



UNIFORMED SERVICES UNIVERSITY OF THE HEALTH SCIENCES



SUBJECT: USUHS Radiation Safety Guide

Instruction 6402-M

(EHS)

FEB 15 2006

ABSTRACT

This Instruction provides procedures and establishes policies for controlling the use of radioactive material and radiation sources, licensed by the Nuclear Regulatory Commission, at the Uniformed Services University of the Health Sciences (USUHS).

A. Reissuance and Purpose. This Instruction reissues USUHS Instruction 6402-M and provides procedures and establishes policies for use of radioactive material and radiation sources at the USUHS.

B. Reference. See *Enclosure 1, Appendix I.*

C. Applicability. The provisions of this Instruction apply to all USUHS employees, civilian and military, who work at or occupy research laboratory space in University campus buildings.

D. Policy. It is USUHS policy to follow the regulatory guidelines of the Nuclear Regulatory Commission (NRC), conditions set forth in the University's NRC radioactive material licenses, and the procedures described in this Instruction.

E. Responsibilities.

1. University employees shall adhere to NRC rules and regulations and the guidelines and procedures of this Instruction.

2. The Radiation Safety Officer shall:

a. Implement the USUHS Radiation Safety Program IAW the procedures set forth in the NRC radioactive material licenses and the USUHS Radiation Safety Guide (see paragraph F. Procedures).

b. Have full knowledge of the purpose and requirements of the Radiation Safety Program.

c. Inform executive management of any unusual incidents or accidents involving the use of radiation sources at USUHS.

3. The Radiation Safety Committee shall:

a. Act as the governing body for establishing policy and procedures of the radiation safety program at the USUHS.

b. Meet at least once each calendar quarter to review the USUHS Radiation Safety Program.

c. Act as approval authority for all uses and users of radioactive material at the USUHS.

4. The Principal Investigator shall:
Ensure the use of all approved
radioactive material, under their
supervision, is conducted in a safe and
careful manner consistent with the rules
and regulations set forth in this

Instruction and IAW the conditions set
forth in the Radionuclide Experimental
Authorization (REA) issued to their
section.

F. Procedures. *See Enclosure 1.*



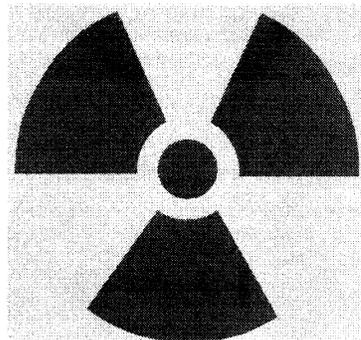
Charles L. Rice, M.D.
President

Enclosure:

1. USUHS Radiation Safety Guide



RADIATION SAFETY GUIDE



**Uniformed Services University
of the Health Sciences
Instruction 6402-M**

Bethesda, Maryland

10 November 2005

Foreword

Radionuclides are used in numerous laboratories and in many research studies that are conducted at the Uniformed Services University of the Health Sciences (USUHS). There are risks associated with the use of these radioactive materials. Like many chemical reagents and much of the equipment found in laboratories, radioisotopes can be a hazard if not used carefully.

The USUHS Radiation Safety Officer (RSO) and members of the Radiation Safety Committee (RSC) are the executive managers of the Radiation Safety Program at this institution. Personnel at all levels of this University must commit themselves to the concept of keeping all radiation doses to researchers, staff, and the general public **AS LOW AS IS REASONABLY ACHIEVABLE (ALARA)**. Cooperation with, and support of the Radiation Safety Division staff and the RSO is paramount in implementing the ALARA concept and maintaining compliance with all federal laws governing the use of licensed radioactive material.

Procedures outlined in this guide were established as a means of controlling the use of radioisotopes at USUHS. They are designed to protect the University community from unnecessary exposure to ionizing radiation, and to comply with requirements of the Nuclear Regulatory Commission (NRC). Each individual who uses radioactive material has a responsibility to be familiar with, and conform to the following:

- The ALARA concept.
- Security, control, and safe use of radioactive material.
- Department of Defense (DoD), NRC directives, and Federal rules and regulations.
- Complying with USUHS policies, Instructions, and procedures.

Workers have the **RESPONSIBILITY** to report unsafe practices or actions that are not in compliance with the University Radiation Safety Program to their supervisor and/or the RSO. All personnel who use radiation sources are expected to become familiar with all the USUHS radiation safety regulations and to conduct all protocols in accordance with them.

USUHS Radiation Safety Committee

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I. Radiation Safety Organization at the University

A. NRC Licenses

USUHS procures and uses radioisotopes under Nuclear Regulatory Commission (NRC) Byproduct Materials License #19-23344-01 and two gamma self-shielded irradiators under Byproduct Materials License #19-23344-02. The licenses require that employees use NRC approved procedures for the acquisition, control, and disposal of all radioactive material. Procedures include those applicable to all institutions using licensed material as contained in the Code of Federal Regulations (CFR), and other governing agencies that are specified in the licenses granted to the University. These procedures are designed to protect individuals in the University community from unnecessary exposure to ionizing radiation.

The NRC periodically inspects the USUHS. NRC inspections are unannounced and comprehensive in nature. If the NRC finds the USUHS is not complying with license conditions, they may issue citations, fines, or in the case of serious infractions, suspend or revoke the University's radioactive material license.

B. Radiation Safety Committee

The members of the Radiation Safety Committee (RSC) govern the radiation safety program at USUHS. This committee is a group of professionals appointed by the University President to establish policy and procedures involving the use of radioactive material, and to oversee all aspects of radiation safety at USUHS facilities. The committee meets at least once each calendar quarter to review the University's radiation safety program. The duties of the RSC include:

1. Reviewing recommendations on ways to maintain individual and collective doses ALARA.
2. Reviewing, and approving or disapproving, on the basis of safety and with regard to their training and experience, requests by investigators for permission to use radioactive material.
3. Reviewing the training and experience of the Radiation Safety Officer (RSO) and approving or disapproving appointment.
4. Reviewing on the basis of safety, and approving or disapproving with the advice of the RSO, any request for amendment or renewal of the NRC Byproduct Materials License.
5. Reviewing on the basis of safety, and approving with the advice of the RSO, the use of any research laboratory located at USUHS for use of radioactive material. Laboratories no longer using radioactive material may be released for general use after a complete closeout survey has been performed on the laboratory.
6. Reviewing on the basis of safety, and approving with the advice of the RSO, changes in procedures and policies in the Radiation Safety Program at USUHS.
7. Reviewing quarterly, with the assistance of the RSO, a summary of the occupational

radiation dose records of all personnel working with byproduct material.

8. Reviewing quarterly, with the assistance of the RSO, all incidents involving byproduct material with respect to the cause and subsequent actions taken.

9. Reviewing annually, with the assistance of the RSO, the radiation safety program at USUHS.

10. Reviewing for final action/disposition any program or procedure involving the use of radioactive material or a radiation-producing device which has been suspended by the RSO.

C. Radiation Safety Officer

The Radiation Safety Officer (RSO) is the executive manager for the radiation safety program and the Executive Secretary for the RSC at USUHS. The RSO is responsible for implementation and day-to-day management of the radiation safety program in accordance with DoD and NRC directives and regulations and policies formulated by the members of the USUHS RSC. The professional and technical staff at the Center for Environmental Health and Occupational Safety (EHS) assists the RSO. In addition to the responsibilities in 10 CFR Part 35.21, the RSO:

1. Formulates, implements and exercises staff supervision over the radiation safety program.
2. Provides consultation and advice on the degree of hazards associated with radiation and the effectiveness of control measures.
3. Advises and assists all radiation workers in all matters pertaining to radiation safety, including instructing and training of workers and others in the safe use of radioactive material and radiation sources.
4. Ensures that all radioactive materials are properly receipted, used, stored, handled, shipped, and disposed of according to applicable directives.
5. Executes a documented program designed to keep radiation doses and releases to the environment at ALARA.
6. Each calendar quarter, provides the RSC summary information on personnel radiation doses, ALARA investigations, and routine reports on the use, storage, and disposal of radioactive material.
7. Assists the RSC in formulating policy for the radiation safety program at USUHS.
8. Reviews all applications for use of radioactive material to ensure completeness, and recommends approval or disapproval to the RSC.
9. Provides an annual review of the radiation safety program to the RSC.

10. Reviews and approves procurement of all radioactive material to ensure compliance with NRC License conditions.

11. Evaluates hazard potential and adequacy of protective measures for existing and proposed operations.

12. Investigates radiation accidents, incidents and overexposures to determine the cause and necessary corrective actions to prevent recurrence.

13. Suspends a program or procedure involving the use of radioactive material or radiation producing devices that are determined to deviate from prescribed procedures and directives.

14. Maintains the NRC Byproduct Material Licenses, supporting documentation, decommissioning records, and appropriate requests for amendments and renewals.

D. Principal Investigator (REA Holder) Using Radioactive Material

In the USUHS Radiation Safety Program, a Principal Investigator (PI) is defined as a professional at the University who has applied for and received a Radionuclide Experimental Authorization (REA) from the RSC to use radioactive material in a specified research program. A PI is responsible for all work conducted under his/her REA. A PI's responsibilities include:

1. Ensuring that USUHS and NRC approved procedures are followed when procuring, using, and disposing of radioactive material.

2. Training and supervising users handling radioactive material under the PI's authorization. This includes ensuring that all senior investigators, independent users, and supervised users working under the PI's authorization attend annual radiation safety training provided by the Radiation Safety Office staff.

3. Making sure that their REA is current with regard to the quantities of radioactive material used, the counting instrumentation used, the procedures being followed, and the names of workers who handle radioactive material.

E. Senior Investigator

A Senior Investigator (SI) is an individual who has been approved by the RSC for the use of radioactive material in an unsupervised capacity, and is working under the auspices of a PI. An SI may supervise the radioisotope work performed by an Independent User or Supervised User.

F. Independent User

An Independent User (IU) is an individual who has been approved by the RSO for the independent use of radioactive material in an unsupervised capacity, and is working under the auspices of a PI or SI. The IU may supervise the radioisotope work performed by a Supervised User.

G. Supervised User

A Supervised User (SU) may not use radionuclides unless he/she is under the supervision of a PI, SI or IU. A supervisor should be in close proximity to the work being conducted so that he/she is available to direct and assist the supervised user in proper isotope handling techniques, and to prevent radioactive spills and contamination. For routine isotope work (simple laboratory bench top procedures which the SU has previously performed on multiple occasions under the direct visual supervision by the responsible PI, SI or IU) direct supervision may be liberally defined as the PI, SI or IU being within the confines of the USUHS buildings.

II. Controlling Access To Posted Laboratories

A. Posted Laboratories

All work with radioactive material must be conducted in laboratories approved by the RSC. These labs are marked with a sign on each door that contains a yellow and magenta radiation warning symbol and warns of radioactive material or radiation areas within the room. The warnings on the sign will vary according to the following conditions:

1. Laboratories approved for radionuclide use but not containing significant radiation fields will be labeled with the words: "Caution Radioactive Material."

2. Laboratories in which there are areas with dose rates greater than 2 mrem/hr are posted with the words: "Caution: Radiation Area." NOTE: The RSC has established this level as a control measure rather than the use of "Restricted Area" as defined by 10 CFR 20.1003.

B. Access to Posted Laboratories

During normal working hours, access to USUHS is not restricted, and principal investigators are responsible to see that visitors and unauthorized individuals do not wander into their laboratories. Visitors must obtain permission from the principal investigator responsible for the laboratory before entering. Laboratories posted as radiation areas, and laboratories classified as Type B laboratories by the RSO (see part VII) will be entered only by personnel given permission by the RSO or his/her designated representative. These laboratories must always be locked or the radioactive material must be secured in a locked container when not attended by authorized laboratory personnel.

C. Access to Posted Laboratories by Minors

Minors (individuals under the age of 18) will not be allowed inside posted laboratories without permission of the RSO. Visits of school groups or children of University employees must be approved by the RSO. Minors under the age of 16 will not be allowed to work in posted laboratories. Workers between the ages of 16 and 18 may be allowed to work in posted laboratories with the permission of the RSO. Handling of radioactive material by minors is discouraged, but may be allowed if the quantity of radioactive material handled is limited to no greater than the activity levels listed in 10 CFR Part 30.71, Schedule B.

D. Access to Posted Laboratories by Custodial Personnel

Custodial workers will be allowed access to a posted laboratory **ONLY** at the request, or with the permission, of the PI (REA holder). The PI may admit custodial workers for the sole purpose of sweeping, mopping, and polishing the floors **ONLY** when there is reasonable assurance that the floor is free of radioactive contamination. The Facilities Department contracts the stripping and waxing of all University floors and this must be coordinated with the PI **BEFORE** contract workers are admitted into a posted laboratory.

Custodial workers admitted to a posted laboratory are prohibited from cleaning counter tops or equipment. PIs will further place all non-radioactive and non-biological waste for disposal outside the posted laboratory to prevent custodial workers from seeking access to the laboratory to pick up these materials. Custodial workers are prohibited from entering a posted laboratory in order to collect trash.

III. Personnel Dosimetry

A. Dosimeters

The determination to issue a thermoluminescent dosimeter (TLD) for either whole body or extremity monitoring will be made by the RSO or his representative. In general, personnel working with radioactive material or ionizing radiation producing devices will be issued dosimeters. Exceptions to this are those individuals working exclusively with low energy beta emitters (^3H , ^{14}C , or ^{35}S). Dosimeters must be issued if an individual could receive a dose in any calendar year in excess of 10 percent of the NRC dose limits for a calendar year. For individuals between 16 and 18 years of age, a dosimeter must be issued if the individual could receive 0.05 rem in one year from any source external to the body (10 percent of the annual limit for minors). A declared pregnant woman wearing a dosimeter will be restricted to a limit of 0.5 rem to the embryo/fetus for the duration of the pregnancy, and any exposure received must be distributed as evenly as possible throughout the pregnancy. Information on amounts and types of radiation that the worker will be using will be obtained at the time of the initial radiation safety briefing. TLDs (dosimeters) will be exchanged at 12-week intervals. Dosimeters must be worn on the trunk of the body at or above the waist. Dosimeters must not be taken home or left in the laboratory at locations where they may be exposed to radiation from radioactive sources. Lost or damaged dosimetry devices should be reported immediately to EHS personnel.

B. Thyroid Counts for Radioiodine Users

Thyroid counts on persons using radioiodine will be performed at the frequency outlined in part XIII (Radioiodine).

C. Bioassay

Individuals using more than 10 milliCuries tritium on a laboratory bench top, or more than 100 milliCuries tritium per month in a chemical fume will be required to submit a urine sample to EHS for analysis once each calendar quarter. Individuals handling these quantities of tritium in a single procedure will be required to submit a urine sample within 48 hours prior to the procedure, and another urine sample within 72 hours immediately following the procedure.

D. Personnel Dosimetry Records

Each new radiation worker must provide information on previous work history with radioactive material at the time of their initial radiation safety training. Former employers will be contacted to obtain records of prior exposure to occupational radiation.

A permanent file of each worker's radiation exposure history will be kept by EHS. Personnel may obtain a copy of their exposure history by submitting a written request to the RSO.

E. ALARA Investigational Action Levels

The University is committed to keeping individual and collective doses to all personnel and releases of radioactive material to the environment as low as is reasonably achievable (ALARA). The Radiation Safety Program has implemented the following ALARA investigational levels:

ALARA Investigational Levels:	Level I (millirem)	Level II (millirem)
Total effective dose equivalent (Sum of the deep dose equivalent and the committed effective dose equivalent)	100	200
Shallow dose equivalent (Dose to the skin or any extremity)	1000	2000
Eye dose equivalent	500	1000

1. The RSO will review the dose of each individual whose quarterly dose exceeds Investigational Level I and will report the results of such reviews at the first RSC meeting following the quarter when the dose was recorded.

2. The RSO will investigate in a timely manner the causes of all personnel doses equaling or exceeding Investigational Level II and, if warranted, will take corrective action. A report of the completed investigation, corrective actions taken, and a copy of the individual's doses will be presented to the RSC at its first meeting following the completion of the investigation. The details of the reports will be included in the RSC minutes.

3. The RSO recommends, and members of the RSC approve or disapprove investigational levels for occupational external radiation doses which, when exceeded, will initiate review or investigation by the RSC and/or the RSO.

4. In cases where a worker's or a group of workers' doses need to exceed an investigational level, a new, higher investigational level may be established for that individual or group on the basis that it is consistent with good ALARA practices. Justification for new investigational levels will be documented.

IV. Obtaining Authorization To Use Radioactive Material at USUHS

Radionuclide use is controlled at the University by allowing only Principal Investigators (PI) to order radioactive material for laboratory use under an approved Radionuclide Experimental Authorization (REA). An REA must be approved by the RSC, usually during the RSC quarterly meeting. Interim approval of the REA may be granted after a complete review by the RSO and recommendations, with any conditions, are submitted by the RSO to the Chairman of the RSC. The Chairman may approve or disapprove the recommendation for Interim Approval. Any REA that is granted interim approval must be approved or disapproved by the RSC at the next regularly scheduled RSC meeting. Investigators planning to use radioactive material should apply for an REA well in advance to avoid delay in the approval process.

A. Application for a Radionuclide Experimental Authorization (REA)

Application for an REA can be submitted on a USUHS Form 6041 (Application for Radionuclide Experimental Authorization) to the Radiation Safety Officer at the Center for Environmental Health and Occupational Safety (EHS). USUHS Form 6042 (Summary of Radiological Training and Experience) should be submitted for each individual seeking approval status as a Principal Investigator, Senior Investigator and/or Independent User.

Information required for USUHS Form 6041 includes:

1. Names of all personnel who will handle the radioactive material.
2. Source description including: where the isotopes will be used and stored; the form and amount (activity) of each isotope that will be ordered at any one time, the maximum amount stored in the laboratory at any one time, and the maximum amount used in any single experimental procedure.
3. Security measures for the storage of the radioisotopes and radioactive waste.
4. The total anticipated volume of radioactive waste that will be generated. Procedures for handling and minimizing the amount of radioactive waste by laboratory personnel should also be described.
5. Description of the experimental procedures in which the radioactive material will be used. This description should include details on the use of shielding, chemical fume hoods, counting equipment and steps taken to limit personnel radiation exposure.

An REA granted to a principal investigator is specific with respect to these five items. Any changes to the granted REA due to procedural or personnel changes must be submitted for approval as an authorization amendment on USUHS Form 380.

An REA expires one year from the date of approval and must be renewed at that time if work with radionuclides is to continue. An REA request can be recommended for interim approval by the RSO, and granted interim approval status by the Chairman of the RSC. All requests for REA renewals will be approved or disapproved by the RSC at its next regularly scheduled meeting.

USUHS Form 6042 supplies the RSO and the RSC with information on the radionuclide handlers' experience with radionuclides. The RSC evaluates this background, which should include all formal training in radiation safety and practical laboratory experience with the handling of radioactive material. A USUHS Form 6042 is not required for radionuclide handlers who are designated as Supervised Users.

B. Amendments to an REA

An REA must be amended to reflect any changes in procedures and/or personnel who handle radioactive material. Amendments are requested by submitting a completed USUHS Form 380 to the RSO, which outlines the planned changes in sufficient detail to allow review of the request by the RSC. Amendments, after proper review and recommendations by the RSO for interim approval, may be approved by the Chairman, RSC. All amendments with interim approval must be reviewed and approved or disapproved by the RSC at their next regularly scheduled meeting. Amendments to add or delete Supervised Users, Independent Users, or laboratory rooms are approved by the RSO, and do not require review by the RSC.

C. Training and Experience for Radioisotope Handlers (Supervised Users)

All individuals must complete the following requirements before being allowed to handle radioactive material in any capacity at USUHS.

1. Attend a 90-minute initial radiation safety class given by the RSO or his representative.
2. As determined by the RSO, obtain a personnel dosimetry device, unless the user is working in laboratories where the only radionuclides being used are Hydrogen-3, Carbon-14, or Sulfur-35.
3. Be listed as a radionuclide user (Supervised User) on a current REA.

Personnel authorized to use radioactive material must also attend an annual radiation safety refresher training class. This training is offered periodically during the year by the Radiation Safety Office staff. The RSO will require additional training when the need exists.

D. Training & Experience for Principal Investigators (REA Holders) and Senior Investigators

PIs and SIs must have completed, at a minimum, 30 hours of training on the safe use of radioisotopes in the laboratory. This training requirement can be a combination of documented training given at the University and previous training received at other institutions where investigators used similar radioisotopes. Equivalent training such as a two credit hours college course in radiation safety or evidence of other formal training courses may also meet this requirement when evidence of the training is presented to the RSC. Work experience can be submitted as a substitute for formal training. All such experience must be summarized on a USUHS Form 6042 and submitted for review by the RSC. When available, certificates of completion, a course syllabus or other documentation of training received at another institution, will be provided for RSC review.

In addition, the PI or SI should have at least 6 months experience at using the type of radiation (e.g. alpha, beta, gamma, and neutron) and the physical form of the radioactive material being requested. The RSC may require additional training based on the complexity and potential safety hazard of the procedures being used in the laboratory.

E. Training & Experience Requirements for Independent Users

IUs must have completed, as a minimum, an eight-hour independent user course covering radiation safety in the laboratory. The IU course is presented by EHS in a classroom version, on a limited basis throughout the year, and through a self-study manual available at any time from the RSO, or in some cases, the PI. Successful completion of the course will be determined by written examination with a passing grade of 70%, regardless of whether the course was completed in the classroom or by self-study.

The IU must have at least three months experience using the type of radiation (e.g. alpha, beta, gamma, and neutron) and the physical form of the radioactive material being requested. The RSO may require additional training based on the complexity and potential safety hazard associated with the type of procedure being performed in the laboratory.

F. Training Requirements for Ancillary Staff

USUHS Ancillary Staff, which includes Facilities, Housekeeping, Logistics (Shipping and Receiving), Security, and Laboratory Animal Medicine, are provided annual training that includes:

- (a) Areas where radioactive material is used and stored.
- (b) Potential hazards associated with radioactive material.
- (c) An individual's obligation to report unsafe conditions to the RSO and/or applicable authorities.
- (d) Appropriate response to emergencies or unsafe conditions.
- (e) Locations where copies of pertinent regulations, licenses, and other material required by regulations are posted or made available.

(f) Types of signs and labels used on radioactive material or posted on laboratory doors and equipment.

(g) Security of Radioactive Material.

G. The RSC may modify the training and experience requirements for any category of radionuclide user on an individual basis. However, protection of the health and safety of the worker, coworkers, and the environment will remain paramount in any decision to modify training from prescribed procedures outlined in this manual.

**APPLICATION FOR
RADIONUCLIDE EXPERIMENTAL AUTHORIZATION**

1. Principal Investigator: _____ 2. Department: _____
3. Senior Investigators: _____ 4. Independent Users: _____
5. Other persons handling radioactive material: _____

6. Radionuclide	Chemical Form	Largest Quantity Used per Experiment	No. Experiments per Month	Maximum Amount of Single Source Ordered	Maximum Amount of Each Nuclide Stored in Lab

7. On an attached sheet, describe each experimental procedure in which radioactive material will be used. Include information on containment (hoods, etc.), shielding, length of time various parts of the procedure take for completion, length of time individuals will be exposed to radioactive material during the procedure and the number of procedures to be carried out during each quarter.
8. List the laboratories in which the radioactive material will be used:
9. List the storage location for radioactive material and the methods for physical security of radioactive material.
10. Hazards Description: If any hazard is checked yes, provide additional information on procedures designed to minimize the hazard.
- a. Will heat be applied to material containing radionuclides? ___ YES ___ NO
 - b. Will a vacuum or pressure be applied? ___ YES ___ NO
 - c. Will gases or vapor be produced? ___ YES ___ NO
 - d. Will procedures involve the use of animals? ___ YES ___ NO
 - e. Will dry or powdered material containing radionuclides be produced? ___ YES ___ NO

11. On an attached sheet address the following radioactive waste issues:

a. Describe the types and quantities of radioactive waste which will be generated. The anticipated volume should be stated. Procedures for handling and reducing the waste volume by laboratory personnel should be described.

b. If animals are to be injected with radioactive material, describe anticipated percent uptake in the target organ, what remains in the carcass, and procedures for handling the carcass as radioactive waste.

12. Comment on any special hazards not listed above and/or special procedures to be used to reduce the potential exposure to radiation and the radioactive material.

13. Signature of Principal Investigator _____ Date _____

14. Signature of Department Chairman _____ Date _____

USUHS Form 6041 (EHS) REV (11/2005)

SUMMARY OF RADIOISOTOPE TRAINING & EXPERIENCE

1. Name:

2. Department:

3. Phone:

4. Formal Radiation Safety Training. Attach certificate with a course description or outline of subjects taught.

Course Title and Location Date of Attendance Course Length Subjects

5. Experience with radioisotopes. (Continue on additional sheets if needed.)

ISOTOPE	MAX SIZE SOURCE (mCi)	PROCEDURE & ACTIVITY (mCi)	LOCATION OF EXPERIENCE	DATES OF EXPERIENCE	FREQUENCY OF USE OF ISOTOPES

6. Signature: _____ Date: _____

V. Procurement of Radioactive Materials

A. Purchasing Radioactive Material

All orders for radioactive material must be approved by the Radiation Safety Office before the USUHS purchasing department can process the order. Authorized users place orders for radioactive material using an electronic ordering system (EOS). The EOS currently used at the USUHS includes the College and University Financial System (CUFS) or the Henry Jackson Foundation Financials Peoplesoft system. All purchase orders for radioactive material are reviewed and approved by EHS before a purchase order is issued. This review includes verification that the principal investigator has been authorized to order the radionuclide in the quantities and chemical forms requested.

An approved radioactive material order will be assigned a source control number by the Radiation Safety Office. This number is used for accountability purposes and should be provided to the Radiation Safety Office when requesting information about a specific order, or when picking up radioactive material.

B. Other Types of Procurement

Arrangements made with any organization or individual to obtain borrowed or no-cost radioactive material must be first coordinated with the USUHS RSO. The organization or person providing such material must have certification from the Radiation Safety Office that the USUHS is licensed to receive it. EHS must also obtain certification from the shipping manufacturer that they are licensed by the NRC or Agreement State to possess and ship the radioactive material. The Radiation Safety Office is responsible to see that DOT and NRC regulations are adhered to with respect to the transport and receipt of the radioactive package. No radioactive material may be obtained in any manner by USUHS personnel without prior approval from the Radiation Safety Office.

EHS will assign the radioactive source control number at the time arrangements are made for its procurement. The radioactive material will be received and processed by EHS following the same procedures used for purchased material.

C. Receipt of Radioactive Material

Upon receipt of a radioactive package, the Logistics Receiving section will check that the shipping papers match the purchase request and that the purchase was approved by EHS. EHS technicians conduct pick up of source package deliveries from Receiving twice each day. If a shipment arrives late at the end of the normal duty day, Receiving section personnel, trained in recognizing special labeled packaging of radioactive material, will then notify EHS of its arrival. EHS will pick up the package and receive it as outlined in part VI.

When placing orders for radioactive materials, USUHS Purchasing will inform suppliers or vendors that deliveries are not to be made during non-duty hours. In special cases, a PI may make arrangements with EHS for an off-duty hour delivery. Security must be notified of the approximate time of delivery. Upon delivery of the package, Security will notify EHS personnel "on call" and

escort the delivery person so they may place the package in room A2033, which is a secured radioactive material storage area.

VI. Source Accountability

A. EHS Receipt Procedures for Radioactive Material

EHS personnel will take possession of the radioactive package from the Receiving section and transport it to Room A2033 to survey it for removable contamination on the surface, and for external exposure rates as required by 10 CFR Part 20.1906. Removable radioactive contamination in excess of 0.01 microcuries per 100 square centimeters of package surface must be reported to the delivering carrier and to the NRC. Radiation levels in excess of 200 millirem per hour at the package surface, or in excess of 10 millirem per hour at one meter from the package surface, are also reported. The package is opened and the vial containing the radioactive material is surveyed for removable contamination. Any contamination found during the survey of the source is indicated on USUHS Form 6033 (Radioactive Material Survey).

Following the receipt survey, the PI is notified of the package's arrival. After survey results indicate that no removable contamination or excess radiation levels are present, the source is then transported by the designated EHS radiation safety technician from Room A2033 to the appropriate authorized user in the PI's lab.

B. Transfer of Sources to the Authorized User

Radioactive sources may only be delivered to individuals listed on the PI's REA as radionuclide users. The authorized person who accepts the source will sign USUHS Form 6033 (Radioactive Material Survey), which is then filed by EHS. The user is given a copy of USUHS Form 6034 (Source Utilization Log), or USUHS Form 6045 (Iodine Utilization Log) if the nuclide is Iodine-125.

C. Maintenance of Source Utilization Log

The PI is responsible for maintaining USUHS Form 6034 (Source Utilization Log). Source Utilization Logs issued to users will be stored in a folder or binder and located in the laboratory near the Radiation Survey Log and in a location accessible to EHS personnel. Logs must be updated each time radionuclides are used or disposed of as waste. It is important that logs be kept up-to-date to facilitate EHS personnel in the removal radioactive waste from the laboratory or in conducting surveys. When the exact activity of a nuclide placed in waste is unknown, an estimate of the activity will be made. Activity of radionuclides on hand may be corrected for decay at the discretion of the user.

Logs for depleted sources must be returned to EHS after all radioactive material is used or is no longer needed. Copies of these logs may be submitted to EHS for the purpose of reporting quarterly radioactive material inventories held by the PI.

D. Quarterly Radionuclide Source Inventory

At the end of each calendar quarter, a computer printout with a list of radionuclide sources possessed by the PI is sent to the PI (REA Holder). Sources are identified by source number, radionuclide, and chemical form.

A physical check must be conducted of all radioactive material. Sources not listed on the printout, or sources listed which are no longer in the possession of the PI, must be brought to the attention of EHS. The activity of the sources listed should be checked and corrected if there are changes due to disposal or decay of the source.

Quarterly inventory sheets must be returned to EHS with 15 working days after notification that the inventory is due.

EHS does not routinely store sources for PIs. On rare occasions EHS has temporarily stored sources and then, on a monthly basis, a computer printout with a list of radionuclide sources being stored by EHS is sent to the PI. Sources found to be kept in storage for more than 5 half-lives or in excess of 2 years are subject to disposal as radioactive waste by EHS. Investigators who wish to retain these sources must provide a written request with justification to the RSO.

RADIOACTIVE SOURCE ORDER and RECEIPT FORM

SOURCE ORDER INFORMATION

Order Date: _____ Req. ID#: _____ EHS: _____

Vendor: _____ Isotope: _____

PI: _____ REA #: _____

mCi Ordered: _____ Chemical Form: _____

SOURCE RECEIPT & SURVEY INFORMATION

Date Received: _____ Received By: _____ Surveyor Initials: _____

PACKAGE LABEL: NONE _____ White I _____ Yellow II _____ Yellow III _____

DOT-TYPE: STC _____ TYPE 7A _____ Other _____

Survey Instrument: Victoreen Model 190 Serial # _____

Exposure Readings(mR/hr) Surface _____ 1 meter _____ Package Material _____

Package Smear _____ Source Smear _____

Laboratory results (dpm/100cm squared): Package swipe _____ Source swipe _____

STORAGE: -80 Freezer _____ Refrigerator _____ Freezer _____ Lead Cave _____

LAB NOTIFICATION INFORMATION

Person Contacted: _____ By _____ Date _____

Issued By: _____ Issued to: _____ Date _____

EHS Req. #: _____

Reviewer Name, Date, Comments:

Iodination Utilization Log

Principal Investigator: _____

REA Number: _____

Source Control Number: _____

Date In Lab: _____

Date Arrived: _____

Date of Disposal: _____

Nuclide: _____

mCi Quantity: _____

Chemical/Physical Form: _____

			Amount Disposed of (mCi)						
			At Iodination			As Labeled Compounds in Laboratory			
Date	mCi on Hand	mCi Quantity Used	Solid Waste	Liquid Waste	Transported to Laboratory	Scintillation Waste	Solid Waste	Liquid Waste	Animal Waste

VII. Use Of Radioactive Material

A. User Responsibilities

All persons using radioactive material at USUHS will be familiar with these procedures as well as the specific safety precautions specified in the REA. In addition to the initial 90-minute radiation safety training, all users must attend an annual radiation safety refresher class. PIs are responsible for seeing that all personnel handling radioactive material within their jurisdiction follow NRC rules and regulations, the USUHS License, and conditions of their REA.

EHS personnel are available for guidance, training, and to review laboratory procedures upon request of the PI.

B. General Rules For All Radioactive Material Usage

1. The area within the laboratory where the experiment is to be performed will be covered with absorbent material surrounded with yellow tape or tape with the standard radiation caution symbol. If possible, work should be conducted in a tray lined with absorbent paper and in a chemical or radionuclide fume hood.

2. Disposable gloves and lab coats or other protective garments will be worn at all times when handling radioactive material. Protective garments will not be taken from the lab to the cafeteria or to public areas outside the University.

3. All radioactive wastes should be placed in marked containers that have been approved by EHS.

4. Laboratories will be locked, or the radioactive material secured in locked containers, when authorized personnel are not present.

5. Never pipette solutions by mouth.

6. Use the smallest quantity of radioactivity compatible with the objective of the experiment.

7. After using radioactive material, wash your hands and monitor hands, clothing, and soles of shoes before leaving a posted laboratory.

8. Work carefully and regularly monitor the work area to avoid accidental contamination.

9. Label containers of radioactive material clearly, indicating nuclide, total activity, and date.

10. Do not apply cosmetics, eat, drink, smoke, or chew in a posted laboratory.
11. Do not store food, drink or personal effects with radioactive material.
12. Know how to react in case of a spill or personal contamination.
13. Wear assigned dosimetry devices when working with radioactive material.

C. Classification of Radioisotope Laboratories

1. Radionuclides in use are divided into four groups depending upon their relative radiotoxicity. This classification depends upon half-life, type and energy of radiation, and distribution to body tissues. These groups are:

Group 1:

Pb-210	Po-210	RA-223	Ra-226	Ra-228	Ac-227	Th-227	Th-228	Th-230
Pa-231	U-230	U-232	U-233	U-234	Np-237	Pu-238	Pu-239	Pu-240
Pu-241	Pu-242	Am-241	Am-243	Cm-242	Cm-243	Cm-244	Cm-245	Cm-246
Cf-249	Cf-250	Cf-252						

Group 2:

Na-22	Cl-36	Ca-45	Sc-46	Mn-54	Co-56	Co-60	Sr-89	Sr-90
Y-91	Zr-95	Ru-106	Ag-110m	Cd-115m	In-114m	Sb-124	Sb-125	Te-127m
Te-129m	I-124	I-125	I-126	I-131	I-133	Cs-134	Cs-137	Ba-140
Ce-144	Eu-154	Tb-160	Tm-170	Hf-181	Ta-182	Ir-192	Tl-204	Bi-207
Bi-210	At-211	Pn-212	Ra-224	Ac-228	Pa-230	Th-234	U-236	Bk-249
Eu-152(13y)								

Group 3:

Be-7	C-14	F-18	Na-24	Cl-38	Si-31	P-32	S-35	Ar-41
K-42	K-43	Ca-47	Sc-47	Sc-48	V-48	Cr-51	Mn-52	Mn-56
Fe-52	Fe-55	Fe-59	Co-57	Co-58	Ni-63	Ni-65	Cu-64	Zn-65
Zn-69m	Ga-72	As-73	As-74	As-76	As-77	Se-75	Br-82	Kr-85m
Kr-87	Rb-86	Sr-85	Sr-91	Y-90	Y-92	Y-93	Zr-97	Nb-93m
Nb-95	Mo-99	Tc-96	Tc-97m	Tc-97	Tc-99	Ru-97	Ru-103	Ru-105
Rb-105	Pd-103	Pd-109	Ag-105	Ag-111	Cd-109	Cd-115	In-111	In-115m
Sn-113	Sn-125	Sb-122	Te-125m	Te-127	Te-129	Te-131m	Te-132	I-130
I-132	I-134	I-135	Xe-135	Cs-131	Cs-136	Ba-131	La-140	Ce-141
Ce-143	Pr-142	Pr-143	Nd-147	Nd-149	Pm-147	Pm-149	Sm-151	Sm-152
Eu-155	Gd-153	Gd-159	Dy-165	Dy-166	Ho-166	Er-169	Er-171	Tm-171
Yb-175	Lu-177	W-181	W-185	W-187	Re-183	Re-186	Re-188	Os-185
Os-191	Os-193	Ir-190	Ir-194	Pt-191	Pt-193	Pt-197	Au-196	Au-198
Au-199	Hg-197	Hg-197m	Hg-203	Tl-200	Tl-201	Tl-202	Pb-203	Ri-205
Bi-212	Rn-220	Rn-222	Th-231	Pa-233	Np-239	Eu-152(9.2hr)		

Group 4:

H-3	O-15	Ar-37	Co-58m	Ni-59	Zn-69	Ge-71	Kr-85	Sr-85m
Rb-87	Y-91m	Zr-93	Nb-97	Tc-96m	Tc-99m	Rh-103m	In-113m	I-129
Xe-131m	Xe-133	Cs-134m	Cs-135	Sm-147	Re-187	Os-191m	Pt-193m	Pt-197m
Th-232	Th-Nat	U-235	U-238	U-Nat				

The IAEA refers to Groups 1-4 as **High Toxicity, Medium Toxicity -- Upper Sub-Group A, Medium Toxicity -- Lower Sub-Group B** and **Low Toxicity** respectively.

2. Laboratories are classified as either Type C or Type B labs. High activity laboratories (Type A) are not present at USUHS. The RSC determines the class of laboratory required for a specific operation at the time of the review of the proposed use of radionuclides. This determination is based on the following criteria:

Radiotoxicity Group of Radionuclide	Types of Laboratories Required for Levels of Activity Specified Below		
	TYPE C	TYPE B	TYPE A
1	< 10 μCi (< 0.37 MBq)	10 μCi to 1 mCi (0.37 MBq to 37 MBq)	> 1 mCi (> 37 MBq)
2	< 1 mCi (< 37 MBq)	1 mCi to 100 mCi (37 MBq to 3700 MBq)	> 100 mCi (> 3700 MBq)
3	< 100 mCi (< 3700 MBq)	100 mCi to 1 Ci (3700 MBq to 37 GBq)	> 1 Ci (> 37 GBq)
4	< 100 mCi (< 3700 MBq)	100 mCi to 10 Ci (3700 MBq to 370 GBq)	> 10 Ci (> 370 GBq)

The laboratory classification will be modified according to the type of operation being conducted using the following factors.

Simple Storage	x 100
Very Simple Wet Operations	x 10
Normal chemical Operations	x 1
Complex Wet Operations	x 0.1
Simple Dry Operations	x 0.1
Work With Volatile Compounds	x 0.1
Dry Dusty Operations	x 0.01

These factors will be increased by a factor of 10 when operations are conducted within a fume hood, and by a factor of 100 when conducted within a HEPA filtered glove box.

3. Special conditions, in addition to those listed for all labs, for operations in Class B laboratories include:

- a. Laboratory work surfaces are to be covered with absorbent paper.
- b. Bench top procedures will be conducted in paper lined trays in order to contain a spill.
- c. No office space or desks are allowed in Type B labs.
- d. All individuals working in Type B labs may be candidates for the quarterly bioassay program as determined by the RSO.

- e. Personnel must not enter these laboratories without EHS approval.
- f. Weekend and after-hours work must be approved by EHS.
- g. Type B labs will be surveyed twice per month by EHS.

D. Labeling and Storage of Radionuclides

1. Radioactive waste containers will be labeled with: "Caution Radioactive Waste" or "Caution - Radioactive Material."
2. Containers with more than the following quantities of a radionuclide will be labeled with a radioactive warning label describing the isotope, activity, and name of responsible person.

microCuries	Nuclides
1	I-125, Cd-109
10	P-32, Na-22, Fe-59, Gd-153, Hg-203, Au-195, Sc-46, Sr-89
100	P-33, S-35, Ca-45, Na-24, Co-57, In-111, Rb-86, Se-75, Sr-85, Ce-141, Nb-95, Ru-103, Sn-113
1000	H-3, C-14, Cr-51

Limits for nuclides not listed are contained in 10 CFR Part 20, Appendix C.

Although the NRC requires these quantities to be labeled, it is advisable to label any quantity of radioactive material/waste with tape containing the radioactive warning symbol. Trays of scintillation vials can be marked by attaching radiation warning tape to the tray.

3. Radioactive sources must be securely stored in a place where they are not likely to be accidentally spilled or taken by unauthorized personnel. Sources must be shielded if they emit high-energy beta particles or gamma rays of any energy.

E. Transporting Radioactive Material at USUHS

1. Radioactive material will not be taken from the premises of USUHS without prior coordination through RSO. Transport of radioactive material from USUHS will comply with Department of Transportation (DOT) and NRC requirements for packaging and transport of radioactive materials. The RSO will ensure that these requirements are met.

2. The RSO will be notified prior to any transfer radioactive material to another PI within the USUHS or to another institution. The PI will submit EHS Form 6037A (Request for Transfer of Radioactive Source Between USUHS PIs) to the RSO for any intended transfer of radioactive material within USUHS. The PI will submit USUHS Form 6037 (Request for Transfer of Radioactive Material Outside USUHS) to the RSO for any intended transfer of radioactive material outside of the USUHS. EHS will transfer the source accountability paperwork to the new user. If the source is to be sent to another institution, EHS must receive certification from that institution that it is authorized to receive the radioactive material being shipped.

3. Care will be used in transporting radioactive material in the hallways or between buildings at USUHS. Sources will be in covered containers, preferably non-breakable, and must not be left unattended. Sources emitting high-energy beta particles, or gamma rays, will be shielded so that the exposure rate one meter from the source is less than 10 mR/hr. Any package containing radioactive material with an exposure rate greater than 1 mR/hr at contact with the outside of the shipping carton must be transported on a handcart. Individuals transporting radioactive material within USUHS will wear lab coats and, when appropriate, dosimetry devices.

F. Shielding

The appropriate shielding for radionuclides in the laboratory will be determined by the RSO at the time of the REA review. Sufficient shielding will be used to keep the exposure rate at one meter from the source to less than 2 mR/hr.

G. Surveys

After procedures with radionuclides are completed, ensure that: 1) a full radiological survey of the work area has been accomplished (see part X of this guide for details), and 2) your personnel protective equipment has functioned properly by surveying your hands, laboratory coat, and shoes for evidence of contamination. If contamination is detected, notify your PI, check the procedures in part XI of this guide, and contact EHS for assistance. For Hydrogen-3, Carbon-14, and Sulfur-35, it is necessary to take wipes of the laboratory surfaces, and of the hands and feet (the soles of shoes) using filter papers that can be counted in liquid scintillation counter. Surveys which show removable contamination greater than $200 \text{ pCi}/100 \text{ cm}^2$ ($450 \text{ dpm}/100 \text{ cm}^2$) is considered contaminated, and will be decontaminated by laboratory personnel. Levels of removable contamination greater than $450 \text{ pCi}/100 \text{ cm}^2$ ($1000 \text{ dpm}/100 \text{ cm}^2$) is the action level for notifying EHS personnel. Laboratory personnel will decontaminate the area under the direction of EHS personnel.

Not all laboratories using radionuclides are equipped with a survey meter. Hydrogen-3 users will not be issued radiation instruments for conducting their survey. Laboratories may be grouped and share instruments on an area basis. All Type B laboratories will be issued a survey instrument dedicated for use in that laboratory unless the only isotope in use is Hydrogen-3.

H. Contaminated Surfaces and Equipment

Instruments and glassware which are repeatedly used with radioactive material may be stored in their contaminated condition if they are properly bagged, marked with the radiation warning symbol, and placed in a secured container such as a lock drawer or cupboard which must also show the radioactive material warning symbol.

Interior surfaces of certain equipment items such as centrifuges may be allowed to contain low levels of contamination if the equipment is properly marked and closed so that contaminated surfaces are not exposed to the room. Any liquid, paper, or equipment that comes in contact with these surfaces will be considered radioactive and disposed of as radioactive waste.

I. Removal and Repair of Contaminated Equipment

All laboratory equipment that is repeatedly used with radioactive material or posted with a "CAUTION RADIOACTIVE MATERIAL" label must have a survey for removable radioactive contamination if the equipment is to be worked on or moved from the lab. Equipment will not be released to maintenance, transferred from one location to another, loaned, or the property turned-in, unless the removable contamination is less than 200 dpm/100 cm². In addition, such equipment may not be repaired by maintenance personnel in the laboratory or sent out for repairs without clearance from EHS. It is the responsibility of laboratory personnel to request a survey for removable radioactive contamination. EHS personnel will perform the survey and will certify that the equipment is below the release limit for radioactive contamination. A USUHS Log Form 6052, Equipment Condition (see page 26), must be attached to the equipment, and signed by the RSO, before the item can be repaired or removed from the posted laboratory.

J. Allowable Surface Contamination

Any lab area surveyed by a portable survey meter, and found to have a count rate greater than the background, will be wipe tested for removable contamination. Any laboratory surface with removable contamination greater than 200 pCi/100 cm² (450 dpm/100 cm²) is considered contaminated, and will be decontaminated by laboratory personnel. Levels of removable contamination greater than 450 pCi/100 cm² (1000 dpm/100 cm²) is the action level for notifying EHS personnel. For contamination levels above the action level, laboratory personnel will decontaminate the area under the direction of EHS personnel.



EQUIPMENT CONDITION

USUHS ID No. _____

If no ID No., DESCRIPTION:

1. Has this equipment been used with any of the following hazards?

	YES	NO
RADIOLOGICAL		
BIOLOGICAL		
CHEMICAL		

2. Has this equipment been cleaned/decontaminated in accordance with approved procedures/protocols?

YES _____ NO _____

3. If radioactive material has been used in, or is contained in, this equipment, Radiation Safety Officer Certification is mandatory.

RSO SEAL

4. Requestor must certify above:

NAME (PRINT) _____

SIGNATURE _____

DATE _____

USUHS LOG FORM 6052 (10/88)

VIII. Disposal of Radioactive Waste

A. Solid Radioactive Waste

EHS provides solid waste containers to each posted laboratory. The container is marked with the radioactive warning symbol "Caution Radioactive Waste" or "Caution Radioactive Material" prominently displayed on the side and lid of the container. Solid radioactive waste, including damp paper, and solid containers with residual moisture on the surfaces, will be placed in these containers. Test tubes and vials containing pourable quantities of radioactive liquid must be emptied before placing them in solid waste containers.

Radioactive SHARPS (hypodermic needles, broken pipettes, etc.) should be disposed of in a red SHARPS container. These containers must be labeled with a radioactive warning symbol, "Caution Radioactive Waste" or "Caution Radioactive Material".

Radioactive material will never be placed in regular waste containers or in containers that are not marked with the radiation warning symbol.

B. Liquid Radioactive Waste

Plastic cubitainers are available for disposal of liquid radioactive waste. They will be marked with a radioactive warning label with the words "Warning Radioactive Material" or "Warning Radioactive Waste." Cubitainers need to be placed in a plastic tray or pan of sufficient size to contain the liquid volume should the cubitainer leak. Absorbent pads should also be placed underneath the cubitainer to absorb minor spillage. Care should be taken when disposing of radioactive liquid not to contaminate the sides of the containers.

C. Scintillation Vials

All liquid scintillation vials will be placed into boxes (flats) provided by EHS personnel or received from the vial supplier. Vials should not be mixed with regard to size, composition, and contents; i.e. a box may contain only 20 ml glass vials of one isotope or a box may contain 4 ml plastic vials of a single isotope. For each flat of LSC vials turned in, a EHS Form 375, Radioactive Waste Documentation Card, must be filled out.

D. Animal Carcasses

All animal carcasses and tissue samples containing radioactive material will be bagged in strong plastic bags and securely fastened. A radioactive carcass tag indicating the date of disposal, responsible investigator, nuclide, source control number, and its activity must be attached to the bag. The carcasses may be placed temporarily (less than 72 hours) in an appropriately labeled freezer. EHS must be promptly notified to conduct a waste pickup of the carcasses. Animal carcasses and tissue samples containing 0.05 microCuries per gram or less of Hydrogen-3 or Carbon-14, may be disposed of without regard to radioactivity; PROVIDED that the method of disposal would not permit its use as food for humans or animals, and such disposal has been approved by the RSO.

E. Waste Documentation

Each solid, liquid, and scintillation waste container must have a EHS Form 375, Radioactive Waste Documentation Card (*see page 30*), attached to it. Each time waste is placed in one of these containers, the nuclide, activity, date of disposal, and source control number must be entered on the EHS Form 375 card. The activity recorded on these cards and animal carcass tags must agree with entries made on the appropriate Source Utilization Log, USUHS Form 6034 (*see page 18*). The bottom of EHS Form 375 must be completed PRIOR to waste pickup by EHS personnel. You must also list any non-radiological hazards, if present, and enter the Department, PI, and room number on the form.

F. Waste Pickup from Laboratories

Radioactive waste is picked up by EHS personnel and taken to the EHS warm storage area until disposed of through the "decay in storage" program, or removal for burial by a licensed radioactive waste contractor. No other personnel are authorized to remove radioactive waste from the laboratory. Laboratory personnel will not allow waste to generate to a level where it is overflowing and could create a contamination or radiation exposure hazard. Laboratories must notify EHS personnel when waste containers are at 75 percent capacity to arrange for pick up of the waste. EHS must be notified for immediate pick up of radioactive waste which creates radiation areas with dose rates greater than 2 mR/hr.

G. Radioactive Waste Drain System

Laboratory personnel are not allowed to discharge any liquid radioactive waste to the sanitary sewage system. All liquid waste generated in the laboratory is placed in plastic cubitainers for removal by EHS personnel when full to 75 percent capacity. The cubitainers are issued to authorized users from EHS. EHS personnel are notified when liquid waste needs to be collected. The liquid waste is placed in holding tanks for decay and dilution. The liquid waste is disposed of in accordance with 10 CFR 20.2003 under the supervision of the RSO.

IX. Handling Animals Containing Radioactive Material

A. Housing of Radioactive Animals

Unless otherwise approved by the RSO or the RSC, all laboratory animals with body burdens of radioactive material or contaminated with radioactive material and are kept for more than 24 hours will be housed in the Laboratory Animal Medicine facility. Each room containing radioactive animals will be posted. If the ambient dose rate is greater than 2 mR/hr, the room will be considered to be a radiation area and a sign must be posted with the radiation warning symbol, "Caution: Radiation Area". Only personnel authorized by EHS will be permitted to enter.

Each radioactive animal or group of animals will be housed in cages that are prominently labeled with the radiation warning label. The isotope, date of injection, activity injected and the name of the responsible investigator will be written on the label.

B. Cleaning of Cages and Disposal of Contaminated Bedding

Bedding from cages in which radioactive animals are housed will be considered as radioactive material and disposed of as such. Contaminated bedding will be removed from cages by EHS personnel using the proper techniques of handling contaminated bedding. Cages used to house animals containing radioactive material will be surveyed by EHS, decontaminated if necessary, and washed in the cage washer only after approval by EHS. Other cages will be surveyed by EHS and either decontaminated under the direction of EHS personnel or disposed of as radioactive waste following EHS radioactive waste disposal procedures.

X. Laboratory Surveys

A. Laboratory Surveys Conducted by Researchers

PIs are responsible for ensuring containment of all radioactive material being used in their laboratories and will ensure surveys are performed in the laboratory after each experimental procedure involving radionuclides or, as a minimum, after the final experimental procedure of the day involving radionuclides. The method of conducting these surveys, and the minimum level of activity allowed on exposed laboratory surfaces are outlined in page 23, part VII.

Surveys for most nuclides will be conducted using a survey meter issued by EHS personnel, unless otherwise approved by the RSO. Surveys in laboratories using Hydrogen-3, Carbon-14, and/or Sulfur-35 will be conducted by wiping surfaces with filter paper swipes and then counting them in a liquid scintillation counter.

Surveys will be documented at the time of the survey and kept in a laboratory radiation survey log record. Each log entry must include location of survey measurements, results of the wipe sample counts and/or survey meter readings, the model, serial number, and calibration due date of survey meter used, and the initials of the worker who conducted the survey. A diagram of the laboratory

outlining survey and sampling points should be included as a reference. The survey log will be available for inspection during routine laboratory surveys conducted by EHS personnel.

Surveys for Hydrogen-3, Carbon-14 and Sulfur-35 will be conducted by wiping surfaces and counting the wipes in liquid scintillant. Surveys for high level beta and gamma emitting isotopes will be conducted with a survey meter that has been calibrated within the past 12 months prior to conducting the survey. Areas of survey showing removable contamination of $200 \text{ pCi}/100 \text{ cm}^2$ ($450 \text{ dpm}/100 \text{ cm}^2$) will be decontaminated by laboratory personnel and resurveyed. Contamination levels in excess of $450 \text{ pCi}/100 \text{ cm}^2$ ($1,000 \text{ dpm}/100 \text{ cm}^2$) must be reported immediately to EHS. Laboratory personnel will decontaminate such an area under EHS supervision.

B. EHS Surveys of Posted Laboratories

EHS personnel will conduct bi-weekly surveys of all Type B laboratories and monthly surveys of all Type C laboratories. The surveys consist of swipe samples and room radiation levels taken at random locations within the laboratory, with emphasis on radionuclide work areas, phone receivers, handles/knobs, and high traffic areas.

C. Allowable Surface Contamination

Any bench top, floor, or other laboratory or equipment surface with removable contamination greater than $200 \text{ pCi}/100 \text{ cm}^2$ ($450 \text{ dpm}/100 \text{ cm}^2$) is considered contaminated, and will be decontaminated by laboratory personnel. Levels of removable contamination greater than $450 \text{ pCi}/100 \text{ cm}^2$ ($1,000 \text{ dpm}/100 \text{ cm}^2$) is the action level for notifying EHS personnel. For contamination levels above the action level, laboratory personnel will decontaminate the area under the direction of EHS personnel. Surfaces of some equipment and hoods may be allowed greater surface contamination levels with the approval of the RSO.

D. De-posting of Radiological Laboratories

Laboratories where use of radioactive material will not occur for an extensive period of time (i.e., one year or longer) will be considered for de-posting. Requests for de-posting should be made in writing to the RSO on EHS Form 380 (Radionuclide Experimental Authorization Amendment Request). Use of this form will expedite provision of the required information for review by the RSO.

XI. Procedures For Radionuclide Spills And Emergencies

A. Emergency Planning

It is the responsibility of the PI to anticipate situations that may arise in the routine use of radionuclides leading to spills or unnecessary exposure to radiation. Careful planning of experimental procedures must be conducted to reduce the probability of spills or exposure.

The PI will ensure that:

- An emergency spill kit is available in the laboratory for use.
- All personnel using radioactive material under his/her supervision know how to manage a spill or personnel contamination incident.
- Workers are aware of spill emergency procedures and notification procedures.

B. Immediate Action for Simple Spills

If radioactive material is spilled in a laboratory, the following actions will be taken:

1. WARN NEARBY PERSONNEL. Take steps to avoid contaminating others with the spilled material, and prevent the spread of contamination to otherwise "clean" areas.
2. PREVENT THE SPREAD OF CONTAMINATION. Put absorbent paper over the visible spill areas.
3. PREVENT TRAFFIC THROUGH THE SPILL AREA.
4. CALL THE RADIATION SAFETY DIVISION (EHS). 295-3390/9443. After normal working hours or on weekends call Security on 295-3038. EHS personnel are always on call to respond to spills and other radionuclide emergencies.
5. Under the direction of EHS personnel, clean up the spill using disposable gloves and absorbent paper. Carefully fold the absorbent paper with the clean side out and place in a plastic bag for transfer to a radioactive waste container. Also, put contaminated gloves and any other contaminated material in the bag. After clean up, survey the area, your hands, clothing and shoes to ensure that decontamination was successful.
6. EHS personnel will conduct an independent follow-up survey of the cleanup.

C. Additional Actions for Spills Involving Contamination of Clothing or Skin

1. REMOVE CONTAMINATED CLOTHING. Clean laboratory coats or surgical gowns can be used to preserve modesty. Contaminated clothing must be placed in a plastic bag and turned over to radiation safety personnel.
2. WASH CONTAMINATED SKIN WITH MILD SOAP AND WARM WATER. Do not use abrasives or solvents on the skin. Follow any additional guidance provided by the EHS personnel.

D. Actions for Contaminated Wounds

In the case of contaminated wounds it is important to notify EHS as soon as possible. Rapid treatment of the wound will help reduce the possibility of internal absorption of radioactive material. Flush the wound with water and treat using appropriate first aid measures. NEVER WITHHOLD FIRST AID TO A CONTAMINATED PERSON.

E. Possible Airborne Contamination

Spills of dry or powdered radioactive material, or spills of iodine or other large sources in solution, are potential sources of airborne contamination. After spills in this category:

1. QUICKLY COVER THE SPILL WITH ABSORBENT MATERIAL.
2. LEAVE THE LAB IMMEDIATELY AND CLOSE THE DOOR.
3. NOTIFY EHS.
4. WAIT IN PLACE UNTIL EHS PERSONNEL ARRIVE.

XII. Control of Access To Laboratories

A. Posting of Laboratories

All laboratories at USUHS in which radioactive material are used are posted with the yellow and magenta radiation warning symbol. Wording on the symbol will depend on the following conditions:

1. Caution: Radioactive Material. These laboratories use radionuclides, but in quantities that present no external exposure hazard.

2. Caution: Radiation Area. These laboratories may include areas with an external exposure rate greater than 2 mR/hr. Individuals who have not been permitted entry by the RSO must stay out.

B. Access to Posted Laboratories

All laboratory entrances will be securely locked, or the radioactive material must be secured in a locked container or freezer when authorized personnel are absent from the lab. Minors (persons under 18 years of age) are not allowed to enter without permission of the RSO or his/her designated representative. Additionally, minors are required to obtain and submit to RSO a signed parental consent form before entering such laboratories. Other visitors should have permission from the responsible PI before entering any posted areas.

Entry into Class B laboratories or laboratories posted as Radiation Areas is prohibited to all those who have not been given specific permission to enter by the RSO or his/her designated

representative. Instructions which accompany the yellow and magenta radiation warning symbol must be adhered to without question.

XIII. Iodination Procedures

A. General

An iodination is a procedure conducted by a researcher where an isotope of iodine in the form of Sodium Iodide (NaI) is bound to some biochemical for use as a tracer. This procedure poses a greater risk to receiving an internal exposure because iodine may be released as free iodine gas during the binding process and may subsequently be inhaled and promptly taken up by the thyroid.

B. Dose Limits

The following occupational exposure standards apply to the use of Iodine-125:

$$\begin{aligned}\text{Annual limit of Intake (ALI), Inhalation} &= 60 \mu\text{Ci} \\ \text{Derived Air Concentration (DAC)} &= 3 \times 10^{-8} \mu\text{Ci/ml} \\ \text{Effluent Air Concentration to an unrestricted area} &= 3 \times 10^{-10} \mu\text{Ci/ml}\end{aligned}$$

Only I-125 may be used in an iodination procedure. Other isotopes of iodine may be considered and reviewed when a protocol requesting their use is submitted to the RSC.

C. Containment

The University maintains special chemical fume hoods that are approved and are dedicated for the use of radioiodine. These hoods are located in rooms B2091 and C2073. The system consists of two levels of containment, a chemical fume hood exhausted through a HEPA filter, and an inner plexiglas box which draws air from the fume hood and exhausts through a charcoal filter back into the fume hood. This box is placed inside the chemical fume hood that is HEPA filtered. Prior to the start of the procedure, EHS personnel will conduct measurements to ensure that the chemical fume hood is operating with a face flow velocity greater than 80 feet per minute (fpm) and that the handling isolation box is operating at a face flow velocity greater than 60 fpm.

D. Air Sampling

Two air-sampling tubes filled with activated charcoal are used in tandem at each of three air sampling locations during the iodination procedure. Air sampling is continuous at each location during this procedure and they are:

1. Researcher breathing zone (no greater than 8 inches from the nose and mouth).
2. Room air (room exhaust) at the return air vent nearest the fume hood.
3. Air exhausted from the inner isotope handling/isolation box into the fume hood.

E. Contamination Monitoring

EHS personnel will perform a pre-iodination survey of the hood and surrounding area as part of their room preparation and document any findings on the survey form. Immediately after the iodination procedure, EHS personnel will conduct monitoring of the laboratory area and chemical fume hood to check for contamination. Areas found to have greater than $200 \text{ pCi}/100 \text{ cm}^2$ ($450 \text{ dpm}/100 \text{ cm}^2$) of removable contamination must be decontaminated.

F. Spills/Emergency Procedures

Spills of radioiodine during an iodination procedure should be treated the same as an airborne spill discussed in page 32, part XI.

G. Thyroid Bioassay

Researchers who perform iodination procedures must be evaluated for the presence of radioiodine in his/her thyroid. The pre-study baseline evaluation must be performed within the 48-hour period preceding the iodination procedure. A post-iodination evaluation will be performed from 24 to 72 hours following the iodination procedure. All thyroid screenings will be performed with the appropriate radiation detector located in the EHS front office in Room A2020. The EHS department will maintain copies of the thyroid evaluations. If the evaluation indicates an activity greater than $0.05 \text{ } \mu\text{Ci}$, a follow-up evaluation will be scheduled and obtained one to two weeks later. Additionally, the experimental protocol will be reviewed for possible improvement in handling procedures and containment of radioactive material. If thyroid activity is greater than $0.10 \text{ } \mu\text{Ci}$, the researcher may perform no further iodinations until containment methods are improved and/or experimental procedures are modified.

H. Training

All persons performing iodinations must be an approved PI, SI or IU. Three iodinations must be performed under the direct supervision of an approved iodinator. Newly assigned researchers who have proven recent experience in conducting iodination procedures at their previous employment may be exempted from this requirement. A minimum of six months experience using radioisotopes is required before achieving iodinator status. USUHS Form 6043, Iodination Qualification Certification must be completed.

IODINATION QUALIFICATION CERTIFICATION

I, _____, hereby certify that:

- A. I have read and understand Part XIII, Iodination Procedures, of the USUHS Radiation Safety Guide.
- B. I have been instructed in proper use of the portable survey meter used to monitor exposures during iodinations.
- C. I am fully aware of the potential hazards involved with the use of radioiodine.
- D. I am fully aware of the necessity of participation in the thyroid bioassay program. I understand that my authorization to perform further iodinations may be revoked if I fail to comply with the bioassay requirements.
- E. I know the locations of, and understand the procedures for air sampling that EHS conducts during iodinations.

Signature

Date

I, _____, hereby certify that the above named individual has:

- A. Been informed about the potential hazards involving the use of radioiodine as it applies to the particular procedure in which he/she is involved.
- B. Performed three iodination procedures under supervision, and has my full confidence in his/her ability to safely perform this procedure.

PI/SI/IU Signature

Date

XIV. Security of Radioactive Material

A. Access to Laboratories Containing Radioactive Material

During normal working hours, access to USUHS is not restricted, and PIs have a responsibility to ensure that visitors and unauthorized individuals do not wander into posted laboratories or rooms containing licensed radioactive material.

B. Security of Radioactive Material

It is essential that containers of radioactive material be secured against unauthorized removal from the laboratory. When sources of radioactive material are in a room they must:

1. Be under constant surveillance by a member of the laboratory staff when outside a locked container, or,
2. Be secured in a locked container such as a refrigerator, freezer, drawer, or,
3. Be secured by locking the entrance door to the lab.

Isotopes actively being used in an experimental procedure, samples being counted overnight, and sealed sources built into counting instruments are exempted from the requirement to be secured in a locked container while unattended. However, appropriate care will be taken to lock the laboratory entrance door when leaving these isotopes unattended.

C. Security of the Gamma Irradiators

Additional protective measures required for the self-shielded irradiators include:

1. Access to the irradiators is limited to authorized personnel only. Authorized personnel are those who have been granted approval by the RSO and are listed on an approved access roster.
2. Other personnel who may require access to the irradiator room (i.e. maintenance or contract workers) must be escorted by an authorized individual.
3. Security surveillance and electronic monitoring devices must be installed to immediately detect unauthorized access to the irradiator room.

Appendix A

Transportation Instructions for Radioactive Material

Requirements for the transportation of radioactive material on campus and to other institutions must comply with both the NRC and DOT regulations. Transporting may involve walking or driving radioactive material across campus, or shipping off campus. The Radiation Safety Officer (RSO) must be notified before any transfers take place. This is to ensure that proper procedures are followed and movement of radioactive material is tracked. Any transfers of radioactive material (possession transferred from one principal investigator to another) must be pre-authorized by the RSO and performed by the Radiation Safety Division staff.

Package Preparation

All packages used to transport radioactive material must be strong, tight containers that will not leak under normal transportation conditions (such as dropping, jarring or temperature extremes). If liquid is shipped, use at least twice the amount of absorbent needed to contain the entire volume, in case the container should break or leak. If you are not sure whether the container you plan to use is adequate, contact the RSO.

Transportation on Campus

Whenever radioactive material is transported from one building to another, the RSO must be notified of the following information:

- When the material will need to be moved.
- The names of the person sending and receiving the material (if different).
- The sending and receiving locations.
- The nuclide(s) being moved.
- The chemical form of the isotope.
- The total activity in mCi.
- Number of containers.
- Phone numbers of responsible persons.
- Any special conditions.

Transfer to another building Material will be prepared in an appropriate container (see Package Preparation above) and moved by the Radiation Safety Division staff. The package must have a radioactive warning label with the isotope, activity in DPM, uCi or mCi and date. Clearly identify the principal investigator and one other contact in case of an accident or loss of the package. The package must be tested for removable contamination before it leaves its place of origin and after it reaches its destination.

Driving to another building. The transportation of radioactive material is regulated by the Nuclear Regulatory Commission (NRC) and the Department of Transportation (DOT).

Researchers at USUHS are not authorized to move any radioactive material on a public road or base road. The RSO will prepare documentation and transport your material. The sender's responsibility is to contact the RSO in advance, and properly package the radioactive material.

Material will be moved by RSO staff using an appropriate container (see Package Preparation above). The RSO will determine what package labeling is required. Do not seal the package. The condition of the package must be checked and a leak test performed by the RSO. An authorized user must be present at the receiving location to take possession of the material at the arranged time.

Shipping Radioactive Material

The Radiation Safety Office is the only office authorized to ship radioactive material at USUHS. When radioactive material is preparing to shipped, whether it is radioactive samples or a piece of equipment being returned for repairs, the RSO must be informed in advance. **Do not expect to send shipments out immediately.** Federal regulations must be followed regardless of the quantity being sent.

Shipments can only be made to institutions that are licensed to possess radioactive material. When shipping to another licensee, it is required that prior authorization is obtained from the receiving RSO at that location. License information must be on record or obtained before the shipment can be sent. To initiate this process, the person sending the material must have the following information:

- The name of the person sending the material.
- Facility name and address.
- The name of the person receiving the material.
- The Radiation Safety Officer's (or other staff member) name and phone number.
- The nuclide(s) being sent.
- The chemical form of each isotope.
- The total activity in mCi for each isotope.
- Number of containers in the shipment.
- Any special conditions.

Prepare to ship your material using an appropriate container (see Package Preparation above). The RSO will determine what package labeling is required. Do not seal the package, as the condition of the package must be checked and a leak test performed by the RSO. Labels will be placed on the package, if required. When the package and paperwork are in order, the RSO staff will transport the package to the shipping company vendor for shipping. Copies of the shipping papers, material return form, and any other paperwork will be made and maintained for review at the Radiation Safety Division.

APPENDIX B

Pregnant Radiation Worker Policy at USUHS

Title 10, Code of Federal Regulations, Part 20 describes dose limits to the fetus of declared pregnant radiation workers at the Uniformed Services University, and what the workers must do to assure that exposures or risks are maintained at or below the legal requirements. Appendix F contains information concerning the risks to the unborn fetus from exposure to ionizing radiation.

Requirements are:

- 1. The occupational radiation exposure limit for a declared pregnant radiation worker is 500 mrem to the fetus for the entire gestation.**
- 2. Exposures to the fetus will be maintained below 50 mrem per month.**
- 3. Declaration of pregnancy is voluntary and pregnant radiation workers must declare their pregnancy in writing to the Radiation Safety Officer for the fetal limits to take effect. If no written declaration is submitted, the limits remain at the occupational exposure limit to a radiation worker (5 rem per year).**
- 4. If exposures occurred between the time of conception and the declaration date, the exposures will be subtracted from the permitted exposure limits, and the balance will be prorated over the remaining months.**
- 5. An information meeting is scheduled between the pregnant worker and a health physicist staff member to review the previous exposures, discuss any particular concerns and review any special precautions while working with radiation.**
- 6. At the determination of the Radiation Safety Officer, pregnant radiation workers may be supplied with two radiation dosimeters, one for the mother (whole body), and one for the fetus (abdomen). These badges will be exchanged monthly in order to assure that exposure spikes do not occur, and to document that exposures do not exceed the 50 mrem/month cap.**
- 7. Exposure records for the fetus may be tracked separately from the mother. This would be done to reduce confusion and assure that the accumulated dose rolls over into the next year if the pregnancy carries into that year.**

There are few laboratories where radiation levels would be high enough that a fetus would receive 500 mrem. The likelihood of any dose to the fetus is almost non-existent at USUHS with the types and quantities of radioactive materials used. Most nuclides pose little risk of external radiation to the worker. For those who work with ^{32}P , the risk is also very small; although ^{32}P is a high energy beta nuclide, it can only penetrate the tissue at 7 - 10 mm, and not to the depth of the fetus. If you are pregnant, planning to become pregnant, or simply would like more information, please call the RSO.

APPENDIX C
RADIATION UNITS

RADIOLOGICAL UNITS

<u>Unit</u>	<u>Symbol</u>	<u>Brief Description</u>	<u>Use</u>
Curie	Ci	3.7×10^{10} disintegrations per second (2.22 x 10 ¹² DPM)	Special unit of activity
Becquerel	Bq	1 disintegration per second	SI unit of activity
Roentgen	R	2.58×10^{-4} C/kg. (photons in air)	Special unit of exposure; applies only to gamma and x radiation
Rad	rad	0.01 J/kg (100 ergs/g)	Special dose unit; applies to any radiation
Gray	Gy	1 J/kg.	SI unit of dose (Equals 100 rads)
Dose Equivalent	H	Dose x Q x any other modifying factors	Radiation protection
Quality Factor	Q	Biological effectiveness related to type of radiation	Radiation protection
Rem	rem	Rad dose x Q x any other modifying factors	Special unit of human dose equivalent
Sievert	Sv	Gy x Q x any other modifying factors	SI unit of human dose equivalent (Equals 100 rem)

RELATIONSHIP BETWEEN SPECIAL AND SI UNITS

Activity:	$1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq} = 2.22 \times 10^{12} \text{ DPM}$
Exposure:	$1 \text{ R} = 2.58 \times 10^{-4} \text{ C/kg.}$ The special unit for exposure is the Roentgen. There is no SI unit for exposure; it is simply expressed in C/kg.
Dose:	100 rads = 1 Gy
Dose Equivalent:	100 rems = 1 Sv
KeV:	Kilo (1,000) electron volts
MeV:	Mega (1,000,000) electron volts
	$1 \text{ MeV} = 1000 \text{ keV}$
	$1 \text{ KeV} = .001 \text{ MeV}$
	$1 \text{ Ci} = 3.7 \times 10^{10} \text{ Bq} = 37 \text{ GBq}$
	$27 \text{ uCi} = 1 \times 10^6 \text{ Bq} = 1 \text{ MBq}$
	$1 \text{ rad} = 0.01 \text{ Gy} = 10 \text{ mGy}$
	$1 \text{ rem} = 0.01 \text{ Sv} = 10 \text{ mSv}$

APPENDIX D
RADIONUCLIDE DATA
FOR MOST COMMON RADIOISOTOPES
AT USUHS

HYDROGEN - 3

[³H]

PHYSICAL DATA

- Beta Energy: 18.6 keV (maximum)
5.7 keV (average) (100% abundance)
- Physical Half-Life: 12.3 years
- Biological Half-Life: 10 - 12 days
- Effective Half-Life: 10 - 12 days *
- * Forcing liquids to tolerance (3-4 liters/day) will reduce the effective half-life of 3H by a factor of 2 or 3. (Relatively easy to flush out of system with fluids.)
- Specific Activity: 9640 Ci/gram
- Maximum Beta Range in Air: 6 mm = 0.6 cm = 1/4"
- Maximum Beta Range in Water: 0.006 mm = 0.0006 cm = 3/10,000"
- Penetrability in Matter or Tissue: Insignificant*
- * [0% of beta particle energy transmitted through dead layer of skin]

RADIOLOGICAL DATA

- Least radiotoxic of all radionuclides
- Critical Organ: Body Water or Tissue
- Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Contamination (Absorption)
- External exposure from weak ³H beta energy - not a radiological concern
- Internal exposure & contamination are primary radiological concerns
- Committed Dose Equivalent (CDE): 64 mrem/mCi (ingested)
64 mrem/mCi (inhaled)
64 mrem/mCi (puncture)
- Committed Effective Dose Equivalent (CEDE): 90 mrem/mCi (ingested)
63 mrem/mCi (inhaled)
- Annual Limit on Intake (ALI)*: 80 mCi (ingestion or inhalation) [³H₂O]
* [1.0 ALI = 80 mCi (³H) = 5,000 mrem CEDE]
- Skin Contamination Exposure Rate: 57,900 mrad/hr/mCi (contact)*
* Exposure rate to dead layer of skin only
* Skin contamination of 1.0 uCi/cm² = 0 mrad/hr dose rate to basal cells
- Rule of Thumb: 0.001 uCi/ml of ³H in urine sample is indicative of a total integrated whole body dose of approximately 10 mrem (average person) if no treatment is instituted (i.e., flush with fluids). [NCRP-65, 1980]

SHIELDING

- None required.

SURVEY INSTRUMENTATION

- **CANNOT** detect ³H using a G-M or NaI survey meter.
- Liquid scintillation counter (indirect) is the only monitoring method.

RADIATION MONITORING DOSIMETERS

- Whole Body Badge or Finger Rings: Not needed (beta energy too low).

RADIOACTIVE WASTE

- Solid, liquids, scintillation vials, pathological materials, animal carcasses.

REGULATORY COMPLIANCE INFORMATION

- Derived Air Concentration (DAC): $2.0 \text{ E}^{-5} \text{ uCi/cc}$ (occupational)
- Airborne Effluent Release Limit: $1.0 \text{ E}^{-7} \text{ uCi/cc}$ *
* [Applicable to the assessment & control of dose to the public (10 CFR 20.1302). If this concentration was inhaled continuously for over one year the resulting TEDE would be 50 mrem.]
- Controlled Area Removable Contamination Limit: 2,200 dpm/100 cm².
- Urinalysis (Byproduct License): **Required** when handling $\geq 100 \text{ mCi } ^3\text{H}$.

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Inherent Volatility (at STP): **SUBSTANTIAL**
- Experimental uses include: total body water measurements & in-vivo labeling of proliferatory cells by injection of tritium-labeled compounds (i.e., thymidine). Tritium labeling is also used in a variety of metabolic studies.
- Oxidation of ³H gas in air is usually slow (< 1% per day).
- Absorption of ³H inhaled in air is much less when it is present as elemental ³H than as tritiated water (HTO).
- Tritium penetrates the skin, lungs, and GI tract either as tritiated water or in the gaseous form.
- As gaseous hydrogen, ³H entering the lung or GI tract is completely absorbed and rapidly dispersed within the body.
- Some ³H is incorporated into cellular components and has a long turnover rate.
- Forcing fluids reduces integrated internal exposures from ³H.
- Monitor for ³H contamination using only wipe-testing (bench tops, floors, refrigerator/freezer handles, phone, etc.).
- Always wear a lab coat & disposable gloves when handling ³H.
- Skin contamination, inhalation, ingestion, or absorption through the skin is assumed to be completely and instantaneously absorbed and rapidly mixed with total body water.
- The volume of total body water (standard man) is 42,000 ml.
- The concentration of ³H in urine is assumed to be the same as in total body water.
- Detection limit of ³H in urine: $1.08\text{E}^{-5} \text{ uCi/ml}$ (approximately).
- For a continuous inhalation exposure at a rate of 1/365 of an ALI per day, the equilibrium concentration of ³H in urine is 0.073 uCi/ml. [NOTE: 1/365 of 80 mCi (ALI) = 219 uCi]
- The predicted concentration activity normalized to unit intake from inhalation is $2.204 \text{ E}^{-5} \text{ uCi/ml/uCi of } ^3\text{H}$.
- Beta dose rates from 1.0 mCi ³H point source:

<u>Distance</u>	<u>Rad/hr</u>
0.25 cm	10,293.00
0.50 cm	28.12
0.56 cm	1.12

CARBON - 14

[¹⁴C]

PHYSICAL DATA

- Beta Energy: 156 keV (maximum)
49 keV (average) (100% abundance)
- Physical Half-Life: 5730 years
- Biological Half-Life: 12 days
- Effective Half-Life: 12 days (bound)
- Effective Half-Life: 40 days (unbound)
- Specific Activity: 4460 mCi/gram
- Maximum Beta Range in Air: 24.00 cm = 10 inches
- Maximum Beta Range in Water/Tissue: *0.28 mm = 0.012 inches
- Maximum Range in Plexiglas/Lucite/Plastic: 0.25 mm = 0.010 inches

*Fraction of ¹⁴C beta particles transmitted through dead layer of skin: At 0.007 cm depth = 1%

RADIOLOGICAL DATA

- Critical Organ: Fat Tissue
- Routes of Intake: Ingestion, Inhalation, Skin Contact
- External exposure: Deep dose from weak ¹⁴C beta particles is not a radiological concern
- Internal exposure & contamination: Primary radiological concerns
- Committed Dose Equivalent (CDE): 2.08 mrem/uCi (ingested)
(Fat Tissue) 2.07 mrem/uCi (puncture)
2.09 mrem/uCi (inhalation)
- Committed Effective Dose Equivalent (CEDE): 1.54 mrem/uCi (ingested)
- Annual Limit on Intake (ALI)*: 2 mCi (ingestion of labeled organic compound)
2000 mCi (inhalation of carbon monoxide)
200 mCi (inhalation of carbon dioxide)

*[1.0 ALI = 2 mCi (ingested C- 14 organic compound) = 5,000 mrem CEDE]

- Skin Contamination Dose Rate: 1090-1180 mrem per 1.0 uCi/cm² (7 mg/cm² depth)
- Dose Rate to Basal Cells from Skin Contamination, 1.0 uCi/cm² = 1400 mrad/hour.
- Immersion in ¹⁴C Contaminated Air = 2.183E⁷ mrem/year per uCi/cm³ at 70 um depth of tissue and 4.07E⁶ mrem/year per uCi/cm³ value averaged over dermis.

SHIELDING

- None required (≤3 mm Plexiglas).

SURVEY INSTRUMENTATION

- Can detect ¹⁴C using a thin-window G-M survey meter; survey meter probe **must** be at close range (1 cm.).
- G-M survey meters have very low counting efficiency for ¹⁴C (5%).
- Liquid scintillation counter (indirect counting) may be used to detect removable ¹⁴C on wipes.

RADIATION MONITORING DOSIMETERS

- Not needed (beta energy too low).
- ^{14}C Beta Dose Rate: 6.32 rad/hr at 1.0 cm. in air per 1.0 mCi ^{14}C
- Skin Contamination Dose Rate: 13.33 mrad/hr per uCi on skin
- Dose Rate from a 1 mCi isotropic point source of ^{14}C :

<u>Distance</u>	<u>Rad/Hr</u>
1.0 cm	1241.4
2.0 cm	250.4
15.2 cm	0.126
20.0 cm	0.0046

GENERAL RADIOLOGICAL SAFETY INFORMATION

- Urinalysis: Not Required; however, prudent after a ^{14}C radioactive spill or suspected intake.
- Inherent volatility (at STP): Not Significant.
- Possibility of organic ^{14}C compounds being absorbed through gloves.
- Care should be taken NOT to generate $^{14}\text{CO}_2$ gas which could be inhaled.
- Internal Dose is the concern: Skin contamination, ingestion, inhalation, and puncture.
- Always wear a lab coat and disposable gloves when working with ^{14}C .
- The concentration of carbon in adipose tissue, including the yellow marrow, is about 3 times the average whole body concentration. No other organ or tissue of the body concentrates stable carbon to any significant extent.
- The fractional absorption of dietary carbon (uptake to blood) is usually in excess of 0.90.
- Three main classes of carbon compounds may be inhaled: organic compounds, gases (CO or CO_2), and aerosols of carbon containing compounds such as carbonates and carbides.

Organic Compounds - Most organic compounds are NOT very volatile under normal circumstances; the probability of these being inhaled as vapors is therefore small. In circumstances where such substances are inhaled, it would be prudent to assume that once they enter the respiratory system they are instantaneously and completely translocated to the systemic circulation without changing their chemical form.

Gases - The inhalation of CO and its retention in body tissues has been studied extensively. Since gas has a relatively low solubility in tissue water, doses due to absorbed gas in tissues are insignificant in comparison with doses due to the retention of CO bound to hemoglobin. CO_2 in the blood exists mainly as a bicarbonate.

Carbonates & Carbides - It is assumed that inhaled or ingested ^{14}C labeled compounds are instantaneously and uniformly distributed throughout all organs & tissues of the body where they are retained with a biological half-life of 12-40 days.

PHOSPHORUS - 32

[³²P]

PHYSICAL DATA

- Beta energy: 1.709 MeV (maximum)
0.690 MeV (average, 100% abundance)
- Physical half-life: 14.3 days
- Biological half-life: 1155 days
- Effective half-life: 14.1 days (bone) / 13.5 days (whole body)
- Specific activity: 285,000 Ci/gm
- Maximum range in air: 610 cm = 240 inches = 20 feet
- Maximum range in water/tissue: 0.76 cm = 1/3 inch
- Maximum range in Plexiglas/lucite/plastic: 0.61 cm = 3/8 inch
- Half-Value Layer (HVL): 2.00 mm (water/tissue)

RADIOLOGICAL DATA

- Critical organ (biological destination) (soluble forms): Bone
- Critical organs (insoluble forms or non-transportable ³²P compounds): Lung (inhalation) and G.I. tract/lower large intestine (ingestion).
- Routes of intake: Ingestion, inhalation, puncture, wound, skin contamination (absorption).
- External and internal exposure from ³²P.
- Committed Dose Equivalent (CDE): 32 mrem/uCi (ingested)
(Organ Doses) 37 mrem/uCi (puncture)
96 mrem/uCi (inhaled/Class W/lungs)
22 mrem/uCi (inhaled/Class D/bone marrow)
- Committed Effective Dose Equivalent (CEDE): 7.50 mrem/uCi (ingested/WB)
5.55 mrem/uCi (inhale/Class D)
13.22 mrem/uCi (inhale/Class W)
- Skin contamination dose rate: 8700-9170 mrem/uCi/cm²/hr. (7 mg/cm² or 0.007 cm depth in tissue).
- Dose rate to basal cells from skin contamination of 1.0 uCi/cm² (localized dose) = 9200 mrad/hr.
- Bone receives approximately 20% of the dose ingested or inhaled for soluble ³²P compounds.
- Tissues with rapid cellular turnover rates show higher retention due to concentration of phosphorous in the nucleoproteins.
- ³²P is eliminated from the body primarily via urine.
- Phosphorus metabolism; see ³³P Fact Sheet.

SHIELDING

- ≤3/8 inch thick Plexiglas/acrylic/lucite/plastic/wood.
- Do not use lead foil or sheets! Penetrating Bremsstrahlung x-ray will be produced!
- Use lead sheets or foil to shield Bremsstrahlung x-rays only **after** low density Plexiglas/acrylic/lucite/wood shielding.

SURVEY INSTRUMENTATION

- GM survey meter and a pancake probe.
- Low-energy NaI probe is used **only to detect Bremsstrahlung x-rays**.
- Liquid scintillation counter (indirect counting) may be used to detect removable surface contamination of ³²P on smears or wipes.

DOSE RATES

(From unshielded 1.0 mCi isotropic point source)

<u>Distance</u>	<u>Rads/hr</u>
1.00 cm	348
15.24 cm	1.49
10.00 ft	0.0015

- 78,000 mrad/hr at surface of 1.0 mCi ³²P in 1 ml liquid.
- 26,000 mrad/hr at mouth of open vial containing 1.0 mCi ³²P in 1.0 ml liquid.

GENERAL PRECAUTIONS

- Because it is a bone seeker, special precautions must be taken to minimize any chance of introducing into the body.
- Airborne contamination can be generated through drying (dust), rapid boiling, or expelling solutions through syringe needles and pipette tips, due to aerosols.
- Personnel radiation monitors (whole body and finger rings) are **required** when handling > 1.0 mCi of ³²P at any time.
- Never work directly over an open container; avoid direct eye exposure from penetrating ³²P beta particles.
- Always wear a lab coat and disposable gloves when handling ³²P.
- Monitor personnel work areas and floors using a GM survey meter equipped with a pancake (beta) probe for surface contamination.
- Monitor for removable surface contamination by smearing or wiping where ³²P is used.
- Use low-density (low atomic number) shielding material to shield ³²P and reduce the generation of Bremsstrahlung x-rays. The following materials are low atomic number materials: Plexiglas, acrylic, lucite, plastic, wood, or water.
- Do NOT use lead foil, lead sheets, or other high density materials (metals) to shield ³²P directly. Materials with atomic number higher than that of aluminum (Z = 13) should NOT be used. Penetrating Bremsstrahlung x-rays will be generated in lead and other high density shielding material.
- Safety glasses or goggles are recommended when working with ³²P.
- Typical GM survey meter with pancake probe efficiency is $\geq 45\%$. Typical liquid scintillation counter counting efficiency for ³²P (full window/maximum) $\geq 85\%$.
- Typical detection limit of ³²P in urine specimens using a liquid scintillation counter = $1.1 \text{ E}^{-7} \text{ uCi/ml}$.

PHOSPHORUS - 33

[³³P]

PHYSICAL DATA

- Beta energy: 0.249 MeV (maximum, 100% abundance)
0.085 MeV (average)
- Physical half-life: 25.4 days
- Biological half-life: 19 days (40% of intake; 30% rapidly eliminated from body, remaining 30% decays)
- Effective half-life: 24.9 days (bone)
- Specific activity: 1,000 - 3,000 Ci/millimole
- Maximum beta range in air: 89 cm = 35 inches = 3 feet
- Maximum range in water/tissue: 0.11 cm = 0.04 inch
- Maximum range in plexiglas/lucite/plastic: 0.089 cm = 0.035 inch
- Half-Value Layer (HVL): 0.30 mm (water/tissue)

RADIOLOGICAL DATA

- Critical organ (biological destination) (soluble forms): Bone marrow
- Critical organs (insoluble forms or non-transportable ³³P compounds): Lung (inhalation) and G.I. tract/Lower large intestine (ingestion).
- Routes of intake: Ingestion, inhalation, puncture, wound, skin contamination (absorption).
- Internal exposure and contamination are the primary radiological concerns.
- Committed Dose Equivalent (CDE): 0.5 mrem/mCi (inhalation).
- Skin contamination dose rate: 2,910 mrem/hr/uCi/cm² (7 mg/cm² or 0.007 cm depth in tissue).
- Fraction of ³³P beta particles transmitted through the dead skin layer is about 14%.
- Tissues with rapid cellular turnover rates show higher retention due to concentration of phosphorus in the nucleoproteins.
- ³³P is eliminated from the body primarily via urine.
- Phosphorus metabolism: 30% is rapidly eliminated from body
40% has a 19-day biological half-life
60% of ³³P (ingested) is excreted from body in first 24 hrs

SHIELDING

- Not required; however low density material is recommended, e.g., 3/8 inch thick plexiglas, acrylic, lucite, plastic or plywood.

SURVEY INSTRUMENTATION

- GM survey meter with a pancake probe.
- Liquid scintillation counting of wipes may be used to detect removable surface contamination.

PERSONNEL DOSIMETERS

- Are not required, since they do not detect this low energy nuclide.

GENERAL PRECAUTIONS

- Inherent volatility (STP): Insignificant
- Skin dose and contamination are the primary concerns.
- Drying can form airborne ³³P contamination.
- Monitor work areas for contamination, using smears or wipes to check for removable contamination.

SULFUR - 35

[³⁵S]

PHYSICAL DATA

- Beta energy: 167 keV (maximum)
53 keV (average) (100% abundance)
- Physical Half Life: 87.4 days
- Biological Half Life: 623 days (unbound ³⁵S)
- Effective Half Life: 44 - 76 days (unbound ³⁵S)
- Specific Activity: 42,400 Ci/g
- Maximum Beta Range in Air: 26.00 cm. = 10.2 in.
- Maximum Beta Range in Water or Tissue: 0.32 mm. = 0.015 in.
- Maximum Beta Range in Plexiglas or Lucite: 0.25 mm. = 0.01 in.
- Fraction of ³⁵S betas transmitted through dead layer of skin = 12%

RADIOLOGICAL DATA

- Critical organ: Testis
- Routes of Intake: Ingestion, inhalation, puncture, wound, skin contamination (absorption)
- External exposure (deep dose) from weak ³⁵S beta particles is not a radiological concern.
- Internal exposure and contamination are the primary radiological concerns.
- Committed dose equivalent (CDE): 10.00 mrem/uCi (ingested)
0.352 mrem/uCi (puncture)
- Committed Effective Dose Equivalent (CEDE): 2.6 mrem/uCi (ingested)*
*(Assumes a 90 day biological half life)
- Annual Limit on Intake (ALI)*: 10 mCi (ingestion of inorganic ³⁵S compounds)
6 mCi (Ingestion of elemental ³⁵S)
8 mCi (ingestion of sulfides or sulfates/LLI)**
10 mCi (inhalation of ³⁵S vapors)
20 mCi (inhalation of sulfides or sulfates)
2 mCi (inhalation of elemental ³⁵S)
- *1.0 ALI = 10 mCi (inhaled ³⁵S vapors) = 5,000 mrem CEDE
- ** 1.0 ALI = 8 mCi (ingestion sulfides/sulfates LLI) = 50,000 mrem CDE
- Skin Contamination Dose Rate: 1,170 - 1,260 mrem/uCi/cm²/hr. (7.0 mg/cm² depth)
- Beta Dose Rates for ³⁵S: 14.94 rad/h (contact) in air per 1.0 mCi
0.20 rad/h (6 inches) in air per 1.0 mCi

SHIELDING

- None required (≤ 3 mm Plexiglas shields; shielding optional).

SURVEY INSTRUMENTATION

- Can detect using a thin window G-M survey meter (pancake), however, probe **MUST** be at close range, recommend 1 cm distance.
- G-M survey meter has low efficiency, usually 4 - 6%.
- Liquid scintillation counter (wipes, smears) may be used for secondary, **but will NOT detect nonremovable contamination!**

SULFUR - 35

[³⁵S]

PHYSICAL DATA

- Beta energy: 167 keV (maximum)
53 keV (average) (100% abundance)
- Physical Half Life: 87.4 days
- Biological Half Life: 623 days (unbound ³⁵S)
- Effective Half Life: 44 - 76 days (unbound ³⁵S)
- Specific Activity: 42,400 Ci/g
- Maximum Beta Range in Air: 26.00 cm. = 10.2 in.
- Maximum Beta Range in Water or Tissue: 0.32 mm. = 0.015 in.
- Maximum Beta Range in Plexiglas or Lucite: 0.25 mm. = 0.01 in.
- Fraction of ³⁵S betas transmitted through dead layer of skin = 12%

RADIOLOGICAL DATA

- Critical organ: Testis
- Routes of Intake: Ingestion, inhalation, puncture, wound, skin contamination (absorption)
- External exposure (deep dose) from weak ³⁵S beta particles is not a radiological concern.
- Internal exposure and contamination are the primary radiological concerns.
- Committed dose equivalent (CDE): 10.00 mrem/uCi (ingested)
0.352 mrem/uCi (puncture)
- Committed Effective Dose Equivalent (CEDE): 2.6 mrem/uCi (ingested)*
*(Assumes a 90 day biological half life)
- Annual Limit on Intake (ALI)*: 10 mCi (ingestion of inorganic ³⁵S compounds)
6 mCi (Ingestion of elemental ³⁵S)
8 mCi (ingestion of sulfides or sulfates/LLI)**
10 mCi (inhalation of ³⁵S vapors)
20 mCi (inhalation of sulfides or sulfates)
2 mCi (inhalation of elemental ³⁵S)

*1.0 ALI = 10 mCi (inhaled ³⁵S vapors) = 5,000 mrem CEDE

** 1.0 ALI = 8 mCi (ingestion sulfides/sulfates LLI) = 50,000 mrem CDE

- Skin Contamination Dose Rate: 1,170 - 1,260 mrem/uCi/cm²/hr. (7.0 mg/cm² depth)
- Beta Dose Rates for ³⁵S: 14.94 rad/h (contact) in air per 1.0 mCi
0.20 rad/h (6 inches) in air per 1.0 mCi

SHIELDING

- None required (≤ 3 mm Plexiglas shields; shielding optional).

SURVEY INSTRUMENTATION

- Can detect using a thin window G-M survey meter (pancake), however, probe **MUST** be at close range, recommend 1 cm distance.
- G-M survey meter has low efficiency, usually 4 - 6%.
- Liquid scintillation counter (wipes, smears) may be used for secondary, **but will NOT detect nonremovable contamination!**

RADIATION MONITORING DEVICES

- (Badges): Not needed, because ^{35}S beta energy is too low, and is not an external radiation hazard
- Dose Rate from a 1 millicurie unshielded isotropic point source of ^{35}S :

<u>Distance</u>	<u>Rad/hr</u>
1.0 cm	1173.6
2.5 cm	93.7
15.24 cm	0.2
20.00 cm	0.01

GENERAL RADIATION SAFETY INFORMATION

- Urinalysis: Not required, but may be requested by Health Physics staff after a spill or personnel contamination involving ^{35}S .
- Inherent volatility (STP): **SIGNIFICANT** for ^{35}S methionine and cysteine.
- Radiolysis of ^{35}S amino acids (cysteine and methionine) during storage and use may lead to the release of volatile impurities. Volatile impurities are small ($\leq 0.05\%$).
- Metabolic behavior of organic compounds of sulfur (cysteine and methionine) differs considerably from the metabolic behavior of inorganic compounds.
- Organic compounds of sulfur (cysteine and methionine) become incorporated into various metabolites. Thus, sulfur entering the body as an organic compound is often tenaciously retained.
- The fractional absorption of sulfur from the gastrointestinal tract is typically $> 60\%$ for organic compounds of sulfur. Elemental sulfur is less well absorbed from the GI tract than are inorganic compounds of the element (80% for all inorganic compounds and 10% for sulfur in its elemental form). Elemental sulfur is an NRC inhalation Class W (meaning it is retained for weeks in the body).
- Inhalation of the gases SO_2 , COS, H_2S , and CS_2 must be considered. Sulfur entering the lungs in these forms is completely and instantaneously translocated to the transfer compartment; from there, its metabolism is the same as that of sulfur entering the transfer compartment following ingestion or inhalation of any other organic compound of sulfur.
- Contamination of internal surfaces of storage and reaction vessels may occur (rubber stoppers, gaskets or o rings).
- Vials of ^{35}S labeled cysteine and methionine should be opened and used in ventilated enclosures (exhaust hoods).
- The volatile components of ^{35}S labeled amino acids should be opened and used in ventilated enclosures (exhaust hoods).
- The volatile components of ^{35}S labeled cysteine and methionine are presumed to be hydrogen sulfide (H_2S) and methyl mercaptan (CH_3SH), respectively.
- ^{35}S vapors may be released when opening vials containing labeled amino acids, during any incubating of culture or cells containing ^{35}S , and the storage of ^{35}S contaminated wastes.
- Excessive contamination can be found on the inside surfaces and in water reservoirs of incubators used for ^{35}S work. Most notable surface contamination can be found on rubber seals of incubators and centrifuges.
- Radiolytic breakdown may occur during freezing processes, releasing as much as 1.0 uCi of ^{35}S per 8.0 mCi vial of ^{35}S amino acid during the thawing process.
- ^{35}S labeled amino acids work should be conducted in an exhaust hood designated for radiolytic work.
- Vent ^{35}S amino acid stock vials with an open-ended charcoal-filled disposable syringe. Activated charcoal has a high affinity for ^{35}S vapors.
- Place an activated carbon or charcoal canister, absorbent sheet, or tray (50-100 grams of granules evenly distributed in a tray or dish) into an incubator to passively absorb ^{35}S vapors. Discard absorbers which exhibit survey meter readings above normal area background levels in the solid radioactive waste.

CALCIUM – 45

[⁴⁵Ca]

PHYSICAL DATA

- Beta energy: 257 keV (maximum)
77 keV (average) (100% abundance)
- Physical Half Life: 162.6 days
- Biological Half Life: Bone 18,000 days
- Effective Half Life: 163 days
- Specific Activity: 17,800 Ci/g max.
- Maximum Beta Range in Air: 52.00 cm. = 20.0 in.
- Maximum Beta Range in Water or Tissue: 0.62 mm. = 0.024 in.
- Maximum Beta Range in Plexiglas or Lucite: 0.53 mm. = 0.021 in.

RADIOLOGICAL DATA

- Critical organ: Bone; Lung [Inhalation]
- Routes of Intake: Ingestion, inhalation, puncture, wound, skin contamination (absorption)
- External exposure (deep dose) from weak ⁴⁵Ca beta particles is not a radiological concern.
- Internal exposure and contamination are the primary radiological concerns.
- Committed dose equivalent (CDE): 35.8 mrem/uCi (Lung) & 16.2 mrem/uCi (Bone) of ⁴⁵Ca inhaled
19.4 mrem/uCi (Bone) of ⁴⁵Ca ingested.
- Committed Effective Dose Equivalent (CEDE): 3.2 mrem/uCi (ingested)
- Annual Limit on Intake (ALI)*: 0.80 mCi (inhalation)
2 mCi (Ingestion)

SHIELDING

- None required (≤ 3 mm Plexiglas shields; shielding optional).

SURVEY INSTRUMENTATION

- Can detect using a thin window G-M survey meter (pancake), however, probe **MUST** be at close range, recommend 1 cm distance.
- G-M survey meter has low efficiency, usually 4 - 6%.
- Liquid scintillation counter (wipes, smears) may be used for secondary, **but will NOT detect nonremovables**.

RADIATION MONITORING DEVICES

- (Badges): Not needed, because ⁴⁵Ca beta energy is too low, and is not an external radiation hazard.

GENERAL RADIATION SAFETY INFORMATION

- Use protective clothing and equipment: laboratory coat, gloves, and eye protection. Change gloves if they become contaminated.
- Monitor the work area frequently with a GM survey instrument. If such an instrument is not available, perform wipe tests counted in liquid scintillation. Clean up contamination immediately.
- Urine bioassay is the most readily available method to assess intake. Provide a urine sample to Radiation Safety after any accident/incident in which an intake is suspected.
- Use extra caution when handling ⁴⁵Ca due to its high affinity for bone tissue. Its long biological half life could cause damage to blood producing tissues within the bone.
- The 257 keV β 's are able to penetrate the gloves and the outer layer of skin. Monitor your gloves frequently when working.
- Wear a radiation badge when handling 1.0 mCi or more vials.
- Volatile or powder chemical forms should be handled in a certified fume hood.

CHROMIUM - 51

[⁵¹Cr]

PHYSICAL DATA

Gamma Energy: 320 keV (9.8% abundance) *
 X-ray Energy: 5 keV (22% abundance) *
 *[Percent of disintegration resulting in this radiation being emitted]

No Betas Emitted

Specific Gamma Constant: 0.017 mR/hr per mCi at 1.0 meter

Physical Half-Life: 27.8 days
 Biological Half Life: 616.0 days
 Effective Half-Life: 26.6 days (whole body)

Specific Activity: 92,000 Curies/gram
 Specific Activity (microspheres): 63.56 mCi/gram

RADIOLOGICAL DATA

- Critical Organ: Lower large intestine (LLI)
- Routes of Intake: Ingestion, inhalation, skin contact
- External & internal exposure and contamination are radiological concerns.

Committed Dose Equivalent (CDE): 0.15 mrem/uCi (ingested/gonad)
 1.41 mrem/uCi (inhalation/lung/Class W)

Committed Dose Equivalent (CDE): 1.20 mrem/uCi (ingested/GI tract/LLI)
 0.22 mrem/uCi (inhaled/LLI Wall/Class D)

Committed Effective Dose Equivalent (CEDE): 0.107 mrem/uCi (ingested)
 0.211 mrem/uCi (inhalation/Class D)
 0.211 mrem/uCi (inhalation/Class W)

Annual Limit on Intake (ALI)*: 20 mCi (inhalation/Class W & Y)
 52 mCi (inhalation/Class D/soluble)
 40 mCi (ingestion)

*[1.0 ALI = 40 mCi (⁵¹Cr ingested) = 5,000 mrem CEDE (Whole Body)]

SHIELDING

- Use 1/4" - 1/2" lead shielding for ⁵¹Cr

Half - Value Layer (lead):	2.0 mm = 0.07"
Half - Value Layer (concrete):	2.8 cm = 1.10"
Half - Value Layer (Plexiglas):	4.8 cm = 1.90"
Tenth - Value Layer (lead):	5.6 mm = 0.22"
Tenth - Value Layer (concrete):	9.3 cm = 3.66"
Tenth - Value Layer (Plexiglas):	17.2 cm = 6.80"
Maximum range in lead:	7 mm. = 0.5"
Maximum range in Plexiglas:	65 cm. = 22.0"

SURVEY INSTRUMENTATION

- Survey meter equipped with a NaI scintillation probe is recommended.
- Survey meter equipped with a G-M pancake/detector or standardized cylindrical probe is very **inefficient** for the detection of ⁵¹Cr (very low counting efficiency).
- Smears or wipes counted in a liquid scintillation counter (indirect) is best for the detection of **removable** ⁵¹Cr surface contamination.

PERSONAL RADIATION MONITORING DOSIMETERS

Whole body & extremity badges required.

REGULATORY COMPLIANCE INFORMATION

- Derived Air Concentration (DAC):

(inhalation)	2.0E ⁻⁵ uCi/cc (Class D)
	1.0E ⁻⁵ uCi/cc (Class W)
	8.0E ⁻⁶ uCi/cc (Class Y)

- Airborne Effluent Release Limit*:

	6.0E ⁻⁸ uCi/cc (Class D)
	3.0E ⁻⁸ uCi/cc (Class W & Y)

* Applicable to the assessment & control of dose to the public (10 CFR 20.1302). If this concentration was inhaled continuously for over one year the resulting TEDE would be 50 mrem.

- Urinalysis: Not required; however, may be requested in the event of a spill of ⁵¹Cr.
- Whole Body Bioassay: May be prudent in the event of a suspected intake of ⁵¹Cr through ingestion, inhalation, skin absorption, or a wound.
- Gamma (photon) exposure rates from 1.0 mCi ⁵¹Cr point source:

<u>Distance</u>	<u>mrads/hr.</u>
1.0 cm	160.0
5.0 cm	6.4
10.0 cm	1.6
100.0 cm	0.016
- Inherent Volatility (STP): Insignificant/Negligible.

IODINE - 125

[¹²⁵I]

PHYSICAL DATA

- Gamma Energies: 35.5 keV (7% abundance/93% internally converted, gamma)
(No betas emitted) 27.0 keV (113%, x-ray)
27-32 keV (14%, x-ray)
31.0 keV (26%, x-ray)
- Specific Gamma Ray Constant: 0.27 to 0.70 mR/hr per mCi at 1 meter
(Current literature indicates 0.27 mR/hr per mCi at 1 meter.)
- Physical Half-Life: 60.1 days
- Biological Half-Life: 120-138 days (unbound iodine) - thyroid elimination
- Effective Half-Life: 42 days (unbound iodine) - thyroid gland
- Specific Activity: 17,400 Ci/gm (theoretical/carrier free)
- Intrinsic Specific Activity: 22.0 Ci/millimole

RADIOLOGICAL DATA

- Critical Organ (Biological Destination): Thyroid
- Routes of Intake: Ingestion, inhalation (most probable), puncture, wound, skin contamination (absorption).
- External and internal exposure and contamination concerns exist in use of ¹²⁵I.
- Committed Dose Equivalent (CDE): 814 mrem/mCi (thyroid/inhalation/class "D")
(Organ Doses) 1185 mrem/mCi (thyroid/ingestion/NaI form)
910 mrem/mCi (thyroid/inhalation)
1258 mrem/mCi (any organ/puncture/adult)
- Committed Effective Dose Equivalent(CEDE): 24 mrem/mCi (whole body/inhalation)

SHIELDING

- Lead foil or sheets (1/32 to 1/16 inch thick): 0.152 mm lead foil
- Half Value Layer: 0.02 mm = 0.008 inches

SURVEY INSTRUMENTATION

- Survey meter equipped with a low energy NaI scintillation probe is necessary.
- Survey meters equipped with GM pancakes or end window GM probes are inefficient. These probes are not useful for contamination monitoring; they are only about 0.1% efficient.

DOSE RATES

(From unshielded 1.0 mCi isotropic point source)

<u>Distance</u>	<u>mrads/hr.</u>
1.00 cm	156 - 275
10.00 cm	15.5 - 27.5
100.00 cm	0.156 -0.28
6.00 in	6.5

(Some literature indicates 0.7 mrad/hr per mCi at 100 cm.)

- Individuals who will be using ¹²⁵I in the NaI or KI chemical form are required to obtain a thyroid scan to be used as a baseline reference prior to use.
- The thyroid gland accumulates 20 - 30% of the soluble radioiodine taken in by the body. All radioiodines in the body can be assumed to be eliminated quite rapidly via the urine.

- Thyroid Bioassay is **required by law** when handling ≥ 1 mCi in the ^{125}I in the sodium or potassium iodide chemical form. In accordance with the NRC license and MSU's commitment to ALARA, the threshold amount is taken to be 0.1 mCi. The thyroid scan is to be obtained not less than 24 hours but not more than one week after the handling or use of that quantity and form of ^{125}I . In addition, all workers who assist or observe in manipulations of the above quantity and type of ^{125}I , or are sufficiently close to the process so that intake is possible (within a few meters and in the same room) are required to obtain thyroid scans under the same conditions listed above.
- Fume hood sash glass provides adequate shielding for most iodinations. Extra shielding is not recommended, since it impedes air flow into the hood.
- Shielding is not required for most uses of this nuclide due to the low energy and low amounts typically used.
- Use a cannula adapter needle to vent stock vials of ^{125}I used for iodinations. This prevents puff releases.
- Segregate waste from iodinations (free) from other (bound) ^{125}I waste and store it in the fume hood, in tightly sealed ziplok bags (solid waste) or screw top containers (liquid waste) until waste pickup.
- Cover test tubes used to count or separate fractions from iodinations with parafilm or other tight caps to prevent release while counting or moving outside the fume hood.

APPENDIX E

USNRC REGULATORY GUIDE 8.29

INSTRUCTIONS CONCERNING RISKS

FROM

OCCUPATIONAL RADIATION EXPOSURE



U.S. NUCLEAR REGULATORY COMMISSION

Revision 1
February 1996

REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 8.29

(Draft was issued as DG-8012)

INSTRUCTION CONCERNING RISKS FROM OCCUPATIONAL RADIATION EXPOSURE

A. INTRODUCTION

Section 19.12 of 10 CFR Part 19, "Notices, Instructions and Reports to Workers: Inspection and Investigations," requires that all individuals who in the course of their employment are likely to receive in a year an occupational dose in excess of 100 mrem (1 mSv) be instructed in the health protection issues associated with exposure to radioactive materials or radiation. Section 20.1206 of 10 CFR Part 20, "Standards for Protection Against Radiation," requires that before a planned special exposure occurs the individuals involved are, among other things, to be informed of the estimated doses and associated risks.

This regulatory guide describes the information that should be provided to workers by licensees about health risks from occupational exposure. This revision conforms to the revision of 10 CFR Part 20 that became effective on June 20, 1991, to be implemented by licensees no later than January 1, 1994. The revision of 10 CFR Part 20 establishes new dose limits based on the effective dose equivalent (EDE), requires the summing of internal and external dose, establishes a requirement that licensees use procedures and engineering controls to the extent practicable to achieve occupational doses and doses to members of the public that are as low as is reasonably achievable (ALARA), provides for planned special exposures, establishes a

dose limit for the embryo/fetus of an occupationally exposed declared pregnant woman, and explicitly states that Part 20 is not to be construed as limiting action that may be necessary to protect health and safety during emergencies.

Any information collection activities mentioned in this regulatory guide are contained as requirements in 10 CFR Part 19 or 10 CFR Part 20. These regulations provide the regulatory bases for this guide. The information collection requirements in 10 CFR Parts 19 and 20 have been cleared under OMB Clearance Nos. 3150-0044 and 3150-0014, respectively.

B. DISCUSSION

It is important to qualify the material presented in this guide with the following considerations.

The coefficient used in this guide for occupational radiation risk estimates, 4×10^{-4} health effects per rem, is based on data obtained at much higher doses and dose rates than those encountered by workers. The risk coefficient obtained at high doses and dose rates was reduced to account for the reduced effectiveness of lower doses and dose rates in producing the stochastic effects observed in studies of exposed humans.

The assumption of a linear extrapolation from the lowest doses at which effects are observable down to

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This guide was issued after consideration of comments received from the public. Comments and suggestions for improvements in these guides are encouraged at all times, and guides will be revised, as appropriate, to accommodate comments and to reflect new information or experience.

Written comments may be submitted to the Rules Review and Directives Branch, DFIPS, ADM, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001.

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the occupational range has considerable uncertainty. The report of the Committee on the Biological Effects of Ionizing Radiation (Ref. 1) states that

"... departure from linearity cannot be excluded at low doses below the range of observation. Such departures could be in the direction of either an increased or decreased risk. Moreover, epidemiologic data cannot rigorously exclude the existence of a threshold in the 100 mrem dose range. Thus, the possibility that there may be no risk from exposures comparable to external natural background radiation cannot be ruled out. At such low doses and dose rates, it must be acknowledged that the lower limit of the range of uncertainty in the risk estimates extends to zero."

The issue of beneficial effects from low doses, or hormesis, in cellular systems is addressed by the United Nations Scientific Committee on the Effects of Atomic Radiation (Ref. 2). UNSCEAR states that "... it would be premature to conclude that cellular adaptive responses could convey possible beneficial effects to the organism that would outweigh the detrimental effects of exposures to low doses of low-LET radiation."

In the absence of scientific certainty regarding the relationship between low doses and health effects, and as a conservative assumption for radiation protection purposes, the scientific community generally assumes that any exposure to ionizing radiation can cause biological effects that may be harmful to the exposed person and that the magnitude or probability of these effects is directly proportional to the dose. These effects may be classified into three categories:

Somatic Effects: Physical effects occurring in the exposed person. These effects may be observable after a large or acute dose (e.g., 100 rems¹ (1 Sv) or more to the whole body in a few hours); or they may be effects such as cancer that may occur years after exposure to radiation.

Genetic Effects: Abnormalities that may occur in the future children of exposed individuals and in subsequent generations (genetic effects exceeding normal incidence have not been observed in any of the studies of human populations).

Teratogenic Effects: Effects such as cancer or congenital malformation that may be observed in children who were exposed during the fetal and embryonic stages of development (these effects have been observed from

high, i.e., above 20 rems (0.2 Sv), acute exposures).

The normal incidence of effects from natural and manmade causes is significant. For example, approximately 20% of people die from various forms of cancer whether or not they ever receive occupational exposure to radiation. To avoid increasing the incidence of such biological effects, regulatory controls are imposed on occupational doses to adults and minors and on doses to the embryo/fetus from occupational exposures of declared pregnant women.

Radiation protection training for workers who are occupationally exposed to ionizing radiation is an essential component of any program designed to ensure compliance with NRC regulations. A clear understanding of what is presently known about the biological risks associated with exposure to radiation will result in more effective radiation protection training and should generate more interest on the part of the workers in complying with radiation protection standards. In addition, pregnant women and other occupationally exposed workers should have available to them relevant information on radiation risks to enable them to make informed decisions regarding the acceptance of these risks. It is intended that workers who receive this instruction will develop respect for the risks involved, rather than excessive fear or indifference.

C. REGULATORY POSITION

Instruction to workers performed in compliance with 10 CFR 19.12 should be given prior to occupational exposure and periodically thereafter. The frequency of retraining might range from annually for licensees with complex operations such as nuclear power plants, to every three years for licensees who possess, for example, only low-activity sealed sources. If a worker is to participate in a planned special exposure, the worker should be informed of the associated risks in compliance with 10 CFR 20.1206.

In providing instruction concerning health protection problems associated with exposure to radiation, all occupationally exposed workers and their supervisors should be given specific instruction on the risk of biological effects resulting from exposure to radiation. The extent of these instructions should be commensurate with the radiological risks present in the workplace.

The instruction should be presented orally, in printed form, or in any other effective communication media to workers and supervisors. The appendix to this guide provides useful information for demonstrating compliance with the training requirements in 10 CFR Parts 19 and 20. Individuals should be given an opportunity to discuss the information and to ask questions. Testing is recommended, and each trainee should be asked to acknowledge in writing that the instruction has been received and understood.

¹In the International System of Units (SI), the rem is replaced by the sievert; 100 rems is equal to 1 sievert (Sv).

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this regulatory guide.

Except in those cases in which an applicant or licensee proposes acceptable alternative methods for

complying with specified portions of the Commission's regulations, the guidance and instructional materials in this guide will be used in the evaluation of applications for new licenses, license renewals, and license amendments and for evaluating compliance with 10 CFR 19.12 and 10 CFR Part 20.

REFERENCES

1. National Research Council, *Health Effects of Exposure to Low Levels of Ionizing Radiation*, Report of the Committee on the Biological Effects of Ionizing Radiation (BEIR V), National Academy Press, Washington, DC, 1990.
2. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), *Sources and Effects of Ionizing Radiation*, United Nations, New York, 1993.

APPENDIX

INSTRUCTION CONCERNING RISKS FROM OCCUPATIONAL RADIATION EXPOSURE

This instructional material is intended to provide the user with the best available information about the health risks from occupational exposure to ionizing radiation. Ionizing radiation consists of energy or small particles, such as gamma rays and beta and alpha particles, emitted from radioactive materials, which can cause chemical or physical damage when they deposit energy in living tissue. A question and answer format is used. Many of the questions or subjects were developed by the NRC staff in consultation with workers, union representatives, and licensee representatives experienced in radiation protection training.

This Revision 1 to Regulatory Guide 8.29 updates the material in the original guide on biological effects and risks and on typical occupational exposure. Additionally, it conforms to the revised 10 CFR Part 20, "Standards for Protection Against Radiation," which was required to be implemented by licensees no later than January 1, 1994. The information in this appendix is intended to help develop respect by workers for the risks associated with radiation, rather than unjustified fear or lack of concern. Additional guidance concerning other topics in radiation protection training is provided in other NRC regulatory guides.

1. What is meant by health risk?

A health risk is generally thought of as something that may endanger health. Scientists consider health risk to be the statistical probability or mathematical chance that personal injury, illness, or death may result from some action. Most people do not think about health risks in terms of mathematics. Instead, most of us consider the health risk of a particular action in terms of whether we believe that particular action will, or will not, cause us some harm. The intent of this appendix is to provide estimates of, and explain the bases for, the risk of injury, illness, or death from occupational radiation exposure. Risk can be quantified in terms of the probability of a health effect per unit of dose received.

When x-rays, gamma rays, and ionizing particles interact with living materials such as our bodies, they may deposit enough energy to cause biological damage. Radiation can cause several different types of events such as the very small physical displacement of molecules, changing a molecule to a different form, or ionization, which is the removal of electrons from atoms and molecules. When the quantity of radiation energy deposited in living tissue is high enough, biological damage can occur as a result of chemical bonds being broken and cells being damaged or killed. These effects can result in observable clinical symptoms.

The basic unit for measuring absorbed radiation is the rad. One rad (0.01 gray in the International System of units) equals the absorption of 100 ergs (a small but measurable amount of energy) in a gram of material such as tissue exposed to radiation. To reflect biological risk, rads must be converted to rems. The new international unit is the sievert (100 rems = 1 Sv). This conversion accounts for the differences in the effectiveness of different types of radiation in causing damage. The rem is used to estimate biological risk. For beta and gamma radiation, a rem is considered equal to a rad.

2. What are the possible health effects of exposure to radiation?

Health effects from exposure to radiation range from no effect at all to death, including diseases such as leukemia or bone, breast, and lung cancer. Very high (100s of rads), short-term doses of radiation have been known to cause prompt (or early) effects, such as vomiting and diarrhea,¹ skin burns, cataracts, and even death. It is suspected that radiation exposure may be linked to the potential for genetic effects in the children of exposed parents. Also, children who were exposed to high doses (20 or more rads) of radiation prior to birth (as an embryo/fetus) have shown an increased risk of mental retardation and other congenital malformations. These effects (with the exception of genetic effects) have been observed in various studies of medical radiologists, uranium miners, radium workers, radiotherapy patients, and the people exposed to radiation from atomic bombs dropped on Japan. In addition, radiation effects studies with laboratory animals, in which the animals were given relatively high doses, have provided extensive data on radiation-induced health effects, including genetic effects.

It is important to note that these kinds of health effects result from high doses, compared to occupational levels, delivered over a relatively short period of time.

Although studies have not shown a consistent cause-and-effect relationship between current levels of occupational radiation exposure and biological effects, it is prudent from a worker protection perspective to assume that some effects may occur.

¹These symptoms are early indicators of what is referred to as the acute radiation syndrome, caused by high doses delivered over a short time period, which includes damage to the blood-forming organs such as bone marrow, damage to the gastrointestinal system, and, at very high doses, can include damage to the central nervous system.

3. What is meant by early effects and delayed or late effects?

EARLY EFFECTS

Early effects, which are also called immediate or prompt effects, are those that occur shortly after a large exposure that is delivered within hours to a few days. They are observable after receiving a very large dose in a short period of time, for example, 300 rads (3 Gy) received within a few minutes to a few days. Early effects are not caused at the levels of radiation exposure allowed under the NRC's occupational limits.

Early effects occur when the radiation dose is large enough to cause extensive biological damage to cells so that large numbers of cells are killed. For early effects to occur, this radiation dose must be received within a short time period. This type of dose is called an acute dose or acute exposure. The same dose received over a long time period would not cause the same effect. Our body's natural biological processes are constantly repairing damaged cells and replacing dead cells; if the cell damage is spread over time, our body is capable of repairing or replacing some of the damaged cells, reducing the observable adverse conditions.

For example, a dose to the whole body of about 300–500 rads (3–5 Gy), more than 60 times the annual occupational dose limit, if received within a short time period (e.g., a few hours) will cause vomiting and diarrhea within a few hours; loss of hair, fever, and weight loss within a few weeks; and about a 50 percent chance of death if medical treatment is not provided. These effects would not occur if the same dose were accumulated gradually over many weeks or months (Refs. 1 and 2). Thus, one of the justifications for establishing annual dose limits is to ensure that occupational dose is spread out in time.

It is important to distinguish between whole body and partial body exposure. A localized dose to a small volume of the body would not produce the same effect as a whole body dose of the same magnitude. For example, if only the hand were exposed, the effect would mainly be limited to the skin and underlying tissue of the hand. An acute dose of 400 to 600 rads (4–6 Gy) to the hand would cause skin reddening; recovery would occur over the following months and no long-term damage would be expected. An acute dose of this magnitude to the whole body could cause death within a short time without medical treatment. Medical treatment would lessen the magnitude of the effects and the chance of death; however, it would not totally eliminate the effects or the chance of death.

DELAYED EFFECTS

Delayed effects may occur years after exposure. These effects are caused indirectly when the radiation changes parts of the cells in the body, which causes the normal function of the cell to change, for example,

normal healthy cells turn into cancer cells. The potential for these delayed health effects is one of the main concerns addressed when setting limits on occupational doses.

A delayed effect of special interest is genetic effects. Genetic effects may occur if there is radiation damage to the cells of the gonads (sperm or eggs). These effects may show up as genetic defects in the children of the exposed individual and succeeding generations. However, if any genetic effects (i.e., effects in addition to the normal expected number) have been caused by radiation, the numbers are too small to have been observed in human populations exposed to radiation. For example, the atomic bomb survivors (from Hiroshima and Nagasaki) have not shown any significant radiation-related increases in genetic defects (Ref. 3). Effects have been observed in animal studies conducted at very high levels of exposure and it is known that radiation can cause changes in the genes in cells of the human body. However, it is believed that by maintaining worker exposures below the NRC limits and consistent with ALARA, a margin of safety is provided such that the risk of genetic effects is almost eliminated.

4. What is the difference between acute and chronic radiation dose?

Acute radiation dose usually refers to a large dose of radiation received in a short period of time. Chronic dose refers to the sum of small doses received repeatedly over long time periods, for example, 20 mrem (or millirem, which is 1-thousandth of a rem) (0.2 mSv) per week every week for several years. It is assumed for radiation protection purposes that any radiation dose, either acute or chronic, may cause delayed effects. However, only large acute doses cause early effects; chronic doses within the occupational dose limits do not cause early effects. Since the NRC limits do not permit large acute doses, concern with occupational radiation risk is primarily focused on controlling chronic exposure for which possible delayed effects, such as cancer, are of concern.

The difference between acute and chronic radiation exposure can be shown by using exposure to the sun's rays as an example. An intense exposure to the sun can result in painful burning, peeling, and growing of new skin. However, repeated short exposures provide time for the skin to be repaired between exposures. Whether exposure to the sun's rays is long term or spread over short periods, some of the injury may not be repaired and may eventually result in skin cancer.

Cataracts are an interesting case because they can be caused by both acute and chronic radiation. A certain threshold level of dose to the lens of the eye is required before there is any observable visual impairment, and the impairment remains after the exposure is stopped. The threshold for cataract development

from acute exposure is an acute dose on the order of 100 rads (1 Gy). Further, a cumulative dose of 800 rads (8 Gy) from protracted exposures over many years to the lens of the eye has been linked to some level of visual impairment (Refs. 1 and 4). These doses exceed the amount that may be accumulated by the lens from normal occupational exposure under the current regulations.

5. What is meant by external and internal exposure?

A worker's occupational dose may be caused by exposure to radiation that originates outside the body, called "external exposure," or by exposure to radiation from radioactive material that has been taken into the body, called "internal exposure." Most NRC-licensed activities involve little, if any, internal exposure. It is the current scientific consensus that a rem of radiation dose has the same biological risk regardless of whether it is from an external or an internal source. The NRC requires that dose from external exposure and dose from internal exposure be added together, if each exceeds 10% of the annual limit, and that the total be within occupational limits. The sum of external and internal dose is called the total effective dose equivalent (TEDE) and is expressed in units of rems (Sv).

Although unlikely, radioactive materials may enter the body through breathing, eating, drinking, or open wounds, or they may be absorbed through the skin. The intake of radioactive materials by workers is generally due to breathing contaminated air. Radioactive materials may be present as fine dust or gases in the workplace atmosphere. The surfaces of equipment and workbenches may be contaminated, and these materials can be resuspended in air during work activities.

If any radioactive material enters the body, the material goes to various organs or is excreted, depending on the biochemistry of the material. Most radioisotopes are excreted from the body in a few days. For example, a fraction of any uranium taken into the body will deposit in the bones, where it remains for a longer time. Uranium is slowly eliminated from the body, mostly by way of the kidneys. Most workers are not exposed to uranium. Radioactive iodine is preferentially deposited in the thyroid gland, which is located in the neck.

To limit risk to specific organs and the total body, an annual limit on intake (ALI) has been established for each radionuclide. When more than one radionuclide is involved, the intake amount of each radionuclide is reduced proportionally. NRC regulations specify the concentrations of radioactive material in the air to which a worker may be exposed for 2,000 working hours in a year. These concentrations are termed the derived air concentrations (DACs). These limits are

the total amounts allowed if no external radiation is received. The resulting dose from the internal radiation sources (from breathing air at 1 DAC) is the maximum allowed to an organ or to the worker's whole body.

6. How does radiation cause cancer?

The mechanisms of radiation-induced cancer are not completely understood. When radiation interacts with the cells of our bodies, a number of events can occur. The damaged cells can repair themselves and permanent damage is not caused. The cells can die, much like the large numbers of cells that die every day in our bodies, and be replaced through the normal biological processes. Or a change can occur in the cell's reproductive structure, the cells can mutate and subsequently be repaired without effect, or they can form precancerous cells, which may become cancerous. Radiation is only one of many agents with the potential for causing cancer, and cancer caused by radiation cannot be distinguished from cancer attributable to any other cause.

Radiobiologists have studied the relationship between large doses of radiation and cancer (Refs. 5 and 6). These studies indicate that damage or change to genes in the cell nucleus is the main cause of radiation-induced cancer. This damage may occur directly through the interaction of the ionizing radiation in the cell or indirectly through the actions of chemical products produced by radiation interactions within cells. Cells are able to repair most damage within hours; however, some cells may not be repaired properly. Such misrepaired damage is thought to be the origin of cancer, but misrepair does not always cause cancer. Some cell changes are benign or the cell may die; these changes do not lead to cancer.

Many factors such as age, general health, inherited traits, sex, as well as exposure to other cancer-causing agents such as cigarette smoke can affect susceptibility to the cancer-causing effects of radiation. Many diseases are caused by the interaction of several factors, and these interactions appear to increase the susceptibility to cancer.

7. Who developed radiation risk estimates?

Radiation risk estimates were developed by several national and international scientific organizations over the last 40 years. These organizations include the National Academy of Sciences (which has issued several reports from the Committee on the Biological Effects of Ionizing Radiations, BEIR), the National Council on Radiation Protection and Measurements (NCRP), the International Commission on Radiological Protection (ICRP), and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Each of these organizations continues to review new research findings on radiation health risks.

Several reports from these organizations present new findings on radiation risks based upon revised estimates of radiation dose to survivors of the atomic bombing at Hiroshima and Nagasaki. For example, UNSCEAR published risk estimates in 1988 and 1993 (Refs. 5 and 6). The NCRP also published a report in 1988, "New Dosimetry at Hiroshima and Nagasaki and Its Implications for Risk Estimates" (Ref. 7). In January 1990, the National Academy of Sciences released the fifth report of the BEIR Committee, "Health Effects of Exposure to Low Levels of Ionizing Radiation" (Ref. 4). Each of these publications also provides extensive bibliographies on other published studies concerning radiation health effects for those who may wish to read further on this subject.

8. What are the estimates of the risk of fatal cancer from radiation exposure?

We don't know exactly what the chances are of getting cancer from a low-level radiation dose, primarily because the few effects that may occur cannot be distinguished from normally occurring cancers. However, we can make estimates based on extrapolation from extensive knowledge from scientific research on high dose effects. The estimates of radiation effects at high doses are better known than are those of most chemical carcinogens (Ref. 8).

From currently available data, the NRC has adopted a risk value for an occupational dose of 1 rem (0.01 Sv) Total Effective Dose Equivalent (TEDE) of 4 in 10,000 of developing a fatal cancer, or approximately 1 chance in 2,500 of fatal cancer per rem of TEDE received. The uncertainty associated with this risk estimate does not rule out the possibility of higher risk, or the possibility that the risk may even be zero at low occupational doses and dose rates.

The radiation risk incurred by a worker depends on the amount of dose received. Under the linear model explained above, a worker who receives 5 rems (0.05 Sv) in a year incurs 10 times as much risk as another worker who receives only 0.5 rem (0.005 Sv). Only a very few workers receive doses near 5 rems (0.05 Sv) per year (Ref. 9).

According to the BEIR V report (Ref. 4), approximately one in five adults normally will die from cancer from all possible causes such as smoking, food, alcohol, drugs, air pollutants, natural background radiation, and inherited traits. Thus, in any group of 10,000 workers, we can estimate that about 2,000 (20%) will die from cancer without any occupational radiation exposure.

To explain the significance of these estimates, we will use as an example a group of 10,000 people, each exposed to 1 rem (0.01 Sv) of ionizing radiation. Using the risk factor of 4 effects per 10,000 rem of dose, we estimate that 4 of the 10,000 people might die from

delayed cancer because of that 1-rem dose (although the actual number could be more or less than 4) in addition to the 2,000 normal cancer fatalities expected to occur in that group from all other causes. This means that a 1-rem (0.01 Sv) dose may increase an individual worker's chances of dying from cancer from 20 percent to 20.04 percent. If one's lifetime occupational dose is 10 rems, we could raise the estimate to 20.4 percent. A lifetime dose of 100 rems may increase chances of dying from cancer from 20 to 24 percent. The average measurable dose for radiation workers reported to the NRC was 0.31 rem (0.0031 Sv) for 1993 (Ref. 9). Today, very few workers ever accumulate 100 rems (1 Sv) in a working lifetime, and the average career dose of workers at NRC-licensed facilities is 1.5 rems (0.015 Sv), which represents an estimated increase from 20 to about 20.06 percent in the risk of dying from cancer.

It is important to understand the probability factors here. A similar question would be, "If you select one card from a full deck of cards, will you get the ace of spades?" This question cannot be answered with a simple yes or no. The best answer is that your chance is 1 in 52. However, if 1000 people each select one card from full decks, we can predict that about 20 of them will get an ace of spades. Each person will have 1 chance in 52 of drawing the ace of spades, but there is no way we can predict which persons will get that card. The issue is further complicated by the fact that in a drawing by 1000 people, we might get only 15 successes, and in another, perhaps 25 correct cards in 1000 draws. We can say that if you receive a radiation dose, you will have increased your chances of eventually developing cancer. It is assumed that the more radiation exposure you get, the more you increase your chances of cancer.

The normal chance of dying from cancer is about one in five for persons who have not received any occupational radiation dose. The additional chance of developing fatal cancer from an occupational exposure of 1 rem (0.01 Sv) is about the same as the chance of drawing any ace from a full deck of cards three times in a row. The additional chance of dying from cancer from an occupational exposure of 10 rem (0.1 Sv) is about equal to your chance of drawing two aces successively on the first two draws from a full deck of cards.

It is important to realize that these risk numbers are only estimates based on data for people and research animals exposed to high levels of radiation in short periods of time. There is still uncertainty with regard to estimates of radiation risk from low levels of exposure. Many difficulties are involved in designing research studies that can accurately measure the projected small increases in cancer cases that might be caused by low exposures to radiation as compared to the normal rate of cancer.

These estimates are considered by the NRC staff to be the best available for the worker to use to make an informed decision concerning acceptance of the risks associated with exposure to radiation. A worker who decides to accept this risk should try to keep exposure to radiation as low as is reasonably achievable (ALARA) to avoid unnecessary risk.

9. If I receive a radiation dose that is within occupational limits, will it cause me to get cancer?

Probably not. Based on the risk estimates previously discussed, the risk of cancer from doses below the occupational limits is believed to be small. Assessment of the cancer risks that may be associated with low doses of radiation are projected from data available at doses larger than 10 rems (0.1 Sv) (Ref. 3). For radiation protection purposes, these estimates are made using the straight line portion of the linear quadratic model (Curve 2 in Figure 1). We have data on cancer probabilities only for high doses, as shown by the solid line in Figure 1. Only in studies involving radiation doses above occupational limits are there dependable determinations of the risk of cancer, primari-

ly because below the limits the effect is small compared to differences in the normal cancer incidence from year to year and place to place. The ICRP, NCRP, and other standards-setting organizations assume for radiation protection purposes that there is some risk, no matter how small the dose (Curves 1 and 2). Some scientists believe that the risk drops off to zero at some low dose (Curve 3), the threshold effect. The ICRP and NCRP endorse the linear quadratic model as a conservative means of assuring safety (Curve 2).

For regulatory purposes, the NRC uses the straight line portion of Curve 2, which shows the number of effects decreasing linearly as the dose decreases. Because the scientific evidence does not conclusively demonstrate whether there is or is not an effect at low doses, the NRC assumes for radiation protection purposes, that even small doses have some chance of causing cancer. Thus, a principle of radiation protection is to do more than merely meet the allowed regulatory limits; doses should be kept as low as is reasonably achievable (ALARA). This is as true for natural carcinogens such as sunlight and natural radiation as it is for those that are manmade, such as cigarette smoke, smog, and x-rays.

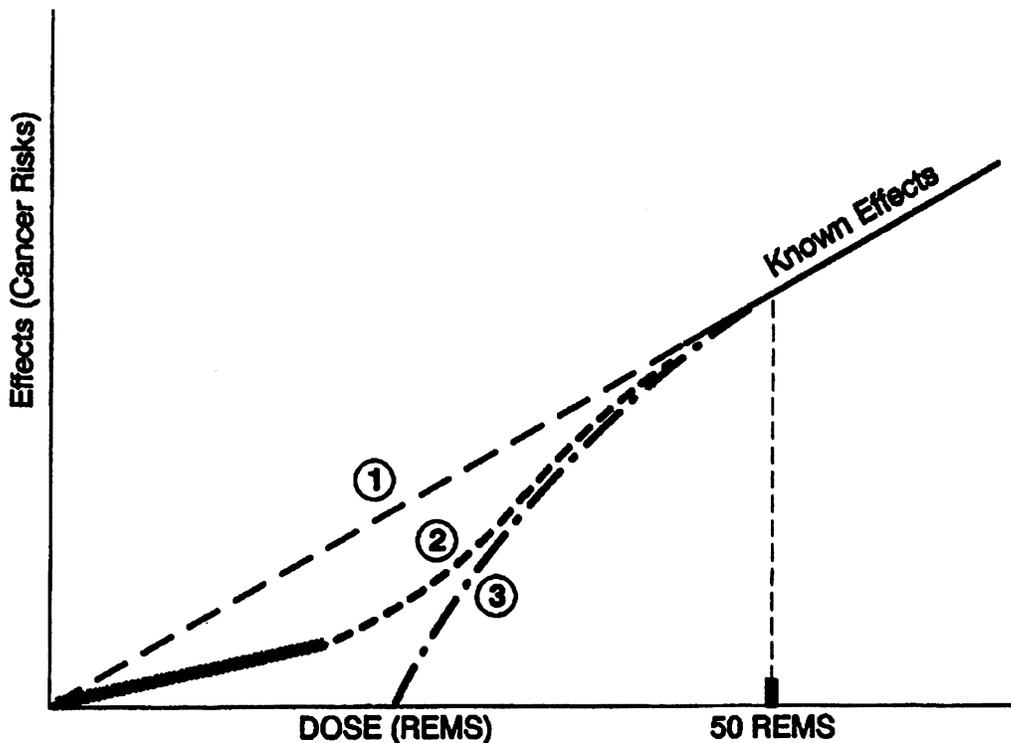


Figure 1. Some Proposed Models for How the Effects of Radiation Vary With Doses at Low Levels

10. How can we compare the risk of cancer from radiation to other kinds of health risks?

One way to make these comparisons is to compare the average number of days of life expectancy lost because of the effects associated with each particular health risk. Estimates are calculated by looking at a large number of persons, recording the age when death occurs from specific causes, and estimating the average number of days of life lost as a result of these early deaths. The total number of days of life lost is then averaged over the total observed group.

Several studies have compared the average days of life lost from exposure to radiation with the number of days lost as a result of being exposed to other health risks. The word "average" is important because an individual who gets cancer loses about 15 years of life expectancy, while his or her coworkers do not suffer any loss.

Some representative numbers are presented in Table 1. For categories of NRC-regulated industries with larger doses, the average measurable occupational dose in 1993 was 0.31 rem (0.0031 Sv). A simple calculation based on the article by Cohen and Lee (Ref. 10) shows that 0.3 rem (0.003 Sv) per year from age 18 to 65 results in an average loss of 15 days. These estimates indicate that the health risks from occupational radiation exposure are smaller than the risks associated with many other events or activities we encounter and accept in normal day-to-day activities.

It is also useful to compare the estimated average number of days of life lost from occupational exposure to radiation with the number of days lost as a result of

working in several types of industries. Table 2 shows average days of life expectancy lost as a result of fatal work-related accidents. Table 2 does not include non-accident types of occupational risks such as occupational disease and stress because the data are not available.

These comparisons are not ideal because we are comparing the possible effects of chronic exposure to radiation to different kinds of risk such as accidental death, in which death is inevitable if the event occurs. This is the best we can do because good data are not available on chronic exposure to other workplace carcinogens. Also, the estimates of loss of life expectancy for workers from radiation-induced cancer do not take into consideration the competing effect on the life expectancy of the workers from industrial accidents.

11. What are the health risks from radiation exposure to the embryo/fetus?

During certain stages of development, the embryo/fetus is believed to be more sensitive to radiation damage than adults. Studies of atomic bomb survivors exposed to acute radiation doses exceeding 20 rads (0.2 Gy) during pregnancy show that children born after receiving these doses have a higher risk of mental retardation. Other studies suggest that an association exists between exposure to diagnostic x-rays before birth and carcinogenic effects in childhood and in adult life. Scientists are uncertain about the magnitude of the risk. Some studies show the embryo/fetus to be more sensitive to radiation-induced cancer than adults, but other studies do not. In recognition of the possibility of increased radiation sensitivity, and because dose to the

Table 1 Estimated Loss of Life Expectancy from Health Risks^a

<i>Health Risk</i>	<i>Estimate of Life Expectancy Lost (average)</i>
Smoking 20 cigarettes a day	6 years
Overweight (by 15%)	2 years
Alcohol consumption (U.S. average)	1 year
All accidents combined	1 year
Motor vehicle accidents	207 days
Home accidents	74 days
Drowning	24 days
All natural hazards (earthquake, lightning, flood, etc.)	7 days
Medical radiation	6 days
Occupational Exposure	
0.3 rem/y from age 18 to 65	15 days
1 rem/y from age 18 to 65	51 days

^aAdapted from Reference 10.

Table 2 Estimated Loss of Life Expectancy from Industrial Accidents^a

<i>Industry Type</i>	<i>Estimated Days of Life Expectancy Lost (Average)</i>
All industries	60
Agriculture	320
Construction	227
Mining and Quarrying	167
Transportation and Public Utilities	160
Government	60
Manufacturing	40
Trade	27
Services	27

^aAdapted from Reference 10.

embryo/fetus is involuntary on the part of the embryo/fetus, a more restrictive dose limit has been established for the embryo/fetus of a declared pregnant radiation worker. See Regulatory Guide 8.13, "Instruction Concerning Prenatal Radiation Exposure."

If an occupationally exposed woman declares her pregnancy in writing, she is subject to the more restrictive dose limits for the embryo/fetus during the remainder of the pregnancy. The dose limit of 500 mrem (5 mSv) for the total gestation period applies to the embryo/fetus and is controlled by restricting the exposure to the declared pregnant woman. Restricting the woman's occupational exposure, if she declares her pregnancy, raises questions about individual privacy rights, equal employment opportunities, and the possible loss of income. Because of these concerns, the declaration of pregnancy by a female radiation worker is voluntary. Also, the declaration of pregnancy can be withdrawn for any reason, for example, if the woman believes that her benefits from receiving the occupational exposure would outweigh the risk to her embryo/fetus from the radiation exposure.

12. Can a worker become sterile or impotent from normal occupational radiation exposure?

No. Temporary or permanent sterility cannot be caused by radiation at the levels allowed under NRC's occupational limits. There is a threshold below which these effects do not occur. Acute doses on the order of 10 rems (0.1 Sv) to the testes can result in a measurable but temporary reduction in sperm count. Temporary sterility (suppression of ovulation) has been observed in women who have received acute doses of 150 rads (1.5 Gy). The estimated threshold (acute) radiation dose for induction of permanent sterility is about 200 rads (2 Gy) for men and about 350 rads (3.5 Gy)

for women (Refs. 1 and 4). These doses are far greater than the NRC's occupational dose limits for workers.

Although acute doses can affect fertility by reducing sperm count or suppressing ovulation, they do not have any direct effect on one's ability to function sexually. No evidence exists to suggest that exposures within the NRC's occupational limits have any effect on the ability to function sexually.

13. What are the NRC occupational dose limits?

For adults, an annual limit that does not exceed:

- 5 rems (0.05 Sv) for the total effective dose equivalent (TEDE), which is the sum of the deep dose equivalent (DDE) from external exposure to the whole body and the committed effective dose equivalent (CEDE) from intakes of radioactive material.
- 50 rems (0.5 Sv) for the total organ dose equivalent (TODE), which is the sum of the DDE from external exposure to the whole body and the committed dose equivalent (CDE) from intakes of radioactive material to any individual organ or tissue, other than the lens of the eye.
- 15 rems (0.15 Sv) for the lens dose equivalent (LDE), which is the external dose to the lens of the eye.
- 50 rems (0.5 Sv) for the shallow dose equivalent (SDE), which is the external dose to the skin or to any extremity.

For minor workers, the annual occupational dose limits are 10 percent of the dose limits for adult workers.

For protection of the embryo/fetus of a declared pregnant woman, the dose limit is 0.5 rem (5 mSv) during the entire pregnancy.

The occupational dose limit for adult workers of 5 rems (0.05 Sv) TEDE is based on consideration of the potential for delayed biological effects. The 5-rem (0.05 Sv) limit, together with application of the concept of keeping occupational doses ALARA, provides a level of risk of delayed effects considered acceptable by the NRC. The limits for individual organs are below the dose levels at which early biological effects are observed in the individual organs.

The dose limit for the embryo/fetus of a declared pregnant woman is based on a consideration of the possibility of greater sensitivity to radiation of the embryo/fetus and the involuntary nature of the exposure.

14. What is meant by ALARA?

ALARA means "as low as is reasonably achievable." In addition to providing an upper limit on an individual's permissible radiation dose, the NRC requires that its licensees establish radiation protection

programs and use procedures and engineering controls to achieve occupational doses, and doses to the public, as far below the limits as is reasonably achievable. "Reasonably achievable" also means "to the extent practicable." What is practicable depends on the purpose of the job, the state of technology, the costs for averting doses, and the benefits. Although implementation of the ALARA principle is a required integral part of each licensee's radiation protection program, it does not mean that each radiation exposure must be kept to an absolute minimum, but rather that "reasonable" efforts must be made to avert dose. In practice, ALARA includes planning tasks involving radiation exposure so as to reduce dose to individual workers and the work group.

There are several ways to control radiation doses, e.g., limiting the time in radiation areas, maintaining distance from sources of radiation, and providing shielding of radiation sources to reduce dose. The use of engineering controls, from the design of facilities and equipment to the actual set-up and conduct of work activities, is also an important element of the ALARA concept.

An ALARA analysis should be used in determining whether the use of respiratory protection is advisable. In evaluating whether or not to use respirators, the goal should be to achieve the optimal sum of external and internal doses. For example, the use of respirators can lead to increased work time within radiation areas, which increases external dose. The advantage of using respirators to reduce internal exposure must be evaluated against the increased external exposure and related stresses caused by the use of respirators. Heat stress, reduced visibility, and reduced communication associated with the use of respirators could expose a worker to far greater risks than are associated with the internal dose avoided by use of the respirator. To the extent practical, engineering controls, such as containments and ventilation systems, should be used to reduce workplace airborne radioactive materials.

15. What are background radiation exposures?

The average person is constantly exposed to ionizing radiation from several sources. Our environment and even the human body contain naturally occurring radioactive materials (e.g., potassium-40) that contribute to the radiation dose that we receive. The largest source of natural background radiation exposure is terrestrial radon, a colorless, odorless, chemically inert gas, which causes about 55 percent of our average, nonoccupational exposure. Cosmic radiation originating in space contributes additional exposure. The use of x-rays and radioactive materials in medicine and dentistry adds to our population exposure. As shown below in Table 3, the average person receives an annu-

al radiation dose of about 0.36 rem (3.6 mSv). By age 20, the average person will accumulate over 7 rems (70 mSv) of dose. By age 50, the total dose is up to 18 rems (180 mSv). After 70 years of exposure this dose is up to 25 rems (250 mSv).

Table 3 Average Annual Effective Dose Equivalent to Individuals in the U.S.^a

<i>Source</i>	<i>Effective Dose Equivalent (mrems)</i>
Natural	
Radon	200
Other than Radon	<u>100</u>
Total	300
Nuclear Fuel Cycle	0.05
Consumer Products ^b	9
Medical	
Diagnostic X-rays	39
Nuclear Medicine	<u>14</u>
Total	<u>53</u>
Total	about 360 mrems/year

^aAdapted from Table 8.1, NCRP 93 (Ref. 11).

^bIncludes building material, television receivers, luminous watches, smoke detectors, etc. (from Table 5.1, NCRP 93, Ref. 11).

16. What are the typical radiation doses received by workers?

For 1993, the NRC received reports on about a quarter of a million people who were monitored for occupational exposure to radiation. Almost half of those monitored had no measurable doses. The other half had an average dose of about 310 mrem (3.1 mSv) for the year. Of these, 93 percent received an annual dose of less than 1 rem (10 mSv); 98.7 percent received less than 2 rems (20 mSv); and the highest reported dose was for two individuals who each received between 5 and 6 rems (50 and 60 mSv).

Table 4 lists average occupational doses for workers (persons who had measurable doses) in various occupations based on 1993 data. It is important to note that beginning in 1994, licensees have been required to sum external and internal doses and certain licensees are required to submit annual reports. Certain types of licensees such as nuclear fuel fabricators may report a significant increase in worker doses because of the exposure to long-lived airborne radionuclides and the requirement to add the resultant internal dose to the calculation of occupational doses.

Table 4 Reported Occupational Doses for 1993^a

Occupational Subgroup	Average Measurable Dose per Worker (millirems)
Industrial Radiography	540
Commercial Nuclear Power Reactors	310
Manufacturing and Distribution of Radioactive Materials	300
Low-Level Radioactive Waste Disposal	270
Independent Spent Nuclear Fuel Storage	260
Nuclear Fuel Fabrication	130

^aFrom Table 3.1 in NUREG-0713 (Ref. 9).

17. How do I know how much my occupational dose (exposure) is?

If you are likely to receive more than 10 percent of the annual dose limits, the NRC requires your employer, the NRC licensee, to monitor your dose, to maintain records of your dose, and, at least on an annual basis for the types of licensees listed in 10 CFR 20.2206, "Reports of Individual Monitoring," to inform both you and the NRC of your dose. The purpose of this monitoring and reporting is so that the NRC can be sure that licensees are complying with the occupational dose limits and the ALARA principle.

External exposures are monitored by using individual monitoring devices. These devices are required to be used if it appears likely that external exposure will exceed 10 percent of the allowed annual dose, i.e., 0.5 rem (5 mSv). The most commonly used monitoring devices are film badges, thermoluminescence dosimeters (TLDs), electronic dosimeters, and direct reading pocket dosimeters.

With respect to internal exposure, your employer is required to monitor your occupational intake of radioactive material and assess the resulting dose if it appears likely that you will receive greater than 10 percent of the annual limit on intake (ALI) from intakes in 1 year. Internal exposure can be estimated by measuring the radiation emitted from the body (for example, with a "whole body counter") or by measuring the radioactive materials contained in biological samples such as urine or feces. Dose estimates can also be made if one knows how much radioactive material was in the air and the length of time during which the air was breathed.

18. What happens if a worker exceeds the annual dose limit?

If a worker receives a dose in excess of any of the annual dose limits, the regulations prohibit any occupational exposure during the remainder of the year in which the limit is exceeded. The licensee is also required to file an overexposure report with the NRC and provide a copy to the individual who received the dose. The licensee may be subject to NRC enforcement action such as a fine (civil penalty), just as individuals are subject to a traffic fine for exceeding a speed limit. The fines and, in some serious or repetitive cases, suspension of a license are intended to encourage licensees to comply with the regulations.

Radiation protection limits do not define safe or unsafe levels of radiation exposure. Exceeding a limit does not mean that you will get cancer. For radiation protection purposes, it is assumed that risks are related to the size of the radiation dose. Therefore, when your dose is higher your risk is also considered to be higher. These limits are similar to highway speed limits. If you drive at 70 mph, your risk is higher than at 55 mph, even though you may not actually have an accident. Those who set speed limits have determined that the risks of driving in excess of the speed limit are not acceptable. In the same way, the revised 10 CFR Part 20 establishes a limit for normal occupational exposure of 5 rems (0.05 Sv) a year. Although you will not necessarily get cancer or some other radiation effect at doses above the limit, it does mean that the licensee's safety program has failed in some way. Investigation is warranted to determine the cause and correct the conditions leading to the dose in excess of the limit.

19. What is meant by a "planned special exposure"?

A "planned special exposure" (PSE) is an infrequent exposure to radiation, separate from and in addition to the radiation received under the annual occupational limits. The licensee can authorize additional dose in any one year that is equal to the annual occupational dose limit as long as the individual's total dose from PSEs does not exceed five times the annual dose limit during the individual's lifetime. For example, licensees may authorize PSEs for an adult radiation worker to receive doses up to an additional 5 rems (0.05 Sv) in a year above the 5-rem (0.05-Sv) annual TEDE occupational dose limit. Each worker is limited to no more than 25 rems (0.25 Sv) from planned special exposures in his or her lifetime. Such exposures are only allowed in exceptional situations when alternatives for avoiding the additional exposure are not available or are impractical.

Before the licensee authorizes a PSE, the licensee must ensure that the worker is informed of the purpose and circumstances of the planned operation, the estimated doses expected, and the procedures to keep the doses ALARA while considering other risks that may

be present. (See Regulatory Guide 8.35, "Planned Special Exposures.")

20. Why do some facilities establish administrative control levels that are below the NRC limits?

There are two reasons. First, the NRC regulations state that licensees must take steps to keep exposures to radiation ALARA. Specific approval from the licensee for workers to receive doses in excess of administrative limits usually results in more critical risk-benefit analyses as each additional increment of dose is approved for a worker. Secondly, an administrative control level that is set lower than the NRC limit provides a safety margin designed to help the licensee avoid doses to workers in excess of the limit.

21. Why aren't medical exposures considered as part of a worker's allowed dose?

NRC rules exempt medical exposure, but equal doses of medical and occupational radiation have equal risks. Medical exposure to radiation is justified for reasons that are quite different from the reasons for occupational exposure. A physician prescribing an x-ray, for example, makes a medical judgment that the benefit to the patient from the resulting medical information justifies the risk associated with the radiation. This judgment may or may not be accepted by the patient. Similarly, each worker must decide on the benefits and acceptability of occupational radiation risk, just as each worker must decide on the acceptability of any other occupational hazard.

Consider a worker who receives a dose of 3 rems (0.03 Sv) from a series of x-rays in connection with an injury or illness. This dose and any associated risk must be justified on medical grounds. If the worker had also received 2 rems (0.02 Sv) on the job, the combined dose of 5 rems (0.05 Sv) would in no way incapacitate the worker. Restricting the worker from additional job exposure during the remainder of the year would not have any effect on the risk from the 3 rems (0.03 Sv) already received from the medical exposure. If the individual worker accepts the risks associated with the x-rays on the basis of the medical benefits and accepts the risks associated with job-related exposure on the basis of employment benefits, it would be unreasonable to restrict the worker from employment involving exposure to radiation for the remainder of the year.

22. How should radiation risks be considered in an emergency?

Emergencies are "unplanned" events in which actions to save lives or property may warrant additional doses for which no particular limit applies. The revised 10 CFR Part 20 does not set any dose limits for emergency or lifesaving activities and states that nothing in

Part 20 "shall be construed as limiting actions that may be necessary to protect health and safety."

Rare situations may occur in which a dose in excess of occupational limits would be unavoidable in order to carry out a lifesaving operation or to avoid a large dose to large populations. However, persons called upon to undertake any emergency operation should do so only on a voluntary basis and with full awareness of the risks involved.

For perspective, the Environmental Protection Agency (EPA) has published emergency dose guidelines (Ref. 2). These guidelines state that doses to all workers during emergencies should, to the extent practicable, be limited to 5 rems (0.05 Sv). The EPA further states that there are some emergency situations for which higher limits may be justified. The dose resulting from such emergency exposures should be limited to 10 rems (0.1 Sv) for protecting valuable property, and to 25 rems (0.25 Sv) for lifesaving activities and the protection of large populations. In the context of this guidance, the dose to workers that is incurred for the protection of large populations might be considered justified for situations in which the collective dose to others that is avoided as a result of the emergency operation is significantly larger than that incurred by the workers involved.

Table 5 presents the estimates of the fatal cancer risk for a group of 1,000 workers of various ages, assuming that each worker received an acute dose of 25 rems (0.25 Sv) in the course of assisting in an emergency. The estimates show that a 25-rem emergency dose might increase an individual's chances of developing fatal cancer from about 20% to about 21%.

Table 5
Risk of Premature Death from Exposure to 25-Rems (0.25-Sv) Acute Dose

<i>Age at Exposure (years)</i>	<i>Estimated Risk of Premature Death (Deaths per 1,000 Persons Exposed)</i>
20-30	9.1
30-40	7.2
40-50	5.3
50-60	3.5

Source: EPA-400-R-92-001 (Ref. 2).

23. How were radiation dose limits established?

The NRC radiation dose limits in 10 CFR Part 20 were established by the NRC based on the recommendations of the ICRP and NCRP as endorsed in Federal radiation protection guidance developed by the EPA

(Ref. 12). The limits were recommended by the ICRP and NCRP with the objective of ensuring that working in a radiation-related industry was as safe as working in other comparable industries. The dose limits and the principle of ALARA should ensure that risks to workers are maintained indistinguishable from risks from background radiation.

24. Several scientific reports have recommended that the NRC establish lower dose limits. Does the NRC plan to reduce the regulatory limits?

Since publication of the NRC's proposed rule in 1986, the ICRP in 1990 revised its recommendations for radiation protection based on newer studies of radiation risks (Ref. 13), and the NCRP followed with a revision to its recommendations in 1993. The ICRP recommended a limit of 10 rems (0.1 Sv) effective dose equivalent (from internal and external sources), over a 5-year period with no more than 5 rems (0.05 Sv) in 1 year (Ref. 13). The NCRP recommended a cumulative limit in rems, not to exceed the individual's age in years, with no more than 5 rems (0.05 Sv) in any year (Ref. 14).

The NRC does not believe that additional reductions in the dose limits are required at this time. Because of the practice of maintaining radiation exposures ALARA (as low as is reasonably achievable), the average radiation dose to occupationally exposed persons is well below the limits in the current Part 20 that became mandatory January 1, 1994, and the average doses to radiation workers are below the new limits recommended by the ICRP and the NCRP.

25. What are the options if a worker decides that the risks associated with occupational radiation exposure are too high?

If the risks from exposure to occupational radiation are unacceptable to a worker, he or she can request a transfer to a job that does not involve exposure to radiation. However, the risks associated with the exposure to radiation that workers, on the average, actually receive are comparable to risks in other indus-

tries and are considered acceptable by the scientific groups that have studied them. An employer is not obligated to guarantee a transfer if a worker decides not to accept an assignment that requires exposure to radiation.

Any worker has the option of seeking other employment in a nonradiation occupation. However, the studies that have compared occupational risks in the nuclear industry to those in other job areas indicate that nuclear work is relatively safe. Thus, a worker may find different kinds of risk but will not necessarily find significantly lower risks in another job.

26. Where can one get additional information on radiation risk?

The following list suggests sources of useful information on radiation risk:

- The employer—the radiation protection or health physics office where a worker is employed.
- Nuclear Regulatory Commission Regional Offices:
 - King of Prussia, Pennsylvania (610) 337-5000
 - Atlanta, Georgia (404) 331-4503
 - Lisle, Illinois (708) 829-9500
 - Arlington, Texas (817) 860-8100
- U.S. Nuclear Regulatory Commission
 - Headquarters
 - Radiation Protection & Health Effects Branch
 - Office of Nuclear Regulatory Research
 - Washington, DC 20555
 - Telephone: (301) 415-6187
- Department of Health and Human Services
 - Center for Devices and Radiological Health
 - 1390 Piccard Drive, MS HFZ-1
 - Rockville, MD 20850
 - Telephone: (301) 443-4690
- U.S. Environmental Protection Agency
 - Office of Radiation and Indoor Air
 - Criteria and Standards Division
 - 401 M Street NW.
 - Washington, DC 20460
 - Telephone: (202) 233-9290

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14. National Council on Radiation Protection and Measurements, *Limitation of Exposure to Ionizing Radiation*, NCRP Report No. 116, March 1993.

*Copies are available for inspection or copying for a fee from the NRC Public Document Room at 2120 L Street NW., Washington, DC; the PDR's mailing address is Mail Stop LL-6, Washington, DC 20555; telephone (202) 634-3273; fax (202) 634-3343. Copies may be purchased at current rates from the U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20402-9328 (telephone (202) 512-2249); or from the National Technical Information Service by writing NTIS at 5285 Port Royal Road, Springfield, VA 22161.

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- U.S. Nuclear Regulatory Commission, "Instruction Concerning Prenatal Radiation Exposure," Regulatory Guide 8.13, Revision 2, December 1987.²
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- U.S. Nuclear Regulatory Commission, "Planned Special Exposures," Regulatory Guide 8.35, June 1992.²
- U.S. Nuclear Regulatory Commission, "Radiation Dose to the Embryo/Fetus," Regulatory Guide 8.36, July 1992.²

¹Copies are available for inspection or copying for a fee from the NRC Public Document Room at 2120 L Street NW., Washington, DC; the PDR's mailing address is Mail Stop LL-6, Washington, DC 20555-0001; telephone (202) 634-3273; fax (202) 634-3343. Copies may be purchased at current rates from the U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20402-9328 (telephone (202) 512-2249); or from the National Technical Information Service by writing NTIS at 5285 Port Royal Road, Springfield, VA 22161.

²Single copies of regulatory guides may be obtained free of charge by writing the Office of Administration, Attn: Distribution and Services Section, USNRC, Washington, DC 20555, or by fax at (301) 415-2260. Copies are available for inspection or copying for a fee from the NRC Public Document Room at 2120 L Street NW., Washington, DC; the PDR's mailing address is Mail Stop LL-6, Washington, DC 20555-0001; telephone (202) 634-3273; fax (202) 634-3343.

REGULATORY ANALYSIS

A separate regulatory analysis was not prepared for this Revision 1 to Regulatory Guide 8.29. A value/impact statement, which evaluated essentially the same subjects as are discussed in a regulatory analysis, accompanied Regulatory Guide 8.29 when it was issued in July 1981.

This Revision 1 to Regulatory Guide 8.29 is needed to conform with the Revised 10 CFR Part 20, "Standards for Protection Against Radiation," as published

May 21, 1991 (56 FR 23360). The regulatory analysis prepared for 10 CFR Part 20 provides the regulatory basis for this Revision 1 of Regulatory Guide 8.29, and it examines the costs and benefits of the rule as implemented by the guide. A copy of the "Regulatory Analysis for the Revision of 10 CFR Part 20" (PNL-6712, November 1988), is available for inspection and copying for a fee in the NRC's Public Document Room at 2120 L Street NW., Washington, DC 20555-0001.

APPENDIX F

USNRC REGULATORY GUIDE 8.13

INSTRUCTIONS CONCERNING PRENATAL

RADIATION EXPOSURE



U.S. Nuclear Regulatory Commission
REGULATORY GUIDE
Office of Nuclear Regulatory Research

REGULATORY GUIDE 8.13
(Draft was issued as DG-8014)

INSTRUCTION CONCERNING PRENATAL RADIATION EXPOSURE

A. INTRODUCTION

The Code of Federal Regulations in 10 CFR Part 19, "Notices, Instructions and Reports to Workers: Inspection and Investigations," in Section 19.12, "Instructions to Workers," requires instruction in "the health protection problems associated with exposure to radiation and/or radioactive material, in precautions or procedures to minimize exposure, and in the purposes and functions of protective devices employed." The instructions must be "commensurate with potential radiological health protection problems present in the work place."

The Nuclear Regulatory Commission's (NRC's) regulations on radiation protection are specified in 10 CFR Part 20, "Standards for Protection Against Radiation"; and 10 CFR 20.1208, "Dose to an Embryo/Fetus," requires licensees to "ensure that the dose to an embryo/fetus during the entire pregnancy, due to occupational exposure of a declared pregnant woman, does not exceed 0.5 rem (5 mSv)." Section 20.1208 also requires licensees to "make efforts to avoid substantial variation above a uniform monthly exposure rate to a declared pregnant woman." A declared pregnant woman is defined in 10 CFR 20.1003 as a woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.

This regulatory guide is intended to provide information to pregnant women, and other personnel, to help them make decisions regarding radiation exposure during pregnancy. This Regulatory Guide 8.13 supplements Regulatory Guide 8.29, "Instruction Concerning Risks from Occupational Radiation Exposure" (Ref. 1), which contains a broad discussion of the risks from exposure to ionizing radiation.

Other sections of the NRC's regulations also specify requirements for monitoring external and internal occupational dose to a declared pregnant woman. In 10 CFR 20.1502, "Conditions Requiring Individual Monitoring of External and Internal Occupational Dose," licensees are required to monitor the occupational dose to a declared pregnant woman, using an individual monitoring device, if it is likely that the declared pregnant woman will receive, from external sources, a deep dose equivalent in excess of 0.1 rem (1 mSv). According to Paragraph (e) of 10 CFR 20.2106, "Records of Individual Monitoring Results," the licensee must maintain

records of dose to an embryo/fetus if monitoring was required, and the records of dose to the embryo/fetus must be kept with the records of dose to the declared pregnant woman. The declaration of pregnancy must be kept on file, but may be maintained separately from the dose records. The licensee must retain the required form or record until the Commission terminates each pertinent license requiring the record.

The information collections in this regulatory guide are covered by the requirements of 10 CFR Parts 19 or 20, which were approved by the Office of Management and Budget, approval numbers 3150-0044 and 3150-0014, respectively. The NRC may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number.

B. DISCUSSION

As discussed in Regulatory Guide 8.29 (Ref. 1), exposure to any level of radiation is assumed to carry with it a certain amount of risk. In the absence of scientific certainty regarding the relationship between low dose exposure and health effects, and as a conservative assumption for radiation protection purposes, the scientific community generally assumes that any exposure to ionizing radiation may cause undesirable biological effects and that the likelihood of these effects increases as the dose increases. At the occupational dose limit for the whole body of 5 rem (50 mSv) per year, the risk is believed to be very low.

The magnitude of risk of childhood cancer following in utero exposure is uncertain in that both negative and positive studies have been reported. The data from these studies “are consistent with a lifetime cancer risk resulting from exposure during gestation which is two to three times that for the adult” (NCRP Report No. 116, Ref. 2). The NRC has reviewed the available scientific literature and has concluded that the 0.5 rem (5 mSv) limit specified in 10 CFR 20.1208 provides an adequate margin of protection for the embryo/fetus. This dose limit reflects the desire to limit the total lifetime risk of leukemia and other cancers associated with radiation exposure during pregnancy.

In order for a pregnant worker to take advantage of the lower exposure limit and dose monitoring provisions specified in 10 CFR Part 20, the woman must declare her pregnancy in writing to the licensee. A form letter for declaring pregnancy is provided in this guide or the licensee may use its own form letter for declaring pregnancy. A separate written declaration should be submitted for each pregnancy.

C. REGULATORY POSITION

1. Who Should Receive Instruction

Female workers who require training under 10 CFR 19.12 should be provided with the information contained in this guide. In addition to the information contained in Regulatory Guide 8.29 (Ref. 1), this information may be included as part of the training required under 10 CFR 19.12.

2. Providing Instruction

The occupational worker may be given a copy of this guide with its Appendix, an explanation of the

contents of the guide, and an opportunity to ask questions and request additional information. The information in this guide and Appendix should also be provided to any worker or supervisor who may be affected by a declaration of pregnancy or who may have to take some action in response to such a declaration.

Classroom instruction may supplement the written information. If the licensee provides classroom instruction, the instructor should have some knowledge of the biological effects of radiation to be able to answer questions that may go beyond the information provided in this guide. Videotaped presentations may be used for classroom instruction. Regardless of whether the licensee provides classroom training, the licensee should give workers the opportunity to ask questions about information contained in this Regulatory Guide 8.13. The licensee may take credit for instruction that the worker has received within the past year at other licensed facilities or in other courses or training.

3. Licensee's Policy on Declared Pregnant Women

The instruction provided should describe the licensee's specific policy on declared pregnant women, including how those policies may affect a woman's work situation. In particular, the instruction should include a description of the licensee's policies, if any, that may affect the declared pregnant woman's work situation after she has filed a written declaration of pregnancy consistent with 10 CFR 20.1208.

The instruction should also identify who to contact for additional information as well as identify who should receive the written declaration of pregnancy. The recipient of the woman's declaration may be identified by name (e.g., John Smith), position (e.g., immediate supervisor, the radiation safety officer), or department (e.g., the personnel department).

4. Duration of Lower Dose Limits for the Embryo/Fetus

The lower dose limit for the embryo/fetus should remain in effect until the woman withdraws the declaration in writing or the woman is no longer pregnant. If a declaration of pregnancy is withdrawn, the dose limit for the embryo/fetus would apply only to the time from the estimated date of conception until the time the declaration is withdrawn. If the declaration is not withdrawn, the written declaration may be considered expired one year after submission.

5. Substantial Variations Above a Uniform Monthly Dose Rate

According to 10 CFR 20.1208(b), "The licensee shall make efforts to avoid substantial variation above a uniform monthly exposure rate to a declared pregnant woman so as to satisfy the limit in paragraph (a) of this section," that is, 0.5 rem (5 mSv) to the embryo/fetus. The National Council on Radiation Protection and Measurements (NCRP) recommends a monthly equivalent dose limit of 0.05 rem (0.5 mSv) to the embryo/fetus once the pregnancy is known (Ref. 2). In view of the NCRP recommendation, any monthly dose of less than 0.1 rem (1 mSv) may be considered as not a substantial variation above a uniform monthly dose rate and as such will not require licensee justification. However, a monthly dose greater than 0.1 rem (1 mSv) should be justified by the licensee.

D. IMPLEMENTATION

The purpose of this section is to provide information to licensees and applicants regarding the NRC staff's plans for using this regulatory guide.

Unless a licensee or an applicant proposes an acceptable alternative method for complying with the specified portions of the NRC's regulations, the methods described in this guide will be used by the NRC staff in the evaluation of instructions to workers on the radiation exposure of pregnant women.

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APPENDIX

QUESTIONS AND ANSWERS CONCERNING PRENATAL RADIATION EXPOSURE

1. Why am I receiving this information?

The NRC's regulations (in 10 CFR 19.12, "Instructions to Workers") require that licensees instruct individuals working with licensed radioactive materials in radiation protection as appropriate for the situation. The instruction below describes information that occupational workers and their supervisors should know about the radiation exposure of the embryo/fetus of pregnant women.

The regulations allow a pregnant woman to decide whether she wants to formally declare her pregnancy to take advantage of lower dose limits for the embryo/fetus. This instruction provides information to help women make an informed decision whether to declare a pregnancy.

2. If I become pregnant, am I required to declare my pregnancy?

No. The choice whether to declare your pregnancy is completely voluntary. If you choose to declare your pregnancy, you must do so in writing and a lower radiation dose limit will apply to your embryo/fetus. If you choose not to declare your pregnancy, you and your embryo/fetus will continue to be subject to the same radiation dose limits that apply to other occupational workers.

3. If I declare my pregnancy in writing, what happens?

If you choose to declare your pregnancy in writing, the licensee must take measures to limit the dose to your embryo/fetus to 0.5 rem (5 millisievert) during the entire pregnancy. This is one-tenth of the dose that an occupational worker may receive in a year. If you have already received a dose exceeding 0.5 rem (5 mSv) in the period between conception and the declaration of your pregnancy, an additional dose of 0.05 rem (0.5 mSv) is allowed during the remainder of the pregnancy. In addition, 10 CFR 20.1208, "Dose to an Embryo/Fetus," requires licensees to make efforts to avoid substantial variation above a uniform monthly dose rate so that all the 0.5 rem (5 mSv) allowed dose does not occur in a short period during the pregnancy.

This may mean that, if you declare your pregnancy, the licensee may not permit you to do some of your normal job functions if those functions would have allowed you to receive more than 0.5 rem, and you may not be able to have some emergency response responsibilities.

4. Why do the regulations have a lower dose limit for the embryo/fetus of a declared pregnant woman than for a pregnant worker who has not declared?

A lower dose limit for the embryo/fetus of a declared pregnant woman is based on a consideration of greater sensitivity to radiation of the embryo/fetus and the involuntary nature of the exposure. Several scientific advisory groups have recommended (References 1 and 2) that the dose to the embryo/fetus be limited to a fraction of the occupational dose limit.

5. What are the potentially harmful effects of radiation exposure to my embryo/fetus?

The occurrence and severity of health effects caused by ionizing radiation are dependent upon the type and total dose of radiation received, as well as the time period over which the exposure was received. See Regulatory Guide 8.29, "Instruction Concerning Risks from Occupational Exposure" (Ref. 3), for more information. The main concern is embryo/fetal susceptibility to the harmful effects of radiation such as cancer.

6. Are there any risks of genetic defects?

Although radiation injury has been induced experimentally in rodents and insects, and in the experiments was transmitted and became manifest as hereditary disorders in their offspring, radiation has not been identified as a cause of such effect in humans. Therefore, the risk of genetic effects attributable to radiation exposure is speculative. For example, no genetic effects have been documented in any of the Japanese atomic bomb survivors, their children, or their grandchildren.

7. What if I decide that I do not want any radiation exposure at all during my pregnancy?

You may ask your employer for a job that does not involve any exposure at all to occupational radiation dose, but your employer is not obligated to provide you with a job involving no radiation exposure. Even if you receive no occupational exposure at all, your embryo/fetus will receive some radiation dose (on average 75 mrem (0.75 mSv)) during your pregnancy from natural background radiation.

The NRC has reviewed the available scientific literature and concluded that the 0.5 rem (5 mSv) limit provides an adequate margin of protection for the embryo/fetus. This dose limit reflects the desire to limit the total lifetime risk of leukemia and other cancers. If this dose limit is exceeded, the total lifetime risk of cancer to the embryo/fetus may increase incrementally. However, the decision on what level of risk to accept is yours. More detailed information on potential risk to the embryo/fetus from radiation exposure can be found in References 2-10.

8. What effect will formally declaring my pregnancy have on my job status?

Only the licensee can tell you what effect a written declaration of pregnancy will have on your job status. As part of your radiation safety training, the licensee should tell you the company's policies with respect to the job status of declared pregnant women. In addition, before you declare your pregnancy, you may want to talk to your supervisor or your radiation safety officer and ask what a declaration of pregnancy would mean specifically for you and your job status.

In many cases you can continue in your present job with no change and still meet the dose limit for the embryo/fetus. For example, most commercial power reactor workers (approximately 93%) receive, in 12 months, occupational radiation doses that are less than 0.5 rem (5 mSv) (Ref. 11). The licensee may also consider the likelihood of increased radiation exposures from accidents and abnormal events before making a decision to allow you to continue in your present job.

If your current work might cause the dose to your embryo/fetus to exceed 0.5 rem (5 mSv), the licensee has various options. It is possible that the licensee can and will make a reasonable accommodation that will allow you to continue performing your current job, for example, by having another qualified employee do a small part of the job that accounts for some of your radiation exposure.

9. What information must I provide in my written declaration of pregnancy?

You should provide, in writing, your name, a declaration that you are pregnant, the estimated date of conception (only the month and year need be given), and the date that you give the letter to the licensee. A form letter that you can use is included at the end of these questions and answers. You may use that letter, use a form letter the licensee has provided to you, or write your own letter.

10. To declare my pregnancy, do I have to have documented medical proof that I am pregnant?

NRC regulations do not require that you provide medical proof of your pregnancy. However, NRC regulations do not preclude the licensee from requesting medical documentation of your pregnancy, especially if a change in your duties is necessary in order to comply with the 0.5 rem (5 mSv) dose limit.

11. Can I tell the licensee orally rather than in writing that I am pregnant?

No. The regulations require that the declaration must be in writing.

12. If I have not declared my pregnancy in writing, but the licensee suspects that I am pregnant, do the lower dose limits apply?

No. The lower dose limits for pregnant women apply only if you have declared your pregnancy in writing. The United States Supreme Court has ruled (in *United Automobile Workers International Union v. Johnson Controls, Inc.*, 1991) that “Decisions about the welfare of future children must be left to the parents who conceive, bear, support, and raise them rather than to the employers who hire those parents” (Reference 7). The Supreme Court also ruled that your employer may not restrict you from a specific job “because of concerns about the next generation.” Thus, the lower limits apply only if you choose to declare your pregnancy in writing.

13. If I am planning to become pregnant but am not yet pregnant and I inform the licensee of that in writing, do the lower dose limits apply?

No. The requirement for lower limits applies only if you declare in writing that you are already pregnant.

14. What if I have a miscarriage or find out that I am not pregnant?

If you have declared your pregnancy in writing, you should promptly inform the licensee in writing that you are no longer pregnant. However, if you have not formally declared your pregnancy in writing, you need not inform the licensee of your nonpregnant status.

15. How long is the lower dose limit in effect?

The dose to the embryo/fetus must be limited until you withdraw your declaration in writing or you

inform the licensee in writing that you are no longer pregnant. If the declaration is not withdrawn, the written declaration may be considered expired one year after submission.

16. If I have declared my pregnancy in writing, can I revoke my declaration of pregnancy even if I am still pregnant?

Yes, you may. The choice is entirely yours. If you revoke your declaration of pregnancy, the lower dose limit for the embryo/fetus no longer applies.

17. What if I work under contract at a licensed facility?

The regulations state that you should formally declare your pregnancy to the licensee in writing. The licensee has the responsibility to limit the dose to the embryo/fetus.

18. Where can I get additional information?

The references to this Appendix contain helpful information, especially Reference 3, NRC's Regulatory Guide 8.29, "Instruction Concerning Risks from Occupational Radiation Exposure," for general information on radiation risks. The licensee should be able to give this document to you.

For information on legal aspects, see Reference 7, "The Rock and the Hard Place: Employer Liability to Fertile or Pregnant Employees and Their Unborn Children—What Can the Employer Do?" which is an article in the journal *Radiation Protection Management*.

You may telephone the NRC Headquarters at (301) 415-7000. Legal questions should be directed to the Office of the General Counsel, and technical questions should be directed to the Division of Industrial and Medical Nuclear Safety.

You may also telephone the NRC Regional Offices at the following numbers: Region I, (610) 337-5000; Region II, (404) 562-4400; Region III, (630) 829-9500; and Region IV, (817) 860-8100. Legal questions should be directed to the Regional Counsel, and technical questions should be directed to the Division of Nuclear Materials Safety.

REFERENCES FOR APPENDIX

1. National Council on Radiation Protection and Measurements, *Limitation of Exposure to Ionizing Radiation*, NCRP Report No. 116, Bethesda, MD, 1993.
2. International Commission on Radiological Protection, *1990 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 60, Ann. ICRP 21: No. 1-3, Pergamon Press, Oxford, UK, 1991.
3. USNRC, "Instruction Concerning Risks from Occupational Radiation Exposure," Regulatory Guide 8.29, Revision 1, February 1996.¹¹ (Electronically available at www.nrc.gov/NRC/RG/index.html)
4. Committee on the Biological Effects of Ionizing Radiations, National Research Council, *Health Effects of Exposure to Low Levels of Ionizing Radiation (BEIR V)*, National Academy Press, Washington, DC, 1990.
5. United Nations Scientific Committee on the Effects of Atomic Radiation, *Sources and Effects of Ionizing Radiation*, United Nations, New York, 1993.
6. R. Doll and R. Wakeford, "Risk of Childhood Cancer from Fetal Irradiation," *The British Journal of Radiology*, 70, 130-139, 1997.
7. David Wiedis, Donald E. Jose, and Timm O. Phoebe, "The Rock and the Hard Place: Employer Liability to Fertile or Pregnant Employees and Their Unborn Children—What Can the Employer Do?" *Radiation Protection Management*, 11, 41-49, January/February 1994.
8. National Council on Radiation Protection and Measurements, *Considerations Regarding the Unintended Radiation Exposure of the Embryo, Fetus, or Nursing Child*, NCRP Commentary No. 9, Bethesda, MD, 1994.
9. National Council on Radiation Protection and Measurements, *Risk Estimates for Radiation Protection*, NCRP Report No. 115, Bethesda, MD, 1993.

¹¹Single copies of regulatory guides, both active and draft, and draft NUREG documents may be obtained free of charge by writing the Reproduction and Distribution Services Section, OCIO, USNRC, Washington, DC 20555-0001, or by fax to (301)415-2289, or by email to <DISTRIBUTION@NRC.GOV>. Active guides may also be purchased from the National Technical Information Service on a standing order basis. Details on this service may be obtained by writing NTIS, 5285 Port Royal Road, Springfield, VA 22161. Copies of active and draft guides are available for inspection or copying for a fee from the NRC Public Document Room at 2120 L Street NW., Washington, DC; the PDR's mailing address is Mail Stop LL-6, Washington, DC 20555; telephone (202)634-3273; fax (202)634-3343.

10. National Radiological Protection Board, *Advice on Exposure to Ionising Radiation During Pregnancy*, National Radiological Protection Board, Chilton, Didcot, UK, 1998.
11. M.L. Thomas and D. Hagemeyer, "Occupational Radiation Exposure at Commercial Nuclear Power Reactors and Other Facilities, 1996," Twenty-Ninth Annual Report, NUREG-0713, Vol. 18, USNRC, 1998.²²

²²Copies are available at current rates from the U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20402-9328 (telephone (202)512-1800); or from the National Technical Information Service by writing NTIS at 5285 Port Royal Road, Springfield, VA 22161. Copies are available for inspection or copying for a fee from the NRC Public Document Room at 2120 L Street NW., Washington, DC; the PDR's mailing address is Mail Stop LL-6, Washington, DC 20555; telephone (202)634-3273; fax (202)634-3343.

FORM LETTER FOR DECLARING PREGNANCY

This form letter is provided for your convenience. To make your written declaration of pregnancy, you may fill in the blanks in this form letter, you may use a form letter the licensee has provided to you, or you may write your own letter.

DECLARATION OF PREGNANCY

To: _____

In accordance with the NRC's regulations at 10 CFR 20.1208, "Dose to an Embryo/Fetus," I am declaring that I am pregnant. I believe I became pregnant in _____ (only the month and year need be provided).

I understand the radiation dose to my embryo/fetus during my entire pregnancy will not be allowed to exceed 0.5 rem (5 millisievert) (unless that dose has already been exceeded between the time of conception and submitting this letter). I also understand that meeting the lower dose limit may require a change in job or job responsibilities during my pregnancy.

(Your signature)

(Your name printed)

(Date)

REGULATORY ANALYSIS

A separate regulatory analysis was not prepared for this regulatory guide. A regulatory analysis prepared for 10 CFR Part 20, "Standards for Protection Against Radiation" (56 FR 23360), provides the regulatory basis for this guide and examines the costs and benefits of the rule as implemented by the guide. A copy of the "Regulatory Analysis for the Revision of 10 CFR Part 20" (PNL-6712, November 1988) is available for inspection and copying for a fee at the NRC Public Document Room, 2120 L Street NW, Washington, DC, as an enclosure to Part 20 (56 FR 23360).

APPENDIX G
USNRC FORM 3
NOTICE TO EMPLOYEES



NOTICE TO EMPLOYEES

STANDARDS FOR PROTECTION AGAINST RADIATION (PART 20); NOTICES; INSTRUCTIONS AND REPORTS TO WORKERS; INSPECTIONS (PART 19); EMPLOYEE PROTECTION

WHAT IS THE NUCLEAR REGULATORY COMMISSION?

The Nuclear Regulatory Commission is an independent Federal regulatory agency responsible for licensing and inspecting nuclear power plants and other commercial uses to radioactive materials.

WHAT DOES THE NRC DO?

The NRC's primary responsibility is to ensure that workers and the public are protected from unnecessary or excessive exposure to radiation and that nuclear facilities, including power plants, are constructed to high quality standards and operated in a safe manner. The NRC does this by establishing requirements in Title 10 of the Code of Federal Regulations (10 CFR) and in licenses issued to nuclear users.

WHAT RESPONSIBILITY DOES MY EMPLOYER HAVE?

Any company that conducts activities licensed by the NRC must comply with the NRC's requirements. If a company violates NRC requirements, it can be fined or have its license modified, suspended or revoked.

Your employer must tell you which NRC radiation requirements apply to your work and must post NRC Notices of Violation involving radiological working conditions.

WHAT IS MY RESPONSIBILITY?

For your own protection and the protection of your co-workers, you should know how NRC requirements relate to your work and should obey them. If you observe violations of the requirements or have a safety concern, you should report them.

WHAT IF I CAUSE A VIOLATION?

If you engaged in deliberate misconduct that may cause a violation of the NRC requirements, or would have caused a violation if it had not been detected, or deliberately provided inaccurate or incomplete information to either the NRC or to your employer, you may be subject to enforcement action. If you report such a violation, the NRC will consider the circumstances surrounding your reporting in determining the appropriate enforcement action, if any.

HOW DO I REPORT VIOLATIONS AND SAFETY CONCERNS?

If you believe that violations of NRC rules or the terms of the license have occurred, or if you have a safety concern, you should report them immediately to your supervisor. You may report violations or safety concerns directly to the NRC. However, the NRC encourages you to raise your concerns with the

licensee since it is the licensee who has the primary responsibility for, and is most able to ensure, safe operation of nuclear facilities. If you choose to report your concern directly to the NRC, you may report this to an NRC inspector or call or write to the NRC Regional Office serving your area. If you send your concern in writing, it will assist the NRC in protecting your identity if you clearly state in the beginning of your letter that you have a safety concern or that you are submitting an allegation. The NRC's toll-free SAFETY HOTLINE for reporting safety concerns is listed below. The addresses for the NRC Regional Offices and the toll-free telephone numbers are also listed below.

WHAT IF I WORK WITH RADIOACTIVE MATERIAL OR IN THE VICINITY OF A RADIOACTIVE SOURCE?

If you work with radioactive materials or near a radiation source, the amount of radiation exposure that you are permitted to receive may be limited by NRC regulations. The limits on your exposure are contained in sections 20.1201, 20.1207, and 20.1208 of Title 10 of the Code of Federal Regulations (10 CFR 20) depending on the part of the regulations to which your employer is subject. While these are the maximum allowable limits, your employer should also keep your radiation exposure as far below those limits as "reasonably achievable."

MAY I GET A RECORD OF MY RADIATION EXPOSURE?

Yes. Your employer is required to advise you of your dose annually if you are exposed to radiation for which monitoring was required by NRC. In addition, you may request a written report of your exposure when you leave your job.

HOW ARE VIOLATIONS OF NRC REQUIREMENTS IDENTIFIED?

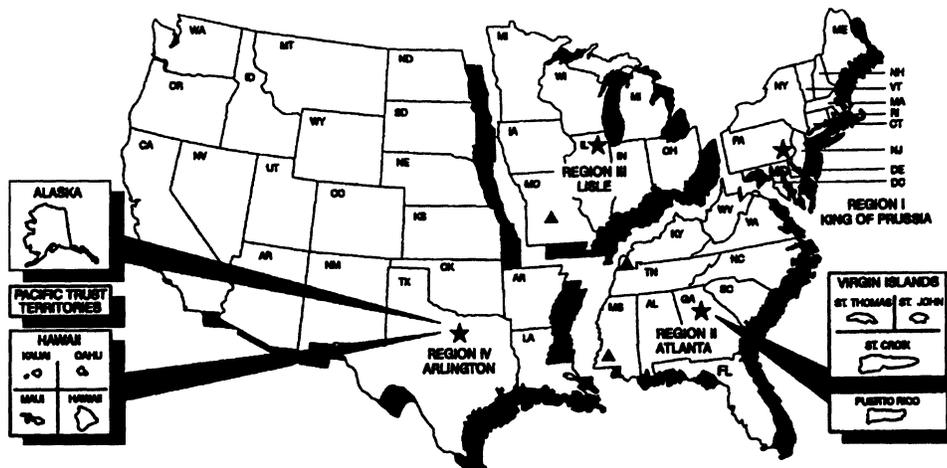
NRC conducts regular inspections at licensed facilities to assure compliance with NRC requirements. In addition, your employer and site contractors conduct their own inspections to assure compliance. All inspectors are protected by Federal law. Interference with them may result in criminal prosecution for a Federal offense.

MAY I TALK WITH AN NRC INSPECTOR?

Yes. NRC inspectors want to talk to you if you are worried about radiation safety or have other safety concerns about licensed activities, such as the quality of construction or operations at your facility. Your employer may not prevent you from talking with an inspector. The NRC will make all reasonable efforts to protect your identity where appropriate and possible.

MAY I REQUEST AN INSPECTION?

Yes. If you believe that your employer has not corrected violations involving radiological working conditions, you may request an inspection. Your request



▲ - Callaway Plant Site in Missouri and Grand Gulf Plant Site in Mississippi are under the purview of Region IV. The Paducah Gaseous Diffusion Plant in Kentucky is under the purview of Region III.

should be addressed to the nearest NRC Regional Office and must describe the alleged violation in detail. It must be signed by you or your representative.

HOW DO I CONTACT THE NRC ?

Talk to an NRC inspector on-site or call or write to the nearest NRC Regional Office in your geographical area (see map below). If you call the NRC's toll-free SAFETY HOTLINE during normal business hours, your call will automatically be directed to the NRC Regional Office for your geographical area. If you call after normal business hours, your call will be directed to the NRC's Headquarters Operations Center, which is manned 24 hours a day.

CAN I BE FIRED FOR RAISING A SAFETY CONCERN?

Federal Law prohibits an employer from firing or otherwise discriminating against you for bringing safety concerns to the attention of your employer or the NRC. You may not be fired or discriminated against because you:

- ask the NRC to enforce its rules against your employer;
- refuse to engage in activities which violate NRC requirements;
- provide information or are about to provide information to the NRC or your employer about violations of requirements or safety concerns;
- are about to ask for, or testify, help, or take part in an NRC, Congressional, or any Federal or State proceeding.

WHAT FORMS OF DISCRIMINATION ARE PROHIBITED?

It is unlawful for an employer to fire you or discriminate against you with respect to pay, benefits, or working conditions because you help the NRC or raise a safety issue or otherwise engage in protected activities. Violations of Section 211 of the Energy Reorganization Act (ERA) of 1974(42 U.S.C. 5851) include actions such as harassment, blacklisting, and intimidation by employers of (i) employees who bring safety concerns directly to their employers or to the NRC; (ii) employees who have refused to engage in an unlawful practice, provided that the employee has identified the illegality to the employer; (iii) employees who have testified or are about to testify before Congress or in any Federal or State proceeding regarding any provision (or proposed provision) of the ERA or the Atomic Energy Act (AEA) of 1954; (iv) employees who have commenced or caused to be commenced a proceeding for the administration or enforcement of any requirement imposed under the ERA or AEA or who have, or are about to, testify, assist, or participate in such a proceeding.

HOW DO I FILE A DISCRIMINATION COMPLAINT?

If you believe that you have been discriminated against for bringing violations or safety concerns to the NRC or your employer, you may file a complaint with the NRC or the U.S. Department of Labor (DOL) if you desire a personal

remedy, you must file a complaint with the DOL pursuant to Section 211 of the ERA. Your complaint to the DOL must describe in detail the basis for your belief that the employer discriminated against you on the basis of your protected activity, and it must be filed in writing either in person or by mail within 180 days of the discriminatory occurrence. Additional information is available at the DOL website at www.osha.gov. Filing an allegation, complaint, or request for action with the NRC does not extend the requirement to file a complaint with the DOL within 180 days. You must file the complaint with the DOL. To do so you may contact the Allegation Coordinator in the appropriate NRC Region, as listed below, who will provide you with the address and telephone number of the correct OSHA Regional office to receive your complaint. You may also check your local telephone directory under the U.S. Government listings for the address and telephone number of the appropriate OSHA Regional office.

WHAT CAN THE DEPARTMENT OF LABOR DO?

If your complaint involves a violation of Section 211 of the ERA by your employer, it is the DOL, NOT THE NRC, that provides the process for obtaining personal remedy. The DOL will notify your employer that a complaint has been filed and will investigate your complaint.

If the DOL finds that your employer has unlawfully discriminated against you it may order that you be reinstated, receive back pay, or be compensated for any injury suffered as a result of the discrimination and be paid attorney's fees and costs.

Relief will not be awarded to employees who engage in deliberate violations of the Energy Reorganization Act or the Atomic Energy Act.

WHAT WILL THE NRC DO?

The NRC will evaluate each allegation of harassment, intimidation, or discrimination. Following this evaluation, an investigator from the NRC's Office of Investigations may interview you and review available documentation. Based on the evaluation, and, if applicable, the interview, the NRC will assign a priority and a decision will be made whether to pursue the matter further through investigation. The assigned priority is based on the specifics of the case and its significance relative to other ongoing investigations. The NRC may not pursue an investigation to the point that a conclusion can be made whether the harassment, intimidation, or discrimination actually occurred. Even if NRC decides not to pursue an investigation, if you have filed a complaint with DOL the NRC will monitor the results of the DOL investigation.

If the NRC or DOL finds that unlawful discrimination has occurred, the NRC may issue a Notice of Violation to your employer, impose a fine, or suspend, modify, or revoke your employer's NRC license.

UNITED STATES NUCLEAR REGULATORY COMMISSION REGIONAL OFFICE LOCATIONS

A representative of the Nuclear Regulatory Commission can be contacted by employees who wish to register complaints or concerns about radiological working conditions or other matters regarding compliance with Commission rules and regulations at the following addresses and telephone numbers.

REGIONAL OFFICES

REGION	ADDRESS	TELEPHONE
I	U.S. Nuclear Regulatory Commission, Region I 475 Allendale Road King of Prussia, PA 19406-1415	(800)432-1156
II	U.S. Nuclear Regulatory Commission, Region II Atlanta Federal Center 61 Forsyth Street, S.W., Suite 23T85 Atlanta, GA 30303-3415	(800) 577-8510
III	U.S. Nuclear Regulatory Commission, Region III 801 Warrenville Road Lisle, IL 60532-4351	(800)522-3025
IV	U.S. Nuclear Regulatory Commission, Region IV 611 Ryan Plaza Drive, Suite 400 Arlington, TX 76011-8064	(800) 952-9677

<p>To report safety concerns or violations of NRC requirements by your employer,</p> <p>telephone:</p> <p>NRC SAFETY HOTLINE</p> <p>1-800-695-7403</p>	<p>To report incidents involving fraud, waste, or abuse by an NRC employee or NRC contractor,</p> <p>telephone:</p> <p>OFFICE OF THE INSPECTOR GENERAL</p> <p>HOTLINE</p> <p>1-800-233-3497</p>
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APPENDIX H

GLOSSARY

Glossary

Absorbed Dose

The amount of energy imparted to matter by ionizing radiation per unit mass of irradiated material. The unit of absorbed dose is the rad, which is 100 ergs/gram.

Absorption

The phenomenon by which radiation imparts some or all of its energy to any material through which it passes.

Activation

The process of making a material radioactive by bombardment with neutrons, protons, or other nuclear radiation.

Activity

The number of nuclear disintegrations occurring in a given quantity of material per unit time.

Acute Exposure

The absorption of a relatively large amount of radiation (or intake of radioactive material) over a short period of time.

Acute Health Effects

Prompt radiation effects (those that would be observable within a short period of time) for which the severity of the effect varies with the dose, and for which a practical threshold exists.

Adult

An individual 18 or more years of age.

ALARA

(Acronym for “As Low As Reasonably Achievable”) making every reasonable effort to maintain exposures to radiation as far below the dose limits as is practical consistent with the purpose for which the licensed activity is undertaken, taking into account the state of technology, the economics of improvements in relation to state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials in the public interest.

Alpha Particle

A strongly ionizing particle emitted from the nucleus during radioactive decay having a mass and charge equal in magnitude to a helium nucleus, consisting of 2 protons and 2 neutrons with a double positive charge.

Alpha Ray

A stream of fast-moving helium nuclei (alpha particles), a strongly ionizing and weakly penetrating radiation.

Anion

A negatively charged ion.

Annual Limit of Intake (ALI)

The derived limit for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in a year. ALI is the smaller value of intake of a given radionuclide in a year by the reference man that would result in a committed effective dose equivalent of 5 rems (0.05 Sv) or a committed dose equivalent of 50 rems (0.5 Sv) to any individual organ or tissue.

Atom

The smallest particle of an element which is capable of entering into a chemical reaction.

Attenuation

The process by which a beam of radiation is reduced in intensity when passing through some material. It is the combination of absorption and scattering processes and leads to a decrease in flux density of the beam when projected through matter.

Background Radiation

Ionizing radiation arising from radioactive material other than the one directly under consideration. Background radiation due to cosmic rays and natural radioactivity is always present. There may also be background radiation due to the presence of radioactive substances in other parts of the building, in the building material itself, etc.

Becquerel

The international (SI) the unit for radioactivity in which the number of disintegrations is equal to one disintegration per second. A charged particle emitted from the nucleus of an atom during radioactive decay.

Beta Particle

Charged particle emitted from the nucleus of an atom during radioactive decay. A negatively charged beta particle is identical to an electron. A positively charged beta particle is called a positron.

Beta Ray

A stream of high speed electrons or positrons of nuclear origin more penetrating, but less ionizing than alpha rays.

Bioassay

The determination of kinds, quantities or concentrations, and, in some cases, the locations of radioactive material in the human body, whether by direct measurement (in vivo counting) or by analysis and evaluation of materials excreted or removed from the human body.

Body Burden

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

Bremsstrahlung

Electromagnetic (x-ray) radiation produced by the deposition of charged particles in matter. Secondary photon radiation (x-ray) produced by the deceleration of charged particles through matter. Usually associated with energetic beta emitters, e.g., ³²P.

Calibration

Determination of variation from standard, or accuracy, of a measuring instrument to ascertain necessary correction factors. The check or correction of the accuracy of a measuring instrument to assure proper operational characteristics.

Cation

A positively charged ion.

Charged Particle

An ion. An elementary particle carrying a positive or negative electric charge.

Chronic Exposure

The absorption of radiation (or intake of radioactive materials over a long period of time), i.e., over a lifetime.

Committed Dose Equivalent

The dose equivalent to organs or tissues of reference that will be received from an intake of radioactive material by an individual during the 50-year period following the intake.

Committed Effective Dose Equivalent

The sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to these organs or tissues.

Contamination, Radioactive

Deposition of radioactive material in any place where it is not desired, and particularly in any place where its presence may be harmful. The harm caused may be a source of excessive exposure to personnel or the validity of an experiment or a procedure.

Controlled Area

An area, outside of a restricted area but inside the site boundary, access to which can be limited by the licensee for any reason.

Cosmic Radiation

Penetrating ionizing radiation, both particulate and electromagnetic, originating in space. Secondary cosmic rays, formed by interactions in the earth's atmosphere, account for about 45 to 50 millirem annually.

Coulomb

The meter-kilogram-second unit of electric charge, equal to the quantity of charge transferred in one second by a constant current of one ampere.

Count

The external indication of a device designed to enumerate ionizing events. It may refer to a single detected event or to the total registered in a given period of time. The term is often erroneously used to designate a disintegration, ionizing event, or voltage pulse.

Critical Organ

The organ or tissue, the irradiation of which will result in the greatest hazard to the health of the individual or his descendants.

Curie

The quantity of any radioactive material in which the number of disintegrations is 3.7×10^{10} per second. Abbreviated Ci.

Daughter Products

Isotopes that are formed by the radioactive decay of some other isotope. In the case of radium-226, for example, there are ten successive daughter products, ending in the stable isotope lead-206.

Decay, Radioactive

Disintegration of the nucleus of an unstable nuclide by the spontaneous emission of charged particles and/or photons.

Declared Pregnant Worker

A woman who has voluntarily informed her employer, in writing, of her pregnancy and the estimated date of conception.

Decontamination

The reduction or removal of contaminating radioactive material from a structure, area, object, or person. Decontamination may be accomplished by (1) treating the surface to remove or decrease the contamination, (2) letting the material stand so that the radioactivity is decreased as a result of natural decay, and (3) covering the contamination to shield or attenuate the radiation emitted.

Deep Dose Equivalent

Applies to external whole-body exposure and is the dose equivalent at a tissue depth of one centimeter (1000 mg/cm^2).

Delayed Health Effects

Radiation health effects which are manifested long after the relevant exposure. The vast majority are stochastic, that is, the severity is independent of dose and the probability is assumed to be proportional to the dose, without threshold.

Department of Transportation (DOT)

A governmental agency responsible for promoting the safe transportation of hazardous materials by all modes (land, air, water).

Depleted Uranium

Uranium having a percentage of uranium-235 smaller than the 0.7% found in natural uranium. It is obtained from spent (used) fuel elements or as byproduct tails, or residues, from uranium isotope separation.

Derived Air Concentration (DAC)

The concentration of a given radionuclide in air which, if breathed by the reference man for a working year of 2,000 hours under conditions of light work (inhalation rate 1.2 cubic meters of air per hour), results in an intake of one ALI.

Disintegration

See decay, radioactive.

Dose or Radiation Dose

A generic term that means absorbed dose, dose equivalent, effective dose equivalent, committed dose equivalent, committed effective dose equivalent, or total effective dose equivalent, as defined in other paragraphs of this section.

Dose Equivalent (HT)

The product of the absorbed dose in tissue, quality factor, and all other necessary modifying factors at the location of interest. The units of dose equivalent are the rem and the sievert (Sv). The ICRP defines this as the equivalent dose, which is sometimes used in other countries.

Dose Rate

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

Dosimeter

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

Dosimetry

The theory and application of the principles and techniques involved in the measurement and recording of radiation doses. Its practical aspect is concerned with the use of various types of radiation instruments with which measurements are made (see film badge; thermoluminescent dosimeter; Geiger-Mueller counter).

Effective Dose Equivalent

The sum of the products of the dose equivalent to the organ or tissue and the weighting factors applicable to each of the body organs or tissues that are irradiated.

Efficiency (radiation detection instrument)

A measure of the probability that a count will be recorded when radiation is indicated by a detector. Usage varies considerably so be aware of which factors (window, transmission, sensitive volume, energy dependence, etc.) are included in a given case. For example, at Michigan State University, researchers are referring to the percent of total activity present for a given nuclide detected by the radiation detection instrument being used.

Electromagnetic Radiation

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

Electron

Negatively charged elementary particle which is a constituent of every neutral atom. Its unit of negative electricity equals 4.8×10^{-19} coulombs. Its mass is 0.000549 atomic mass units.

Electron Capture

A mode of radioactive decay involving the capture of an orbital electron by its nucleus. Capture from the particular electron shell is designated as "K-electron capture," "L-electron capture," etc. X-rays are produced.

Electron Volt

A unit of energy equivalent to the amount of energy gained by an electron in passing through a potential difference of 1 volt. Abbreviated eV. Radioisotopic energy is typically measured in MeV (Million electron Volts).

Erg

The unit of energy or work in the centimeter-gram-second system; the work performed by a force acting over a distance of one centimeter so as to result in a one gram mass being accelerated at a rate of one centimeter per second each second.

Exposure

(1) Being exposed to ionizing radiation or radioactive material. (2) A measure of the ionization produced in air by x or gamma radiation. It 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 air in the volume element. The special unit of exposure is the Roentgen.

External Dose

That portion of the dose equivalent received from radiation sources outside the body.

Extremity

Hand, elbow, arm below the elbow, foot, knee, or leg below the knee.

Eye Dose Equivalent

Applies to the external exposure of the lens of the eye and is taken as the dose equivalent at a tissue depth of 0.3 centimeter (300 mg/cm^2).

Film Badge

A packet of photographic film used for the approximate measurement of radiation exposure for personnel monitoring purposes. The badge may contain two or more films of differing sensitivity, and it may contain filters which shield parts of the film from certain types of radiation.

Fission

The splitting of a nucleus into at least two other nuclei and the release of a relatively large amount of energy. Two or three neutrons are usually released during this type of transformation.

Gamma Ray

Very penetrating electromagnetic radiation of nuclear origin. Except for origin, identical to x-ray.

Geiger-Mueller (G-M) Counter

A radiation detection and measuring instrument. It consists of a gas-filled tube containing electrodes, between which there is an electrical voltage but no current flowing. When ionizing radiation passes through the tube, a short, intense pulse of current passes from the negative electrode to the positive electrode and is measured or counted. The number of pulses per second measures the intensity of radiation.

Gray

The international (SI) unit of absorbed dose in which the energy deposited is equal to one Joule per kilogram (1 J/kg).

Half-Life, Biological

Time required for the body to eliminate 50 percent of a dose of any substance by the regular processes of elimination. This time is approximately the same for both stable isotopes and radionuclides of a particular element.

Half-Life, Effective

Time required for a radioactive nuclide in a system to be diminished by 50 percent as a result of the combined action of radioactive decay and biological elimination.

$$\text{Effective half-life} = \frac{\text{Biological half-life} \times \text{Radioactive half-life}}{\text{Biological half-life} + \text{Radioactive half-life}}$$

Half-Life, Radioactive

Time required for a radioactive substance to lose 50 percent of its activity by decay. Each radionuclide has a unique half-life.

Half Value Layer

The thickness of any specified material necessary to reduce the intensity of an x-ray or gamma ray beam to one-half its original value.

Health Physics

A term in common use for that branch of radiological science dealing with the protection of personnel from harmful effects of ionizing radiation. The science concerned with the recognition, evaluation and control of health hazards from ionizing and non-ionizing radiation.

High Radiation Area

An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.1 rem (1 mSv) in one hour at thirty centimeters from the radiation source or from any surface that the radiation penetrates.

Hot Spot

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

Individual Monitoring Devices

Devices designed to be worn by a single individual for the assessment of dose equivalent such as film badges, thermoluminescent dosimeters (TLDs), pocket ionization chambers, and personal air sampling devices.

Intake

Quantity of material introduced into the body by inhalation, ingestion or through the skin (absorption, puncture, etc.)

Inverse Square Law

The intensity of radiation at any distance from a point source varies inversely as the square of that distance. For example: if the radiation exposure is 100 R/hr at 1 inch from a source, the exposure will be 0.01 R/hr at 100 inches.

Ion

An atom that has too many or too few electrons, causing it to be chemically active (such as an electron that is not associated (in orbit) with a nucleus). Ions may be positively or negatively charged, and vary in size.

Ionization

The process by which a neutral atom or molecule acquires either a positive or a negative charge.

Ionizing Radiation

Any radiation capable of displacing electrons from atoms or molecules, thereby producing ions. Examples, alpha, beta, gamma, x-rays, neutrons and ultraviolet light. High doses of ionizing radiation may produce severe skin or tissue damage.

Ionization Chamber

An instrument designed to measure the quantity of ionizing radiation in terms of the charge of electricity associated with ions produced within a defined volume.

Ionizing Radiation

Alpha particles, beta particles, gamma rays, x-rays, neutrons, high speed electrons, high speed protons, and other particles or electromagnetic radiation capable of producing ions.

Isotopes

Nuclides having the same number of protons in their nuclei, and hence having the same atomic number, but differing in the number of neutrons, and therefore in the mass number. Almost identical chemical properties exist between isotopes of a particular element.

Kinetic Energy

The energy that a body possesses by virtue of its mass and velocity, the energy of motion.

Joule

The meter-kilogram-second unit of work or energy, equal to the work done by a force of one Newton when its point of application moves through a distance of one meter in the direction of the force.

Labeled Compound

A compound consisting, in part, of labeled molecules. By observations of radioactivity or isotopic composition this compound or its fragments may be followed through physical, chemical or biological processes.

LD_{50/60}

The dose of radiation expected to cause death within 60 days to 50 percent of those exposed.

Licensed Material

Source material, special nuclear material, or byproduct material received, possessed, used, transferred or disposed of under a general or specific license issued by the Nuclear Regulatory Commission.

Licensee

The holder of the license.

Limits

The permissible upper bounds of radiation exposures, contamination or releases.

Member of the Public

An individual in a controlled or unrestricted area (who is not a radiation worker). However, an individual is not a member of the public during any period in which the individual receives an occupational dose.

Microcurie (uCi)

A one-millionth of a curie (1/1,000,000), (0.000001 Ci). (See Curie.)

Millicurie (mCi)

A one-thousandth of a curie (1/1000th), (0.001 Ci). (See Curie.)

MilliRoentgen (mR)

A sub multiple of the Roentgen equal to one-thousandth (1/1000th) of a Roentgen. (See Roentgen.)

Minor

An individual less than 18 years of age, as pertains to radiation exposure limits, works with radioactive materials (not a member of the general public).

Molecule

A group of atoms held together by chemical forces. A molecule is the smallest unit of a compound that can exist by itself and retain all its chemical properties.

Monitoring

The measurement of radiation levels, concentrations, surface area concentrations or quantities of radioactive material and the use of the results of these measurements to evaluate potential exposures and doses.

Natural Radiation

Ionizing radiation, not from manmade sources, arising from radioactive material other than the one directly under consideration. Natural radiation due to cosmic rays, soil, natural radiation in the human body and other sources of natural radioactivity are always present. The levels of the natural radiation vary with location, weather patterns and time to some degree.

Neutron

An elementary particle with a mass approximately the same as that of a hydrogen atom and electrically neutral. It has a half-life in minutes and decays in a free state into a proton and an electron.

Non-Removable Contamination

Contamination adhering to the surface of structures, areas, objects or personnel and will not be readily picked up or wiped up by physical or mechanical means during the course of a survey or during decontamination efforts.

NARM

Any naturally occurring or accelerator-produced radioactive materials. It does not include byproduct, source, or special nuclear material.

Neutron

An uncharged elementary particle with a mass slightly greater than that of the proton, and found in the nucleus of every atom heavier than hydrogen.

NORM

Naturally occurring radioactive materials.

Nuclear Regulatory Commission (NRC)

An independent federal regulatory agency responsible for licensing and inspecting nuclear power plants, universities and other facilities using radioactive materials.

Nucleus

The small, central, positively charged region of an atom that carries essentially all the mass. Except for the nucleus of ordinary (light) hydrogen, which has a single proton, all atomic nuclei contain both protons and neutrons. The number of protons determines the total positive charge, or atomic number; this is the same for all the atomic nuclei of a given chemical element. The total number of neutrons and protons is called the mass number.

Nuclide

A species of atom characterized by its mass number, atomic number, and energy state of its nucleus, provided that the atom is capable of existing for a measurable time.

Occupational Dose

The dose received by an individual in the course of employment in which the individual's assigned duties involve exposure to radiation and to radioactive material from licensed and unlicensed sources of radiation, whether in the possession of the licensee or other person. Occupational dose does not include dose received from background radiation, as a patient from medical practices, from voluntary participation in medical research programs, or as a member of the general public.

Particle Accelerator

Any machine capable of accelerating electrons, protons, deuterons, or other charged particles in a vacuum and of discharging the resultant particulate or other radiation into a medium at energies usually in excess of 1 MeV. The National Superconducting Cyclotron Laboratory is a particle accelerator.

Photon

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

P i g

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

Pocket Dosimeter

A small ionization detection instrument that indicates radiation exposure directly. An auxiliary charging device is usually necessary.

Positron

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

Principal Investigator (P.I.)

A faculty member, assistant professor or higher (no visiting faculty), appointed by the licensee, who has been approved through the Radiation Safety Committee for the purchase and use of radioactive materials.

Protective Barriers

Barriers of radiation absorbing material, such as lead, concrete, plaster and plastic used to reduce radiation exposure.

Proton

An elementary nuclear particle with a positive electric charge located in the nucleus of an atom.

Public Dose

The dose received by a member of the public from exposure to radiation and to radioactive material released by a licensee, or to another source of radiation. It does not include occupational dose or doses received from background radiation, as a patient from medical practices, or from voluntary participation in medical research programs.

Quality Factor (Q)

A modifying factor that is used to derive dose equivalent from absorbed dose. It corrects for varying risk potential due to the type of radiation.

Rad

The special unit of absorbed dose. One rad is equal to an absorbed dose of 100 ergs/gram or 62.4×10^6 MeV per gram.

Radiation Area

An area, accessible to individuals, in which radiation levels could result in an individual receiving a dose equivalent in excess of 0.005 rem (0.05 mSv) in one hour at thirty centimeters from the radiation source or from any surface that the radiation penetrates.

Radiation Worker

An individual who uses radioactive materials under the licensee's control. Individuals must be trained and have passed a radiation safety examination prior to beginning work with radioactive materials.

Radiography

The making of shadow images on photographic film by the action of ionizing radiation.

Radioisotope

A nuclide with an unstable ratio of neutrons to protons placing the nucleus in a state of stress. In an attempt to reorganize to a more stable state, it may undergo various types of rearrangement that involve the release of radiation.

Radiology

That branch of medicine dealing with the diagnostic and therapeutic applications of radiant energy, including xrays and radioisotopes.

Radionuclide

A radioactive isotope of an element.

Radiosensitivity

The relative susceptibility of cells, tissues, organs, organisms, or other substances to the injurious action of radiation.

Radiotoxicity

A term referring to the potential of an isotope to cause damage to living tissue by absorption of energy from the disintegration of the radioactive material introduced into the body.

Reference Man

A hypothetical aggregation of human physical and physiological characteristics arrived at by international consensus. These characteristics may be used by researchers and public health workers to standardize results of experiments and to relate biological insult to a common base.

Relative Biological Effectiveness

For a particular living organism or part of an organism, the ratio of the absorbed dose of a reference radiation that produces a specified biological effect to the absorbed dose of the radiation of interest that produces the same biological effect.

Rem

The special unit of dose equivalent. The dose equivalent in rems is numerically equal to the absorbed dose in rads multiplied by the quality factor, distribution factor, and any other necessary modifying factors.

Removable Contamination

Contamination deposited on the surface of structures, areas, objects or personnel that can readily be picked up or wiped up by physical or mechanical means during the course of a survey or during decontamination efforts.

Restricted Area

An area, access to which is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials. Restricted area does not include areas used as residential quarters, but separate rooms in a residential building may be set apart as a restricted area.

Roentgen (R)

The quantity of x or gamma radiation such that the associated corpuscular emission per 0.001293 gram of dry air produces, in air, ions carrying one electrostatic unit of quantity of electricity of either sign. Amount of energy is equal to 2.58×10^{-4} coulombs/kg air. The Roentgen is a special unit of exposure.

Scintillation Counter

A counter in which light flashes produced in a scintillator by ionizing radiation are converted into electrical pulses by a photomultiplier tube.

Sealed Source

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.

Shallow Dose Equivalent

Applies to the external exposure of the skin or an extremity and is taken as the dose equivalent at a tissue depth of 0.007 centimeter (7 mg/cm^2) averaged over an area of one square centimeter.

Shielding Material

Any material which is used to absorb radiation and thus effectively reduce the intensity of radiation, and in some cases eliminate it. Lead, concrete, aluminum, water and plastic are examples of commonly used shielding material.

Sievert

The international unit (SI) of dose equivalent (DE, human exposure unit), which is equal to 100 rem. It is obtained by multiplying the number of grays by the quality factor, distribution factor, and any other necessary modifying factors.

Site Boundary

That line beyond which the land or property is not owned, leased, or otherwise controlled by the licensee.

Somatic Effects of Radiation

Effects of radiation limited to the exposed individual, as distinguished from genetic effects, which may also affect subsequent unexposed generations.

Source Material

1. Uranium or thorium in any combination of uranium and thorium in any physical or chemical form; or,
2. Ores that contain, by weight, one-twentieth of 1 percent (0.05%), or more, of uranium, thorium, or any combination of uranium and thorium. Source material does not include special nuclear material.

Special Nuclear Material

1. Plutonium, uranium-233, uranium enriched in the isotope 233 or in the isotope 235, and any other material that the Nuclear Regulatory Commission determines to be special nuclear material, but does not include source material; or,
2. Any material artificially enriched by any of the foregoing but does not include source material.

Specific Activity

Total radioactivity of a given nuclide per gram of a compound, element or radioactive nuclide.

Stable Isotope

An isotope that does not undergo radioactive decay.

Stochastic Effects

Health effects that occur randomly and for which the probability of the effect occurring, rather than its severity, is assumed to be a linear function of dose without threshold. Hereditary effects and cancer incidence are examples of stochastic effects.

Survey

An evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal or presence of radioactive material or other sources of radiation. When appropriate, such an evaluation includes a physical survey of the location of radioactive material and measurements or calculations of levels of radiation, or concentrations or quantities of radioactive material present.

Terrestrial Radiation

The portion of the natural radiation (background) that is emitted by naturally occurring radioactive materials in the earth.

Thermoluminescent Dosimeter (TLD)

Crystalline materials that emit light if they are heated after they have been exposed to radiation.

Total Effective Dose Equivalent (TEDE)

The sum of the deep dose equivalent (for external exposures) and the committed effective dose equivalent (for internal exposures).

Tracer, Isotopic

The isotope or non natural mixture of isotopes of an element which may be incorporated into a sample to make possible observation of the course of that element, alone or in combination, through a chemical, biological, or physical process. The observations may be made by measurement of radioactivity or of isotopic abundance.

Tritium

A radioactive isotope of hydrogen (one proton, two neutron). Because it is chemically identical to natural hydrogen, tritium can easily be taken into the body by any ingestion or inhalation path. Decays by beta emission. Its radioactive half-life is about 12.5 years.

Unrestricted Area

An area, access to which is neither limited nor controlled by the licensee.

Unstable Isotope

A radioisotope.

Uptake

Quantity of material taken up into the extracellular fluids. It is usually expressed as a fraction of the deposition in the organ from which uptake occurs.

Very High Radiation Area

An area accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads (5 grays) in one hour at one meter from a radiation source or from any surface that the radiation penetrates.

Weighting Factor (WT)

For an organ or tissue (T) is the proportion of the risk of stochastic effects resulting from irradiation of that organ or tissue to the total risk of stochastic effects when the whole body is irradiated uniformly. Presently, the organ dose weighting defined by the NRC and the ICRP differ.

Whole Body

For purposes of external exposure, head, trunk (including male gonads), arms above the elbow, or legs above the knee.

Wipe (smear or wipe test)

A procedure in which a swab, e.g., filter paper or cotton tipped applicator, is rubbed on a surface and its radioactivity measured to determine if the surface is contaminated with loose (removable) radioactive material.

X-rays

Penetrating electromagnetic radiations having wave lengths shorter than those of visible light. They are usually produced by bombarding a metallic target with fast electrons in a high vacuum. In nuclear reactions it is customary to refer to photons originating in the nucleus as gamma rays, and those originating in the extranuclear part of the atom as x-rays. These rays are sometimes called Roentgen rays after their discoverer, W.C. Roentgen.

APPENDIX I
REFERENCES

References and Other Resources

SELECTED BIBLIOGRAPHY (and additional sources of information)

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- Fundamentals of Radiological Protection. 1993. Radiation Safety Associates Publications, 19 Pendleton Drive, P.O. Box 19, Hebron, CT 06248. (203) 228-0824
- Radiological Health Handbook. 1970. Compiled and edited by the Bureau of Radiological Health and The Training Institute, Environmental Control Administration. Washington, D. C.: Government Printing Office.
- Chart of the Nuclides. 14th edition. Available as wall chart (50" x 29") or booklet (8 1/2" x 11") from: GE Nuclear Energy, General Electric Company, Nuclear Energy Operations, 175 Curtner Ave, M/C 397, San Jose, CA 95125. Cost: approx. \$12.

The Medical Internal Radiation Dose Committee (MIRD) of the Society of Nuclear Medicine publishes a series of pamphlets giving methods and data for absorbed dose calculations. The pamphlets may be purchased from MIRD Committee, 404 Church Ave., Suite 15, Maryville, TN 37801.

The National Council on Radiation Protection and Measurements (NCRP) issues reports providing information and recommendations based on leading scientific judgment on matters of radiation protection and measurement. Reports are available from NCRP Publications, 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814.

The International Commission on Radiation Units and Measurements (ICRU) issues reports concerned with the definition, measurement, and application of radiation quantities in clinical radiology and radiobiology. Reports are available from ICRU, 7910 Woodmont Ave., Suite 800, Bethesda, MD 20814.

The International Commission on Radiological Protection (ICRP) issues reports dealing with the basic principles of radiation protection. The reports may be obtained from Pergamon Press, Maxwell House, Fairview Part, Elmsford, NY 10523.

The International Atomic Energy Agency issues many publications pertaining to the nuclear science field, including the proceedings of symposia, a Safety Series covering topics in radiation protection, a Technical Reports Series, a Bibliographical Series, and a Review Series. A complete catalog of publications may be obtained from the Publishing Section, International Atomic Energy Agency, Karnter Ring 11, P. O. Box 590, A-1011 Vienna, Austria. Publications may be ordered from UNIPUB, Inc., P. O. Box 433, New York, NY 10016.

National Consensus Standards relating to radiation protection provide information and guidance, and are often incorporated into the regulations of the Nuclear Regulatory Commission. The major national organization issuing such standards is the American National Standards Institute (ANSI), 1430 Broadway, New York, NY 10018.

The U. S. Nuclear Regulatory Commission issues guides that describe methods acceptable to the NRC staff for implementing specific parts of the Commission's regulations. Request information from the U. S. Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Director, Office of Nuclear Regulatory Research.

Health Physics, the official journal of the Health Physics Society, is a valuable source of information in radiation protection.

Health Physics Society Newsletter, a publication of the Health Physics Society, 8000 Westpark Dr., Ste 130, McLean, VA 22102.

Radiation Protection Management: The Journal of Applied Health Physics, RSA Publications, 19 Pendleton Drive, P.O. Box 19, Hebron, CT 06248.

OTHER REFERENCE RESOURCES

Excellent resources are available on the computer internet. Several are listed below.

ORCBS WWW Home Page: <http://www.orcbs.msu.edu>

RADSAFE: A listserv for radiation safety. To subscribe, send an email request to:
romulus.ehs.usuc.edu

SAFETY: A world wide listserv for general safety. To subscribe, send email request to
uvmvm.uvm.edu

Radiation and Health Physics Home Page: <http://www.umich.edu/~bbusby/>

University of Michigan Radiation Safety Home Page: <http://www.umich.edu/~oseh/rss.html>

DOE Office of Human Radiation Experiments Home Page: <http://www.eh.doe.gov/ohre/home.htm>

U.S. Nuclear Regulatory Commission Home Page: <http://www.nrc.gov/>

Health Physics Society Home Page: <http://www.hps.org/hps>

Safety Mother Lode (Comprehensive safety listings):
<http://www.sas.ab.ca/biz/christie/safelist.html#web>

Radiation and Us: <http://www.einet.net/galaxy/Community/Health/Environmental-Health/bruce-busby/rad.htm>

TIPTOP (A good Physics home page): <http://www.tp.umu.se/TIPTOP/>

Radiation Biology Home Page: <http://www.science.ubc.ca/departments/physics/radbio/HomePage.html>

APPENDIX J
EHS EMERGENCY NOTIFICATION

EHS EMERGENCY NOTIFICATION

Emergency Notification

In case of emergencies involving only radioactive material (RAM):

Mon - Fri, 8 a.m. to 5 p.m.:.....301-295-9443

After hours emergency (Security).....301-295-3038

For medical emergencies call:.....777

EHS must be notified when the following occurs:

- Radioactive contamination outside a licensed area.
- Deliberate misuse of radioactive material. All inquiries will be kept in confidence. (Deliberate misuse of RAM will result in loss of use privileges and could result in criminal action.)
- Known or suspected personnel contamination, inhalation, injection, or ingestion of RAM.
- Any accident resulting in direct exposure to personnel.
- Known or suspected loss of radioactive material, including loss to the air or sewer.
- Contaminated or damaged radioactive material shipments.