 | 1.E-04 | - | St/St/ |
| Tc-99 | 2.E-06 | 3.E-07 | - | SW/St/ |
| Tc-101 | 1.E-04 | 2.E-04 | - | St/St/ |
| Tc-104 | 3.E-05 | 4.E-05 | - | St/St/ |
| Ru-94 | 2.E-05 | 3.E-05 | 2.E-05 | St/St/St |
| Ru-97 | 8.E-06 | 5.E-06 | 5.E-06 | St/St/St |
| Ru-103 | 7.E-07 | 4.E-07 | 3.E-07 | St/St/St |
| Ru-105 | 6.E-06 | 6.E-06 | 5.E-06 | St/St/St |
| Ru-106 | 4.E-08 | 2.E-08 | 5.E-09 | St/St/St |
| Rh-99m | 2.E-05 | 3.E-05 | 3.E-05 | St/St/St |
| Rh-99 | 1.E-06 | 9.E-07 | 8.E-07 | St/St/St |
| Rh-100 | 2.E-06 | 2.E-06 | 2.E-06 | St/St/St |
| Rh-101m | 5.E-06 | 3.E-06 | 3.E-06 | St/St/St |
| Rh-101 | 2.E-07 | 3.E-07 | 7.E-08 | St/St/St |
| Rh-102m | 2.E-07 | 2.E-07 | 5.E-08 | St/St/St |
| Rh-102 | 4.E-08 | 7.E-08 | 2.E-08 | St/St/St |
| Rh-103m | 4.E-04 | 5.E-04 | 5.E-04 | St/St/St |
| Rh-105 | 5.E-06 | 3.E-06 | 2.E-06 | St/St/St |
| Rh-106m | 1.E-05 | 1.E-05 | 1.E-05 | St/St/St |
| Rh-107 | 1.E-04 | 1.E-04 | 1.E-04 | St/St/St |
| Pd-100 | 6.E-07 | 5.E-07 | 6.E-07 | St/St/St |
| Pd-101 | 1.E-05 | 1.E-05 | 1.E-05 | St/St/St |
| Pd-103 | 3.E-06 | 2.E-06 | 1.E-06 | St/St/St |
| Pd-107 | 9.E-06 | 3.E-06 | 2.E-07 | K /St/St |
| Pd-109 | 3.E-06 | 2.E-06 | 2.E-06 | St/St/St |
| Ag-102 | 8.E-05 | 9.E-05 | 8.E-05 | St/St/St |
| Ag-103 | 4.E-05 | 6.E-05 | 5.E-05 | St/St/St |
| Ag-104m | 4.E-05 | 5.E-05 | 5.E-05 | St/St/St |
| Ag-104 | 3.E-05 | 6.E-05 | 6.E-05 | St/St/St |
| Ag-105 | 4.E-07 | 7.E-07 | 7.E-07 | St/St/St |

| Radionuclide | Inhaled Air - Lung Retention Class D (µCi/mL) | W (µCi/mL) | Y (µCi/mL) | Stochastic or Organ1/ (D / W / Y) |
|---|---|---|---|---|
| Ag-106m | 3.E-07 | 4.E-07 | 4.E-07 | St/St/St |
| Ag-106 | 7.E-05 | 9.E-05 | 8.E-05 | St/St/St |
| Ag-108m | 8.E-08 | 1.E-07 | 1.E-06 | St/St/St |
| Ag-110m | 6.E-08 | 8.E-08 | 4.E-06 | St/St/St |
| Ag-111 | 7.E-07 | 4.E-07 | 4.E-07 | L /St/St |
| Ag-112 | 3.E-06 | 4.E-06 | 4.E-06 | St/St/St |
| Ag-115 | 4.E-05 | 4.E-05 | 3.E-05 | St/St/St |
| Cd-104 | 3.E-05 | 5.E-05 | 5.E-05 | St/St/St |
| Cd-107 | 2.E-05 | 2.E-05 | 2.E-05 | St/St/St |
| Cd-109 | 1.E-08 | 5.E-08 | 5.E-08 | K /K /St |
| Cd-113m | 1.E-09 | 4.E-09 | 5.E-09 | K /K /St |
| Cd-113 | 9.E-10 | 3.E-09 | 6.E-09 | K /K /St |
| Cd-115m | 2.E-08 | 5.E-08 | 6.E-08 | K /St/St |
| Cd-115 | 6.E-07 | 5.E-07 | 6.E-07 | St/St/St |
| Cd-117m | 5.E-06 | 7.E-06 | 6.E-06 | St/St/St |
| Cd-117 | 5.E-06 | 7.E-06 | 6.E-06 | St/St/St |
| In-109 | 2.E-05 | 3.E-05 | - | St/St/ |
| In-110 (69 min) | 2.E-05 | 2.E-05 | - | St/St/ |
| In-110 (5 h) | 7.E-06 | 8.E-06 | - | St/St/ |
| In-111 | 3.E-06 | 3.E-06 | - | St/St/ |
| In-112 | 3.E-04 | 3.E-04 | - | St/St/ |
| In-113m | 6.E-05 | 8.E-05 | - | St/St/ |
| In-114m | 3.E-08 | 4.E-08 | - | St/St/ |
| In-115m | 2.E-05 | 2.E-05 | - | St/St/ |
| In-115 | 6.E-10 | 2.E-09 | - | St/St/ |
| In-116m | 3.E-05 | 5.E-05 | - | St/St/ |
| In-117m | 1.E-05 | 2.E-05 | - | St/St/ |
| In-117 | 7.E-05 | 9.E-05 | - | St/St/ |
| In-119m | 5.E-05 | 6.E-05 | - | St/St/ |
| Sn-110 | 5.E-06 | 5.E-06 | - | St/St/ |
| Sn-111 | 9.E-05 | 1.E-04 | - | St/St/ |
| Sn-113 | 5.E-07 | 2.E-07 | - | St/St/ |
| Sn-117m | 5.E-07 | 6.E-07 | - | BS/St/ |
| Sn-119m | 1.E-06 | 4.E-07 | - | St/St/ |
| Sn-121m | 4.E-07 | 2.E-07 | - | St/St/ |
| Sn-121 | 6.E-06 | 5.E-06 | - | St/St/ |
| Sn-123m | 5.E-05 | 6.E-05 | - | St/St/ |
| Sn-123 | 3.E-07 | 7.E-08 | - | St/St/ |
| Sn-125 | 4.E-07 | 2.E-07 | - | St/St/ |
| Sn-126 | 2.E-08 | 3.E-08 | - | St/St/ |
| Sn-127 | 8.E-06 | 8.E-06 | - | St/St/ |

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| Radionuclide | Inhaled Air - Lung Retention Class D (µCi/mL) | W (µCi/mL) | Y (µCi/mL) | Stochastic or Organ1/ (D / W / Y) |
|---|---|---|---|---|
| Sn-128 | 1.E-05 | 1.E-05 | - | St/St/ |
| Sb-115 | 1.E-04 | 1.E-04 | - | St/St/ |
| Sb-116m | 3.E-05 | 6.E-05 | - | St/St/ |
| Sb-116 | 1.E-04 | 1.E-04 | - | St/St/ |
| Sb-117 | 9.E-05 | 1.E-04 | - | St/St/ |
| Sb-118m | 8.E-06 | 9.E-06 | - | St/St/ |
| Sb-119 | 2.E-05 | 1.E-05 | - | St/St/ |
| Sb-120 (16 min) | 2.E-04 | 2.E-04 | - | St/St/ |
| Sb-120 (6 d) | 9.E-07 | 6.E-07 | - | St/St/ |
| Sb-122 | 1.E-06 | 4.E-07 | - | St/St/ |
| Sb-124m | 3.E-04 | 3.E-04 | - | St/St/ |
| Sb-124 | 4.E-07 | 1.E-07 | - | St/St/ |
| Sb-125 | 1.E-06 | 2.E-07 | - | St/St/ |
| Sb-126m | 8.E-05 | 8.E-05 | - | St/St/ |
| Sb-126 | 4.E-07 | 2.E-07 | - | St/St/ |
| Sb-127 | 9.E-07 | 4.E-07 | - | St/St/ |
| Sb-128 (9 h) | 2.E-06 | 1.E-06 | - | St/St/ |
| Sb-128 (10 min) | 2.E-04 | 2.E-04 | - | St/St/ |
| Sb-129 | 4.E-06 | 4.E-06 | - | St/St/ |
| Sb-130 | 3.E-05 | 3.E-05 | - | St/St/ |
| Sb-131 | 1.E-05 | 1.E-05 | - | T /T / |
| Te-116 | 9.E-06 | 1.E-05 | - | St/St/ |
| Te-121m | 8.E-08 | 2.E-07 | - | BS/St/ |
| Te-121 | 2.E-06 | 1.E-06 | - | St/St/ |
| Te-123m | 9.E-08 | 2.E-07 | - | BS/St/ |
| Te-123 | 8.E-08 | 2.E-07 | - | BS/BS/ |
| Te-125m | 2.E-07 | 3.E-07 | - | BS/St/ |
| Te-127m | 1.E-07 | 1.E-07 | - | BS/St/ |
| Te-127 | 9.E-06 | 7.E-06 | - | St/St/ |
| Te-129m | 3.E-07 | 1.E-07 | - | St/St/ |
| Te-129 | 3.E-05 | 3.E-05 | - | St/St/ |
| Te-131m | 2.E-07 | 2.E-07 | - | T /T / |
| Te-131 | 2.E-06 | 2.E-06 | - | T /T / |
| Te-132 | 9.E-08 | 9.E-08 | - | T /T / |
| Te-133m | 2.E-06 | 2.E-06 | - | T /T / |
| Te-133 | 9.E-06 | 9.E-06 | - | T /T / |
| Te-134 | 1.E-05 | 1.E-05 | - | T /T / |
| I-120m | 9.E-06 | - | - | St/ / |
| I-120 | 4.E-06 | - | - | T / / |
| I-121 | 7.E-06 | - | - | T / / |
| I-123 | 3.E-06 | - | - | T / / |

| Radionuclide | Inhaled Air - Lung Retention Class D (µCi/mL) | W (µCi/mL) | Y (µCi/mL) | Stochastic or Organ1/ (D / W / Y) |
|---|---|---|---|---|
| I-124 | 3.E-08 | - | - | T / / |
| I-125 | 3.E-08 | - | - | T / / |
| I-126 | 1.E-08 | - | - | T / / |
| I-128 | 5.E-05 | - | - | T / / |
| I-129 | 4.E-09 | - | - | St/ / |
| I-130 | 3.E-07 | - | - | T / / |
| I-131 | 2.E-08 | - | - | T / / |
| I-132m | 4.E-06 | - | - | T / / |
| I-132 | 3.E-06 | - | - | T / / |
| I-133 | 1.E-07 | - | - | T / / |
| I-134 | 2.E-05 | - | - | T / / |
| I-135 | 7.E-07 | - | - | E / / |
| | | | | T / / |
| Cs-125 | 6.E-05 | - | - | St/ / |
| Cs-127 | 4.E-05 | - | - | St/ / |
| Cs-129 | 1.E-05 | - | - | St/ / |
| Cs-130 | 8.E-05 | - | - | St/ / |
| Cs-131 | 1.E-05 | - | - | St/ / |
| Cs-132 | 2.E-06 | - | - | St/ / |
| Cs-134m | 6.E-05 | - | - | St/ / |
| CS-134 | 4.E-08 | - | - | St/ / |
| Cs-135m | 8.E-05 | - | - | St/ / |
| Cs-135 | 5.E-07 | - | - | St/ / |
| Cs-136 | 3.E-07 | - | - | St/ / |
| Cs-137 | 7.E-08 | - | - | St/ / |
| Cs-138 | 2.E-05 | - | - | St/ / |
| | | | | St/ / |
| Ba-126 | 6.E-06 | - | - | St/ / |
| Ba-128 | 7.E-07 | - | - | St/ / |
| Ba-131m | 6.E-04 | - | - | St/ / |
| Ba-131 | 3.E-06 | - | - | St/ / |
| Ba-133m | 4.E-06 | - | - | St/ / |
| Ba-133 | 3.E-07 | - | - | St/ / |
| Ba-135m | 5.E-06 | - | - | St/ / |
| Ba-139 | 1.E-05 | - | - | St/ / |
| Ba-140 | 6.E-07 | - | - | St/ / |
| Ba-141 | 3.E-05 | - | - | St/ / |
| Ba-142 | 6.E-05 | - | - | St/ / |
| | | | | St/ / |
| La-131 | 5.E-05 | 7.E-05 | - | St/St/ |
| La-132 | 4.E-06 | 5.E-06 | - | St/St/ |
| La-135 | 4.E-05 | 4.E-05 | - | St/St/ |
| La-137 | 3.E-08 | 1.E-07 | - | L /E / |
| La-138 | 2.E-09 | 6.E-09 | - | St/St/ |

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| Radionuclide | Inhaled Air - Lung Retention Class D (µCi/mL) | W (µCi/mL) | Y (µCi/mL) | Stochastic or Organ1/ (D / W / Y) |
|---|---|---|---|---|
| La-140 | 6.E-07 | 5.E-07 | - | St/St/ |
| La-141 | 4.E-06 | 5.E-06 | - | St/St/ |
| La-142 | 9.E-06 | 1.E-05 | - | St/St/ |
| La-143 | 4.E-05 | 4.E-05 | - | St/St/ |
| Ce-134 | - | 3.E-07 | 3.E-07 | /St/St |
| Ce-135 | - | 2.E-06 | 2.E-06 | /St/St |
| Ce-137m | - | 2.E-06 | 2.E-06 | /St/St |
| Ce-137 | - | 6.E-05 | 5.E-05 | /St/St |
| Ce-139 | - | 3.E-07 | 2.E-07 | /St/St |
| Ce-141 | - | 3.E-07 | 3.E-07 | /St/St |
| Ce-143 | - | 8.E-07 | 7.E-07 | /St/St |
| Ce-144 | - | 1.E-08 | 6.E-09 | /St/St |
| Pr-136 | - | 1.E-04 | 9.E-05 | /St/St |
| Pr-137 | - | 6.E-05 | 6.E-05 | /St/St |
| Pr-138m | - | 2.E-05 | 2.E-05 | /St/St |
| Pr-139 | - | 5.E-05 | 5.E-05 | /St/St |
| Pr-142m | - | 7.E-05 | 6.E-05 | /St/St |
| Pr-142 | - | 8.E-07 | 8.E-07 | /St/St |
| Pr-143 | - | 3.E-07 | 3.E-07 | /St/St |
| Pr-144 | - | 5.E-05 | 5.E-05 | /St/St |
| Pr-145 | - | 4.E-06 | 3.E-06 | /St/St |
| Pr-147 | - | 8.E-05 | 8.E-05 | /St/St |
| Nd-136 | - | 2.E-05 | 2.E-05 | /St/St |
| Nd-138 | - | 3.E-06 | 2.E-06 | /St/St |
| Nd-139m | - | 7.E-06 | 6.E-06 | /St/St |
| Nd-139 | - | 1.E-04 | 1.E-04 | /St/St |
| Nd-141 | - | 3.E-04 | 3.E-04 | /St/St |
| Nd-147 | - | 4.E-07 | 3.E-07 | /St/St |
| Nd-149 | - | 1.E-05 | 1.E-05 | /St/St |
| Nd-151 | - | 8.E-05 | 8.E-05 | /St/St |
| Pm-141 | - | 8.E-05 | 7.E-05 | /St/St |
| Pm-143 | - | 3.E-07 | 3.E-07 | /St/St |
| Pm-144 | - | 5.E-08 | 5.E-08 | /St/St |
| Pm-145 | - | 7.E-08 | 8.E-08 | /BS/St |
| Pm-146 | - | 2.E-08 | 2.E-08 | /St/St |
| Pm-147 | - | 6.E-08 | 6.E-08 | /BS/St |
| Pm-148m | - | 1.E-07 | 1.E-07 | /St/St |
| Pm-148 | - | 2.E-07 | 2.E-07 | /St/St |
| Pm-149 | - | 8.E-07 | 8.E-07 | /St/St |
| Pm-150 | - | 8.E-06 | 7.E-06 | /St/St |

| Radionuclide | Inhaled Air - Lung Retention Class D (µCi/mL) | W (µCi/mL) | Y (µCi/mL) | Stochastic or Organ1/ (D / W / Y) |
|---|---|---|---|---|
| Pm-151 | - | 2.E-06 | 1.E-06 | /St/St |
| Sm-141m | - | 4.E-05 | - | /St/ |
| Sm-141 | - | 7.E-05 | - | /St/ |
| Sm-142 | - | 1.E-05 | - | /St/ |
| Sm-145 | - | 2.E-07 | - | /St/ |
| Sm-146 | - | 1.E-11 | - | /BS/ |
| Sm-147 | - | 2.E-11 | - | /BS/ |
| Sm-151 | - | 4.E-08 | - | /BS/ |
| Sm-153 | - | 1.E-06 | - | /St/ |
| Sm-155 | - | 9.E-05 | - | /St/ |
| Sm-156 | - | 4.E-06 | - | /St/ |
| Eu-145 | - | 8.E-07 | - | /St/ |
| Eu-146 | - | 5.E-07 | - | /St/ |
| Eu-147 | - | 7.E-07 | - | /St/ |
| Eu-148 | - | 2.E-07 | - | /St/ |
| Eu-149 | - | 1.E-06 | - | /St/ |
| Eu-150 (12 h) | - | 3.E-06 | - | /St/ |
| Eu-150 (34 yr) | - | 8.E-09 | - | /St/ |
| Eu-152m | - | 3.E-06 | - | /St/ |
| Eu-152 | - | 1.E-08 | - | /St/ |
| Eu-154 | - | 8.E-09 | - | /St/ |
| Eu-155 | - | 4.E-08 | - | /BS/ |
| Eu-156 | - | 2.E-07 | - | /St/ |
| Eu-157 | - | 2.E-06 | - | /St/ |
| Eu-158 | - | 2.E-05 | - | /St/ |
| Gd-145 | 7.E-05 | 7.E-05 | - | St/St/ |
| Gd-146 | 5.E-08 | 1.E-07 | - | St/St/ |
| Gd-147 | 2.E-06 | 2.E-06 | - | St/St/ |
| Gd-148 | 3.E-12 | 1.E-11 | - | BS/BS/ |
| Gd-149 | 9.E-07 | 1.E-06 | - | St/St/ |
| Gd-151 | 2.E-07 | 5.E-07 | - | BS/St/ |
| Gd-152 | 4.E-12 | 2.E-11 | - | BS/BS/ |
| Gd-153 | 6.E-08 | 3.E-07 | - | BS/St/ |
| Gd-159 | 3.E-06 | 2.E-06 | - | St/St/ |
| Tb-147 | - | 1.E-05 | - | /St/ |
| Tb-149 | - | 3.E-07 | - | /St/ |
| Tb-150 | - | 9.E-06 | - | /St/ |
| Tb-151 | - | 4.E-06 | - | /St/ |
| Tb-153 | - | 3.E-06 | - | /St/ |
| Tb-154 | - | 2.E-06 | - | /St/ |

| Radionuclide | Inhaled Air - Lung Retention Class D (µCi/mL) | W (µCi/mL) | Y (µCi/mL) | Stochastic or Organ1/ (D / W / Y) |
|---|---|---|---|---|
| Tb-155 | - | 3.E-06 | - | /St/ |
| Tb-156m (24 h) | - | 3.E-06 | - | /St/ |
| Tb-156m (5 h) | - | 1.E-05 | - | /St/ |
| Tb-156 | - | 6.E-07 | - | /St/ |
| Tb-157 | - | 1.E-07 | - | /BS/ |
| Tb-158 | - | 8.E-09 | - | /St/ |
| Tb-160 | - | 1.E-07 | - | /St/ |
| Tb-161 | - | 7.E-07 | - | /St/ |
| Dy-155 | - | 1.E-05 | - | /St/ |
| Dy-157 | - | 3.E-05 | - | /St/ |
| Dy-159 | - | 1.E-06 | - | /St/ |
| Dy-165 | - | 2.E-05 | - | /St/ |
| Dy-166 | - | 3.E-07 | - | /St/ |
| Ho-155 | - | 7.E-05 | - | /St/ |
| Ho-157 | - | 6.E-04 | - | /St/ |
| Ho-159 | - | 4.E-04 | - | /St/ |
| Ho-161 | - | 2.E-04 | - | /St/ |
| Ho-162m | - | 1.E-04 | - | /St/ |
| Ho-162 | - | 1.E-03 | - | /St/ |
| Ho-164m | - | 1.E-04 | - | /St/ |
| Ho-164 | - | 3.E-04 | - | /St/ |
| Ho-166m | - | 3.E-09 | - | /St/ |
| Ho-166 | - | 7.E-07 | - | /St/ |
| Ho-167 | - | 2.E-05 | - | /St/ |
| Er-161 | - | 3.E-05 | - | /St/ |
| Er-165 | - | 8.E-05 | - | /St/ |
| Er-169 | - | 1.E-06 | - | /St/ |
| Er-171 | - | 4.E-06 | - | /St/ |
| Er-172 | - | 6.E-07 | - | /St/ |
| Tm-162 | - | 1.E-04 | - | /St/ |
| Tm-166 | - | 6.E-06 | - | /St/ |
| Tm-167 | - | 8.E-07 | - | /St/ |
| Tm-170 | - | 9.E-08 | - | /St/ |
| Tm-171 | - | 1.E-07 | - | /BS/ |
| Tm-172 | - | 5.E-07 | - | /St/ |
| Tm-173 | - | 5.E-06 | - | /St/ |
| Tm-175 | - | 1.E-04 | - | /St/ |
| Yb-162 | - | 1.E-04 | 1.E-04 | /St/St |
| Yb-166 | - | 8.E-07 | 8.E-07 | /St/St |

| Radionuclide | Inhaled Air - Lung Retention Class D (µCi/mL) | W (µCi/mL) | Y (µCi/mL) | Stochastic or Organ1/ (D / W / Y) |
|---|---|---|---|---|
| Yb-167 | - | 3.E-04 | 3.E-04 | /St/St |
| Yb-169 | - | 3.E-07 | 3.E-07 | /St/St |
| Yb-175 | - | 1.E-06 | 1.E-06 | /St/St |
| Yb-177 | - | 2.E-05 | 2.E-05 | /St/St |
| Yb-178 | - | 2.E-05 | 1.E-05 | /St/St |
| Lu-169 | - | 2.E-06 | 2.E-06 | /St/St |
| Lu-170 | - | 9.E-07 | 8.E-07 | /St/St |
| Lu-171 | - | 8.E-07 | 8.E-07 | /St/St |
| Lu-172 | - | 5.E-07 | 5.E-07 | /St/St |
| Lu-173 | - | 1.E-07 | 1.E-07 | /BS/St |
| Lu-174m | - | 1.E-07 | 9.E-08 | /BS/St |
| Lu-174 | - | 5.E-08 | 7.E-08 | /BS/St |
| Lu-176m | - | 1.E-05 | 1.E-05 | /St/St |
| Lu-176 | - | 2.E-09 | 3.E-09 | /BS/St |
| Lu-177m | - | 5.E-08 | 3.E-08 | /BS/St |
| Lu-177 | - | 9.E-07 | 9.E-07 | /St/St |
| Lu-178m | - | 8.E-05 | 7.E-05 | /St/St |
| Lu-178 | - | 5.E-05 | 5.E-05 | /St/St |
| Lu-179 | - | 8.E-06 | 6.E-06 | /St/St |
| Hf-170 | 2.E-06 | 2.E-06 | - | St/St/ |
| Hf-172 | 4.E-09 | 2.E-08 | - | BS/BS/ |
| Hf-173 | 5.E-06 | 5.E-06 | - | St/St/ |
| Hf-175 | 4.E-07 | 5.E-07 | - | BS/St/ |
| Hf-177m | 2.E-05 | 4.E-05 | - | St/St/ |
| Hf-178m | 6.E-10 | 2.E-09 | - | BS/BS/ |
| Hf-179m | 1.E-07 | 3.E-07 | - | BS/St/ |
| Hf-180m | 9.E-06 | 1.E-05 | - | St/St/ |
| Hf-181 | 7.E-08 | 2.E-07 | - | BS/St/ |
| Hf-182m | 4.E-05 | 6.E-05 | - | St/St/ |
| Hf-182 | 3.E-10 | 1.E-09 | - | BS/BS/ |
| Hf-183 | 2.E-05 | 2.E-05 | - | St/St/ |
| Hf-184 | 3.E-06 | 3.E-06 | - | St/St/ |
| Ta-172 | - | 5.E-05 | 4.E-05 | /St/St |
| Ta-173 | - | 8.E-06 | 7.E-06 | /St/St |
| Ta-174 | - | 4.E-05 | 4.E-05 | /St/St |
| Ta-175 | - | 7.E-06 | 6.E-06 | /St/St |
| Ta-176 | - | 5.E-06 | 5.E-06 | /St/St |
| Ta-177 | - | 8.E-06 | 7.E-06 | /St/St |
| Ta-178 | - | 4.E-05 | 3.E-05 | /St/St |
| Ta-179 | - | 2.E-06 | 4.E-07 | /St/St |
| Ta-180m | - | 3.E-05 | 2.E-05 | /St/St |

| Radionuclide | Inhaled Air - Lung Retention Class D (μCi/mL) | W (μCi/mL) | Y (μCi/mL) | Stochastic or Organ1/ (D / W / Y) |
|---|---|---|---|---|
| Ta-180 | - | 2.E-07 | 1.E-08 | /St/St |
| Ta-182m | - | 2.E-04 | 2.E-04 | /St/St |
| Ta-182 | - | 1.E-07 | 6.E-08 | /St/St |
| Ta-183 | - | 5.E-07 | 4.E-07 | /St/St |
| Ta-184 | - | 2.E-06 | 2.E-06 | /St/St |
| Ta-185 | - | 3.E-05 | 3.E-05 | /St/St |
| Ta-186 | - | 1.E-04 | 9.E-05 | /St/St |
| W-176 | 2.E-05 | - | - | St/ / |
| W-177 | 4.E-05 | - | - | St/ / |
| W-178 | 8.E-06 | - | - | St/ / |
| W-179 | 7.E-04 | - | - | St/ / |
| W-181 | 1.E-05 | - | - | St/ / |
| W-185 | 3.E-06 | - | - | St/ / |
| W-187 | 4.E-06 | - | - | St/ / |
| W-188 | 5.E-07 | - | - | St/ / |
| Re-177 | 1.E-04 | 2.E-04 | - | St/St/ |
| Re-178 | 1.E-04 | 1.E-04 | - | St/St/ |
| Re-181 | 4.E-06 | 4.E-06 | - | St/St/ |
| Re-182 (64 h) | 1.E-06 | 9.E-07 | - | St/St/ |
| Re-182 (12 h) | 5.E-06 | 6.E-06 | - | St/St/ |
| Re-184m | 1.E-06 | 2.E-07 | - | St/St/ |
| Re-184 | 2.E-06 | 6.E-07 | - | St/St/ |
| Re-186m | 7.E-07 | 6.E-08 | - | St/St/ |
| Re-186 | 1.E-06 | 7.E-07 | - | SW/St/ |
| Re-187 | 3.E-04 | 4.E-05 | - | St/St/ |
| Re-188m | 6.E-05 | 6.E-05 | - | SW/St/ |
| Re-188 | 1.E-06 | 1.E-06 | - | St/St/ |
| Re-189 | 2.E-06 | 2.E-06 | - | St/St/ |
| Os-180 | 2.E-04 | 2.E-04 | 2.E-04 | St/St/St |
| Os-181 | 2.E-05 | 2.E-05 | 2.E-05 | St/St/St |
| Os-182 | 2.E-06 | 2.E-06 | 2.E-06 | St/St/St |
| Os-185 | 2.E-07 | 3.E-07 | 3.E-07 | St/St/St |
| Os-189m | 1.E-04 | 9.E-05 | 7.E-05 | St/St/St |
| Os-191m | 1.E-05 | 9.E-06 | 7.E-06 | St/St/St |
| Os-191 | 9.E-07 | 7.E-07 | 6.E-07 | St/St/St |
| Os-193 | 2.E-06 | 1.E-06 | 1.E-06 | St/St/St |
| Os-194 | 2.E-08 | 2.E-08 | 3.E-09 | St/St/St |
| Ir-182 | 6.E-05 | 6.E-05 | 5.E-05 | St/St/St |
| Ir-184 | 1.E-05 | 1.E-05 | 1.E-05 | St/St/St |
| Ir-185 | 5.E-06 | 5.E-06 | 4.E-06 | St/St/St |

| Radionuclide | Inhaled Air - Lung Retention Class D (µCi/mL) | W (µCi/mL) | Y (µCi/mL) | Stochastic or Organ1/ (D / W / Y) |
|---|---|---|---|---|
| Ir-186 | 3.E-06 | 3.E-06 | 2.E-06 | St/St/St |
| Ir-187 | 1.E-05 | 1.E-05 | 1.E-05 | St/St/St |
| Ir-188 | 2.E-06 | 2.E-06 | 1.E-06 | St/St/St |
| Ir-189 | 2.E-06 | 2.E-06 | 2.E-06 | St/St/St |
| Ir-190m | 8.E-05 | 9.E-05 | 8.E-05 | St/St/St |
| Ir-190 | 4.E-07 | 4.E-07 | 4.E-07 | St/St/St |
| Ir-192m | 4.E-08 | 9.E-08 | 6.E-09 | St/St/St |
| Ir-192 | 1.E-07 | 2.E-07 | 9.E-08 | St/St/St |
| Ir-194m | 4.E-08 | 7.E-08 | 4.E-08 | St/St/St |
| Ir-194 | 1.E-06 | 8.E-07 | 8.E-07 | St/St/St |
| Ir-195m | 1.E-05 | 1.E-05 | 9.E-06 | St/St/St |
| Ir-195 | 2.E-05 | 2.E-05 | 2.E-05 | St/St/St |
| Pt-186 | 2.E-05 | - | - | St/ / |
| Pt-188 | 7.E-07 | - | - | St/ / |
| Pt-189 | 1.E-05 | - | - | St/ / |
| Pt-191 | 3.E-06 | - | - | St/ / |
| Pt-193m | 2.E-06 | - | - | St/ / |
| Pt-193 | 1.E-05 | - | - | St/ / |
| Pt-195m | 2.E-06 | - | - | St/ / |
| Pt-197m | 2.E-05 | - | - | St/ / |
| Pt-197 | 4.E-06 | - | - | St/ / |
| Pt-199 | 6.E-05 | - | - | St/ / |
| Pt-200 | 1.E-06 | - | - | St/ / |
| Au-193 | 6.E-06 | 7.E-06 | 7.E-06 | St/St/St |
| Au-194 | 2.E-06 | 2.E-06 | 2.E-06 | St/St/St |
| Au-195 | 1.E-06 | 6.E-07 | 2.E-07 | St/St/St |
| Au-198m | 3.E-07 | 4.E-07 | 4.E-07 | St/St/St |
| Au-198 | 5.E-07 | 1.E-06 | 1.E-06 | St/St/St |
| Au-199 | 1.E-06 | 1.E-06 | 1.E-06 | St/St/St |
| Au-200m | 8.E-07 | 1.E-06 | 1.E-06 | St/St/St |
| Au-200 | 2.E-05 | 3.E-05 | 3.E-05 | St/St/St |
| Au-201 | 6.E-05 | 9.E-05 | 9.E-05 | St/St/St |
| Hg-193m (Org) | 6.E-06 | - | - | St/ / |
| Hg-193m (Inorg) | 4.E-06 | 3.E-06 | - | St/St/ |
| Hg-193m (Vapor) | - | 4.E-06 | - | /St/ |
| Hg-193 (Org) | 3.E-05 | - | - | St/ / |
| Hg-193 (Inorg) | 2.E-05 | 2.E-05 | - | St/St/ |
| Hg-193 (Vapor) | - | 1.E-05 | - | /St/ |
| Hg-194 (Org) | 1.E-08 | - | - | St/ / |
| Hg-194 (Inorg) | 2.E-08 | 5.E-08 | - | St/St/ |
| Hg-194 (Vapor) | - | 1.E-08 | - | /St/ |

| Radionuclide | Inhaled Air - Lung Retention Class D (μCi/mL) | W (μCi/mL) | Y (μCi/mL) | Stochastic or Organ1/ (D / W / Y) |
|---|---|---|---|---|
| Hg-195m (Org) | 3.E-06 | - | - | St/ / |
| Hg-195m (Inorg) | 2.E-06 | 2.E-06 | - | St/St/ |
| Hg-195m (Vapor) | - | 2.E-06 | - | /St/ |
| Hg-195 (Org) | 2.E-05 | - | - | St/ / |
| Hg-195 (Inorg) | 1.E-05 | 1.E-05 | - | St/St/ |
| Hg-195 (Vapor) | - | 1.E-05 | - | /St/ |
| Hg-197m (Org) | 4.E-06 | - | - | St/ / |
| Hg-197m (Inorg) | 3.E-06 | 2.E-06 | - | St/St/ |
| Hg-197m (Vapor) | - | 2.E-06 | - | /St/ |
| Hg-197 (Org) | 6.E-06 | - | - | St/ / |
| Hg-197 (Inorg) | 5.E-06 | 4.E-06 | - | St/St/ |
| Hg-197 (Vapor) | - | 3.E-05 | - | /St/ |
| Hg-199m (Org) | 7.E-05 | - | - | St/ / |
| Hg-199m (Inorg) | 6.E-05 | 7.E-05 | - | St/St/ |
| Hg-199m (Vapor) | - | 3.E-05 | - | /St/ |
| Hg-203 (Org) | 3.E-07 | - | - | St/ / |
| Hg-203 (Inorg) | 5.E-07 | 5.E-07 | - | St/St/ |
| Hg-203 (Vapor) | - | 3.E-07 | - | /St/ |
| Tl-194m | 6.E-05 | - | - | St/ / |
| Tl-194 | 3.E-04 | - | - | St/ / |
| Tl-195 | 5.E-05 | - | - | St/ / |
| Tl-197 | 5.E-05 | - | - | St/ / |
| Tl-198m | 2.E-05 | - | - | St/ / |
| Tl-198 | 1.E-05 | - | - | St/ / |
| Tl-199 | 3.E-05 | - | - | St/ / |
| Tl-200 | 5.E-06 | - | - | St/ / |
| Tl-201 | 9.E-06 | - | - | St/ / |
| Tl-202 | 2.E-06 | - | - | St/ / |
| Tl-204 | 9.E-07 | - | - | St/ / |
| Pb-195m | 8.E-05 | - | - | St/ / |
| Pb-198 | 3.E-05 | - | - | St/ / |
| Pb-199 | 3.E-05 | - | - | St/ / |
| Pb-200 | 3.E-06 | - | - | St/ / |
| Pb-201 | 9.E-06 | - | - | St/ / |
| Pb-202m | 1.E-05 | - | - | St/ / |
| Pb-202 | 2.E-08 | - | - | St/ / |
| Pb-203 | 4.E-06 | - | - | St/ / |
| Pb-205 | 6.E-07 | - | - | St/ / |
| Pb-209 | 2.E-05 | - | - | St/ / |
| Pb-210 | 1.E-10 | - | - | BS/ / |
| Pb-211 | 3.E-07 | - | - | St/ / |
| Pb-212 | 1.E-08 | - | - | St/ / |

| Radionuclide | Inhaled Air - Lung Retention Class D (µCi/mL) | W (µCi/mL) | Y (µCi/mL) | Stochastic or Organ1/ (D / W / Y) |
|---|---|---|---|---|
| Pb-214 | 3.E-07 | - | - | St/ / |
| Bi-200 | 3.E-05 | 4.E-05 | - | St/St/ |
| Bi-201 | 1.E-05 | 2.E-05 | - | St/St/ |
| Bi-202 | 2.E-05 | 3.E-05 | - | St/St/ |
| Bi-203 | 3.E-06 | 2.E-06 | - | St/St/ |
| Bi-205 | 1.E-06 | 5.E-07 | - | St/St/ |
| Bi-206 | 6.E-07 | 4.E-07 | - | St/St/ |
| Bi-207 | 7.E-07 | 2.E-07 | - | St/St/ |
| Bi-210m | 2.E-09 | 3.E-10 | - | K /St/ |
| Bi-210 | 1.E-07 | 1.E-08 | - | K /St/ |
| Bi-212 | 1.E-07 | 1.E-07 | - | St/St/ |
| Bi-213 | 1.E-07 | 2.E-07 | - | St/St/ |
| Bi-214 | 3.E-07 | 4.E-07 | - | St/St/ |
| Po-203 | 3.E-05 | 4.E-05 | - | St/St/ |
| Po-205 | 2.E-05 | 3.E-05 | - | St/St/ |
| Po-207 | 1.E-05 | 1.E-05 | - | St/St/ |
| Po-210 | 3.E-10 | 3.E-10 | - | E /St/ |
| At-207 | 1.E-06 | 9.E-07 | - | St/St/ |
| At-211 | 3.E-08 | 2.E-08 | - | St/St/ |
| Rn-220 | 8.E-09 4/ | -4/ | -4/ | -4/ |
| Rn-222 | 3.E-08 4/ | -4/ | -4/ | -4/ |
| Fr-222 | 2.E-07 | - | - | St/ / |
| Fr-223 | 3.E-07 | - | - | St/ / |
| Ra-223 | - | 3.E-10 | - | /St/ |
| Ra-224 | - | 7.E-10 | - | /St/ |
| Ra-225 | - | 3.E-10 | - | /St/ |
| Ra-226 | - | 3.E-10 | - | /St/ |
| Ra-227 | - | 6.E-06 | - | /BS/ |
| Ra-228 | - | 5.E-10 | - | /St/ |
| Ac-224 | 1.E-08 | 2.E-08 | 2.E-08 | BS/St/St |
| Ac-225 | 1.E-10 | 3.E-10 | 3.E-10 | BS/St/St |
| Ac-226 | 1.E-09 | 2.E-09 | 2.E-09 | BS/St/St |
| Ac-227 | 2.E-13 | 7.E-13 | 2.E-12 | BS/BS/St |
| Ac-228 | 4.E-09 | 2.E-08 | 2.E-08 | BS/BS/St |
| Th-226 | - | 7.E-08 | 6.E-08 | /St/St |
| Th-227 | - | 1.E-10 | 1.E-10 | /St/St |

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| Radionuclide | Inhaled Air - Lung Retention Class D (µCi/mL) | W (µCi/mL) | Y (µCi/mL) | Stochastic or Organ 1/ (D / W / Y) |
|---|---|---|---|---|
| Th-228 | - | 4.E-12 | 7.E-12 | /BS/St |
| Th-229 | - | 4.E-13 | 1.E-12 | /BS/BS |
| Th-230 | - | 3.E-12 | 7.E-12 | /BS/BS |
| Th-231 | - | 3.E-06 | 3.E-06 | /St/St |
| Th-232 | - | 5.E-13 | 1.E-12 | /BS/BS |
| Th-234 | - | 9.E-08 | 6.E-08 | /St/St |
| Pa-227 | - | 5.E-08 | 4.E-08 | /St/St |
| Pa-228 | - | 5.E-09 | 5.E-09 | /BS/St |
| Pa-230 | - | 2.E-09 | 1.E-09 | /St/St |
| Pa-231 | - | 7.E-13 | 2.E-12 | /BS/BS |
| Pa-232 | - | 9.E-09 | 2.E-08 | /BS/BS |
| Pa-233 | - | 3.E-07 | 2.E-07 | /St/St |
| Pa-234 | - | 3.E-06 | 3.E-06 | /St/St |
| U-230 | 2.E-10 | 1.E-10 | 1.E-10 | BS/St/St |
| U-231 | 3.E-06 | 2.E-06 | 2.E-06 | St/St/St |
| U-232 | 9.E-11 | 2.E-10 | 3.E-12 | BS/St/St |
| U-233 | 5.E-10 | 3.E-10 | 2.E-11 | BS/St/St |
| U-234 | 5.E-10 | 3.E-10 | 2.E-11 | BS/St/St |
| U-235 | 6.E-10 | 3.E-10 | 2.E-11 | BS/St/St |
| U-236 | 6.E-10 | 3.E-10 | 2.E-11 | BS/St/St |
| U-237 | 1.E-06 | 7.E-07 | 6.E-07 | St/St/St |
| U-238 | 6.E-10 | 3.E-10 | 2.E-11 | BS/St/St |
| U-239 | 8.E-05 | 7.E-05 | 6.E-05 | St/St/St |
| U-240 | 2.E-06 | 1.E-06 | 1.E-06 | St/St/St |
| Np-232 | - | 1.E-06 5/ | - | /BS/ |
| Np-233 | - | 1.E-03 5/ | - | /St/ |
| Np-234 | - | 1.E-06 5/ | - | /St/ |
| Np-235 | - | 5.E-07 5/ | - | /BS/ |
| Np-236 (1.E+05 yr) | - | 1.E-11 5/ | - | /BS/ |
| Np-236 (22 h) | - | 2.E-08 5/ | - | /BS/ |
| Np-237 | - | 2.E-12 5/ | - | /BS/ |
| Np-238 | - | 4.E-08 5/ | - | /BS/ |
| Np-239 | - | 1.E-06 5/ | - | /St/ |
| Np-240 | - | 3.E-05 5/ | - | /St/ |
| Pu-234 | - | 9.E-08 5/ | 8.E-08 5/ | /St/St |
| Pu-235 | - | 1.E-03 5/ | 1.E-03 5/ | /St/St |
| Pu-236 | - | 7.E-12 5/ | 1.E-11 5/ | /BS/St |
| Pu-237 | - | 1.E-06 5/ | 1.E-06 5/ | /St/St |
| Pu-238 | - | 3.E-12 5/ | 7.E-12 5/ | /BS/BS |
| Pu-239 | - | 2.E-12 5/ | 6.E-12 5/ | /BS/BS |

| Radionuclide | Inhaled Air - Lung Retention Class D (µCi/mL) | W (µCi/mL) | Y (µCi/mL) | Stochastic or Organ 1/ (D / W / Y) |
|---|---|---|---|---|
| Pu-240 | - | 2.E-12 3/ | 6.E-12 3/ | /BS/BS |
| u-241 | - | 1.E-10 3/ | 3.E-10 3/ | /BS/BS |
| Pu-242 | - | 2.E-12 3/ | 6.E-12 3/ | /BS/BS |
| Pu-243 | - | 1.E-05 3/ | 1.E-05 3/ | /St/St |
| Pu-244 | - | 2.E-12 3/ | 6.E-12 3/ | /BS/BS |
| Pu-245 | - | 2.E-06 3/ | 2.E-06 3/ | /St/St |
| Am-237 | - | 1.E-04 3/ | - | /St/ |
| Am-238 | - | 1.E-06 3/ | - | /BS/ |
| Am-239 | - | 5.E-06 3/ | - | /St/ |
| Am-240 | - | 1.E-06 3/ | - | /St/ |
| Am-241 | - | 2.E-12 3/ | - | /BS/ |
| Am-242m | - | 2.E-12 3/ | - | /BS/ |
| Am-242 | - | 3.E-08 3/ | - | /BS/ |
| Am-243 | - | 2.E-12 3/ | - | /BS/ |
| Am-244m | - | 2.E-06 3/ | - | /BS/ |
| Am-244 | - | 7.E-08 3/ | - | /BS/ |
| Am-245 | - | 3.E-05 3/ | - | /St/ |
| Am-246m | - | 7.E-05 3/ | - | /St/ |
| Am-246 | - | 4.E-05 3/ | - | /St/ |
| -238 | - | 4.E-07 3/ | - | /St/ |
| m-240 | - | 2.E-10 3/ | - | /BS/ |
| Cm-241 | - | 9.E-09 3/ | - | /BS/ |
| Cm-242 | - | 1.E-10 3/ | - | /BS/ |
| Cm-243 | - | 3.E-12 3/ | - | /BS/ |
| Cm-244 | - | 4.E-12 3/ | - | /BS/ |
| Cm-245 | - | 2.E-12 3/ | - | /BS/ |
| Cm-246 | - | 2.E-12 3/ | - | /BS/ |
| Cm-247 | - | 2.E-12 3/ | - | /BS/ |
| Cm-248 | - | 6.E-13 3/ | - | /BS/ |
| Cm-249 | - | 6.E-06 3/ | - | /BS/ |
| Bk-245 | - | 5.E-07 | - | /St/ |
| Bk-246 | - | 1.E-06 | - | /St/ |
| Bk-247 | - | 2.E-12 | - | /BS/ |
| Bk-249 | - | 9.E-10 | - | /BS/ |
| Bk-250 | - | 2.E-07 | - | /BS/ |
| Cf-244 | - | 2.E-07 3/ | 2.E-07 3/ | /St/St |
| Cf-246 | - | 4.E-09 3/ | 4.E-09 3/ | /St/St |
| Cf-248 | - | 4.E-11 3/ | 5.E-11 3/ | /BS/St |
| Cf-249 | - | 2.E-12 3/ | 6.E-12 3/ | /BS/BS |
| Cf-250 | - | 5.E-12 3/ | 1.E-11 3/ | /BS/St |

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| Radionuclide | Inhaled Air - Lung Retention Class D (µCi/mL) | W (µCi/mL) | Y (µCi/mL) | Stochastic or Organ1/ (D / W / Y) |
|---|---|---|---|---|
| Cf-251 | - | 2.E-123/ | 5.E-123/ | /BS/BS |
| Cf-252 | - | 1.E-113/ | 2.E-113/ | /BS/St |
| Cf-253 | - | 8.E-103/ | 7.E-103/ | /St/St |
| Cf-254 | - | 9.E-123/ | 7.E-123/ | /St/St |
| Es-250 | - | 3.E-07 | - | /BS/ |
| Es-251 | - | 4.E-07 | - | /BS/ |
| Es-253 | - | 6.E-10 | - | /St/ |
| Es-254m | - | 4.E-09 | - | /St/ |
| Es-254 | - | 4.E-11 | - | /BS/ |
| Fm-252 | - | 6.E-09 | - | /St/ |
| Fm-253 | - | 4.E-09 | - | /St/ |
| Fm-254 | - | 4.E-08 | - | /St/ |
| Fm-255 | - | 9.E-09 | - | /St/ |
| Fm-257 | - | 1.E-10 | - | /E / |
| Md-257 | - | 4.E-08 | - | /St/ |
| Md-258 | - | 1.E-10 | - | /BS/ |

1/ A determination of whether the DACs are controlled by stochastic (St) or nonstochastic (organ) dose, or if they both give the same result (E) for each lung retention class is given in this column. The key to the organ notation for nonstochastic dose is: BS = Bone surface, K = Kidney, L = Liver, SW = Stomach wall, and T = Thyroid. A blank indicates that no calculations are performed for the lung retention class shown.

2/ The ICRP identifies tritiated water and carbon as having immediate uptake and distribution; therefore no solubility classes are designated. For purposes of this table, the DAC values are shown as being constant, independent of solubility class. For tritiated water, the inhalation DAC values allow for an additional 50% absorption through the skin, as described in ICRP Publication No. 30: Limits for Intakes of Radionuclides by Workers. For elemental tritium, the DAC values are based solely on consideration of the dose-equivalent rate to the tissues of the lung from inhaled tritium gas contained within the lung, without absorption in the tissues.

3/ A dash indicates no values given for this data category.

4/ These values are appropriate for protection from radon combined with its short-lived daughters and are based on information given in ICRP Publication 32: Limits for Inhalation of Radon Daughters by Workers and Federal Guidance Report No. 11: Limiting Values of Radionuclide Intake and Air Concentrations, and Dose Conversion Factors for Inhalation, Submersion, and Ingestion (EPA 520/1-88-020). The values given are for 100% equilibrium concentration conditions of the radon daughters with the parent. To allow for an actual measured equilibrium concentration or a demonstrated equilibrium concentration, the values given in this table should be multiplied by the ratio (100%/actual %) or (100%/demonstrated %), respectively. Alternatively, the DAC values for Rn-220 and Rn-222 may be replaced by 1 WL* and 1/3 WL,* respectively, for appropriate limiting of daughter concentrations. Because of the dosimetric considerations for radon, no $f_1$ or lung clearance values are listed.

* A "Working Level" (WL) is any combination of short-lived radon daughters, in one liter of air without regard to the degree of equilibrium, that will result in the ultimate emission of 1.3 E+05 MeV of alpha energy.

5/ For the calculations, $f_1$ values were obtained from ICRP Publication 48: The Metabolism of Plutonium and Related Elements. It is assumed that the effective dose equivalents for inhalation are unchanged even though the $f_1$ values have changed. This is because the contribution to organ dose from inhalation is dependent mainly on transfer from lung to blood when $f_1$ values are small. Also, the gastrointestinal tract dose would be unchanged because the fraction of activity passing through the tract is $(1.0 - f_1)$.

# APPENDIX C

## SURFACE RADIOACTIVITY GUIDES

## SURFACE RADIOACTIVITY GUIDES

| NUCLIDE | REMOVABLE[1,2] | TOTAL[1,2] (FIXED PLUS REMOVABLE) |
|---|---|---|
| U-nat, U-235, U-238 | 1,000 dpm a/100cm$^2$ | 5,000 dpm a/100cm$^2$ and associated decay products |
| Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129 | 20 dpm/100cm$^2$ | 300 dpm/100cm$^2$ |
| Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133 | 200 dpm/100cm$^2$ | 1,000 dpm/100cm$^2$ |
| Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above[4] | 1,000 dpm b-g/100cm$^2$ | 5,000 dpm b-g/100cm$^2$ |

1 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.

2 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 guide values. For purposes of averaging, any square meter of surface shall be considered to be above the activity guide G if: (1) from measurements of a representative number - of sections it is determined that the sum of all contamination levels for each section divided by the number of sections is greater than or equal to G; or (2) it is determined that the sum of the activity of all isolated spots or particles in any 100 cm$^2$ area exceeds 3G.

3 The amount of removable radioactive material per 100 cm$^2$ of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe 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 should be based on the actual area and the entire surface should be wiped. Except for transuranics and Ra-226, Ra-228, Ac-227, Th-228, Th-230, and Pa-231 alpha emitters, it is not necessary to use wiping 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 levels are within the limits for removable contamination.

4 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.