U.S. Department of Energy
Washington, D.C.

ORDER

DOE 5480.11

12-21-88

SUBJECT: RADIATION PROTECTION FOR OCCUPATIONAL WORKERS

1. PURPOSE. To establish radiation protection standards and program requirements for the Department of Energy (DOE) and DOE contractor operations with respect to the protection of the worker from ionizing radiation.

2. SCOPE. The provisions of this Order apply. to all Departmental Elements and contractors performing work for the Department as provided by law and/or contract and as implemented by the appropriate contracting officer.

3. SUPERCESSION. This Order supersedes DOE 5480.1A, ENVIRONMENTAL PROTECTION, SAFETY, AND HEALTH PROTECTION PROMAM FOR DOE OPERATIONS, of 8-13-81, Chapter XI, "Requirements for Radiation Protection."

4. EFFECTIVE DATE. 1-1-89.

5. POLICY.

a. It is the policy of DOE to implement radiation protection standards that are consistent with the Presidential approved guidance to Federal Agencies promulgated by the Environmental Protection Agency (EPA) and based on the recommendations by authoritative organizations, e.g., the National Council on Radiation Protection and Measurements (NCRP), and the International Commission on Radiological Protection (ICRP).

b. It is the policy of DOE to operate its facilities and conduct its activities so that radiation exposures are maintained within the limits promulgated by this order and as far below the limits of this Order as reasonably achievable. This policy applies to annual, committed, and cumulative dose equivalents.

6. REFERENCES. The following documents provide useful information for implementing and/or a basis for the requirements of this Order.

a. DOE 1324.2A, RECORDS DISPOSITION, of 9-13-88, which prescribes policies, procedures, standards, and guidelines for the orderly disposition of records of the DOE and its operating contractors.

b. DOE 5'000.3, UNUSUAL OCCURRENCE REPORTING, of 11-7-84, which describes procedures and requirements for reporting unusual occurrences.

DISTRIBUTION
All Departmental Elements

INITIATED BY
Assistant Secretary for
Environment, Safety, and Health

c. DOE 5480.19, ENVIRONMENT, SAFETY, AND HEALTH PROGRAM FOR DEPARTMENT OF ENERGY OPERATIONS, of 9-23-86, which outlines environmental, safety, and health protection policies and responsibilities.

d. DOE 5480.4, ENVIRONMENTAL PROTECTION, SAFETY, AND HEALTH PROTECTION STANDARDS, of 5-15-84, which identifies mandatory and recommended environment, safety, and health standards.

e. DOE 5480.5, SAFETY OF NUCLEAR FACILITIES, of 9-23-86, which establishes DOE'S nonreactor nuclear facility safety program.

f. DOE 5480.6, SAFETY OF DEPARTMENT OF ENERGY-OWNED NUCLEAR REACTORS, of 9-23-86, which establishes DOE reactor safety program.

g. DOE 5480.15, DEPARTMENT OF ENERGY LABORATORY ACCREDITATION PROGRAM FOR PERSONNEL DOSIMETRY, of 12-14-87, which defines requirements for participation in the DOE Laboratory Accreditation Program.

h. DOE 5482.19, ENVIRONMENT, SAFETY, AND HEALTH APPRAISAL PROGRAM, of 9-23-86, which establishes the DOE environmental protection, safety, and health protection appraisal program.

i. DOE 5484.1, ENVIRONMENTAL PROTECTION, SAFETY, AND HEALTH PROTECTION INFORMATION REPORTING REQUIREMENTS, of 2-24-81, which establish procedures for the reporting of information having environmental protection, safety, or health protection significance.

j. DOE Orders in the 5500 series that outline responsibilities for emergency preparedness.

k. DOE 5700.69, QUALITY ASSURANCE, of 9-23-86, which sets forth actions for establishing, implementing, and maintaining actions to assure quality achievement in ODE programs.

l. DOE 6430.1, GENERAL DESIGN CRITERIA, of 12-12-83, which provides general design criteria for the acquisition of DOE facilities.

m. DOE publication DOE/EH-0026, "Handbook for the" Department of Energy Laboratory Accreditation Program for Personnel Dosimetry Systems," which provides operating procedures for the program and is available from the National Technical Information Service.

n. DOE publication DOE/EH-0027, 'Department of Energy Standard for the Testing of Personnel Dosimetry Systems" which provides the performance testing criteria used to accredit personnel dosimeters and is available from the National Technical Information Service.

o. DOE publication PNL-6577, "Health Physics Manual of Good Practices for Reducing Radiation Exposure to Levels that are As Lou As Reasonably Achievable (ALARA),' of 7-88, that provides contractor personnel with general guidance regarding programs and techniques to reduce radiation exposure to as low as reasonably achievable. This document may be purchased from the National Technical Information Service.

p. DOE publication DOE/EH-0070, 'External Dose-Rate Conversion Factors for Calculation of Dose to the Public," of 7-88, which provides conversion factors for use in calculating dose from radionuclides external to the body and is available from the National Technical Information Service.

q. DOE publication DOE/EH-0071, "Internal Dose Conversion Factors for Calculation of Dose to the Public," of 7-88, which provides conversion factors for use in calculating dose from radionuclides in the body and is available from the National Technical Information Service.

r. Nuclear Energy Agency report, "Assessment and Recording of Radiation Dose to Workers," of 1986, which provides recommended technical procedures for a unified approach for dose assessment and recording. This document is available from the Organization for the Economic Co-operation and Development, Paris, France.

s. The following reports of the National Council on Radiation Protection and Measurements (NCRP) available from the National Council on Radiation Protection and Measurements, Bethesda, Maryland.

(1) NCRP Report 84, "General Concepts for the Dosimetry of Internally Deposited Radionuclides."

(2) NCRP Report 87, "Use of Bioassay Procedures for Assessment of Internal Radionuclide Deposition.'

(3) NCRP Report 91, "Recommendations on Limits for Exposure to Ionizing Radiation."

t. The following International Commission on Radiological Protection (ICRP) publications available from Pergamon Press, Elmsford, New York.

(1) ICRP Publication 23, *Reference Man Anatomical Physiological and Metabolic Characteristics."

(2) ICRP Publication 26, 'Recommendations of the International Commission on Radiological Protection."

(3) ICRP Publication 30, "Limits for Intakes of Radionuclides by Workers."

(4) ICRP Publication 32, "Limits for Inhalation of Radon Daughters by Workers."

(5) ICRP Publication 37. 'Cost-Benefit Analysis In the Optimization of Radiation Protection."

(6) ICRP Publication 48, "The Metabolism of Plutonium and Related Elements."

u. Environmental Protection Agency standards:

(1) "Radiation Protection Guidance to the Federal Agencies for Occupational Exposure," Federal Register, Vol. 52, No. 17, 1987.

(2) Title 40 CFR Part 141, 'National Interim Primary Drinking Water Regulations (Safe Drinking Water Act)," which prescribes radionuclide concentration limits for public drinking water.

v. The following American National Standards Institute (ANSI) standards available from American National Standards Institute, New York, New York.

(1) N2. 1-1971, "Radiation Symbol."

(2) N2.3-1979, 'Immediate Evacuation Signal for Use in Industrial Installations Where Radiation Exposures May Occur."

(3) N8.3-1979, "Criticality Accident Alarm."

(4) N12.1-1971, "Fissile Material Symbol."

(s) N13.1-1982, "Guide to Sampling Airborne Radioactive Materials in a Nuclear Facility."

(6) N13.2-1982, 'Administrative Practices in Radiation Monitoring (A Guide for Management)."

(7) N13.3-1981, "Dosimetry for Criticality Accidents."

(8) N13.4-1983, "Specifications of Portable X- or Gamma Radiation Survey Instruments."

(9) N13.5-1982, 'Performance Specifications for Direct Reading and Indirect Reading Pocket Dosimeters for X- and Gamma Radiation."

(10) N13.6-1972, "Practice for Occupational Radiation Exposure Record Systems." (Reaffirmed in 1982)

(11) N13.15-1981, 'Performance of Personnel Thermoluminescence Dosimetry Systems."

(12) N317-1985, 'Performance Criteria for Instrumentation Used for Inplant Plutonium Monitoring."

(13) N319-1984, 'Personnel Neutron Dosimeters (Neutron Energies Less Than 20 MeV)."

(14) N320-1985, 'Performance Specifications for Reactor Emergency Radiological Monitoring Instrumentation."

(15) N322-1983 , 'Inspection and Test Specifications for Direct and Indirect Reading Quartz Fiber Pocket Dosimeters."

(16) N323-1983, "Radiation Protection Instrumentation Test and Calibrations."

(17) N510-1980 , 'Testing of Nuclear Air Cleaning Systems."

(18) 288.2 - 1980, "Practices for Respiratory Protection."

w. Executive Order 12344, "Naval Nuclear Propulsion Program," of 2-1-82, which establishes the responsibilities of the Director, Naval Nuclear Propulsion Program for the joint DOE/Navy Naval Nuclear Propulsion Program.

7. RESPONSIBILITIES AND AUTHORITIES.

a. The Secretary. Many provisions in this Order permit and/or necessitate the exercise of discretion and/or judgment in carrying out the requirements of the Order. In those instances, the determination of whether, in the exercise of such discretion and/or judgment, the requirements of this Order were complied with, rests initially with the relevant Departmental authority and ultimately, with the Secretary. The Secretary retains the sole and final authority to determine what acts are necessary to comply with this Order. This authority may be delegated by the Secretary as appropriate.

b. In addition to those responsibilities and authorities contained in DOE 5480.16, the following responsibilities and authorities are assigned, as follows:

(1) Assistant Secretary for Environment, Safety and Health (EH-1):

(a) Develops DOE radiation protection policy and requirements; and

(b) Approves, if warranted, requests for specific exceptions to this Order.

(2) Program Assistant Secretaries Implement ODE radiation protection policy and requirements in programs and facilities for which they have programmatic or custodial responsibility and through the DOE contractors for which they have contract administration.

(3) Heads of Field Organizations.

(a) Implement the provisions of this Order for activities for which they have direct or custodial responsibility and through the DOE contractors for which they have contract administration.

(b) Process specific requests for exceptions to this Order [See paragraph 7b(1) (b)].

(c) In emergency situations, where immediate decisions and actions are required, approve, if warranted, requests for exceptions from the requirements of this Order and report such action in accordance with DOE 5484.1.

(d) Temporarily suspend the requirements of this Order when doing so is, in their judgment, necessary to minimize danger to life or property or to protect public health or safety. Whenever this provision is invoked, such suspension and the reason therefore is to be reported to EH-1 at the earliest practicable time.

(4) Deputy Assistant Secretary for Naval Reactors Executive Order 12344, statutorily" prescribed by PL 98-525 (42 USC 7158 note), establishes the responsibilities of the Director, Naval Nuclear Propulsion Program for the joint DOE/Navy Naval Nuclear Propulsion Program. Within the Department, the Director (who is also the Deputy Assistant Secretary for Naval Reactors) is responsible for prescribing and enforcing standards and regulations for control of

radiation and radioactivity as they affect the safety and health of workers, operators, and the general public for Naval Reactors facilities and activities. Accordingly, the provisions of this Order do not apply to Naval Reactors facilities and activities except as determined by the Director.

8. DEFINITIONS.

a. Annual Limit on Intake (ALI). The quantity of a single radionuclide which, if inhaled or ingested in 1 year, would irradiate a person, represented by reference man (ICRP Publication 23) to the limiting value for control of the workplace (paragraph 9j(2)).

b. As Low As Reasonably Achievable (ALARA). "An approach to radiation protection to control or manage exposures (both individual and collective to the workforce and general public) as low as social, technical, economic, practical, and public policy considerations permit. As used in this Order, ALARA is not a dose limit but a process, which has the objective of dose levels as far below applicable limits of the Order as reasonably achievable.

c. Area Terms.

(1) Controlled Area. Any area to which access is controlled in order to protect individuals from exposure to radiation and radioactive materials.

(2) Radiological Area. Any area within a controlled area where an individual can receive a dose equivalent greater than 5 mrem (50 microsieverts) in 1 hour at 30 cm from the radiation source or any surface through which the radiation penetrates. or where airborne radioactive concentrations greater than 1/10 of the derived air concentrations are present (or are likely to be), or where surface contamination levels greater than those specified in Attachment 2 of this Order are present. .

d. Derived Air Concentration (DAC). Quantity obtained by dividing the ALI for any given radionuclide by the volume of air breathed by an average worker during a working year (2.4×10^3 m^3).

e. Dose Terms.

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

(2) **Dose Equivalent (H)** The product of absorbed dose (D) in rads (or gray) in tissue, quality factor (Q), and other modifying factors (N). Dose equivalent (H) is expressed in units of rem (or sievert).

(3) **Annual Dose Equivalent.** The dose equivalent received in year. Annual dose equivalent is expressed in units of rem (or sievert).

(4) **Shallow, Deep, and Lens of Eye Dose Equivalent.** The dose equivalent at the respective depths of 0.007 cm, 1.0 cm, and 0.3 cm in tissue.

(5) **Effective Dose Equivalent (H_E).** The sum over specified tissues of the products of the dose equivalent in tissue (H_t) and the weighting factor (W_t) for that tissue, i.e., $H_E = \Sigma W_t$ Ht. The effective dose equivalent is expressed in units of rem (or sievert).

(6) **Annual Effective Dose Equivalent.** The effective dose equivalent received in year. The annual effective dose equivalent is expressed in units of rem (or sievert).

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

(8) **Committed Effective Dose Equivalent ($H_{E,50}$).** The sum of the committed dose equivalents to various tissues in the body, each multiplied by its weighting factor. It does not include contributions from external dose. Committed effective dose equivalent is expressed in units of rem (or sievert).

(9) **Collective Dose Equivalent.** The sum of the dose equivalents of all individuals in an exposed population. Collective dose equivalent is expressed in units of person-rem (or person-sievert).

(lo) **Collective Effective Dose Equivalent.** The sum of the effective dose equivalents of all individuals in an exposed population. Collective effective dose equivalent is expressed in units of person-rem (or person-sievert).

(11) **Cumulative Annual Effective Dose Equivalent.** The sum of the annual effective dose equivalents recorded for an individual for

each year of employment at a DOE or DDE contractor facility since the effective date of this *Order.*

(12) **Weighting Factor (W_t).** Is used in the calculation of ● nnual ● nd committed effective dose equivalent to ● quate the risk arising - from the irradiation of tissue T to the total risk when the whole body is uniformly irradiated. The weighting factors as defined in ICRP Publication 26 and NCRP Report 91 are:

Organs or Tissues	Weighting Factor
Gonads	0.25
Breasts	0.15
Red Bone Marrow	0.12
Lungs	0.12
Thyroid	0.03
Bone Surfaces	0.03
Remainder[1]	0.30

[1] 'Remainder" means the *five* other *organs or* tissue with the highest dose (e.g., liver, kidney, spleen, thymus, adrenal, pancreas, stomach, small intestine, upper large intestine or lower large intestine). The weighting factor for each remainder organ or tissue is 0.06. The *extremities, skin,* ● nd lens of the ● ye ● re excluded from the "remainder" organs or tissue for ● ssessment of effective dose equivalent.

f. **Extremity.** Extremity includes hands ● nd arms below the elbow or feet ● nd legs below the knee.

g. **Monitoring.** Actions intended to detect and evaluate radiological conditions.

h. **Non-Stochastic Effects.** Effects such-as the opacity of the lens of the eye for which the severity of the effect varies with the dose, and for which a threshold may ● xist.

i. **Occupational Worker.** An Individual who is ● ither a DOE or DDE contractor employee; an ● mployee of a subcontractor to ● DOE contractor; or an individual who visits to perform work for or in conjunction with DOE or utilizes DOE facilities.

j. **Quality Factor** (Q). A modifying factor that is ● mployed to derive dose equivalent from absorbed dose (paragraph 9f(5)).

k. **Radiation Worker**. An occupational worker whose job assignment requires work on, with, or In the proximity of radiation producing machines or radioactive materials, ● rid/or who has the potential of being routinely exposed ● bove 0.1 rem (0.001 sievert) per year, which is the sum of the ● nnual effective dose equivalent from ● xternal irradiation and the committed effective dose ● quivalent from internal irradiation.

l. **Stochastic Effects**. Malignant and hereditary disease for which the probability of an effect occurring, rather than its severity, is regarded ● s ● function of dose without ● threshold for radiation protection purposes.

9. **REQUIREMENTS FOR RADIATION PROTECTION OF OCCUPATIONAL WORKERS. UNBORN CHILD, STUDENTS, MINORS, AND ONSITE MEMBERS OF THE PUBLIC.**

a. **Maintaining Radiation Exposures As Low As Reasonably Achievable (ALARA)**. It is DOE's policy that ● xposures to radiation resulting from DOE operations be maintained within limiting values given in paragraph 9 and as far below all limiting values ● s reasonably achievable. This policy applies to ● nnual, committed, ● nd cumulative dose ● quivalents. Plans and programs used to ● ssure that occupational radiation exposures are maintained ALARA shall be documented. The DOE publication PNL-6577, 'Health Physics Manual of Good Practices for Reducing Radiation Exposure to Levels that ● re As Low As Reasonably Achievable (ALARA)," presents a guide on useful practices for achieving the objective of the ALARA process.

b. **Radiation Protection Standards for Internal and External Exposure for Occupational Workers**. The exposure of an occupational worker to radiation resulting from routine DOE ● ctivities shall not cause the limiting values for ● ssessed dose specified herein and summarized in Figure 1 to be exceeded. Continued ● xposure of any worker over ● substantial portion of a working lifetime at or near the limiting values for ● ssessed dose to individual workers should be ● voided. (Note: Natural background ● nd therapeutic and diagnostic medical ● xposures ● re not to be included In dose records or In ● ssessment of dose against limiting values.)

(1) **Stochastic Effects**. The limiting value of ● nnual ● ffective dose ● quivalent from both internal ● nd ● xternal sources received in ● ny year by an occupational worker is 5 rem (0.05 sievert).

(2) **Non-Stochastic Effects**. The limiting value of annual dose ● quivalent received in any year by an occupational worker, for individual organs and tissue is 15 rem (0.15 sievert) to the lens

of the eye or SO rem (0.5 sievert) to ● ny other organ, tissue (including the skin of the whole body), or extremity of the body.

(3) Unborn Child. The limiting value of annual dose ● quivalent 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 (0.005 sievert). Efforts should be made to ● void substantial variation above the uniform monthly exposure rate that would satisfy this limiting *value.* If the dose to the unborn child is determined to have already ● xceeded 0.5 rem (0.005 sievert) by the time ● worker notifies her employer in writing of her pregnancy, the worker shall not be assigned to tasks where ● dditional occupational exposure is likely. The limiting value of dose equivalent to the unborn and the ● ssignment of female workers (who have declared pregnancy in writing to their employer) to tasks 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].

c. Planned Special Exposure. Planned special exposures (non-emergency} that would result in an individual exceeding the annual effective dose equivalent limit are allowed in highly unusual situations where ● lternative!i which would avoid higher exposures are unavailable or impractical. Such planned special exposures, together with the annual occupational dose received or anticipated to be received in that year, shall not exceed 2 times the ● nnual effective dose equivalent limit specified in paragraph 9b(1). Planned special exposures require the ● pproval of the Head of the DOE Field Organization. A second planned special exposure to the same individual at any time requires the approval of the Assistant Secretary for Environment, Safety, and Health (EH-1). Documentation of planned special exposures shall be *maintained* in an individual's occupational exposure history.

d. Radiation Protection Standards for Internal and External Exposure to Minors and Students.

(1) Minors. An individual under age 18 shall neither be employed in, nor allowed to ● nter, controlled areas in such ● manner that he or she exceeds a limiting value of 0.1 rem (0.001 sievert) per year from the sum of the committed effective dose ● quivalent from internal irradiation and the annual effective dose equivalent from external irradiation,

(2) Students Students under age 18 shall not be exposed to radiation during individually authorized educational activities such that he or she exceeds a limiting value of 0.1 rem (0.001 sievert) per year from the sum of the committed effective dose equivalent from internal irradiations and the annual effective dose equivalent from external irradiation. This exposure shall be considered a part of the limit for workers under age 18 and not supplemental to it [i.e., where individuals under age 18 are exposed to radiation both as a student and as a minor In a year, their exposure as a student shall be added to their exposure as a minor and the total is not to exceed the single limiting value of 0.1 rem for minors].

Stochastic Effects	5 rem (annual effective dose equivalent)
Non-Stochastic Effects	
Lens of eye	15 rem (annual dose equivalent)
Extremity	50 rem (annual dose equivalent)
Skin of the whole body	50 rem (annual dose equivalent)
Organ or tissue	50 rem (annual dose equivalent)
Unborn Child	
Entire gestation period	0.5 rem (annual dose equivalent)

Figure 1
Radiation Protection Standards
Limiting Values for Assessed Dose from Exposure of
Occupational Workers to Radiation

e. Radiation Protection Standards for Public Entering a Controlled Area. The effective dose equivalent received by any member of the public resulting from exposure during direct onsite access to a DOE facility shall not exceed a limiting value of 0.1 rem (0.001 sievert) per year from the committed effective dose equivalent from internal irradiation plus the effective dose equivalent from any external irradiation. In addition, exposures shall not cause a dose equivalent to any tissue

(including the skin and the lens of the eye) to exceed 5 rem (0.05 sievert) per year for any member of the public. Guidance for entry during emergency conditions is provided in paragraph 9p of this Order.

f. Procedural Requirements.

(1) Combining Internal and External Dose Equivalent. The annual effective dose equivalent to an individual shall be determined by summing the annual effective dose equivalents from internally deposited radionuclides *and* from external exposure to radioactive material and/or radiation generating devices resulting from DOE activities. When in-vivo and/or in-vitro measurements confirm the retention of radionuclides in the body, with respect to evaluating conformance with the limiting value for occupational exposure, the annual effective dose equivalent due to all radionuclides retained in the body from these intakes shall be assessed for as long as the annual effective dose equivalent is 10 mrem or greater. Exposures to the skin, extremities, and lens of the eye are not included in the determination of the annual effective dose equivalent. For uniform external Irradiation of the whole body, a weighting factor (W_t) equal to one may be used. This whole body dose is to be measured in accordance with the provisions in paragraph 99(1). Non-uniform external and internal irradiation values of W_t for organs and tissues are defined in paragraph 8e(12).

(2) Non-Uniform Exposure to Skin. For non-uniform exposures to skin from x rays, beta radiation, or skin contamination, one of the following assessments shall be made and recorded:

(a) When the area of skin exposed is >100 cm^2 the maximum value of dose averaged over any area of 100 cm^2 is to be assessed, recorded, and included in the annual skin (shallow) dose equivalent.

(b) When the area of skin exposed is $\geq$10 cm^2 but <100 cm^2 the dose equivalent to that tissue is to be determined by:

$$H = fD$$

where: D is the maximum dose averaged over a 1 cm^2 of skin and f is the fraction of skin exposed compared to 100 cm^2. In no case shall an "f" of <0.1 be used. This value of dose is to be recorded and included in the annual skin (shallow) dose equivalent.

(c) When the area of skin exposed is <10 cm^2 the maximum value of dose averaged over any 1 cm^2 is to be assessed and recorded in the individual's occupational exposure history as a special entry but is not to be included in the annual skin (shallow) dose equivalent.

(3) Emergency or Accidental Exposures. When an occupational worker has been exposed to radiation in excess of the limits specified in this Order as a result of an unplanned or accidental situation, the decision to allow the worker to return to work in a radiological area shall be made by operating management based on advice from health physics and medical personnel and the concurrence of the worker and shall be subject to the approval of the DOE field organization manager. The dose received in an unplanned or accidental situation is to be documented in the radiation exposure record of the exposed individual pursuant to paragraph 9m(2) and reported pursuant to DOE 5484.1. The operating contractor is to verify to the head of the responsible field organization that the conditions under which the emergency or accidental exposures were received have been terminated. The resumption of operations following an emergency or accidental exposure in excess of the occupational limits specified in this Order shall be subject to the approval of the head of the responsible field organization. Investigations and reporting shall be conducted pursuant to DOE 5484.1 and DOE 5000.3.

(4) Air and Water Concentration Guides.

(a) Air. Derived air concentration (DAC) values for control of the workplace are given in Attachment 1. They were derived from the ICRP Publication 30 values for committed effective dose equivalent values, translated to conventional U.S. units of rem and curie. The ICRP Publication 23 recommended annual inhalation volume for male workers (40 hr/wk, 50 wk/yr) was assumed to be 2400 m^3. The DAC values or other air concentration values shall not be used for the calculation of internal dose equivalent received by a worker except for unusual circumstances where bioassay data is unavailable or inadequate.

(b) Water. Concentrations of radionuclides in drinking water in controlled areas shall not exceed the standards given in 40 CFR Part 141.

(5) Quality Factors. The dose equivalent limits specified in this chapter are expressed in terms of rem; this requires that the

absorbed dose (expressed in rads) be multiplied by an appropriate quality factor (Q). The quality-factors to be used for determining dose equivalent in rem are shown in Figures 2 and 3.

RADIATION TYPE	QUALITY FACTOR (Q)*
X-rays, gamma rays, positrons, electrons (including tritium beta particles)	1
Neutrons, ≤ 10 keV	3
Neutrons, > 10 keV	10
Protons and singly-charged particles of unknown energy with rest mass greater than one atomic mass unit	10
Alpha particles and multiple-charged particles (and particles of unknown charge) of unknown energy	20

*Where spectral data is sufficient to identify the energy of the neutrons, the Q values in Figure 3 may be used.

Figure 2
Quality Factors

NEUTRON ENERGY	$\bar{Q}$	NEUTRON FLUX DENSITY
MeV		cm^{-2} s^{-1}
2.5×10^{-8} (thermal)	2	680
1×10^{-7}	2	680
1×10^{-6}	2	560
1×10^{-5}	2	560
1×10^{-4}	2	580
1×10^{-3}	2	680
1×10^{-2}	2.5	700
1×10^{-1}	7.5	115
5×10^{-1}	11	27
1	11	19
2.5	9	20
5	8	16
7	7	17
10	6.5	17
14	7.5	12
20	8	11
40	7	10
60	5.5	11
1×10^{2}	4	14
2×10^{2}	3.5	13
3×10^{2}	3.5	11
4×10^{2}	3.5	10

Mean quality factors, $\bar{Q}$,* and values of neutron flux density which, in 40 hours, result in a maximum dose equivalent of 100 mrem.

* Maximum value of Q in a 30-cm dosimetry phantom.

Figure 3
Quality Factors for Neutrons

9. Monitoring. Occupational workers shall be monitored, as appropriate, to demonstrate compliance with the radiation protection standards in paragraph 9b and to estimate the dose equivalents received from external and internal sources of radiation. Workplaces shall be

routinely monitored, as appropriate, for identification and control of potential exposure sources.

(1) External Radiation. Personnel dosimetry programs shall be adequate to demonstrate compliance with the radiation protection standards provided in paragraph 9b. Personnel dosimeters shall be routinely calibrated and shall meet the requirements of the DOE laboratory Accreditation Program for Personnel Dosimetry as specified in DDE 5480.15. Personnel dosimetry shall be provided to radiation workers who have the potential to exceed in a year any one of the following from external *sources:*

(a) One hundred mrem (0.001 sievert) annual effective dose equivalent to the whole body.

(b) Five rem (0.05 sievert) annual dose equivalent to the skin.

(c) Five rem (0.05 sievert) annual dose equivalent to any extremity.

(d) One and a half rem (0.015 sievert) annual dose equivalent to the lens of the eye.

(2) Internal Radiation. Internal dose evaluation programs (including routine bioassay programs) shall be adequate to demonstrate compliance with the radiation protection standards in paragraph 9b. Such programs are required for radiation workers exposed to surface or airborne radioactive contamination where the worker could receive 0.1 rem (0.001 sievert) 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 (0.05 sievert) annual dose equivalent.

(3) Workplace.

(a) Air Monitoring. Ambient air monitoring shall be performed in occupied areas with the potential to exceed 10 percent of any derived air concentration values given in Attachment 1. Representative ambient air monitoring samples should be taken in strategic locations to detect and evaluate airborne radioactive material at work locations. Data obtained from air monitoring shall be used for *assessing* the *control of* airborne radioactive material in the workplace; it should not normally be used to evaluate the dose equivalent to radiation

workers. Air monitors shall be routinely calibrated and maintained, and should be capable of measuring one DAC when averaged over 8 hours (8 DAC-hours).

(b) Radiation Monitoring. Appropriate stationary (area) and/or portable radiation instruments shall be available and used to measure dose rates for the purpose of controlling exposure to radiation. These instruments shall be routinely calibrated and maintained. The combination of instruments used shall provide capability to measure types of radiation (neutron, gamma, beta, or x-radiation) and dose rates characteristic of that which could be encountered at that facility.

(4) Contamination Control and Monitoring. Appropriate instruments and techniques shall be used to provide contamination monitoring and control as described below:

(a) Workplace Surfaces Outside Radiological Areas should be maintained essentially free of removable contamination but in any case contamination shall not exceed the levels defined in Attachment 2. Acceptable levels for total (fixed plus removable) contamination are also listed in Attachment 2.

(b) Workplace Surfaces in Radiological Areas shall be posted (paragraph 9k) and controlled, as appropriate. The degree of control from simple (e.g., shoe covers and lab coat) to complex (e.g., multiple layers of protective clothing and respiratory protection) should be based on the specific contaminants present and the level of contamination.

(c) Personnel and Personal Property Contamination Monitoring shall be provided, as appropriate, and used immediately prior to or after exits from radiological areas established to control surface or airborne radioactive contamination. If monitoring is performed after the exit, appropriate controls shall be implemented to prevent the loss of control of contamination. Detectable contamination on personnel and personal property should be removed by appropriate decontamination methods.

h. Methods of Estimating Dose Equivalent. Methods of estimating the dose equivalent from external and internal sources of radiation are to be appropriate to the workplace conditions and consistent with the recommendations of NCRP, ICRP, and EPA.

i. **Releases of Materials and Equipment from Radiological Areas** The following requirements apply for the release of materials and equipment from radiological areas for conditional use in controlled areas. In all cases, contaminated property shall be cleaned as thoroughly as practical before release. These requirements are not applicable to the release of materials or equipment for unrestricted use since such use could result in exposure to the general public. (NOTE: Requirements contained in this order do not pertain to either induced radioactivity or decontamination and decommissioning release limits.)

(1) Material and equipment in radiological areas established to control surface or airborne radioactive material shall be treated as radioactive material and shall not be released from radiological areas to controlled areas if any of the following conditions exist:

(a) Measurements of accessible surfaces show that either the total or removable contamination levels exceed the guides specified in Attachment 2; or

(b) Prior use suggests that the contamination levels on inaccessible surfaces are likely to exceed the guides specified in Attachment 2.

(2) Material and equipment exceeding the total and removable contamination levels specified in Attachment 2 shall be conditionally released for movement onsite from one radiological area for immediate placement in another radiological area only *if* appropriate monitoring and control procedures are established and exercised.

(3) Under exceptional conditions, material and equipment with fixed contamination" that exceed the limits specified in Attachment 2 may be released for use *in* controlled areas outside radiological areas. As a condition of such *release,* the materials shall be routinely monitored, clearly labeled and/or tagged to alert personnel of the contaminated status, and have appropriate administrative procedures established and exercised to maintain control of these items.

(4) The records for release of potentially contaminated material and equipment shall describe the property, the date Of the last monitoring operation, the identity of the individual who Performed the monitoring operation, the type and identification number of the monitoring instrument used, and the results of the monitoring operation,

j. Design and control. Radiation exposure rates in controlled workplace ● reas should be reduced to ● s low ● s reasonably achievable levels by proper facility design ● nd control. The primary means for maintaining ● xposures as low ● s reasonably ● chievable ● re to be through physical controls, e.g., confinement, ventilation, remote handling, and shielding. Administrative controls ● nd procedural requirements ● re to be considered supplemental means to achieve control.

(1) Design. During the design of facilities, the following objectives shall be ● pplied:

(a) Optimization. Optimization principles, ● s discussed in ICRP Publication 37, are to be utilized in developing and justifying facil ity design ● nd physical controls.

(b) External Radiation Exposure. The design objectives for personnel exposure from external sources of radiation in continuously occupied controlled areas ● re ALARA and not ● xceeding 0.5 mrem (5 microsieverts) per hour on average. The design objectives for exposure rates for potential exposure to a radiation worker where occupancy is generally not continuous "are ALARA ● nd not ● xceeding 20 percent of the applicable standard in paragraphs 9b(1) ● nd (2).

(c) Internal Radiation Exposure. As a design objective, ● xposure of personnel to inhalation of airborne radioactive materials is to be avoided under normal operating conditions to the ● xtent reasonably achievable. This will normally be accomplished by confinement ● nd ventilation.

(d) Maintenance, Decontamination, and Decomissioning. Ease of maintenance and decontamination and decommissioning is to be considered in facility design ● nd selection of materials.

(2) Control. During routine operations, the combination of design and control procedures shall provide that,- with respect to the radiological workplace, the ● nticipated magnitude of the prospective committed effective dose equivalent from intakes plus any effective dose equivalent from external exposure will not ● xceed 5 rem (0.05 sievert) in ● year, ● nd the anticipated magnitude of the committed dose ● quivalent to any organ or tissue from intakes plus ● ny dose equivalent from external ● xposure will not ● xceed 50 reins (0.5 sievert) in a year. Compliance with these requirements shall be demonstrated through appropriate workplace monitoring pursuant to the provisions of paragraph 9g(3).

k. " Posting and Labeling. Areas in DOE nuclear facilities shall be posted In accordance with the provisions given below. Radioactive material and/or its container shall be individually labeled where normal posting of the area ● nd control of the material would not provide ● dequate protection. The design of signs, labels, and the radiation symbol shall conform to ANSI N12.1-1971 and ANSI N2.1-1971. The background color is to be yellow; the symbol color may be black or magenta.

(1) Controlled Area. The access *to* any controlled ● rea where radioactive materials or elevated radiation fields may be *present* shall be clearly and conspicuously posted ● s a controlled ● rea. The type of sign used may be selected by the contractor with the approval of the field organization to avoid conflict with local security requirements.

(2) Radiological Area.

(a) Posting for External Radiation. The access to *any* ● rea where an individual can ● t anytime during normal operations receive a dose equivalent greater than 5 mrem (50 microsieverts) in 1 hour ● t 30 centimeters from the radiation source or ● ny surface through which radiation penetrates shall be posted ● s below. In addition, the anticipated dose rate or *range* of dose rates shall be included on or in conjunction with each of the signs, as appropriate.

1 "Radiation Area" for any ● rea within a controlled ● rea where an individual can receive a dose equivalent greater than 5 mrem (50 microsieverts) but less than 100 mrem (1 millisievert) in 1 hr at 30 cm from the radiation source or from any surface through which the radiation penetrates,

2 "High Radiation Area" for ● ny ● rea within a controlled ● rea where ● n individual can receive a dose ● quivalent of 100 mrem or greater (0.001 sievert) but less than 5 rem (0.05 sievert) *in* 1 hr at 30 cm *from the* radiation source or from ● ny surface through which the radiation penetrates, and

3 "Very High Radiation Area" for any area within a controlled area where an individual can receive a dose of 5 rem (0.05 sievert) or greater in 1 hour at 30 cm from the radiation source or from any surface through which the radiation penetrates.

(b) **Posting for Airborne Radioactive Material.** The access to any area where airborne radioactive material concentrations greater than 1/10 of the derived air concentrations (Attachment 1) are present shall be clearly and conspicuously posted with a sign that identifies the radiological conditions which exist (e.g., "Airborne Radioactivity Area=). The type of sign used shall be consistent with the radiation protection control policies established at the facility and may be selected by the contractor with the approval of the field organization.

(c) **Posting for Surface Contamination.** The access to any area where surface contamination levels greater. than 10 times those specified in Attachment 2 are present shall be clearly and conspicuously posted with a sign that identifies the radiological conditions which exist (e.g., "Contamination Area"). The type of sign used shall be consistent with the radiation control policies established at the facility and may be selected by the contractor with the approval of the field organization.

1. **Entry Control Program.** An appropriate entry control program shall be established for radiological areas. This should include a buffer area prior to entry to a radiological area where appropriate. The level of control should be consistent with the degree of hazard. Signs and barricades, control devices on entrances, conspicuous visual and/or audible alarms, locked entrance ways, and/or administrative procedures should be used as appropriate to ensure that personnel entry into radiological areas is controlled. Step-off pads and protective clothing shall be required for entry to contaminated areas. For very high radiation areas, the entry control program shall include at a minimum one of the following:

(1) Control devices on each entrance or access point which function automatically to prevent entry when a very high radiation area exists; permit entry only after the radiation level is reduced below 0.1 rem (0.001 sievert) per hour; and prevent use or operation of the radiation source, thereby preventing the existence of a very high radiation area, while an individual is in the area.

(2) A control device which energizes a conspicuous visible or audible alarm signal so that the individual entering the very high radiation area through a failed control device is aware of the radiation level and radiation protection personnel are aware of

the entry. Administrative procedures shall define the required actions of personnel when alarms are activated.

(3) Locked entry ways, except during periods when access to the area is required, with positive control over and radiation surveys made for the initial entry and periodically as necessary.

(4) Control devices that will automatically generate audible and visible alarm signals to alert personnel in the area before use or operation of the radiation source and in sufficient time to permit evacuation of the area or the activation of a secondary control device which will prevent use or operation of the source.

m. Records. As a minimum, the records specified below of the radiation protection program and dosimetry records for all individuals for whom monitoring is provided shall be generated and maintained, commencing with the effective date of this Order. Information and data developed pursuant to this Order shall be retained consistent with the requirements of DOE 1324.2A, RECORDS DISPOSITION.

(1) ALARA. Records of ALARA programs shall be maintained by field organizations and operating contractors to demonstrate the adequacy of the ALARA plans and programs and their implementation.

(2) Individual Occupational Dose Records. Individual occupational internal and external dose records and records of the programs used to assess individual doses shall be generated and maintained sufficient to provide appropriate reports to the employee, management, and those required by DOE 5484.1. Efforts should be made to obtain records of occupational exposure received prior to employment at the site. Records should be readily available for all current employees. As a minimum, the following data shall be recorded and retained for individuals for whom monitoring, as appropriate, was provided.

(a) Internal Exposure.

1 Annual effective dose equivalent received during the year from radioactive material deposited in the body;

2 Annual dose equivalent to organ or tissue of concern received during the year from radioactive material deposited in the body;

3 Committed effective dose equivalent from intakes Occurring during the year;

4 Committed dose equivalent to organ or tissue of concern from intakes occurring during the year.

(b) External Exposure.

1 Annual effective dose equivalent from external sources of radiation received during the year.

2 Annual dose equivalent to the lens of the eye.

3 Annual dose equivalent to the skin.

4 Annual dose equivalent to the extremities received during the year, including: (1) hands and forearm below the elbow and (2) feet and legs below the knee.

(c) Summation of Internal and External Dose Equivalents.

1 Summation of the annual effective dose equivalents received from external and internal sources during the year.

2 Cumulative annual effective dose equivalent received from external and internal sources while employed at the facility, since the effective date of this Order.

(d) Programs to Determine Individual Exposures. Data necessary to support or re-calculate doses at a later date shall be maintained pursuant to Section 4 of ANSI N13.6-1972.

(3) Monitoring and Area Control Records Records that establish the conditions under which individuals were exposed, such as facility radiological conditions (as generated by the monitoring programs) and surveys for the release of personal property and workplace surfaces, shall be kept to provide a chronological, historical record pursuant to Section 5 of ANSI N13.6-1972.

(4) Monitoring Methods Records. Records shall be kept to document the appropriateness, quality, and accuracy of monitoring methods, techniques, and procedures in use during any given period pursuant to Section 6 of ANSI N13.6-1972. Changes in equipment, techniques, and procedures are to be documented and the documents maintained.

(5) Training Records. Training records of plant employees, radiation workers, and radiation safety personnel shall be retained 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 should also be retained.

n. **Reports to Employees.** Records of exposure should be made available to all occupational workers on an Individual basis and should be provided to terminated employees as soon as the data is available but within 90 days of termination. A summary of annual, cumulative, and committed effective dose equivalent shall be provided to each radiation worker on an annual basis. The cumulative effective dose equivalent is the sum of the annual effective dose equivalents recorded for each year of employment since the effective-date of the Order. Detailed information concerning a worker's exposure shall be made available to the worker upon the request of the worker, consistent with the provisions of the Privacy Act (5 USC 552a).

o. **Radiation Safety Training.**

(1) **All Employees.** All occupational workers who may enter a controlled area at a DOE facility shall receive an orientation in radiation safety within 1 month of their initial assignment to and prior to potential exposure to radiation at that facility. Retraining shall be provided when there are significant changes to radiation protection policies and procedures which affect general plant employees and should be provided every 2 years. Generic training (not specific to a facility) in all or some of the topics listed below may be waived provided: this training has been received at another DOE facility; there is provision of proof-of-training in the form of a certification document containing the individual's name, date of training, and specific topics covered; and an appropriate official has certified the training of the individual. The level of training is to be commensurate with the employee's job assignment with the initial orientation including, but not limited to:

(a) The risk of low-level occupational radiation exposure, Including cancer and genetic effects;

(b) The risk of prenatal radiation exposure;

(c) Basic radiation protection concepts;

(d) DOE and company radiation protection policies and procedures;

(e) Employee and management responsibilities for radiation safety;

(f) Emergency procedures.

(2) Radiation Workers Radiation worker training programs and retraining shall be established and conducted at a sufficient frequency (not to exceed a period of 2 *years)* to familiarize the worker with the fundamentals of radiation protection and the ALARA process. Training should include both classroom and applied training. The training shall be concurrent with assignment as a radiation worker only if the worker is accompanied by and under the direct supervision of a trained radiation worker; otherwise, the training shall precede assignment as a radiation worker. Generic training (not specific to a facility) in all or some of the topics listed below may be waived provided: this training has been received at another DOE facility; there is provision of proof-of-training in the form of a certification document containing the individual's name, date of training, and specific topics covered; and an appropriate official has certified the training of the individual. The knowledge of radiation safety fundamentals possessed by radiation workers should be certified by examination prior to an unsupervised assignment. The training should emphasize procedures specific to an Individual's job assignment. Additionally, the level of training in the following topics is to be commensurate with each worker's assignment:

(a) Radioactivity and radioactive decay;

(b) Characteristics of ionizing radiation;

(c) Han-made radiation sources;

(d) Acute effects of exposure to radiation;

(e) Risks associated with occupational radiation exposures;

(f) Special considerations in the exposure of women of reproductive age;

(9) Dose-equivalent limits;

(h) Mode of exposure-- internal and external;

(i) Dose-equivalent determinations;

(j) Basic protective measures--time, distance, shielding;

(k) Specific plant procedures for maintaining exposure ● s low as - is reasonably achievable;

(1) Radiation survey instrumentation--cal ibration ● nd limitations;

(m) Radiation men[d] toring programs and procedures;

(n) Contamination control, including protective clothing ● nd equipment and workplace design;

(o) Personnel decontamination;

(p) Emergency procedures;

(q) Warning signs and ● larms;

(r) Responsibilities of employees ● nd management;

(s) Interaction with radiation protection staff;

(t) Operational procedures associated with specific job assignments (e.g., radiation generating machines, glove boxes).

(3) Radiat ion Protection Technician. Radiation protection technician training ● nd retraining programs shall be established and conducted at a sufficient frequency, not to exceed ● very 2 years, to familiarize technicians with the fundamentals of radiation protection and the proper procedures for maintaining exposures ALARA. This program shall include both classroom ● nd applied training and shall precede or be concurrent with assignment as a radiation protection technician while under the supervision of ● trained individual. The knowledge of radiation safety fundamentals possessed by radiation protection technicians should be certified by ● xamination prior to an unsupervised work ● ssignment. The training program should include the topics listed in the paragraph (2) ● bove ● nd should emphasize procedures specific to the facility where the technician is assigned. The leve[l] of training in each topic is to be commensurate with the technician's assignment.

p. **Guidance and Requirements for Emergency Exposure During Rescue and Recovery Activities.**

(1) **Purpose.** This paragraph provides emergency action guidance for determining appropriate actions for the rescue and recovery of persons and the protection of health and property in the event of an emergency.

(2) **General Considerations.**

(a) Controlling exposure to radiation during rescue and recovery actions is extremely complex. Multiple hazards and alternate methods are to be taken into account; and prompt, sound judgment and flexibility of action are crucial to the success of any emergency actions. The risk of injury to those persons involved in the rescue and recovery activities should be minimized, to the extent practical. However, the control of radiation exposures should be consistent with the immediate objectives of saving human life, recovering deceased victims, and/or protection of health and property.

(b) To avoid unnecessarily restricting action, a rigid upper limit of exposure for lifesaving action is not specified; rather, judgment is left up to the officials in charge to evaluate any proposed action involving further radiation exposure. The evaluation should consider risk versus benefit, i.e., weighing the risks of radiation insults, actual or potential, against the benefits [social, economic, etc] to be gained. Essential elements in risk determinations include potential exposure, biological consequences related to the exposure, and the number of people involved.

(c) These instructions also recognize that accident situations involving the saving of lives will require different basis for action than those required to recover deceased victims or to protect property. In the latter instances, the amount of exposure expected to be received by persons should be controlled as much as possible within occupational exposure limits.

(d) Any rescue action that might involve substantial personal risk should be performed by volunteers. When feasible, volunteers should be evaluated with respect to age and previous exposure history. Each emergency worker should be advised of the known or anticipated hazards prior to

participation by the person onsite having the emergency action responsibility.

(3) Emergency Situations. Specific dose criteria and judgment factors are set forth for the three types of emergency action: Type 1, saving of human life; Type 2, recovery of deceased victims; and Type 3, protection of health and property.

(a) Saving of Human Life.

1 Attempts to rescue victims of an incident should be regarded in the same context as any other emergency action involving the rescue of victims, regardless of the type of hazard involved.

2 If the victim is considered to be alive, the course of action should be determined by the person onsite having the emergency action responsibility.

3 The potential amount of exposure to rescue personnel for each specific Type 1 emergency action shall be evaluated by the person onsite having the emergency action responsibility. The emergency situation should be immediately evaluated and an exposure objective should be established for the rescue mission. The evaluation of the inherent risks should consider:

a The reliability of the prediction of radiation injury from measured/estimated dose rates. In this context, consideration should be given to the uncertainties associated with the specific instruments and techniques used to estimate the dose rate. This is especially crucial when the estimated dose approximates 100 rad (1 gray) or more.

b The effects of acute external and/or internal exposure.

c The capability to reduce risk through physical mechanisms such as the use of protective equipment, remote manipulation equipment, or similar means.

d The probability of success of the rescue action.

(b) **Recovery of Deceased Victims.**

1 The recovery of deceased victims should be well planned. Except as provided in subparagraph 3 below, the amount of radiation exposure received by persons in recovery operations shall be controlled within existing occupational exposure limits.

2 When fatalities are located in inaccessible areas due to high direct radiation fields, and when the recovery mission would result in exposure in excess of occupational exposure limits specified in this chapter, special remote recovery devices should be used to retrieve bodies, as appropriate.

3 When it is not feasible to recover bodies without personnel entering the area, the official in charge may determine it necessary to exceed the occupational exposure limits specified in this chapter. The planned exposure of an individual participating in the recovery should not exceed 10 rem (0.1 sievert) per year.

(c) Protection of Health and Property. When the risk (probability and magnitude) of the radiation hazard either bears significantly on the state of health of people, or may result in loss of property, so that immediate remedial action is needed, the following criteria should apply:

1 When the official in charge deems it essential to reduce a potential hazard to protect health or prevent a substantial loss of property, a planned exposure objective not to exceed 10 rem (0.] sievert) per year may be permitted for individuals participating in the operation. However, under special circumstances, the official in charge of emergency action at the incident may elect to permit volunteers in emergency exposure objective not to exceed 25 rem (0.25 sievert) in any year.

2 When, the risk of radiation following the incident is such that life might be in jeopardy, or that there might be severe effects on health or the public or loss of property inimical to the public safety, the criteria for saving of human life shall apply.

q. Nuclear Accident Dosimetry. These requirements are applicable to DOE contractor installations possessing Sufficient quantities and kinds of fissile material to potentially constitute a critical mass as defined in DOE 5480.5, and where the excessive exposure of personnel to radiation from a nuclear accident is possible.

(1) Basic Elements. The baste elements of nuclear accident dosimetry shall include:

(a) A method to conduct initial 'screening' of personnel involved in nuclear accidents to determine if they have received a significant radiation exposure:

(b) Methods for analysis of biological-materials (including sodium-24 activity in blood and phosphorus-32 activity in hair).

(c) A system of fixed units capable of yielding estimated radiation dose and the approximate neutron spectrum at their locations.

(d) Personnel dosimeters capable of furnishing sufficient information to determine neutron and gamma dose and/or dose equivalent.

(e) Counting facilities to evaluate fixed rid/or personnel dosimeters, sodium in blood, and phosphorus in hair.

(2) Fixed Nuclear Accident Dosimeter Units.

(a) The fixed unit shall be capable of determining neutron dose in rad (gray) with an accuracy of ± 25 percent.

(b) The fixed unit shall be capable of providing the approximate neutron spectrum to permit the conversion of rad to rem.

(c] The dose range capability of the neutron components of the fixed unit shall extend from 10 rad (0.1 gray) to about 10,000 rad (100 gray).

(d) The gamma ray components of the fixed unit shall be capable of measuring fission gamma radiation in the presence of neutrons with an accuracy of approximately ± 20 percent.

(e) The dose range capability of the gamma components shall

extend from 10 rem (0.10 sievert) to about 10,000 rem (100 sievert).

(f) The number of dosimeter units needed and their placement will depend on the nature of the operation, structural design of the facility, and accessibility of areas to personnel. Consideration should be given to the need for remote retrieval mechanisms. The number and placement of dosimeters shall be periodically re-evaluated, as appropriate, to ensure that modifications to facility design and use have not affected performance. An analysis that demonstrates that the dosimeters and their placement will satisfy the performance criteria contained in paragraph q shall be documented. The analysis shall include the number of units, their location, and effect of intervening shielding. Ease of recovery after criticality event should be considered in the placement of the fixed units.

(3) Personnel Nuclear Accident Dosimeter Units.

(a) Personnel Nuclear Accident Dosimeter Units shall be worn by all personnel who enter a controlled area that contains locations requiring an installed criticality alarm system as given in paragraph 11c(3) (g) of DOE 5480.5.

(b) Dosimeters worn by the worker should be capable of determining gamma dose from 10 rad (0.1 gray) to 1000 rad (10 gray) with an accuracy of ± 20 percent and neutron dose from 1.0 rad (0.01 gray) to 1000 rad (10 gray) with an accuracy of ± 30 percent without dependence upon fixed unit data.

r. Contractor Internal Audits.

(1) Contractor internal audits of all functional elements of the radiation protection program shall be conducted as often as necessary but no less frequently than every 3 years. The audit should include, but is not limited to:

(a) External dosimetry;

(b) Internal dosimetry;

(c) Portable and fixed instrumentation;

(d) Respirators;

(e) Contamination control;

(f) Radiological monitoring;

(g) ALARA program;

(h) Nuclear accident dosimetry;

(i) Source material control;

(j) X-ray protection;

(k) Training;

(l) Posting;

(m) Records.

(2) In conducting such audits, the guidelines set forth in DOE 5482.1 shall be followed.

BY ORDER OF THE SECRETARY OF ENERGY:

LAURENCE F. DAVENPORT
Assistant Secretary
Management and Administration

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 Attachment 1, page 4, Figure 1. 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 (μCi/mL); (3) inhaled air DAC for lung retention class W (μCi/mL); (4) inhaled air DAC for lung retention class Y (μCi/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 μm be used. *For situations where the* particle size distribution is known to differ significantly from 1 μm, 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.

Alternative absorption factors and lung retention classes for specific compounds are listed by element in Table 2 for cross-referencing with the inhalation DACs in Table 1. The data shown in Figure 2 are listed by element in alphabetical order.

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]

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.

(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.3/ These factors ● re based on the metabolic data and dosimetry models recommended by the ICRP in its Publication No. 30.3/

The air immersion DAC values shown *in* Table 3 ● re based on ● stochastic limit of 5 rem (0.05 Sv) per year or ● nonstochastic (organ) dose limit of 50 rem (0.5 Sv) per year. Figure 3 contains three columns of Information: (1) radionuclide; (2) half-life in units of seconds (s), minutes (rein), hours (h), days (d), *or* years *(y);* ● nd (3) ● tr immersion MC (µCi/mL). The data in Table 3 ● *re* listed by radionuclide in order of increasing ● tmic mass. The ● ir immersion DACs were calculated for ● continuous, nonshielded exposure via immersion In ● semi-infinite atmospheric cloud. The dose conversion factors used to calculate the DAC values *for* air immersion were taken from the DOE report External Dose-Rate Conversion Factors for Calculation of Des@ to the Public.4/ The DAC value for air immersion listed in Table 3 for ● given radionuclide is determined ● ither by ● limit on ● nnual ● ffective dose equivalent, which provides ● limit on stochastic radiation ● ffects, or by a limit on ● nnul dose equivalent to any organ, which provides ● limit on nonstochastic radiation ● ffects. For most of the radionuclides listed In Table 3, the DAC value is determined by the limit on ● nnual ● ffect+ve dose equivalent. Thus, the few cases where the DAC value is determined by the limit on ● nnual dose equivalent to skin ● re Indicated in the figure *by* ● n ● ppropriate footnote. Again, the DACs listed in Figure 3 ● ccount only for immersion In ● semi-infinite cloud ● nd do not ● ccount for Inhalation or Ingestion ● closures. Three classes of radionuclides ● re included in the ● ir immersion DACs given in Figure 3, ● s. described below.

(1) Class 1. The first class of radionuclides includes selected noble *gases* ● *nd* short-lived ● ctivation products that occur In gaseous form. For these radionuclides, inhalation doses ● re negligible compared to the ● xternal dose from immersion in an ● tmospheric cloud.

(2) Class 2. The second class of radionuclides includes those for which a OAC value for inhalation has been calculated (using the ICRP Inhalation dose ● quivalent factors), but for which the DAC value for ● xternal ● xposure to a *contaminated* ● tmospheric cloud is more *restrictive* (i.e.,

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

4/ u.S. Department of Energy (DOE). 1988. External Dose-Rate Conversion Factors for Calculation of Dose to the Public. Washington, D.C.

results in a lower DAC value). These radionuclides generally have half-lives of a few hours or less, or are eliminated from the body following inhalation sufficiently rapidly to limit the inhalation dose.

(3) Class 3. The third class of radionuclides includes selected isotopes with relatively short half-lives that were not considered in ICRP Publication 30. These radionuclides typically have half-lives that are less than 10 minutes, they do not occur as the decay product of a longer-lived radionuclide, or they lack sufficient decay data to permit internal dose calculations. These radionuclides are also typified by a radioactive emission of highly intense, high-energy photons and rapid removal from the body following inhalation.

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 ● t 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-n (Org)2/	2.E-04	2.E-04	2.E-04	St/St/St
C-n (CO)2/	5.E-04	5.E-04	5.E-04	St/St/St
C-n (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/ /

Radionuclide	Inhaled Air - Lung Retention Class D (µCi/mL)	W (µCi/mL)	Y (µCi/mL)	Stochastic or Organ1/ (D / U / 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	S. E-OS	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	S.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-OS	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-so		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	5.E-06		5.E-06	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-06		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-08	St/St/St
Ag-110m	6.E-08	J, E-08	4.E-08	St/St/St
Ag-111	7.E-07	4.E-07	4.E-07	L /St/St
Ag-I 12	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
Cc-109	1.E-08	5.E-08	5.E-08	K /K /St
Cd-1 13m	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
Cc-115m	2.E-08	5.E-08	6.E-08	K /St/St
Cc-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 rein)	2.E-05	2.E-05		St/St/
In-110 (S h)	7.E-06	8.E-06		St/St/
In-ill	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/

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			St/ /
I-129	4. E-09			T / /
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			E / /
I-135	7. E-07			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/ /
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/ /
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/

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	3.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 / U / 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)	u (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		& /
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		@t/
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		SS/SS/
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
78-184		2.E-06	2.E-06	/St/St
Ta-185		3.E-05	3.E-05	/St/St
18-166		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		SW/St/
Re-186	1.E-06	7.E-07		St/St/
Re-187	3.E-04	4.E-05		SW/St/
Re-188m	6.E-05	6.E-05		St/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	1.E-05	8.E-06	8.E-06	St/St/St
Au-194	3.E-06	2.E-06	2.E-06	St/St/St
Au-195	5.E-06	6.E-07	2.E-07	St/St/St
Au-198m	1.E-06	5.E-07	5.E-07	St/St/St
Au-198	2.E-06	7.E-07	7.E-07	St/St/St
Au-199	4.E-06	2.E-06	2.E-06	St/St/St
Au-200m	1.E-06	1.E-06	1.E-06	St/St/St
Au-200	3.E-05	3.E-05	3.E-05	St/St/St
Au-201	9.E-05	1.E-04	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/ /
11-197	5.E-05			St/ /
Tl-198m	2.E-05			St/ /
Tl-198	1.E-05			St/ /
11-199	3.E-05			St/ /
11-200	5.E-06			St/ /
Tl-201	9.E-06			St/ /
Tl-202	2.E-06			St/ /
71-204	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 Organ[1]/ (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

Radionuclide	Inhaled Air - Lung Retention Class D (µCi/mL)	W (µCi/mL)	Y (µCi/mL)	Stochastic or Organ1/ (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]/		/SS/
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 Organ1/ (D / W / Y)
Pu-240		2.E-12[5]/	6.E-12[5]/	/BS/BS
Pu-241		1.E-10[5]/	3.E-10[5]/	/BS/BS
Pu-242		2.E-12[5]/	6.E-12[5]/	/BS/BS
Pu-243		1.E-05[5]/	1.E-05[5]/	/St/St
Pu-244		2.E-12[5]/	6.E-12[5]/	/BS/BS
Pu-245		2.E-06[5]/	2.E-06[5]/	/St/St
Am-237		1.E-04[5]/		/St/
Am-238		1.E-06[5]/		/BS/
Am-239		5.E-06[5]/		/St/
Am-240		1.E-06[5]/		/St/
Am-241		2.E-12[5]/		/BS/
Am-242m		2.E-12[5]/		/BS/
Am-242		3.E-08[5]/		/BS/
Am-243		2.E-12[5]/		/BS/
Am-244m		2.E-06[5]/		/BS/
Am-244		7.E-08[5]/		/BS/
Am-245		3.E-05[5]/		/St/
Am-246m		7.E-05[5]/		/St/
Am-246		4.E-05[5]/		/St/
Cm-238		4.E-07[5]/		/St/
Cm-240		2.E-10[5]/		/BS/
Cm-241		9.E-09[5]/		/BS/
Cm-242		1.E-10[5]/		/BS/
Cm-243		3.E-12[5]/		/SS/
Cm-244		4.E-12[5]/		/BS/
Cm-245		2.E-12[5]/		/BS/
Cm-246		2.E-12[5]/		/BS/
Cm-247.		2.E-12[5]/		/BS/
Cm-248		6.E-13[5]/		/BS/
Cm-249		6.E-06[5]/		/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[5]/	2.E-07[5]/	/St/St
Cf-246		4.E-09[5]/	4.E-09[5]/	/St/St
Cf-248		4.E-11[5]/	5.E-11[5]/	/BS/St
Cf-249		2.E-12[5]/	6.E-12[5]/	/BS/BS
Cf-250		5.E-12[5]/	1.E-11[5]/	/BS/St

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-12[5]/	5.E-12[5]/	/BS/BS
Cf-252		1.E-11[5]/	2.E-11[5]/	/BS/St
Cf-253		8.E-10[5]/	7.E-10[5]/	/St/St
Cf-254		9.E-12[5]/	7.E-12[5]/	/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 are now 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 protecti On from radon combined with its short-lived daughters ● nd are based on information given In ICRP Publication 32: Limits for Inhalation of Radon Daughters by Workers ● nd Federal Guidance Report No. 11: Limiting Values of Radionuclide Intake ● nd Air Concentrations. ● nd Dose Conversion Factors for Inhalation, Submersion, ● nd Ingestion (EPA 520/1-88-020). The values given ● re for 100% equilibrium concentration conditions of the radon daughters with the parent. To ● now for ● n ● ctusl 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 ● nd Rn-222 may be replaced by 1 WL* ● d 1/3 WL,* respectively, for appropriate limiting of daughter concentrations. Because of the dosimetric considerations for radon, no f_1 or lung clearance values ● re listed.

* A 'Working Level (WL) is any combination of short-lived radon daughters, in one liter of ● lr without regard to the degree of equilibrium, that will result In the ultimate emission of 1.3 E+05 MeV of ● lpha ● nergy.

5/ For the calculations, f_1 values were obtained from ICRP Publication 48: The Metabolism of Plutonium and Related Elements. It is ● ssumed that the ● ffectfve dose ● quivalents for Inhalation ● re unchanged ● ven 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 bleed when f_1 values ● re ● all. Also, the gastrointestinal tract dose would be unchanged because the fraction of activity passing through the tract is $(1.0 - f_1)$.

Table 2

Alternative Absorption Factors ● nd Lung Retention Classes for Specific Compounds

Element/ Symbol	Atomic Number	Compound	f_1	Lung Retention Class
Actinium/ Ac	89	Oxides, hydroxides	1.E-03	Y
		Halides, nitrates	1.E-03	W
		All *others*	1.E-03	D
Aluminum/ Al	13	Oxides, hydroxides, carbides, halides, nitrates, ● lemental form	1.E-02	W
		All others	1.E-02	D
Americium/ Am	95	All forms	1.E-03	W
Antimony/ Sb	51	Oxides, hydroxides, halides, sulphides, sulphates, nitrates	1.E-01	D
		All others	1.E-02	W
Arsenic/ As	33	All forms	5.E-01	W
Astatine/ At	85	All (as ● halide)	1.E+00	W or D; dependent upon ● ssociated ● lement
Barium/ Ba	56	All forms	1.E-01	D
Berkelium/ Bk	97	All forms	5.E-04	W
Beryllium/ Be	4	Oxides, halides, nitrates	5.E-03	Y
		All others	5.E-03	W
Bismuth/ Bi	83	All ● xcept nitrates	5.E-02	W
		Nitrates	5.E-02	D
Bromine/ Br	35	Bromides	1.E+00	W or D; dependent upon ● ssociated element

Element/ Symbol	Atomic Number	Compound	f_1	Lung Retention Class
Cadmium/ Cd	48	Oxides, hydroxides	5.E-02	Y
		Sulphates, halides	5.E-02	W
		All others	5.E-02	D
calcium/ Ca	20	All forms	3.E-01	W
Californium/ Cf	98	Oxides, hydroxides	1.E-03	Y
		All others	1.E-03	W
Carbon/ C	6	Oxides[1]		D
		Organic (^{11}C)	1.E+00	W
		Organic (^{14}C)	1.E+00	W
Cerium/ Ce	58	Oxides, hydroxides, fluorides	3.E-04	Y
		All others	3.E-04	W
Cesium/ Cs	55	All forms	1.E+00	D
Chlorine/ Cl	17	Chloride	1.E+00	W or D: dependent upon associated element
Chromium/ Cr	24	Oxides, hydroxides	1.E-01	Y
		Halides, nitrates	1.E-01	W
		All others	1.E-01	o
		Ingestion[2]		
		Trivalent	1.E-02	-
		Hexavalent	1.E-01	
Cobalt/ Co	27	Oxides, hydroxides, halides, nitrates	5.E-02	Y
		All others	5.E-02	W
		Ingestion only[2]	3.E-01	-
Copper/ Cu	29	Oxides, hydroxides	5.E-01	Y
		Sulphites, halides, nitrates	5.E-01	W
		All others	5.E-01	D

Element/ Symbol	Atomic Number	Compound	f_1	Lung Retention Class
Curium/ Cm	96	All forms	1.E-03	W
Dysprosium/ Dy	66	All forms	3.E-04	W
Einsteinium/ Es	99	All forms	5.E-04	W
Erbium/ Er	68	All forms	3.E-04	W
Europium/ Eu	63	All forms	1.E-03	W
Fermium/ Fm	100	All forms	5.E-04	W
Fluorine/ F	9	Fluoride	1.E+00	Y, W, or D; dependent upon associated element
Francium/ Fr	87	All forms	1.E+00	D
Gadolinium/ Gd	64	Oxides, hydroxides, fluorides	3.E-04	W
		All others	3.E-04	
Gallium/ Ga	31	Oxides, hydroxides, carbides, halides, nitrates,	1.E-03	W
		All others	1.E-03	D
Germanium/ Ge	32	Oxides, sulphides, halides	1.E+00	W
		All others	1.E+00	D

Element/ Symbol	Atomic Number	Compound	f_1	Lung Retention Class
Gold/ Au	79	Oxides, hydroxides	1.E-01	Y
		Halides, nitrates	1.E-01	W
		All others	1.E-01	D
Hafnium/ Hf	72	Oxides, hydroxides, halides, carbides, nitrates	2.E-03	W
		All others	2.E-03	D
Holmium/ Ho	67	All forms	3.E-04	W
Hydrogen/ H	1	Mater, elemental	1.E+00	
Indium/ In	49	Oxides, hydroxides, halides	2.E-02	W
		All others	2.E-02	0
Iodine/ I	53	All forms	1.E+00	0
Iridium/ Ir	77	Oxides, hydroxides	1.E-02	Y
		Halides, nitrates, metallic form	1.E-02	W
		All others	1.E-02	D
Iron/ Fe	26	Oxides, hydroxides, halides	1.E-01	W
		All others	1.E-01	0
Lanthanum/ La	57	Oxides, hydroxides	1.E-03	W
		All others	1.E-03	D
Lead/ Pb	82	All forms	2.E-01	0
Lutetium/ Lu	71	Oxides, hydroxides, fluorides	3.E-04	Y
		All others	3.E-04	W
Magnesium/ Mg	12	Oxides, hydroxides, carbides, halides, nitrates	5.E-01	W
		All others	5.E-01	0

Element/ Symbol	Atomic Number	Compound	f_1	Lung Retention Class
Manganese/ Mn	25	Oxides, hydroxides, halides, nitrates	1.E-01	W
		All others	1.E-01	D
Mendelevium/ Md	101	All forms	5.E-04	W
Mercury/ Hg	80	Oxides, hydroxides, halides, nitrates, sulphites	2.E-02	W
		Sulphates, elemental form	2.E-02	D
		Organic form	1.E+00	D
		Vapor[1]	-	D
Molybdenum/ no	42	Oxides, hydroxides, MoS_2	5.E-02	Y
		All others	8.E-01	D
		Ingestion[2]		
		MoS_2	5.E-02	-
		All Others	8.E-01	-
Neodymium/ Nd	60	Oxides, hydroxides, carbides, fluorides	3.E-04	W
		All others	3.E-04	Y
Neptunium/ Np	93.0	All forms	1.E-03	W
Nickel/ Ni	28	Oxides, hydroxides	5.E-02	W
		All others (vapor)[1]		D
Niobium/ Nb	41	Oxides, hydroxides	1.E-02	Y
		All others	1.E-02	W
Osmium/ Os	76	Oxides, hydroxides	1.E-02	Y
		Halides, nitrates	1.E-02	W
		All others	1.E-02	D
Palladium/ Pd	46	Oxides, hydroxides	5.E-03	Y
		Nitrates	5.E-03	W
		All others	5.E-03	D

Element/ Symbol	Atomic Number	Compound	f_1	Lung Retention Class
Phosphorus/ P	15	Phosphates	8.E-01	W or D; dependent upon associated element
Platinum/ Pt	78	All forms	1.E-02	D
Plutonium/ Pu	94	Oxides, hydroxides	1.E-05	Y
		Nitrates	1.E-04	W
		All other	1.E-03	W
		[Note: Use same values for ingestion]		
Polonium/ Po	84	Oxides, hydroxides, nitrates	1.E-01	U
		All others	1.E-01	D
Potassium/ K	19	All forms	1.E+00	D
Praseodymium/ Pr	59	Oxides, hydroxides, carbides, fluorides	3.E-04	Y
		All others	3.E-04	W
Promethium/ Pm	61	Oxides, hydroxides, carbides, fluorides	3.E-04	Y
		All others	3.E-04	W
Protactinium/ Pa	91	Oxides, hydroxides	1.E-03	Y
		All others	1.E-03	W
Radium/ Ra	88	All forms	2.E-01	W

Element/ symbol	Atomic Number	Compound	f_1	Lung Retention Class
Rhenium/ Re	75	Oxides, hydroxides, halides, nitrates	8.E-01	U
		All others	8.E-01	D
Rhodium/ Rh	45	Oxides, hydroxides	5.E-02	Y
		Halides	5.E-02	W
		All others	5.E-02	D
Rubidium/ Rb	37	All forms	1.E+00	D
Ruthenium/ Ru	44	Oxides, hydroxides	5.E-02	Y
		Halides	5.E-02	W
		All others	5.E-02	D
Samarium/ Sm	62	All forms	3.E-04	W
Scandium/ Sc	21	All forms	1.E-04	Y
Selenium/ Se	34	Oxides, hydroxides,, carbides	8.E-01	W
		All others	8.E-01	D
		Ingestion only[2/]	5.E-02	
Silicon/ Si	14	Ceramic forms	1.E-02	Y
		Oxides, hydroxides, carbides, nitrates	1.E-02	W
		All others	1.E-02	D
Silver/ Ag	47	Oxides, hydroxides	5.E-02	Y
		Nitrates, sulphides	5.E-02	W
		All others, ● le- mental form	5.E-02	D
Sodium/ Na	11	All forms	1.E+00	D
Strontium/ Sr	38	$SrTiO_3$	1.E-02	Y
		All others (soluble)	3.E-01	D

Element/ Symbol	Atomic Number	Compound	f_1	Lung Retention Class
Sulfur/ S	16	All Inorganic	8.E-01	D
		Elemental Form	8.E-01	W
		Gases	1.E+00	D
		Ingestion[2]/		
		All Inorganic	1.E-01	
Tantalum/ Ta	73	Oxides, hydroxides, halides, carbides, nitrates, nitrides	1.E-03	Y
		All others	1.E-03	W
Technetium/ Tc	43	Oxides, hydroxides, halides, nitrates	8.E-01	W
		All others	8.E-01	D
Tellurium/ Te	52	Oxides, hydroxides, nitrates	2.E-01	W
		All others	2.E-01	D
Terbium/ Tb	65	All forms	3.E-04	W
Thallium/ Tl	81	All forms	1.E+00	D
Thorium/ Th	90	Oxides, hydroxides	2.E-04	Y
		All others	2.E-04	W
Thulium/ Tm	69	All forms	3.E-04	W
Tin/ Sn	50	Oxides, hydroxides, halides, nitrates, sulphides, $Sn_3(PO_4)_4$	2.E-02	W
		All others	2.E-02	D
Titanium/ Ti	22	$SrTiO_3$	1.E-02	Y
		Oxides, hydroxides, carbides, halides, nitrates	1.E-02	W
		All others	1.E-02	D

Element/ symbol	Atomic Number	Compound	f_1	Lung Retention Class
Tungsten/ W	74	Ingestion 2/		
		Tungstic acid	1.E-02	
		All others	3.E-01	
Uranium/ U	92	UO_2, U_3O_8	2.E-03	Y
		UO_3, tetravalent compounds	5.E-02	W
		UF_6, uranyl compounds	5.E-02	D
Vanadium/ V	23	Oxides, hydroxides, carbides, halides	1.E-02	W
		All others	1.E-02	D
Ytterbium/ Yb	70	Oxides, hydroxides, fluorides	3.E-04	Y
		All others	3.E-04	W
Yttrium/ Y	39	Oxides, hydroxides	1.E-04	Y
		All others	1.E-04	W
Zinc/ Zn	30	All forms	5.E-01	Y
Zirconium/	40	Carbides	2.E-03	Y
		Oxides, hydroxides, halides, nitrates	2.E-03	W
		All others	2.E-03	D

1/ A dash indicates no data for the value shown.
2/ For ingestion, no lung retention classes are listed.

Table 3

Derived Air Concentrations (DAC) for Workers from External Exposure During Immersion in a Contaminated Atmospheric Cloud

Radionuclide	Half-Life	Air Immersion DAC (μCi/mL)
C-11	20.48 min	4.E-06
N-13	9.97 min	4.E-06
N-16	7.13 s	7.E-07
O-15	122.24 S	4.E-06
F-18[1/]	109.74 min	4.E-06
Na-24[1/]	15.00 h	9.E-07
Mg-27[2/]	9.458 min	5.E-06
Al-28[2/]	2.240 min	2.E-06
Cl-38[1/]	37.21 min	3.E-06
Ar-37	35.02 d	3.E-00
Ar-39	2 6 9 yr	2.E-04[3/]
Ar-41	1.827 h	3.E-06
K-43[1/]	22.6 h	5.E-06
Ca-49[2/]	8.719 min	1.E-06
Sc-44[1/]	3.927 h	2.E-06
Sc-46m[2/]	18.72 s	5.E-05
Ti-45[1/]	3.08 h	5.E-06
Ti-51[2/]	5.752 min	1.E-05
V-52[2/]	3.75 min	3.E-06
Cr-49[1/]	42.09 min	5.E-06
Mn-52m[1/]	21.4 min	2.E-06
Mn-56[1/]	2.5785 h	2.E-06
Mn-57[2/]	1.47 min	6.E-05
Co-60m[1/]	10.47 min	1.E-03
Ni-57[1/, 4/]	36.08 h	2.E-06
Ni-65[1/, 5/]	2.520 h	8.E-06

Radionuclide	Half-Life	Air Immersion DAC (uCi/mL)
Cu-61[1]	3.408 h	5.E-06
Cu-62[2]	9.74 min	5.E-06
Ga-66[1]	9.40 h	2.E-06
Ga-68[1]	68.0 min	5.E-06
Ga-72[1]	14.1 h	1.E-06
Se-73[1]	7.15 h	4.E-06
Br-77[1]	57.04 h	1.E-05[6]
Br-80[1]	17.4 min	5.E-05
Br-82[1]	35.30 h	1.E-06
Br-84[1]	31.80 min	2.E-06
Br-85[2]	172 S	5.E-05
Kr-79	35.04 h	2.E-05
Kr-81	2.1E+05 yr	5.E-04
Kr-83m	1.83 h	5.E-02
Kr-85	10.72 yr	1.E-04[3]
Kr-85m	4.48 h	3.E-05
Kr-87	76.3 min	5.E-06
Kr-88	2.84 h	2.E-06
Kr-89	3.16 min	2.E-06
Kr-90	32.32 S	3.E-06
Rb-81[1]	4.58 h	8.E-06
Rb-82[2]	1.25 min	2.E-06
Rb-88[1]	17.8 min	7.E-06
Rb-89[1]	15.44 min	2.E-06
Rb-90[2]	157 s	2.E-06
Rb-90m[2]	258 S	1.E-06
Sr-85m[1]	67.66 min	2.E-05
Sr-87m[1]	2.805 h	6.E-05
Sr-92[1]	2.71 h	3.E-06
Sr-93[2]	7.3 min	2.E-06
Y-86[1]	14.74 h	1.E-06
Y-90m[1]	3.19 h	5.E-06[6]
Y-91m[1]	49.71 min	9.E-06
Nb-90[1]	14.60 h	1.E-07
Nb-94m[2]	6.26 min	9.E-04

Radionuclide	Half-Life	Air Immersion DAC (μCi/mL)
Nb-97[1/]	72.1 min	7.E-06
Nb-97m[1/]	60 s	6.E-06
Mo-91[2/]	15.49 min	4.E-06
Mo-101[1/]	14.61 min	3.E-06
Tc-95[1/]	20.0 h	5.E-06
Tc-96m[1/]	51.5 min	1.E-04
Tc-99m[1/]	6.02 h	3.E-05
Tc-101[1/]	14.2 min	1.E-05
Ru-105[1/]	4.44 h	5.E-06
Rh-105m[2/]	45 s	1.E-04
Rh-106[2/]	29.92 s	2.E-05
Ag-108[2/]	2.37 min	2.E-04
Ag-109m[2/]	39.6 s	1.E-03
Ag-110[2/]	24.57 s	9.E-05
Cd-111m[2/]	48.7 min	1.E-05
Cd-117[1/]	2.49 h	4.E-06
Cd-117m[1/]	3.36 h	2.E-06
In-113m[1/]	1.658 h	2.E-05
In-114[2/]	71.9 s	1.E-04
In-116m[1/]	54.15 min	2.E-06
In-117[1/]	43.8 min	7.E-06
Sb-117[1/]	2.80 h	3.E-05
Sb-126m[1/]	19.0 min	3.E-06
Sb-129[1/]	4.40 h	3.E-06
Te-133[1/]	12.45 min	5.E-06
Te-133m[1/]	55.4 min	2.E-06
Te-134[1/]	41.8 min	5.E-06
I-122[2/]	3.62 ● fn	5.E-06
I-128[1/]	24.99 min	5.E-05
I-132[1/]	2.30 h	2.E-06
I-134[1/]	" 52.6 min	1.E-06
I-135[1/]	6.61 h	7.E-07[6/]
I-136[2/]	83 s	1.E-06

Radionuclide	Half-Life	Air Immersion DAC (μCi/mL)
Xe-122	20.1 h	8.E-05
Xe-123	2.14 h	7.E-06
Xe-125	16.$ *h*	2.E-05
Xe-127	36.406 d	1.E-05
Xe-129m	8.89 d	2.E-04
Xe-131m	11.84 d	5.E-04
Xe-133	5.245 d	1.E-04
Xe-133m	2.19 d	1.E-04
Xe-135	9.11 *h*	2.E-05
Xe-135m	15.36 min	1.E-05
Xe-137	3.83 min	2.E-05
Xe-138	14.13 min	4.E-06
Cs-126[2]/	1.64 min	" 4.E-06
Cs-129[1]/	32.06 h	1.E-05[6]/
es-lo@	32.2 min	2.E-06
Cs-139[2]/	9.40 min	1.E-05
Ba-137m[2]/	2.552 min	7.E-06
Ba-141[1]/	18.27 min	5.E-06
Ba-142[1]/	10.70 min	5.E-06
La-142[1]/	95.4 min	1.E-06
Pr-144m[2]/	7.2 min	9.E-04
Nd-149[1]/	1.73 h	1.E-05
Gd-162[2]/	9.7 min	1.E-05
Td-162[2]/	7.76 min	4.E-06
Dy-157[1]/	8.06 *h*	1.E-05
Re-182m[1]/	12.7 h	4.E-06
Os-190m[2]/	9.9 min	3.E-06
Ir-190m[1]/	3.2 h	8.E-05[6]/
Au-195m[2]/	30.6 s	2.E-05

Radionuclide	Half-Life	Air Immersion DAC (μCi/mL)
Tl-200[1]	26.1 h	3.E-06
Tl-207[2]	4.77 min	4. E-05[3]
Tl-208[2]	3.053 min	1.E-06
Tl-209[2]	2.20 min	2. E-W
Tl-210[2]	1.30 min	1.E-06
Pb-204m2[2]	66.9 min	2.E-06
Bi-211[2]	2.13 min	1.E-04
Po-211[2]	0.516 S	5.E-04
Rn-220	55.61 s	8.E-09[6]
Rn-222	3.824 d	3.E-08[6]
Th-233[2]	22.3 min	1.E-04
Pa-234[1]	6.70 h	2.E-06
Pa-234m2[2]	1.17 min	4.E-05[3]
U-239[1]	23.40 min	8.E-05[6]
Np-240[1]	65 ● In	4.E-06
Np-240m2[2]	7.4 min	1.E-05
Am-246[1]	25.0 min	4.E-06

1/ Committed effective dose equivalent from inhalation is calculated in ICRP Publication 30, but the MC value for external ● cposure to ● contaminated ● tmospheric cloud is more restrictive than the DAC value for Inhalation.

2/ Committed ● *ffutlve* dose equivalent from inhalation is not calculated In ICRP Publication 30, but DAC value for external ● cposure to contaminated cloud should be more restrictive than DAC value for inhalation due to relatively short half-life of radionuclide.

3/ DAC value is determined by limit on ● nusl dose equivalent to skin, rather than limit on ● nnual effective dose equivalent.

4/ DAC value ● pplfes to radionuclide in vapor form only; DAC value for inhalation is more restrictive for radionuclide in inorganic form.

5/ DAC value ● pplies to radionuclide in inorganic or vapor form.

6/ DAC value for ● xposure to contaminated ●tmospheric cloud is the same ● s DAC value for inhalation. See footnote 4/ to Table 1 on page 24 of Attachment 1.

SURFACE RADIOACTIVITY GUIDES

NUCLIDE1/	REMOVABLE2/3/	TOTAL2/3/ (FIXED PLUS REMOVABLE)
U-nat, U-235, U-238, and associated decay products	1,000 dpm α/100 cm²	5,000 dpm α/100 cm²
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, 1-125, 1-129	20 dpm/100 cm²	300 dpm/100 cm²
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, 1-133	200 dpm/100 cm²	1,000 dpm/100 cm²
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above.3/	1,000 dpm p-r/zoo cm²	5,000 dpm p-r/loo cm²

1/ Where surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides should apply independently.

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

3/ The levels may be averaged over one square meter provided the maximum surface activity in any area of 100 cm² 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 n of sections it is determined that 1/n $\Sigma_n S_i \geq G$, where S_i is the dis/min-100 cm² determined from measurement of section i; or (2) it is determined that the sum of the activity of 811 isolated spots or particles in any 100 cm² area exceeds Xi.

a/ The amount of removable radioactive material per 100 cm² 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 contaminate on on objects of surface area less than 100 cm² 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.

b/ 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.