Princeton University OFFICE OF OCCUPATIONAL HEALTH & SAFETY
JAMES FORRESTAL CAMPUS
PRINCETON, NEW JERSEY 08540
609-452-5294

January 4, 1980

Mr. Michael A. Lamastra
License Management Branch
Division of Fuel Cycle and Material Safety
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Lamastra:

RE: License No. 29-05185-24
Control No. 96184

This information, as requested in your letter of July 19, 1979, and a revised Radiation Safety Guide* is submitted in support of our application, dated August 24, 1978, requesting renewal of Princeton University's Byproduct Materials License. The numbered items below correspond to the numbered items in your letter of July 19.

1. The bioassay program for individuals using tritium and radioiodine is described in Section 12 of the University Radiation Safety Guide. The criteria for radioiodine bioassays were derived from the final version of Regulatory Guide 8.20, dated September, 1979, rather than the preliminary for-comment version of the guide which you sent to us with your letter of July 19.

   When a thyroid burden in excess of 0.12 μCi of I-125 or 0.04 μCi of I-131 or a tritium urinary excretion rate in excess of 5 μCi/liter is measured, action, including investigation and corrective action, is taken. Notification of the NRC, when appropriate, is made.

2. Procedures for the receipt of packages containing radioactive material, including receipt during off-duty hours, are described in Section 8 of the Radiation Safety Guide. Arrangements have been made with the various receiving areas and the Security Department to secure packages against unauthorized removal, to notify responsible individuals of a package's arrival, and to isolate or promptly deliver packages which produce excessive radiation levels in unrestricted areas.

ITEM # 21

* Any reference in this document to the Radiation Safety Guide is understood to mean the Fourth Edition, December 1979

3. The training of laboratory personnel is described in Section 6, item I, of the Radiation Safety Guide. Laboratory personnel are instructed in the physical and biological effects of radiation, the risks of radiation exposure, the structure and operating procedures of the University radiation safety program, relevant regulations, and details on the safe use of sources of radiation.

   Appropriate security personnel have attended training sessions conducted by the Office of Occupational Health and Safety on an as-needed basis. Plans have now been made to present yearly sessions. The training given to security personnel consists of basic information on radiation hazards and risks, information on appropriate emergency response, an orientation to the facilities in which radioisotopes are used, and procedures for the off-hours receipt of packages containing radioactive materials.

   The custodial staff does not collect radioactive waste, and they are involved with the cleanup of radioactive spills only after the contamination has been significantly reduced with a cleanup by lab personnel and even then only under supervision by Office of Occupational Health and Safety staff. Training sessions for custodial personnel are regularly conducted by the Building Services Department, and they include instruction on radiation safety. Attendance at the program by all new custodial personnel and at periodic refresher sessions is required. The Office of Occupational Health and Safety has been requested to provide input on a proposed revision of the subject material for the radiation safety section of the program.

4. General laboratory safety procedures and general emergency response guidelines are detailed in Sections 10 and 17, respectively, of the Radiation Safety Guide, available in each laboratory. Additionally, OHS Form #12, "Abbreviated Radiation Emergency Guidelines," which is attached as Appendix A, is posted in each laboratory. OHS Form #31, "Emergency Information," attached as Appendix B, which is posted near the entrance to each laboratory, lists the specific hazards found in each laboratory and provides specific emergency instructions; it is checked and updated periodically.

5. Before a responsible investigator is allowed to possess or use radioisotopes, an evaluation of the proposed usage is made, as described in items 13 and 14C of our license renewal application letter of August 24, 1978. As part of this evaluation, the need for special wipe test surveys, radiation level surveys, or air sampling is assessed and, if determined to be necessary, the

appropriate surveys are made conditions of approval for authorization to use radioisotopes. Generally, special surveys are performed when unusually large amounts of radioisotopes are ordered or when unusual laboratory procedures are performed.

Routine wipe test surveys of each laboratory currently using radioisotopes are normally performed at two week intervals by the Office of Occupational Health and Safety. Wipe test surveys and radiation level surveys are also made prior to the decommissioning of any facility in which radioisotopes are no longer used or stored and prior to maintenance and repair work on equipment which has been used to store or process radioisotopes.

Section 10, item D, of the Radiation Safety Guide describes the requirements for surveys by individuals using radioisotopes.

The document, "Methods and Frequencies for Conducting Surveys," enclosed with your letter of July 19 is obviously intended to be applied to medical institutions and, in the absence of any such facility, is not appropriate for Princeton University, but we did find it to be of professional interest.

6. All survey meters are calibrated or checked for operational response every six months by the Health Physics staff. Ionization chamber survey meters are calibrated using either Co-60 sources with activity ranging from 16 to 57 mCi or a 25 mCi Ra-226 source. These sources have calibrations traceable to the N.B.S. The calibrator consists of a source placed in a collimator at the end of a track with moving platform. The response of an instrument can be checked at any point over those ranges appropriate to our needs. Instruments are normally calibrated at points located approximately 1/3 and 2/3 of the full scale for each appropriate range.

   Survey meters of the G-M and proportional type are checked for operational response only and are not normally calibrated to indicate dose rates. They are checked for operational response with a variety of sources and/or pulse generators, as appropriate. Our Eberline Pac 4G proportional meter, our primary contamination survey instrument, is checked using Tc-99 and Po-210 sources, to verify that the count rate matches that expected, according to the certificates which accompanied the sources.

   Neutron survey meters are checked with either a 0.1 Ci or 1 Ci Pu-Be source.

7. Section 10, item R, of the Radiation Safety Guide describes University policy with respect to animal use and care in radioisotope work. At present, the only use of animals in radioisotope work is for in vitro procedures and procedures which do not require extended housing and care. If it should become necessary to house and care for animals containing radioactivity, the Radiation Safety Committee will require the researcher to take appropriate precautions which may include the isolation of radioactivity-containing animals, the provision of adequate ventilation, the collection and disposal of contaminated wastes and carcasses, and steps to ease the decontamination of cages and the facility.

   There are presently no animal caretakers handling animals containing radioactivity, other than responsible investigators and persons working under their direct supervision. Caretakers would, however, be given specific instruction on avoiding personal contamination, the isolation and disposal of wastes and carcasses, and the cleaning and decontamination of animal facilities.

8. Section 10, items I and J, of the Radiation Safety Guide describe requirements for the use of radioisotopes in procedures which produce airborne radioactivity. Additionally, the results of breathing zone air sampling, performed when I-125 was first introduced into research at Princeton University, indicate that the MPC_a for release to restricted areas was not closely approached during routine protein iodinations which are routinely performed in fume hoods. Because of this and because the literature indicates that the results of air sampling do not closely correlate with thyroid uptake of I-125, air sampling is primarily performed for those situations where new or unusual procedures which may release volatile or gaseous radioactive material are being carried out. Also, when bioassay reveals an uptake of tritium or iodine-125 in excess of the action levels defined in item 1, air sampling for those procedures which led to the uptake is conducted as part of the investigation. With respect to releases of I-125 to unrestricted areas, the results of earlier hood exhaust air sampling indicate that releases of I-125 to the environment during routine experiments are not excessive. If operations are planned which are likely to release excessive amounts of I-125 or tritium to the environment, air sampling will be performed.

   When air sampling is performed, typically a breathing zone air sample is taken. For the measurement of I-125, a personal air pump with a charcoal filter or cartridge is used, and the filter or cartridge is afterwards counted using a liquid scintillator or a NaI well counter. For the measurement of tritium, a Johnson Triton air sampler is used. All air sampling surveys are performed by the staff of the Office of Occupational Health and Safety.

9. The Radiation Safety Guide has been extensively revised; two copies of the Fourth Edition dated December, 1979, are enclosed.

We have, since receipt of your letter last July, completed an exhaustive review of our radiation safety program. This activity was, of course, to some extent prompted by your inquiry. Having completed this effort, we admit to the timeliness of your suggestions, and we feel that our program has been strengthened as a result of your initiatives. In responding, we have attempted to deal forthrightly with the concerns addressed in your letter, and you will find that in many instances we adopted the procedures and protocols suggested in the various guidelines and regulatory guides you sent to us. In other instances, it was necessary and sensible to adapt them to better meet the needs and requirements of an academically oriented research program using radioactive materials, generally in small quantities, as tracers, on an intermittent schedule.

We trust that receipt of this information and the enclosed materials will enable you to expeditiously complete your review of our license renewal application. Please feel free to contact me at any time if you have any questions regarding our radiation safety program or the enclosed materials.

Sincerely,

Jack C Faust

Jack C. Faust
Director

JCF/ae

cc: R. M. May
L. A. Pyle, M.D.
A. Sinisgalli
Radiation Safety Committee
File 9.1b

Attachments (in duplicate)
Radiation Safety Guide
Appendix A - OHS Form #12
Appendix B - OHS Form #31

PRINCETON UNIVERSITY

RADIATION SAFETY GUIDE

RULES, REGULATIONS & PROCEDURES

Edited by

the Health Physics Staff

of the

Office of Occupational Health and Safety

and

Approved by

the Radiation Safety Committee

and

the Committee on

Occupational Safety and Health

First Edition June, 1962
Second Edition June, 1965
Third Edition September, 1967
Fourth Edition December, 1979

MASTER REVISION SHEET

This is a permanent record of all revisions which have occurred in the University Radiation Safety Guide. All pages in the University Radiation Safety Guide are dated December 5, 1979, with the exception of the following:

December 7, 1979
15.1, 15.2, 15.3, 15.4, 15.5, 15.6, 15.7

Preface

This Radiation Safety Guide, edited by the Health Physics Staff and approved by the University Radiation Safety Committee and the Committee on Occupational Safety and Health, sets forth the *modus operandi* for all those who want to use any "Source of Radiation" at Princeton University. The Guide is applicable only to ionizing radiations. Guidelines for the safe use of non-ionizing radiation, such as microwaves, lasers, etc., appear in a separate guide entitled, "Safety in the Use of Non-ionizing Electromagnetic Radiation," available from the Office of Occupational Health and Safety.

Most of the rules and regulations included in this Guide are binding on the University and the "Authorized User" by reason of their enactment in government regulations and the University licenses. Every attempt has been made to include in the Guide sufficient information to enable a "User" to comply with the regulations by simply following the Guide. In cases of doubt, the reader is advised to consult the basic regulations or the "Health Physicist." The Guide also contains appendices which provide basic and useful information. Throughout the Guide, the terms "shall" and "must" are used in the obligatory sense; "should" and "may" are used in the permissive sense.

The rules, regulations and procedures described in this Guide are applicable in their entirety to all persons and departments at Princeton University with the exception of the Plasma Physics Laboratory. That Laboratory is a major Department of Energy contractor and as such is not subject to the licensing requirements and other regulations promulgated by the Nuclear Regulatory Commission or the New Jersey State Department of Environmental Protection. Consequently, while the University health and safety policy is applicable to the Plasma Physics Laboratory, much of the detail and most of the procedures described in this guide are not.

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APPENDICES

1. RADIATION SAFETY PROGRAM

A. Introduction

In September 1971 a consolidation and reorganization of the Princeton University safety organization was completed, and a comprehensive, integrated occupational health and safety program established. This was done, in the words of former President Goheen, "... to better carry out the responsibility we [the University] assume to prevent, to the best of our ability, injury and death to students, staff and members of the general public...and to enable the institution to discharge its legal, moral and regulatory obligations more effectively and efficiently." Since radiation safety is an integral part of the University's health and safety program, an understanding of the overall structure and organization is essential to an understanding of the radiation safety program.

The four primary components or elements of the University's safety organization include a University Committee on Occupational Safety and Health, responsible for policy; an Office of Occupational Health and Safety, responsible for monitoring the implementation of the Committee's decisions; a network of "Departmental Health and Safety Coordinators"; and an explicit statement of health and safety policy.

The University Committee on Occupational Safety and Health is appointed by the President and consists of faculty, research staff members, and University administrators and those *ex officio* members necessary for the conduct of the Committee's business. The Committee normally meets several times during the academic year and is responsible for developing health and safety policy, advising the President and monitoring the progress of the health and safety program. A list of the membership is included in Appendix A.

The Office of Occupational Health and Safety is a division of the University's Health Services. Its staff, consisting of health physicists, industrial hygienists, a safety engineer, a sanitarian and supporting clerical and technical staff, functions in an advisory and consultive capacity. They assist the academic and operating departments in the implementation of the health and safety policy and in maintaining compliance with all applicable Federal, State and local health and safety regulations and standards. The health and safety staff provides a variety of services, consultations, evaluations and audits. The Director of the Occupational Health and Safety Office is responsible to the Director of the University Health Services who, in turn, is responsible to the Vice-president for Administrative Affairs. The Director also serves as Executive Secretary for the Committee on Occupational Safety and Health and the Radiation Safety Committee. A list of the senior Occupational Health and Safety staff is included in Appendix A.

The "Departmental Health and Safety Coordinator" is the individual, or individuals, designated by the department chairman or office head, who acts on behalf of the department in health and safety matters. The coordinator is the primary liaison between the department and the Occupational Health and Safety staff and is generally responsible for becoming familiar with departmental activities involving actual or potential hazards. Coordinators in departments using "Sources of Radiation" have additional responsibilities described below. In the absence of an appointed coordinator, health and safety matters are referred directly to the chairman or office head.

The health and safety policy of Princeton University is to provide, to the best of the University's ability, a safe and healthful environment, free from recognizable hazards for students, staff and visitors, and to comply with all applicable safety and health regulations and standards.

B. Radiation Safety Program

1. Policy and Purpose

Princeton University's radiation safety policy is an extension of the previously stated occupational safety and health policy and applies to the use of "Sources of Radiation" in the various teaching, research and operating activities. The purpose of the radiation safety program is to provide a structure and organization which insures continuing implementation of the radiation safety policy throughout the University. The objectives of this program are:

a. to insure control of the possession and use of "Sources of Radiation" in University teaching, research and operating programs to minimize, in so far as practicable, hazards to personnel and property associated with the use of such materials, machines and devices; and,

b. to insure compliance with all Federal, State and local laws covering the use of such materials, machines and devices.

2. Radiation Safety Committee

The Radiation Safety Committee is appointed by the President on recommendation of the Chairman of the Committee on Occupational Safety and Health. It consists of faculty, research staff members, and University administrators, several of whom are knowledgable in the safe use of "Sources of Radiation," and certain *ex officio* members. The Radiation Safety Committee develops and recommends radiation safety policy to its parent committee and monitors the progress and continuity of the radiation safety program. Additionally, and in accordance with the requirements of the various University radioactive materials licenses, the Committee reviews and either approves or denies applications for proposed usage of "Sources of Radiation." Since most of the work of this Committee is done on a continuing basis, formal meetings of the Committee are infrequent, normally one or two per year. A list of the membership is included in Appendix A.

3. Health Physics Section

The "Health Physicists" and supporting technical staff comprise the Health Physics Section of the Office of Occupational Health and Safety. The Head of the Health Physics Section reports to the Director of the Office of Occupational Health and Safety. The "Health Physicists" are listed in Appendix A.

The health physics staff provides a variety of radiation safety services, evaluations and audits, all directed towards assisting the "Authorized User" and his or her department in implementing the radiation safety policy and in controlling exposure to radiation and radioactive materials. The group functions with a strong service orientation, informing the "Authorized User" of his or her obligations and assisting the "User" to anticipate and identify potential radiation safety problems. In carrying out these responsibilities, every reasonable effort is made to relieve the research and operating staffs of as much of the mandated administrative and recordkeeping detail as is possible. In addition, a number of technical measurements and evaluations are made as a service to the "Authorized User." However, it is neither possible nor desirable to relieve the "Authorized User" of the binding responsibility to insure that "Sources of Radiation" under his or her control are used safely and in accordance with all applicable rules and regulations.

4. Health Physics Section Responsibilities

The responsibilities of the Health Physics Section include:

a. administration of the five University licenses

b. control of acquisition of "Sources of Radiation" in accordance with provisions of the various licenses

c. maintenance of all centralized records required by regulation and pertinent to the radiation safety program

d. administration of the centralized personnel monitoring program

e. administration of the centralized radioactive waste program

f. provision of radiation safety consultations and participation in preoperational research planning with faculty, research personnel and support staff

g. inspection and surveys of laboratories and areas where "Sources of Radiation" are used

h. conducting radiation safety training seminars and assisting the "Authorized User" in instructing radiation workers

i. advising and assisting University personnel regarding the shipment of radioactive materials and monitoring all outgoing and certain incoming shipments of radioactive material

j. performing required leak tests for all "Sealed Sources"

k. collection and dissemination of radiation safety information including radioisotope fact sheets, regulatory guides, regulatory changes, health and safety advisories, etc.

l. provision of assistance and advice in all radiation emergencies and supervision of special decontamination operations

m. performing first echelon maintenance and periodic calibration of laboratory survey equipment

n. investigation and analysis of radiation incidents including, for example, spills of radioactive materials, releases, etc., and development of recommendations to prevent reoccurrences

o. auditing the progress and continuity of the radiation safety program

p. developing and refining radiation detection, shielding and health protection techniques

q. when appropriate, representing the University at public hearings concerned with questions of radiation safety

r. provision of advice and assistance to academic,and operating departments for the acquisition of radiation detection and dosimetry equipment

s. provision of assistance in the design of new and renovated laboratories in which "Sources of Radiation" are to be used

t. acting as primary liaison between the University, the "Authorized Users" and the various regulatory agencies and accompanying regulatory personnel during their inspection of any University operation.

5. Radiation Safety Responsibilities of the "Departmental Health and Safety Coordinator"

The role of the "Departmental Health and Safety Coordinator" has been described elsewhere; however, there are two specific responsibilities in those departments where "Sources of Radiation" are used. These include:

a. reviewing and approving or denying applications for authorization for "Sources of Radiation"; and,

b. arranging for the appointment of an alternate coordinator during an extended absence. The Office of Occupational Health and Safety should be notified of all such appointments and the effective dates.

6. Broad License

The existence of a comprehensive University radiation safety program enables the University to hold a Nuclear Regulatory Commission broad byproduct materials license. Under this concept the Nuclear Regulatory Commission delegates its responsibility to license the possession and use of radioactive materials to the University Radiation Safety Committee in accordance with the procedures and guidelines established in this Guide and in the University's license application. This concept has over the years contributed to the effectiveness of the University's radiation safety effort, it is more economical and it provides for more effective control and a higher degree of radiation safety. An internal licensing capability also reduces the time required to obtain an authorization number (license) from months to weeks with obvious benefits to one interested in research.

2. DEFINITIONS

When any of the following defined terms appear in the text of this Guide, their meaning is as defined below, and they appear within quotation marks, and the first letter of each word is capitalized.

A. "Airborne Radioactivity Area"

Any room, enclosure, or operating area in which airborne radioactive materials exist or are likely to exist in concentrations in excess of the amounts specified in Table 1, Column 1 of Appendix B or in which they exist in concentrations which when averaged over the number of hours in any week during which individuals are in the area, exceed 25 percent of the amount specified above.

B. "Authorized User"

The individual who has been authorized (licensed) by the Radiation Safety Committee to possess and use "Sources of Radiation." This includes individuals possessing Authorization Numbers and/or Limited Possession Numbers and individuals authorized to possess and/or use "Radiation Producing Machines and Devices."

C. "Byproduct Material"

Any radioactive material (except "Special Nuclear Material") yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing "Special Nuclear Material."

D. "Departmental Health and Safety Coordinator"

The individual(s), appointed by the department chairman or office head, who is responsible for the departmental health and safety effort and who is the department's primary liaison with the staff of the Office of Occupational Health and Safety.

E. "Generally Licensed Devices"

Devices and equipment into which radioactive materials are built, the distribution of which to the general public is authorized under the terms of a general license, in accordance with 10 CFR Part 31.

F. "Health Physicist"

An individual who, on the basis of professional training and qualifications, is designated by the Director of the Office of Occupational Health and Safety to advise faculty and staff on radiation safety.

G. "High Radiation Area"

Any area, accessible to personnel, in which there exists radiation at such levels that a major portion of the body may receive in any one hour a dose in excess of 100 millirems.

H. "Human Use"

The intentional internal or external administration of radiation or radioactive material to human beings.

NOTE: Any such contemplated use shall first be discussed with the Human Use and Radiation Safety Committees, both of which shall make a recommendation to the University Research Board. In addition, specific licenses for "Human Use" have to be obtained from the Nuclear Regulatory Commission and/or the State of New Jersey.

I. "Limited Possessor"

One who has been issued a Limited Possession Number by the Radiation Safety Committee.

J. "Personnel Monitor Contact"

The individual designated by a department to assist the Office of Occupational Health and Safety staff with the internal administration and logistics of the department's personnel monitoring program.

K. "Principal Investigator"

An individual, holding a faculty or research position, who is immediately responsible for the conduct and the safety of a research project.

L. "Radiation Area"

Any area, accessible to personnel, in which there exists radiation at such levels that a major portion of the body may receive in any hour a dose in excess of five millirems or in any five consecutive days a dose in excess of 100 millirems.

M. "Radiation Producing Machine or Device"

A machine or device capable of generating radiation, such as x-ray producing machines, particle accelerators, high voltage power supplies, electron microscopes, high voltage rectifiers, high voltage projection equipment, and other types of high voltage machines.

In general, each single unit capable of producing radiation must be considered as a separate device; however, at the discretion of the "Health Physicist," a number of units which form an administrative, spatial, or functional entity, and which are combined, modified, and separated during the course of a research program, may be considered one device.

N. "Radiation Worker List"

A list generated and maintained by the Office of Occupational Health and Safety on which the "Authorized User" provides the names and supplemental information for individuals working with "Sources of Radiation" under his or her authorization.

O. "Restricted Area"

Any area, access to which is controlled by the department or "Authorized User" for the purpose of protecting individuals from undue exposure to radiation and radioactive materials.

NOTE: "Restricted Area" includes all "Radiation Areas," "High Radiation Areas," rooms or areas in which there are present radioactive materials in such quantities that "Caution: Radioactive Material" signs are required in accordance with Section 9 of this Guide, and certain other areas which may be so defined by the "Health Physicist."

P. "Sealed Source"

A radioactive material that is permanently bonded or fixed in a capsule or matrix designed to prevent release and dispersal of the radioactive material under the most severe conditions which are likely to be encountered in normal use and handling and which is used in that configuration.

Q. "Source Material"

Uranium or thorium or any combination thereof, in any physical or chemical form; or ores which contain by weight 0.05 percent or more of uranium, thorium, or any combination thereof. "Source Material" does not include "Special Nuclear Material."

R. "Sources of Radiation"

Radioisotopes, radioactivated materials (by irradiation or by exchange processes), "Radiation Producing Machines or Devices," "Generally Licensed Devices," and those quantities of radioisotopes thought of as exempt quantities.

S. "Special Nuclear Material"

Plutonium, uranium-233, uranium enriched in the isotope 233 or in the isotope 235, or any material artificially enriched by any of the foregoing, but does not include "Source Material."

T. "Unrestricted Area"

Any area, access to which is not controlled by the department or the "Authorized User" for the purpose of protecting individuals from exposure to radiation and radioactive material. Areas not owned by the University are unavoidably classified as unrestricted.

U. "User"

A person using "Sources of Radiation" at Princeton University. This includes all "Authorized Users" and all persons using "Sources of Radiation" under the supervision and/or authorization of an "Authorized User."

V. "10 CFR Part 19," "10 CFR Part 20"

A shorthand notation for Parts 19 and 20 of Title 10 of the Code of Federal Regulations. Title 10 contains the regulations issued pursuant to the 1954 Atomic Energy Act and is presently administered by the Nuclear Regulatory Commission. Part 19, entitled "Notices, Instructions, and Reports to Workers; Inspections," and Part 20, entitled "Standards for Protection Against Radiation," are two parts of Title 10. Other parts of general interest include Part 30: "...Domestic Licensing of Byproduct Material," Part 33: "Specific Domestic Licenses of Broad Scope for Byproduct Material," and Part 71: "Packaging of Radioactive Material for Transport and Transportation of Radioactive Material...."

3. RESPONSIBILITY FOR COMPLIANCE WITH UNIVERSITY AND GOVERNMENT RADIATION SAFETY REGULATIONS

A. Ultimate Responsibility

Departmental chairmen and laboratory directors bear the ultimate responsibility for radiation safety, for the enforcement of the recommendations of the Radiation Safety Committee, and for the enforcement of University and government regulations.

B. Responsibilities of the Health Physics Section

The Health Physics Section of the Office of Occupational Health and Safety holds only consulting and advisory roles in relation to the University teaching, research and operational staff. If the "Health Physicist" finds that an improper or hazardous practice or condition exists, he or she shall recommend corrective action to the individuals involved and to the "Authorized User." If the practice or condition remains uncorrected, the "Health Physicist" will discuss the situation with the "Departmental Health and Safety Coordinator," the departmental chairman, and/or the laboratory director. If the practice or condition continues to exist, and the condition is serious, it will be referred to the Radiation Safety Committee and, if need be, other University officials, as appropriate, for action.

C. Committee Attention

Questions relating to radiation safety or matters related to the radiation safety program may be brought before the Radiation Safety Committee by either departmental chairmen or "Authorized Users," or by the Secretary of the Committee who shall entertain suggestions from all interested parties.

D. Government Regulations

1. Federal Law

The use of "Byproduct Material" is subject to the regulations promulgated by the Nuclear Regulatory Commission in "10 CFR Part 19" and "10 CFR Part 20" and 10 CFR Parts 30, 31, 33, and 71. In addition, the use of "Source Material" and "Special Nuclear Material" is subject to the regulations in 10 CFR Parts 40 and 70.

2. State Law

At Princeton University the use of naturally-occurring and accelerator-produced radioactive materials and the use of "Radiation Producing Machines and Devices" are subject to the regulations contained in the New Jersey Radiation Protection Code promulgated in Title 7, Chapter 28 of the New Jersey Administrative Code.

E. License Conditions

Each license issued by the Nuclear Regulatory Commission and the State of New Jersey, under which individuals at Princeton University are authorized to possess or use "Sources of Radiation," contains several conditions to which "Authorized Users" are bound. An "Authorized User" is bound to the conditions of the applicable license.

4. AUTHORIZATION FOR RADIOISOTOPES (INCLUDING ACTIVATED MATERIALS) AND AUTHORIZATION PROCEDURES

A. Authorization

1. All persons planning to possess or use radioisotopes at Princeton University must obtain prior approval of the Radiation Safety Committee and/or the "Health Physicist" for each radioisotope. Persons not qualified for authorization, according to the requirements stated in Section B below, must use radioisotopes only under the supervision of an "Authorized User."

2. The first step to obtain authorization is the filing of an application through the Office of Occupational Health and Safety. Applicants are advised that the application process may take several weeks (or longer if an amendment to a University license must be obtained) and are, therefore, urged to submit their application sufficiently in advance of the planned starting date to avoid delays. The filing of an application sets in motion a procedure which provides for a thorough review of the radiation safety aspects of the proposed usage. The final step in the procedure is the issuance by the Office of Occupational Health and Safety of an Authorization Number or a Limited Possession Number.

3. Temporary Approval

   The "Health Physicist" is authorized by the Committee to grant a temporary approval, if specifically requested, at his or her discretion. Temporary approval is valid for 30 days and is normally issued within 36 hours of receipt of an acceptable completed application.

4. Duration of Authorization

   Each Authorization Number and Limited Possession Number is coterminous with the applicable University license or terminates with the severance from the University of the "Authorized User." In some instances specific expiration dates are established at the request of the "Health Physicist."

5. Revocation

   The Committee has the right and responsibility to revoke any authorization granted by it if, in its opinion, sufficient justification exists for such action.

6. Amendments

   Any change in the use of a radioisotope from that described in the application shall be discussed with the "Health Physicist." Significant changes which could affect radiation safety, such as the use of an open source as opposed to a "Sealed Source," the *in vivo* use of radioisotopes in animals as opposed to *in vitro* work, use of dry powders instead of a less hazardous form, etc., require an amendment. Any such amendments may be approved by the "Health Physicist" except that the "Health Physicist" has the option to refer proposed changes to the Radiation Safety Committee. Increases in the amount of radioisotope authorized for use require a new application.

B. Classes of Authorizations: Description

1. Authorization Numbers

There are two kinds of Authorization Numbers: one for Radioisotopes and one for Activations. They are distinguished as follows:

a. A Radioisotope Authorization Number authorizes possession and use of the requested amount of a specific radioisotope (and its daughters) in accordance with the statements and representations made in the application. Radioisotopes are generally acquired by purchase from a commercial supplier.

b. An Activation Authorization Number authorizes activation of a sample for radioisotope production in an accelerator, reactor, etc.,and subsequent possession and use of the product radioactivities in accordance with the statements and representations made in the application. Several types of activations are recognized and are explained in paragraph 3 below.

c. Only persons who are "Principal Investigators," hold a faculty or research position, and have had significant previous experience with radioisotopes similar to those being requested may apply for an Authorization Number. Upon recommendation of the "Health Physicist" the requirement for a faculty or research position may be waived when the applicant has had extensive radioisotope experience.

d. The amount of radioactive material and the scope of work permitted under an Authorization Number is, in general, limited by the terms and conditions of the relevant University license.

2. Limited Possession Numbers

a. A Limited Possession Number is a restricted or limited Authorization Number. The scope of the activities permitted and the required qualifications of the applicant differ in the following ways:

1) The applicant does not have to meet the qualifications established for a "Principal Investigator." Less emphasis is placed on previous experience with "Sources of Radiation." Therefore, the scope of work permitted is restricted.

2) The maximum amount of radioactivity authorized for use by an individual holding a Limited Possession Number is limited to 100 times the amount listed in column A of Appendix C of a single radioisotope or the equivalent prorated quantity of several as illustrated in the footnote to Appendix C, except that the total amount for any radioisotope may not exceed 15 mCi. However, persons holding at least one valid Authorization Number and therefore meeting the qualifications of a "Principal Investigator" may hold an unlimited number of Limited Possession Numbers, provided no single quantity authorized exceeds the amount described above for a single radioisotope.

3) Limited Possession Numbers are issued at the discretion of the "Health Physicist" and without Committee review, although the Committee is periodically informed of all new Limited Possession Numbers issued. The "Health Physicist" may, at his or her discretion, elect to require full Committee review.

b. Limited Possession Numbers are also issued to authorize possession of "Generally Licensed Devices," such as smoke detector heads, spark gaps, thickness gauges, etc., which contain radioactive material. The licenses for all such devices have general requirements, the specifics of which are dealt with in the application process.

3. Categories of Activation Authorizations

a. An "onsite-internal" activation for radioisotope production is one performed at a University facility by and for University personnel and their collaborators. Persons desiring authorization must obtain an Activation Authorization Number.

There is also the case of "onsite-internal" irradiations not performed for the specific purpose of radionuclide production which may cause the incidental activation of target holders, machine components, shielding, etc., e.g. target irradiations to produce secondary particle beams. The irradiation may be arranged at the discretion of the "Authorized User" responsible for the facility, and no Authorization Number is issued, provided the irradiation meets the following criteria:

1) it is performed with the active participation of an individual associated on a full-time basis with the

University facility at which the irradiation is done; and,

2) no activated material will leave the facility in which the material was incidentally produced.

The "Authorized User" may, however, request a review of the proposed irradiation by the "Health Physicist" and the Radiation Safety Committee. The "Authorized User" has the responsibility for radiation safety, including the inventory and management of any radioactive materials produced.

b. An "onsite-external" activation is one performed at a Princeton University facility to produce radioactive materials used by non-University personnel at either an on- or off-campus location. Regardless of where the material is ultimately taken, any person desiring such an activation must file an application for an Authorization Number with the Radiation Safety Committee through the Office of Occupational Health and Safety.

If the proposed use includes any transport of the activated material outside the facility at which it was produced, a formal agreement (part of the application procedure) must be executed by a duly authorized representative of the applicant's organization. Certain conditions regarding such activations have been established by the New Jersey Bureau of Radiation Protection. These are:

1) The person desiring the activation must demonstrate to the Office of Occupational Health and Safety that his or her organization is duly authorized to possess and use the requested materials under the provisions of an appropriate government license.

2) The "Health Physicist" is responsible for reporting the transfer on the next monthly radioisotope inventory and State Report, indicating the amount of activity, and the date of transfer, the recipient, and the address of organization.

c. An "offsite" activation is one performed for Princeton University personnel at an off-campus facility not owned or operated by the University when the resulting radioactivity, however small or purified, is to be brought on campus. Persons desiring such an activation must obtain an Activation Authorization Number.

C. How To Apply for Authorization

1. Obtain the necessary forms from the Office of Occupational

Health and Safety and discuss the proposed work with the "Departmental Health and Safety Coordinator" and the "Health Physicist."

2. Complete the forms, making sure that they are consistent with the guidelines given in Section B above for Authorization Numbers or Limited Possession Numbers. Please type or print in black ink.

3. Consult with the "Health Physicist" to review the proposal and to obtain any assistance needed to complete the application.

4. Sign the completed application and obtain the signature of the "Departmental Health and Safety Coordinator" (or in his or her absence the signature of the department chairman). Forward the completed application to the Office of Occupational Health and Safety.

D. Processing and Review of Applications for Authorization

1. Authorization Numbers

Upon receipt of a completed application:

a. The "Health Physicist" reviews the application, interviews the applicant, inspects the proposed facilities, and, on the basis of the information obtained, recommends either that the application be approved, conditionally approved, or denied. At this time, if requested, the thirty day temporary approval will be considered.

b. Copies of the application with the "Health Physicist's" recommendations regarding approval or denial, any conditions suggested by the "Health Physicist," and all supporting documentation are sent to the Radiation Safety Committee.

c. Each member of the Committee reviews the application and may approve, conditionally approve, or deny it. Since an application must be unanimously approved by all available Committee members, a reasonable attempt is made to remove any objections and resolve any concerns. Committee members are urged to discuss with the "Health Physicist" and the applicant any conditions they wish to impose and objections which could lead to a denial before making a final decision. The Committee members sign the application, annotating it with any comments or conditions, and return it to the Office of Occupational Health and Safety. Denials must be specifically indicated.

d. Following final processing and review of the application, the applicant is notified by memo that the application has been approved and authorization granted. A copy is sent to the Chairman of the Radiation Safety Committee and "Departmental Health and Safety Coordinator." This memo indicates the Authorization Number that has been assigned, the relevant University license, and any conditions or other pertinent information. A copy of the application and all supporting documentation is also returned to the "Authorized User."

e. If the application is denied, a copy of it and all supporting documentation is returned to the applicant, indicating the reasons for denial. The applicant may appeal the decision at a special meeting of the Radiation Safety Committee, requested through the Secretary of the Committee.

2. Limited Possession Numbers

The procedure followed for a Limited Possession Number is the same as that for an Authorization Number except that:

a. The application and supporting documentation is not distributed to the Radiation Safety Committee and the Committee does not review the application.

b. The Committee is notified of all Limited Possession Numbers issued by the "Health Physicist."

5. AUTHORIZATION AND REGISTRATION FOR "RADIATION PRODUCING MACHINES AND DEVICES"

Authorization to use "Radiation Producing Machines and Devices" is handled similarly to that for radioisotopes. However, there are substantial inherent differences which arise from such factors as the length and uncertainties of the acquisition process and the complexity of installation. These result in the continuing involvement of the "Health Physicist" with the individual acquiring the machine or device, culminating in a final authorization after the machine or device has been installed and tested. The procedures which follow have been devised to take into account these differences and to allow some flexibility in the process.

A. Approval

All persons planning to possess or use "Radiation Producing Machines or Devices" must first consult with and obtain the approval of the "Health Physicist" before purchasing, accepting, or receiving as a gift any such machine or device.

B. Authorization Procedure

The procedure for obtaining authorization to use "Radiation Producing Machines and Devices" is handled as follows:

1. Prior to the acquisition of such a machine, the individual who will be responsible for the machine or device must consult with the "Health Physicist."

2. The "Health Physicist" reviews with the individual the intended use, the safety specifications of the machine or device, the rules and regulations pertaining to the operation of the machine or device, and other aspects of radiation safety.

3. On the basis of the information obtained during the discussions, the "Health Physicist" issues an initial authorization which permits acquisition to proceed. The initial authorization takes the form of a memo to the individual which states that acquisition of the machine or device is approved and which details the conditions, if any, under which acquisition is authorized.

4. The individual notifies the Office of Occupational Health and Safety when the machine or device arrives so that he or she may review plans for installation with the "Health Physicist." At this time such factors as the adequacy of shielding, direction of the beam, and occupancy of adjoining areas are considered.

5. Final authorization to use the machine or device is given by the "Health Physicist" after compliance with the appropriate regulations has been demonstrated and after initial radiation surveys have demonstrated that the machine or device can be operated safely. At the discretion of the "Health Physicist," final authorization to use the machine or device may be referred to the Radiation Safety Committee.

6. Authorization for a machine or device constructed at the University follows the procedures given above except that contact between the responsible individual and the "Health Physicist" is more continuous and extensive.

C. State Registration

Every "Radiation Producing Machine or Device," with the exceptions noted below, must be registered with the State of New Jersey's Bureau of Radiation Protection within 15 days of its initial installation. Electrical equipment, not primarily intended to produce radiation, which generates radiation levels of 0.5 mrem/hour or less at 5 cm from any readily accessible surface and machines or devices in storage do not need to be registered. The registration process is performed by the Office of Occupational Health and Safety which maintains the centralized records. An initial registration fee and an annual fee are assessed by the State for each registered "Radiation Producing Machine and Device" and are ultimately paid by the department and/or "Authorized User." The Office of Occupational Health and Safety must also be notified when a machine or device is disassembled, taken out of service, sold, transferred, or discarded so that the State can be notified.

D. Requirements

The requirements for labelling, warning signs, procedures, and dose limits for "Radiation Producing Machines and Devices" are given in Section 16.

E. Purchase Orders

Under a formal agreement between the Purchasing Department and the Office of Occupational Health and Safety, requisitions for the purchase of x-ray diffraction machines, electron microscopes, and other types of "Radiation Producing Machines and Devices" are forwarded to the Office of Occupational Health and Safety for approval. Because there may be requirements and State specifications of which the purchaser is unaware, it is in the purchaser's best interest to confer with the "Health Physicist" before a price quotation or delivery date is requested.

F. Changes in Responsibility or Location

The Office of Occupational Health and Safety must be promptly notified of changes in responsibility for and location of such machines or devices.

6. THE "AUTHORIZED USER'S" RESPONSIBILITIES

A. Acquisition of Authorization

Before any person can begin work with "Sources of Radiation," he or she must satisfy the Radiation Safety Committee and/or the "Health Physicist" through the authorization process that he or she is qualified by training and experience and that the laboratory is properly equipped to handle them safely. Persons not meeting the requirements for authorization must work with "Sources of Radiation" only under the supervision of an "Authorized User."

B. Supervisory Responsibility

The "Authorized User" assumes responsibility for the actions of those persons using "Sources of Radiation" under his or her supervision.

C. Familiarity with Radiation Safety Guide

The "Authorized User" shall become acquainted and comply with the Radiation Safety Guide and shall insure that other persons under his or her supervision also are acquainted and comply with this Guide. The Radiation Safety Guide must, at all times, be available to these persons.

D. Compliance with Government Regulations

The "Authorized User" shall become acquainted and comply with all applicable government regulations and shall insure that all persons under his or her supervision also are acquainted and comply with them.

E. Radiation Safety

The acceptance of an authorization obligates the "Authorized User" to insure radiation safety to him or herself, to all others who can be affected by the presence or use of his or her "Sources of Radiation," and to University property. Prior to short absences the "Authorized User" shall appoint a specific individual to be responsible for radiation safety in his or her absence. An extended absence of the "Authorized User" necessitates a change in responsibility which, in general, means that another individual must obtain the necessary authorization.

F. Records

"Authorized Users" are obligated to maintain certain records. These include those items needed for orderly management of the laboratory such as receipt, use, transfer and disposal records. The "Authorized User" should also keep those records needed to demonstrate an adequate level of radiation safety, such as survey records.

G. Survey Instruments

The "Authorized User" shall acquire or have available and shall maintain survey instruments appropriate for the radiation in use.

H. Reporting of Incidents

The "Authorized User" shall report to the Office of Occupational Health and Safety any loss or theft, incident, accident, major spill, etc.,involving "Sources of Radiation." Such incidents are normally discussed with the Radiation Safety Committee by the "Health Physicist."

I. Training and Orientation of Personnel

The "Authorized User" is responsible to insure that persons using radioisotopes under the provisions of his or her authorization are aware of the hazards associated with the use of "Sources of Radiation," are adequately trained in safe handling techniques and procedures, and are familiar with the appropriate regulations and all appropriate University license conditions including the Radiation Safety Guide.

The Office of Occupational Health and Safety provides a training program which meets these requirements. Unless the "Authorized User" is prepared to provide training determined to be equivalent by the Office of Occupational Health and Safety, then he or she must insure that undergraduate and graduate students and technical staff periodically attend the training program offered by the Health Physics Section. These individuals must attend an initial training session and are encouraged to attend a refresher session once a year. In any event, they must attend a refresher session at least every two years.

Participation in the Health Physics Section training program by members of the post-doctoral research staff is left to the discretion of the "Authorized User." Participation in the program by post-doctoral research staff and faculty is encouraged.

J. "Radiation Worker List"

The "Authorized User" is responsible for reporting the names of all radiation workers under his or her supervision to the Office of Occupational Health and Safety so that essential radiation safety services, such as personnel monitoring, bioassay services, radiation safety training, prenatal exposure information for women, and special services, are provided for these workers.

To this end the Office of Occupational Health and Safety sends to each "Authorized User," three times a year, a "Radiation Worker List" update to which names can be added or deleted. However, an "Authorized User" should report changes in laboratory personnel immediately, without waiting for the arrival of the "Radiation

Worker List" update, so that the essential services can be provided most efficiently.

K. Exposure Control

The "Authorized User" has the responsibility to control work assignments and to insure that work is carried out in such a manner that the radiation dose to any person from external "Sources of Radiation" and internally deposited radionuclides under his or her control does not exceed the dose limits listed in Appendix D.

L. Emergency Response

The "Authorized User" is responsible for establishing radiation emergency procedures appropriate to the activities in his or her laboratory, and is responsible to insure that all individuals under his or her supervision are familiar with these procedures and those described in OHS Form #12 and in Section 17 of this Guide. Section 17 provides guidelines which may be useful in formulating emergency procedures for some of the common types of radiation emergencies.

M. Terminations

In the event that an "Authorized User" severs his or her association with the University or discontinues work with "Sources of Radiation," he or she shall inform the Office of Occupational Health and Safety, shall insure that proper and safe disposal and/or transfer of "Sources of Radiation" is affected, and shall insure that his or her facility is left in a radiologically safe condition.

7. RADIOISOTOPE ACQUISITION

A. Purchase

Radioisotopes may be purchased by any "Authorized User" with authorization for the specific radioisotope being ordered; the quantity of the order must be such that the amount ordered when added to the amount present in the "Authorized User's" current inventory (including wastes on hand) does not exceed the authorized possession limit.

1. Purchase Requisitions

   All requisitions for radioisotopes must have the explicit approval of the Office of Occupational Health and Safety before they can be processed by the Purchasing Department. Purchase requisitions are completed and processed as follows:

   a. The "Authorized User" completes the purchase requisition, making certain that the quantity and the radioisotope are clearly indicated, and includes the appropriate Authorization or Limited Possession Number and his or her signature. A designated representative of the "Authorized User" may sign requisitions only if the Office of Occupational Health and Safety has been notified in writing by the "Authorized User" that the individual is so permitted.

   b. The "Authorized User" must become familiar with the arrangement for processing purchase requisitions within his or her department, since departmental ordering procedures vary.

   c. Following internal handling of the requisition, the blue copy of the requisition is sent to the Office of Occupational Health and Safety who verifies that, the "Authorized User" is authorized for that radioisotope and the possession limit is not exceeded. The approved requisition is then sent to the Purchasing Department.

2. Phone Orders

   Orders which must be expedited are placed in the following manner:

   a. The "Authorized User" or designated representative phones the Purchasing Department, providing the buyer with all the necessary information about the order.

   b. The "Authorized User" or designated representative phones the Office of Occupational Health and Safety, providing the name of the "Authorized User," the name of the caller (if not the "Authorized User"), the radioisotope, and the quantity to be ordered.

c. The Office of Occupational Health and Safety verifies authorization for the radioisotope and checks that the possession limit is not exceeded. The Office of Occupational Health and Safety phones the Purchasing Department to verbally approve or disapprove the order. The Purchasing Department will phone the order to the vendor only after approval of the order by the Office of Occupational Health and Safety has been received.

d. The "Authorized User" or designated representative completes a purchase requisition as described in paragraph 1.a above, clearly indicating that "this order is a confirmation of a phone order placed on (fill in the specific date)."

e. The process is completed as described in paragraphs 1.b and 1.c above.

B. Loans and Transfers

Loans and transfers of radioisotopes are permitted only to "Authorized Users." The Office of Occupational Health and Safety must be notified when transfers are made of such size that inventory and control procedures or health and safety considerations are affected. Off-campus transfers must have the prior approval of the Office of Occupational Health and Safety, and written approval of the recipient organization must be provided to the Office of Occupational Health and Safety.

8. RECEIPT AND OPENING OF PACKAGES CONTAINING RADIOISOTOPES

A. Requirements

Paragraph 20.205 of "10 CFR Part 20" places certain requirements on the recipients of packages containing radioactive material. These requirements, which are primarily designed to cause the detection of leaking packages and packages with excess radiation levels, include the leak testing of certain packages and the monitoring of radiation levels for other packages within a specified time after receipt. The "Authorized User" is responsible to see that these requirements are met. However, the Office of Occupational Health and Safety assists the "Authorized User" in meeting these requirements by setting up a procedure in which, after notification by the "Authorized User" of a package receipt, the Office of Occupational Health and Safety monitors the package and keeps the required records. Paragraph B describes the categories of packages for which monitoring is required and details the procedure to be followed after the receipt of such packages.

The majority of packages containing radioactive material received at the University do not require the monitoring specified by regulation, but there are procedures which should be followed whenever any such package arrives. These procedures are provided in Paragraph C.

B. Package Categories and Monitoring Requirements

1. Categories of Packages

   a. "Monitoring exempt" packages are those which do not require leak testing or radiation surveys after receipt. They are described as follows:

      1) Packages containing no more than 10 mCi of radioactive material consisting solely of tritium, carbon-14, sulfur-35, or iodine-125

      2) Packages containing only radioisotopes with half-lives of less than 30 days and a total quantity of 100 mCi or less

      3) Packages containing only radioactive material as gases or in "special form "*

      4) Packages containing the following:

         a) 0.01 mCi or less of transuranium radioisotopes and certain isotopes of actin-

*"special form" refers to radioactive material which is solid or encapsulated and so designed that the radioactivity is not released under a series of rigorous tests which are described in 10 CFR Part 71.

ium, protactinium, radium, uranium, and thorium. The "Health Physicist" should be consulted for specific information.

b) 0.1 mCi or less of certain isotopes of argon, barium, bismuth, europium, krypton, lead, protactinium, radium, radon, strontium, thorium, uranium, and xenon. The "Health Physicist" should be consulted for details.

c) 1 mCi or less of all other radioisotopes

5) Packages containing only radioactive material in other than liquid form and not containing more than 1 mCi of the radioisotopes listed in 4.a above, 50 mCi of the radioisotopes listed in 4.b above, or 3 Ci of all other radioisotopes.

b. The following table lists the "monitoring exempt" package quantities for the radioisotopes most commonly received at the University, assuming the package contains liquid, as is the usual case.

Radioisotope	"Monitoring Exempt" Quantity (mCi)
Carbon-14	10
Chromium-51	100
Cobalt-60	1
Iodine-125	10
Manganese-54	1
Mercury-203	1
Phosphorus-32	100
Sulfur-35	10
Tritium	10

Questions about other cases and radioisotopes should be referred to the "Health Physicist."

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c. "Monitoring required" packages are all packages which do not meet the requirements for "monitoring exempt" packages. Leak testing is required for all such packages, and radiation surveys are required for certain of these.

2. Procedure for Receipt of "Monitoring Required" Packages

a. The "Authorized User" is advised by the Office of Occupational Health and Safety when a purchase order is placed that the package will require monitoring by the Office of Occupational Health and Safety upon receipt.

b. The "Authorized User" must notify the Office of Occupational Health and Safety when the package arrives so that the package can be monitored within the required period of time. That period of time is within 3 hours of receipt normally or within 18 hours of receipt if the package arrives after normal working hours.

c. The monitoring is performed by the Office of Occupational Health and Safety. The package must not be opened beforehand.

C. General Procedures for Opening Packages

1. Reports of damaged or leaking packages must be made promptly to the Office of Occupational Health and Safety. The "Health Physicist" reports the receipt of damaged or leaking packages to the appropriate regulatory agency.

2. Do not allow yourself to be enticed by the vendor into returning a damaged or incorrect shipment unless you are certain that the item can be returned safely and legally. It is not recommended that a practice be made of returning damaged or incorrect shipments of radioactive material. However, their return is possible under certain conditions. Packages that have been opened or damaged must not be returned without prior consultation with the "Health Physicist" to determine whether or not the return shipment can be made legally. The "Health Physicist" should also be consulted prior to the return of unopened packages to advise on the legal requirements of the return.

3. The opening of packages must be done only in a properly equipped laboratory and by the "Authorized User" or by an adequately trained individual designated by the "Authorized User."

4. The opening of packages should be done in a fume hood, and full use should be made of protective clothing and protective equipment such as shields, tongs, etc.

5. Before any attempt is made to open a package, the packing list, which is usually attached to the exterior of the package, should be reviewed to verify that the order's radioisotope content, quantity, and chemical compositon are correct. Errors with respect to these items sometimes occur, and it is easier to return an unopened package. If the package is unfamiliar, seek out any special opening instructions.

6. The exterior of the package should be leak tested by using an absorbent material to wipe the surface and counting the material for radioactivity. As the package is opened, each successive layer of packing material should be leak tested, if practical. Significant removable contamination should be reported to the Office of Occupational Health and Safety. Removable contamination on the outer surface of the package in excess of 0.01 μCi per 100 cm^2 must be reported immediately to the Office of Occupational Health and Safety.

7. Radiation levels at the outer surface of the package should be measured, and instances of unusual or excessive dose rates should be reported to the Office of Occupational Health and Safety. Dose rates in excess of 200 mrem/hour at the package surface and 10 mrem/hour 3 feet from the package surface must be reported immediately to the Office of Occupational Health and Safety. Measurements of radiation levels for even those packages for which external radiation is not expected, such as tritium, may reveal the occasional package which contains the wrong radioisotopes.

8. If the packing slip was packed inside the outer package, verify that the contents of the package are correct as ordered before opening any inner container. Remove the inner container and verify the contents as labelled against the packing slip, checking for radioisotope content, quantity, specific activity, chemical composition, and physical form.

9. Determine the dose rate from the inner container and take appropriate precautions. Supply additional shielding as needed.

10. Leak test the inner container for gross contamination, making certain to check for broken seals, breakage, loss of contents, or change in color of the absorbent material around the container.

11. Dispose of unneeded contaminated packing materials as radioactive waste.

12. Deface or remove radioactive material labels on any empty, uncontaminated package before placing the package in the nonradioactive waste. If a package has been established to be uncontaminated, cost considerations indicate that the package should be discarded as ordinary trash.

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D. After Hours Receipt

The receipt of packages containing radioactive materials after hours, i.e., after receiving areas have closed for the day or weekend, rarely occurs, and arranging for their receipt at such times is not encouraged. "Authorized Users" and the Purchasing Department should provide the radioisotope supplier with the operating hours of the receiving room to which the package is to be sent and should instruct the supplier to have the shipment arrive during these hours. It is possible that, due to inclement weather, a late delivery, or other unforeseen circumstances, a package may be received after hours. To properly handle such situations the following procedures have been established with the Security Department, which, on occasion, may be asked to accept such packages.

1. If a "User" becomes aware that a shipment will arrive late and it is important that the materials be received that same day, he or she should contact the Office of Occupational Health and Safety and the Security Department at its non-emergency telephone number and provide the following information:

   a. The name of the radioisotope supplier

   b. The name of the delivery service, if known

   c. The name of the individual to whom the package is addressed

   d. The telephone number(s) where that individual can be contacted when the package arrives

   e. Specific instructions on handling the package

   f. The radioisotope and quantity.

2. In the event a package containing radioactive materials is delivered to the Security Office, ragardless of whether the package's arrival was expected, the Security Department will make every reasonable effort to contact the "Health Physicist" and the individual to whom the package is addressed.

3. The "User" to whom the package is addressed or the "Authorized User," if the addressee is not available, is responsible to remove the package from the Security Office at the earliest possible time.

E. Other Requirements

Paragraph 20.205 of "10 CFR Part 20" specifies other requirements, such as arrangements for the receipt of packages containing very large amounts of radioactivity. Such packages are not normally received at the University, and the "Health Physicist" will discuss any special requirements for the receipt and handling of unusual packages during the authorization procedure.

9. POSTING, LABELLING, TAGGING, AND SIGNALLING REQUIREMENTS

A. Posting Requirements

By regulation each laboratory using "Sources of Radiation" must have posted or otherwise readily available (except as noted below by an asterisk) the following items:

1. "10 CFR Part 19," "10 CFR Part 20," as amended, 10 CFR parts 30, 33, and 71, as amended, and 10 CFR Part 31, when appropriate
2. Princeton University Radiation Safety Guide
3. NRC Broad License #29-05185-24, as amended, when appropriate

*4. Form NRC-3, "Notice to Employees," must be posted. Contract areas must also post Form DOE-9, "Notice to Employees "

5. Laboratories where "Source Material" is used must also have 10 CFR Part 40 and NRC license SUD #381
6. Laboratories where "Special Nuclear Material" is used must also have 10 CFR Part 70 and NRC License SNM #356
7. Laboratories where materials or equipment licensed by the State of New Jersey are present:

   a. New Jersey Radiation Protection Code, as amended

   b. New Jersey Broad License #80066, if appropriate

   *c. Form BRP-D14, "Notice to Employees," must be posted

*8. OHS Form #12, "Accident Procedures and Emergency Phone Numbers," must be posted

9. OHS Form #31, "Emergency Information."

B. Design Specifications

All signs, labels, tags, and signals used to indicate the presence of "Sources of Radiation" must conform with "10 CFR Part 20" or the New Jersey Radiation Protection Code, as appropriate.

Caution: Some commercially available items may not meet specifications.

C. Posting of Radiation Areas

1. Each "Radiation Area" as defined in Section 2 shall be con-

*These items must be posted in a conspicuous place where they will be seen by all persons working in or frequenting a "Restricted Area."

spicuously posted with a sign or signs bearing the radiation symbol and the words:

CAUTION

RADIATION AREA

2. Each "High Radiation Area" as defined in Section 2 shall be conspicuously posted with a sign or signs bearing the radiation symbol and the words:

CAUTION

HIGH RADIATION AREA

NOTE: Access to "High Radiation Areas" shall be interlocked in such a manner that: 1) the radiation level is reduced to the point that the person(s) entering the area shall absorb less than 100 mrem/hour, or 2) a visible and/or audible signal shall make the individual and the supervisor of the activity (experiment, radiation producing machine, etc.) aware of the entry and the existing danger, or 3) the area shall be maintained locked except during periods when access to the area is required, with positive control over each entry.

An area established as a "High Radiation Area" for less than 30 days must be posted but requires only direct surveillance to prevent unauthorized entry.

3. Each "Airborne Radioactivity Area" as defined in Section 2 shall be conspicuously posted with a sign or signs bearing the radiation symbol and the words:

CAUTION

AIRBORNE RADIOACTIVITY AREA

D. Posting of Areas Containing Radioactive Materials

Each entrance to areas or rooms in which radioactive material is used or stored in an amount greater than 10 times that listed in column A of Appendix C (except that the amount for natural uranium or thorium is 100 times that given in Appendix C), shall bear a durable, clearly visible label bearing the radiation symbol and the words:

CAUTION

RADIOACTIVE MATERIAL

E. Labelling of Equipment and Containers

1. Any equipment (vaults, refrigerator, etc.) or container in which radioactive material is stored or used, in an amount greater than that listed in column A of Appendix C (except that the amount for natural uranium or thorium is ten times that given in Appendix C), shall bear a durable, clearly visible label bearing the radiation symbol and the words:

   CAUTION

   RADIOACTIVE MATERIAL

   This label shall, when practicable, also identify the radioisotope, the amount in Curie units, and the date of assay.

   The outside of a shielded container must also bear this label as well as the inner container.

2. Labels are not required on laboratory containers such as beakers, flasks, test tubes, etc.,used transiently in laboratory procedures under supervision or if the concentration of the radioactive material in the container does not exceed that specified in Table I, Appendix B.

F. Tagging of "Sealed Sources"

All "Sealed Sources" shall bear a durable, legible and visible tag permanently attached to the source. The tag shall be at least one inch square, shall bear the standard radiation symbol and at least the following:

CAUTION - RADIOACTIVE MATERIAL - DO NOT HANDLE

NOTIFY CIVIL AUTHORITIES IF FOUND

NOTE: Properly designed tags are available from the Office of Occupational Health and Safety. If tagging is not feasible or desirable due to source design, properly inscribed pressure-sensitive tape is also available.

G. "Radiation Producing Machines and Devices"

There are special requirements for labels, signs, and signals for "Radiation Producing Machines and Devices." The details are found in Section 16.

10. LABORATORY PROCEDURES FOR RADIOISOTOPES

A. Radioisotope Inventory

In each laboratory a Radioisotope Inventory Log shall be maintained, containing an inventory of radioisotopes, noting element and mass number, date received, amount received, dates of withdrawal for use and amount withdrawn, date of disposal of waste, manner of disposal, and estimated amount of waste. In short, a continual record must be maintained from receipt to disposal or decay.

The maintenance of an inventory of target activity levels for the targets which are routinely activated and investigated at the Jadwin Cyclotron is difficult because of the broad spectrum of activities and activity levels met in these targets. However, it is possible to estimate activity levels or to express the data in mr/hour at some specified distance. It is necessary that a record be kept indicating the disposition of these materials.

B. Reports

At present, two monthly reports must be filed by the "Authorized User" with the Office of Occupational Health and Safety: an inventory of radioisotopes on hand and a summary of radioisotope disposals. The State of New Jersey requires that all radioactive materials be registered, but the Office of Occupational Health and Safety has negotiated an agreement whereby the State will accept a periodic inventory report in lieu of the radioisotope registration requirement. The Office of Occupational Health and Safety collects and collates the inventory data from all "Authorized Users" and files the required State report. The "Authorized User's" inventory report (using OHS form #5) is filed with the Office of Occupational Health and Safety no later than the eighth day of each month and identifies all radioactive material on hand, including wastes. The forms for these reports are available from the Office of Occupational Health and Safety.

C. Survey Equipment

A person using open or "Sealed Sources," opening packages containing radioisotopes, or performing physical or chemical manipulation of radioisotopes must have immediately available a suitable, operative radiation detector. This detector must be able to indicate either dose rate or activity as may be proper considering the nature and activity of the source.

D. Operational Surveys

In addition to the routine surveys made by the Office of Occupational Health and Safety, laboratory personnel shall conduct surveys. The purpose of these surveys is to gauge the exposure to radiation of workers performing a particular procedure and to spot check for possible areas of contamination. During any procedure in which significant radiation levels may occur, a radiation level survey should be made. After any procedure in which the possibility of contamination exists, spot checks for contamination shall be made. A record of such surveys should be kept even if the findings are negative; the entries need not be elaborate.

E. Personal Surveys

Following the physical or chemical manipulation of radioisotopes, thorough checks of one's person and clothing for contamination should be made.

F. Smoking and Eating Restrictions

Smoking, eating and drinking in radioisotope laboratories is not permitted. Food shall not be placed or stored in any equipment such as refrigerators, freezers or ovens in which radioisotopes are stored or used.

G. Protective Clothing

Protective clothing, including gloves and a lab coat, should be worn at all times for work with open radioactive sources, but gloves and laboratory clothing must be worn when handling 20 or more times the quantities given in column A of Appendix C. It is especially important to wear gloves whenever high specific activity material is used. Protective shoe covers may also be needed during particularly messy operations, such as the cleaning of contaminated areas and equipment.

Since shoes do provide protection for the feet, the wearing of sandals or other open-toed shoes during radioisotope work is strongly discouraged.

H. Inhouse Movement of Radioisotopes

Radioisotopes moved within a building should be moved in such a way that no radioactive material can be readily released from its container under normal conditions and with sufficient forethought to minimize the spillage of radioactive material. The inner container must be marked "RADIOACTIVE" during transport and shielding must be provided as needed. Radioactive material may not be left unattended during transit. These precautions become especially important when radioactive material is moved through unrestricted areas.

NOTE: Section 14 describes requirements for the intracampus and off-campus transportation and shipment of radioactive materials.

I. Fume Hoods and Glove Boxes

Experiments involving the use of open radioactive sources which could result in airborne radioactivity should be carried out in fume hoods or glove boxes. Because even ordinary laboratory manipulations can result in the release of airborne radioactivity, all "Users" are strongly urged to use a chemical fume hood or glove box for any physical or chemical manipulation of radioisotopes.

Any use of a biological safety cabinet for radioactive materials should be discussed beforehand with the "Health Physicist." Biological safety cabinets may not be suitable, for instance, for volatile substances such as radioiodine, since in many cases some air from the cabinet is exhausted to the room.

Except as noted below, hoods for radioisotope work must have an average face velocity of at least 50 linear feet per minute. Experiments involving alpha-emitting radioisotopes and radioiodines must be performed in hoods with an average face velocity of at least 95 linear feet per minute. Hood and glove box surfaces should be protected to prevent contamination of fixed surfaces that may be difficult to decontaminate.

In consideration of University maintenance personnel who may be called to repair possibly contaminated hoods, all hoods which have been used for radioisotope work are labelled by the Office of Occupational Health and Safety, "This hood used for Radioactive Material." Any "User" who wishes to use an unlabelled hood for radioisotope work should obtain the proper label from the Office of Occupational Health and Safety.

J. Airborne Radioactivity

For experiments that may result in the release of airborne radioactive material, a routine air sampling and bioassay program may be required. No operation may be planned and performed that will knowingly result in the release of airborne radioactivity in excess of the permissible levels given in Appendix B.

Caution: It should be remembered that the use of volatile or powdered radioisotopes may result in significant airborne concentrations of radioactive material.

K. Pipetting

Mouth pipetting of radioactive material is prohibited.

L. Dummy Runs

Work which requires extensive physical and/or chemical manipulation of radioisotopes should not be performed with radioactive material until the techniques, procedures, and equipment have been tested in a "dummy" or trial run.

M. Working Surfaces

All work involving physical or chemical manipulation of open radioactive sources shall be performed directly on work surfaces suitable for containment of contamination and easy decontamination. The lining of work surfaces with plastic backed absorbent paper has been found to reduce the spread of contamination.

N. Labelling

Although labelling of equipment and containers is required only under certain conditions (see Section 9), it is good practice to label all contaminated objects and work surfaces to indicate the presence of radioactive material. Such labelling reduces confusion and prevents others from unsuspectingly using contaminated equipment.

O. Opening of Shipments

The opening of shipments of radioisotopes must be done in a properly equipped laboratory and only by the "Authorized User" or by an adequately trained individual designated by the "Authorized User." Additional details are found in Section 8.

P. Security

Access to "Restricted Areas" must be controlled, and visitors should be supervised by a responsible member of the laboratory. Radioisotopes shall not be left unattended in places where unauthorized persons may have access to them. Unoccupied laboratories in which radioactive material is stored shall be locked or otherwise secured to prevent its removal.

Radioactive materials stored in an "Unrestricted Area" must be secured from removal by unauthorized persons, and radioactive materials in use in an "Unrestricted Area" must be under reasonably constant surveillance.

Q. Special Equipment and Requirements

In cases where the use of radioactive material presents unique or unusual hazards, special radiation safety equipment, precautions, and procedures may be required as determined in consultation with the "Health Physicist." These might include specialized shielding and equipment, clothing, monitoring equipment, etc. Such requirements are generally made conditions of approval for authorization.

R. Animal Use and Care

The use and care of animals used for *in vivo* experiments with radioisotopes must be done in compliance with the provisions of the 1970 Animal Welfare Act and University policy, as determined by the Animal Care Subcommittee of the University Research Board. In addition to those requirements, consideration must be given to the special problems of animal waste collection, the disposal of carcasses, airborne radioactivity resulting from exhaled radioactive materials, and the cleaning and decontamination of cages. Required precautions, as determined by the "Health Physicist," are generally made conditions of approval for authorization.

11. EXTERNAL DOSE CONTROL AND PERSONNEL MONITORING

A. Control

As a matter of policy and practical necessity, the "Authorized User" must be the individual responsible for controlling the dose received by personnel under his or her supervision and/or using "Sources of Radiation" under his or her authorization so that no person receives a total dose in excess of the maximum permissable limits specified in Appendix D. The total dose includes both that due to exposure to external "Sources of Radiation" and exposure to internally deposited radioisotopes. The monitoring of radiation dose provides information essential to the control process. The program under which external dose is monitored is described below while the program under which the dose due to internally deposited radioisotopes is monitored is described in Section 12.

B. External Monitoring Requirement

By regulation any person who receives or is likely to receive more than 25 percent (5 percent for minors) of the maximum permissible dose (see Appendix D) or who enters a "High Radiation Area" must be provided with and must wear personnel monitoring devices. The "Authorized User" is responsible for insuring that persons under his or her supervision and/or using "Sources of Radiation" under his or her authorization are provided with suitable personnel monitors and that these monitors are actually worn when appropriate. Any question of interpretation of this section shall be referred to the "Health Physicist."

C. Centralized Personnel Monitoring Program

The Office of Occupational Health and Safety administers a centralized personnel monitoring program which is utilized by all laboratories requiring personnel monitoring. In the operation of this program the Office of Occupational Health and Safety provides, upon request, personnel monitors for routine and temporary use, distributes personnel monitors to the departments, collects personnel monitors from the department after use, ships the monitors to the personnel monitoring service vendor for interpretation, receives and distributes the dose reports to the departments, maintains centralized records, investigates unusual or excessive doses, and honors requests for dose history summaries. The "Authorized User" continually reviews the need for personnel monitoring and requests personnel monitoring service from the Office of Occupational Health and Safety, notifies that office when service is no longer needed, arranges for the distribution and collection of personnel monitors in accordance with departmentally established procedures, reviews the reports of personnel monitoring results for the purpose of controlling dose, and takes positive action to insure that all monitored individuals under his or her supervision are informed of their dose status. In certain departments, individuals designated as "Personnel Monitor Contacts" coordinate the distribution and collection of monitors and receive dose reports from the Office of Occupational Health and Safety. It is up to the "Authorized User" to make arrangements with the "Personnel Monitor Contact" regarding receipt of the dose report.

There are certain features of the personnel monitoring program which concern the "Authorized User" and all monitored individuals. These are:

1. The University is required to control the exposure of the individual radiation worker to "Sources of Radiation" at Princeton University so that his or her total occupational dose, including the dose due to radiation exposure outside the immediate control of the University (e.g., at other universities, national laboratories, second jobs, etc.), does not exceed the maximum permissible limits specified in Appendix D. University employees, students, faculty, etc., must therefore promptly report to the Office of Occupational Health and Safety any occupational dose received under conditions outside the University's control and should request that all dose information be routinely sent to the Princeton University Office of Occupational Health and Safety.

2. A cumulative summary of the occupational radiation dose received by any individual monitored for exposure to radiation at Princeton University is available from the Office of Occupational Health and Safety upon request. Such a summary is also available at any time following the termination of the individual's employment. The request for the cumulative summary must include the dates of employment, department of employment, and social security number.

3. Any individual who has been monitored for exposure to radiation during a calendar quarter in which he or she terminates employment at the University, at the time of termination, may request a summary of the dose received during that quarter. This information may be requested of the worker by subsequent employers during that calendar quarter.

D. Suspected Overexposures

1. If it appears that an individual has received or is suspected of receiving a dose greater than the maximum permissible dose limits specified in Appendix D, the Office of Occupational Health and Safety must be notified immediately. The "Health Physicist" will take steps to determine the actual dose, investigate and document the circumstances, file reports if required, and recommend corrective or preventative action.

2. Individuals who are believed to have been overexposed shall be suspended from further work with "Sources of Radiation" pending the outcome of the "Health Physicist's" investigation.

E. Exposure of Minors

Because the allowable dose to persons under 18 is limited to 10% or less of the limits specified in Appendix D, it is recommended that minors not be employed as full-time radiation workers.

F. Exposure of Pregnant Women

There are special requirements relating to the dose limits for pregnant women (see Appendix D). Because of this, each female radiation worker, at the time of the beginning of work with "Sources of Radiation," is provided by the Office of Occupational Health and Safety with an information packet discussing the risks of prenatal exposure and the special requirements. A female radiation worker who discovers she is pregnant is strongly encouraged to discuss future work assignments with the "Authorized User."

G. Exposure of Visitors

1. The host, i.e. the person visited, bears the responsibility of insuring that his or her visitors, who may include guests, maintenance and repair personnel, etc., are informed of the hazards, comply with all applicable rules, regulations, and procedures, and wear personnel monitors when appropriate.

2. There are very few circumstances in which any real contribution to the scientific community can result from the visit of a child to a "Restricted Area." For this reason, such visits shall be discouraged and should not be permitted without benefit of careful consideration. Prolonged or frequent visits by children to "Restricted Areas" are prohibited.

12. INTERNAL DOSE CONTROL AND BIOASSAYS

A. Control

As a matter of policy and practical necessity, the "Authorized User" must be the individual responsible for controlling the dose received by personnel under his or her supervision and/or using "Sources of Radiation" under his or her authorization so that no person receives a total dose in excess of the maximum permissible limits specified in Appendix D. The total dose includes both that due to exposure to internally deposited radioisotopes and exposure to external "Sources of Radiation." The monitoring of radiation dose provides information essential to the control process. The program under which the dose due to internally deposited radioisotopes is monitored is described below while the program under which the external dose is monitored is described in Section 11.

B. Internal Monitoring Requirement

The "Authorized User" is responsible for insuring that persons under his or her supervision or using radioisotopes under his or her authorization are provided with bioassay services when the criteria given below are met.

Bioassays commonly involve urinalysis, external counting of the thyroid, breath analysis, or whole body counting.

1. Special Bioassays

Bioassay analyses may be required of any person or persons who:

a. have been exposed to air or water concentrations of radioactive material equal to or in excess of 25 percent of those specified in Table I of Appendix B

b. have been involved in a spill, an incident, or other occurrence during which significant amounts of radioactive material may have been taken into the body either by inhalation, ingestion, or by absorption through the skin or a wound.

2. Routine Bioassays

The use of any radioisotope may require that routine bioassays be required upon the determination of the "Health Physicist." Such a determination has been made for certain uses of tritium and radioiodine; the criteria for bioassay for these radioisotopes are described below:

a. Tritium

Routine bioassays are required for those persons who handle tritium under the following conditions:

1) Use in an open room with possible release*

Form	Minimum Amount of ^3H Requiring Bioassay After Single Use
^3H gas in a sealed vessel	1 Ci
Nucleotide precursors	10 mCi
HTO and other forms	100 mCi

2) Use in an adequate fume hood with possible release*

Form	Minimum Amount of ^3H Requiring Bioassay After Single Use
^3H gas in a sealed vessel	10 Ci
Nucleotide precursors	100 mCi
HTO and other forms	1 Ci

3) The "Health Physicist" may determine, depending on handling procedures and other conditions, that bioassays are required for the use of smaller or greater amounts of tritium.

4) Frequency

Bioassay samples should be submitted within 48 hours of the initial exposure to tritium and then once a month while routine use of tritium continues.

5) Types of Required Bioassays

The tritium bioassay program for each individual should consist of the following bioassays:

a) Baseline (not more than one month prior to the beginning of any tritium use requiring bioassay)

*Possible release means that the possibility of a significant airborne release of radioactive material exists because 1) the techniques used to process the material may create an aerosol, 2) the material is inherently volatile, or 3) the techniques used to process the material may increase its volatility.

b) Routine

c) Post operational (within one month of last tritium use)

d) Follow up (to follow the course of a significant uptake of tritium)

b. Radioiodine

Routine bioassays are required for those persons who handle iodine-125 or iodine-131 under the following conditions:

1) Use in an open room with possible release*

Form	Minimum Amount of Iodine Requiring Bioassay After Single Use
Volatile	1 mCi
Bound to non-volatile agent	10 mCi

2) Use in an adequate fume hood with possible release*

Form	Minimum Amount of Iodine Requiring Bioassay After Single Use
Volatile	10 mCi
Bound to non-volatile agent	100 mCi

3) The "Health Physicist" may determine, depending on handling procedures and other conditions, that bioassays are required for the use of smaller or larger amounts of radioiodine.

4) Frequency

Bioassays should be performed within 6 to 72 hours after the initial exposure to radioiodine and then

*Possible release means that the possibility of a significant airborne release of radioactive material exists because 1) the techniques used to process the material may create an aerosol, 2) the material is inherently volatile, or 3) the techniques used to process the material may increase its volatility.

once a month while routine use of radioiodine continues.

5) Types of Required Bioassays

The bioassay program for each individual should consist of the following bioassays:

a) Baseline (within one month prior to the beginning of any use of radioiodine requiring bioassay)

b) Routine

c) Post operational (within one month of the last possible exposure to radioiodine, when work is being discontinued)

d) Follow up (to follow the course of a significant uptake of radioiodine)

6) Depending on the nature of the work and if a significant uptake of radioiodine is found for one individual, other persons who frequent the laboratory may be required by the "Health Physicist" to obtain bioassays.

C. Arrangements for Bioassays

Arrangements for bioassays are made by contacting the Office of Occupational Health and Safety.

13. LEAK TESTING REQUIREMENTS FOR "SEALED SOURCES" AND "GENERALLY LICENSED DEVICES"

A. "Sealed Sources"

1. Initial Test

a. Unless a certificate is available indicating that a leak test has been made within the last six months, each "Sealed Source" obtained from another organization shall be tested, prior to use, for contamination and/or leakage. The exceptions to this requirement are those "Sealed Sources" which

1) contain only tritium

2) contain only radioisotopes with a half-life of thirty days or less

3) contain radioactivity consisting entirely of a gas.

b. All "Sealed Sources" fabricated by University personnel must be inspected and tested for construction defects, contamination, and leakage immediately after fabrication and prior to use or transfer. If the test reveals any construction defects or 0.005 μCi or greater of contamination, the source must be repaired and/or decontaminated and retested before use.

2. Periodic Leak Test

a. Each "Sealed Source" shall be tested for contamination and/or leakage at intervals not exceeding six months, except that sources designed for the purpose of emitting alpha particles shall be tested at intervals not exceeding three months unless exempted below.

b. "Sealed Sources" are exempt from the required periodic leak test if:

1) they contain only tritium

2) the half-life of the contents is thirty days or less

3) they contain 100 μCi or less of beta and/or gamma emitting material or 10 μCi or less of alpha emitting material

4) the activity consists entirely of a gas.

c. For "Sealed Sources" fabricated by University personnel, the "Health Physicist" may, at his or her discretion, elect to require periodic leak testing, regardless of the source's activity or characteristics.

3. "Sealed Sources" containing plutonium, regardless of activity, are not exempted from any of the tests described in paragraphs 1 and 2 above.

4. Plated sources of alpha emitting materials, while not technically "Sealed Sources," must be leak tested in accordance with the requirements of paragraphs 1 and 2 above.

5. "Sealed Sources" containing radioisotopes licensed by the State of New Jersey shall not be opened.

B. "Generally Licensed Devices"

By the licensing arrangements through which "Generally Licensed Devices" are manufactured and sold, special leak testing or inspection requirements may be imposed on the manufacturer or owner. The "Authorized User" must bring such requirements to the attention of the Office of Occupational Health and Safety when the device is obtained.

C. Leakage Defined

If any of the required tests indicate the presence of 0.005 μCi or more of transferable radioactivity, the source is considered leaking or contaminated and shall immediately be withdrawn from service and be either decontaminated and/or repaired and retested, or disposed of as radioactive waste or returned to the supplier as appropriate. For information on returning sources,see Sections 8 and 14.

D. Filing of Report

In the event a source is determined to be contaminated and/or leaking, a report must be filed within five days with the Nuclear Regulatory Commission or the State of New Jersey indicating the test results, the equipment used and the corrective action taken.

E. Performance of Test

The Office of Occupational Health and Safety performs the required leak tests for all University "Sealed Sources" and, when required, "Generally Licensed Devices," maintains the required records, suggests corrective actions where indicated, and files the necessary reports. To assist in the implementation of this service each "Authorized User" must:

1. inform the Office of Occupational Health and Safety in writing of the receipt or manufacture of a new source or of plans to dispose of an old source

2. provide the Office of Occupational Health and Safety with a copy of the test certificate received with purchased "Sealed Sources"

3. make expeditiously available, preferably at a central point, sources and devices for the scheduled tests.

14. TRANSPORTATION AND SHIPMENT OF RADIOACTIVE MATERIALS

The "Authorized User" is responsible for insuring that radioactive materials moved between buildings on campus or transported off campus by individuals under his or her authorization are transported in accordance with all applicable regulations, including those set forth in this Guide.

A. Intra Campus Transportation

"Limited quantities" of radioactive material, as defined in paragraph C.2.a of this section, may be transported between buildings on campus provided the following conditions are met:

1. Radioactive material must be moved in such a manner that material cannot readily be released from the package under normal conditions.

2. A liquid, gas or dispersible solid must be transported in a suitable vessel with an outer container wall of leak-resistant, non-shatterable material.

3. A liquid must be packaged with sufficient absorbent material to completely absorb twice the volume of liquid, e.g., approximately a 4.5:1 ratio by volume for fine grade vermiculite.

4. The inner container must be clearly marked with a "Radioactive Materials" label listing the amount and identity of the radioisotope.

5. Adequate shielding must be provided when appropriate.

6. The inner container must be placed within a closed, strong outer package known to be free of contamination.

7. The outer package must bear a notice that the Office of Occupational Health and Safety (provide a phone number) should be notified if the package is found.

If it is necessary to transport more than a "limited quantity" of a radioisotope or a radioisotope not included in the "limited quantity" definition,the "Health Physicist" must be notified beforehand.

B. Off Campus Transportation

Radioisotopes transported to or from destinations outside the University or transferred from one University campus to another shall be packaged and transported in accordance with all pertinent regulations. See paragraph C for details. In addition:

1. An individual preparing a radioactive substance for shipment shall have the responsibility to insure full compliance with pertinent regulations with respect to packaging, marking,labelling,shipping papers for the package and pla-

carding and routing for the transport vehicle, where applicable.

2. An individual affiliated with the University who will transport radioactive material prepared for shipment by an individual or agency not associated with the University has the responsibility to become acquainted with regulations relating to transportation of the material in question to satisfy him or herself that the conditions of packaging and transport comply with those regulations.

3. The "Health Physicist" should be consulted well in advance of the transport of any radioactive material so that the "Authorized User" who is transporting the material can be made aware of the specific regulations and requirements applying to the planned shipment. In planning for the transport of the material, allowances should be made for the time needed to obtain proper packaging and to obtain advance permission to travel on certain roads, bridges and tunnels, all of which may take several weeks.

4. When radioactive material is transported in a private vehicle, the material shall be in the charge of an individual knowledgeable about and familiar with radioisotopes. Personnel monitors should be worn by driver and passengers when appropriate. The radiation dose to the driver and passengers must be considered, and the package should be located and adequately shielded so that the dose to the occupants is minimized.

   In addition to the markings and labels required by law, a package transported in a private vehicle by an individual affiliated with the University shall be marked with a label bearing the name and University address of the owner, a statement that the contents may be dangerous if removed, and asking that the Princeton University Office of Occupational Health and Safety be notified if the package is involved in an accident or if the package is found. Phone numbers should be provided on this label. It is preferable that the package not be left in an unattended car, but if it is absolutely necessary, the package shall be locked in the car, preferably in the trunk.

5. When an individual not associated with the University transports radioactive material from the University, such actions are done with the understanding that the individual and his or her parent organization are responsible to insure full compliance with all regulations pertinent to the shipment of the material.

C. Selected Shipping Regulations

1. General Comments

   A complex body of regulations governing highway, rail, air and water transportation of radioactive materials has been promulgated by Federal, State and local authorities. The regulations are revised often, and new ones are added. Due to this and their volume and variety, any attempted abstract of the regulations runs the risk of misleading oversimplifications. The following commments are intended as a guide for preliminary planning; final details should be checked with the "Health Physicist" at the earliest possible date.

2. Selected Department of Transportation (DOT) Regulations

The Nuclear Regulatory Commission has ruled that DOT regulations, which appear in Title 49 of the Code of Federal Regulations Parts 171 through 178, apply to both the interstate and intrastate transportation of radioactive materials. Additionally, most state and local authorities use the DOT regulations as a starting point for their own rules. The most widely appropriate regulations are summarized below, subject to the qualification indicated in paragraph 1 above.

a. Exemptions (49 CFR 173.391)

Certain shipments of radioactive materials are exempt from all of the requirements which normally apply to such transportation only if they meet all of the following conditions:

1) The shipment must contain a "limited quantity" of radioisotopes. A "limited quantity," for the radioisotopes most commonly used at the University (i.e., ^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{60}Co, ^{125}I, ^{137}Cs) is one millicurie or less.

2) The packaging must consist of a strong, tight package such that there will be no leakage of radioactive material under normal conditions of transportation.

3) The dose rate at any point external to the package shall not exceed 0.5 mrem/hour.

4) There must be no significant removeable surface contamination on the exterior of the package.

5) The outside of the inner container must be marked "Radioactive."

6) Shipping papers describing the material and bearing the proper certifications must accompany the package. (49 CFR 172.200-172.204)

b. All shipments of radioactive materials not meeting the conditions given above must be packaged, marked, labelled, placarded and provided with shipping papers as described below:

1) The outer package must be one of several types, closely described by the regulations, approved for radioactive materials (49 CFR 173.394-396). No dimension may be less than 4 inches, and the outside of the package must incorporate a security seal (49 CFR 173.393).

2) Liquid radioactive materials must be packaged within a leak- and corrosion- resistant inner container, surrounded by enough absorbent material to absorb at least twice the volume of the liquid radioactive contents (49 CFR 173.393 (g)).

3) Radiation levels may not exceed 200 mrem/hour at any point on the outer package surface or 10 mrem/hour at 0.92 meters from the package, unless the transport vehicle meets the criteria for a "sole use" vehicle (49 CFR 173.393 (i)).

4) There must be no significant removeable surface contamination on the exterior of the package (49 CFR 173.393 (h) and 173.397).

5) The package must be labelled with "Radioactive White-I," "Radioactive Yellow - II," or "Radioactive Yellow - III" labels, depending on the external radiation levels (49 CFR 172.403).

6) The package must be marked with the proper shipping name of the material and any other required markings (49 CFR 172.300-172.310).

7) The package must be accompanied by shipping papers describing the hazardous material and bearing the required certifications (49 CFR 172.200-172.204).

8) A vehicle transporting a package bearing "Radioactive Yellow - III" labels must be placarded on four sides (49 CFR 172.500-172.556).

3. Postal Service Regulations (39 CFR Parts 14 and 15)

"Limited quantities" only of radioactive material, as defined above, may be shipped through the mail, with requirements similar to those of the DOT for shipping "limited quantities." Packages shipped by the Postal Service must prevent leakage of the contents during normal postal handling, and the inner container must be labelled "Radioactive Material- No Label Required." All other requirements are the same.

4. Regulating Agencies

Agencies involved in the regulation of the transportation of radioactive materials include:

a. Nuclear Regulatory Commission

b. United States Department of Transportation

c. New Jersey State Bureau of Radiation Protection

d. New Jersey Department of Transportation

e. United States Postal Service

f. New Jersey Highway Authority

g. New Jersey Turnpike Authority

h. The Port Authority of New York and New Jersey

i. Triborough Bridge and Tunnel Authority

j. New York City Department of Health

k. New York Thruway Authority

l. Federal Aviation Agency

m. United States Coast Guard

December 5, 1979

15. RADIOACTIVE WASTE DISPOSAL

There are strict requirements placed on the University regarding the manner and methods used for the disposal of radioactive wastes. These apply to the entire University as the licensee. In order to comply with these requirements the following procedures are established.

A. Centralized Radioactive Waste Disposal Program

The Office of Occupational Health and Safety administers a centralized radioactive waste disposal program which is used by all persons and groups with disposal needs. The items listed below describe general features of the program, while detailed waste disposal procedures are provided in paragraph D.

1. Waste collection is made by the vendor normally on the fourth Monday of each month. Requests for waste pickups and replacement waste containers are arranged by calling the Office of Occupational Health and Safety no later than noon of the Thursday prior to the scheduled pickup. Non-routine waste pickup can be arranged for other than scheduled times if necessary. However, such special requests should be held to a minimum.

2. All radioactive experimental wastes and first rinses shall be placed in radioactive material waste containers.

3. The date, radioisotope and amount of radioactive materials placed in these waste containers must be recorded on the tag fastened to the can. A reasonable estimate of the activity is sufficient if an accurate figure is not possible. Waste containers will not be accepted by the vendor unless they are accompanied by a completed tag.

4. Radioactive material waste containers should not be used for non-radioactive wastes nor should they be used as disposal containers for other toxic wastes.

5. Each radioactive material waste container in the laboratory, once it has been designated for use for a particular type of radioactive waste, i.e., dry solid waste, small volume liquid waste, etc., as described in paragraph D, should be labelled to indicate its designation.

6. The chemical compatibility and hazard characteristics of radioactive wastes placed within the same container should always be considered.

7. Radioactive material waste containers shall be placed in a safe location to prevent damage and should be kept separate from waste cans for non-radioactive material to avoid cross-contamination.

8. Careful consideration should be given to external dose rates created by the addition of gamma, neutron and high energy beta emitters to the waste containers. It may become necessary to shield the materials or the waste container or to relocate the container to a less accessible area. The vendor cannot, by regulation, remove containers with dose rates in excess of 200 mrem/hour on contact and/or 10 mrem/hour at 1 meter.

9. Only authorized radioactive material waste containers provided by the vendor or approved by the "Health Physicist" may be used for waste shipment. The use of other than authorized containers for waste storage within the laboratory is discouraged, since custodial personnel are trained to recognize the authorized containers, but may be allowed after consultation with the "Health Physicist."

10. Each waste container used for radioactive waste collection in labs and each container used for the subsequent shipment of wastes shall be inspected for corrosion or damage which could affect the integrity of its containment, prior to its being placed in service. Containers used for the local collection of wastes and/or for extended periods of time shall be inspected regularly. Containers whose integrity is suspect shall not be used for waste collection or shipment.

11. The contents of each radioactive material waste container shall be inspected by a laboratory or departmental representative prior to pickup by the vendor to insure that the wastes are properly separated into the appropriate container in accordance with the packaging requirements found in paragraph D.

B. Sanitary Sewage System

Use of the University sanitary sewage system as a primary means of radioisotope waste disposal is prohibited. This is necessary because the permissible water concentrations established by Federal and State laws are low and because the complexity and size of the University sanitary sewage system preclude the establishment of monitoring systems. However, some disposal to the sanitary sewer is unavoidable and is permitted subject to the following conditions:

1. No radioactive material may be placed in the sanitary sewer unless it is readily soluble or dispersible in water.

2. The total of all daily disposals made by each "Authorized User" and all persons using radioisotopes under his or her authorization must be limited to less than the amount specified in column A of Appendix C, provided the identity and quantity of the radioisotope is relatively well-known, and provided the "User" provides sufficient local dilution to

insure compliance with the daily concentration limits set forth in Table I of Appendix B. A record of such disposals shall be kept and reported monthly to the Office of Occupational Health and Safety on OHS Form #11.

3. In order to insure compliance with the University monthly average concentration and yearly total (1 Curie) limit, the Office of Occupational Health and Safety each month computes and records the concentrations and cumulative total quantity disposed. The input data for each calendar month, including negative reports, shall be provided on OHS Form #11 by each "Authorized User" generating such waste. The report is due at the Office of Occupational Health and Safety no later than the eighth day of the following month.

C. Incineration and Burial

There are no facilities at the University for incineration or burial of radioactive wastes.

D. Radioactive Waste Disposal Procedures

The following procedures are required by the waste disposal service vendor to insure that University radioactive waste is suitable for burial at the limited number of burial sites within this country. Wastes received at these sites are subject to inspection, and severe repercussions, including litigation, fines, and refusal to accept future waste shipments from the University, may result if our waste is found to be improperly packaged. Before the waste disposal service vendor can accept a waste container for pickup, the "Authorized User" or a departmental representative must sign a certification that the waste has been properly packaged. The container must also be labelled with one of several markings described below, which is also a certification that the container has been packaged in accordance with the instructions of the date shown.

Specific departmental arrangements for the disposal and collection of radioactive waste vary and should be carefully checked with the "Departmental Health and Safety Coordinator" and/or the departmental administrative officer. All steps in the following procedures, including selection of a waste container, designation of the container for a particular type of waste, lining of the container, layering with vermiculite, keeping account of and limiting the amount of liquid that goes into a container, labelling, etc., are done by either the "Authorized User" or the departmental representative, depending on specific departmental procedures.

As procedures are revised and transmitted to the Office of Occupational Health and Safety by the waste disposal service vendor, the revised procedures will be sent as soon as possible to "Authorized Users" and other appropriate persons. These pages in the Guide will be revised and furnished to all appropriate persons as soon as possible.

The following pages provide detailed waste disposal procedures.

The procedures which follow are those transmitted to the University by the waste disposal service vendor on December 3, 1979. All waste picked up after January 1, 1980 must be in compliance with these procedures.

1. Classification of Wastes for Transportation

   Most of the radioactive waste generated at the University falls into the transportation classification of "low specific activity" (LSA), and the containers routinely provided by the waste disposal service vendor are suitable only for that classification. Additionally, the procedures described in paragraphs 2, 3, 4, and 5 below assume that the waste can be properly described as LSA material. If radioactive waste does not meet the following criteria, the Office of Occupational Health and Safety must be notified promptly so that alternative waste disposal procedures may be arranged.

   LSA material consists of the following materials:

   a. Uranium and thorium ores and concentrates of those ores

   b. Unirradiated natural or depleted uranium or unirradiated natural thorium

   c. Tritium oxide in aqueous solution in concentrations not exceeding 5 mCi/ml

   d. Material in which the activity is essentially uniformly distributed and in which the estimated average concentration does not exceed, for the radioisotopes most commonly used at the University (i.e., ^{3}H, ^{14}C, ^{32}P, ^{35}S, ^{45}Ca; ^{60}Co, ^{125}I, ^{137}Cs), 300 μCi per gram of contents. If it is necessary to dispose of a radioisotope not listed here, the "Health Physicist" should be consulted beforehand.

   e. Objects of non-radioactive material externally contaminated with radioactive material, provided the contamination is not readily dispersible and the contamination, when averaged over an area of 1 m^2, does not exceed 1 μCi/cm^2, for those radioisotopes mentioned above.

2. Dry Solid Waste (DSM 12/79)

   a. Dry solid wastes are disposed of in the 5, 30, or 55 gallon dry waste containers provided by the vendor. These drums may be filled to capacity as long as the following weights--100, 280, or 400 pounds respectively -- are not exceeded.

b. Dry solid waste containers are meant only for dry waste, and therefore, free liquids, liquids in vials or other containers, or liquids absorbed on other material, regardless of volume and including droplet amounts, must not be placed in dry waste containers.

c. The container must be labelled "DSM-12/79" to indicate compliance with these procedures.

3. Small Volume Liquid Waste (SVL 12/79)

a. Small volume liquid waste refers to closed vials, containers, devices, etc., which contain any liquid in amounts less than 50 ml, or open pipettes, syringes, tubes, etc., which contain droplets of liquid.

b. Small volume liquid wastes are placed in the 30 or 55 gallon containers provided by the vendor. The containers must first be lined with a 4 mil thick or two 2 mil thick poly liners. The container is then filled with alternating layers of Grade 4 agricultural vermiculite and waste material, beginning and ending with vermiculite. The container must eventually contain enough vermiculite to absorb twice the total amount of liquid present.*

c. An alternative method to lining the whole container is to use individual 4 mil or double 2 mil bags, provided each bag is layered as described above.

d. The liner or bags must be sealed prior to waste collection.

e. The container must be labelled "SVL-12/79" to indicate compliance with these procedures.

4. Large Volume Liquid Waste (DWLVL 12/79)

a. The vendor supplies the University with a liquid waste container, consisting of a 30 gallon drum filled with vermiculite, which is, in turn, overpacked with a 55 gallon drum. The space between the two drums is filled with vermiculite. The liquid waste is poured directly into the bung hole of the 30 gallon drum lid. Since no more

*This is approximately a 4.5:1 ratio by volume for Grade 4 agricultural vermiculite.

than 10 gallons of liquid may be added to each 30 gallon container, a careful record must be kept, listing the volume of each disposal of liquid to the container.

b. An alternative method acceptable to the vendor is to use one gallon polyethylene bottles filled with vermiculite.** These bottles are used in the laboratory as bench top waste containers. After filling, these bottles are sealed with plastic or metal caps and placed into a specially prepared liquid waste container. Vermiculite is then placed between the one gallon containers.

c. The pH of all liquid disposed must be between 6.0 and 9.0.

d. The container must be labelled "DWLVL-12/79" to indicate compliance with these procedures.

5. Animal Carcasses or Biological Waste (DWAC 12/79)

   a. Animal carcasses or biological waste are disposed of in a special double-walled 55 gallon container.

   b. The inner 30 gallon container is lined with a 4 mil or double 2 mil poly liner. The lined container is then filled with alternating layers of a vermiculite-lime mixture (using at least 1 part lime for every 10 parts of vermiculite) and waste.

   c. After the liner and 30 gallon container are sealed, vermiculite is placed around and covering the 30 gallon container.

   d. The container must be labelled "DWAC-12/79" to indicate compliance with these procedures.

6. There must be no mixing of waste categories within each waste container.

7. Non-routine waste disposal situations, such as odd-shaped, exotic, or unusually large materials, require that the Office of Occupational Health and Safety be contacted as soon as the disposal need is recognized to arrange for special handling through the waste disposal service vendor.

**Available from the Office of Occupational Health and Safety, prefilled with vermiculite, prelabelled, and provided to the departments at cost.

16. REQUIREMENTS AND PRECAUTIONS FOR THE USE OF "RADIATION PRODUCING MACHINES AND DEVICES"

Radiation can be produced by certain pieces of electronic apparatus, including high voltage power supplies and other high voltage equipment with an associated vacuum, as a by-product of operation. Questions concerning the suspected emission of radiation from equipment should be directed to the "Health Physicist."

A. Analytical X-Ray Installations

The State of New Jersey has set forth requirements for "analytical x-ray equipment," and the "Authorized User" is responsible to insure that these requirements are met.

1. Definition

"Analytical x-ray equipment" means any device or combination of devices utilizing x-rays to determine the microscopic structure or composition of material, including but not limited to, x-ray diffraction, x-ray spectroscopy, x-ray fluorescence or fluorescence x-ray spectroscopy equipment. Electron microscopes are not regarded as analytical x-ray equipment.

2. General Requirements

a. Warning Signs and Lights

All "analytical x-ray equipment" must have the following items:

1) A clearly visible label, near any switch energizing an x-ray tube, which bears the radiation symbol and the words: "Caution: This Equipment Produces X-Rays When Energized. To Be Operated Only By Authorized Personnel "

2) A clearly visible label, near the x-ray tube housing, which bears the radiation symbol and the words: "Caution: High Intensity X-Ray Beam "

3) a clearly visible fail-safe* warning light, near any switch energizing an x-ray tube, labelled with these words: "X-Ray On "

*As used for the purposes of Section 16, "fail-safe" means that all failures of warning and safety systems that can reasonably be anticipated will cause the equipment to fail in a mode such that personnel are safe from exposure to radiation.

4) a clearly visible fail-safe warning light in a conspicuous place near the x-ray tube which indicates when the x-ray tube is producing x-rays.

b. Operating Procedures and Dose Limits

All analytical x-ray equipment must have the following items and meet the following requirements:

1) Written operating and alignment procedures provided by the manufacturer or the person in charge of the unit

2) Procedures such that the dose received by the operator during operation and alignment does not exceed 37.5 mrem in one hour to the hands and forearms and 2.5 mrem in one hour to the whole body or lens of the eye

3) A radiation survey to insure that the dose rates transmitted through the beam stop or from other components of the unit, such as high voltage rectifiers, do not exceed the limits set forth in Subchapter 21 of the N.J. Radiation Protection Code

4) Finger or wrist personnel monitors for all persons who operate, repair or align this equipment

5) A radiation survey each time a new installation is placed into operation or each time changes are made that could affect the degree of radiation protection

6) All safety devices, either required by the regulations or provided at the time of the equipment's installation, must be maintained in a fully functional condition.

7) Safety devices must be tested at least once every six months and records kept of the testing.

3. Requirements for Open Beam X-Ray Systems

An open beam system is a system for which it is possible to place any part of the body in any possible x-ray path. In addition to the general requirements found in paragraph 2 above, the following requirements must be met:

a. Safety Devices

The following items are required:

1) A clearly visible warning indicator near each x-ray tube shutter, which indicates when the shutter is open

2) A barrier between the "Radiation Area" and the "Restricted Area"

3) For new x-ray equipment acquired after February 1, 1980, and for older equipment transferred from one user to another after February 1, 1980, there must be:

   a) a guard or interlock to prevent entry of any part of the body into the primary beam

   b) A beam shutter for each port of the tube housing. The shutter must be interlocked so that the port will be open only when the collimator or apparatus coupling is in place. Shutters at unused ports must be secured.

b. Dose Rates

1) All parts of the system, except the tube housing, shall be constructed so that, with all shutters closed, the stray radiation measured 5 cm from any surface does not exceed 0.25 mrem/hour.

2) The x-ray tube housing shall be constructed so that, with all shutters closed, the leakage radiation measured 5 cm from its surface does not exceed 2.5 mrem/hour.

4. Requirements for Enclosed Beam X-Ray Systems

An enclosed beam system is a system in which all possible x-ray paths are fully enclosed so that any part of the body cannot enter the enclosure. In addition to the general requirements found in paragraph 2 above, the following requirements must be met:

a. Safety Devices

There must be:

1) Enough interlocks to prevent the generation of x-rays or the emergence of the primary beam when any section of the enclosure is opened during routine operation, alignment or maintenance

2) A chamber or coupled chambers enclosing the radiation source, sample, detector and analyzing crystal, which cannot be entered by any part of the body during normal operation

3) A sample chamber closure with a fail-safe interlock so that no x-ray beam can enter an open sample chamber.

b. Dose Limits

The equipment must be so constructed that the dose rate due to leakage radiation at 5 cm from any accessible surface does not exceed 0.25 mrem/hour during normal operation.

B. General Labelling and Warning Sign Requirements

1. Any "Radiation Producing Machine or Device," even if the production of radiation is incidental to the device or machine's purpose, must be labelled on the control panel or a conspicuous surface with a label stating that ionizing radiation is produced when the machine or device is in operation. Labels may be obtained from the Office of Occupational Health and Safety.

2. The provisions of Section 9 apply to all "Radiation Producing Machines and Devices."

C. General Precautions

1. Analytical x-ray equipment is capable of producing primary or diffracted beams of radiation that are hazardous because of the extremely high exposure rates. Data on the radiation hazards from such equipment is included in Appendix I.

2. Analytical x-ray equipment should be placed in a room separate from other work areas whenever possible.

3. When not in operation, equipment whose primary purpose is the production of radiation should be secured in such a way as to be accessible to, or operable by, authorized personnel only.

4. Equipment whose primary purpose is the production of radiation should not be left operating unattended unless there are suitable indicators present to show that the equipment is switched on. Open beam equipment should never be left unattended during operation without adequate safeguards.

5. Tampering with interlocks is strongly discouraged, but it is recognized that there may be times when such tampering is unavoidable. Explicit steps must be taken to inform all "Users" of the machine or device that the particular interlock is inoperable, and a sign with the individual's name and description of the status of the interlock must be placed on the equipment.

6. When "Radiation Producing Machines or Devices" are used by several people, there must be effective communication on the status of the machine or device, particularly during repair and modification operations.

7. Radiation surveys should be made after each modification of apparatus.

8. It is strongly recommended that a suitable ratemeter with audible output be present in any area in which open beam analytical x-ray equipment is used. A properly placed ratemeter may provide an audible warning that such equipment is producing radiation.

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17. EMERGENCY PROCEDURES

A. Emergency Assistance

Assistance for any emergency, including one involving radiation, at the University is obtained by dialing 2-3131 for an emergency on the Main Campus, and 2-5700 (or 3333 for a call from a Plasma Physics Laboratory phone) for an emergency on the Forrestal Campus, and providing the information requested. The "Authorized User" responsible for the laboratory or facility should also be notified.

Abbreviated radiation emergency procedures (OHS Form #12) are posted in each laboratory.

B. Radiation Emergency Guidelines

In the event a radioactive substance escapes from its normal confines (by spill, evaporation, vaporization, combustion, escape of gas, liquid or solid, etc.) in an amount which may exceed ten times the quantities listed in column A, Appendix C, the "Health Physicist" shall be notified promptly. Immediately after the occurrence of the incident and pending the arrival of the "Health Physicist" certain steps, as described below, should be taken. Although each incident is unique, and some of the following steps may not apply or other actions may be called for in a particular emergency situation, the actions listed here provide good guidelines for appropriate preliminary emergency response.

1. Minor Spill

A minor spill involves the spill of a radioactive material in such quantities or under such circumstances that a significant internal or external radiation hazard is not created, and which will not produce significant airborne contamination. If a minor spill occurs:

a. Notify all other persons in the room at once.

b. Limit the number of persons in the area to those needed to deal with the spill.

c. Don protective clothing.

d. Take immediate steps to confine the spill. For liquid spills drop absorbent paper on the spill. For dry spills, dampen thoroughly or place damp absorbent materials over the spill, taking care not to spread the contamination. Water may generally be used except where chemical reaction with water would generate an air contaminant. Oil may then be a reasonable substitute.

e. Delineate and block off the contaminated area to insure that others will not walk through the area.

f. Do not allow anyone to leave the contaminated area without being monitored. Make note of the names of all persons involved with the spill.

2. Major Spill

A major spill of radioactive material occurs in such quantities or under such circumstances that a significant internal or external radiation hazard to personnel, including those outside the immediate vicinity of the spill, exists, but which does not produce significant airborne contamination. If a major spill occurs:

a. Notify all persons not involved in the spill to vacate the room at once.

b. If the spill is liquid, and the hands are protected, right the container.

c. If the spill is on the skin, flush thoroughly.

d. If the spill is on clothing, discard outer or protective clothing at once.

e. Vacate and secure the room to prevent re-entry. Keep the area clear of spectators.

f. Limit the movement of persons involved in the spill to a specified area of assembly to prevent the spread of contamination. Do not allow anyone to leave the area of assembly without being monitored. Make note of the names of all persons involved in the spill.

3. Possibility of Airborne Contamination

An airborne release of radioactive material may occur due to evaporation; vaporization; explosion; combustion; formation of a smoke, dust or spray; gas escape, etc. If an airborne release occurs:

a. Evacuate all persons from the room or area immediately.

b. Shut all doors to the room or area.

c. Post guards, as needed, to insure that no one re-enters the room or area and to keep the general area clear of spectators.

d. Assemble all persons who were present in the room or area at the time of the incident. The place of assembly should be near the contaminated area to minimize the spread of contamination, but far enough removed to prevent continued involvement. Do not permit these persons, except in instances of clear medical emergency, to leave the place of assembly until after the "Health Physicist" has arrived.

e. If contamination of the skin or clothing is known or suspected, begin personal decontamination as follows:

1) Remove all contaminated clothing.

2) Wash contaminated areas of skin with mild soap and water.

f. Do not allow anyone to remain in or re-enter the area in which airborne contamination occurred unless it is certain that the person has adequate respiratory and personal protection.

4. Contamination of Wounds

   Flush contaminated minor cuts with large volumes of tepid running water, while spreading the edges of the gash.

5. Ingestion of Radioisotopes

   Unless vomiting is contraindicated:

   a. Induce vomiting by placing a finger well back in the throat.

   b. Have the victim drink a pint of water, and induce vomiting again.

6. First Aid

   When a serious injury requiring prompt first aid has occurred, the first aid should not be delayed or withheld because of the possibility that the victim is contaminated. Protective clothing is generally available and should be worn when appropriate.

C. Radiation Emergency Follow-up

The guidelines provided above describe immediate action to be taken by laboratory personnel before the arrival of the "Health Physicist." The "Health Physicist" will assist in the management of the incident by providing additional monitoring capabilities as necessary, assessing radiation doses (both internal and external), recommending decontamination plans, investigating the incident, providing required documentation, and developing recommendations to prevent reoccurrences.

D. Spills of Small Quantities of Radioisotopes

The spill of a radioisotope in an amount less than ten times the quantity indicated in column A of Appendix C need not be treated as an incident for the purposes of this section. The area must be decontaminated and the matter should be discussed with the "Health Physicist."

However, cases involving the contamination of the skin and the ingestion or inhalation of radioisotopes, regardless of the quantity, must be reported to and discussed with the "Health Physicist."

E. Emergencies in Unattended Facilities

Emergencies in laboratories and other facilities may occur at times, such as after normal working hours and during weekends and holidays, when no knowledgeable personnel are present. In these cases it is imperative that persons possessing specific knowledge of the facility and current knowledge of its activities be contacted at the earliest possible time. This is important to insure the safety of those attempting to cope with the emergency, and to permit an effective response which will minimize the adverse effects of the emergency on ongoing research and operational activities. For these reasons the "Authorized User" must post, on or near the entrance to each facility in which "Sources of Radiation" are stored or used, a completed OHS Form #31. This form is used University-wide and is readily recognized as a source of emergency information. This form:

1. provides names and phone numbers of the "Authorized User" and other knowledgeable personnel
2. identifies special or unique hazards
3. provides special instructions for emergency response personnel.

F. After Hours Notification

For emergencies which occur during other than normal working hours, emergency assistance is requested as described in paragraph A, and the "Health Physicist" and the "Authorized User" should be contacted. Names and phone numbers for the "Health Physicist" are given on OHS Form #12, while names and phone numbers for the "Authorized User" are provided on OHS Form #31.

18. MEDICAL CONSIDERATIONS

A. Radiation Incidents

1. Notification

In the event of a suspected or known high exposure to external radiation or a significant uptake of radioisotopes, the Office of Occupational Health and Safety and the Isabella McCosh Infirmary must be notified immediately.

2. Overexposure

Persons with a known or suspected high exposure to external radiation shall report to the Isabella McCosh Infirmary.

3. Contamination

a. Any person who reports to the Isabella McCosh Infirmary with minor injuries and suspected minor radioactive contamination should make the possibility of contamination known to the receptionist and the examining physician.

b. If local efforts at decontamination have failed, individuals who are personally contaminated, but otherwise uninjured, shall be taken directly to the Princeton Medical Center.

4. Serious Traumatic Injury

If a seriously injured person who is known or suspected of being contaminated or having been overexposed to radiation is taken to the Princeton Medical Center, information about the contamination or overexposure must be communicated to first aid and rescue personnel and the Medical Center.

B. Slit-Lamp Eye Examinations

1. All personnel potentially exposed to fast neutrons to the extent that they require personnel monitoring are provided with slit-lamp eye examinations for incipient cataracts at the following times:

   a. at initiation

   b. at intervals of approximately two years

   c. at termination.

   For the purposes of this section, initiation and termination shall be deemed to occur at the beginning and end, respectively, of the individual's potential exposure to fast neutrons.

2. The Office of Occupational Health and Safety schedules the eye examinations with a local ophthamologist at no expense to the examinee. The medical records are maintained by the Isabella McCosh Infirmary.

3. The "Authorized User" must report changes in personnel to the Office of Occupational Health and Safety as early as possible to facilitate scheduling of initial and termination examinations.

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19. LABORATORY DESIGN AND ORGANIZATION

One of the most effective ways of controlling exposure to radiation, particularly exposure to internally deposited radioisotopes, is through proper design and organization of the laboratory.

A. Design and Planning

Departments and "Authorized Users" planning new construction or renovations of facilities to be used for the storage or use of "Sources of Radiation" should obtain the advice of the "Health Physicist" as early as possible, preferably in the planning stage.

B. Organization

A laboratory in which "Sources of Radiation" are to be used or stored should be carefully organized, and consideration should be given to keeping it physically and operationally separate from personnel and functions which are not involved with the "Sources of Radiation." Establishing a laboratory for the use of "Sources of Radiation" in the corner of an ordinary laboratory as an afterthought is strongly discouraged. Such an action is acceptable only if the activity with "Sources of Radiation" is and will remain at a low level, and if all persons having access to the laboratory are thoroughly oriented. The best time to develop an organizational plan is prior to the application for authorization for radioisotopes or prior to obtaining authorization for a "Radiation Producing Machine or Device." The "Health Physicist" should be consulted at the earliest possible time for advice on organization.

20. FINANCIAL CONSIDERATIONS

A. Distribution of Contracted Service Costs

1. Under terms of a policy promulgated by the University Research Board, certain clearly identifiable and basic costs arising from the use of "Sources of Radiation" are distributed on a monthly basis among those departments for which such services are provided. These generally are contracted service costs and at present include:

   a. personnel monitoring

   b. radioactive waste disposal

   c. slit-lamp eye examinations

   d. New Jersey State registration and annual fees for "Radiation Producing Machines and Devices "

   e. radiological bioassays.

2. In the interest of economy and operating efficiency, the Office of Occupational Health and Safety functions as a central clearing house in these matters. The office administers and monitors the various yearly orders and maintains the mandated recordkeeping aspects of the radiation safety program.

3. Only the actual basic costs of the above services are distributed by this procedure. No overhead charges or operating costs of the Office of Occupational Health and Safety are included.

B. Procedure for Monthly Cost Distribution

1. The costs to be distributed are determined by those invoices of contracted services paid by the Controller's Office during the preceding month and which appear on the Occupational Health and Safety Office's Monthly Statement of Account. There may have been other contracted services rendered for which invoices have not yet cleared the Controller's Office. These costs are generally included in the following monthly distribution.

2. A copy of the analysis of costs to be distributed is provided for the Controller's Office. A more detailed analysis is prepared for each department, identifying the various film badge accounts, number and size of various waste containers removed, names of persons receiving slit-lamp eye examinations, and other

information helpful to the departments. These detailed analyses are sent to a designated representative, usually the "Department Health and Safety Coordinator," with a request that the representative inform the Controller's Office of the account number or numbers against which these charges are to be applied.

3. Departments establish their own means of applying their internal costs distribution among the "Authorized Users" and make their own arrangements with the Controller's Office for notification of these internal distributions.

4. The departments are responsible for informing the Office of Occupational Health and Safety of any changes in their designee. Such notification should be made by memorandum to the Occupational Health and Safety Office.

C. Financial Planning

Persons planning to use "Sources of Radiation" in their research or work are advised to give careful consideration to the financial aspects of such an undertaking. These costs can be considerable and might include the costs of monitoring equipment such as portable monitors and air samplers, signs and labels, protective equipment, etc., in addition to the monthly distribution of contracted services. Departments are advised to consider the costs involved in decommissioning a laboratory or moving a facility to a new quarters.

21. MISCELLANEOUS

A. Maintenance Work

Departments in which "Sources of Radiation" are used shall insure that University maintenance personnel are informed of that fact and that they are advised to consult with the "Authorized User" and the "Health Physicist" before commencing work. Maintenance work and certain custodial services, such as repairs to fume hoods in which radioactive materials have been used, plumbing repairs to sinks, janitorial services during the cleanup of spills, etc., should be done only after such consultation with, and in some cases, under the direct supervision of Health Physics personnel.

APPENDIX A

COMMITTEE ON OCCUPATIONAL SAFETY AND HEALTH (as of July 1, 1979)

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Professor of Biology
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Director, University Health Services
Isabella McCosh Infirmary

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*The Chairman of the Radiation Safety Committee and the Director of the Office of Occupational Health and Safety are *ex officio* members of the Committee on Occupational Safety and Health. Appointments normally run from July 1 through June 30 of the following year; however, in order to insure continuity, appointments do not expire until appointment of the new Committee is completed.

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OCCUPATIONAL HEALTH AND SAFETY SENIOR STAFF

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APPENDIX B

Concentrations in Air and Water Above Natural Background

(see footnotes on page B.7)

Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Actinium (89)	Ac 227	S	2×10^{-12}	6×10^{-5}	8×10^{-14}	2×10^{-6}
		I	3×10^{-11}	9×10^{-3}	9×10^{-13}	3×10^{-4}
	Ac 228	S	8×10^{-8}	3×10^{-3}	3×10^{-9}	9×10^{-5}
		I	2×10^{-8}	3×10^{-3}	6×10^{-10}	9×10^{-5}
Americium (95)	Am 241	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		* I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Am 242m	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	3×10^{-10}	3×10^{-3}	9×10^{-12}	9×10^{-5}
	Am 242	S	4×10^{-8}	4×10^{-3}	1×10^{-9}	1×10^{-4}
		I	5×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
	Am 243	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Am 244	S	4×10^{-6}	1×10^{-1}	1×10^{-7}	5×10^{-3}
		I	2×10^{-5}	1×10^{-1}	8×10^{-7}	5×10^{-3}
Antimony (51)	Sb 122	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
	Sb 124	S	2×10^{-7}	7×10^{-4}	5×10^{-9}	2×10^{-5}
		I	2×10^{-8}	7×10^{-4}	7×10^{-10}	2×10^{-5}
	Sb 125	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	3×10^{-8}	3×10^{-3}	9×10^{-10}	1×10^{-4}
Argon (18)	A 37	Sub[2]	6×10^{-3}	....	1×10^{-4}	....
	A 41	Sub	2×10^{-6}	....	4×10^{-8}	....
Arsenic (33)	As 73	S	2×10^{-6}	1×10^{-2}	7×10^{-8}	5×10^{-4}
		I	4×10^{-7}	1×10^{-2}	1×10^{-8}	5×10^{-4}
	As 74	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	5×10^{-5}
		I	1×10^{-7}	2×10^{-3}	4×10^{-9}	5×10^{-5}
	As 76	S	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
		I	1×10^{-7}	6×10^{-4}	3×10^{-9}	2×10^{-5}
	As 77	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
Astatine (85)	At 211	S	7×10^{-9}	5×10^{-5}	2×10^{-10}	2×10^{-6}
		I	3×10^{-8}	2×10^{-3}	1×10^{-9}	7×10^{-5}
Barium (56)	Ba 131	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Ba 140	S	1×10^{-7}	8×10^{-4}	4×10^{-9}	3×10^{-5}
		I	4×10^{-8}	7×10^{-4}	1×10^{-9}	2×10^{-5}
Berkelium (97)	Bk 249	S	9×10^{-10}	2×10^{-2}	3×10^{-11}	6×10^{-4}
		I	1×10^{-7}	2×10^{-2}	4×10^{-9}	6×10^{-4}
	Bk 250	S	1×10^{-7}	6×10^{-3}	5×10^{-9}	2×10^{-4}
		I	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
Beryllium (4)	Be 7	S	6×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
		I	1×10^{-6}	5×10^{-2}	4×10^{-8}	2×10^{-3}
Bismuth (83)	Bi 206	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
		I	1×10^{-7}	1×10^{-3}	5×10^{-9}	4×10^{-5}
	Bi 207	S	2×10^{-7}	2×10^{-3}	6×10^{-9}	6×10^{-5}
		I	1×10^{-8}	2×10^{-3}	5×10^{-10}	6×10^{-5}
	Bi 210	S	6×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
		I	6×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
	Bi 212	S	1×10^{-7}	1×10^{-2}	3×10^{-9}	4×10^{-4}
		I	2×10^{-7}	1×10^{-2}	7×10^{-9}	4×10^{-4}

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(see footnotes on page B.7)

Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Bromine (35)	Br 82	S	1×10^{-6}	8×10^{-3}	4×10^{-8}	3×10^{-4}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Cadmium (48)	Cd 109	S	5×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
		I	7×10^{-8}	5×10^{-3}	3×10^{-9}	2×10^{-4}
	Cd 115m	S	4×10^{-8}	7×10^{-4}	1×10^{-9}	3×10^{-5}
		I	4×10^{-8}	7×10^{-4}	1×10^{-9}	3×10^{-5}
	Cd 115	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Calcium (20)	Ca 45	S	3×10^{-8}	3×10^{-4}	1×10^{-9}	9×10^{-6}
		I	1×10^{-7}	5×10^{-3}	4×10^{-9}	2×10^{-4}
	Ca 47	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	3×10^{-5}
Californium (98)	Cf 249	S	2×10^{-12}	1×10^{-4}	5×10^{-14}	4×10^{-6}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	2×10^{-5}
	Cf 250	S	5×10^{-12}	4×10^{-4}	2×10^{-13}	1×10^{-5}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	3×10^{-5}
	Cf 251	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
	Cf 252	* S	6×10^{-12}	2×10^{-4}	2×10^{-13}	7×10^{-6}
		* I	3×10^{-11}	2×10^{-4}	1×10^{-12}	7×10^{-6}
	Cf 253	S	8×10^{-10}	4×10^{-3}	3×10^{-11}	1×10^{-4}
		I	8×10^{-10}	4×10^{-3}	3×10^{-11}	1×10^{-4}
	Cf 254	S	5×10^{-12}	4×10^{-6}	2×10^{-13}	1×10^{-7}
		I	5×10^{-12}	4×10^{-6}	2×10^{-13}	1×10^{-7}
Carbon (6)	C 14	S	4×10^{-6}	2×10^{-2}	1×10^{-7}	8×10^{-4}
	(CO_2)	Sub	5×10^{-5}	....	1×10^{-6}	....
Cerium (58)	Ce 141	S	4×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	2×10^{-7}	3×10^{-3}	5×10^{-9}	9×10^{-5}
	Ce 143	S	3×10^{-7}	1×10^{-3}	9×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
	Ce 144	S	1×10^{-8}	3×10^{-4}	3×10^{-10}	1×10^{-5}
		I	6×10^{-9}	3×10^{-4}	2×10^{-10}	1×10^{-5}
Cesium (55)	Cs 131	S	1×10^{-5}	7×10^{-2}	4×10^{-7}	2×10^{-3}
		I	3×10^{-6}	3×10^{-2}	1×10^{-7}	9×10^{-4}
	Cs 134m	S	4×10^{-5}	2×10^{-1}	1×10^{-6}	6×10^{-3}
		I	6×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
	Cs 134	S	4×10^{-8}	3×10^{-4}	1×10^{-9}	9×10^{-6}
		I	1×10^{-8}	1×10^{-3}	4×10^{-10}	4×10^{-5}
	Cs 135	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	9×10^{-8}	7×10^{-3}	3×10^{-9}	2×10^{-4}
	Cs 136	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	9×10^{-5}
		I	2×10^{-7}	2×10^{-3}	6×10^{-9}	6×10^{-5}
	Cs 137	S	6×10^{-8}	4×10^{-4}	2×10^{-9}	2×10^{-5}
		I	1×10^{-8}	1×10^{-3}	5×10^{-10}	4×10^{-5}
Chlorine (17)	Cl 36	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
		I	2×10^{-8}	2×10^{-3}	8×10^{-10}	6×10^{-5}
	Cl 38	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	7×10^{-8}	4×10^{-4}
Chromium (24)	Cr 51	S	1×10^{-5}	5×10^{-2}	4×10^{-7}	2×10^{-3}
		I	2×10^{-6}	5×10^{-2}	8×10^{-8}	2×10^{-3}

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(see footnotes on page B.7)

Element (atomic number)	Isotope[1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Cobalt (27)	Co 57	S	3×10^{-6}	2×10^{-2}	1×10^{-7}	5×10^{-4}
		I	2×10^{-7}	1×10^{-2}	6×10^{-9}	4×10^{-4}
	Co 58m	S	2×10^{-5}	8×10^{-2}	6×10^{-7}	3×10^{-3}
		I	9×10^{-6}	6×10^{-2}	3×10^{-7}	2×10^{-3}
	Co 58	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-8}	3×10^{-3}	2×10^{-9}	9×10^{-5}
	Co 60	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	5×10^{-5}
		I	9×10^{-9}	1×10^{-3}	3×10^{-10}	3×10^{-5}
Copper (29)	Cu 64	S	2×10^{-6}	1×10^{-2}	7×10^{-8}	3×10^{-4}
		I	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
Curium (96)	Cm 242	S	1×10^{-10}	7×10^{-4}	4×10^{-12}	2×10^{-5}
		* I	2×10^{-10}	7×10^{-4}	6×10^{-12}	2×10^{-5}
	Cm 243	S	6×10^{-12}	1×10^{-4}	2×10^{-13}	5×10^{-6}
		I	1×10^{-10}	7×10^{-4}	3×10^{-12}	2×10^{-5}
	Cm 244	S	9×10^{-12}	2×10^{-4}	3×10^{-13}	7×10^{-6}
		I	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
	Cm 245	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Cm 246	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
	Cm 247	S	5×10^{-12}	1×10^{-4}	2×10^{-13}	4×10^{-6}
		I	1×10^{-10}	6×10^{-4}	4×10^{-12}	2×10^{-5}
	Cm 248	S	6×10^{-13}	1×10^{-5}	2×10^{-14}	4×10^{-7}
		I	1×10^{-11}	4×10^{-5}	4×10^{-13}	1×10^{-6}
	Cm 249	S	1×10^{-5}	6×10^{-2}	4×10^{-7}	2×10^{-3}
		I	1×10^{-5}	6×10^{-2}	4×10^{-7}	2×10^{-3}
Dysprosium (66)	Dy 165	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	7×10^{-8}	4×10^{-4}
	Dy 166	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
Einsteinium (99)	Es 253	S	8×10^{-10}	7×10^{-4}	3×10^{-11}	2×10^{-5}
		I	6×10^{-10}	7×10^{-4}	2×10^{-11}	2×10^{-5}
	Es 254m	S	5×10^{-9}	5×10^{-4}	2×10^{-10}	2×10^{-5}
		I	6×10^{-9}	5×10^{-4}	2×10^{-10}	2×10^{-5}
	Es 254	S	2×10^{-11}	4×10^{-4}	6×10^{-13}	1×10^{-5}
		I	1×10^{-10}	4×10^{-4}	4×10^{-12}	1×10^{-5}
	Es 255	S	5×10^{-10}	8×10^{-4}	2×10^{-11}	3×10^{-5}
		I	4×10^{-10}	8×10^{-4}	1×10^{-11}	3×10^{-5}
Erbium (68)	Er 169	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	4×10^{-7}	3×10^{-3}	1×10^{-8}	9×10^{-5}
	Er 171	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Europium (63)	Eu 152	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	(T/2 = 9.2 hrs)	I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	Eu 152	S	1×10^{-8}	2×10^{-3}	4×10^{-10}	8×10^{-5}
	(T/2 = 13 yrs)	I	2×10^{-8}	2×10^{-3}	6×10^{-10}	8×10^{-5}
	Eu 154	S	4×10^{-9}	6×10^{-4}	1×10^{-10}	2×10^{-5}
		I	7×10^{-9}	6×10^{-4}	2×10^{-10}	2×10^{-5}
	Eu 155	S	9×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}
		I	7×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(see footnotes on page B.7)

Element (atomic number)	Isotope[1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Fermium (100)	Fm 254	S	6×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
		I	7×10^{-8}	4×10^{-3}	2×10^{-9}	1×10^{-4}
	Fm 255	S	2×10^{-8}	1×10^{-3}	6×10^{-10}	3×10^{-5}
		I	1×10^{-8}	1×10^{-3}	4×10^{-10}	3×10^{-5}
	Fm 256	S	3×10^{-9}	3×10^{-5}	1×10^{-10}	9×10^{-7}
		I	2×10^{-9}	3×10^{-5}	6×10^{-11}	9×10^{-7}
Fluorine (9)	F 18	S	5×10^{-6}	2×10^{-2}	2×10^{-7}	8×10^{-4}
		I	3×10^{-6}	1×10^{-2}	9×10^{-8}	5×10^{-4}
Gadolinium (64)	Gd 153	S	2×10^{-7}	6×10^{-3}	8×10^{-9}	2×10^{-4}
		I	9×10^{-8}	6×10^{-3}	3×10^{-9}	2×10^{-4}
	Gd 159	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
Gallium (31)	Ga 72	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
Germanium (32)	Ge 71	S	1×10^{-5}	5×10^{-2}	4×10^{-7}	2×10^{-3}
		I	6×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
Gold (79)	Au 196	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	6×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
	Au 198	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-5}
	Au 199	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	8×10^{-7}	4×10^{-3}	3×10^{-8}	2×10^{-4}
Hafnium (72)	Hf 181	S	4×10^{-8}	2×10^{-3}	1×10^{-9}	7×10^{-5}
		I	7×10^{-8}	2×10^{-3}	3×10^{-9}	7×10^{-5}
Holmium (67)	Ho 166	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
Hydrogen (1)	H3	S	5×10^{-6}	1×10^{-1}	2×10^{-7}	3×10^{-3}
		I	5×10^{-6}	1×10^{-1}	2×10^{-7}	3×10^{-3}
		Sub	2×10^{-3}	....	4×10^{-5}	....
Indium (49)	In 113m	S	8×10^{-6}	4×10^{-2}	3×10^{-7}	1×10^{-3}
		I	7×10^{-6}	4×10^{-2}	2×10^{-7}	1×10^{-3}
	In 114m	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
		I	2×10^{-8}	5×10^{-4}	7×10^{-10}	2×10^{-5}
	In 115m	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	4×10^{-4}
	In 115	S	2×10^{-7}	3×10^{-3}	9×10^{-9}	9×10^{-5}
		I	3×10^{-8}	3×10^{-3}	1×10^{-9}	9×10^{-5}
Iodine (53)	I 125	S	5×10^{-9}	4×10^{-5}	8×10^{-11}	2×10^{-7}
		I	2×10^{-7}	6×10^{-3}	6×10^{-9}	2×10^{-4}
	I 126	S	8×10^{-9}	5×10^{-5}	9×10^{-11}	3×10^{-7}
		I	3×10^{-7}	3×10^{-3}	1×10^{-8}	9×10^{-5}
	I 129	S	2×10^{-9}	1×10^{-5}	2×10^{-11}	6×10^{-8}
		I	7×10^{-8}	6×10^{-3}	2×10^{-9}	2×10^{-4}
	I 131	S	9×10^{-9}	6×10^{-5}	1×10^{-10}	3×10^{-7}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	I 132	S	2×10^{-7}	2×10^{-3}	3×10^{-9}	8×10^{-6}
		I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	I 133	S	3×10^{-8}	2×10^{-4}	4×10^{-10}	1×10^{-6}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
	I 134	S	5×10^{-7}	4×10^{-3}	6×10^{-9}	2×10^{-5}

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(see footnotes on page B.7)

Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Iodine (53)	I 134	I	3×10^{-6}	2×10^{-2}	1×10^{-7}	6×10^{-4}
	I 135	S	1×10^{-7}	7×10^{-4}	1×10^{-9}	4×10^{-6}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
Iridium (77)	Ir 190	S	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Ir 192	S	1×10^{-7}	1×10^{-3}	4×10^{-9}	4×10^{-5}
		I	3×10^{-8}	1×10^{-3}	9×10^{-10}	4×10^{-5}
	Ir 194	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
Iron (26)	Fe 55	S	9×10^{-7}	2×10^{-2}	3×10^{-8}	8×10^{-4}
		I	1×10^{-6}	7×10^{-2}	3×10^{-8}	2×10^{-3}
	Fe 59	S	1×10^{-7}	2×10^{-3}	5×10^{-9}	6×10^{-5}
		I	5×10^{-8}	2×10^{-3}	2×10^{-9}	5×10^{-5}
Krypton (36)	Kr 85m	Sub	6×10^{-6}	----------	1×10^{-7}	----------
	Kr 85	Sub	1×10^{-5}	----------	3×10^{-7}	----------
	Kr 87	Sub	1×10^{-6}	----------	2×10^{-8}	----------
	Kr 88	Sub	1×10^{-6}	----------	2×10^{-8}	----------
Lanthanum (57)	La 140	S	2×10^{-7}	7×10^{-4}	5×10^{-9}	2×10^{-5}
		I	1×10^{-7}	7×10^{-4}	4×10^{-9}	2×10^{-5}
Lead (82)	Pb 203	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	4×10^{-4}
	Pb 210	S	1×10^{-10}	4×10^{-6}	4×10^{-12}	1×10^{-7}
		I	2×10^{-10}	5×10^{-3}	8×10^{-12}	2×10^{-4}
	Pb 212	S	2×10^{-8}	6×10^{-4}	6×10^{-10}	2×10^{-5}
		I	2×10^{-8}	5×10^{-4}	7×10^{-10}	2×10^{-5}
Lutetium (71)	Lu 177	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Manganese (25)	Mn 52	S	2×10^{-7}	1×10^{-3}	7×10^{-9}	3×10^{-5}
		I	1×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
	Mn 54	* S	4×10^{-7}	4×10^{-3}	1×10^{-8}	1×10^{-4}
		I	4×10^{-8}	3×10^{-3}	1×10^{-9}	1×10^{-4}
	Mn 56	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Mercury (80)	Hg 197m	S	7×10^{-7}	6×10^{-3}	3×10^{-8}	2×10^{-4}
		I	8×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	Hg 197	S	1×10^{-6}	9×10^{-3}	4×10^{-8}	3×10^{-4}
		I	3×10^{-6}	1×10^{-2}	9×10^{-8}	5×10^{-4}
	Hg 203	S	7×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
		I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
Molybdenum (42)	Mo 99	S	7×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
Neodymium (60)	Nd 144	S	8×10^{-11}	2×10^{-3}	3×10^{-12}	7×10^{-5}
		I	3×10^{-10}	2×10^{-3}	1×10^{-11}	8×10^{-5}
	Nd 147	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	2×10^{-7}	2×10^{-3}	8×10^{-9}	6×10^{-5}
	Nd 149	S	2×10^{-6}	8×10^{-3}	6×10^{-8}	3×10^{-4}
		I	1×10^{-6}	8×10^{-3}	5×10^{-8}	3×10^{-4}

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(see footnotes on page B.7)

Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Neptunium (93)	Np 237	S	4×10^{-12}	9×10^{-5}	1×10^{-13}	3×10^{-6}
		I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	Np 239	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	7×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
Nickel (28)	Ni 59	S	5×10^{-7}	6×10^{-3}	2×10^{-8}	2×10^{-4}
		I	8×10^{-7}	6×10^{-3}	3×10^{-8}	2×10^{-5}
	Ni 63	S	6×10^{-8}	8×10^{-4}	2×10^{-9}	3×10^{-5}
		I	3×10^{-7}	2×10^{-2}	1×10^{-8}	7×10^{-4}
	Ni 65	S	9×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Niobium (Columbium) (41).	Nb 93m	S	1×10^{-7}	1×10^{-2}	4×10^{-9}	4×10^{-4}
		I	2×10^{-7}	1×10^{-2}	5×10^{-9}	4×10^{-4}
	Nb 95	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	1×10^{-7}	3×10^{-3}	3×10^{-9}	1×10^{-4}
	Nb 97	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
Osmium (76)	Os 185	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	5×10^{-8}	2×10^{-3}	2×10^{-9}	7×10^{-5}
	Os 191m	S	2×10^{-5}	7×10^{-2}	6×10^{-7}	3×10^{-3}
		I	9×10^{-6}	7×10^{-2}	3×10^{-7}	2×10^{-3}
	Os 191	S	1×10^{-6}	5×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Os 193	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	3×10^{-7}	2×10^{-3}	9×10^{-9}	5×10^{-5}
Palladium (46)	Pd 103	S	1×10^{-6}	1×10^{-2}	5×10^{-8}	3×10^{-4}
		I	7×10^{-7}	8×10^{-3}	3×10^{-8}	3×10^{-4}
	Pd 109	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
Phosphorus (15)	P 32	S	7×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
		I	8×10^{-8}	7×10^{-4}	3×10^{-9}	2×10^{-5}
Platinum (78)	Pt 191	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
	Pt 193m	S	7×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
*	Pt 193	S	1×10^{-6}	3×10^{-2}	4×10^{-8}	9×10^{-4}
		I	3×10^{-7}	5×10^{-2}	1×10^{-8}	2×10^{-3}
	Pt 197m	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	1×10^{-3}
		I	5×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
	Pt 197	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Plutonium (94)	Pu 238	S	2×10^{-12}	1×10^{-4}	7×10^{-14}	5×10^{-6}
		I	3×10^{-11}	8×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 239	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
		I	4×10^{-11}	8×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 240	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
		I	4×10^{-11}	8×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 241	S	9×10^{-11}	7×10^{-3}	3×10^{-11}	2×10^{-4}
		I	4×10^{-8}	4×10^{-2}	1×10^{-9}	1×10^{-3}

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

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Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Plutonium (94)	Pu 242	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
		I	4×10^{-11}	9×10^{-4}	1×10^{-12}	3×10^{-5}
	Pu 243	S	2×10^{-6}	1×10^{-2}	6×10^{-8}	3×10^{-4}
		I	2×10^{-6}	1×10^{-2}	8×10^{-8}	3×10^{-4}
	Pu 244	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	4×10^{-6}
		I	3×10^{-11}	3×10^{-4}	1×10^{-12}	1×10^{-5}
Polonium (84)	Po 210	S	5×10^{-10}	2×10^{-5}	2×10^{-11}	7×10^{-7}
		I	2×10^{-10}	8×10^{-4}	7×10^{-12}	3×10^{-5}
Potassium (19)	K 42	S	2×10^{-6}	9×10^{-3}	7×10^{-8}	3×10^{-4}
		I	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
Praseodymium (59)	Pr 142	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
	Pr 143	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	5×10^{-5}
		I	2×10^{-7}	1×10^{-3}	6×10^{-9}	5×10^{-5}
Promethium (61)	Pm 147	S	6×10^{-8}	6×10^{-3}	2×10^{-9}	2×10^{-4}
		I	1×10^{-7}	6×10^{-3}	3×10^{-9}	2×10^{-4}
	Pm 149	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
Protoactinium (91)	Pa 230	S	2×10^{-9}	7×10^{-3}	6×10^{-11}	2×10^{-4}
		I	8×10^{-10}	7×10^{-3}	3×10^{-11}	2×10^{-4}
	Pa 231	S	1×10^{-12}	3×10^{-5}	4×10^{-14}	9×10^{-7}
		I	1×10^{-10}	8×10^{-4}	4×10^{-12}	2×10^{-5}
	Pa 233	S	6×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
		I	2×10^{-7}	3×10^{-3}	6×10^{-9}	1×10^{-4}
Radium (88)	Ra 223	S	2×10^{-9}	2×10^{-5}	6×10^{-11}	7×10^{-7}
		I	2×10^{-10}	1×10^{-4}	8×10^{-12}	4×10^{-6}
	Ra 224	S	5×10^{-9}	7×10^{-5}	2×10^{-10}	2×10^{-6}
		I	7×10^{-10}	2×10^{-4}	2×10^{-11}	5×10^{-6}
	Ra 226	S	3×10^{-11}	4×10^{-7}	3×10^{-12}	3×10^{-8}
		I	5×10^{-11}	9×10^{-4}	2×10^{-12}	3×10^{-5}
	Ra 228	S	7×10^{-11}	8×10^{-7}	2×10^{-12}	3×10^{-8}
		I	4×10^{-11}	7×10^{-4}	1×10^{-12}	3×10^{-5}
Radon (86)	Rn 220	S	3×10^{-7}	----------	1×10^{-8}	----------
	Rn 222 [3] ***		*** 3×10^{-8}	----------	3×10^{-9}	----------
Rhenium (75)	Re 183	S	3×10^{-6}	2×10^{-2}	9×10^{-8}	6×10^{-4}
		I	2×10^{-7}	8×10^{-3}	5×10^{-9}	3×10^{-4}
	Re 186	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-5}
	Re 187	S	9×10^{-6}	7×10^{-2}	3×10^{-7}	3×10^{-3}
		I	5×10^{-7}	4×10^{-2}	2×10^{-8}	2×10^{-3}
	Re 188	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
Rhodium (45)	Rh 103m	S	8×10^{-5}	4×10^{-1}	3×10^{-6}	1×10^{-2}
		I	6×10^{-5}	3×10^{-1}	2×10^{-6}	1×10^{-2}
	Rh 105	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Rubidium (37)	Rb 86	S	3×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
		I	7×10^{-8}	7×10^{-4}	2×10^{-9}	2×10^{-5}
	Rb 87	S	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	7×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}

APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

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Element (atomic number)	Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Ruthenium (44)	Ru 97	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	3×10^{-4}
	Ru 103	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	8×10^{-8}	2×10^{-3}	3×10^{-9}	8×10^{-5}
	Ru 105	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
	Ru 106	S	8×10^{-8}	4×10^{-4}	3×10^{-9}	1×10^{-5}
		I	6×10^{-9}	3×10^{-4}	2×10^{-10}	1×10^{-5}
Samarium (62)	Sm 147	S	7×10^{-11}	2×10^{-3}	2×10^{-12}	6×10^{-5}
		I	3×10^{-10}	2×10^{-3}	9×10^{-12}	7×10^{-5}
	Sm 151	S	6×10^{-8}	1×10^{-2}	2×10^{-9}	4×10^{-4}
		I	1×10^{-7}	1×10^{-2}	5×10^{-9}	4×10^{-4}
	Sm 153	S	5×10^{-7}	2×10^{-3}	2×10^{-8}	8×10^{-5}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	8×10^{-5}
Scandium (21)	Sc 46	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
		I	2×10^{-8}	1×10^{-3}	8×10^{-10}	4×10^{-5}
	Sc 47	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	9×10^{-5}
	Sc 48	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
Selenium (34)	Se 75	S	1×10^{-6}	9×10^{-3}	4×10^{-8}	3×10^{-4}
		I	1×10^{-7}	8×10^{-3}	4×10^{-9}	3×10^{-4}
Silicon (14)	Si 31	S	6×10^{-6}	3×10^{-2}	2×10^{-7}	9×10^{-4}
		I	1×10^{-6}	6×10^{-3}	3×10^{-8}	2×10^{-4}
Silver (47)	Ag 105	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	8×10^{-8}	3×10^{-3}	3×10^{-9}	1×10^{-4}
	Ag 110m	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
		I	1×10^{-8}	9×10^{-4}	3×10^{-10}	3×10^{-5}
	Ag 111	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	4×10^{-5}
		I	2×10^{-7}	1×10^{-3}	8×10^{-9}	4×10^{-5}
Sodium (11)	Na 22	S	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
		I	9×10^{-9}	9×10^{-4}	3×10^{-10}	3×10^{-5}
	Na 24	S	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
		I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}
Strontium (38)	Sr 85m	S	4×10^{-5}	2×10^{-1}	1×10^{-6}	7×10^{-3}
		I	3×10^{-5}	2×10^{-1}	1×10^{-6}	7×10^{-3}
	Sr 85	S	2×10^{-7}	3×10^{-3}	8×10^{-9}	1×10^{-4}
		I	1×10^{-7}	5×10^{-3}	4×10^{-9}	2×10^{-4}
	Sr 89	S	3×10^{-8}	3×10^{-4}	3×10^{-10}	3×10^{-6}
		I	4×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
	Sr 90	S	1×10^{-9}	1×10^{-5}	3×10^{-11}	3×10^{-7}
		I	5×10^{-9}	1×10^{-3}	2×10^{-10}	4×10^{-5}
	Sr 91	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	3×10^{-7}	1×10^{-3}	9×10^{-9}	5×10^{-5}
	Sr 92	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
Sulfur (16)	S 35	S	3×10^{-7}	2×10^{-3}	9×10^{-9}	6×10^{-5}
		I	3×10^{-7}	8×10^{-3}	9×10^{-9}	3×10^{-4}
Tantalum (73)	Ta 182	S	4×10^{-8}	1×10^{-3}	1×10^{-9}	4×10^{-5}
		I	2×10^{-8}	1×10^{-3}	7×10^{-10}	4×10^{-5}

APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(see footnotes on page B.7)

Element (atomic number)		Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Technetium (43)		Tc 96m	S	8×10^{-5}	4×10^{-1}	3×10^{-6}	1×10^{-2}
			I	3×10^{-5}	3×10^{-1}	1×10^{-6}	1×10^{-2}
		Tc 96	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
			I	2×10^{-7}	1×10^{-3}	8×10^{-9}	5×10^{-5}
		Tc 97m	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
			I	2×10^{-7}	5×10^{-3}	5×10^{-9}	2×10^{-4}
		Tc 97	S	1×10^{-5}	5×10^{-2}	4×10^{-7}	2×10^{-3}
			I	3×10^{-7}	2×10^{-2}	1×10^{-8}	8×10^{-4}
		Tc 99m	S	4×10^{-5}	2×10^{-1}	1×10^{-6}	6×10^{-3}
			I	1×10^{-5}	8×10^{-2}	5×10^{-7}	3×10^{-3}
		Tc 99	S	2×10^{-6}	1×10^{-2}	7×10^{-8}	3×10^{-4}
			I	6×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
Tellurium (52)		Te 125m	S	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
			I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
		Te 127m	S	1×10^{-7}	2×10^{-3}	5×10^{-9}	6×10^{-5}
			I	4×10^{-8}	2×10^{-3}	1×10^{-9}	5×10^{-5}
		Te 127	S	2×10^{-6}	8×10^{-3}	6×10^{-8}	3×10^{-4}
			I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
		Te 129m	S	8×10^{-8}	1×10^{-3}	3×10^{-9}	3×10^{-5}
			I	3×10^{-8}	6×10^{-4}	1×10^{-9}	2×10^{-5}
		Te 129	S	5×10^{-6}	2×10^{-2}	2×10^{-7}	8×10^{-4}
			I	4×10^{-6}	2×10^{-2}	1×10^{-7}	8×10^{-4}
		Te 131m	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
			I	2×10^{-7}	1×10^{-3}	6×10^{-9}	4×10^{-5}
		Te 132	S	2×10^{-7}	9×10^{-4}	7×10^{-9}	3×10^{-5}
			I	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
Terbium (65)		Tb 160	S	1×10^{-7}	1×10^{-3}	3×10^{-9}	4×10^{-5}
			I	3×10^{-8}	1×10^{-3}	1×10^{-9}	4×10^{-5}
Thallium (81)		Tl 200	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
			I	1×10^{-6}	7×10^{-3}	4×10^{-8}	2×10^{-4}
		Tl 201	S	2×10^{-6}	9×10^{-3}	7×10^{-8}	3×10^{-4}
			I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
		Tl 202	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
			I	2×10^{-7}	2×10^{-3}	8×10^{-9}	7×10^{-5}
		Tl 204	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
			I	3×10^{-8}	2×10^{-3}	9×10^{-10}	6×10^{-5}
Thorium (90)	*	Th 227	S	3×10^{-10}	5×10^{-4}	1×10^{-11}	2×10^{-5}
			I	2×10^{-10}	5×10^{-4}	6×10^{-12}	2×10^{-5}
		Th 228	S	9×10^{-12}	2×10^{-4}	3×10^{-13}	7×10^{-6}
			I	6×10^{-12}	4×10^{-4}	2×10^{-13}	1×10^{-5}
		Th 230	S	2×10^{-12}	5×10^{-5}	8×10^{-14}	2×10^{-6}
			I	1×10^{-11}	9×10^{-4}	3×10^{-13}	3×10^{-5}
	*	Th 231	S	1×10^{-6}	7×10^{-3}	5×10^{-8}	2×10^{-4}
			I	1×10^{-6}	7×10^{-3}	4×10^{-8}	2×10^{-4}
		Th 232	S	3×10^{-11}	5×10^{-5}	1×10^{-12}	2×10^{-6}
			I	3×10^{-11}	1×10^{-3}	1×10^{-12}	4×10^{-5}
	+*	Th natural	S	6×10^{-11}	6×10^{-5}	2×10^{-12}	2×10^{-6}
				6×10^{-11}	6×10^{-4}	2×10^{-12}	2×10^{-5}

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(see footnotes on page B.7)

Element (atomic number)		Isotope [1]	†	Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Thorium (90)		Th 234	S	6×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
			I	3×10^{-8}	5×10^{-4}	1×10^{-9}	2×10^{-5}
Thulium (69)		Tm 170	S	4×10^{-8}	1×10^{-3}	1×10^{-9}	5×10^{-5}
			I	3×10^{-8}	1×10^{-3}	1×10^{-9}	5×10^{-5}
		Tm 171	S	1×10^{-7}	1×10^{-2}	4×10^{-9}	5×10^{-4}
			I	2×10^{-7}	1×10^{-2}	8×10^{-9}	5×10^{-4}
Tin (50)		Sn 113	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	9×10^{-5}
			I	5×10^{-8}	2×10^{-3}	2×10^{-9}	8×10^{-5}
		Sn 125	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
			I	8×10^{-8}	5×10^{-4}	3×10^{-9}	2×10^{-5}
Tungsten (Wolfram) (74)		W 181	S	2×10^{-6}	1×10^{-2}	8×10^{-8}	4×10^{-4}
			I	1×10^{-7}	1×10^{-2}	4×10^{-9}	3×10^{-4}
		W 185	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
			I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
		W 187	S	4×10^{-7}	2×10^{-3}	2×10^{-8}	7×10^{-5}
			I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
Uranium (92)		U 230	S	3×10^{-10}	1×10^{-4}	1×10^{-11}	5×10^{-6}
			I	1×10^{-10}	1×10^{-4}	4×10^{-12}	5×10^{-6}
		U 232	S	1×10^{-10}	8×10^{-4}	3×10^{-12}	3×10^{-5}
			I	3×10^{-11}	8×10^{-4}	9×10^{-13}	3×10^{-5}
		U 233	S	5×10^{-10}	9×10^{-4}	2×10^{-11}	3×10^{-5}
			I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	**	U 234	S[4]	6×10^{-10}	9×10^{-4}	2×10^{-11}	3×10^{-5}
			I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	**	U 235	S[4]	5×10^{-10}	8×10^{-4}	2×10^{-11}	3×10^{-5}
			I	1×10^{-10}	8×10^{-4}	4×10^{-12}	3×10^{-5}
		U 236	S	6×10^{-10}	1×10^{-3}	2×10^{-11}	3×10^{-5}
			I	1×10^{-10}	1×10^{-3}	4×10^{-12}	3×10^{-5}
	**	U 238	S[4]	7×10^{-11}	1×10^{-3}	3×10^{-12}	4×10^{-5}
			I	1×10^{-10}	1×10^{-3}	5×10^{-12}	4×10^{-5}
		U 240	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
			I	2×10^{-7}	1×10^{-3}	6×10^{-9}	3×10^{-5}
	**	U-natural	S[4]	1×10^{-10}	1×10^{-3}	5×10^{-12}	3×10^{-5}
			I	1×10^{-10}	1×10^{-3}	5×10^{-12}	3×10^{-5}
Vanadium (23)		V 48	S	2×10^{-7}	9×10^{-4}	6×10^{-9}	3×10^{-5}
			I	6×10^{-8}	8×10^{-4}	2×10^{-9}	3×10^{-5}
Xenon (54)		Xe 131m	Sub	2×10^{-5}	....	4×10^{-7}	....
		Xe 133	Sub	1×10^{-5}	....	3×10^{-7}	....
		Xe 133m	Sub	1×10^{-5}	....	3×10^{-7}	....
		Xe*135	Sub	4×10^{-6}	....	1×10^{-7}	....
Ytterbium (70)		Yb 175	S	7×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
			I	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Yttrium (39)		Y 90	S	1×10^{-7}	6×10^{-4}	4×10^{-9}	2×10^{-5}
			I	1×10^{-7}	6×10^{-4}	3×10^{-9}	2×10^{-5}
		Y 91m	S	2×10^{-5}	1×10^{-1}	8×10^{-7}	3×10^{-3}
			I	2×10^{-5}	1×10^{-1}	6×10^{-7}	3×10^{-3}
		Y 91	S	4×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
			I	3×10^{-8}	8×10^{-4}	1×10^{-9}	3×10^{-5}
		Y 92	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
			I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		Y 93	S	2×10^{-7}	8×10^{-4}	6×10^{-9}	3×10^{-5}
			I	1×10^{-7}	8×10^{-4}	5×10^{-9}	3×10^{-5}

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(see footnotes on page B.7)

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Element (atomic number)	Isotope[1]		Table I Column 1 Air (μCi/ml)	Table I Column 2 Water (μCi/ml)	Table II Column 1 Air (μCi/ml)	Table II Column 2 Water (μCi/ml)
Zinc (30)	Zn 65	S	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
		I	6×10^{-8}	5×10^{-3}	2×10^{-9}	2×10^{-4}
	Zn 69m	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	Zn 69	S	7×10^{-6}	5×10^{-2}	2×10^{-7}	2×10^{-3}
		I	9×10^{-6}	5×10^{-2}	3×10^{-7}	2×10^{-3}
Zirconium (40)	Zr 93	S	1×10^{-7}	2×10^{-2}	4×10^{-9}	8×10^{-4}
		I	3×10^{-7}	2×10^{-2}	1×10^{-8}	8×10^{-4}
	Zr 95	S	1×10^{-7}	2×10^{-3}	4×10^{-9}	6×10^{-5}
		I	3×10^{-8}	2×10^{-3}	1×10^{-9}	6×10^{-5}
	Zr 97	S	1×10^{-7}	5×10^{-4}	4×10^{-9}	2×10^{-5}
		I	9×10^{-8}	5×10^{-4}	3×10^{-9}	2×10^{-5}
Any single radionuclide not listed above with decay mode other than alpha emission or spontaneous fission and with radioactive half-life less than 2 hours.		Sub	1×10^{-6}		3×10^{-8}	
Any single radionuclide not listed above with decay mode other than alpha emission or spontaneous fission and with radioactive half-life greater than 2 hours.			3×10^{-9}	9×10^{-5}	1×10^{-10}	3×10^{-6}
Any single radionuclide not listed above, which decays by alpha emission or spontaneous fission.			6×10^{-13}	4×10^{-7}	2×10^{-14}	3×10^{-8}

[1] Soluble (S); Insoluble (I).

[2] "Sub" means that values given are for submersion in a semispherical infinite cloud of airborne material.

40 FR 50704

[3] These radon concentrations are appropriate for protection from radon-222 combined with its short-lived daughters. Alternatively, the value in Table I may be replaced by one-third (1/3) "working level." (A "working level" is defined as any combination of short-lived radon-222 daughters, polonium-218, lead-214, bismuth-214 and polonium-214, in one liter of air, without regard to the degree of equilibrium, that will result in the ultimate emission of 1.3 x 10[5] MeV of alpha particle energy.) The Table II value may be replaced by one-thirtieth (1/30) of a "working level." The limit on radon-222 concentrations in restricted areas may be based on an annual average.

39 FR 23990

‡4. For soluble mixtures of U-238, U-234 and U-235 in air chemical toxicity may be the limiting factor. If the percent by weight (enrichment) of U-235 is less than 5, the concentration value for a 40-hour workweek, Table I, is 0.2 milligrams uranium per cubic meter of air average. For any enrichment, the product of the average concentration and time of exposure during a 40-hour workweek shall not exceed 8×10^{-3} SA μCi-hr/ml, where SA is the specific activity of the uranium inhaled. The concentration value for Table II is 0.007 milligrams uranium per cubic meter of air. The specific activity for natural uranium is 6.77×10^{-7} curies per gram U. The specific activity for other mixtures of U-238, U-235 and U-234, if not known, shall be:

$SA = 3.6 \times 10^{-7}$ curies/gram U — U-depleted

$SA = (0.4 + 0.38 E + 0.0034 E^2) 10^{-6}$ — $E \geq 0.72$

where E is the percentage by weight of U-235, expressed as percent.

*Amended 37 FR 23319.

**Amended 39 FR 23990; footnote redesignated 40 FR 50704.

***Amended 40 FR 50704.

†Amended 38 FR 29314.

‡Amended 39 FR 25463; redesignated 40 FR 50704.

[25 FR 10914] NOTE. In any case where there is a mixture in air or water of more than one radionuclide, the limiting values for purposes of this Appendix should be determined as follows:

1. If the identity and concentration of each radionuclide in the mixture are known, the limiting values should be derived as follows: Determine, for each radionuclide in the mixture, the ratio between the quantity present in the mixture and the limit otherwise established in Appendix B for the specific radionuclide when not in a mixture. The sum of such ratios for all the radionuclides in the mixture may not exceed "1" (i.e., "unity").

EXAMPLE: If radionuclides A, B, and C are present in concentrations C_A, C_B, and C_C, and if the applicable MPC's, are MPC_A, and MPC_B, and MPC_C respectively, then the concentrations shall be limited so that the following relationship exists:

$$\frac{C_A}{MPC_A}+\frac{C_B}{MPC_B}+\frac{C_C}{MPC_C}\leq 1$$

[30 FR 15801] 2. If either the identity or the concentration of any radionuclide in the mixture is not known, the limiting values for purposes of Appendix B shall be:

a. For purposes of Table I, Col. 1—6×10^{-13}

b. For purposes of Table I, Col. 2—4×10^{-7}

c. For purposes of Table II, Col. 1—2×10^{-14}

d. For purposes of Table II, Col. 2—3×10^{-8}

[26 FR 11046] 3. If any of the conditions specified below are met, the corresponding values specified below may be used in lieu of those specified in paragraph 2 above.

a. If the identity of each radionuclide in the mixture is known but the concentration of one or more of the radionuclides in the mixture is not known, the concentration limit for the mixture is the limit specified in Appendix "B" for the radionuclide in the mixture having the lowest concentration limit; or

b. If the identity of each radionuclide in the mixture is not known, but it is known that certain radionuclides specified in Appendix "B" are not present in the mixture, the concentration limit for the mixture is the lowest concentration limit specified in Appendix "B" for any radionuclide which is not known to be absent from the mixture; or

[30 FR 15801]

c. Element (atomic number) and isotope	Table I		Table II	
	Column 1 Air (µCi/ml)	Column 2 Water (µCi/ml)	Column 1 Air (µCi/ml)	Column 2 Water (µCi/ml)
If it is known that Sr 90, I 125, I 126, I 129, I 131, (I 133, table II only), Pb 210, Po 210, At 211, Ra 223, Ra 224, Ra 226, Ac 227, Ra 228, Th 230, Pa 231, Th 232, Th-nat, Cm 248, Cf 254, and Fm 256 are not present	----------	9×10^{-5}	----------	3×10^{-6}
If it is known that Sr 90, I 125, I 126, I 129, (I 131, I 133, table II only), Pb 210, Po 210, Ra 223, Ra 226, Ra 228, Pa 231, Th-nat, Cm 248, Cf 254, and Fm 256 are not present	----------	6×10^{-5}	----------	2×10^{-6}
If it is known that Sr 90, I 129, (I 125, I 126, I 131, table II only), Pb 210, Ra 226, Ra 228, Cm 248, and Cf 254 are not present	----------	2×10^{-5}	----------	6×10^{-7}
If it is known that (I 129, table II only), Ra 226, and Ra 228 are not present	----------	3×10^{-6}	----------	1×10^{-7}
If it is known that alpha-emitters and Sr 90, I 129, Pb 210, Ac 227, Ra 228, Pa 230, Pu 241, and Bk 249 are not present	3×10^{-9}	----------	1×10^{-10}	----------
If it is known that alpha-emitters and Pb 210, Ac 227, Ra 228, and Pu 241 are not present	3×10^{-10}	----------	1×10^{-11}	----------
If it is known that alpha-emitters and Ac 227 are not present	3×10^{-11}	----------	1×10^{-12}	----------
If it is known that Ac 227, Th 230, Pa 231, Pu 238, Pu 239, Pu 240, Pu 242, Pu 244, Cm 248, Cf 249 and Cf 251 are not present	3×10^{-12}	----------	1×10^{-13}	----------

[40 FR 50704] 4. If a mixture of radionuclides consists of uranium and its daughters in ore dust prior to chemical separation of the uranium from the ore, the values specified below may be used for uranium and its daughters through radium-226, instead of those from paragraphs 1, 2, or 3 above.

[39 FR 23990] a. For purposes of Table I, Col. 1—1×10^{-10} µCi/ml gross alpha activity; or 5×10^{-11} µCi/ml natural uranium; or 75 micrograms per cubic meter of air natural uranium.

b. For purposes of Table II, Col. 1—3×10^{-12} µCi/ml gross alpha activity; or 2×10^{-12} µCi/ml natural uranium; or 3 micrograms per cubic meter of air natural uranium.

[26 FR 11046] 5. For purposes of this note, a radionuclide may be considered as not present in a mixture if (a) the ratio of the concentration of that radionuclide in the mixture (C_A) to the concentration limit for that radionuclide specified in Table II of Appendix B (MPC_A) does not exceed 1/10 (i.e. $\frac{C_A}{MPC_A}\leq\frac{1}{10}$) and (b) the sum of such ratios for all the radionuclides considered as not present in the mixture does not exceed 1/4

(i.e. $\frac{C_A}{MPC_A}+\frac{C_B}{MPC_B}+\ldots\ldots\leq\frac{1}{4}$).

APPENDIX C

Basic Quantities and Body Burdens for Various Radioisotopes

Radioisotope[(a)(b)]	Column A Basic Quantity[(c)] (μCi)	Column B Maximum Permissible Body Burden[(d)] (μCi)
Americium-241	0.01	0.05
Antimony-122	100	---
Antimony-124	10	10
Antimony-125	10	40
Arsenic-73	100	300
Arsenic-74	10	---
Arsenic-76	10	---
Arsenic-77	100	---
Barium-131	10	---
Barium-133	10	---
Barium-140	10	4
*Beryllium-7	50	600
*Bismuth-207	0.1	2
Bismuth-210	1	0.04
Bromine-82	10	10
Cadmium-109	10	20
Cadmium-115m	10	3
Cadmium-115	100	---
Calcium-45	10	30
Calcium-47	10	5
Carbon-14	100	300

Radioisotope[a][b]	Column A Basic Quantity[c] (μCi)	Column B Maximum Permissible Body Burden[d] (μCi)
Cerium-141	100	30
Cerium-143	100	---
Cerium-144	1	5
Cesium-131	1000	700
Cesium-134m	100	---
Cesium-134	1	20
Cesium-135	10	200
Cesium-136	10	30
Cesium-137	10	30
Chlorine-36	10	80
Chlorine-38	10	---
*Chromium-51	50	800
*Cobalt-57	0.1	---
Cobalt-58m	10	---
Cobalt-58	10	30
Cobalt-60	1	10
Copper-64	100	---
Dysprosium-165	10	---
Dysprosium-166	100	---
Erbium-169	100	---
Erbium-171	100	---
Europium-152 (9.2 hr)	100	---

Radioisotope[a][b]	Column A Basic Quantity[c] (μCi)	Column B Maximum Permissible Body Burden[d] (μCi)
Europium -152 (13 yr)	1	20
Europium-154	1	5
Europium-155	10	70
*Fluorine-18	50	---
Gadolinium-153	10	90
Gadolinium-159	100	---
Gallium-72	10	---
*Germanium-68	0.1	---
Germanium-71	100	---
Gold-198	100	---
Gold-199	100	---
Hafnium-181	10	4
Holmium-166	100	---
Hydrogen-3	1000	1000
*Hydrogen-3	250	1000
Indium-113m	100	---
Indium-114m	10	6
Indium-115m	100	---
Indium-115	10	30
Iodine-125	1	3.8[e]
Iodine-126	1	1
Iodine-129	0.1	3
Iodine-131	1	0.7

Radioisotope[a][b]	Column A Basic Quantity[c] (μCi)	Column B Maximum Permissible Body Burden[d] (μCi)
Iodine-132	10	0.3
Iodine-133	1	0.3
Iodine-134	10	0.2
Iodine-135	10	0.3
Iridium-192	10	6
Iridium-194	100	---
*Iron-55	50	1000
Iron-59	10	20
Krypton-85	100	---
Krypton-87	10	---
Lanthanum-140	10	---
Lutetium-177	100	---
*Manganese-52	1	---
*Manganese-54	0.1	20
Manganese-56	10	---
Mercury-197m	100	4
Mercury-197	100	20
Mercury-203	10	4
Molybdenum-99	100	8
Neodymium-147	100	10
Neodymium-149	100	---
Nickel-59	100	1000
Nickel-63	10	200

Radioisotope[a][b]	Column A Basic Quantity[c] (μCi)	Column B Maximum Permissible Body Burden[d] (μCi)
Nickel-65	100	---
Niobium-93m	10	200
Niobium-95	10	40
Niobium-97	10	---
Osmium-185	10	---
Osmium-191m	100	---
Osmium-191	100	---
Osmium-193	100	---
*Palladium-103	50	20
Palladium-109	100	---
Phosphorus-32	10	6
Platinum-191	100	---
Platinum-193m	100	---
Platinum-193	100	70
Platinum-197m	100	---
Platinum-197	100	---
Plutonium-239	0.01	0.04
Polonium-210	0.1	0.03
Potassium-42	10	---
Praesodymium-142	100	---
Praesodymium-143	100	---
Promethium-147	10	60
Promethium-149	10	---

Radioisotope[a][b]	Column A Basic Quantity[c] (μCi)	Column B Maximum Permissible Body Burden[d] (μCi)
*Radium-226 + daughters	0.1	0.1
Rhenium-186	100	---
Rhenium-188	100	---
Rhodium-103m	100	---
Rhodium-105	100	---
Rubidium-86	10	30
Rubidium-87	10	200
Ruthenium-97	100	---
Ruthenium-103	10	---
Ruthenium-105	10	---
Ruthenium-106	1	---
Samarium-151	10	100
Samarium-153	100	---
Scandium-46	10	10
Scandium-47	100	---
Scandium-48	10	---
Selenium-75	10	90
Silicon-31	100	---
*Silver-105	1	---
*Silver-109	0.1	---
Silver-110m	1	---
Silver-111	100	---
*Sodium-22	10	10
Sodium-24	10	---

Radioisotope[a][b]	Column A Basic Quantity[c] (μCi)	Column B Maximum Permissible Body Burden[d] (μCi)
Strontium-85	10	60
Strontium-89	1	4
Strontium-90	0.1	2
Strontium-91	10	---
Strontium-92	10	---
Sulphur-35	100	90
Tantalum-182	10	7
*Technetium-96	1	---
Technetium-97m	100	---
Technetium-97	100	60
Technetium-99m	100	---
Technetium-99	10	---
Tellurium-125m	10	20
Tellurium-127m	10	7
Tellurium-127	100	---
Tellurium-129m	10	3
Tellurium-129	100	---
Tellurium-131m	10	---
Tellurium-132	10	---
Terbium-160	10	20
Thallium-200	100	---
Thallium-201	100	---
Thallium-202	100	---

Radioisotope[a][b]	Column A Basic Quantity[c] (μCi)	Column B Maximum Permissible Body Burden[d] (μCi)
Thallium-204	10	10
*Thorium (natural)	50	0.01
Thulium-170	10	9
Thulium-171	10	90
Tin-113	10	30
Tin-125	10	---
Tritium (See Hydrogen-3)		
Tungsten-181	10	---
Tungsten-185	10	---
Tungsten-187	100	---
*Uranium (natural)	50	0.005
Uranium-233	0.01	0.05
Uranium-234-Uranium-235	0.01	0.03
*Vanadium-48	1	---
Xenon-131m	1000	---
Xenon-133	100	---
Xenon-135	100	---
Ytterbium-175	100	---
Yttrium-90	10	---
Yttrium-91	10	5
Yttrium-92	100	---
Yttrium-93	100	---
Zinc-65	10	60
Zinc-69m	100	0.7

Radioisotope[a][b]	Column A Basic Quantity[c] (μCi)	Column B Maximum Permissible Body Burden[d] (μCi)
Zinc-69	1000	0.8
Zirconium-93	10	100
Zirconium-95	10	20
Zirconium-97	10	----
Any alpha emitting radionuclide not listed above or mixtures of alpha emitters of unknown composition	0.01	----
Any radionuclide other than alpha emitting radionuclides, not listed above, or mixtures of beta emitters of unknown composition	0.1	----

*State-licensed radioisotopes (see footnote b).

(a) The preceding table contains all radioisotopes listed in Appendix C of "10 CFR Part 20" and paragraphs 4.19, 4.20, and 10.9 of the New Jersey Radiation Protection Code.

(b) The possession and use of naturally-occurring and accelerator-produced radioisotopes are regulated by the State of New Jersey. Those radioisotopes for which the source is known to be primarily naturally-occurring materials or accelerator production, and are thus most likely to be subject tc State jurisdication, have been marked with an asterisk. For those cases in which a radioactive material is known to have been produced in an accelerator or obtained from naturally occurring material and the radioisotope is not marked in the table with an asterisk, the "Health Physicist" must be consulted to obtain the correct basic quantity.

(c) For the purposes of Sections 4 and 9, where there is involved a combination of radioisotopes in known amounts, the limit for the combination should be derived as follows:

Determine, for each radioisotope in the combination, the ratio between the quantity present in the combination and the limit otherwise established, in the table , for the radioisotope when not in combination. The sum of such ratios for all the radioisotopes in combination may not exceed "1."

EXAMPLE: If an individual holds a Limited Possession Number for 2 mCi of C-14 and 10 mCi of H-3, he or she must be qualified and apply for an Authorization Number in order to possess more than 1.3 mCi of S-35. This is determined as follows:

$$\frac{2000\ \mu Ci\ ^{14}C}{10{,}000\ \mu Ci} + \frac{10{,}000\ \mu Ci\ ^{3}H}{15{,}000\ \mu Ci} + \frac{1300\ \mu Ci\ ^{35}S}{10{,}000\ \mu Ci} = 1$$

The denominator in each of the above ratios was obtained by multiplying figures in the table by 100 or using a maximum limit of 15 mCi as indicated in Section 4.

(d)
The values for maximum permissible body burden are taken from "Recommendations of the International Commission on Radiation Protection (ICRP): Report of Committee II on Permissible Dose for Internal Radiation," 1959. Maximum permissible body burden is defined as that amount of the radioisotope which, when continuously present in the body, will result in the maximum permissible dose rate to the critical organ, that organ of the body whose damage by radiation results in the greatest damage to the body. The values for maximum permissible body burden in this table are for the case where the radioisotope is present as a soluble compound.

(e)
The value for maximum permissible body burden for I-125 does not come from the 1959 ICRP report but is, instead, an approximate value derived from the maximum permissible concentration of I-125 in air established by the Nuclear Regulatory Commission.

APPENDIX D

Maximum Permissible Doses and Concentrations

1. External Dose

The maximum permissible dose (MPD) as established by "10 CFR Part 20" and the New Jersey Radiation Protection Code is as follows:

	Rem Per Calendar Year	Rem Per Calendar Quarter	Cumulative Life Total Rem
Whole Body Exposure; head and trunk; active blood-forming organs; lens of eyes; or gonads	5	1.25	<5(N-18) where N is age at last birthday
Hands and forearms; feet and ankles	75	18.75	
Skin of whole body	30	7.5	

2. Internal Dose

Internal occupational doses are limited by established controls over the concentration of airborne and waterborne radioactive materials. The limits are specified in Table I, Appendix B. The limits set forth in Appendix B are based on a 40 hour week, and an adjustment shall be made in the concentration limits if the number of exposure hours is either greater or less than 40 in any seven consecutive days.

3. Minors

The permissible dose limits for minors, persons under 18 years of age,are as follows:

a. Dose limits for external radiation are limited to 10 percent or less of the limits specified in paragraph 1 above.

b. Exposure limits for airborne and waterborne concentrations of radioisotopes are those specified in Table II, Appendix B. The concentration may be averaged over periods not greater than one week.

4. Pregnant Women and Women of Child-Bearing Age

The dose limits for pregnant women are determined by consideration of the dose to the unborn child. The maximum dose received by the fetus, as a result of an occupationally received dose to the mother, shall not exceed 500 mrem. Since women of child-bearing age may be pregnant without realizing it during the first months of pregnancy, they may wish to routinely use the dose limits for pregnant women.

5. "Unrestricted Areas"

Radiation levels in excess of the following are not permitted in "Unrestricted Areas":

a. radiation levels which, if an individual were continuously present in the area, could result in a dose to the individual in excess of two millirems in any one hour; or

b. radiation levels which, if an individual were continuously present in the area, could result in a dose to the individual in excess of 100 millirems in any seven consecutive days; or

c. radiation levels which could result in an individual receiving a dose in excess of 500 millirems in one calendar year.

6. Effluents

Permissible concentrations in effluents released (air and water) to unrestricted areas are those specified in Table II of Appendix B. The concentration limits may be averaged over one year for the entire University. This paragraph does not apply to disposals to the sanitary sewers which are described in Section 15.

7. Medical Exemptions

None of the limits in this appendix are to be interpreted as applying to the intentional exposures of patients to radiation for the purpose of diagnosis or therapy.

APPENDIX E

Roentgens, Rads, Rems, and other Units

1. Roentgen (R)

The Roentgen (R) is the special unit of exposure, which is the measure of the ionization produced in air by x or gamma radiation. Exposure is the sum of the electrical charges on all ions of one sign produced in air when all electrons liberated by photons in a volume element of air are completely stopped in air, divided by the mass of the air in the volume element. Specifically, the Roentgen is defined as 2.58×10^{-4} Coulombs of charge produced by x or gamma rays per kilogram of air. Thus, the Roentgen characterizes a radiation field by an indirect measurement of an effect, namely, the ionization produced in air.

The Roentgen has several limitations. For example, it is limited to x or gamma radiation; it is impractical above several MeV; and more importantly, it is not a measure of absorbed dose. It is retained and used because it is satisfactory for most gamma energies encountered and because measurement of air ionization is still widely used.

2. Rad

The energy actually absorbed by a sample or a biological system is obviously more important than the effect the incident energy has on air, especially when attempting to relate dose and effect. For this reason the concept of absorbed dose is used; i.e., the energy absorbed per unit mass. An absorbed dose applies to the energy deposited by any kind of radiation in any kind of material. The special unit of absorbed dose, the rad, is equivalent to the absorption of 100 ergs of energy per gram of material.

3. Relationship Between the Roentgen and the Rad

It can be shown that one gram of air will absorb 87 ergs of energy and that one gram of soft tissue will absorb 96 ergs of energy when exposed to a radiation field which produces an exposure of one Roentgen. This is true to within two percent for gamma energies from 0.1 MeV to 3 MeV. Thus, for many practical health physics problems, over the range of energies usually encountered, the rad and Roentgen are often used interchangeably.

4. Rem

For radiation protection purposes it is useful to define a quantity, the dose equivalent, which describes the effect of radiation on tissue. Equal absorbed doses of radiation may not always give rise to equal risks of a given biological effect, since the biological effectiveness may be affected by differences in the type of radiation or irradiation conditions. Thus, the dose equivalent is defined to be the product of the absorbed dose and a modifying factor or factors:

Dose Equivalent = Absorbed Dose (rads) x Quality Factor, where the quality factor, the most common modifying factor, takes into account the relative effectiveness of the radiation in producing a biological effect. The special unit of dose equivalent is the rem.

5. Quality Factor

The values for quality factor given in the table below are those recommended by the International Commission on Radiological Protection in ICRP Publication 26:

Type of Radiation	Quality Factor (QF)
x or gamma rays	1
Beta particles, electrons	1
*Neutrons and protons of unknown energy	10
Singly charged particles of unknown energy with rest mass greater than 1 amu	10
Alpha particles	20
Particles of multiple or unknown charge of unknown energy	20

*QF is a function of energy. The values of QF for neutrons and protons of known energy are found in ICRP Publication 21. The QF for neutrons is also tabulated in Appendix G.

The value of the quality factor for each type of radiation depends on the distribution of the absorbed energy in a mass of tissue. For example, the increased effectiveness of neutrons relative to gamma rays is believed to be related to the higher specific ionization of the recoil protons liberated by neutron bombardment as compared to the specific ionization of the secondary electrons arising from gamma ray irradiation. The values of quality factor are known to vary with the biological effect being observed, and in some cases are still a matter of controversy for the same biological effect.

6. Curie (Ci)

The Curie is the special unit of activity, which is a measure of the amount of radioactivity present in a substance. One Curie is that amount of radioactive material which will produce 3.70×10^{10} nuclear transformations (disintegrations) per second.

7. New Units

The International Commission on Radiation Units has called for a conversion from the present radiation units to the Systême Internationale system of measurements. These new units will be phased into use and will replace the old units over the next few years. They are:

Quantity

1 Bequerel (Bq) = 1 disintegration per second; replaces the Curie.

Exposure

No special unit; Coulombs per kilogram will be used instead of the Roentgen.

Absorbed Dose

1 Gray (Gy) = 10^4 ergs per gram; replaces the rad as a unit.

Dose Equivalent

1 Sievert (Sv) is equivalent to 100 rems, but replaces the rem as a unit.

APPENDIX F

Gamma and Beta Dose Rate Data

1. Gamma dose rate data

All values are given in mrem/hour for the distances specified. Roentgens have been converted to rads (soft tissues) and then to rems using a QF of 1.

a. Gamma dose rates per millicurie for various gamma energies assuming 1 gamma ray per disintegration:

Photon Energy (MeV)	Dose Rate (mrem/hr @ 30 cm)
0.02	2.1
0.03	0.92
0.05	0.42
0.10	0.49
0.20	1.1
0.30	1.8
0.50	3.1
0.60	3.7
0.80	4.8
1.0	5.8
1.5	7.9
2.0	9.7
3.0	12.8

Adapted from Table A-3 in The Physics of Radiology by H. Johns and J. Cunningham, Charles C. Thomas, Publisher (1974).

b. Gamma dose rates per millicurie for some commonly used gamma emitters:

Radioisotope	Dose Rate (mrem/hr/mCi) @ 30 cm	Dose Rate (mrem/hr/mCi) @ 100 cm
^{7}Be	∿ 0.32	∿ 0.03
^{24}Na	20	1.8
^{51}Cr	0.17	0.02
^{54}Mn	5.0	0.45
^{59}Fe	6.8	0.61
^{60}Co	14	1.3
^{125}I	∿ 0.75	∿ 0.07
^{131}I	2.3	0.21
^{137}Cs	3.5	0.32
^{203}Hg	1.4	0.12
^{226}Ra and Daughters	8.8	0.79

Adapted from Radiological Health Handbook, 1970 edition.

c. A useful rule of thumb for estimating the dose rate from a point source gamma emitter:

mrem/hr @ 30 cm = 6 (A) (E)

where A = source activity in millicuries
E = total gamma energy per disintegration in MeV

Over the energy range 0.07 to 4 meV this yields a value within $\pm$ 20% of the true value.

2. Beta dose rate data

a. Beta dose rates to skin from a 1 millicurie unshielded point source, neglecting air absorption:

Maximum Beta Energy (MeV)	Dose Rate @ 10 cm (rem/hr/mCi)
0.25	2.2
0.30	3.4
0.40	5.0
0.50	5.2
0.60	5.1
0.80	4.9
1.0	4.6
1.5	4.0
2.0	3.6

from "Rough Estimates of Beta Doses to the Skin" by W.G. Cross, Health Physics, 11 (453), 1965.

b. A useful rule of thumb for estimating the skin dose rate from a beta particle emitter (assuming one beta particle per disintegration):

The dose rate from an unshielded point source is 5 rem/hour/millicurie at 10 cm.

This yields values good to within a factor of two, for beta emitters with a maximum beta energy greater than 300 KeV.

APPENDIX G

Neutron Dose Data

1. Conversion factors and effective quality factors for neutrons, as recommended by the International Commission on Radiation Protection in ICRP Publication 21

Neutron energy (MeV)	Conversion factor (neutrons/cm · sec per mrem/hr)	Effective QF[a]
2.5×10^{-8} (thermal)	260	2.3
1×10^{-6}	220	2
1×10^{-4}	240	2
0.01	280	2.
0.1	48	7.4
0.5	14	11
1	8.5	10.6
2	7.0	9.3
5	6.8	7.8
10	6.8	6.8
20	6.5	6.0
50	6.1	5.0

[a] Maximum dose equivalent divided by the absorbed dose at the depth where the maximum dose equivalent occurs.

2. The Nuclear Regulatory Commission has set forth a similar but somewhat more conservative table, which indicates the neutron flux equivalent to 100 mrem in 40 hours, in "10 CFR Part 20." The data in the table above have been chosen for inclusion, however, because they are based on more current information and because effective quality factors are provided in the ICRP table. It should be noted that the NRC, using the information from the table in "10 CFR Part 20," states that, when the energy distribution is unknown, 14×10^6 neutrons/cm^2 shall be assumed to be equivalent to one rem.

3. Averaged neutron dose per unit flux for several neutron sources. Data provided by M. Awschalom.

Source	$mrem/n/cm^2$
^{239}Pu-Be	3.5×10^{-5}
^{235}U (Fission)	2.8×10^{-5}
1/E spectrum (0-24 MeV)	7.9×10^{-6}

4. Dose rate from 1 Curie ^{239}Pu-Be source: 2.2 mrem/hr @ 100 cm based on typical emission rate of 2×10^6 n/sec.

December 5, 1979

APPENDIX H

Relative Hazard from Absorption of Various Radioisotopes into the Body[a]

Hazard Classes for Various Radioisotopes[b]	Activity Ranges[c] Low Level	Medium Level	High Level
Very High Hazard			
A. ^{210}Po, ^{227}Ac, ^{228}Th, ^{230}Th, ^{237}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{242}Cm, transuranium elements	Up to 100 µCi	10 µCi to 10 mCi	Over 1 mCi
*B. ^{210}Pb, ^{226}Ra, ^{228}Ra, ^{241}Am			
High Hazard			
A. ^{45}Ca, ^{90}Sr, ^{129}I, ^{210}Bi, ^{224}Ra, ^{233}U, ^{22}Na, ^{46}Sc, ^{60}Co, ^{106}Ru, ^{125}I, ^{131}I, ^{137}Cs, ^{144}Ce	Up to 1 mCi	100 µCi to 100 mCi	Over 10 mCi
Medium Hazard			
A. ^{14}C, ^{31}Si, ^{32}P, ^{35}S, ^{36}Cl, ^{47}Sc, ^{55}Fe, ^{89}Sr, ^{90}Y, ^{204}Tl, ^{220}Rn, ^{235}U	Up to 10 mCi	1 mCi to 1 Ci	Over 100 mCi
*B. ^{24}Na, ^{42}K, ^{48}V, ^{51}Cr, ^{54}Mn, ^{56}Mn, ^{59}Fe, ^{64}Cu, ^{65}Zn, ^{86}Rb, ^{99}Mo, ^{109}Cd, ^{113}Sn, ^{140}Ba, ^{190}Ir, ^{198}Au, ^{222}Rn			
Low Hazard			
A. ^{3}H, ^{18}F, ^{59}Ni, ^{69}Zn, ^{71}Ge, ^{238}U, Natural Th, Natural U, Noble Gases	Up to 100 mCi	10 mCi to 10 Ci	Over 1 Ci
*B. ^{7}Be			

*Emits gamma radiation in amounts significant for external exposure

(a) Adapted from NBS handbook #92, "Safe Handling of Radioactive Materials," March 1964

(b) The estimated relative hazards of radionuclides are based on their physical properties and their maximum permissible concentrations in air and water. The classifications above are for soluble forms of the radionuclides and take into account the types of compounds in which the nuclides are encountered, their specific activity, their volatility, and the maximum permissible dose limits.

(c) The levels within the activity ranges refer to the degree of protection required against internal deposition for the quantity of radioisotope present. The ranges overlap at the upper and the lower end of each level, indicating that there are no sharp transitions between the quantity levels, group classifications, or associated protection techniques. Modifying factors may be applied to the quantities handled, according to the complexity of the handling operation. The following table indicates how the quantities listed above might be modified, according to the type of operation:

Use	Modifying Factor
Storage only	x 100
Simple wet operation	x 10
Normal chemical operation	x 1
Complex chemical operation with high spill risk	x 0.1
Simple dry operation	x 0.1
Dry, dusty operation	x 0.01

The amount of activity handled and the type of operation performed will affect the protective techniques designed into a laboratory, such as floor, wall, and work bench finishes, ventilation, fume hoods, and other items including shielding and glove boxes.

As an example of how the table might be used, consider the following situation:

Suppose the "Health Physicist" has determined that, in order for an individual to receive an Authorization Number for a quantity of I-125 that corresponds to a high level of activity, an individual's lab must possess a charcoal filtered glove box. Since the table indicates that the use of more than 10 mCi of I-125 is considered a high level of activity, the "Health Physicist" would require a researcher planning to use 20 mCi of I-125 in normal chemical operations to have a charcoal filtered glove box. If, on the other hand, the researcher plans only to store the 20 mCi of I-125, a glove box would not be required because the modifying factor of 100 for storage raises the activity equivalent to a high level to more than 1 Ci.

APPENDIX I

Hazards of Analytical X-Ray Equipment

A. Sources of Radiation

The National Bureau of Standards Handbook 111 provides the following information on the sources of radiation hazards from analytical x-ray equipment.

Hazardous radiation may come from the following sources:

1. The primary beam

   The primary beam is most hazardous because of the extremely high exposure rates. Exposure rates of 4 X 10^5 R/min at the port have been reported for ordinary diffraction tubes.

2. Leakage or scatter of the primary beam through cracks in ill fitting or defective equipment

   The leakage or scatter of the primary beam through apertures in ill fitting or defective equipment can produce very high intensity beams of possibly small and irregular cross section.

3. Penetration of the primary beam through the tube housing, shutters or diffraction apparatus

   The hazard resulting from penetration of the useful beam through shutters or the x-ray tube housing is slight in well designed equipment. Adequate shielding is easily attained at the energies commonly used for diffraction and fluoresence analysis.

4. Secondary emission from the sample or other material exposed to the primary beam

5. Diffracted rays

   Diffracted beams also tend to be small and irregular in shape. They may be directed at almost any angle with respect to the main beam, and occasionally involve exposure rates of the order of 80 R/h for short periods.

6. Radiation generated by rectifiers in the high voltage power supply

   Radiation from the high voltage power supply may result from gassy rectifiers. The effective potential is twice the potential applied to the x-ray tube. This condition can arise at any time and the only effective countermeasure is to shield the assembly that contains the rectifiers.

B. Typical Exposure Rates

1. The following table provides information on typical exposure rates measured in and near diffractometers and spectrometers.

Point of measurement	Approximate exposure rate[(a)] (mR/second)
Inside specimen chamber of spectrometer	10,000
Inside crystal chamber of spectrometer	5
Outside exit window of spectrometer	0.0005
At open port of diffraction tube tower	2,000
At sample position of diffractometer	5
At receiving slit of diffractometer	0.5
At exit collimator of Debye-Scherrer Camera (with no collimator in position)	100

(a) Assuming maximum tube operation

Adapted from "Incidence, Detection and Monitoring of Radiation from X-Ray Instrumentation" by R. Jenkins and D. Haas in X-Ray Spectrometry, 4 (33), 1975.

2. The following table provides information on typical exposure rates measured under various conditions, using a copper target:

KvP	mA	R/min*	Filter
35	18	2000	None
35	15	360	Nickel
35	30	600	Nickel
35	19	2900	Nickel
50	40	620	Vanadium

* measured at 6 inches from tube port

Taken from "X-Ray Diffraction and Other Analytical X-Ray Hazards: A Continuing Problem" by J. Lubenau *et al*. (1967), a paper presented at the 1967 Health Physics Society Annual Meeting.

3

[illegible] EMERGENCY PROCEDURES

ALL PERSONS [illegible] SHOULD [illegible] SECTION 17 OF [illegible] UNIVERSITY [illegible] SAFETY GUIDE. THE FOLLOWING IS INTENDED ONLY AS A READY REFERENCE.

ANY ACCIDENT [illegible]

1) [illegible] FOR FORRESTAL AREA[illegible] AND PRO[illegible] THE OFFICER WITH THE INFORMATION HE OR SHE [illegible]QUESTS.

2) CONTACT THE "AUTHORIZED USER" (PERSON RESPONSIBLE FOR THE LABORATORY). NAMES AND PHONE NUMBERS ARE PROVIDED ON FORM #31 - "EMERGENCY INFORMATION" - POSTED ON OR NEAR THE LABORATORY ENTRANCE.

3) CALL OCCUPATIONAL HEALTH & SAFETY OFFICE AT 2-5294.

4) OUTSIDE NORMAL WORKING HOURS, CONTACT <u>TWO</u> OF THE FOLLOWING:

J.J. SUNDRA	924-5008
S.M. DUPRE	921-6734
R.R. MILWICZ	466-3443
O.A. GRIESBACH	924-4193
T.L. GRIECO	896-2115

<u>RADIATION EMERGENCY GUIDELINES</u>

AFTER COMPLETING THE ABOVE, AND WHILE AWAITING THE ARRIVAL OF THE "HEALTH PHYSICIST", PROCEED AS FOLLOWS:

1) EVACUATE THE AREA IMMEDIATELY.

2) BLOCK OFF AREA OR OTHERWISE INSURE THAT OTHERS WILL NOT ENTER.

3) ASSEMBLE ALL PERSONS WHO WERE IN THE LABORATORY AT THE TIME OF THE INCIDENT. THE PLACE OF ASSEMBLY SHOULD BE NEAR THE CONTAMINATED AREA IN ORDER TO MINIMIZE THE SPREAD OF CONTAMINATION, BUT FAR ENOUGH REMOVED TO PREVENT CONTINUED INVOLVEMENT.

4) WHERE AIRBORNE CONTAMINATION IS SUSPECTED, SECURE THE AFFECTED AREA COMPLETELY BY SHUTTING ALL DOORS.

5) KEEP BY-STANDERS AT A SAFE DISTANCE.

6) TAKE OTHER ACTION AS APPROPRIATE.

7) CONSULT SECTION 17 OF THE UNIVERSITY RADIATION SAFETY GUIDE FOR ADDITIONAL INFORMATION.

APPENDIX B

EMERGENCY INFORMATION

Building ______________ Floor ______________ Room No. ______________

RESPONSIBLE INDIVIDUAL ______________ Extension ______________ Hom[illegible]

IN AN EMERGENCY DIAL: MAIN CAMPUS : 2-3131 FORRESTAL CAMPUS: PPL PHONES : 3333 [redacted] NON-PPL PHONES: 2-5700 or 2-3131 PROVIDE INFORMATION REQUESTED, THEN:	LIST TOXIC, PATHOGENIC, RADIOACTIVE OR OTHERWISE HAZARDOUS MATERIALS OR AGENTS AND ANY UNIQUE HAZARDS	PROVIDE [illegible] AND/OR WA[illegible]
1. Notify RESPONSIBLE INDIVIDUAL listed above. 2. Notify AT LEAST ONE of the following:		

ALL DEPARTMENTS: mail one carbon copy to Security Office, Stanhope Hall
FORRESTAL CAMPUS DEPARTMENTS: mail an extra copy to Security Office, Smith House

O.H.& S. Form #31 (Rev. 4/79)