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MANUAL OF RADIATION PROTECTION STANDARDS

March 1, 1960

HANFORD ATOMIC PRODUCTS OPERATION

GENERAL ELECTRIC COMPANY

Operated for the Atomic Energy Commission by the General Electric Company under contract number AT(45-1)-1350.

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PREFACE

This Manual of Radiation Protection Standards contains Hanford Atomic Products Operation policies relevant to control of work with ionizing radiation and radioactive material. The Radiation Protection Operation, Hanford Laboratories, establishes Standards for radiation protection by authority of HAPO Organization and Policy Guide 3.5; it is the responsibility of all supervision to enforce these Standards.

These Standards are formulated from several sources, including: recommendations of recognized authorities such as the National Committee on Radiation Protection and Measurements; Atomic Energy Commission directives for which HAPO has contractual obligations; federal and state statutes applicable to work with radioactive materials; research in the radiological sciences at Hanford Works and other institutions; and policies and procedures which have been developed over the years for the local conditions.

These Radiation Protection Standards are promulgated to achieve the following goals:

1. Prevent ionizing radiation injuries to any individual.
2. Control individual accumulated exposures to ionizing radiation.
3. Limit exposures to the population in the neighborhood of the Hanford plant to within values presently considered acceptable by the National Committee on Radiation Protection and Measurements.
4. Minimize the casual exposure of humans to ionizing radiation.

Persons working in zones where ionizing radiation is or may be present should be fully informed of the nature of the ionizing radiations present and the protective measures required. Ultimately, protection against ionizing radiation has to rest with the individual.

"Shall" and "should" have a special usage throughout the Manual. "Shall" is used when compliance with the policies is considered necessary to meet HAPO standards of protection. "Should" indicates that the policies are to be applied where practicable; these may be changed from time to time to meet local conditions at Hanford, and in general are included in the Standards as administrative guides.

GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: TABLE OF CONTENTS	CLASSIFICATION:

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3-1-60	7-1-57	1 OF 1	Table of Contents

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: GLOSSARY OF RADIATION UNITS AND TERMS	CLASSIFICATION: Radiation Units and Nomenclature

I. POLICY

Terms and definitions relevant to radiation protection practices at HAPO shall be uniformly applied and shall conform to definitions formulated by the NCRP and ICRP.

II. RESPONSIBILITY

1. The Radiation Protection Operation is responsible for defining radiation protection units and terms that apply at HAPO.
2. The users of radiation protection terms and units at HAPO shall uniformly apply the terms presented in this Standard in formal presentations and documents.

III. STANDARDS

The following is an alphabetical listing of terms and units in common usage at HAPO. Other terms and definitions may be added as the need becomes apparent or as revisions or additional terms are issued by the NCRP and ICRP.

Activity Density — The quantity of either a specified radionuclide or a mixture of radionuclides per unit quantity of matter (e.g., $\mu c\ I^{131}$/gram vegetation).

Authorized Signatory — A supervisor or other person designated by management responsible for immediate planning of specific work in a Radiation Zone and for proper execution of the plan by himself or his subordinates.

Body Burden — The amount of radioactive material in the body at the time of interest.

Casual Exposure — The unintentional exposure of humans to significant quantities of ionizing radiation.

Conditional Release — The release from established Radiation Zone work areas of contaminated materials for further use or disposal under stated conditions (e.g., a contaminated railroad car may be provisionally released to travel between specified locations).

Contamination, Radioactive — The presence of radioactive material where it is undesirable, harmful, or causes interference.

Controlled Area — A defined area in which the exposure of personnel to radiation or to radioactive material is under the supervision of a radiation safety officer. (This implies that a

controlled area is one that requires control of access, occupancy, or working conditions for radiation protection purposes.)

Controlled Exposure — The limiting of occupational exposures to ionizing radiation by administrative means. At HAPO, human exposures to ionizing radiation are controlled by means of:

1. Formalized practices and procedures which control access, occupancy and working conditions for radiation protection purposes.
2. Routine evaluation of these practices and procedures by Radiation Protection specialists.
3. Routine evaluation of individual exposures.

Controlled Injury Zone — A Radiation Zone wherein there are radioactive substances available to such an extent that an accident involving the ingestion, inhalation or injection of foreign matter into the human body could result in a deposition of the radioactive substance(s) exceeding the body burden values stated in Appendix A.

Critical Organ — For internally deposited radionuclides, that organ of the body receiving the specified radionuclide that results in the greatest physiological damage to the body. For exposure to ionizing radiation from external sources, the critical organs are usually the skin, blood-forming organs, gonads and eyes.

Curie — A unit of radioactivity defined as the quantity of radioactive nuclide in which the number of disintegrations per second is 3.7×10^{10}, denoted by "c". Microcurie (μc) - 1/1,000,000 curie; millicurie (mc) - 1/1,000 curie.

Dose — A quantity of radiation.

Absorbed Dose — of any ionizing radiation is the energy imparted to matter by ionizing particles per unit mass of irradiated material at the place of interest. The unit of absorbed dose is the rad. One rad is 100 ergs per gram.

Derma Dose — As used at HAPO, a term relating personnel meter measurements to the exposure record. Thus, an exposure recorded as a "derma dose" is assumed to be the absorbed dose in the dermal layer of skin (below a nominal depth of 7 mg/cm^2) from gamma or X-rays or neutrons, or beta rays or any combination of ionizing radiation with a half value layer of greater than 1 mm of soft tissue.

Exposure Dose — of X or gamma radiation at a certain place is a measure of the radiation that is based upon its ability to produce ionization. The unit of exposure dose is the roentgen. One roentgen is an exposure dose of X or gamma radiation such that the associated corpuscular

emission per 0.001293 gram of air produces, in air, ions carrying one electrostatic unit of quantity of electricity of either sign.

Penetrating Dose — As used at HAPO, a term relating personnel meter measurements to the exposure record. Thus, an exposure recorded as a "penetrating dose" is assumed to be an absorbed dose from gamma or X-rays, or neutrons of sufficient penetration to affect the critical organs, principally the blood-forming organs.

RBE Dose — See RBE and rem.

Dose Rate — A radiation dose received per unit time.

Exposure — To avoid ambiguity with the concept of dose, this word should be used in the descriptive sense of "being exposed to".

Extremities — The hands and forearms, feet and ankles.

ICRP — International Commission on Radiological Protection. A group of authorities, functioning under the auspices of the International Congress of Radiology, and concerning itself with basic principles of radiation protection.

Instruments — See RPS 2.1 - Personnel Monitoring - Instrumentation.

Ion — An atom, or aggregate of atoms, which is not electrically neutral (e.g., negative ion, positive ion). In certain circumstances an electron may be described as a "negative ion".

Ionizing Radiation — Electromagnetic radiation (X-ray or gamma ray photons or quanta), or corpuscular radiation (alpha particles, beta particles, electrons, positrons, protons, neutrons and heavy particles) capable of producing ions.

X-rays — Electromagnetic ionizing radiation which originates from the field outside the nucleus of the atom, or resulting from loss of energy of charged particles (e.g., electrons). Of shorter wave length than ultraviolet radiation.

Gamma Rays — Electromagnetic ionizing radiation which originates within the nucleus of the atom. (Often the terms "X-rays" or "γ rays" are used indiscriminately in radiology. Scientifically. there is no distinction between the properties of X-ray photons and gamma ray photons of the same energy.)

Alpha Particle (α ray) — Corpuscle consisting of the positively charged nucleus of a helium atom and emitted by certain radioactive atomic nuclei.

Electron — Subatomic particle having a rest mass of 9.107×10^{-28} gram and a charge of negative electricity of 4.802×10^{-10} e.s.u.

Beta Particle (β ray)	An electron (or positron) originating from nuclear processes.
Positron	A positive electron, which can be formed in the beta decay of many radionuclides.
Proton	A nuclear particle of unit mass number having a charge equal and opposite to that of an electron. The nucleus of the hydrogen atom (not of the nuclides deuterium and tritium) is a proton.
Neutron	Radioactive corpuscle which has no electric charge and has a mass slightly greater than that of the proton. A free neutron decays with a half-life of 10 to 30 minutes to a proton and an electron. The type of interaction which occurs between neutrons and atoms depends upon the kinetic energy of the former. If the kinetic energy of the neutrons lies between about 20 Kev and 10 Mev (so-called "fast neutrons") or between 10 Mev and 500 Mev (so-called "high energy neutrons"), they can set in motion the nuclei of atoms with which they collide with sufficient velocity to ionize matter. "Slow neutrons", which are usually classed as having energies up to 0.1 ev, and including "thermal neutrons" which have energies (about 0.025 ev) associated with room temperatures, enter into nuclear reactions with atoms they meet, resulting in the emission of ionizing radiations. Between slow and fast neutrons is a group known as "epithermal neutrons" or "intermediate neutrons".
Linear Energy Transfer of an Ionizing Particle (LET)	Energy dissipated per unit distance along the path of an ionizing particle, usually in electron volts per micron of length.
Maximum Permissible Concentration (MPC)	The quantity of radioactive nuclide(s) in unit volume or weight of air, water, etc., which is prescribed to limit external and/or internal doses to within established values. Most limits are based on the limiting body burden of the radionuclide(s) in adult humans, assuming continuous exposure and a single nuclide as the sole source of intake, and using average or standardized biological parameters.
Maximum Permissible Limit	The dose of radiation or body burden of radionuclides which, under any combination of circumstances, is not expected to cause appreciable bodily injury to the average individual at any time during his lifetime. As used here, "appreciable bodily injury" means any injury or effect that the average person would regard as being objectionable and/or competent medical authorities would regard as being deleterious to the health and well-being of the individual.
NCRP	National Committee on Radiation Protection and Measurements. A body of nationally recognized authorities who propound recommendations within the broad field of radiation protection. These recommendations are normally published in the National Bureau of Standards Handbooks.

Non-Controlled Exposure — The exposure to ionizing radiation under conditions which are beyond those defined as Controlled Exposure. Generally, exposures to the public.

Operating Group — The supervision and personnel responsible for the operation of the work area involved.

Rad — Unit of absorbed dose. Written as rad. It is 100 ergs per gram. Millirad (mrad) = 1/1,000 rad.

Radiation Monitoring Group — The supervision and personnel of an organizational group with the designated responsibility for adequate radiation protection practices.

Radiation Work Procedure — See Standard Operating Procedure.

Radiation Zone — An area or item of equipment requiring access control for personnel protection purposes. See RPS 4.1 for specific Radiation Zone criteria.

Relative Biological Effectiveness (RBE) — The appropriate value of the biological effectiveness of the radiation in question, relative to that of X-radiation with an average specific ionization of 100 ion pairs per micron of water, for the particular biological system and biological effect under consideration and for the conditions under which the radiation is received.

RBE VALUES

The following values of RBE for all the critical organs according to the value of the average specific ionization occurring in the critical organ in which it is highest, are recommended for the determination of permissible tissue doses in rads from external sources by relations:

$$\text{Permissible dose in rads} = \frac{\text{Permissible dose in rems}}{\text{RBE}}$$

The specific ionization is expressed in ion pairs per micron of water in terms of its air equivalent. RBE is expressed in terms of the pertinent biological effectiveness of ordinary X-rays taken as one (average specific ionization of 100 ion pairs per micron of water, or linear transfer of 3.5 Kev per micron of water).

1. X-rays, electrons and positrons of any specific ionization RBE = 1
2. Heavy ionizing particles

Average specific ionization (ion pairs per micron of water)	RBE	Average linear energy transfer to water (Kev per micron)
100 or less	1	3.5 or less
100 to 200	1 to 2	3.5 to 7.0
200 to 650	2 to 5	7.0 to 23
650 to 1500	5 to 10	23 to 53
1500 to 5000	10 to 20	53 to 175

For practical purposes, an RBE of 10 is applicable to fast neutrons and protons up to 10 Mev and an RBE of 20 to heavy recoil nuclei for whole body irradiation and the most sensitive critical organs.

Rem	The quantity of any radiation such that the energy imparted to a biological system (cell, tissue, organ, or organism) per gram of living matter by the ionizing particles present in the region of interest, has the same biological effectiveness as an absorbed dose of one rad from lightly filtered X-rays generated at potentials of 200 to 300 kilovolts. A dose in rems is equal to the dose in rads multiplied by the appropriate RBE. Written as rem.
Roentgen (r)	See Dose.
Servicing Group	Supervision and personnel performing auxiliary services for the operating group, or functioning in the area or facilities to which the operating group is assigned.
Shall	Mandatory to insure adequate protection against radiation. Indicates necessity in order to meet currently accepted standards of protection.
Should	To be applied (recommended) whenever practicable, with the intent of minimizing personnel exposures. Indicates advisory requirements that are to be applied when possible.
Significant	In the present state of the art, it is impracticable to stipulate numerical limits for "significant" which would be applicable to all cases, without being absurdly restrictive in some. It is intended that qualified Radiation Protection Specialists exercise good judgment along the general lines of past operating experience at HAPO. Borderline cases should be referred to the Radiation Protection Operation for an opinion.
Special Work Permit (SWP)	A written instruction sheet signed by authorized signatories of the operating, Radiation Monitoring and servicing groups involved, prior to the start of work in a Radiation Zone, which clearly defines the work which will be done, the protective clothing to be worn, the necessary radiation survey measurements and time limits, and any special instructions for the safe performance of work in the presence of ionizing radiation. An SWP is invalidated at the conclusion of the shift on which it was authorized, but may be re-instated by signature of the involved supervision of the incoming shift to signify agreement with the conditions and restrictions. Also sometimes called a Radiation Work Permit (RWP).
Specific Activity - Gram Element	Total radioactivity of a given nuclide per gram of element (e.g., $\mu c\ P^{32}$/gram $P^{32} + P^{31}$).
Specific Activity -	Total radioactivity of a given nuclide per gram of the radioactive nuclide (e.g., $\mu c\ Pu^{239}$/gram Pu^{239}).

Standard Operating Procedure (SOP) — Standard Operating Procedures are written rules for work involving radiation or radioactive materials. Each SOP shall clearly define the work to be done, location of the work, protective apparel and equipment required, methods of radiation and contamination control, applicable dose rates and time limits or the manner in which they are to be determined, and the personnel exposure records to be maintained. The SOP shall be approved and signed by appropriate authorized signatories of the Radiation Monitoring, operating, and servicing groups concerned. In some areas the Standard Operating Procedures defining conditions for work in Radiation Zones may be called Radiation Work Procedures.

An SOP may be valid for an indefinite period, revisions being made when necessary and as determined by periodic reviews by Area Supervision of any signatory unit in conformance with changes in the conditions under which it was issued.

Time Limit — The amount of time a person may be exposed to a specified dose rate or may stay in a Radiation Zone under the conditions prescribed in the Standard Operating Procedure or Special Work Permit for the job.

Units — For reports and publications, the quantity of radioactive material shall be stated in microcuries, with the mass in grams, and the volume in cubic centimeters.

Waste, Radioactive — See RPS 7.1 and 7.2.

IV. PHILOSOPHY

Several of the Standards contain the heading Philosophy. These headings are included whenever it is felt that background information, or an indication of the basis, reason, approach, or rationale would assist in clarifying the intent of the Standard. In the Philosophy for RPS 1.1, it would appear appropriate to briefly discuss the format of this edition of the HAPO Manual of Radiation Protection Standards.

Each Standard contains three headings: Policy, Responsibility, and Standards. Some include Administrative Guides. These headings are intended to provide:

Policy - A short statement of the accepted HAPO means of fulfilling the title of the Standard.

Responsibility - A means for indicating the group considered most appropriate to fulfill at least a portion of the stated policy. The words assure and insure are frequently used in this heading. Insure is intended to indicate underwriting or guarantee; assure to indicate making certain or confirming.

Standards - A listing of criteria, gauges, measurements, and limits which are judged necessary to maintain an adequate radiation protection program at HAPO. These are not necessarily

arranged in order of importance. In fact, many of the Standards which could appropriately be found in several places in the Manual, have only been mentioned once. This was done both in the interest of brevity and in the expectation that the users of this Manual would be familiar with the entire contents and would, therefore, apply the various portions of the Manual as appropriate.

Administrative Guides - Statements of accepted practice proposed to achieve a reasonable degree of uniformity in the interpretation of the basic policy and standards.

HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: PERSONNEL MONITORING - INSTRUMENTATION	CLASSIFICATION: Radiation Measurements

I. POLICY

The measurement of ionizing radiation encountered in the monitoring of personnel and/or the monitoring of effluents released to the air, ground, or water shall be with approved-type instruments and in accordance with approved procedures.

II. RESPONSIBILITY

1. The Manager, Radiation Protection, is responsible for designating approved-type instruments for use in personnel monitoring.
2. The Calibrations Operation is responsible for the procurement, calibration, maintenance and distribution of portable radiation monitoring instruments.
3. The Radiological Development Operation is responsible for preparation and issuance of procedures detailing the field use of radiation monitoring instruments in consultation with the using components concerned.
4. The user of personnel monitoring instruments shall assure himself of the limitations and procedures pertinent to the instrument in hand.
5. Specifications for portable radiation monitoring instruments for user groups are established by Calibrations Operation in cooperation with the using components concerned.
6. Specifications for functional sources for field use are established by Calibrations Operation in cooperation with the using components concerned.
7. Specifications for semi-portable and fixed radiation monitoring instruments shall be approved by the Radiation Protection Operation.
8. Procurement and control of semi-portable and fixed instruments are by the using components. In order to assure standards of uniformity, the Radiation Protection Operation shall be consulted concerning specifications and uses. Acceptance testing of these instruments is the responsibility of the using component.

III. STANDARDS

1. Only portable radiation monitoring instruments issued and calibrated by the Calibrations Operation shall be used for controlling and evaluating personnel exposure.
2. Portable radiation monitoring instruments shall be calibrated on the basis of a schedule published by the Calibrations Operation. Only instruments dated within the calibration period should be used to monitor personnel.
3. Functional checks of portable radiation monitoring instruments shall be performed by operating personnel on a frequency which will reasonably assure that the instrument is operating within calibration limits.
4. Qualitative field measurements of low-level ionizing radiation should normally be performed with count-rate type instruments.
5. Quantitative field measurements of ionizing radiation should normally be performed with dose-rate type instruments.
6. Specifications for new personnel monitoring devices and instruments designed and/or developed at HAPO or available elsewhere shall be approved by RPO. Acceptance testing of prototypes of such equipment shall be performed by RPO.

Calibration procedures and calibration frequencies shall be established for each type of equipment.
Devices purchased or designed for test and evaluation shall not be used for radiation monitoring of personnel. When such devices are tested, care should be exercised in introducing them to the field groups to insure that they do not compromise the existing monitoring programs.

c. Radiation monitoring instruments are:

a. Portable Radiation Monitoring Instruments

Radiation detection, dose rate measuring, or dose measuring instruments with self-contained power supply, used for the monitoring of personnel, and/or the monitoring of effluents to the ground, air, or water. Usually the instrument is equipped with a handle, strap, clip, or other device for holding and carrying and is of such weight and size to be quite easily carried by one person.

b. Semi-Portable Radiation Monitoring Instruments

Radiation detection, dose rate measuring, or dose measuring instruments usually requiring an outside power supply, used for the monitoring of personnel and/or the monitoring of effluents to the ground, air, or water. Frequently the instrument is of such weight and size that it cannot be easily carried by one person, but may be equipped with wheels, casters, or skids to facilitate movement.

c. Fixed Radiation Monitoring Instruments

Radiation detection, dose rate measuring, or dose measuring instruments used for the monitoring of personnel and/or the monitoring of effluents released to ground, air, or water, which require special installation such as wiring, piping, etc. They are usually considered to be a building fixture.

HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: STANDARDS AND CONTROLS FOR HUMAN EXPOSURE TO IONIZING RADIATION	CLASSIFICATION: Exposure Standards

I. POLICY

1. Human exposure to ionizing radiation shall be kept as low as practical.
2. The exposure limits prescribed below shall be applicable to all persons subject to HAPO radiation protection controls.

II. RESPONSIBILITY

1. The Radiation Protection Operation is responsible for establishing the maximum permissible limits and controls at HAPO, relevant to man, for exposures to ionizing radiation and radioactive contamination.
2. It is the responsibility of the management of each HAPO facility to employ detailed protection controls appropriate to the facility and the work, and responsive to the Radiation Protection Standards in this Manual.

III. STANDARDS

1. Occupational External Exposure

Occupational exposure as a result of ionizing radiation from a source external to the human body shall not exceed:

a. 5 rems multiplied by the number of years between the person's age and age 18, including not more than 3 rems in any 13 consecutive weeks, to the whole body, head and trunk, active blood-forming organs, eyes or gonads, due to radiation of sufficient penetrating power to affect a significant fraction of the critical tissue;

b. 10 rems multiplied by the number of years between the person's age and age 18, including not more than 6 rems in any 13 consecutive weeks, to the skin of the major portion of the body, due to radiation of very low penetrating power (half-value less than 1 mm of soft tissue);

c. 75 rems/year, including not more than 25 rems in any 13 consecutive weeks, to the hands, forearms, feet or ankles.

2. Occupational Internal Exposure

Occupational exposure resulting from radionuclides in the human body shall be consistent as far as possible with the age-proration and dose principles above.

a. The body burden of the radionuclides shall be limited to the maximum permissible body burden listed in Appendix A.

b. For mixtures of radionuclides in the body, the body burden of the mixture shall be determined and limited in accordance with the principles contained in NBS Handbook 69, Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure.

3. Mixed Exposures

The radiation dose from both external and internal exposure sources shall be limited such that the average annual dose does not exceed 15 rems for most individual organs of the body, or 30 rems when the critical organ is the thyroid or skin, or 5 rems when the gonads, or the blood-forming organs, or the lens of the eyes, or whole-body is the critical organ.

4. Special Authorizations

On rare occasions, unusual cases may warrant individual exposures above the limits contained in the Standards. These will require the express authorization of the Manager, Radiation Protection.

5. Accidental or Emergency Exposures

Information on accidental and emergency exposures appears in RPS 6.3.

6. Medical Exposures

Radiation exposures received during medical examinations will not be included in the record of occupational radiation exposure of the person.

7. Minimum Age for Radiation Workers

Persons under 18 years of age shall not be assigned Radiation Zone work.

8. Prior Employment Record

When any person accepts employment in radiation work, it shall be assumed for purposes of controlling subsequent exposures that he has received his age-prorated dose up to that time unless: (1) satisfactory records from prior radiation employment show the previous exposures; or (2) it can be satisfactorily demonstrated that he has not been employed in radiation work.

9. Human Exposure Outside the Controlled Area

The radiation or radioactive material outside the HAPO controlled area, and attributable to normal operations within the controlled area, shall be such that it is improbable that any individual will receive an external radiation dose of more than 0.5 rem in any one year.

The maximum permissible body burden of radionuclides in persons outside the controlled area, and attributable to normal operations within the controlled area, shall not exceed one-tenth of the applicable body

burden listed in Appendix A. The body burden may be averaged over periods up to one year.

IV. OPERATIONAL CONTROLS

1. Occupational External Exposure

The control of external exposure is primarily achieved at HAPO through the personnel meter program. Therefore, the following exposure limitations are to be applied by facility management to assure that HAPO Radiation Protection Standards are met:

a. The "whole body dose", evaluated through the personnel meter program, should not be permitted to exceed 1 rem in any regular four-week badge period, or 5 rems including 3 r in any calendar year.
b. The "skin dose", evaluated through the personnel meter program, should not be permitted to exceed 2 rems in any regular four-week badge period, or 10 rems in any calendar year.
c. The "extremity dose", evaluated through the personnel meter program or job monitoring, should not be permitted to exceed 8 rems in any regular four-week badge period, or 40 rems in any calendar year.
d. Application of the four-week badge period shall be such that the exposure standards in III are not exceeded.

2. Occupational Internal Exposure

Control of internal dose at HAPO is achieved by limiting the average concentrations of radioactive materials in the air, water or food taken into the body.

a. Air-borne radionuclides should be minimized through appropriate local operational controls. In general, there should be no planned exposures to air concentrations which exceed the limits contained in Appendix A without respiratory protection. (Tritium is the exception. Control for exposure to air-borne tritium should be based on limiting the whole-body dose to a total of 1 rem in any four-week period and 5 rems in any calendar year.) Whenever air-borne concentrations are likely to exceed the limits listed in Appendix A, apparel as noted in RPS 4.7, Radiological Protective Apparel, shall be worn.
b. Drinking water concentrations should be kept to the minimum practical. Whenever the drinking water in HAPO facilities exceeds one-tenth of the limits listed in Appendix A, local operational controls should be enacted to reduce the concentrations to below one-tenth of this limit. See also RPS 7.2, Radioactive Materials Released to the Environs.
c. Personal contamination shall be minimized through appropriate local operational controls. Whenever human contamination in excess of that stated in RPS 4.7, Radiological Protective Apparel, is likely to result, appropriate personnel protective apparel shall be worn.
d. Whenever the body burden from a radionuclide(s) exceeds one-half the applicable limit listed in Appendix A, further planned exposure to the offending or biologically similar nuclide shall be prohibited.

3. Occupational Mixed Exposures

When a radiation dose from both external and internal exposure sources is being accumulated by an individual, exposure controls, additional to those listed above, may be necessary. Any special limitations imposed on occupational exposures of such individuals shall be issued by the Manager, Radiation Protection and shall be administered by the facility management involved.

4. Nonoccupational Exposure Control Criteria

The discharge of controlled amounts of radioactive materials to the environs of an atomic energy facility may contribute to the potential nonoccupational exposure of persons living in the vicinity of such a facility. The control of such exposure is primarily established for the purpose of keeping the average dose to the whole population as low as reasonably possible and not because of the likelihood of specific injury to an individual. This control at HAPO is primarily effected through the rate of release of radioactive effluents.

The degree of control necessary takes into consideration a number of factors such as: mode of exposure, possible uptake and concentration in foodstuffs, multiple paths of intake of radionuclides, the critical organs involved, effect of other atomic energy facilities on capacity of environmental dispersal media, and the technological difficulties involved in making direct measurements of the individual dose to a resident of the environs. For these reasons the control criteria are indirect and are usually described in terms of concentrations of radionuclides in air and water at the point of potential intake.

Since an individual's accumulated dose resulting from environmental discharge of radionuclides would normally result from exposure to diverse sources and multiple paths of intake, the actual concentration of any one radionuclide in the environs is important only to the degree that it contributes to the total potential dose from the particular mixture of radionuclides which may be present.

The above considerations shall be implemented by limiting the calculated maximum dose to an individual in these environs to 0.5 rem/year of penetrating radiation and a maximum body burden of 1/20 of the value in Appendix A. Normally this will require that at the point of potential intake, the concentration of radionuclides in air and water of HAPO origin be limited to 1/100 of the applicable MPC specified in Appendix A. Additionally, measurements shall be made which allow consideration of radionuclides in foodstuffs to be factored into the above limitations. These calculations shall utilize the best measurement techniques available. These calculations and concentrations may be averaged up to a one year interval.

V. PHILOSOPHY

The occupational exposure controls listed above, when considered with the reliability of HAPO job and area controls, the probability of multiple radiation exposures in one task, the practical limitations in measurement of

personnel exposures, and the acknowledged degree of uncertainty in different exposure standards, provide reasonable assurance that no individual's dose from whole-body exposure to external radiation sources will exceed the levels prescribed in the Standards.

The National Committee on Radiation Protection and Measurements, whose recommendations form the base for these Standards, acknowledges that fairly wide latitude in the rate of delivery of an individual's dose is permissible. However, the NCRP qualifies this latitude with the statement that desirably an occupational dose should be distributed in time as uniformly as possible.

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: RESPONSIBILITY FOR RADIATION ZONE WORK	CLASSIFICATION: Radiation Controls

I. POLICY

Areas designated as Radiation Zones, and equipment or personnel within these zones, shall be controlled to the extent necessary to assure the radiological protection of personnel.

II. RESPONSIBILITY

1. Custodial responsibilities of Radiation Zones shall be stated specifically by appropriate management.
2. The Operating group having responsibility for a Radiation Zone shall assure that access is limited to authorized persons and that work is authorized in accordance with approved procedures. The Operating group is also responsible for assuring that their Radiation Zone activities are performed with the stated or implied intent of this Manual and that requests for deviations are submitted to the Manager, Radiation Protection, for approval. The prompt reporting of radiation incidents as required by RPS 6.1, Radiation Incidents, is also an Operating group responsibility.
3. Servicing groups performing work within a Radiation Zone shall assure that current radiological working conditions and protective requirements have been determined by qualified personnel and specified in an approved Radiation Work Procedure or Permit.
4. Individuals entering Radiation Zones shall assure themselves that they have met radiation protection requirements contained in a Radiation Work Procedure or Permit.
5. The group responsible for local radiation monitoring shall insure that local Radiation Zone procedures are adequate to control personnel exposure to within prescribed radiation and contamination limits. The group responsible for local radiation monitoring shall also be responsible for submission to RPO of copies of Radiation Work Procedures within their jurisdiction.
6. The Manager, Radiation Protection, is responsible for issuing HAPO Radiation Zone restrictions for specific individuals, based on their radiation exposure history. The review and approval of any deviations to the stated or implied intent of this Manual is also a responsibility of the Manager, Radiation Protection.
7. The Radiation Protection Operation is responsible for prescribing the general criteria for personnel radiological protection and personal dose evaluation measurements and equipment and for determining conformance to the criteria.
8. The responsibility for providing individuals with a suitable radiation protection orientation rests with the immediate supervisor. See RPS 5.5.

III. STANDARDS

1. Radiation Zone Establishment

Radiation Zones are established to identify sources of significant ionizing radiations and to minimize casual exposure. A Radiation Zone is an area, item of equipment, or work location wherein:

IV. PHILOSOPHY

The overriding aspect in any presentation of responsibility for Radiation Zone work is of course the protection of the individual. Thus the responsibility and the standards for achieving adequate control within Radiation Zones at Hanford are based on the individual being informed and upon procedures and operational techniques which, in depth, assist the individual to stay within prescribed radiation protection controls.

GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: RADIATION SYMBOL	CLASSIFICATION: Radiation Controls

I. POLICY

The presence of radiation or radioactive materials within the category of "Radiation Zone" shall be identified by the symbol described below.

II. RESPONSIBILITY

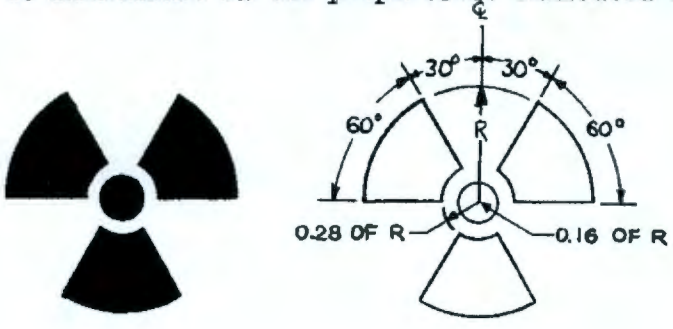
The designers and users of Radiation Zone signs, tags, stickers, etc., shall insure that standardized colors and symbol proportions are met.

III. STANDARDS

1. Symbol

a. The symbol shall be oriented such that two of the vanes are directed upward.

b. The symbol shall be as large as is consistent with the medium used and shall be maintained in the proportions indicated below:



2. Colors

a. Symbol and words (if any) - magenta.

b. Background - lemon yellow.

c. A color shall be acceptable if it is within the Munsell Book of Color limits listed below:

Magenta					Lemon Yellow			
Hue	Color	Value	Chroma		Hue	Color	Value	Chroma
10.0	P	3 or 4	Not less than 6	Limit	2.5	Y	Not less than 8	Not less than 8
1.3	RP	4.2	14.5	Mid-point	5.3	Y	8	12
5.0	RP	3 or 4	Not less than 6	Limit	7.5	Y	Not less than 8	Not less than 8

3. Wording

If any, use RADIATION ZONE, possibly accompanied by an explanatory message such as KEEP OUT, HANDS OFF, STAY THREE FEET AWAY, UNDERGROUND.

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HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: RADIATION GENERATING MACHINES	CLASSIFICATION: Radiation Controls

I. POLICY

Control procedures shall be established to protect personnel who operate, service or have access to the vicinity of a radiation generating machine.

II. RESPONSIBILITY

1. The user of a radiation generating machine is responsible for maintaining adequate radiation protection safeguards at and about the machine.
2. The group responsible for local radiation monitoring is responsible for recommending radiation protection safeguards that are adequate to prevent inadvertent personnel exposure from radiation generating machines located in work areas within their jurisdiction.

III. STANDARDS

1. A "radiation generating machine" is defined as an X-ray generating device (fluoroscope, industrial X-ray machine, spectrometer, etc.) or a particle accelerator (Van de Graaff, cyclotron, electron microscope, etc.) or any other electrical device generating ionizing radiation (including TV tubes) from which personnel may be exposed at a rate exceeding one mrem/hour. Each shall have Radiation Zone status while operating.
2. Radiation generating machines shall be operated only under the authority of a Standard Operating Procedure. This procedure shall be posted at or near the machine.

IV. PHILOSOPHY

The ionizing radiation from radiation generating machines, unlike that from radioactive substances, can be started and stopped upon demand. This feature can result in radiation protection safeguards that also start and stop, making possible electric interlocks and barriers, but also making it difficult to adequately alert nearby workers, especially for mobile machines. It is hoped that emphasizing these problems in a separate Standard will facilitate creating adequate radiation protection safeguards for the machines.

GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT:	CLASSIFICATION:
	OFFSITE OCCUPATIONAL EXPOSURE	Radiation Controls

I. POLICY

HAPO personnel shall observe HAPO Radiation Protection Standards while on official business at offsite locations.

II. RESPONSIBILITY

1. The traveling employee is responsible for notifying the Exposure Evaluation and Records Operation (phone 3384) that he expects to enter Radiation Zones in the course of his official offsite trip.
2. The Radiation Protection Operation is responsible for providing consultation on applicable Standards to be observed during offsite official business and for providing personnel monitoring services deemed necessary to assure the measurement and recording of exposures received by HAPO employees during official offsite business.

III. STANDARDS

1. HAPO employees, while on official offsite business, should conform to local Radiation Protection Standards when these Standards are not in conflict with HAPO Standards.
2. HAPO employees, while within offsite Radiation Zones, shall wear the personnel monitoring devices provided by the HAPO Radiation Protection Operation in addition to devices provided by the offsite facility.
3. The exposure to ionizing radiation sustained by HAPO employees while performing official offsite business, shall be individually evaluated and integrated into HAPO exposure records.

IV. PHILOSOPHY

The probability for excessive exposure to ionizing radiation while on a business trip is small. However, HAPO is charged with the responsibility of determining and recording the significant occupational exposure of each employee, essentially irrespective of where or when received. This is normally accomplished by the HAPO film badge program. Sometimes, however, other means such as bioassay evaluations may be appropriate. Therefore, the potential for exposure is individually determined at the time of the initial telephone notification, rather than by standardizing on one set method for evaluating offsite exposures.

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GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: RELEASE FROM RADIATION ZONE STATUS	CLASSIFICATION: Radiation Controls

I. POLICY

Personnel and equipment, within Radiation Zones, shall be released only in accordance with approved procedures.

II. RESPONSIBILITY

1. The responsible operating group should assure compliance with exit provisions of local Radiation Zone procedures.
2. The group responsible for local radiation monitoring shall assure that established procedures forestall the inadvertent release of contaminated equipment or personnel from established Radiation Zones.

III. STANDARDS

1. Personnel and material unconditionally released from Radiation Zones shall be free from significant radioactive contamination.
2. Release surveys shall be performed with the most sensitive alpha, beta, and gamma detecting instruments available. These surveys shall be made for emitters of alpha, beta, and gamma radiation unless it is known that a given type is not present.
3. Unconditional release surveys should be performed only where the background does not exceed 500 c/m (measured on a GM-type instrument) or 500 d/m (measured on a poppy-type instrument).
4. Appropriate personal surveys should be made by, or in behalf of, personnel exiting from Radiation Zones wherein radioactive contamination is present.
5. Any contamination detected as a result of exit surveys shall be promptly brought to the attention of the group responsible for local radiation monitoring.
6. The number of exits from established Radiation Zones should be minimized.
7. Contaminated excess and surplus materiel may be released by compliance with the following conditions:

   a. For unconditional release there shall be:
      -- no smearable contamination
      -- alpha contamination of < 500 d/m per 100 cm^2
      -- beta-gamma contamination of < 200 c/m per GM probe area
      -- a low probability for occluded or internal contamination.
   b. Equipment found contaminated but to within the levels listed below may be released as "tagged" equipment in accordance with AEC Manual Chapter 5120-1411A:
      -- no smearable contamination
      -- alpha contamination of < 500 d/m per 100 cm^2 (when known to be plutonium free, the alpha contamination shall be < 2000 d/m per 100 cm^2)
      -- beta-gamma contamination of < 600 c/m per GM probe area, when the specific contaminant is unknown. When known, the contaminant is known and is not Sr^{90}, Ca^{45}, Zr^{95}, Bi^{210}, Ra^{226}, then the beta-gamma release limit shall be 1 mrad/hr.
   c. For materiel with surface contamination > 1 mrad/hr, HAPO Radiation Zone requirements shall apply.

8. Equipment removed from a Radiation Zone for further use at HAPO without meeting unconditional release requirements shall itself be identified as a Radiation Zone.
9. Material to be offered for unrestricted public sale shall be free of significant quantities of radioactive contamination.

IV. PHILOSOPHY

At HAPO, Radiation Zones are not separated into "radiation" and "contamination" categories. This is because radiation protection activities are fundamentally concerned with controlling personnel exposures, regardless of the source or type of radiation.

This particular Standard is concerned with insuring that significant quantities of radioactive materials, regardless of physical state, are suitably confined. This goal is believed best achieved by having local controls, rather than by having rigid HAPO-wide Standards which would be unduly restrictive in some cases. However, to achieve flexible radiation controls, each Radiation Zone worker must know and abide with local procedures if adequate confinement of contamination is to be achieved.

D R A F T

GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: SHIPMENT OF RADIOACTIVE MATERIALS	CLASSIFICATION: Radiation Controls

I. POLICY

Offsite shipments of radioactive material from HAPO shall be in accord with federal, state, and specific carrier regulations. Onsite shipments shall comply with HAPO standards and regulations.

II. RESPONSIBILITY

1. Supervision authorizing the shipment is responsible for assuring that applicable regulations are met.
2. For onsite shipments, the group responsible for local radiation monitoring that serves the shipper is responsible for insuring that shipment procedures for radioactive materials are adequate to minimize the casual exposure of personnel.

III. STANDARDS

1. Offsite radioactive shipments of HAPO radioactive material shall conform to current regulations of federal, state and local legal authorities. An abstract of these regulations is contained in Appendix B. Shipping arrangements shall be made through the Traffic Subsection, Construction Engineering and Utilities.
2. Onsite radioactive shipments are those within and between the 100, 200, 300, 600, 700, and 1100 Areas. These constitute transient Radiation Zones and shall be identified as required in RPS 4.1 and 4.2.
3. All onsite radioactive shipments shall be in accordance with either a specific Special Work Permit, a Standard Operating Procedure, or a completed Radioactive Shipment Record form. (In addition, shipments of classified radioactive or other non-inspective material should meet security requirements found in the CE&UO OPG 9.6.)
4. During shipments within HAPO, the radiation level at closest approach should not exceed 50 mrems/hour.
5. Shipments escorted by AEC couriers are exempt from federal and state carrier regulations.

IV. PHILOSOPHY

Nationally, an increasing number and variety of radioactive materials are on the move and the specific tariffs and government regulations regulating these movements are gradually changing to meet the increased traffic. Therefore, although Appendix B provides abstracts of shipping regulations deemed useful as a guide, it is recommended that for unusual or dubious shipments, the latest specific applicable tariff be consulted.

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Onsite shipments are also increasing, especially routine shipments of waste. This type of shipment would appear to be particularly suitable to Standard Operating Procedures and their use is recommended. This is because an SOP tailored to a specific type of shipment has the advantage of being able to spell out the practical details of packaging, loading, securing the load, routine and security approval or escorting, etc., better than a Special Work Permit or Radioactive Shipment Record.

GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: RADIOLOGICAL PROTECTIVE APPAREL	CLASSIFICATION: Radiation Controls

I. POLICY

Adequate protective apparel shall be provided and worn in Radiation Zones wherein significant radioactive contamination is or may be present.

II. RESPONSIBILITY

1. It is the responsibility of each person who enters a Radiation Zone to be aware of, and comply with, whatever protective apparel requirements are specified.
2. The Radiation Work Procedure of a particular Radiation Zone shall specify protective apparel judged necessary to prevent or minimize the spread of contamination to any individual entering the Radiation Zone.
3. The operating group responsible for activities within the particular Radiation Zone shall issue and control the protective apparel.
4. The Radiological Development Operation of the Hanford Laboratories Operation is responsible for designating, after consulting with interested groups, the design and performance specifications for all radiological protective apparel at HAPO with the exception of respiratory equipment. In addition, the field testing and/or evaluation of radiological protective apparel shall be coordinated by the Radiological Development Operation.
5. The evaluation of respiratory equipment, together with the creation of design and performance specifications, is the responsibility of the Industrial Hygiene Operation.

III. STANDARDS

1. Protective apparel in this Standard applies to all body and extremity covering schemes and respiratory equipment relating to radiological protection.
2. Body covering apparel to be used for protection against radioactive contamination shall be predominantly white in color, or else conspicuously identified by appropriate markings.
3. Normally, radiological apparel should be donned freshly laundered. Re-use should be authorized only after the article has been surveyed and released in accordance with local procedures. Special items, such as leather gloves used in handling uranium when judged to be contaminated to less than the prescribed amount, may also be re-used providing the conditions of re-use are specified by procedure.
4. Fresh and used protective apparel shall be kept segregated. The wearing of protective apparel should normally be limited to Radiation Zones.
5. Contamination levels for laundered protective apparel shall be such as to insure that there will be neither a significant radiation exposure nor a spread of contamination to the personal clothing or body of the individual wearing the protective apparel.
6. Work with loose or smearable contamination (nominally, in excess of 500 c/m for β-γ-rays as measured by a GM type instrument or 500 d/m for α-ray as

measured by a poppy type instrument) should normally require the use of protective apparel.

7. Respiratory protection shall be worn in accordance with the below listed conditions:

RESPIRATORY PROTECTION REQUIREMENTS

Contaminant	Concentration μc/cc	Protection Required: None	Respirator or Half Mask	Assault Mask*	Chemox or Fresh Air*
Plutonium	$< 2\times10^{-12}$	x			
	2×10^{-12} to $< 4\times10^{-11}$			x	
	$\geq 4\times10^{-11}$				x
Uranium	$< 6\times10^{-11}$	x			
	6×10^{-11} to $< 1.2\times10^{-10}$		x		
	1.2×10^{-10} to $< 1.2\times10^{-9}$			x	
	$\geq 1.2\times10^{-9}$				x
Mixed Fission Products	$< 1\times10^{-9}$	x			
	1×10^{-9} to $< 2\times10^{-8}$			x	
	$\geq 2\times10^{-8}$				x
Other Than Above	< Occupational Limit listed in Appendix A	x			
	Up to 20X Appendix A			x	
	$\geq$ 20X Appendix A				x

* Respiratory equipment effectiveness is based in part on the fit of the mask of the individual. The face should be clean shaven to secure a seal. When eye glasses with conventional temples are worn, the overall efficiency of full-face masks shall be assumed to be 50 per cent.

The above listed requirements are considered adequate protection against particulate air-borne contamination. In the event that gaseous radioactive contaminants are present, the Industrial Hygiene Operation should be contacted as to appropriate respiratory apparel.

IV. PHILOSOPHY

Radiological apparel is issued primarily to protect workers from the internal contamination that can be acquired by the inhalation, ingestion, injection, or absorption of radioactive materials. To protect against these modes of body entry the radiological status of any Radiation Zone work is carefully established and the radiological apparel that is judged to provide adequate protection is specified. Once this has been done, the individual entering the Radiation Zone must assure himself that the protective clothing is doing the intended job of protection. This may mean checking to determine that the article to be worn is a good fit and is in good repair. Or, it may mean taping shut openings in coveralls, or donning clothing in a sequence that will enable subsequent removal to be effected without cross-contamination. Ultimately, the Radiation Zone worker protects himself through the intelligent and informed use of the provided protective devices.

GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: RECEIPT OF RADIOACTIVE MATERIAL FROM OFFSITE	CLASSIFICATION: Radiation Controls

I. POLICY

Radiation protection procedures shall be established and implemented for handling radioactive materials received from offsite.

II. RESPONSIBILITY

1. Each HAPO organizational component handling mail, packages, or shipping containers which are known or suspected to contain radioactive material is responsible for establishing and implementing procedures for contamination and personnel exposure control in accordance with these Radiation Protection Standards and the recommendations of the group responsible for radiation monitoring for the component.
2. The individual or group ordering the radioactive material should inform the expected recipient (if other than self) of the order and the approximate arrival time of the article.

III. STANDARDS

1. Mail or shipments containing radioactive material from offiste are expected to be found in conformance with the federal regulations (RPS Appendix B) for packaging and labeling. Any apparent violations shall be reported to the HAPO Traffic Subsection for relaying via the AEC to the Bureau of Explosives.
2. If there is apparent damage, leakage or other suspicious characteristic of the article, it should be set aside and the group responsible for local radiation monitoring shall be notified promptly so that appropriate action may be taken.
3. For routine shipments, written standard operating procedures approved by the group responsible for local radiation monitoring should be used.

IV. ADMINISTRATIVE GUIDES

1. If there is evidence that the vehicle transporting radioactive material might be contaminated, it is HAPO practice to survey the vehicle. When contamination is found in excess of the limits prescribed by federal regulations (RPS Appendix B), the driver should be informed and the HAPO Traffic Subsection and AEC-HOO Transportation Branch shall be notified. Private vehicles contaminated by causes outside the control of HAPO shall be decontaminated only upon AEC request.
2. Numerous kinds of commercial equipment now contain radioactive materials in such small quantities that labeling or special packaging is not required by federal shipping regulations. However, the radiation and any escaping contamination may interfere with the sensitive radiation measurements made in many HAPO facilities. When such articles are received or discovered in HAPO facilities, they should be labeled to denote the presence, and if known, the amount and kind of radioactive material.

GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: PERSONNEL MONITORING - EXTERNAL	CLASSIFICATION: Exposure and Monitoring Records

I. POLICY

Each individual who enters a Radiation Zone shall have his exposure to external radiation evaluated.

II. RESPONSIBILITY

1. The Radiation Protection Operation is responsible for designating approved personal radiation monitoring devices and their use.
2. The group responsible for local radiation monitoring shall prescribe the approved personal radiation monitoring devices to be used by entrants to Radiation Zones.
3. Each individual entering a Radiation Zone shall insure that personal monitoring equipment is used as prescribed.
4. The Exposure Evaluation and Records Operation is responsible for supplying, processing, evaluating, and recording all film-type personal radiation monitoring devices at HAPO.

III. STANDARDS

1. The minimum personal monitoring device for Radiation Zone entry shall be a film badge sensitive to beta and gamma radiations.
2. Evaluations of whole body exposure to ionizing radiations may be supplemented by the use of individual ionization chambers, called pencils.
3. For the evaluation of non-routine exposures, special devices (neutron film and pencils, finger rings, etc.) should be prescribed and worn.
4. Personal monitoring devices shall normally be worn at or above the waist on the front of the body and near, but not covering, other units.
5. Records shall be kept for each individual of occupational exposure to ionizing radiation.

IV. PHILOSOPHY

The routinely issued personal monitoring devices in use at HAPO have proven, through many years of use, to be a reliable index of individual exposures. However, the devices are inherently an after-the-fact record. Therefore, although the film badge effects a primary record of exposure, it is emphasized that the primary control of exposure is effected by radiation protection programs presently utilizing dose rate surveys and time limits.

Personnel monitoring equipment at HAPO is highly reliable given reasonable care. However, the badge film record can be altered by heat, liquids, pressure, or light leaks. Also, a pencil may lose its electrostatic charge if opened, distorted, severely jarred, or immersed in liquids. Supervision shall be notified immediately when mistreatment or contamination of any unit is known or suspected, or if any unit is lost, and shall arrange for replacement equipment before the person is further exposed to significant levels of radiation or contamination.

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: PERSONNEL MONITORING - INTERNAL	CLASSIFICATION: Exposure and Monitoring Records

I. POLICY

Each individual routinely working with radioactive materials at HAPO shall have his exposure potential from internally deposited radionuclides evaluated periodically.

II. RESPONSIBILITY

1. The Exposure Evaluation and Records Operation is responsible for processing, evaluating and recording data directly relating to the internal dose of individuals exposed to radioactive materials within the HAPO controlled area.
2. The group responsible for local radiation monitoring is responsible for designating, with the concurrence of the Exposure Evaluation and Records Operation, those individuals who should have their exposure to radionuclides periodically evaluated.

III. STANDARDS

1. The exposure potential from internally deposited radionuclides for individuals who routinely enter HAPO Radiation Zones shall be evaluated at least once a year.
2. Each permanently assigned HAPO employee shall have his exposure potential from internally deposited radionuclides estimated promptly after arrival at Hanford.
3. Each terminating HAPO employee who has entered Radiation Zones in the course of his work assignments should have his exposure potential from deposited radionuclides estimated.
4. A prompt evaluation shall be made for each known or suspected case involving a significant deposition of radioactive material.
5. Records shall be kept for each individual of occupational exposure to ionizing radiation.

IV. PHILOSOPHY

The routine detection of individual exposures to internally deposited radionuclides is based primarily on bioassay techniques. These techniques detect minute amounts of radioactivity and special care must be taken not to introduce contamination into the specimen, or into the equipment. The cooperation of all groups involved in bioassay sampling is necessary to assure that accurate and sensitive evaluation is secured.

GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: CONTAMINATION CONTROL	CLASSIFICATION: Exposure and Monitoring Records

I. POLICY

Contamination control surveys shall be required for HAPO personnel upon each exit from Radiation Zones and work areas where significant radioactive contamination may be present.

II. RESPONSIBILITY

1. The group responsible for local radiation monitoring shall designate the work areas wherein routine personnel surveys shall be required.
2. The operating group should secure and arrange for the maintenance of appropriate personnel monitoring equipment.
3. Individuals within these designated work areas shall comply with local personnel monitoring requirements.

III. STANDARDS

1. The minimum personnel contamination control survey shall be a hand and shoe survey.
2. Personnel surveys shall be performed with sensitive radiation detection instruments.
3. Personnel surveys shall be made before eating, or when leaving the designated work area. Such surveys shall be in addition to the personal surveys required when leaving a Radiation Zone wherein significant radioactive contamination is present.
4. When personal contamination is indicated, the local radiation monitoring or operating group should be notified. Only if he is alone should the person leave the survey location to seek assistance, taking precautions such as donning shoe covers or touching as few objects as possible to minimize the spread of contamination.
5. Follow-up action after personnel contamination is found shall include a survey of the individual's exposed skin surfaces, his protective apparel, the work area and probable source of the contamination if practicable, and the appropriate recording of pertinent data.
6. Any person observing faulty or inoperative personnel monitoring instruments should notify operating supervision.
7. Personnel monitoring equipment should be functionally checked at least once each shift that the designated work area is routinely occupied.

GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: RADIATION PROTECTION RECORDS	CLASSIFICATION: Exposure and Monitoring Records

I. POLICY

Records shall be created and maintained which will allow for the evaluation of human exposures sustained from ionizing radiation of HAPO origin.

II. RESPONSIBILITY

1. The Radiation Protection Operation is responsible for the creation, evaluation and recording of primary exposure data.
2. The group responsible for local radiation monitoring is responsible for the creation, completion and forwarding to Record Center, or to the Exposure Evaluation and Records Operation, of secondary and supporting exposure records.
3. The Exposure Evaluation and Records Operation is responsible for developing and coordinating conformity in HAPO radiation protection record-keeping.

III. STANDARDS

1. Primary Exposure Records are forms or material which constitute the original individual exposure records. Badge film, including processing data, and the recording of gamma and neutron pencil indications, plus bioassay results and evaluations shall constitute the primary exposure records.
2. Secondary Records are forms or charts recording radiological conditions wherein human exposure to ionizing radiation is possible. These supplement the primary records and are used, in general, to evaluate the radiological conditions at HAPO. Examples of secondary records employed to evaluate radiation exposure at HAPO are:

   Radiation Survey Log Sheets
   Air Sample Log Sheets
   Fixed Ionization Chamber-Recorder Charts
   Special Work Permits
   Radiation Work Procedures
   Radiation Incident Records
   Skin Decontamination Records
   Radiation Exposure Estimate Cards
   Hand and Shoe Score Cards
   Thyroid Check Records

3. Supporting Records are the large variety of records in use at HAPO which are not prima facie evidence of personnel exposure but which can and have been used to supplement primary and secondary records. Examples of these records are:

   Radioactive Shipment Records
   Field Check of Portable Instruments

4. All HAPO records are broadly classified into either "record files" or "office files" in accordance with the applicable OPG or Advice on Record Control Programs. In general, primary and secondary exposure records should be considered "record files", while supporting exposure records are normally used as "office files".

5. Primary records shall be contained in individual exposure record files. In addition, secondary records directly relating to real or alleged radiation incidents involving personnel shall be included in individual exposure record files.
6. Primary records should be treated as containing strictly private information.
7. Schedules for the retention, storage and disposal of radiation protection records shall be coordinated with the Exposure Evaluation and Records Operation.
8. The scope and degree of data required from HAPO radiation protection records are described under the following four functional categories.

a. Personnel Radiation Exposure Records

Records accumulated which date, measure and evaluate the occupational exposure of persons to ionizing radiation and radioactive materials:

(1) Individual radiation exposure dossiers, identified by name, social security number, employee and payroll number, and containing the following:

(a) The status of occupational exposure to ionizing radiation from sources external to the body (e.g., personal monitoring film, records of pocket ionization chambers, finger ring film, cumulative exposure summary records, etc.).
(b) Estimates of occupational exposure to ionizing radiation from sources external to the body (e.g., individual exposure estimate records, notations that indicate personnel exposures for a stated interval were estimated not to exceed a stated value, individual hand and shoe contamination check records, etc.).
(c) Evaluation of the presence of radioactive materials occupationally introduced into the body (e.g., bioassay results, scintillation body-monitor surveys, thyroid checks, etc.).
(d) Documentation relative to an individual's involvement in known radiation incidents.
(e) Notations of individuals under diagnostic or therapeutic medical treatment involving radionuclides or radiotherapy when such information is known or volunteered by employees.

(2) Records indicating personnel monitoring device assignments; noting individual time, interval, location, and first-entry processing data for the device.
(3) Procedures (routine and special) which describe and define each type of personnel monitoring device, condition for personnel assignment, means of processing, and measurement techniques.
(4) Procedures (routine and special) which present the criteria for evaluating the personnel dose sustained from exposure to ionizing radiation resulting from occupational activities.

(5) Reports, formal and summary, monthly and annual, quarterly, and audit records of the status and evaluations of occupational personnel exposure to significant sources of ionizing radiations.

b. Radiation Monitoring Records

Documents showing periodic and cumulative determinations of the radiological status of work locations, descriptions of radiation incidents and summary-type reports indicating activities, achievements and advancements in radiation protection:

(1) Air sampling logs and records.
(2) Radiation survey logs and records - listing location, time, personnel involved, radiation levels (maximum exposure).
(3) Continuous recording or detecting radiation device charts or logs, etc.
(4) Radiation incident records containing a listing of personnel involved, an evaluation of personnel exposures, a description of the incident, the incident cause, and appropriate remedial action.
(5) Procedures (routine and special) that define and describe standard practices and policies on survey and monitoring techniques, as related to the control and measurement of functional radiation monitoring activities.
(6) Reports, formal and summary, quarterly, monthly and annual, and audit records of the control and measurement of functional radiation monitoring activities.

c. Environmental Monitoring Records

Documents showing periodic and cumulative determination of the radiological status of the air, water, ground and pertinent flora and fauna immediate to the vicinity of established radiation controlled areas:

(1) Air sample logs and records.
(2) Ground and sanitary water sample logs and records.
(3) Vegetation sample logs and records.
(4) Wild and domestic life sample logs and records.
(5) Radiation level measurements and records.
(6) Waste disposal location and logs.
(7) Procedures (routine and special) that define and describe standard practices and policies on survey, monitoring and evaluation methods and techniques, as related to the control and measurement of functional environmental monitoring activities.
(8) Reports, formal and summary, monthly and annual, quarterly, and audit records of the control, measurement and evaluation of functional environmental monitoring activities.

d. Calibration Records

Documents containing the history of fixed and portable ionizing radiation detection and measuring devices used in evaluating personnel exposures:

(1) Records noting the calibration of each individual radiation detection and measuring instrument. Examples of instruments are: GM survey, CP, and Juno meters; poppies, etc.
(2) Routine and special calibration procedures, and individual-type detection and measuring device specifications.
(3) Records of calibrating standards used in evaluating personnel dosimeters, (e.g., neutron, gamma, and beta film, pocket ionization chambers, metallic foils, etc.).
(4) Instrument maintenance records, listing dates in shop, what was wrong, repairs made, and other details of usage and maintenance.
(5) Summary reports of formal calibration activities (e.g., monthly reports, annual reports, auditing and special reports, etc.).

IV. PHILOSOPHY

Radiation protection records fill several needs. First, to allow management to be aware of and limit human exposures to permissible levels. Second, to reconstruct the radiological status of any location having significant quantities of ionizing radiation arising from HAPO operations. Third, to meet federal, state and contractual obligations. Lastly, to provide an administrative tool for the efficient operation of radiation protection controls.

The Radiation Protection Operation is charged with the responsibility of being able to produce, for all of HAPO, the pertinent records of any individual who has entered a HAPO Radiation Zone. It is thus to the mutual advantage of all HAPO components as well as the Radiation Protection Operation to insure that adequate records are being kept and that the records are created and maintained on forms or by methods that are mutually acceptable.

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: RADIATION EXPOSURE ORIENTATION	CLASSIFICATION: Exposure and Monitoring Records

I. POLICY

Individuals entering Radiation Zones shall be advised, in advance, of pertinent radiation protection devices and measures. Also, full and forthright communications shall be maintained with individual employees concerning real or alleged radiation exposures.

II. RESPONSIBILITY

1. The responsibility for advising an employee of the potential for exposure to radiation at his work location rests with his immediate supervisor.
2. The interpretation and evaluation of individual exposures at Hanford is the responsibility of Exposure Evaluation and Records Operation.
3. The discussion with an individual of his radiation exposure is the joint responsibility of management and the Industrial Medicine Operation. Normally, this discussion is treated as strictly private and is undertaken by the immediate supervisor. In certain cases, or at the request of the individual, an industrial physician will also be present.

III. STANDARDS

1. Radiation Protection Advice - All persons, prior to their initial entrance into a Radiation Zone, shall be given general information sufficient to acquaint the individual with the personal monitoring devices and the radiation protection policies and practices that are in effect at HAPO. In addition, information should be provided concerning the specific radiation protection practices and procedures applicable to the individual's particular work location to a degree sufficient to allow an employee to perform his assignment safely.
2. Individual Radiation Exposures - The exposure of persons at Hanford to external and internal sources of radiation is systematically ascertained and evaluated. Individuals should be advised concerning their exposure as follows:

   a. Promptly in the event of a probable exposure which would affect continued occupational exposure to radiation.
   b. Whenever a significant exposure (external or internal) makes it advisable to temporarily remove a person from Hanford radiation work.
   c. Whenever a person is exposed in a known radiation incident, he will normally be asked to help in investigating the circumstances of both the incident and his possible exposure. After this investigation the person should be informed of his exposure evaluation.
   d. In all cases upon the request of a HAPO employee.
   e. Annually, each HAPO employee should be provided with a summary evaluation of his occupational exposure to radiation.

IV. PHILOSOPHY

At HAPO there are specialized personal monitoring devices and protection programs designed to anticipate and minimize or prevent the undue exposure of persons to ionizing radiation. These have proven successful over the years chiefly because the individual Radiation Zone workers have understood and actively cooperated in the radiation protection program. Continued effectiveness of the radiation protection program has to be based on the realization that ultimately, radiation protection effectiveness rests with an informed individual.

HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: RADIATION INCIDENTS	CLASSIFICATION: Radiation Incidents

I. POLICY

Whenever a situation occurs involving the suspected or known exposure of persons to ionizing radiation of HAPO origin in excess of permissible limits, prompt remedial action shall be undertaken.

II. RESPONSIBILITY

1. Every HAPO employee should accept a voluntary responsibility to notify supervision and/or the group responsible for local radiation monitoring, of real or suspected radiation incidents.
2. Investigative action shall be initiated either by the group responsible for local radiation monitoring or by the operating group involved.
3. Operating supervision is responsible for instigating prompt remedial action upon becoming aware of a radiation incident.
4. The Radiation Protection Operation is responsible for the formal evaluation of exposures of persons to ionizing radiation of HAPO origin.

III. STANDARDS

1. Radiation exposure incidents shall be promptly investigated and personnel exposures evaluated. Incidents shall be categorized as:

   a. Radiation Incident - Type A - A condition or situation which resulted in personnel exposures beyond the maximum permissible exposure limits prescribed in RPS 3.1 - III.
   b. Radiation Incident - Type B - A condition or situation which resulted in a personnel exposure in excess of the operational controls, or in a significant deposition of radionuclides.
   c. Radiation Exposure Occurrence - Type C - A condition or situation where an external exposure in excess of permissible limits, or a significant deposition of radionuclides was judged to have been narrowly averted. Or, a condition or situation which, while not necessarily involving actual personnel exposures to ionizing radiation, is an undesirable event of sufficient importance or widespread interest so as to warrant investigative action.

      "Narrowly averted" factors are too dependent upon actual circumstances to be categorically stated. Each department, therefore, shall prepare and issue criteria which, as closely as feasible, specify what situations within their sphere are potential radiation-exposure incidents. These criteria shall consider at least the following factors: uncontrolled dose rates; internally deposited radionuclides; undue spread of contamination; inadequate monitoring or time keeping; and inadequate protective apparel or procedure.

2. Personnel exposures arising from incidents shall be evaluated promptly. This may require special bioassays, surveys, air samples, film studies,

analyses, etc. As a guide, the following conditions or situations normally require the prompt notification of the Exposure Evaluation and Records Operation:

a. Any positive evidence of a deposition of radionuclides. Examples are a contaminated injury; positive nasal or sputum smears; local skin contamination of 40,000 d/m/100 cm^2 or 50 mrads/hour (beta-gamma) at surface; extensive low-level skin contamination; the exposure of unprotected personnel to atmospheres which are significantly in excess of limits listed in Appendix A.
b. Medical treatment or examination related to an individual's exposure to radiation or contamination.
c. A short-term dose on the order of one rem or greater.
d. Unusual events which may either affect a number of people or involve more than one facility. Examples are: Radiation Zone fires or explosions; accidents involving the transport of radioactive materials; exceeding critical-mass limits; the discharge of radioactive material to the environs significantly in excess of control limits.

3. Preservation of radiation incident information:

a. Radiation incidents and occurrences shall be documented to the extent necessary to describe the incident and evaluate personnel exposures.
b. Sufficient copies of each exposure incident document shall be prepared to allow direct placement in the individual's exposure history file.
c. The Exposure Evaluation and Records Operation shall maintain a master file of radiation incidents at HAPO.
d. The public release of information pertinent to Hanford radiation incidents shall be as specified in OPG 3.6.2.

IV. PHILOSOPHY

Impartial investigation and publicizing of unsafe or undesirable working conditions, practices, or incidents arising during work with radioactive materials is necessary and is beneficial in the improvement of radiation protection procedures and methods, and in the advancement of radiation protection design criteria.

HAPO, as a prime contractor for the AEC, is required to determine the occupational exposures to ionizing radiation of all personnel subject to HAPO radiation protection controls. Concurrent with this requirement is the Radiation Protection Operation's responsibility to insure that the records relating to real or alleged personnel exposures are centrally and comprehensively filed. The radiation incident record is of valuable assistance in fulfilling this requirement and responsibility. Nothing should be allowed to restrict or limit the factual reporting of personnel radiation exposure information and every effort should be made to provide a complete occupational exposure history for each employee involved in an incident.

HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: RADIATION ZONE INJURY AND CONTAMINATION CONTROL	CLASSIFICATION: Radiation Incidents

I. POLICY

Action following Radiation Zone injuries or personnel contamination shall be directed toward minimizing external exposures and minimizing the internal deposition of radionuclides.

II. RESPONSIBILITY

1. Operating supervision, in conjunction with the group responsible for local radiation monitoring, is responsible for insuring that working conditions within Radiation Zones are such as to minimize the possibilities of physical injury.
2. Operating supervision is responsible for insuring that procedures are established which provide for direct remedial action on any Radiation Zone injury or case of personnel contamination.
3. The group responsible for radiation monitoring and the operating group shall mutually designate and appropriately post all Controlled Injury Zones.
4. Each supervisor is responsible for assuring that any known or suspected skin breaks, rashes, or infections of his personnel are adequately protected before allowing entry into a Controlled Injury Zone.
5. The group responsible for radiation monitoring is responsible for assuring that a reliable supply of sanitary water is readily available at each Controlled Injury Zone.
6. The Radiation Protection Operation and the Industrial Medicine Operation shall jointly approve personnel decontamination procedures.
7. The Radiological Development Operation is responsible for coordinating HAPO studies which evaluate radiological reagents and techniques used in the decontamination of personnel and is responsible for publishing approved HAPO personnel decontaminating techniques and listing approved reagents.

III. STANDARDS

1. In severe injuries, medical attention shall take precedence over contamination controls.
2. When radioactive material may have been inhaled, ingested or absorbed, the Industrial Medicine Operation shall be contacted immediately so that necessary prompt remedial treatment may be started.
3. In the event an open wound is sustained in a Radiation Zone which is designated as a Controlled Injury Zone, the following action shall be instituted:

   a. Control any severe bleeding and flush off acidic, caustic, or corrosive reagents.
   b. Flush the wound with sanitary water for at least five minutes and promote bleeding by massaging toward the injury, if required.
   c. Install contamination control tourniquet if appropriate.

d. Notify supervision and the group responsible for local radiation monitoring.
e. Survey the injury, the object which caused the injury, the clothes and exposed skin surface of the injured and of the immediate work area.

4. When skin contamination is detected, operating supervision and the group responsible for local radiation monitoring shall be notified without delay.
5. Personnel decontamination efforts shall be promptly initiated. Until qualified assistance arrives, cleaning efforts should be limited to water flushes or soap and water washing.
6. The decontamination of personnel shall be performed only under standard approved procedures or at the direction of Industrial Medicine Operation personnel.
7. Only approved decontamination reagents and techniques shall be used in the decontamination of personnel.
8. The public release of information pertinent to Hanford radiation incidents shall be as specified in OPG 3.6.2.

GENERAL ELECTRIC

HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: RADIATION ACCIDENTS AND EMERGENCIES	CLASSIFICATION: Radiation Incidents

I. POLICY

Action in an accident or emergency involving radiation or radioactive materials shall be to minimize the radiation exposure of people, employing pre-arranged procedures and equipment wherever practicable.

II. RESPONSIBILITY

1. Each person in a Radiation Zone is responsible for being aware of and complying with radiation protection requirements.
2. Each person working in the vicinity of radiation sources should be generally aware of the kinds of emergencies that might occur and the action he should take. He should promptly notify the appropriate operating or radiation monitoring authority whenever a condition is noted that might jeopardize personnel or property.
3. The group responsible for local radiation monitoring and the appropriate operating group jointly are responsible for preparing general plans of action and for providing equipment to cope with emergencies which are within their jurisdiction. The procedures and available equipment shall be made known to each person at the facility, appropriate to his expected action in an emergency.
4. The authorization of planned exposures greater than the operational controls stated in RPS 3.1 - IV, and subsequent to an accident or emergency, is the responsibility of the manager of the operating group involved. This responsibility should not be redelegated. The prior approval of the Manager, Radiation Protection, should be secured for each of the individuals involved.

III. STANDARDS

1. If the condition which caused the emergency still exists, personnel shall leave the affected area immediately and isolate it against uncontrolled entry.
2. Notification of the accident or emergency shall be given without delay to the local radiation monitoring group. Additionally, when external exposures are estimated to exceed 1 rem, and/or there is probable internal exposure, as evidenced by contaminated injuries, highly contaminated nasal smears, the presence of highly contaminated air, or suspected ingestion of radioactive materials, then the Industrial Medicine Operation and the Exposure Evaluation and Records Operation shall also be notified without delay.
3. Planned exposures greater than the operational controls stated in RPS 3.1 - IV, shall be authorized only for situations requiring direct action to save or protect an individual or to save an item of vital equipment.

   a. For extreme emergencies, planned exposures up to twelve times (12 x 1) the operational controls listed in RPS 3.1 - IV (e.g., 12 rems of whole body exposure) may be authorized.

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b. For unusual circumstances involving vital equipment, planned exposures up to three times (3 x 1) the operational controls listed in RPS 3.1 - IV (e.g., 3 rems of whole body exposure) may be authorized.
c. No more than one-half of these doses should be contributed by penetrating radiation of high specific ionization (e.g., neutrons).
d. Women shall not be authorized for planned exposures greater than the operational controls stated in RPS 3.1 - IV.
e. Any individual who has once received an emergency dose approaching the maximum limit should not be permitted to repeat the exposure.

4. Re-entry into the affected area:

a. Access to the affected area shall be limited to authorized persons.
b. Protective apparel appropriate to the emergency, and which minimizes the possibility of internal deposition of radioactive materials, shall be worn wherever possible (e.g., masks, coveralls, helmets, fire fighting gear, etc.).
c. Re-entry should be limited to the locations wherein the dose rates are known or can be measured with the monitoring instruments in hand.
d. The best available personnel monitoring devices shall be used, including film badges.
e. For critical mass type incidents, no access closer than 50 feet to the suspected area should be made unless it is known that the criticality conditions causing the incident are no longer present. Closer access shall require the express authorization of the Manager of the group responsible for local radiation monitoring.

5. Medical treatment measures shall take precedence over radiation protection measures in cases of severe body injury.
6. Emergency action shall not be delayed because of the lack of an appropriate procedure or authorization.

HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: RADIOACTIVE SOLID WASTE DISPOSAL	CLASSIFICATION: Radioactive Waste Disposal

I. POLICY

Solid radioactive waste disposal shall be accomplished by underground burial where practicable.

II. RESPONSIBILITY

1. The operation or group generating the waste is responsible for instituting procedures that allow for the disposal of solid waste with a minimum of casual exposure to personnel.
2. The group responsible for local radiation monitoring is responsible for establishing routine and periodic survey schedules to determine that waste disposal storage and burial are undertaken with minimal personnel exposures.
3. The Radiation Protection Operation is responsible for being aware of the location of established waste disposal facilities.
4. The Chemical Effluents Technology Operation is responsible for developing technology for the containment or disposal of radioactive wastes and effluents, including criteria for facilities, process controls, and the monitoring of effluent constituents.
5. The landlord responsibilities for waste disposal facilities shall be in accordance with OPG 8.1.

III. STANDARDS

1. Solid radioactive waste is defined as material that is essentially dry or whose fluids are of small volume and adequately contained.
2. Each process area should have permanently designated solid waste disposal locations and an adequate number of intermediate waste disposal locations. These shall be posted as Radiation Zones.
3. Solid waste containers or packages shall be individually identified with a radiation symbol where practicable.
4. Open trenches used to receive waste shall be backfilled at a frequency sufficient to minimize dispersal of radioactive contaminants by wind, rain, wildlife, etc.
5. Terminal conditions for direct ground disposal trenches:

    a. Backfill with a minimum of 2 feet of dirt cover.
    b. Surface dose rate not to exceed 1 mr/hour.
    c. Permanent identification of boundaries of disposal areas both at the site and on master diagrams and plans.
    d. Physical isolation of the disposal grounds throughout the use of the disposal grounds.

6. Isolation of alpha and beta-gamma type contaminants should be practiced.
7. Fire, explosive and toxic byproduct hazards should be considered before placing waste in its common trench.

8. Buried and underground radioactive material, not otherwise demarcated, may be identified by signs bearing the approved radiation symbol and the word "Underground". This means should be used to designate locations where Radiation Zone conditions might be created by disturbance of the ground surface.

HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: RADIOACTIVE LIQUID WASTE DISPOSAL	CLASSIFICATION: Radioactive Waste Disposal

GENERAL

The object of a radioactive liquid waste disposal program is economical storage or dispersion of the wastes in such a manner as to assure safety of the human population, preserve plant and animal resources, and minimize restrictions on the use of land and water.

For the purpose of this Standard, radioactive liquid waste is defined as a solution, suspension, or "sludge" of radioactive material in aqueous, organic or metallic liquid, which is intended for unconfined disposal into or onto the ground or into a river.

DISPOSAL CRITERIA

1. Each waste, whether batch, intermittent or continuous stream, shall be individually evaluated, together with the associated disposal facility. As a corollary, if a disposal facility designed for one waste is to be used for other wastes, then the effect of the combined wastes must be evaluated.

2. The characteristics of the waste, as to content of radioactive and non-radioactive materials, physical composition, volume and flow rate shall be defined. The limit of variations of each characteristic shall also be defined.

3. Radioactive liquid wastes discharged to the Columbia River should not cause activity densities of individual radionuclides in water used for human consumption in excess of the operational controls specified in Radiation Protection Standard 3.1. In practice, the concentration for the waste at the point of release to the river should be further reduced to allow for non-uniform dilution in the river, concentration in aquatic life, irrigated crops and domestic and wild animals, and multiple sources of waste entering the river. An allowance may be permitted for wastes discharged into the ground near the river if solids in suspension are filtered out by the soil or if radionuclides of concern are adsorbed on the soil.

4. Radioactive liquid wastes discharged into the ground are limited by consideration of the future appearance of radionuclides in the Columbia or Yakima Rivers, the possible release of portions of the Hanford Project to public use, and future expansion of plant facilities. Waste containing concentrations of radionuclides greater than the limits specified in Radiation Protection Standard 3.1 may be approved for ground disposal where adequate soil adsorption has been demonstrated or if the liquid will be retained in the soil column for sufficient time to assure decay to the adjusted limits when the radionuclides reach the river. Disposal of a waste to a particular disposal facility shall cease when certain long-lived radionuclides are detected in the ground water* below the facility in concentrations which can be expected to result in concentrations at the point of potential intake that are above the controls noted in RPS 3.1.

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* Ground water is defined as that which is at or below the regional and unconfined ground water table.

5. Liquid wastes slightly contaminated or which potentially may be slightly contaminated with radioactive material may be approved for disposal onto the ground or into open pits. Disposal shall cease when the site constitutes an uncontrolled radiation or contamination problem.

6. Radioactive liquid waste which is immiscible with water or tends to float or sink in water requires special consideration.

INVENTORY

An adequate inventory of all radioactive material disposed of to the environment as liquid waste shall be maintained at HAPO. An adequate inventory is defined as one in which the statistical uncertainties of sampling and volume or flow measurements are consistent with the required analytical accuracy. The volume of each waste, date or period of discharge, source, disposal facility and analytical results are to be appropriately reported to the Hanford Laboratories Operation within twenty (20) days after the end of each month that the disposal facility was used. Analytical results for radionuclides are to be reported in units of absolute quantities disposed of per month (curies or μc per month) and units of average absolute concentration (μc/cc).

RESPONSIBLITIES OF ORGANIZATION ORIGINATING WASTE

The organizational component assigned "user" responsibility for the plant facility originating radioactive liquid waste is responsible for performing, or having performed the following:

1. Determining characteristics of existing and new waste streams and appropriately reporting such data to the Hanford Laboratories Operation.

2. Providing disposal facilities,* and securing specifications and approvals for disposal.

3. Properly disposing of the waste, assuring that the disposed waste is within approved specifications.

4. Sampling and analyzing the waste.

5. Appropriately reporting, demonstrating and documenting the reliability of its inventory data.

6. Reporting each instance of shoreline discharge of reactor effluent or similar waste to the Environmental Monitoring Operation by the next workday. Reporting unusual discharges of any waste as specified in Radiation Protection Standard 6.1.

The originating component's responsibility for the waste shall end when the material has been released to the environment in the approved fashion. The point of release is defined to be the end of the discharge pipe or spillway in the river, or the bottom of the ground disposal facility.

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* Refer to HAPO Organization and Policy Guide 8.1 and 8.2 for responsibilities of landlord and using department that apply to waste disposal.

RESPONSIBILITIES OF HANFORD LABORATORIES OPERATION

The following responsibilities are to be appropriately assumed by functional organizations within Hanford Laboratories Operation:

1. Evaluation of radioactive liquid wastes in relation to associated disposal facilities, employing the best information available from Hanford Laboratories Operation and other sources.

2. Advising the component originating the waste on limits to volume, concentration or total amounts, and on location of disposal facilities to take best advantage of river flows, soil depths, ground water movement or existing facilities.

3. Specification of radionuclides and other waste characteristics for which analyses are required, and the required analytical accuracy.

4. Notification when discharge to any particular ground disposal facility should cease.

5. Advising the concerned "user" component on current release to the Columbia River of reactor effluent which fails to meet established disposal specifications.

6. Conducting periodic audits of liquid waste sampling, analyzing methods, and calculation of inventory data.

7. Stating the location, size, depth and special requirements of wells necessary for monitoring purposes; performing such inspection and acceptance tests for the Hanford Laboratories Operation as may be necessary.

8. Obtaining well drilling logs, samples, geological, hydrological and radiological data during drilling operations.

9. Conducting such sampling, testing and probing of the wells as may be necessary to maintain data on the status of the disposal facilities and the fate of the liquid wastes discharged to the ground.

10. Plant assistance type studies and experiments to establish basic disposal criteria.

11. Maintain current chronological and cumulative waste records.

12. Evaluate the radionuclide content of sanitary water samples secured from the Hanford Project and immediate environs.

PHILOSOPHY

Releases of radioactive materials from the many HAPO facilities are controlled ultimately by measurements as close as possible to the most critical "point of potential uptake" in the environs. The measurements, in general, and the evaluation of exposures are made by the Radiation Protection Operation through the environmental monitoring program.

Day-by-day control is at the "point of release" by the originator of the radioactive effluent. Precise and prompt local control in anticipation of changing levels and locations of exposure in the environs is recognized as impossible, because of the time-lag and such variables as dilution, decay, settling, biological removal and reconcentration, and the combination of exposures from the many independent sources.

The objective is to reduce radiation exposures to the lowest practicable levels, and in any case to make it improbable that any exposure will exceed the corresponding operational control. Averaging of environmental exposures over a year is permitted.

To insure the improbability of average human exposures exceeding the pertinent exposure Standards specified in RPS 3.1, an operational control is imposed on an intermediate, more measurable precursor of exposure, the concentration of radionuclides in air and water. The central inventory of released material also helps guide each facility in establishing its local operational controls for the release of radionuclides to the environment and for a realistic consideration of other contributors to the total exposure.

HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: MAXIMUM PERMISSIBLE BODY BURDEN AND MAXIMUM PERMISSIBLE CONCENTRATIONS OF RADIONUCLIDES IN AIR AND IN WATER FOR OCCUPATIONAL EXPOSURE	CLASSIFICATION: Permissible Limits

Radionuclide	Critical Organ	Total Body Burden μc	Occupational Exposure: Water MPC_w - μc/cc	Occupational Exposure: Air MPC_a - μc/cc	Reference
$H^3(H_2^3O)$ sol.	Body Tissue	10^3	0.1	2×10^{-5}	**
(H_2^3) imm.	Skin			2×10^{-3}	
Be^7 sol.	GI (LLI)*		0.05	10^{-5}	
	Total Body	600	6	6×10^{-6}	
insol.	Lung			10^{-6}	
	GI (LLI)		0.05	9×10^{-6}	
$C^{14}(CO_2)$ sol.	Fat	300	0.02	4×10^{-6}	
imm.	Total Body			5×10^{-5}	
F^{18} sol.	GI (SI)		0.02	5×10^{-6}	
insol.	GI (ULI)		0.01	3×10^{-6}	
Na^{22} sol.	Total Body	10	10^{-3}	2×10^{-7}	
insol.	Lung			9×10^{-9}	
	GI (LLI)		9×10^{-4}	2×10^{-7}	
Na^{24} sol.	GI (SI)		6×10^{-3}	10^{-6}	
	Total Body	7	0.01	2×10^{-6}	
insol.	GI (LLI)		8×10^{-4}	10^{-7}	
Si^{31} sol.	GI (S)		0.03	6×10^{-6}	
	Total Body	30	0.3	4×10^{-5}	
insol.	GI (ULI)		6×10^{-3}	10^{-6}	
P^{32} sol.	Bone	6	5×10^{-4}	7×10^{-8}	
insol.	Lung			8×10^{-8}	
	GI (LLI)		7×10^{-4}	10^{-7}	
P^{33} sol.	Bone		8×10^{-4}		b
S^{35} sol.	Testis	90	2×10^{-3}	3×10^{-7}	
insol.	Lung			3×10^{-7}	
	GI (LLI)		8×10^{-3}	10^{-6}	

* The abbreviations in this column are identified in the Appendix A References - page 23.

** Unless otherwise noted, the values cited are taken from Reference (a) which is NBS Handbook 69.

Radionuclide		Critical Organ	Total Body Burden μc	Occupational Exposure: Water MPC_w - μc/cc	Occupational Exposure: Air MPC_a - μc/cc	Reference
Cl^{36}	sol.	Total Body	80	$2x10^{-3}$	$4x10^{-7}$	
	insol.	Lung			$2x10^{-8}$	
		GI (LLI)		$2x10^{-3}$	$3x10^{-7}$	
Cl^{38}	sol.	GI (S)		0.01	$3x10^{-6}$	
		Total Body	9	0.3	$4x10^{-5}$	
	insol.	GI (S)		0.01	$2x10^{-6}$	
A^{37}	imm.	Skin			$6x10^{-3}$	
A^{41}	imm.	Total Body			$2x10^{-6}$	
K^{42}	sol.	GI (S)		$9x10^{-3}$	$2x10^{-6}$	
		Total Body	10	0.02	$3x10^{-6}$	
	insol.	GI (LLI)		$6x10^{-4}$	10^{-7}	
Ca^{45}	sol.	Bone	30	$3x10^{-4}$	$3x10^{-8}$	
	insol.	Lung			10^{-7}	
		GI (LLI)		$5x10^{-3}$	$9x10^{-7}$	
Ca^{47}	sol.	Bone	5	10^{-3}	$2x10^{-7}$	
	insol.	GI (LLI)		10^{-3}	$2x10^{-7}$	
		Lung			$2x10^{-7}$	
Sc^{44}	sol.	Spleen		1		b
Sc^{46}	sol.	GI (LLI)		10^{-3}	$2x10^{-7}$	
		Liver	10	6	$2x10^{-7}$	
		Total Body	20	6	$3x10^{-7}$	
	insol.	Lung			$2x10^{-8}$	
		GI (LLI)		10^{-3}	$2x10^{-7}$	
Sc^{47}	sol.	GI (LLI)		$3x10^{-3}$	$6x10^{-7}$	
		Total Body	80	200	10^{-5}	
	insol.	GI (LLI)		$3x10^{-3}$	$5x10^{-7}$	
Sc^{48}	sol.	GI (LLI)		$8x10^{-4}$	$2x10^{-7}$	
		Total Body	9	50	$2x10^{-6}$	
	insol.	GI (LLI)		$8x10^{-4}$	10^{-7}	
V^{48}	sol.	GI (LLI)		$9x10^{-4}$	$2x10^{-7}$	
		Total Body	10	0.04	$4x10^{-7}$	
	insol.	Lung			$6x10^{-8}$	
		GI (LLI)		$8x10^{-4}$	10^{-7}	
Cr^{51}	sol.	GI (LLI)		0.05	10^{-5}	
		Total Body	800	0.6	10^{-5}	
	insol.	Lung			$2x10^{-6}$	
		GI (LLI)		0.05	$8x10^{-6}$	

Radionuclide		Critical Organ	Total Body Burden μc	Occupational Exposure: Water MPC_w - μc/cc	Occupational Exposure: Air MPC_a - μc/cc	Reference
Mn^{52}	sol.	GI (LLI)		10^{-3}	2×10^{-7}	
		Total Body	9	0.02	8×10^{-7}	
	insol.	Lung			10^{-7}	
		GI (LLI)		9×10^{-4}	2×10^{-7}	
Mn^{54}	sol.	GI (LLI)		4×10^{-3}	8×10^{-7}	
		Liver	20	0.01	4×10^{-7}	
	insol.	Lung			4×10^{-8}	
		GI (LLI)		3×10^{-3}	6×10^{-7}	
Mn^{56}	sol.	GI (LLI)		4×10^{-3}	8×10^{-7}	
		Total Body	10	0.9	3×10^{-5}	
	insol.	GI (LLI)		3×10^{-3}	5×10^{-7}	
Fe^{55}	sol.	Spleen	10^3	0.02	9×10^{-7}	
		Total Body	3×10^3	0.06	2×10^{-6}	
	insol.	Lung			10^{-6}	
		GI (LLI)		0.07	10^{-5}	
Fe^{59}	sol.	GI (LLI)		2×10^{-3}	4×10^{-7}	
		Spleen	20	4×10^{-3}	10^{-7}	
	insol.	Lung			5×10^{-8}	
		GI (LLI)		2×10^{-3}	3×10^{-7}	
Co^{57}	sol.	GI (LLI)		0.02	3×10^{-6}	
		Total Body	200	0.07	6×10^{-6}	
	insol.	Lung			2×10^{-7}	
		GI (LLI)		0.01	2×10^{-6}	
Co^{58m}	sol.	GI (LLI)		0.08	2×10^{-5}	
		Total Body	200	2	10^{-4}	
	insol.	Lung			9×10^{-6}	
		GI (LLI)		0.06	10^{-5}	
Co^{58}	sol.	GI (LLI)		4×10^{-3}	8×10^{-7}	
		Total Body	30	0.01	10^{-6}	
	insol.	Lung			5×10^{-8}	
		GI (LLI)		3×10^{-3}	5×10^{-7}	
Co^{60}	sol.	GI (LLI)		10^{-3}	3×10^{-7}	
		Total Body	10	4×10^{-3}	4×10^{-7}	
	insol.	Lung			9×10^{-9}	
		GI (LLI)		10^{-3}	2×10^{-7}	
Co^{61}	sol.	Liver		3		b
Ni^{57}	sol.	Liver		1		b
Ni^{59}	sol.	Bone	10^3	6×10^{-3}	5×10^{-7}	
	insol.	Lung			8×10^{-7}	
		GI (LLI)		0.06	10^{-5}	

Radionuclide		Critical Organ	Total Body Burden μc	Occupational Exposure: Water MPC_w - μc/cc	Occupational Exposure: Air MPC_a - μc/cc	Reference
Ni^{63}	sol.	Bone	200	8×10^{-4}	6×10^{-8}	
	insol.	Lung			3×10^{-7}	
		GI (LLI)		0.02	4×10^{-6}	
Ni^{65}	sol.	GI (ULI)		4×10^{-3}	9×10^{-7}	
	insol.	GI (ULI)		3×10^{-3}	5×10^{-7}	
Cu^{64}	sol.	GI (LLI)		0.01	2×10^{-6}	
		Total Body	80	0.5	4×10^{-5}	
	insol.	GI (LLI)		6×10^{-3}	10^{-6}	
Cu^{67}	sol.	Liver		0.1		b
Zn^{65}	sol.	Total Body	60	3×10^{-3}	10^{-7}	
	insol.	Lung			6×10^{-8}	
		GI (LLI)		5×10^{-3}	9×10^{-7}	
Zn^{69m}	sol.	GI (LLI)		2×10^{-3}	4×10^{-7}	
		Prostate	0.7	0.01	4×10^{-7}	
	insol.	GI (LLI)		2×10^{-3}	3×10^{-7}	
Zn^{69}	sol.	GI (S)		0.05	10^{-5}	
		Prostate	0.8	0.2	7×10^{-6}	
	insol.	GI (S)		0.05	9×10^{-6}	
		Lung			5×10^{-5}	
Zn^{72}	sol.	Bone		0.1		b
Ga^{72}	sol.	GI (LLI)		10^{-3}	2×10^{-7}	
		Total Body	10	20	8×10^{-6}	
	insol.	GI (LLI)		10^{-3}	2×10^{-7}	
Ga^{73}	sol.	Bone		8		c
Ge^{69}	sol.	Bone		0.06		b
Ge^{71}	sol.	GI (LLI)		0.05	10^{-5}	
	insol.	Lung			6×10^{-6}	
		GI (LLI)		0.05	8×10^{-6}	
Ge^{75}	sol.	Kidney		10		c
Ge^{77}	sol.	Kidney		0.5		b
Ge^{78}	sol.	Kidney		20		c
As^{73}	sol.	GI (LLI)		0.01	3×10^{-6}	
		Total Body	300	0.2	2×10^{-6}	
	insol.	Lung			4×10^{-7}	
		GI (LLI)		0.01	2×10^{-6}	

Radionuclide		Critical Organ	Total Body Burden μc	Occupational Exposure: Water MPC_w - μc/cc	Occupational Exposure: Air MPC_a - μc/cc	Reference
As^{74}	sol.	GI (LLI)		$2x10^{-3}$	$3x10^{-7}$	
		Total Body	40	0.07	$8x10^{-7}$	
	insol.	GI (LLI)		$2x10^{-3}$	$3x10^{-7}$	
As^{76}	sol.	GI (LLI)		$6x10^{-4}$	10^{-7}	
		Total Body	20	0.4	$5x10^{-6}$	
	insol.	GI (LLI)		$6x10^{-4}$	10^{-7}	
As^{77}	sol.	GI (LLI)		$2x10^{-3}$	$5x10^{-7}$	
		Total Body	80	2	$2x10^{-5}$	
	insol.	GI (LLI)		$2x10^{-3}$	$4x10^{-7}$	
As^{78}	sol.	Kidney		5		c
Se^{75}	sol.	Kidney	90	$9x10^{-3}$	10^{-6}	
	insol.	Lung			10^{-7}	
		GI (LLI)		$8x10^{-3}$	10^{-6}	
Br^{82}	sol.	Total Body	10	$8x10^{-3}$	10^{-6}	
	insol.	GI (LLI)		10^{-3}	$2x10^{-7}$	
Br^{83}	sol.	Total Body		0.7		c
Kr^{85m}	imm.	Total Body			$6x10^{-6}$	
Kr^{85}	imm.	Total Body			10^{-5}	
Kr^{87}	imm.	Total Body			10^{-6}	
Rb^{86}	sol.	Total Body	30	$2x10^{-3}$	$3x10^{-7}$	
	insol.	Lung			$7x10^{-8}$	
		GI (LLI)		$7x10^{-4}$	10^{-7}	
Rb^{87}	sol.	Pancreas	200	$3x10^{-3}$	$5x10^{-7}$	
	insol.	Lung			$7x10^{-8}$	
		GI (LLI)		$5x10^{-3}$	$9x10^{-7}$	
Sr^{85m}	sol.	GI (SI)		0.2	$4x10^{-5}$	
		Total Body	50	3	$2x10^{-4}$	
	insol.	GI (SI)		0.2	$3x10^{-5}$	
Sr^{85}	sol.	Total Body	60	$3x10^{-3}$	$2x10^{-7}$	
	insol.	Lung			10^{-7}	
		GI (LLI)		$5x10^{-3}$	$9x10^{-7}$	
Sr^{87}	sol.	Bone		0.1		b
Sr^{89}	sol.	Bone	4	$3x10^{-4}$	$3x10^{-8}$	
	insol.	Lung			$4x10^{-8}$	
		GI (LLI)		$8x10^{-4}$	10^{-7}	

Radionuclide		Critical Organ	Total Body Burden μc	Occupational Exposure		Reference
				Water MPC_w - μc/cc	Air MPC_a - μc/cc	
Sr^{90}	sol.	Bone	2	$4x10^{-6}$	$3x10^{-10}$	
	insol.	Lung			$5x10^{-9}$	
		GI (LLI)		10^{-3}	$2x10^{-7}$	
Sr^{91}	sol.	GI (LLI)		$2x10^{-3}$	$4x10^{-7}$	
		Total Body	9	0.07	$6x10^{-6}$	
	insol.	GI (LLI)		10^{-3}	$3x10^{-7}$	
Sr^{92}	sol.	GI (ULI)		$2x10^{-3}$	$4x10^{-7}$	
		Total Body	8	0.2	$2x10^{-5}$	
	insol.	GI (ULI)		$2x10^{-3}$	$3x10^{-7}$	
Y^{88}	sol.	Bone		$4x10^{-3}$		b
Y^{90}	sol.	GI (LLI)		$6x10^{-4}$	10^{-7}	
		Total Body	20	80	$3x10^{-6}$	
	insol.	GI (LLI)		$6x10^{-4}$	10^{-7}	
Y^{91m}	sol.	GI (SI)		0.1	$2x10^{-5}$	
		Total Body	20	$6x10^{3}$	$2x10^{-4}$	
	insol.	GI (SI)		0.1	$2x10^{-5}$	
Y^{91}	sol.	GI (LLI)		$8x10^{-4}$	$2x10^{-7}$	
		Bone	5	0.8	$4x10^{-8}$	
	insol.	Lung			$3x10^{-8}$	
		GI (LLI)		$8x10^{-4}$	10^{-7}	
Y^{92}	sol.	GI (ULI)		$2x10^{-3}$	$4x10^{-7}$	
		Total Body	10	800	$3x10^{-5}$	
	insol.	GI (ULI)		$2x10^{-3}$	$3x10^{-7}$	
Y^{93}	sol.	GI (LLI)		$8x10^{-4}$	$2x10^{-7}$	
		Total Body	10	250	10^{-5}	
	insol.	GI (LLI)		$8x10^{-4}$	10^{-7}	
Zr^{93}	sol.	GI (LLI)		0.02	$5x10^{-6}$	
		Bone	100	3	10^{-7}	
	insol.	Lung			$3x10^{-7}$	
		GI (LLI)		0.02	$4x10^{-6}$	
Zr^{95}	sol.	GI (LLI)		$2x10^{-3}$	$4x10^{-7}$	
		Total Body	20	3	10^{-7}	
	insol.	Lung			$3x10^{-8}$	
		GI (LLI)		$2x10^{-3}$	$3x10^{-7}$	
Zr^{97}	sol.	GI (LLI)		$5x10^{-4}$	10^{-7}	
		Total Body	9	100	$5x10^{-6}$	
	insol.	GI (LLI)		$5x10^{-4}$	$9x10^{-8}$	
Nb^{92}	sol.	Bone		$2x10^{-3}$		b

Radionuclide		Critical Organ	Total Body Burden μc	Occupational Exposure: Water MPC_w - μc/cc	Occupational Exposure: Air MPC_a - μc/cc	Reference
Nb^{93m}	sol.	GI (LLI)		0.01	3×10^{-6}	
		Bone	200	3	10^{-7}	
	insol.	Lung			2×10^{-7}	
		GI (LLI)		0.01	2×10^{-6}	
Nb^{95}	sol.	GI (LLI)		3×10^{-3}	6×10^{-7}	
		Total Body	40	10	5×10^{-7}	
	insol.	Lung			10^{-7}	
		GI (LLI)		3×10^{-3}	5×10^{-7}	
Nb^{97}	sol.	GI (ULI)		0.03	6×10^{-6}	
		Total Body	20	4×10^{3}	2×10^{-4}	
	insol.	GI (ULI)		0.03	5×10^{-6}	
Mo^{99}	sol.	Kidney	8	5×10^{-3}	7×10^{-7}	
		GI (LLI)		7×10^{-3}	2×10^{-6}	
	insol.	GI (LLI)		10^{-3}	2×10^{-7}	
Tc^{96m}	sol.	GI (LLI)		0.4	8×10^{-5}	
		Total Body	70	4	4×10^{-4}	
	insol.	Lung			3×10^{-5}	
		GI (LLI)		0.3	5×10^{-5}	
Tc^{96}	sol.	GI (LLI)		3×10^{-3}	6×10^{-7}	
		Total Body	10	0.03	4×10^{-6}	
	insol.	GI (LLI)		10^{-3}	2×10^{-7}	
Tc^{97m}	sol.	GI (LLI)		0.01	2×10^{-6}	
		Total Body	200	0.4	4×10^{-5}	
	insol.	Lung			2×10^{-7}	
		GI (LLI)		5×10^{-3}	9×10^{-7}	
Tc^{97}	sol.	GI (LLI)		0.05	10^{-5}	
		Kidney	60	0.1	10^{-5}	
	insol.	Lung			3×10^{-7}	
		GI (LLI)		0.02	4×10^{-6}	
Tc^{99m}	sol.	GI (ULI)		0.2	4×10^{-5}	
		Total Body	200	2	2×10^{-4}	
	insol.	GI (ULI)		0.08	10^{-5}	
Tc^{99}	sol.	GI (LLI)		0.01	2×10^{-6}	
		Total Body	200	0.4	4×10^{-5}	
	insol.	Lung			6×10^{-8}	
		GI (LLI)		5×10^{-3}	8×10^{-7}	
Ru^{97}	sol.	GI (LLI)		0.01	2×10^{-6}	
		Total Body	100	2	3×10^{-5}	
	insol.	GI (LLI)		0.01	2×10^{-6}	
		Lung			2×10^{-6}	

Radionuclide		Critical Organ	Total Body Burden μc	Occupational Exposure: Water MPC_w - μc/cc	Occupational Exposure: Air MPC_a - μc/cc	Reference
Ru^{103}	sol.	GI (LLI)		$2x10^{-3}$	$5x10^{-7}$	
	insol.	Lung			$8x10^{-8}$	
		GI (LLI)		$2x10^{-3}$	$4x10^{-7}$	
Ru^{105}	sol.	GI (ULI)		$3x10^{-3}$	$7x10^{-7}$	
		Total Body	20	3	$4x10^{-5}$	
	insol.	GI (ULI)		$3x10^{-3}$	$5x10^{-7}$	
Ru^{106}	sol.	GI (LLI)		$4x10^{-4}$	$8x10^{-8}$	
		Total Body	10	0.06	$7x10^{-7}$	
	insol.	Lung			$6x10^{-9}$	
		GI (LLI)		$3x10^{-4}$	$6x10^{-8}$	
Rh^{103m}	sol.	GI (S)		0.4	$8x10^{-5}$	
		Total Body	400	40	$3x10^{-3}$	
	insol.	GI (S)		0.3	$6x10^{-5}$	
Rh^{105}	sol.	GI (LLI)		$4x10^{-3}$	$8x10^{-7}$	
		Total Body	100	0.4	$2x10^{-5}$	
	insol.	GI (LLI)		$3x10^{-3}$	$5x10^{-7}$	
Pd^{103}	sol.	GI (LLI)		0.01	$2x10^{-6}$	
		Kidney	20	0.02	10^{-6}	
	insol.	Lung			$7x10^{-7}$	
		GI (LLI)		$8x10^{-3}$	10^{-6}	
Pd^{109}	sol.	GI (LLI)		$3x10^{-3}$	$6x10^{-7}$	
		Total Body	50	0.4	$3x10^{-5}$	
	insol.	GI (LLI)		$2x10^{-3}$	$4x10^{-7}$	
Pd^{112}	sol.	Kidney		$3x10^{-3}$		b
Ag^{105}	sol.	GI (LLI)		$3x10^{-3}$	$6x10^{-7}$	
	insol.	Lung			$8x10^{-8}$	
		GI (LLI)		$3x10^{-3}$	$5x10^{-7}$	
Ag^{106}	sol.	Liver		2		b
Ag^{110m}	sol.	GI (LLI)		$9x10^{-4}$	$2x10^{-7}$	
		Total Body	10	0.2	$9x10^{-7}$	
	insol.	Lung			10^{-8}	
		GI (LLI)		$9x10^{-4}$	$2x10^{-7}$	
Ag^{111}	sol.	GI (LLI)		10^{-3}	$3x10^{-7}$	
		Total Body	50	1	$6x10^{-6}$	
	insol.	GI (LLI)		10^{-3}	$2x10^{-7}$	
Ag^{112}	sol.	Liver		17		c

Radionuclide	Critical Organ	Total Body Burden μc	Occupational Exposure: Water MPC_w - μc/cc	Occupational Exposure: Air MPC_a - μc/cc	Reference
Cd^{109} sol.	GI (LLI)		5×10^{-3}	10^{-6}	
	Liver	20	0.05	5×10^{-8}	
insol.	Lung			7×10^{-8}	
	GI (LLI)		5×10^{-3}	9×10^{-7}	
Cd^{115m} sol.	GI (LLI)		7×10^{-4}	2×10^{-7}	
	Liver	3	0.03	4×10^{-8}	
insol.	Lung			4×10^{-8}	
	GI (LLI)		7×10^{-4}	10^{-7}	
Cd^{115} sol.	GI (LLI)		10^{-3}	2×10^{-7}	
	Total Body	30	5	5×10^{-6}	
insol.	GI (LLI)		10^{-3}	2×10^{-7}	
Cd^{117IT} sol. ($+Cd^{117}$)	Liver		0.9		b
In^{113m} sol.	GI (ULI)		0.04	8×10^{-6}	
	Total Body	70	400	4×10^{-4}	
insol.	GI (ULI)		0.04	7×10^{-6}	
In^{114m} sol.	GI (LLI)		5×10^{-4}	10^{-7}	
	Kidney	6	0.1	10^{-7}	
insol.	Lung			2×10^{-8}	
	GI (LLI)		5×10^{-4}	8×10^{-8}	
In^{115m} sol.	GI (ULI)		0.01	2×10^{-6}	
	Total Body	80	200	2×10^{-4}	
insol.	GI (ULI)		0.01	2×10^{-6}	
In^{115} sol.	GI (LLI)		3×10^{-3}	6×10^{-7}	
	Kidney	30	0.3	2×10^{-7}	
insol.	Lung			3×10^{-8}	
	GI (LLI)		3×10^{-3}	5×10^{-7}	
Sn^{113} sol.	GI (LLI)		2×10^{-3}	5×10^{-7}	
	Bone	30	0.02	4×10^{-7}	
insol.	Lung			5×10^{-8}	
	GI (LLI)		2×10^{-3}	4×10^{-7}	
Sn^{117} sol.	Bone		0.04		b
Sn^{119} sol.	Bone		0.04		b
Sn^{121IT} sol. ($+Sn^{121}$)	Bone		2×10^{-2}		b
Sn^{121} sol. (27 h)	Bone		1		b
Sn^{123} sol.	Bone		6×10^{-2}		b

Radionuclide	Critical Organ	Total Body Burden μc	Occupational Exposure: Water MPC_w - μc/cc	Occupational Exposure: Air MPC_a - μc/cc	Reference
Sn^{125} sol.	GI (LLI)		5×10^{-4}	10^{-7}	
	Total Body	20	0.05	10^{-6}	
insol.	Lung			8×10^{-8}	
	GI (LLI)		5×10^{-4}	9×10^{-8}	
Sb^{122} sol.	GI (LLI)		8×10^{-4}	2×10^{-7}	
	Total Body	20	0.3	4×10^{-6}	
insol.	GI (LLI)		8×10^{-4}	10^{-7}	
Sb^{124} sol.	GI (LLI)		7×10^{-4}	2×10^{-7}	
	Total Body	10	0.02	2×10^{-7}	
insol.	Lung			2×10^{-8}	
	GI (LLI)		7×10^{-4}	10^{-7}	
Sb^{125} sol.	GI (LLI)		3×10^{-3}	6×10^{-7}	
	Lung	40	0.04	5×10^{-7}	
insol.	Lung			3×10^{-8}	
	GI (LLI)		3×10^{-3}	5×10^{-7}	
Sb^{126} sol.	Bone		0.4		b
Te^{121IT} sol. ($+Te^{121}$ + I^{121} + Xe^{121})	Kidney		2×10^{-2}		b
Te^{125m} sol.	Kidney	29	5×10^{-3}	4×10^{-7}	
insol.	Lung			10^{-7}	
	GI (LLI)		3×10^{-3}	6×10^{-7}	
Te^{127m} sol.	Kidney	7	2×10^{-3}	10^{-7}	
insol.	Lung			4×10^{-8}	
	GI (LLI)		2×10^{-3}	3×10^{-7}	
Te^{127} sol.	GI (LLI)		8×10^{-3}	2×10^{-6}	
	Total Body	80	0.8	6×10^{-5}	
insol.	GI (LLI)		5×10^{-3}	9×10^{-7}	
Te^{129m} sol.	GI (LLI)		10^{-3}	2×10^{-7}	
	Kidney	3	10^{-3}	8×10^{-8}	
insol.	Lung			3×10^{-8}	
	GI (LLI)		6×10^{-4}	10^{-7}	
Te^{129} sol.	GI (S)		0.02	5×10^{-6}	
	Total Body	20	2	10^{-4}	
insol.	GI (ULI)		0.02	4×10^{-6}	
Te^{131m} sol.	GI (LLI)		2×10^{-3}	4×10^{-7}	
	Total Body	10	0.04	3×10^{-6}	
insol.	GI (LLI)		10^{-3}	2×10^{-7}	
	Lung			6×10^{-7}	

Radionuclide	Critical Organ	Total Body Burden μc	Occupational Exposure: Water MPC_w - μc/cc	Occupational Exposure: Air MPC_a - μc/cc	Reference
Te^{132} sol.	GI (LLI)		9×10^{-4}	2×10^{-7}	
	Total Body	10	0.02	10^{-6}	
insol.	GI (LLI)		6×10^{-4}	10^{-7}	
Te^{133} sol.	Kidney		3		b
I^{126} sol.	Thyroid	1	5×10^{-5}	8×10^{-9}	
insol.	Lung			3×10^{-7}	
	GI (LLI)		3×10^{-3}	5×10^{-7}	
I^{129} sol.	Thyroid	3	10^{-5}	2×10^{-9}	
insol.	Lung			7×10^{-8}	
	GI (LLI)		6×10^{-3}	10^{-6}	
I^{130} sol.	Thyroid		2×10^{-4}		b
I^{131} sol.	Thyroid	0.7	6×10^{-5}	9×10^{-9}	
insol.	GI (LLI)		2×10^{-3}	3×10^{-7}	
	Lung			3×10^{-7}	
I^{132} sol.	Thyroid	0.3	2×10^{-3}	2×10^{-7}	
insol.	GI (ULI)		5×10^{-3}	9×10^{-7}	
I^{133} sol.	Thyroid	0.3	2×10^{-4}	3×10^{-8}	
insol.	GI (LLI)		10^{-3}	2×10^{-7}	
I^{134} sol.	Thyroid	0.2	4×10^{-3}	5×10^{-7}	
insol.	GI (S)		0.02	3×10^{-6}	
I^{135} sol.	Thyroid	0.3	7×10^{-4}	10^{-7}	
insol.	GI (LLI)		2×10^{-3}	4×10^{-7}	
Xe^{131m} imm.	Total Body			2×10^{-5}	
Xe^{133} imm.	Total Body			10^{-5}	
Xe^{135} imm.	Total Body			4×10^{-6}	
Cs^{131} sol.	Total Body	700	0.07	10^{-5}	
insol.	Lung			3×10^{-6}	
	GI (LLI)		0.03	5×10^{-6}	
Cs^{132} sol.	Muscle		7×10^{-3}		b
Cs^{134m} sol.	GI (S)		0.2	4×10^{-5}	
	Total Body	100	0.7	10^{-4}	
insol.	GI (ULI)		0.03	6×10^{-6}	
Cs^{134} sol.	Total Body	20	3×10^{-4}	4×10^{-8}	
insol.	Lung			10^{-8}	
	GI (LLI)		10^{-3}	2×10^{-7}	

Radionuclide		Critical Organ	Total Body Burden μc	Occupational Exposure: Water MPC_w - μc/cc	Occupational Exposure: Air MPC_a - μc/cc	Reference
Cs^{135}	sol.	Liver	200	$3x10^{-3}$	$5x10^{-7}$	
	insol.	GI (LLI)		$7x10^{-3}$	10^{-6}	
		Lung			$9x10^{-8}$	
Cs^{136}	sol.	Total Body	30	$2x10^{-3}$	$4x10^{-7}$	
	insol.	Lung			$2x10^{-7}$	
		GI (LLI)		$2x10^{-3}$	$3x10^{-7}$	
Cs^{137}	sol.	Total Body	30	$4x10^{-4}$	$6x10^{-8}$	
	insol.	Lung			10^{-8}	
		GI (LLI)		10^{-3}	$2x10^{-7}$	
Ba^{131}	sol.	GI (LLI)		$5x10^{-3}$	10^{-6}	
	insol.	Lung			$4x10^{-7}$	
		GI (LLI)		$5x10^{-3}$	$9x10^{-7}$	
Ba^{133IT} ($+Ba^{133}$)	sol.	Bone		$2x10^{-2}$		b
Ba^{133} (8 y)	sol.	Bone		$4x10^{-4}$		b
Ba^{135}	sol.	Bone		$2x10^{-3}$		b
Ba^{139}	sol.	Bone		0.1		c
Ba^{140}	sol.	GI (LLI)		$8x10^{-4}$	$2x10^{-7}$	
		Bone	4	$6x10^{-3}$	10^{-7}	
	insol.	Lung			$4x10^{-8}$	
		GI (LLI)		$7x10^{-4}$	10^{-7}	
La^{140}	sol.	GI (LLI)		$7x10^{-4}$	$2x10^{-7}$	
		Total Body	10	60	$2x10^{-6}$	
	insol.	GI (LLI)		$7x10^{-4}$	10^{-7}	
La^{141}	sol.	Bone		2		c
La^{142}	sol.	Bone		5		c
Ce^{139}	sol.	Bone		0.2		b
Ce^{141}	sol.	GI (LLI)		$3x10^{-3}$	$6x10^{-7}$	
		Liver	30	10	$4x10^{-7}$	
	insol.	Lung			$2x10^{-7}$	
		GI (LLI)		$3x10^{-3}$	$5x10^{-7}$	
Ce^{143}	sol.	GI (LLI)		10^{-3}	$3x10^{-7}$	
		Total Body	20	100	$6x10^{-6}$	
	insol.	GI (LLI)		10^{-3}	$2x10^{-7}$	

Radio-nuclide		Critical Organ	Total Body Burden μc	Occupational Exposure: Water MPC_w - μc/cc	Occupational Exposure: Air MPC_a - μc/cc	Reference
Ce^{144}	sol.	GI (LLI)		$3x10^{-4}$	$8x10^{-8}$	
		Bone	5	0.2	10^{-8}	
	insol.	Lung			$6x10^{-9}$	
		GI (LLI)		$3x10^{-4}$	$6x10^{-8}$	
Ce^{145}	sol.	Bone		24		c
Pr^{142}	sol.	GI (LLI)		$9x10^{-4}$	$2x10^{-7}$	
		Total Body	20	300	10^{-5}	
	insol.	GI (LLI)		$9x10^{-4}$	$2x10^{-7}$	
Pr^{143}	sol.	GI (LLI)		10^{-3}	$3x10^{-7}$	
	insol.	Lung			$2x10^{-7}$	
		GI (LLI)		10^{-3}	$3x10^{-7}$	
Pr^{145}	sol.	Bone		1		c
Nd^{144}	sol.	Bone	0.1	$2x10^{-3}$	$8x10^{-11}$	
	insol.	Lung			$3x10^{-10}$	
		GI (LLI)		$2x10^{-3}$	$4x10^{-7}$	
Nd^{147}	sol.	GI (LLI)		$2x10^{-3}$	$4x10^{-7}$	
		Liver	10	8	$4x10^{-7}$	
	insol.	Lung			$2x10^{-7}$	
		GI (LLI)		$2x10^{-3}$	$3x10^{-7}$	
Nd^{149}	sol.	GI (LLI)		$8x10^{-3}$	$2x10^{-6}$	
		Total Body	20	$2x10^{3}$	$9x10^{-5}$	
	insol.	GI (ULI)		$8x10^{-3}$	10^{-6}	
Pm^{147}	sol.	GI (LLI)		$6x10^{-3}$	10^{-6}	
		Bone	60	1	$6x10^{-8}$	
	insol.	Lung			10^{-7}	
		GI (LLI)		$6x10^{-3}$	10^{-6}	
Pm^{148}	sol.	Bone		0.4		b
Pm^{149}	sol.	GI (LLI)		10^{-3}	$3x10^{-7}$	
		Total Body	40	200	$7x10^{-6}$	
	insol.	GI (LLI)		10^{-3}	$2x10^{-7}$	
Pm^{151}	sol.	Bone		2		c
Sm^{147}	sol.	Bone	0.1	$2x10^{-3}$	$7x10^{-11}$	
	insol.	Lung			$3x10^{-10}$	
		GI (LLI)		$2x10^{-3}$	$4x10^{-7}$	
Sm^{151}	sol.	GI (LLI)		0.01	$2x10^{-6}$	
		Bone	100	2	$6x10^{-8}$	
	insol.	Lung			10^{-7}	
		GI (LLI)		0.01	$2x10^{-6}$	

Radio-nuclide	Critical Organ	Total Body Burden μc	Occupational Exposure		Reference
			Water MPC_w - μc/cc	Air MPC_a - μc/cc	
Sm^{153} sol.	GI (LLI)		$2x10^{-3}$	$5x10^{-7}$	
	Total Body	70	300	10^{-5}	
insol.	GI (LLI)		$2x10^{-3}$	$4x10^{-7}$	
Sm^{156} sol.	Bone		100		c
Eu^{152} sol.	GI (LLI)		$2x10^{-3}$	$4x10^{-7}$	
(9.2 hr)	Total Body	20	500	$2x10^{-5}$	
insol.	GI (LLI)		$2x10^{-3}$	$3x10^{-7}$	
Eu^{152} sol.	GI (LLI)		$2x10^{-3}$	$5x10^{-7}$	
(13 yr)	Kidney	20	0.3	10^{-8}	
insol.	Lung			$2x10^{-8}$	
	GI (LLI)		$2x10^{-3}$	$4x10^{-7}$	
Eu^{154} sol.	GI (LLI)		$6x10^{-4}$	10^{-7}	
	Kidney	5	0.09	$4x10^{-9}$	
insol.	Lung			$7x10^{-9}$	
	GI (LLI)		$6x10^{-4}$	10^{-7}	
Eu^{155} sol.	GI (LLI)		$6x10^{-3}$	10^{-6}	
	Kidney	70	2	$9x10^{-8}$	
insol.	Lung			$7x10^{-8}$	
	GI (LLI)		$6x10^{-3}$	10^{-6}	
Eu^{156} sol.	Bone		0.2		c
Eu^{157} sol.	Bone		6		c
Gd^{153} sol.	GI (LLI)		$6x10^{-3}$	10^{-6}	
	Bone	90	5	$2x10^{-7}$	
insol.	Lung			$9x10^{-8}$	
	GI (LLI)		$6x10^{-3}$	10^{-6}	
Gd^{159} sol.	GI (LLI)		$2x10^{-3}$	$5x10^{-7}$	
	Total Body	50	700	$3x10^{-5}$	
insol.	GI (LLI)		$2x10^{-3}$	$4x10^{-7}$	
Tb^{160} sol.	GI (LLI)		10^{-3}	$3x10^{-7}$	
	Bone	20	2	10^{-7}	
insol.	Lung			$3x10^{-8}$	
	GI (LLI)		10^{-3}	$2x10^{-7}$	
Dy^{165} sol.	GI (LLI)		0.01	$3x10^{-6}$	
	Total Body	40	$4x10^{3}$	$2x10^{-4}$	
insol.	GI (LLI)		0.01	$2x10^{-6}$	
Dy^{166} sol.	GI (LLI)		10^{-3}	$2x10^{-7}$	
	Total Body	30	70	$3x10^{-6}$	
insol.	GI (LLI)		10^{-3}	$2x10^{-7}$	

Radionuclide		Critical Organ	Total Body Burden μc	Occupational Exposure: Water MPC_w - μc/cc	Occupational Exposure: Air MPC_a - μc/cc	Reference
Ho^{166}	sol.	GI (LLI)		$9x10^{-4}$	$2x10^{-7}$	
		Total Body	30	200	10^{-6}	
	insol.	GI (LLI)		$9x10^{-4}$	$2x10^{-7}$	
Er^{169}	sol.	GI (LLI)		$3x10^{-3}$	$6x10^{-7}$	
		Total Body	50	50	$2x10^{-6}$	
	insol.	Lung			$4x10^{-7}$	
		GI (LLI)		$3x10^{-3}$	$6x10^{-7}$	
Er^{171}	sol.	GI (ULI)		$3x10^{-3}$	$7x10^{-7}$	
	insol.	GI (ULI)		$3x10^{-3}$	$6x10^{-7}$	
Tm^{170}	sol.	GI (LLI)		10^{-3}	$3x10^{-7}$	
		Bone	9	0.8	$4x10^{-8}$	
	insol.	Lung			$3x10^{-8}$	
		GI (LLI)		10^{-3}	$2x10^{-7}$	
Tm^{171}	sol.	GI (LLI)		0.01	$3x10^{-6}$	
		Bone	90	3	10^{-7}	
	insol.	Lung			$2x10^{-7}$	
		GI (LLI)		0.01	$3x10^{-6}$	
Yb^{169}	sol.	Bone		0.6		b
Yb^{175}	sol.	GI (LLI)		$3x10^{-3}$	$7x10^{-7}$	
		Kidney	30	80	$3x10^{-6}$	
	insol.	GI (LLI)		$3x10^{-3}$	$6x10^{-7}$	
Lu^{177}	sol.	GI (LLI)		$3x10^{-3}$	$6x10^{-7}$	
	insol.	GI (LLI)		$3x10^{-3}$	$5x10^{-7}$	
		Lung			$7x10^{-7}$	
Hf^{181}	sol.	GI (LLI)		$2x10^{-3}$	$4x10^{-7}$	
		Spleen	4	0.9	$4x10^{-8}$	
	insol.	Lung			$7x10^{-8}$	
		GI (LLI)		$2x10^{-3}$	$4x10^{-7}$	
Ta^{182}	sol.	GI (LLI)		10^{-3}	$3x10^{-7}$	
		Total Body	20	2	$9x10^{-8}$	
	insol.	Lung			$2x10^{-8}$	
		GI (LLI)		10^{-3}	$2x10^{-7}$	
Ta^{183}	sol.	Liver		1		b
W^{181}	sol.	GI (LLI)		0.01	$2x10^{-6}$	
		Total Body	100	0.9	$3x10^{-5}$	
	insol.	Lung			10^{-7}	
		GI (LLI)		0.01	$2x10^{-6}$	

Radionuclide		Critical Organ	Total Body Burden μc	Occupational Exposure: Water MPC_w - μc/cc	Occupational Exposure: Air MPC_a - μc/cc	Reference
W^{185}	sol.	GI (LLI)		$4x10^{-3}$	$8x10^{-7}$	
		Total Body	100	1	$5x10^{-5}$	
	insol.	Lung			10^{-7}	
		GI (LLI)		$3x10^{-3}$	$6x10^{-7}$	
W^{187}	sol.	GI (LLI)		$2x10^{-3}$	$4x10^{-7}$	
		Total Body	30	0.5	$2x10^{-5}$	
	insol.	GI (LLI)		$2x10^{-3}$	$3x10^{-7}$	
Re^{183}	sol.	GI (LLI)		0.02	$4x10^{-6}$	
		Total Body	80	0.02	$3x10^{-6}$	
	insol.	Lung			$2x10^{-7}$	
		GI (LLI)		$8x10^{-3}$	10^{-6}	
Re^{184} (50 d)	sol.	Thyroid		$4x10^{-3}$		b
Re^{184} (2.2 d)	sol.	Thyroid		0.2		b
Re^{186}	sol.	GI (LLI)		$3x10^{-3}$	$6x10^{-7}$	
		Total Body	50	0.04	$4x10^{-6}$	
	insol.	GI (LLI)		10^{-3}	$2x10^{-7}$	
Re^{187}	sol.	GI (LLI)		0.07	$2x10^{-5}$	
		Skin	300	0.08	$9x10^{-6}$	
	insol.	Lung			$5x10^{-7}$	
		GI (LLI)		0.04	$7x10^{-6}$	
Re^{188}	sol.	GI (LLI)		$2x10^{-3}$	$4x10^{-7}$	
		Total Body	20	0.06	$7x10^{-6}$	
	insol.	GI (LLI)		$9x10^{-4}$	$2x10^{-7}$	
Os^{185}	sol.	GI (LLI)		$2x10^{-3}$	$5x10^{-7}$	
		Total Body	40	0.2	$6x10^{-6}$	
	insol.	Lung			$5x10^{-8}$	
		GI (LLI)		$2x10^{-3}$	$3x10^{-7}$	
Os^{191m}	sol.	GI (LLI)		0.07	$2x10^{-5}$	
		Total Body	300	7	$2x10^{-4}$	
	insol.	Lung			$9x10^{-6}$	
		GI (LLI)		0.07	10^{-5}	
Os^{191}	sol.	GI (LLI)		$5x10^{-3}$	10^{-6}	
	insol.	Lung			$4x10^{-7}$	
		GI (LLI)		$5x10^{-3}$	$8x10^{-7}$	
Os^{193}	sol.	GI (LLI)		$2x10^{-3}$	$4x10^{-7}$	
		Total Body	50	0.6	$2x10^{-5}$	
	insol.	GI (LLI)		$2x10^{-3}$	$3x10^{-7}$	

Radionuclide		Critical Organ	Total Body Burden μc	Occupational Exposure: Water MPC_w - μc/cc	Occupational Exposure: Air MPC_a - μc/cc	Reference
Ir^{190}	sol.	GI (LLI)		$6x10^{-3}$	10^{-6}	
		Total Body	50	0.06	$2x10^{-6}$	
	insol.	Lung			$4x10^{-7}$	
		GI (LLI)		$5x10^{-3}$	$9x10^{-7}$	
Ir^{192}	sol.	GI (LLI)		10^{-3}	$3x10^{-7}$	
		Kidney	6	$4x10^{-3}$	10^{-7}	
	insol.	Lung			$3x10^{-8}$	
		GI (LLI)		10^{-3}	$2x10^{-7}$	
Ir^{194}	sol.	GI (LLI)		10^{-3}	$2x10^{-7}$	
		Total Body	20	0.3	10^{-5}	
	insol.	GI (LLI)		$9x10^{-4}$	$2x10^{-7}$	
Ir^{195}	sol.	Kidney		0.09		b
Pt^{191}	sol.	GI (LLI)		$4x10^{-3}$	$8x10^{-7}$	
		Total Body	30	0.1	$4x10^{-6}$	
	insol.	GI (LLI)		$3x10^{-3}$	$6x10^{-7}$	
Pt^{193m}	sol.	GI (LLI)		0.03	$7x10^{-6}$	
		Total Body	300	0.8	$3x10^{-5}$	
	insol.	GI (LLI)		0.03	$5x10^{-6}$	
		Lung			$7x10^{-6}$	
Pt^{193}	sol.	Kidney	70	0.03	10^{-6}	
	insol.	Lung			$3x10^{-7}$	
		GI (LLI)		0.05	$8x10^{-6}$	
Pt^{195}	sol.	Kidney		10^{-2}		b
Pt^{197m}	sol.	GI (ULI)		0.03	$6x10^{-6}$	
		Total Body	40	6	$2x10^{-4}$	
	insol.	GI (ULI)		0.03	$5x10^{-6}$	
Pt^{197}	sol.	GI (LLI)		$4x10^{-3}$	$8x10^{-7}$	
		Total Body	80	1	$4x10^{-5}$	
	insol.	GI (LLI)		$3x10^{-3}$	$6x10^{-7}$	
Au^{196}	sol.	GI (LLI)		$5x10^{-3}$	10^{-6}	
		Total Body	40	0.07	$3x10^{-6}$	
	insol.	Lung			$6x10^{-7}$	
		GI (LLI)		$4x10^{-3}$	$8x10^{-7}$	
Au^{198}	sol.	GI (LLI)		$2x10^{-3}$	$3x10^{-7}$	
		Total Body	30	0.1	$4x10^{-6}$	
	insol.	GI (LLI)		10^{-3}	$2x10^{-7}$	
Au^{199}	sol.	GI (LLI)		$5x10^{-3}$	10^{-6}	
		Total Body	100	0.3	10^{-5}	
	insol.	GI (LLI)		$4x10^{-3}$	$8x10^{-7}$	

Radionuclide	Critical Organ	Total Body Burden μc	Occupational Exposure: Water MPC_w - μc/cc	Occupational Exposure: Air MPC_a - μc/cc	Reference
Hg^{197m} sol.	Kidney	4	6×10^{-3}	7×10^{-7}	
insol.	GI (LLI)		5×10^{-3}	8×10^{-7}	
Hg^{197} sol.	Kidney	20	9×10^{-3}	10^{-6}	
insol.	GI (LLI)		0.01	3×10^{-6}	
Hg^{203} sol.	Kidney	4	5×10^{-4}	7×10^{-8}	
insol.	Lung			10^{-7}	
	GI (LLI)		3×10^{-3}	6×10^{-7}	
Tl^{200} sol.	GI (LLI)		0.01	3×10^{-6}	
insol.	GI (LLI)		7×10^{-3}	10^{-6}	
Tl^{201} sol.	GI (LLI)		9×10^{-3}	2×10^{-6}	
	Total Body	100	0.1	10^{-5}	
insol.	GI (LLI)		5×10^{-3}	9×10^{-7}	
Tl^{202} sol.	GI (LLI)		4×10^{-3}	8×10^{-7}	
	Total Body	50	0.03	3×10^{-6}	
insol.	Lung			2×10^{-7}	
	GI (LLI)		2×10^{-3}	4×10^{-7}	
Tl^{204} sol.	GI (LLI)		3×10^{-3}	7×10^{-7}	
	Kidney	10	6×10^{-3}	6×10^{-7}	
insol.	Lung			3×10^{-8}	
	GI (LLI)		2×10^{-3}	3×10^{-7}	
Pb^{203} sol.	GI (LLI)		0.01	3×10^{-6}	
	Total Body	90	0.5	10^{-5}	
insol.	GI (LLI)		0.01	2×10^{-6}	
Pb^{210} sol.	Kidney	0.4	4×10^{-6}	10^{-10}	
	Total Body	4	4×10^{-6}	10^{-9}	
Pb^{212} sol.	Kidney	0.02	6×10^{-4}	2×10^{-8}	
insol.	Lung			2×10^{-8}	
	GI (LLI)		5×10^{-4}	9×10^{-8}	
Bi^{206} sol.	GI (LLI)		10^{-3}	2×10^{-7}	
	Kidney	1	0.04	2×10^{-7}	
insol.	Lung			10^{-7}	
	GI (LLI)		10^{-3}	2×10^{-7}	
Bi^{207} sol.	GI (LLI)		2×10^{-3}	4×10^{-7}	
	Kidney	2	0.04	2×10^{-7}	
insol.	Lung			10^{-8}	
	GI (LLI)		2×10^{-3}	3×10^{-7}	
Bi^{210} sol.	GI (LLI)		10^{-3}	3×10^{-7}	
	Kidney	0.04	2×10^{-3}	6×10^{-9}	
insol.	Lung			6×10^{-9}	
	GI (LLI)		10^{-3}	2×10^{-7}	

Radionuclide		Critical Organ	Total Body Burden μc	Occupational Exposure: Water MPC_w - μc/cc	Occupational Exposure: Air MPC_a - μc/cc	Reference
Bi^{212}	sol.	GI (S)		0.01	$2x10^{-6}$	
		Kidney	0.01	0.02	10^{-7}	
	insol.	Lung			$2x10^{-7}$	
		GI (S)		0.01	$2x10^{-6}$	
Po^{210}	sol.	Spleen	0.03	$2x10^{-5}$	$5x10^{-10}$	
	insol.	Lung			$2x10^{-10}$	
		GI (LLI)		$8x10^{-4}$	$2x10^{-7}$	
At^{211}	sol.	Thyroid	0.02	$5x10^{-5}$	$7x10^{-9}$	
	insol.	Lung			$3x10^{-8}$	
		GI (ULI)		$2x10^{-3}$	$4x10^{-7}$	
Rn^{220}	sol.	Lung			$3x10^{-7}$	
Rn^{222}	sol.	Lung			$3x10^{-8}$	
Ra^{223}	sol.	Bone	0.05	$2x10^{-5}$	$2x10^{-9}$	
		GI (LLI)		$2x10^{-4}$	$4x10^{-8}$	
	insol.	Lung			$2x10^{-10}$	
		GI (LLI)		10^{-4}	$2x10^{-8}$	
Ra^{224}	sol.	Bone	0.06	$7x10^{-5}$	$5x10^{-9}$	
	insol.	Lung			$7x10^{-10}$	
		GI (LLI)		$2x10^{-4}$	$3x10^{-8}$	
Ra^{226}	sol.	Bone	0.1	$4x10^{-7}$	$3x10^{-11}$	
		GI (LLI)		10^{-3}	$3x10^{-7}$	
Ra^{228}	sol.	Bone	0.06	$8x10^{-7}$	$7x10^{-11}$	
	insol.	Lung			$4x10^{-11}$	
		GI (LLI)		$7x10^{-4}$	10^{-7}	
Ac^{227}	sol.	Bone	0.03	$6x10^{-5}$	$2x10^{-12}$	
	insol.	Lung			$3x10^{-11}$	
		GI (LLI)		$9x10^{-3}$	$2x10^{-6}$	
Ac^{228}	sol.	GI (ULI)		$3x10^{-3}$	$6x10^{-7}$	
		Bone	0.04	2	$9x10^{-8}$	
	insol.	Lung			$2x10^{-8}$	
		GI (ULI)		$3x10^{-3}$	$4x10^{-7}$	
Th^{227}	sol.	GI (LLI)		$5x10^{-4}$	10^{-7}	
		Bone	0.02	$8x10^{-3}$	$3x10^{-10}$	
	insol.	Lung			$2x10^{-10}$	
		GI (LLI)		$5x10^{-4}$	$9x10^{-8}$	
Th^{228}	sol.	Bone	0.02	$2x10^{-4}$	$9x10^{-12}$	
	insol.	Lung			$6x10^{-12}$	
		GI (LLI)		$4x10^{-4}$	$7x10^{-8}$	

Radionuclide		Critical Organ	Total Body Burden μc	Occupational Exposure: Water MPC_w - μc/cc	Occupational Exposure: Air MPC_a - μc/cc	Reference
Th^{230}	sol.	Bone	0.05	$5x10^{-5}$	$2x10^{-12}$	
	insol.	Lung			10^{-11}	
		GI (LLI)		$9x10^{-4}$	$2x10^{-7}$	
Th^{231}	sol.	GI (LLI)		$7x10^{-3}$	10^{-6}	
		Total Body	100	900	$4x10^{-5}$	
	insol.	GI (LLI)		$7x10^{-3}$	10^{-6}	
Th^{232}	sol.	Bone	0.04	$5x10^{-5}$	$2x10^{-12}$	
	insol.	Lung			10^{-11}	
		GI (LLI)		10^{-3}	$2x10^{-7}$	
Th^{234}	sol.	GI (LLI)		$5x10^{-4}$	10^{-7}	
		Bone	4	1	$6x10^{-8}$	
	insol.	Lung			$3x10^{-8}$	
		GI (LLI)		$5x10^{-4}$	$9x10^{-8}$	
Th-Nat	sol.	Bone	0.01	$3x10^{-5}$	$2x10^{-12}$	
	insol.	Lung			$4x10^{-12}$	
Pa^{230}	sol.	GI (LLI)		$7x10^{-3}$	$2x10^{-6}$	
		Bone	0.07	0.04	$2x10^{-9}$	
	insol.	Lung			$8x10^{-10}$	
		GI (LLI)		$7x10^{-3}$	10^{-6}	
Pa^{231}	sol.	Bone	0.02	$3x10^{-5}$	10^{-12}	
	insol.	Lung			10^{-10}	
		GI (LLI)		$8x10^{-4}$	10^{-7}	
Pa^{233}	sol.	GI (LLI)		$4x10^{-3}$	$8x10^{-7}$	
		Kidney	40	10	$6x10^{-7}$	
	insol.	Lung			$2x10^{-7}$	
		GI (LLI)		$3x10^{-3}$	$6x10^{-7}$	
U^{230}	sol.	GI (LLI)		10^{-4}	$3x10^{-8}$	
		Kidney	0.01	$7x10^{-3}$	$3x10^{-10}$	
	insol.	Lung			10^{-10}	
		GI (LLI)		10^{-4}	$2x10^{-8}$	
U^{232}	sol.	GI (LLI)		$8x10^{-4}$	$2x10^{-7}$	
		Bone	0.01	$2x10^{-3}$	10^{-10}	
	insol.	Lung			$3x10^{-11}$	
		GI (LLI)		$8x10^{-4}$	10^{-7}	
U^{233}	sol.	GI (LLI)		$9x10^{-4}$	$2x10^{-7}$	
		Bone	0.05	0.01	$5x10^{-10}$	
	insol.	Lung			10^{-10}	
		GI (LLI)		$9x10^{-4}$	$2x10^{-7}$	

Radio-nuclide		Critical Organ	Total Body Burden µc	Occupational Exposure: Water MPC_w - µc/cc	Occupational Exposure: Air MPC_a - µc/cc	Reference
U^{234}	sol.	GI (LLI)		$9x10^{-4}$	$2x10^{-7}$	
		Bone	0.05	0.01	$6x10^{-10}$	
	insol.	Lung			10^{-10}	
		GI (LLI)		$9x10^{-4}$	$2x10^{-7}$	
U^{235}	sol.	GI (LLI)		$8x10^{-4}$	$2x10^{-7}$	
		Kidney	0.03	0.01	$5x10^{-10}$	
	insol.	GI (LLI)		$8x10^{-4}$	10^{-7}	
U^{236}	sol.	GI (LLI)		10^{-3}	$2x10^{-7}$	
		Bone	0.06	0.01	$6x10^{-10}$	
	insol.	Lung			10^{-10}	
		GI (LLI)		10^{-3}	$2x10^{-7}$	
U^{238}	sol.	GI (LLI)		10^{-3}	$2x10^{-7}$	
		Kidney	$5x10^{-3}$	$2x10^{-3}$	$7x10^{-11}$	
	insol.	Lung			10^{-10}	
		GI (LLI)		10^{-3}	$2x10^{-7}$	
U-Nat	sol.	GI (LLI)		$5x10^{-4}$	10^{-7}	
		Kidney	$5x10^{-3}$	$2x10^{-3}$	$7x10^{-11}$	
	insol.	Lung			$6x10^{-11}$	
		GI (LLI)		$5x10^{-4}$	$8x10^{-8}$	
Np^{237}	sol.	Bone	0.06	$9x10^{-5}$	$4x10^{-12}$	
	insol.	Lung			10^{-10}	
		GI (LLI)		$9x10^{-4}$	$2x10^{-7}$	
Np^{239}	sol.	GI (LLI)		$4x10^{-3}$	$8x10^{-7}$	
		Total Body	70	300	10^{-5}	
	insol.	GI (LLI)		$4x10^{-3}$	$7x10^{-7}$	
Pu^{238}	sol.	Bone	0.04	10^{-4}	$2x10^{-12}$	
	insol.	Lung			$3x10^{-11}$	
		GI (LLI)		$8x10^{-4}$	10^{-7}	
Pu^{239}	sol.	Bone	0.04	10^{-4}	$2x10^{-12}$	
	insol.	Lung			$4x10^{-11}$	
		GI (LLI)		$8x10^{-4}$	$2x10^{-7}$	
Pu^{240}	sol.	Bone	0.04	10^{-4}	$2x10^{-12}$	
	insol.	Lung			$4x10^{-11}$	
		GI (LLI)		$8x10^{-4}$	$2x10^{-7}$	
Pu^{241}	sol.	Bone	0.9	$7x10^{-3}$	$9x10^{-11}$	
	insol.	Lung			$4x10^{-8}$	
		GI (LLI)		0.04	$7x10^{-6}$	
Pu^{242}	sol.	Bone	0.05	10^{-4}	$2x10^{-12}$	
	insol.	Lung			$4x10^{-11}$	
		GI (LLI)		$9x10^{-4}$	$2x10^{-7}$	

Radionuclide		Critical Organ	Total Body Burden μc	Occupational Exposure: Water MPC_w - μc/cc	Occupational Exposure: Air MPC_a - μc/cc	Reference
Am^{241}	sol.	Bone	0.05	10^{-4}	$6x10^{-12}$	
	insol.	Lung			10^{-10}	
		GI (LLI)		$8x10^{-4}$	10^{-7}	
Am^{243}	sol.	Bone	0.05	10^{-4}	$6x10^{-12}$	
		Kidney	0.1	10^{-4}	$6x10^{-12}$	
	insol.	Lung			10^{-10}	
		GI (LLI)		$8x10^{-4}$	10^{-7}	
Cm^{242}	sol.	GI (LLI)		$7x10^{-4}$	$2x10^{-7}$	
		Liver	0.05	$3x10^{-3}$	10^{-10}	
	insol.	Lung			$2x10^{-10}$	
		GI (LLI)		$7x10^{-4}$	10^{-7}	
Cm^{243}	sol.	Bone	0.09	10^{-4}	$6x10^{-12}$	
	insol.	Lung			10^{-10}	
		GI (LLI)		$7x10^{-4}$	10^{-7}	
Cm^{244}	sol.	Bone	0.1	$2x10^{-4}$	$9x10^{-12}$	
	insol.	Lung			10^{-10}	
		GI (LLI)		$8x10^{-4}$	10^{-7}	
Cm^{245}	sol.	Bone	0.04	10^{-4}	$5x10^{-12}$	
	insol.	Lung			10^{-10}	
		GI (LLI)		$8x10^{-4}$	10^{-7}	
Cm^{246}	sol.	Bone	0.05	10^{-4}	$5x10^{-12}$	
	insol.	Lung			10^{-10}	
		GI (LLI)		$8x10^{-4}$	10^{-7}	
Bk^{249}	sol.	GI (LLI)		0.02	$4x10^{-6}$	
		Bone	0.7	0.07	$9x10^{-10}$	
	insol.	Lung			10^{-7}	
		GI (LLI)		0.02	$3x10^{-6}$	
Cf^{249}	sol.	Bone	0.04	10^{-4}	$2x10^{-12}$	
	insol.	Lung			10^{-10}	
		GI (LLI)		$7x10^{-4}$	10^{-7}	
Cf^{250}	sol.	Bone	0.04	$4x10^{-4}$	$5x10^{-12}$	
	insol.	Lung			10^{-10}	
Cf^{252}	sol.	GI (LLI)		$7x10^{-4}$	$2x10^{-7}$	
		Bone	0.04	$2x10^{-3}$	$2x10^{-11}$	
	insol.	Lung			10^{-10}	
		GI (LLI)		$7x10^{-4}$	10^{-7}	

COMMENTS ON APPENDIX A

This Appendix contains body burden values and MPC's for water and air for a number of selected radionuclides. These values were compiled from NCRP recommendations contained in the National Bureau of Standards Handbook #69, plus a number of locally derived values. They should be applied as indicated in Radiation Protection Standards 3.1, 4.1, 4.7, 6.1, and 7.2.

Many of the nuclides in this Appendix have two or more MPC's listed for air and for water. Normally, in these cases, the most restrictive value should be applied. The additional MPC's listed are included to facilitate radionuclide comparison and calculations involving mixtures of nuclides.

The critical organ listing is taken from the Handbook #69 column headed Organ of Reference. When Handbook #69 carries more than one critical organ, ordinarily the most restrictive numerical value is selected for Appendix A. When no specific organ of reference is identified in Handbook #69 as a critical organ, the total body burden value is listed.

The values listed are expected to be sufficient for most ordinary situations. For specific values not listed or for special situtations, the office of the Specialist, Radiation Protection, should be contacted.

REFERENCES

* Footnote, page one. The abreviations GI, S, SI, ULI and LLI refer to gastrointestinal tract, stomach, small intestines, upper large intestine, and lower large intestine, respectively.

a. Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure. NBS Handbook 69 (June 1959).

b. Reactor Effluent Monitoring - HW-45725. J. W. Healy, 10-12-56.

c. Influence of Hanford Reactors on Domestic Use of Columbia River Water - HW-36062. J. W. Healy, R. E. Rostenbach, 5-25-55.

HANFORD ATOMIC PRODUCTS OPERATION

RADIATION PROTECTION STANDARDS

ISSUED BY THE MANAGER RADIATION PROTECTION	SUBJECT: ABSTRACT OF FEDERAL REGULATIONS FOR SHIPPERS AND CONSIGNEES OF RADIOACTIVE MATERIALS	CLASSIFICATION:

The following abstract has been prepared by reviewing applicable Interstate Commerce Commission, Civil Aeronautics Board, Coast Guard, and Post Office Department regulations, and tariffs for the various modes of transportation (rail express, highway, water and air), which are derived from these regulations. Since these regulations and tariffs are revised and amended individually, and since individual carriers often have their own restrictions, it is necessary that a shipper or consignee of radioactive materials comply with the latest regulations and tariffs for the pertinent mode or modes of transportation. The latest information can be obtained from the code of Federal Regulations and by reviewing the daily Federal Register for changes issued after the latest codification. These regulations are also published currently in the tariffs and manuals maintained by the Traffic Subsection at HAPO.

Shipments of radioactive material which are escorted by qualified personnel (e.g., AEC) are exempt from the regulations of the Interstate Commerce Commission (73.7 b),* and may be exempted by approval of the Commandant of the Coast Guard (146.02-8) for water shipments, or approval of the Administrator of the Federal Aviation Agency (49.2) for air shipments.

Radioactive materials having more than one hazardous characteristic, i.e., flammable liquid or solid, oxidizing material, corrosive liquid, flammable or nonflammable compressed gas, explosives A, B, or C, or poisons A, B, or C, must be classified according to both dangerous characteristics. In case more than one hazardous characteristic, other than poisons, class D, exists, the most hazardous characteristic will be classified, in addition to class D poisons. Such shipments must be marked, packed, and labeled in accordance with regulations governing both classifications (73.2).

The offering for transportation of any package or container of any material which under conditions normally incident to transportation may polymerize (combine or react with itself), decompose so as to cause, or any material which will cause a dangerous evolution of heat or gas is forbidden (73.21 b and c).

I. GROUPS OF RADIOACTIVE MATERIALS (73.391)

A. Group I - Radioactive materials that emit gamma rays only or both gamma and electrically charged corpuscular rays.

B. Group II - Radioactive materials that emit neutrons and either or both types of radiation characteristic of Group I materials.

C. Group III - Radioactive materials that emit electrically charged corpuscular rays only, i.e., alpha or beta, etc., or any other that is so shielded that the gamma radiation at the surface of the package does not exceed 10 mr/24 hours at any time during transportation.

II. LIMITS ON QUANTITY IN PACKAGE (73.391)

A. Not more than 2000 millicuries of radium, polonium or other members of the radium family of elements, and not more than 2700 millicuries (disintegration rate of 100,000 million (10^{11}) atoms per second) of any other radioactive substance may be packed in one outside container for shipment by

* Decimal references in parentheses throughout abstract are to the Code of Federal Regulations, Parts 71-78 of Title 49 (ICC), Part 146 of Title 46 (Coast Guard), Part 49 of Title 14 (Civil Aeronautics Board), or the Postal Manual (PM---.---) or Air Tariff (AT 6-B,---).

rail freight, rail express, water or highway, except by special arrangements and under conditions approved by the Bureau of Explosives (and Coast Guard or CAB when necessary) or except as specifically provided in subparagraph (B) of this section. Special instructions for air shipments in excess of 2,000 millicuries are given in AT 6-C, IV-B-165.

B. Not more than 300 curies of solid cesium-137, cobalt-60, gold-198, or irridium-192 may be packed in one outside container for shipment by rail freight, rail express, highway or water, except by special arrangements and under conditions approved by the Bureau of Explosives (and Coast Guard or FAA when necessary).

C. Postal regulations (125.24) require, in addition to special care in packaging (conformance to IV) and labeling (see V-C), that a package containing radioactive materials must not emit from its exterior any significant alpha, beta, or neutron radiations and the gamma radiation at any surface of the package must be less than 10 milliroentgens for 24 hours. The package must contain not more than 0.1 millicurie of radium or polonium, or that amount of strontium-89, strontium-90, or barium-140 which disintegrates at a rate of 5 million atoms per second, or that amount of any other radioactive substance which disintegrates at a rate of more than 50 million atoms per second.

III. EXEMPTIONS FROM PRESCRIBED PACKAGING, MARKING, AND LABELING REQUIREMENTS (73.392)

A. Radioactive materials are exempt (except in the mails) from prescribed (49.1c)(146.25-25) packing, marking (except water shipments must be marked to show name of contents), and labeling requirements provided they fulfill all of the following conditions:

1. The package must be such that there can be no leakage of radioactive material under conditions normally incident to transportation.
2. The package must contain not more than 0.1 millicurie of radium or polonium, or that amount of strontium-89, strontium-90 or barium-140 which disintegrates at a rate of 5 million atoms per second, or that amount of any other radioactive substance which disintegrates at a rate of more than 50 million atoms per second.
3. The package must be such that no significant alpha, beta or neutron radiation is emitted from the exterior of the package and the gamma radiation at any surface is less than 10 mr/24 hours.

B. Manufactured articles other than liquids, such as instrument or clock dials or electronic tubes and apparatus, of which radioactive materials are a component part, and luminous compounds, when securely packed in strong outside containers are exempt from specification packaging, marking (except water shipments must be marked to show name of contents), and labeling requirements provided the gamma radiation at any surface of the package is less than 10 mr in 24 hours.

Switchboard or similar apparatus containing electronic tubes, of which radioactive materials are a component part, are exempt from specification packaging, marking, and labeling requirements when shipped in carload or truckload lots or when transported by private motor carrier provided the gamma radiation at any readily accessible surface of the units when prepared for shipment does not exceed 50 mr in 24 hours.

C. Radioactive materials such as ores, residues, salts of natural uranium and thorium, etc., of low activity, packed in strong tight containers, are exempt from specified packing and labeling requirements for shipment in carload lots by rail freight only, (and in planeload lots) provided that gamma radiation or equivalent will not exceed 10 mr/hour at a distance of 12 feet from surface of the car, (at 1 meter from any outside surface of the load in an airplane, 49.41 b) and will not exceed 10 mr/hour at a distance of five feet from either end surface of the car. There must be no loose radioactive material in the car and the shipment must be braced (and lashed in airplanes) so as to prevent leakage or shift of lading under conditions normally incident to transportation. The railroad car must be placarded by the shipper (with the Dangerous - Class D Poison placard). Except when handling is supervised by the Atomic Energy Commission, shipments must be loaded by consignor and unloaded by consignee (73.392). No person shall remain unnecessarily in or close to a railroad car, motor vehicle, or hold, compartment or deck cargo space of a vessel and the shipper must furnish the carrier with such information and equipment as is necessary for the protection of the carrier's employees, warehousemen, stevedores, or other persons engaged in the handling of such cargo (74.532 J, 146.25-35). On board vessels, gamma radiation or equivalent at any point in any space continuously occupied by passengers, crew, or shipments of animals, must not exceed 40 mr/24 hours at any time during transportation.

D. Detonating fuzes with radioactive components (Class A Type 7) are exempt from labeling requirements (73.392) (146.25-25).

E. Empty containers, if authorized for re-use by the Bureau of Explosives must have all openings including removal heads, filling and vent holes, tightly closed before being offered for transportation. Small quantities of the material with which the containers were loaded may remain in "empty" containers and when the vapors remaining therein are unstable, it is permissible to add sufficient inert gas to render the vapors stable (73.29 a, 74.532 e).

F. All containers and accessories which have been used for shipments of radioactive materials when shipped as empty must be sufficiently free of radioactive contamination so as to conform to Section III-A above (73.29 e).

G. Any box car or motor vehicle which, after use for the transportation of radioactive materials in carload or truckload lots, is contaminated with such materials to the extent that a survey of the interior surface shows that the beta-gamma radiation is greater than 10 mr physical equivalent in 24 hours or that the average alpha contamination is greater than 500 disintegrations per minute per 100 square centimeters shall be thoroughly cleaned in such a manner that a resurvey of the inside surface shows the contamination to be below these levels. A certificate to that effect must be furnished to the local agent of the carrier or to the driver of the motor vehicle. Car and motor vehicles which are used solely for the transportation of radioactive materials are exempt from the provisions of this section (73.395).

IV. PACKING AND SHIELDING (73.393, 146.25-30)

A. Radioactive materials that present special hazards due to their tendency to remain fixed in the human body for long periods of time (i.e., radium, plutonium, and radioactive strontium, etc.) must, in addition to the packing

hereinafter prescribed, be packed in inside metal containers, specification 2R, or other container approved by the Bureau of Explosives (and authorized by the Commandant of the Coast Guard, for water shipment).

B. All radioactive materials must be so packed and shielded that the degree of fogging of undeveloped film under conditions normally incident to transportation (24 hours at 15 feet from the package) will not exceed that produced by 11.5 mr of penetrating gamma rays of radium filtered by 1/2 inch of lead.

C. The design and preparation of the package must be such that there will be no significant radioactive surface contamination of any part of the container.

D. The smallest dimension of any outside shipping container for radioactive materials must not be less than 4 inches.

E. All outside shipping containers must be of such design that the gamma radiation will not exceed 200 mr/hr or equivalent at any point of readily accessible surface. Containers must be equipped with handles and protective devices when necessary in order to satisfy this requirement.

F. The outside shipping container for any radioactive material, unless specifically exempt by Section III above or unless approved by the Bureau of Explosives, shall be as follows:

1. Spec. 15 A, 15 B, 19 A, or 19 B (78.168, 78.169, 78.190 or 78.191). Wooden boxes. Authorized for not more than 2,700* millicuries.
2. Spec. 12 B (78.205). Fiberboard boxes. Authorized for not more than 2,700* millicuries.
3. Spec. 21 A or 21 B (78.222 or 78.223). Fiber drums. Authorized for not more than 2,700* millicuries.
4. Spec. 6 A, 6 B, or 6 C; 17 C or 17 H (single-trip) (78.97, 78.98, 78.99, 78.115, or 78.118). Metal barrels or drums. Authorized for not more than 2,700* millicuries.
5. Spec. 55 (78.250). Metal encased, lead or uranium metal-shielded containers. Authorized for not more than 300* curies (see II, or 73.391). Containers must be equipped with a seal.

G. Radioactive materials Group I, liquid, solid or gaseous, must be packed in suitable inside containers completely surrounded by a shield of lead or other suitable material of such thickness that at any time during transportation the gamma radiation at one meter from any point on the radioactive source will not exceed 10 mr/hour. The shield must be so designed that it will not open or break under conditions incident to transportation. The minimum shielding must be sufficient to prevent the escape of any primary corpuscular radiation to the exterior of the outside shipping container (73.393 g) (146.25-30 g).

H. Radioactive materials Group II, liquid, solid, or gaseous, must be packed in suitable inside containers completely shielded so that at any time during transportation the radiation measured at right angles to any point on the long axis of the shipping container will not exceed the following limits:

1. Gamma radiation of 10 mr/hour at 1 meter.
2. Electrically charged corpuscular radiation of 10 mrads/hour at 1 meter.
3. Neutron radiation of 2 mrem/hour at 1 meter.
4. If more than one of the types of radiation named above is present, the radiation of each type must be reduced by shielding so that

* Maximum is 2000 millicuries per package for shipment by air (AT 6-C, II).

the total does not exceed the equivalent of paragraphs 1, 2, or 3.

The shielding must be designed so as to maintain its efficiency under conditions normally incident to transportation, and must provide personnel protection against fast or slow neutrons and all other ionizing radiation originating in the radioactive materials or any part of the aggregate constituting the complete package (73.393 h) (146.25-30 k).

I. Liquid radioactive materials Group I, II and III must, in addition, be packaged in tight glass, earthenware or other suitable inside containers. The inside containers must be surrounded on all sides and within the shield by an absorbent material sufficient to absorb the entire liquid contents and of such nature that its efficiency will not be impaired by chemical reaction with the contents. Where use of shielding is necessary to reduce radiation to limits prescribed by this section, the absorbent cushioning material must be placed within the shield. If the container is packed in a metal container specification 2R or other container approved by the Bureau of Explosives, the absorbent cushioning is not required. (Glass, see IV-K) (73.393 i)(146.25-30 j)

J. Radioactive materials Group III, liquid or solids, must be packed in suitable inside containers completely wrapped and/or shielded with such material as will prevent the escape of primary corpuscular radiation to the exterior of the shipping container, and secondary radiation at the surface of the container must not exceed 10 mr/24 hours, at any time during transportation (73.393 j)(146.25-30 k).

K. For airplane shipment, unless otherwise specified, articles shall be packed only in containers which are securely closed and of such construction as to prevent leakage of the article or distortion of the containers caused by changes in temperature, humidity, and altitude during transportation. Containers and closures in contact with the article shall be resistant to it. For liquids, containers shall be so filled as to provide an ullage (outage) of not less than 5% nor more than 10% (at a minimum temperature of 60° F) according to the nature of the liquid (except where otherwise specified). The containers including closures, shall be capable of withstanding an internal gauge pressure of 15 lb/sq. in. (1.00 kg. per square centimeter) when filled to such ullage (outage). Ampoules, phials, and similar containers of not more than 10 cc. contents each are exempt from the foregoing pressure requirement, providing the total contents of the ampoules, phials, and similar containers in any inside package shall be no greater than as specified for the article concerned. The inside package shall be considered as the "inside container" in such cases and the packaging requirement for the article concerned must be met. Containers which are breakable or puncturable, such as glass, earthenware, plastic or hard rubber (gutta percha) must be packed in strong outside containers suitably cushioned to prevent breakage and leakage. (49.3) (AT 6-C, IV B-1)

L. Specification 2R - Inside Containers - Metal Tubes (78.34):

1. Size - Outside diameter of the tube must not exceed 6 inches and length must not exceed 16 inches exclusive of flanges, or handling, or fastening devices.
2. Manufacture - Stainless steel, malleable iron, or brass having a wall thickness of not less than 3/32 inch for diameter up to two inches and not less than 1/8 inch for diameter up to six inches. The ends of

the tube must be fitted with screw-type closures or flanges (see L-4) except that one or both ends of the tube may be permanently closed by welded or brazed plates. Welded or brazed side seams are authorized.

3. Welding and Brazing - Must be done in a workmanship-like manner and must be free from defects.
4. Closing devices - Must be of screw type, except that securely bolted flange closure provided with suitable gasket is authorized for openings exceeding three inches in diameter. When of screw thread type, number of threads per inch must be not less than U. S. Standard pipe threads. Caps or plugs are authorized.

V. LABELING

A. Unless exempted according to Part III above, each outside container of Group I or II radioactive material being shipped by carriers other than air carriers must be labeled with the red label (73.414 a), and of Group III with the blue label (73.414 b), duly executed and applied by the shipper to that part of the package bearing consignee's name and address (73.404).

(Red printing on white)

(Blue printing on white)

NOTE: Labels for shipments by air (73.414 c) are not shown here but have different wording, and may be used in lieu of labels otherwise prescribed and for local transportation to or from airport (73.402, 13). Either ICC label may be used for shipments by air; however, the shipper's certificate, either on the label or in duplicate on an attached form, must be signed. For shipments on passenger aircraft, the additional certification must be made: "This shipment is within the limitations for passenger aircraft." Carriers may also require the shipper to have the statement certified by an authority approved by the carrier (AT 6-C, Rule 11).

B. Containers shipped as "empty" must have the old labels prescribed (by Federal regulations) removed, obliterated, destroyed, or completely covered by a square white label (73.413) measuring not less than six inches on each side, and bearing thereon the word "EMPTY" in letters not less than one inch high. This does not apply to carload or truckload shipments to be unloaded by consignee (73.29 f).

C. Postal regulations require that the identity or nature of contents of any radioactive materials mailed shall be stated plainly on the outside of the package. Any labels required by Federal laws or regulations shall be pasted to the outside of the parcel (PM 125.7).

VI. LOADING (73.396; 75.655 j; 77.841; 49.25 c; 146.25-35, 40, 45; and AT 6-C, IV B-160)

A. When radioactive materials are loaded by the shipper (as well as the carrier) into railroad cars, motor vehicles, airplanes, or other carriers, the shipper shall observe the following requirements:

1. A container of Group I or II radioactive material must not be placed in vehicles, depots, or other public places closer than 3 feet to an area which may be continuously occupied by passengers, employees, or shipments of animals; closer than 3 feet to the dividing partition in a combination vehicle carrying passengers and/or express shipments; or closer than 15 feet to any package containing undeveloped film. (In aircraft, only the distance to crew members or passengers is limited, as shown in the following table.)

Total Units	Feet to Undeveloped Film	Feet to Dividing Partition	Feet to Area Occupied	
			Less Than 8 Hrs.	More Than 8 Hrs.
0-2*			1*	
3-5*			2*	
6-10*			3*	
1-10	15	3	3	5
11-20	20	4	4	7
21-30	25	5	5	9
31-40	30	6	6	10

*Aircraft

2. If more than one such container is present, the distance must be computed from the above table by adding the number of units shown on the labels on the containers (1 unit = 1 mr/hr at 1 meter, or the amount of radiation which has the same effect on film as 1 mr/hr at 1 meter of hard gamma rays of radium filtered by 1/2 inch of lead).
3. Not more than 40 units of Group I or II radioactive material shall be transported in any land or air vehicle or stored in any public location at one time. A package of Group I or II material remaining in the same building for more than 24 hours must be moved to a different location after each 24 hours. All containers of such material must be carried by the handles when handles are provided. On board ship, if the shipment exceeds 40 units, a distance of at least 60 feet must separate increments of not more than 40 units each. Any hold, compartment, or enclosed deck space containing radioactive materials shall

be so ventilated that there will be no accumulation of radioactive gases therein.

4. Radioactive materials, Groups I, II, or III, must not be loaded, transported, or stored with Class A explosives (detonating or otherwise of maximum hazard, as compared to Class B flammable or Class C minimum hazard explosives), or with samples of explosives. On board vessels, radioactive materials shall not be stored in the same hold or compartment with Class A, B, or C explosives, inflammable liquids or solids, noninflammable compressed gases, cotton; adjacent to or under corrosive liquids; and must be stowed well away from living quarters, refrigerated cargo and foodstuffs not packed in hermetically sealed containers (146.25-35 e).
5. Any tank, barrel, drum or cylinder, not designed to be permanently attached to a carrier shall be reasonably secured against movement within the carrier by which it is being transported. While loading or unloading a motor vehicle, the handbrake shall be securely set and all other reasonable precautions shall be taken to prevent motion of the vehicle. Containers must be so braced as to prevent relative motion thereof while in transit. Containers having valves or other fittings must be so loaded that there will be the minimum likelihood of damage thereto during transportation (77.834).
6. Every motor vehicle other than tank motor vehicles transporting by public highway any quantity of radioactive material requiring the red label shall be marked or placarded on each side and rear with a placard or lettering in letters not less than 3 inches high on a contrasting background as follows: DANGEROUS - RADIOACTIVE MATERIAL (77.823).
7. If any aircraft is engaged frequently in the transportation of radioactive materials, and for any planeload lot, it shall be the responsibility jointly of the shipper and the carrier to monitor all personnel involved so that the accepted limits of personnel radiation exposure are not exceeded. For shipment in planeload lots, it is also the responsibility of the shipper and/or consignee to supervise all loading and unloading operations (49.25 d and 49.41 b-2).
8. If shipped by boat, the consignor or consignee shall advise the person in charge of loading or discharging of the hazards and regulations (146.25-25 c).

VII. VIOLATIONS AND ACCIDENTS TO BE REPORTED (73.11, AT 6-C, Rule 8 and 146.25-50)

Consignees receiving shipments by rail or highway transport must report promptly to the Bureau of Explosives, 30 Vesey Street, New York 7, N. Y., all instances of improper staying and broken, leaking, or defective containers. (Carriers must report same, plus serious violations of shipping regulations and accidents or fires in connection with transportation or storage in transit of radioactive materials. For water shipments, carriers' representative will notify shipper and district Commandant of the nearest U. S. Coast Guard. For air shipments, operator of aircraft will immediately contact shipper for disposal information and notify the nearest representative of the Civil Aeronautics Board or the Federal Aviation Agency.)

CRITICALITY CONSIDERATIONS

Shipments which follow routine ICC or other federal regulations will not require special consideration of the possibility of a critical mass condition arising during shipment or handling. However, shipments escorted by AEC courier or otherwise exempted from shipment quantity limitations, should be reviewed prior to initial assembly to insure that adequate precautions against inadvertent criticality are maintained.

As an example of the quantity of nuclear material requiring criticality consideration, the following is taken from a recent AEC regulation 10 CFR 71 - Regulations to Protect Against Accidental Conditions of Criticality in the Shipment of Special Nuclear Material; maximum limits for unsupervised shipment (but still probably requiring additional approvals from ICC-CAB-Coast Guard and/or the carrier) not requiring prior AEC approval:

Uranium enriched in the isotope U^{235}	100 grams contained Uranium-235
Uranium-233	50 grams
Plutonium	50 grams