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RADIATION SAFETY HANDBOOK

Inolex Chemical Company
Research & Development Facility
Arsenal Business Center
5301 Tacony Street
Building #107, 3rd Floor
Philadelphia, PA 19137

Prepared by: Gilbert R. Mintz, Ph.D.
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This Radiation Safety Handbook contains the current official radiation health and safety regulations and procedures for the company's R & D facilities at the Arsenal Business Center. All R & D personnel who work, or are planning to work with radioactive materials, will be instructed on and required to comply with the regulations and procedures in this Handbook.

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Part I - Radiation Protection Program

A) Responsibilities and Authority of the Radiation Safety Officer:

The Radiation Safety Officer will be responsible for the control and safe use of radioactive materials for the Research & Development group of Inolex Chemical Company. These responsibilities include meeting all requirements specified by the Nuclear Regulatory Commission. The specific duties include:

1) Provide adequate information and training to personnel who work in or frequent areas where radioactive material is used.
2) Receiving and opening shipments of radioactive material arriving at the R & D facility. The safe packaging and shipping of all radioactive material leaving the facility.
3) Maintaining copies of all records.
4) Approving and monitoring all activities involving radioactive materials.
5) Keeping an inventory record of all radioactive material.
6) Performing periodic radiation surveys.
7) Explaining the use of and providing personnel monitoring equipment for individuals using radioactive materials.
8) Determining the need for bioassays.
9) Reporting exposure levels to individuals.
10) Maintain records of all radioactive material not in current use and the amount of any radioactive waste on site.
11) Investigating any overexposures, accidents, spills, loses and thefts.
12) Take the necessary emergency action if control of the radioactive material is lost.

13) Supervise all radiation emergencies and special decontamination operations.

14) Maintain the necessary records and supervise the radioactive waste disposal program.

B) General Responsibilities of Isotope Users

1) Learning and complying with the Radiation Safety Officer's rules for handling radioactive materials and the regulations provided by the Nuclear Regulatory Commission.

2) Completing the authorized user form and submitting it to the Radiation Safety Officer prior to handling radioisotopes.

3) Reporting to the Radiation Safety Officer any radiation exposure or contamination exceeding the limits expressed in the guidelines provided by the Nuclear Regulatory Commission.

4) Using appropriate radiation safety procedures so as to minimize possible radiation exposure to all individuals performing experiments or involved in decontamination procedures.

5) Assisting the Radiation Safety Officer in performing periodic checks on radiation levels and/or contamination of radioisotope storage and work areas.

6) Reporting a radiation spill or potential site of contamination to the Radiation Safety Officer so that the necessary action can be taken.

Part II - Regulations for Use of Radioactive Materials

A) Laboratory Instructions and Precautions for Working with Radioactive Materials

The following instructions pertain to the safe handling and protection of all workers using radioactive isotopes.

1) Personnel Dosimetry

Individuals will be instructed as to the use of film badges to monitor external exposure and permissible doses, levels and concentrations as described in Part 20 "Standards for Protection Against Radiation" section 20.101. The permissible occupational dose limits will be described and records maintained of each individual(s) cumulative exposure levels.

a) film badges will be issued and worn by all individuals working with radioactive isotopes.

b) an outside firm (R. S. Laudauer) will supply and monitor our personnel on a regular basis. Procedures for this routine monitoring will be described to all personnel.

2) Mouth Pipeting

<u>No mouth pipeting</u> of liquids will be allowed in any area restricted for use of radioactive isotopes. Devices for pipetting radioactive solutions must be employed. Mouth pipetting of radioactive solutions is strictly prohibited.

3) Food & Drink

All food, drink and personal items will be confined to areas outside the restricted radioactive area. No food or drink will be allowed near anyone handling radioactive materials. Furthermore, after using all isotopes individuals will be instructed to wash hands thoroughly prior to eating food.

4) Protective Clothing, Gloves, Etc.

All persons working with radioactive materials (solutions) or contaminated items must wear laboratory coats and disposable gloves.

a) Disposable surgical gloves will be available for handling isotopes.

b) While wearing protective gloves to handle radioactive materials <u>NEVER</u> directly touch objects or surfaces that could potentially contaminate non-restricted working areas. Gloves will be removed and discarded into solid radioactive waste containers prior to going to a non-restricted area or at the completion of the work.

5) Area Surveys

The measurement and evaluation of radiation levels in the laboratory will be conducted by the Radiation Safety Officer with the assistance of properly trained laboratory personnel.

a) Routine monitoring of laboratory areas (benches, equipment, etc.) will be done for carbon-14 and tritium as described in the section on "Wipe Test Protocol" (Part III, 4). The frequency and the action that will be taken when positive results are obtained are described under the section on "Radiation Monitoring".

b) Wipe tests will be done after each experiment or on a minimum quarterly basis depending on the frequency level and type of isotope(s) used.

c) Area surveying will be used for the detection and evaluation of surface contamination (high beta and gamma emitters). All laboratory areas using radioactive isotopes will be routinely monitored with a survey instrument by the laboratory scientist or if contamination is suspected.

6) Air Monitoring

The measurement and evaluation of air borne radiation levels will be determined, when necessary by the Radiation Safety Officer. Instructions will be provided to all users of radioactive materials as to the quantity of radioactive material any individual in a restricted area can inhale as specified in Appendix B, Table 1, Column 1, Part 20 "Standards for Protection Against Radiation", for the particular isotope in question.

a) The production of airborn radioactivity should be avoided whenever possible.

b) Air monitoring will also be used to determine the extent of radioactive release into the laboratory when experiments are carried out in the fume hood.

7) Dispersion Control (hood, etc.)

It is extremely important that any volatile radioactive material be confined to a hood or glove box. Depending on the chemical and physical form of the radioactivity the appropriate containment will be required. NEVER use volatile radioactive materials on the bench top.

B) Procedures for Ordering Radioactive Materials

1) Obtaining Approval for Use

Approval for use of all radioactive isotopes must be obtained from the Radiation Safety Officer before any radioisotopes can be purchased or used for experimentation.

All requests will be considered based on the radiation training and experinece of the individual(s) involved. Furthermore, the equipment and details of planned use must be submitted to the Radiation Safety Officer for review. This information must be supplied to the Radiation Safety Officer on two forms: "Protocol for Radioisotope Experimentation" (Appendix) and "Radiation Training, Experience and Exposure History", (cf.Appendix). The information submitted must describe the processes and determinations that will be performed with the radioactive materials.

2) Ordering Radioactive Materials

The purchase of all radioisotopes requires that the appropriate "Radioisotope

Purchase Forms" (cf.Appendix) be filled out and approved by the Radiation Safety Officer. This form will be forwarded to the Purchasing Department. No requisitions for radioactive material will be purchased without the Radiation Safety Officer's signature of approval.

3) Receipt of Radioactive Materials

All shipments of radioisotopes to the company will be addressed to the attention of the Radiation Safety Officer. Upon arrival of a package, The Radiation Safety Officer will review the packing slip and contents and determine if the material sent is what was ordered. The Radiation Safety Officer will be responsible for identifying any possible contamination and determining if the package is intact. If the package appears intact and free of visual damage the Radiation Safety Officer will release the isotope to the user.

C) Disposal of Radioisotopes

1) Transfer and Waste Disposal of Radioactive Material

The Radiation Safety Officer must approve the transfer of all radioactive material from a restricted area to other unrestricted locations in the company.

a) ALL radioactive material to be removed from a radioisotope area must be:

- clearly labeled with the radiation symbols and CAUTION RADIOACTIVE MATERIAL signs. All containers will be marked with the quantity, type of activity, and the surface dose rate (high beta or gamma emitters).
- the exposure rate from the container must be less than 200 millirems per hour at contact and 10 millirems per hour at three feet.
- transferred to an approved location. Arrangements have been made with Teledyne Isotopes, Inc. for periodic removal of the radioactive waste (see section on "Methods of Radioactive Waste Disposal").

b) Equipment which becomes contaminated will be labeled as such and will not be used in unrestricted areas.

2) Radioactive Waste

Work involving radioactive materials generates radioactive waste. These are generally classified as:

Type	Classification (level)	Concentration
	low	uCi/liter
liquid	intermediate	mCi/liter
	high	Ci/liter
	low	10 uCi/gm
solid	intermediate	1 uCi/gm
	high	1 mCi/gm

Most of the wastes from biological research programs are classified as low level radioactive waste, i.e., in the less than 10^{-3} uCi/ml (liquid) or 10^{-3} uCi/gm (solid).

3) Methods of Radioactive Waste Disposal

a) A Nuclear Regulatory Commission licensed commercial disposal service will be used to dispose of our radioactive waste. We have arranged to have Teledyne Isotopes remove our waste.

b) Packaging - General Requirements

All radioactive waste will be packaged as follows:

- all radioactive waste will be packaged in Department of Transportation approved containers.
- isotopes, activity, chemical form (i.e., protein, amino acid, sugar, etc.) and radiation level will be completed on the front side of the radioactive waste disposal record which will be attached to the top of the container.

- no container will contain materials which could create a hazard because of potential explosive materials.

c) Specific Procedures

Procedures for disposal of isotopes by a commercial disposal service (Teledyne Isotopes) are attached (Appendix). The radiation Safety Officer will be responsible for the proper packaging of waste. The Radiation Safety Officer will check and secure all barrels prior to shipment.

d) Aqueous Waste - Sewage Disposal (C-14 & H-3 ONLY)

- NO radioactive waste will be flushed down the sewer.

e) Incineration of Solid Waste (C-14 & H-3 ONLY)

Articles which have become contaminated with radioactive isotopes during the course of experimental work will be collected in a specifically designated waste container and marked with CAUTION RADIOACTIVE MATERIAL signs.

- solid waste will be placed in a plastic bag. The bag will be labeled clearly with the estimated amount of radioactivity and placed in the appropriate container.
- volatile compounds will not be put into a solid waste collection container.
- the company has no facility for incineration of solid waste and thus all contaminated disposables will be removed in separate containers at the time of other waste disposal.
- accordingly, solid waste will be placed in a plastic bag. The bag will be labeled clearly with the estimated amount of radioactivity and placed in the appropriate container.

D) Procedure for Inventory Control and Record Keeping

At the time of radioisotope release a "Record of Isotope Use" form (cf. Appendix) will be issued to the user. This will enable an accurate record to be kept of the quantities of isotope used and remaining after each experiment.

Adequate records will be kept by all individuals using radioisotopes; to include exposure records for all personnel and records of all radioisotopes used. These records will include the isotope, the amount and the date of receipt and the disposition of the entire lot. When the isotope has been completely used up, the record will contain the entire history of the isotope. A separate isotope utilization table will be kept for all radioactive materials (see "Record of Isotope Use Form").

Accurate records will also be kept of periodic monitoring results of all controlled areas. If contamination and spills have occurred, evidence will be provided that these have been appropriately cleaned up.

E) Calibration of Radiation Equipment

Our radiation equipment will be calibrated at least once a quarter but will depend on the number of experiments performed using radioactive materials. If a period of 3-6 months passes where no radioactive materials are used then calibration of the radiation detection equipment will occur prior to initiation of a series of experiments.

F) Notification of the Radiation Safety Officer

1) Each user of radioactive materials will be responsible for notifying the Radiation Safety Officer in the event of a hazardous incident involving the following:

a) Radioactive spills: both minor and major spills as described under Emergency Procedures. (Part IV).

b) Accidental release of radioactive material into the laboratory air.

c) Any accidental ingestion or inhalation of radioactive material of any quantity.

d) Radiation exposure in excess of that which was planned by the investigator.

e) Receipt of mislabeled radioisotopes and/or larger quantities than an individual is authorized to use.

2) The Radiation Safety Officer will take the necessary action to:

a) Identify the degree and cause of contamination and exposure.

b) Isolate any contaminated areas or equipment until it can be properly decontaminated.

c) Evaluate the degree of exposure and contamination for all radioactive spills.

d) Supervise all decontamination procedures.

e) Notify and document findings to regulatory agencies when necessary.

f) In the event of injury the Radiation Safety Officer will arrange for proper medical assistance.

Part III - Precautionary Procedures

A) Radiation Monitoring

1. Receipt of Radioactive Materials

All shipments of radioisotopes into the company will be addressed to the attention of the Radiation Safety Officer. Upon arrival of a package, the Radiation Safety Officer will review the packing slip and contents and determine if the material sent is what was ordered. The Radiation Safety Officer will be responsible for identifying any possible contamination and determine if the package is intact. If the package appears intact and free of visual damage the Radiation Safety Officer will release the isotope to the user.

At the time of radioisotope release a "Record of Isotope Use" form (cf. Appendix) will be issued to the user. This will enable an accurate record to be kept of the quantities of isotope used and remaining after each experiment. The "Record of Isotope Use" form will be submitted to the Radiation Safety Officer after the particular isotope(s) has been completely used.

2) Personnel Monitoring

The Nuclear Regulatory Commission (Part 20.101, Standards for Protection Against Radiation) provides radiation exposure limits allowed for individuals using radioactive materials in the restricted areas. Users of gamma emitters will use film badges to obtain exposure information indicating the necessity for protective devices and continuing monitoring. The permissible exposure limits determined by the Nuclear Regulatory Commission are:

a) Whole body; head and trunk; active blood forming organs; lens of eyes; gonads: 1.25 REMS per calendar quarter

b) Hands and Forearms; feet and ankles:

18.75 REMS per calendar quarter

c) Skin of whole body:

7.5 REMS per calendar quarter

All personnel subject to 25% of these exposure limits are required to be monitored.

- as a general rule film badges will be issued and worn by all individuals working with radioactive isotopes.
- R. S. Laudauer will supply and monitor our personnel on a regular basis.
- as required individuals using or suspected of ingesting high levels of radioactive material will submit a sample of urine on a periodic basis for bioassay monitoring.

3) Area Surveys and Air Sampling

Survey as defined by the Nuclear Regulatory Commission means an evaluation of the radiation hazards incident to the production, use, release, disposal or presence of radioactive materials under a specific set of conditions. When appropriate, such evaluation will include a physical survey of the location of materials and equipment and measurements of levels of radiation or concentrations of radioactive material present.

a) Area Surveys

The measurement and evaluation of radiation levels in the laboratory will be conducted by the Radiation Safety Officer with the assistance of properly trained laboratory personnel.

b) Area surveying will be used as a method to detect and evaluate surface contamination (high beta and gamma emitters).

- routine monitoring of laboratory areas (benches, equipment, etc.) will be done for carbon-14 and tritium as described in the section on "Wipe

Test Protocol" (Part III, 4). The frequency and the action that will be taken when positive results are obtained are described under the section on "Radiation Monitoring".

- Wipe tests will be done after each experiment or on a minimum quarterly basis depending on the frequency level and type of isotope(s) used.
- area surveying will be used for the detection and evaluation of surface contamination (high beta and gamma emitters). All laboratory areas using radioactive isotopes will be routinely monitored with a survey instrument by the laboratory scientist or if contamination is suspected.
- the Radiation Safety Officer will use a Geiger-Mueller counter as part of the routine monitoring of the laboratory for radioactive contamination (see section on Radiation Monitoring, Part III, A).

c) Air Monitoring Surveys

The radiation protection program will require breathing zone and effluent air surveys as part of the air monitoring. The measurement and evaluation of airborne radiation levels will be determined, when necessary by the Radiation Safety Officer. Instructions will be provided to all users of radioactive materials as to the quantity of radioactive material any individual in a restricted area can inhale as specified in Table 1, Column 1 and Appendix B (Part 20, "Standards for Protection Against Radiation" for the particular isotope in question.

1) The production of airborne radioactivity will be avoided whenever possible.
2) If airborne activity is present or is suspected of being present the air will be sampled using a method appropriate for the type of radioactivity and the concentration determined. Results will be recorded and follow-up measurements done to monitor the airborne radioactivity until it is down to background levels.

- air monitoring will also be used to determine the extent of radioactive release into the laboratory when experiments are carried out in the fume hood.
- The appropriate containment will be required depending on the chemical and physical form of the radioactivity. It is extremely important that any volatile radioactive material be confined to a hood. <u>NEVER</u> use volatile radioactive material on the bench top. Accordingly, whenever volatile materials are used in the hood, surveys will be done on the effluent airways.

4. Wipe Test Protocol

This procedure will be followed when low energy beta emitters (tritium and carbon-14 isotopes) are used in the laboratory.

a) Wipe tests will be done quarterly. The areas sampled at each quarterly test period will be designated on the "Record of Radiation Monitoring" sheet (attached to original application).

b) Each wipe sample will be taken from a (10 cm x 10 cm square area). The areas will be chosen based on the frequency that personnel will be in contact with the area. In other words those areas with a high probability of being contaminated will be designated for wipe tests.

c) The wipe test will be performed by wetting a piece of filter paper and rubbing it over the surface to be monitored. The filter paper will be put into a scintillation vial, cocktail added and counted on the tritium or carbon-14 program. The background will be determined by using a wetted filter paper as a blank.

d) The counts per minute (cpm) will be recorded on the "Record of Radiation Monitoring" form (see appendix). The background counts will be recorded and all results will be expressed as "counts above background".

e) Areas of contamination will be determined by monitoring any increase in count rate above background. A corrected value equal to or greater than the background will be decontaminated. Any area found contaminated will be decontaminated with count-off or similar radioactive cleaner and wipe tested again. These values will be recorded in parentheses next to the first value.

f) The results of the previous quarterly wipe test will be available in the laboratory log book with a diagram designating the areas tested.

2) High Energy Beta and Gamma Emitters

a) The designated areas will be monitored monthly with a Geiger-Mueller counter which will be available in the laboratory or from the Radiation Safety Officer. Survey instruments will be used to monitor surfaces of benches, floors, walls, etc. where high beta and gamma emissions may be present.

b) The activity in cpm's measured in the designated areas will be recorded on the "Record of Radiation Monitoring" sheet (see appendix).

c) Areas with values greater than 1000 cpm will be decontaminated immediately and the monitoring procedure repeated until the radioactivity is below 1000 cpm. The final readings will be recorded next to the original value.

d) All users of high beta and gamma emitters will wear a film badge on the chest (outside the laboratory coat) to monitor radioactivity exposure. These badges can be obtained from the Radiation Safety Officer. Arrangements have been made to have R. S. Laudauer (Glenwood, IL) supply badges and monitor radiation exposure of our personnel.

e) Changes in personnel (resignations, transfers, etc.) who have been assigned film badges will be promptly reported to the Radiation Safety Officer.

B) Procedures for Working with Volatile Isotopes

1) All experiments employing volatile radioactive materials will be performed in a fume hood.

2) Laboratory coats and disposable gloves will be worn to minimize any potential radioactive exposure by absorption through the skin.

3) When it is impracticable to limit concentrations of radioactive materials in air below those defined in 20.203 (d)(1)(ii) "Standards for Protection Against Radiation", other precautionary procedures will be taken such as increased monitoring and the use of respiratory equipment. Such equipment will be used to restrict intake of radioactive material by any individual over a seven day period far below the concentrations specified in Appendix B, Table I, (Part 20, "Standards for Protection Against Radiation").

4) The face velocity of the fume hood can be tested with an anemometer. The anemometer will be used to test the ventilating system providing readings of air velocity in cubic feet per minute.

5) The minimum face velocity on the fume hood varies with the opening of the door from 50 to 100 cubic feet per minute. The face velocity will be tested before and after performing any experiments using levels of radioactive materials that exceed the limits specified in Appendix B, Table II (Part 20, "Standards for Protection Against Radiation").

C) Caution Signs and Labels

1) All radioactive materials, restricted areas and storage containers must be properly marked with the appropriate signs.

2) The Radiation Safety Officer will be responsible for distributing and identifying areas and places for the necessary warning information. All signs and labels

indicating radiation must contain the three bladed magenta or purple radioactive caution symbol and a yellow background.

3) All users of radioisotopes will be instructed as to the following types of signs most commonly used:

   a) CAUTION RADIATION AREA: used in areas where exposure to radiation can occur at a level of 5 mrem/hr or greater.

   b) CAUTION RADIOACTIVE MATERIAL: used in any area where radioisotopes are used or stored at quantities greater than these listed in the table below:

Isotope	Quantity
Carbon-14	100 uCi
Hydrogen-3	1000 uCi
Iodine-125	1 uCi
Iodine-131	1 uCi
Phosphorus-32	10 uCi
Sulfur-35	100 uCi

   The following will be labeled with the CAUTION RADIATION AREA signs:

   - all doors to rooms where radioactive material is used.
   - all hoods, refrigerators, centrifuges, and equipment where radioactive material is used or stored.
   - all solid and liquid waste containers.
   - the type of isotope, quantity and date of assay must be clearly specified on the label for radioactive materials.

   c) CAUTION-HIGH RADIATION AREA signs are required in any area where the dose received could equal or be greater than 100 millirems per hour.

D) Bioassay Program

Routine bioassays will be done when individuals handle quantities of radioactive isotopes over specified time periods as outlined in the Regulatory Guides: "Guidelines for Bioassay for Tritium" and Regulatory Guide 8.20 and "Applications of Bioassay for I-125 and I-131". Furthermore, when positive results are obtained we will comply with the necessary action as described in the respective guidelines.

i) Tritium Bioassay Program

a) Types of Bioassays

A bioassay will be done prior to any work with tritium. This will be used to establish a baseline for each individual handling radioactive isotopes. A bioassay program will be initiated when quantities processed by an individual at any time or the total amount processed per month exceed those for the forms of tritium shown in Table I of the "Guidelines for Bioassay for Tritium".

- Routine Urinalysis

  Regular bioassays (urine counts) will be done on all individuals handling tritium at frequencies specified below.

- Final Bioassay

  A bioassay (urine count) will be perfomred as soon as possible but within one month of an individual's exposure to tritium or when the activities with a potential exposure are completed.

- Diagnostic

  Any bioassays that exceed levels given as action points in the "Regulatory Guidelines for Bioassay of Tritium" will receive immediate follow-up bioassays on a weekly basis. If immediate medical attention is warranted as a result of a bioassay, complete and prompt follow-up will be conducted as described in Regulatory

Guide(position 5.1).

b) Frequency

- Initial Routine

  A bioassay sample of 100ml of urine will be taken within three days of any individual working in an area where the levels of tritium used require bioassay as specified in the "Regulatory Guidelines". Follow-up bioassays will be done every two weeks for the duration of the exposure of the individual to tritium. If exposure to tritium is less than every two weeks, bioassays will be performed within 10 days of completion of the handling of tritium.

- Quarterly

  The sampling frequency may be changed to quarterly if the conditions outlined in the "Regulatory Guide" are met.

- Respiratory Protection Devices

  If at any time respiratory protective devices are used to limit exposure, a bioassay sample will be taken within three days.

c) Corresponding Action on Positive Results

- The licensee will make evaluations, take necessary corrective actions and maintain records according to paragraph 20.103 (b)(2) of 10 CFR Part 20 whenever the intake (urine counts) of tritium over a 40 hr. work period exceeds the amount specified in Table I of the "Regulatory Guidelines" (air concentration 5×10^{-6} uCi/ml).

- A survey will be carried out to determine the causes of any large exposures and possible involvement of other employees. The required action will be taken as stated in the "Regulatory Guidelines".

- If bioassay levels exceed limits stated in the "Regulatory Guidelines" reports will be provided to the Nuclear Regulatory Commission as required by section 20.405, 20.408 and 20.409 of 10 CFR Part 20.

2) Bioassay for I-125 and I-131

a) Baseline

A bioassay will be done prior to beginning any work with radioactive iodine to establish a baseline for each individual handling radioactive isotopes. A bioassay program will be initiated when quantities processed by an individual at any one time or the total amount processed per month exceed those for the forms of iodine shown in Table I of the "Regulatory Guide 8.20 Bioassay for I-125 and I-131".

- Routine

Regular bioassays (thyroid counts and/or whole body counts) will be done on all individuals handling radioactive iodine at the frequencies specified below.

- Emergency

If the thyroid uptake exceeds burdens at any time of 0.5 uCi of I-125 or 0.14 uCi of I-131, actions recommended in the "Regulatory Guidelines for Bioassay of I-125 and I-131" will be carried out (cf. Regulatory Position 5(a)).

- Diagnostic

Follow-up bioassays will be performed within two weeks of any initial measurements that exceed measurements determined as action points in the "Regulatory Guidelines" (regulatory position 5).

b) Frequency

- Initial Routine

A bioassay sample or measurement will be obtained within three days of any individual working in the area where the levels of iodine used require bioassay as specified in the "Regulatory Guidelines" (positions 1 and 2 Table 1). If the levels of usage or conditions described in Table I exist, then bioassay will continue every two weeks or longer for the duration of the potential exposure.

- Quarterly

  The sampling frequency may be changed to quarterly if the conditions outlined in the "Regulatory Guide 8.20" positions 4 are met.

- Respiratory Protective Devices

  The use of respiratory protective devices, suits, hoods and gloves will be used to limit radiation exposure. As specified in regulatory position 1(e) "Regulatory Guide 8.20" bioassay measurements will be performed to verify the effectiveness of the protective devices. Bioassays will be performed when necessary as specified in paragraph 20.103 (a)(1) of 10 CFR Part 20 of the Regulatory Guidelines, "Standards for Protection Against Radiation".

c) Corresponding Actions on Positive Results

The licensee will make evaluations, take necessary corrective actions and maintain records as required by paragraphs 20.405, 20.408, and 20.409 of 10 CFR Part 20 whenever the intake (urine counts) of iodine over a 40 hr. work period exceeds the amount specified in Table I of the Regulatory Guidelines.

E. Isotope Storage

Radionuclides, when not in use, will be stored in a manner which excludes the possibility of radiation exposure to individuals and will not be accessible to unauthorized personnel. These materials will be stored in sealed fire and water-proof containers under lock and key. All refrigerators and freezers in public access areas containing radioisotopes will be locked when unattended. Areas designated for radioactive storage will be plainly marked as containing radioactive materials.

F. Shielding

A corner of the laboratory set aside for radioisotope use will be partitioned with 1" thick lead bricks to protect all workers from radiation exposure. This material is of suitable thickness to shield workers from the energy (beta and gamma emitters) of the isotopes during usage and storage (see attached diagram for area restricted to radioisotope use).

Part IV - Emergency Procedures

A) Emergency Assistance

If an accident occurs and radioactive material is spilled, it could result in either over exposure or contamination of investigators. The first concern must be the protection of personnel from radiation hazards; the second concern is to confine the accident (spill) to as small an area as possible. The consequences of most radiation spills will be less severe if the proper action is taken immediately. Accordingly, emergency procedures will be planned and rehearsed by all personnel in the area.

1. Emergency Assitance

In the event of an emergency involving radioactive material the Radiation Safety Officer is to be notified immediately.

Radiation Safety Officer: Gilbert R. Mintz, Ph.D.

Daily 8:00 am - 4:30 pm: (215)289-4703

Off Hours - Evenings/Weekends:(609)426-9592

B) Spills

Radioactive spills involve the unanticipated spread of isotope to areas beyond trays and absorbent papers which are typically used to limit the spread of materials and facilitate clean-up. The clean-up of confined spills will be done under the supervision of the Radiation Safety Officer. Appropriate procedures will be followed for personnel protection, waste disposal and decontamination of all spills. The procedures descrived below will be followed for radioactive materials which have spread beyond confines and involve minor spills or major spills and represent potential radiation hazards to personnel.

1) Minor spills (No Significant External Radiation Hazard to Personnel)

a) Confine the spill immediately.

- for liquid spills, right the container immediately and drop absorbent paper on the entire spill. Use rubber gloves (disposable) to remove the paper.

- for dry materials, dampen it thoroughly wearing protective gloves being extremely careful not to spread the contamination.

b) Notify all persons within hearing distance that a spill has occurred.

c) Restrict access to the area to a minimum number of persons necessary to deal with the spill in the restricted area. Do not walk near the spill area.

d) Notify the Radiation Safety Officer (see Emergency Assistance).

2) Major Spills (Involving Significant External Radiation Hazard to Personnel)

1) Notify all person(s) in the area who are not involved in the spill to leave the immediate area at once.

2) Move away from the spill area immediately.

3) Flush any radioactivity thoroughly from the skin with water. Try not to spread contamination.

4) Clothing contaminated with radioactivity should be removed at once.

5) Personnel will be advised to move to an area where there is no external radiation hazard.

6) Notify the Radiation Safety Officer immediately.

C) Area Decontamination

Areas of contamination will be determined by counting wetted papers and monitoring any increase in count rate over background (see Part III. Radiation Monitoring, Wipe Test Protocol).

1) Areas of contamination will be determined by monitoring any increase in count rate above background.

2) Areas with counts greater than the corrected background will be decontaminated immediately.

3) Any area found contaminated will be decontaminated with count-off or similar radioactive cleaner and wipe tested again.

4) The monitoring procedure will be repeated until the radioactivity is below 1000 cpm.

5) Record the final readings next to the original value on the "Record of Radiation Monitoring " sheet.

6) The Radiation Safety Officer will supervise the decontamination of personnel and of the area. Decontamination and clean-up of the area shall be carried out by the person(s) responsible for the spill.

7) The Radiation Safety Officer will monitor all person(s) for contamination and conduct a complete survey of the area to determine the adequacy of the decontamination.

8) A report on the incident will be submitted to the Radiation Safety Officer.

9) Per Radiation Safety Officer's instructions, begin clean-up and decontamination.

10) Decontamination and clean-up will be carried out by the person(s) responsible for the spill or others who work in the same research group.

11) Protective clothing, will be worn during decontamination. This includes rubber gloves, shoe covers, lab coats or overalls, and respirators.

12) Persons may leave the spill area after the Radiation Safety Officer has monitored them.

13) Work in the area can resume after the Radiation Safety Officer has completed the necessary surveys. A report on the incident will be submitted to the Radiation Safety Officer.

D) Fires

In the event of a fire ask someone to sound the fire alarm if the size of the fire requires the fire department. Contact the Radiation Safety Officer immediately. If radioactive material is not directly involved in the fire try to extinguish the fire without disturbing the shielding around the radioactivity. Proceed to:

1) Keep all personnel out of the danger area during and after extinguishing the fire.

2) Notify the Radiation Safety Officer and remain in the area to assist in filing a report on the incident.

If the fire spreads to an area containing radioactive material proceed to:

1) Leave the area immediately.

2) Pull the fire alarm and call the Radiation Safety Officer immediately.

3) Communicate the approximate level of radioactive involvement to the Radiation Safety Officer.

4) Remain in the general area to assist the Radiation Safety Officer in filing a report on the incident.

Radiation Training, Experience and Exposure History

1. Name ________________________________ Date _____________

2. Briefly describe history of previous radiation exposure.
   (a) Name and address of employer:

   (b) Dates of employment:

   (c) Periods of exposure:

   (d) Previous whole body(REM):

3. Type of Training (include where trained, length of training, course or on the job experience/training)
   (a) Principles of radiation protection:

   (b) Instruments and monitoring techniques for radioactivity measurements:

   (c) Calculations for using and measuring radioactivity:

   (d) Biological effects of radiation:

4. Experience: (previous use of isotopes)

Isotope	Amount(uC)	Duration	Use

________________________________ Signature

_______________ Date

Protocol for Radioisotope Experimentation

1. Name ______________________________ Date ____________

2. Radioisotope ________________ Chemical Form __________

3. Objective of Experiment

4. Provide description of the procedures to be carried out with radioactive material.

5. Maximum amount of activity (mC) to be used in a single experiment.

   Maximum amount of activity (mC) to be ordered per shipment.

6. Names of all persons who will be using isotope(s).

7. Monitoring and counting instruments available.

8. Planned duration of work/project.

9. Expected starting date.

____

Signature

Radioisotope Purchase Form

1. Chemical form ________________ Amount ________________
2. Supplier ____________________ Catalog no. __________
3. Isotope ___________________________
4. Physical form ______________________
5. Specific Activity ___________________
6. Proposed use:

7. Requested by ________________________

______________________________________ ____________
Radiation Safety Officer approval Date

RECORD OF ISOTOPE USE

1. When you receive the isotope record data on the sheet under "Total Amount"
2. As you dispose of the isotope, throughout the experiment, record it below.

DATE ______________________ COMPOUND ______________________

ISOTOPE ______________________ LOT# ______________________

TOTAL AMOUNT uCi ______________ ML ______________________

DISPOSAL	DATE	uCi
TOTALS*		

*uCi ordered should equal uCi disposed of corrected for decay.

____

Signature Department Head

RECORD OF RADIATION MONITORING

Areas of contamination determined by wetting a piece of filter paper, rubbing it over the surface to be monitored and recording the increase in count rate over background

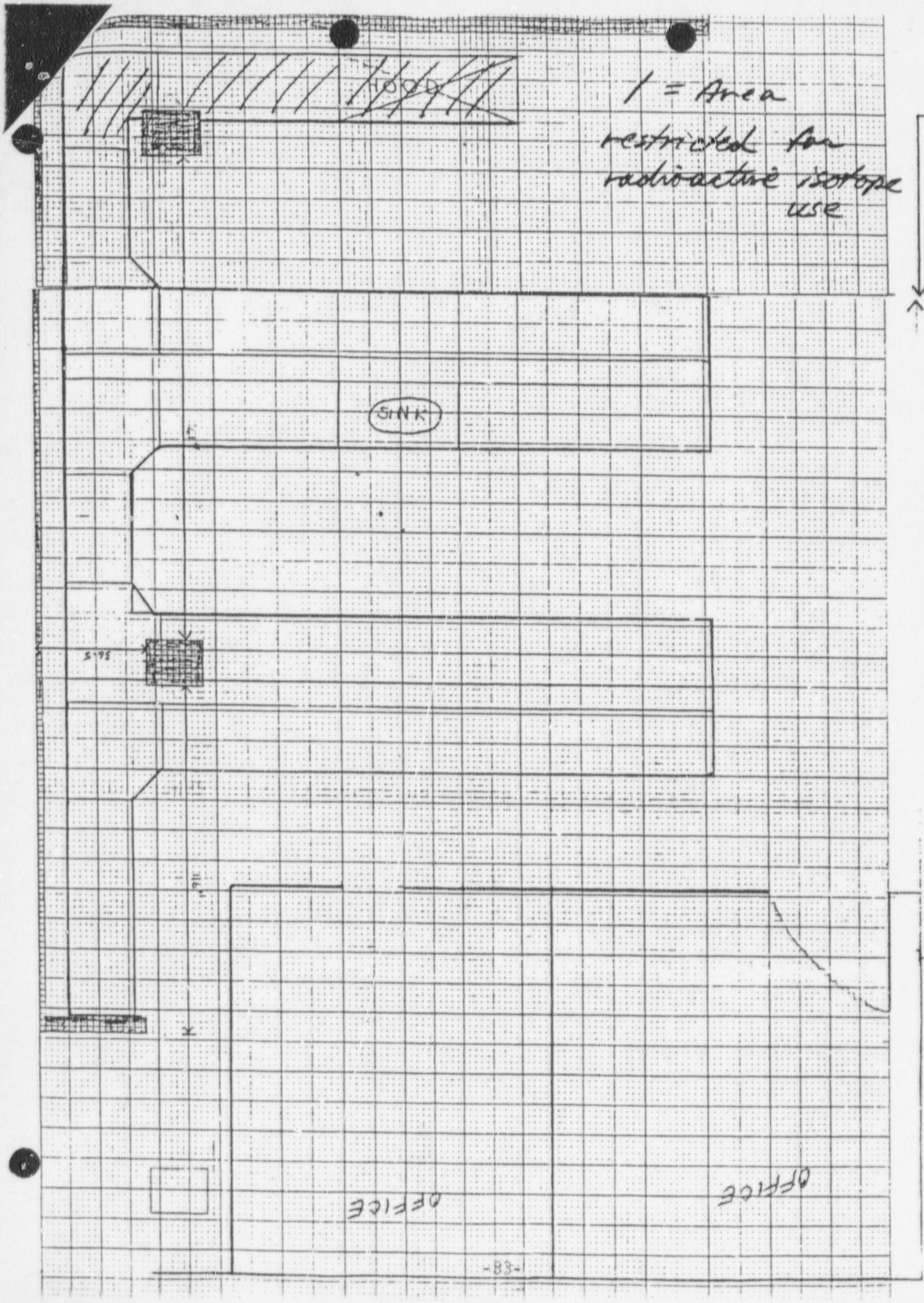
DATE	BACKGROUND (counts)	COUNTS ABOVE BACKGROUND	LOCATION	REMARKS/INITIALS

SIGNATURE DEPARTMENT HEAD

RADIOACTIVE MATERIAL DISPOSAL RECORD

DATE	MATERIAL DESCRIPTION	AMOUNT (uCi/mCi)	CHEMICAL FORM	METHOD OF DISPOSAL	REMARKS/INITIALS

SIGNATURE DEPARTMENT HEAD



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TELEDYNE
ISOTOPES

PACKAGING PROCEDURES FOR RADIOACTIVE WASTE

I.0 GENERAL

I.1 Categories of Radioactive Waste:

There are three disposal facilities being used and the categories for each are listed below:

I.1.1 BURIAL AT RICHLAND, WASHINGTON

1. (DMR) Dry Material destined for Richland
2. (DCR) Dry Compactibles destined for Richland
3. (SVR) Small Volume liquids destined for Richland
4. (LVR) Large Volume liquids destined for Richland
5. (ACR) Animal Carcasses or biological waste destined for Richland

I.1.2 PROCESSING AT QUADREX HPS, GAINESVILLE, FLORIDA

1. (VXN) Scintillation Vials - NRC exempt - Non RCRA regulated
2. (VRN) Scintillation Vials - NRC regulated - Non RCRA regulated
3. (VXR) Scintillation Vials - NRC exempt and RCRA regulated
4. (VRR) Scintillation Vials - NRC regulated and RCRA regulated

I.1.3 PROCESSING AT SCIENTIFIC ECOLOGY GROUP, OAK RIDGE, TENNESSEE

1. (DMS) Dry solid Material destined for S.E.G.
2. (DCS) Dry solid Compactible destined for S.E.G.
3. (SVS) Small Volume liquid destined for S.E.G.

I.2 Items in different categories cannot be mixed in any one container unless specifically authorized.

1.3 The packaging procedure that is used is to be marked on the drum (e.g. DMR-8/87).

I.4 Transuranic and radium waste in excess of 10 nanocuries per gram is not acceptable unless specifically authorized.

I.5 Gaseous waste must meet certain provisions. Please see the burial site's license for details or call the Radiological Services Department Office.

I.6 Special Nuclear Material requires specific approval and will be accepted only upon special request to the Radiological Services Department Office.

I.7 DO NOT EXCEED THE FOLLOWING WEIGHTS UNLESS SPECIFICALLY AUTHORIZED:

5 gallon container - 80 lbs.
30 gallon container - 300 lbs.
55 gallon container - 480 lbs.

I.8 CHEMICAL TOXICITY:

The chemical composition of the materials disposed must be compatible with the procedures which follow. Any additional hazards of the material must be evaluated to determine if additional packaging is required. If materials are listed in N. Irving Sax's "Dangerous Properties of Industrial Materials", Fifth Edition, Van Nostrand Reinhold, as having a THR=HIGH via any route, except IP or IV, specific approval must be obtained from the State of Washington Radiation Control Program. Contact the Radiological Services Department for details.

I.9 PROHIBITIONS

I.9.1 Burial Prohibitions:

Lead and other U.S. EPA hazardous wastes are prohibited from land burial at the current radioactive waste disposal sites. Please ensure there are no Resource Conservation and Recovery Act (RCRA) wastes in your radioactive waste streams.

I.9.2 Scintillation Vial Processing:

Only those isotopes listed in the Quadrex license are allowed for processing. In addition, strict control must be held over the packaging of scintillation vials. No other wastes of any kind are allowed in these containers.

I.10 Special Notes

Two 2 ml liners may be used in place of a single 4 ml liner.

Instead of lining the whole drum, individual 4 ml (or double 2-ml) bags may be substituted, provided each bag is layered as below.

For a list of approved absorbants for use with waste destined for Richland, please see the US Ecology license.

When layering, the absorbant must be the first layer on the bottom and the last layer on the top. Proper volume ratios must be determined by the generator to be used for the different absorbants.

The amount of absorbant must be capable of absorbing twice the amount of liquid present.

I.11 VOIDS - All voids in the containers must be filled to the extent practicable.

TELEDYNE ISOTOPES

II.0 WASTE FOR BURIAL AT US ECOLOGY, RICHLAND, WASHINGTON

II.1 DRY SOLID MATERIAL FOR BURIAL AT RICHLAND, WASHINGTON (DMR-8/87)

II.1.1 Select a 5, 30 or 55-gallon drum.

II.1.2 Fill to capacity with only dry solid materials.

II.1.3 Fill in any voids to the extent practical.

II.1.4 Secure drum cover.

II.1.5 Label drum DMR-8/87, to designate that the drum has been packaged according to these directions.

II.2 DRY SOLID COMPACTIBLES FOR BURIAL AT RICHLAND, WASHINGTON (DCR-8/87)

II.2.1 Select a 30 or 55 gallon container.

II.2.2 Place waste into double 4 mil plastic liners. (Note: For 55 gallon drums, use two sets of double 4 mil bags, each set approximately 27 gallons. If heavy materials are used, please use additional double 4 mil liners and decrease the quantity put into each.)

II.2.3 Twist and seal liners.

II.2.4 Place double 4 mil bags into the selected container.

II.2.5 Replace lid and ring.

II.2.6 Secure ring. DO NOT BOLT.

II.2.7 Label drum DCR-8/87 to indicate it was packaged in accordance with these instructions.

NOTE: DO NOT DISPOSE OF UNPROTECTED SHARP OBJECTS.

NOTE: DO NOT DISPOSE OF NON-COMPACTIBLE ITEMS IN THESE TYPES OF CONTAINERS.

NOTE: ONLY LOW SPECIFIC ACTIVITY MATERIAL IS ACCEPTABLE IN COMPACTIBLE DRUMS. UNDER NO CIRCUMSTANCES SHOULD SOURCES BE PLACED INTO THESE CONTAINERS.

TELEDYNE ISOTOPES

II.3 SMALL VOLUME LIQUID WASTE DESTINED FOR RICHLAND (SVR-8/87)

These drums can contain vials which contain liquids which are acceptable for burial, and each vial must contain less than 50 ml of liquid.

Liquid should not be absorbed directly onto the absorption media (e.i. do not open vials). Any tool or device which contains free standing liquid must be considered small volume liquid waste. Please reference the definition of free standing liquid as found in US Ecology's lisense.

II.3.1 Select only a 30 or 55-gallon drum; 5-gallon pails are not allowed.

II.3.2 Line the drum with 4 ml thick poly liner.

II.3.3 Using an approved absorbant, alternate layers of absorbant with layers of waste.

II.3.4 Twist and seal liner.

II.3.5 Secure drum cover.

II.3.6 Label drum SVR-8/87, to designate that the drum has been packaged according to these instructions.

II.3.7 Special Note: Toluene, Xylene and other flammable liquids in scintillation vials will not be accepted for burial. They must be packaged for reprocessing and meet the reprocessor's license criteria.

I.4 LARGE VOLUME LIQUID WASTE DESTINED FOR RICHLAND (LVR-8/87)

All items containing 50 ml or more of an aqueous liquid may not be disposed in SVR or SVS drums. The liquid must be packaged as follows while the container itself must be either (1) dried and placed in a DMR, DCR, DMS or DCS drum or (2) placed in an SVR or SVS drum once the bulk of the liquid is removed.

II.4.1 Select only the 55-gallon double-walled container for liquid waste.

II.4.2 Remove the 55-gallon drum cover.

II.4.3 Loosen and remove the bung from the 30-gallon drum which has been filled with an approved absorbant.

II.4.4 Pour up to 10 gallons of liquid (pH-6.0 - 9.0) into the absorbant in the 30-gallon drum through the 2-1/2" opening.

II.4.5 Replace bung and tighten.

II.4.6 Twist and seal poly liner.

II.4.7 Secure cover of 55-gallon drum.

II.4.8 Label drum LVR-(8/87) to designate that the drum has been packaged according to these instructions.

II.4.9 SPECIAL NOTE:

Toluene or Xylene and other liquids unacceptable at the burial site cannot be absorbed.

II.5 ANIMAL CARCASSES OR BIOLOGICAL WASTE (ACR-8/87)

Animal carcasses or biological waste must be disposed using a double-walled container. Be sure when ordering to specify a 55-gallon double-walled container for animal carcasses.

II.5.1 Select only a 55-gallon double-walled drum.

II.5.2 Remove inner 30-gallon container and absorbant.

II.5.3 Line 30-gallon drum with 4 ml poly liner. See Section I.10.

II.5.4 Package waste into liner using at least one part slaked lime for every 10 parts of an approved absorbant. Fill completely.

II.5.5 Twist and seal liner.

II.5.6 Seal 30-gallon drum.

II.5.7 Place 30-gallon drum into 55-gallon drum.

II.5.8 Place absorbant around and covering 30-gallon drum.

II.5.9 Secure 55-gallon drum cover.

II.5.10 Label drum ACR-8/87 to designate that drum has been packaged according to these instructions.

III.0 RADIOACTIVE WASTE FOR PROCESSING AT S.E.G., OAK RIDGE, TENNESSEE

III.1 DRY SOLID MATERIAL DESTINED FOR S.E.G. (DMS-8/87)

III.1.1 See the procedure for DMR and follow exactly, except for labelling the container DMS-8/87, however, only Class A unstable materials are acceptable. Please see the S.E.G. license for further details on acceptable materials.

III.2 DRY SOLID COMPACTIBLE DESTINED FOR S.E.G. (DCS-8/87)

III.2.1 See the procedure for DCR and follow exactly, except for labelling the container DCS-8/87, however, only Class A unstable materials are acceptable. Please see the S.E.G. license for further details on acceptable materials.

III.3 SMALL VOLUME LIQUIDS DESTINED FOR S.E.G. (SVS-8/87)

III.3.1 See the procedure for SVR and follow exactly, except for labelling the container SVS-8/87.

III.3.2 The liquids present must be strictly incidental. A couple of examples of incidental liquids are:
a) A drop in the end of a pipette
b) A couple of milliliters in the bottom of a vial
c) Moisture on the sides of a beaker.

III.3.3 Use the absorbant sparingly.

SPECIAL NOTE: In the SVS drum you may mix other dry waste which would be suitable for either the DMS or DCS container. You do not have to segregate these three types as long as the drum is classified as an SVS-8/87.

IV.0 SCINTILLATION VIAL WASTE FOR REPROCESSING AT QUADREX, GAINESVILLE, FLORIDA, (VXN, VRN, VXR, VRR)

These drums may contain scintillation vials which contain Toluene or Xylene or any other flammable scintillation media acceptable according to Quadrex's License No. 1354-1 (State of Florida, Department of Health & Rehabilitative Services).

All drums to Quadrex are packaged identically using the procedure below, however, the labelling and manifesting are specific to the classification selected. The generator is responsible for identifying the isotopes, concentrations and chemical forms of the waste material.

TELEDYNE ISOTOPES

IV.1 Select only a 30 or 55-gallon drum.

IV.2 Line the drum with 4 ml thick poly liner.

IV.3 Add 12 inches of an approved absorbant.

IV.4 Line drum again with another 4 ml thick poly liner.

IV.5 Fill with vials or other containers of less than one pint capacity. NOTE: With one pint containers, add absorbant to suitably cushion these to prevent breakage.

IV.6 Twist and seal liners.

IV.7 Top off the drum with additional absorbant.

IV.8 Secure drum cover.

IV.9 Label drum with the appropriate designation for the descriptions below.

V.10 Classification of Scintillation Vial Drums

As you know, there are many different types of scintillation fluids being used by the industry. The major difference between these fluids is their flashpoint. The state your facility is in may, or may not, regulate these fluids as hazardous waste. Although we have been and will continue to help identify when and where the RCRA regulations apply, it is the generator's responsibility under RCRA regulations to determine if his waste stream is a Hazardous Waste.

"<u>V</u>" - For marking purposes, all scintillation vial drums will have a first charcter of "V".

"<u>X</u>" or "<u>R</u>" - The second character will be either an "X" or an "R". If the drum contains only H-3/C-14 in less than 0.05 uCi/gram concentrations it is an "X". If the drum contains H-3/C-14 as above <u>plus</u> other isotopes listed in Quadrex's license, then it is an NRC "R"egulated material and would be an "R".

"<u>N</u>" or "<u>R</u>" - The third character indicates whether the drum is US EPA RCRA "R"egulated or "N"ot regulated. This classification is simple for those who use a high (greater than 140°F) flashpoint cocktail as these fluids are "N"ot RCRA regulated. If you have a cocktail with a lower flashpoint, the material may, or may not be, "R"egulated. This depends on each state. As the states are currently changing their positions rapidly, we have not included a listing from these procedures. Please call for further information.

PART 20

STANDARDS FOR PROTECTION AGAINST RADIATION

PART 20—STANDARDS FOR PROTECTION AGAINST RADIATION

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52 FR 4601

Authority: Secs. 53, 63, 65, 81, 103, 104, 161, 68 Stat. 930, 933, 935, 936, 937, 948, as amended (42 U.S.C. 2073, 2093, 2095, 2111, 2133, 2134, 2201); secs. 201, as amended, 202, 206, 88 Stat. 1242, as amended, 1244, 1246 (42 U.S.C. 5841, 5842, 5846).

For the purposes of sec. 223, 68 Stat. 958, as amended (42 U.S.C. 2273); §§ 20.101, 20.102, 20.103(a), (b) and (f), 20.104(a) and (b), 20.105(b), 20.106(a), 20.201, 20.202(a), 20.205, 20.207, 20.301, 20.303, 20.304, and 20.305 are issued under sec. 161b, 68 Stat. 948, as amended (42 U.S.C. 2201(b)); and §§ 20.102, 20.103(e), 20.401–20.407, 20.408(b), and 20.409 are issued under sec. 161(o), 68 Stat. 950, as amended (42 U.S.C. 2201(o)).

GENERAL PROVISIONS

§ 20.1 Purpose.

40 FR 8774

(a) The regulations in this part establish standards for protection against radiation hazards arising out of activities under licenses issued by the Nuclear Regulatory Commission and are issued pursuant to the Atomic Energy Act of 1954, as amended, and the Energy Reorganization Act of 1974.

44 FR 32352

(b) The use of radioactive material or other sources of radiation not licensed by the Commission is not subject to the regulations in this part. However, it is the purpose of the regulations in this part to control the possession, use, and transfer of licensed material by any licensee in such a manner that the total dose to an individual (including exposures to licensed and unlicensed radioactive material and to other unlicensed sources of radiation, whether in the possession of the licensee or any other person, but not including exposures to radiation from natural background sources or medical diagnosis and therapy) does not exceed the standards of radiation protection prescribed in the regulations in this part.

40 FR 58847

(c) In accordance with recommendations of the Federal Radiation Council, approved by the President, persons engaged in activities under licenses issued by the Nuclear Regulatory Commission pursuant to the Atomic Energy Act of 1954, as amended, and the Energy Reorganization Act of 1974 should, in addition to complying with the requirements set forth in this part, make every reasonable effort to maintain radiation exposures, and releases of radioactive materials in effluents to unrestricted areas, as low as is reasonably achievable. The term "as low as is reasonably achievable" means as low as is reasonably achievable taking into account the state of technology, and the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to the utilization of atomic energy in the public interest.

§ 20.2 Scope.

52 FR 8225

The regulations in this part apply to all persons who receive, possess, use, or transfer material licensed pursuant to the regulations in Parts 30 through 35, 39, 40, 60, 61, 70, or Part 72 of this chapter, including persons licensed to operate a production or utilization facility pursuant to Part 50 of this chapter and persons licensed to possess power reactor spent fuel in an independent spent fuel storage installation (ISFSI) pursuant to Part 72 of this chapter.

§ 20.3 Definitions.

40 FR 8774

(a) As used in this part:

(1) "Act" means the Atomic Energy Act of 1954 (68 Stat. 919) including any amendments thereto;

(2) "Airborne radioactive material" means any radioactive material dispersed in the air in the form of dusts, fumes, mists, vapors, or gases;

(3) "Byproduct material" means any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material;

40 FR 42557

(4) "Calendar quarter" means not less than 12 consecutive weeks nor more than 14 consecutive weeks. The first calendar quarter of each year shall begin in January and subsequent calendar quarters shall be such that no day is included in more than one calendar quarter or omitted from inclusion within a calendar quarter. No licensee shall change the method observed by him of determining calendar quarters except at the beginning of a calendar year.

(5) "Commission" means the Nuclear Regulatory Commission or its duly authorized representatives;

25 FR 10914

(6) "Government agency" means any executive department, commission, independent establishment, corporation, wholly or partly owned by the United States of America which is an instrumentality of the United States, or any board, bureau, division, service, office, officer, authority, administration, or other establishment in the executive branch of the Government;

(7) "Individual" means any human being;

(8) "Licensed material" means source material, special nuclear material, or by-product material received, possessed, used, or transferred under a general or specific license issued by the Commission pursuant to the regulations in this chapter;

52 FR 8225

(9) "License" means a license issued under the regulations in Parts 30 through 35, 39, 40, 60, 61, 70, or Part 72 of this chapter. "Licensee" means the holder of such license;

25 FR 10914

(10) "Occupational dose" includes exposure of an individual to radiation (i) in a restricted area; or (ii) in the course of employment in which the individual's duties involve exposure to radiation, provided, that "occupational dose" shall not be deemed to include any exposure of an individual to radiation for the purpose of medical diagnosis or medical therapy of such individual.

40 FR 8774

(11) "Person" means: (i) Any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, Government agency other than the Commission or the Department (except that the Department shall be considered a person within the meaning of the regulations in this part to the extent that its facilities and activities are subject to the licensing and related regulatory authority of the Commission pursuant to section 202 of the Energy Reorganization Act of 1974 (88 Stat. 1244)), any State, any foreign government or nation or any political subdivision of any such government or nation, or other entity; and (ii) any legal successor, representative, agent, or agency of the foregoing.

25 FR 10914

(12) "Radiation" means any or all of the following: alpha rays, beta rays, gamma rays, X-rays, neutrons, high-speed electrons, high-speed protons, and other atomic particles; but not sound or radio waves, or visible, infrared, or ultraviolet light;

(13) "Radioactive material" includes any such material whether or not subject to licensing control by the Commission;

25 FR 13952

(14) "Restricted area" means any area access to which is controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials. "Restricted area" shall not include any areas used as residental quarters, although a separate room or rooms in a residential building may be set apart as a restricted area;

27 FR 5905

(15) "Source material" means: (i) Uranium or thorium, or any combination thereof, in any physical or chemical form; or (ii) ores which contain by weight one-twentieth of one percent (0.05%) or more of (*a*) uranium, (*b*) thorium or (*c*) any combination thereof. Source material does not include special nuclear material.

25 FR 10914

(16) "Special nuclear material" means: (i) Plutonium, uranium 233, uranium enriched in the isotope 233 or in the isotope 235, and any other material which the Commission, pursuant to the provisions of section 51 of the act, determines to be special nuclear material, but does not include source material; or (ii) any material artificially enriched by any of the foregoing but does not include source material;

25 FR 13952

(17) "Unrestricted area" means any area access to which is not controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials, and any area used for residential quarters.

(18) "Department" means the Department of Energy established by the Department of Energy Organization Act (Pub. L. 95-91, 91 Stat. 565, 42 U.S.C. 7101 *et seq.*) to the extent that the Department, or its duly authorized representatives, exercises functions formerly vested in the U.S. Atomic Energy Commission, its Chairman, members, officers and components and transferred to the U.S. Energy Research and Development Administration and to the Administrator thereof pursuant to sections 104 (b), (c) and (d) of the Energy Reorganization Act of 1974 (Pub. L. 93-438, 88 Stat. 1233 at 1237, 42 U.S.C. 5814) and retransferred to the Secretary of Energy pursuant to section 301(a) of the Department of Energy Organization Act (Pub. L. 95-91, 91 Stat. 565 at 577-578, 42 U.S.C. 7151).

44 FR 32352

(19) "Termination" means the end of employment with the licensee or, in the case of individuals not employed by the licensee, the end of a work assignment in the licensee's restricted areas in a given calendar quarter, without expectation or specific scheduling of reentry into the licensee's restricted areas during the remainder of that calendar quarter.

25 FR 10914

(b) Definitions of certain other words and phrases as used in this part are set forth in other sections, including:

(1) "Airborne radioactivity area" defined in § 20.203;

(2) "Radiation area" and "high radiation area" defined in § 20.202;

(3) "Personnel monitoring equipment" defined in § 20.202;

(4) "Survey" defined in § 20.201;

(5) Units of measurement of dose (rad, rem) defined in § 20.4;

(6) Units of measurement of radioactivity defined in § 20.5.

52 FR 4601

(20) "Dosimetry processor" means an individual or an organization that processes and evaluates personnel monitoring equipment in order to determine the radiation dose delivered to the equipment.

25 FR 10914

§ 20.4 Units of radiation dose.

(a) "Dose," as used in this part, is the quantity of radiation absorbed, per unit of mass, by the body or by any portion of the body. When the regulations in this part specify a dose during a period of time, the dose means the total quantity of radiation absorbed, per unit of mass, by the body or by any portion of the body during such period of time. Several different units of dose are in current use. Definitions of units as used in this part are set forth in paragraphs (b) and (c) of this section.

(b) The rad, as used in this part, is a measure of the dose of any ionizing radiation to body tissues in terms of the energy absorbed per unit mass of the tissue. One rad is the dose corresponding to the absorption of 100 ergs per gram of tissue. (One millirad (mrad) = 0.001 rad.)

(c) The rem, as used in this part, is a measure of the dose of any ionizing radiation to body tissues in terms of its estimated biological effect relative to a dose of one roentgen (r) of X-rays. (One millirem (mrem) = 0.001 rem.) The relation of the rem to other dose units depends upon the biological effect under consideration and upon the conditions of irradiation. For the purpose of the regulations in this part, any of the following is considered to be equivalent to a dose of one rem:

(1) A dose of 1 r due to X– or gamma radiation;

(2) A dose of 1 rad due to X–, gamma, or beta radiation;

(3) A dose of 0.1 rad due to neutrons or high energy protons;

(4) A dose of 0.05 rad due to particles heavier than protons and with sufficient energy to reach the lens of the eye; If it is more convenient to measure the neutron flux, or equivalent, than to determine the neutron dose in rads, as provided in paragraph (c)(3) of this section, one rem of neutron radiation may, for purposes of the regulations in this part, be assumed to be equivalent to 14 million neutrons per square centimeter incident upon the body; or, if there exists sufficient information to estimate with reasonable accuracy the approximate distribution in energy of the neutrons, the incident number of neutrons per square centimeter equivalent to one rem may be estimated from the following table:

NEUTRON FLUX DOSE EQUIVALENTS

Neutron energy (Mev)	Number of neutrons per square centimeter equivalent to a dose of 1 rem (neutrons/cm²)	Average flux to deliver 100 millirem in 40 hours (neutrons/cm² sec.)
Thermal	970×10^6	670
0.0001	720×10^6	500
0.005	820×10^6	570
0.02	400×10^6	280
0.1	120×10^6	80
0.5	43×10^6	30
1.0	26×10^6	18
2.5	29×10^6	20
5.0	26×10^6	18
7.5	24×10^6	17
10	24×10^6	17
10 to 30	14×10^6	10

(d) For determining exposures to X or gamma rays up to 3 Mev, the dose limits specified in §§ 20.101 to 20.104, inclusive, may be assumed to be equivalent to the "air dose". For the purpose of this part "air dose" means that the dose is measured by a properly calibrated appropriate instrument in air at or near the body surface in the region of highest dosage rate.

§ 20.5 Units of radioactivity.

(a) Radioactivity is commonly, and for purposes of the regulations in this part shall be, measured in terms of disintegrations per unit time or in curies. One curie $= 3.7 \times 10^{10}$ disintegrations per second (dps) $= 2.2 \times 10^{12}$ disintegrations per minute (dpm). Commonly used submultiples of the curie are the millicurie and the microcurie:

(1) One millicurie (mCi) $= 0.001$ curie (Ci) $= 3.7 \times 10^7$ dps.

(2) One microcurie (µCi) $= 0.000001$ curie $= 3.7 \times 10^4$ dps.

(b) [Deleted 40 FR 50704.]

(c) [Deleted 39 FR 23990.]

§ 20.6 Interpretations.

Except as specifically authorized by the Commission in writing, no interpretation of the meaning of the regulations in this part by any officer or employee of the Commission other than a written interpretation by the General Counsel will be recognized to be binding upon the Commission.

§ 20.7 Communications.

Except where otherwise specified in this part, all communications and reports concerning the regulations in this part should be addressed to the Executive Director for Operations, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555. Communications, reports, and applications may be delivered in person at the Commission's offices at 1717 H Street NW., Washington, D.C.; or at 7920 Norfolk Avenue, Bethesda, Maryland.

§ 20.8 Information collection requirements: OMB approval.

(a) The Nuclear Regulatory Commission has submitted the information collection requirements contained in this part to the Office of Management and Budget (OMB) for approval as required by the Paperwork Reduction Act of 1980 (44 U.S.C. 3501 et seq.). OMB has approved the information collection requirements contained in this part under control number 3150-0014.

(b) The approved information collection requirements contained in this part appear in §§ 20.102, 20.103, 20.105, 20.106, 20.203, 20.205, 20.302, 20.311, 20.401, 20.402, 20.403, 20.405, 20.407, 20.408, and 20.409.

(c) This part contains information collection requirements in addition to those approved under the control number specified in paragraph (a) of this section. These information collection requirements and the control numbers under which they are approved are as follows:

(1) In §§ 20.101 and 20.102, Form NRC-4 is approved under control number 3150-0005.

(2) In § 20.401, Form NRC-5 is approved under control number 3150-0006.

PERMISSIBLE DOSES, LEVELS, AND CONCENTRATIONS

§ 20.101 Radiation dose standards for individuals in restricted areas.

(a) In accordance with the provisions of § 20.102(a), and except as provided in paragraph (b) of this section, no licensee shall possess, use, or transfer licensed material in such a manner as to cause any individual in a restricted area to receive in any period of one calendar quarter from radioactive material and other sources of radiation a total occupational dose in excess of the standards specified in the following table:

REMS PER CALENDAR QUARTER

1. Whole body; head and trunk; active blood-forming organs; lens of eyes; or gonads	1¼
2. Hands and forearms; feet and ankles	18¾
3. Skin of whole body	7½

(b) A licensee may permit an individual in a restricted area to receive a total occupational dose to the whole body greater than that permitted under paragraph (a) of this section, provided:

(1) During any calendar quarter the total occupational dose to the whole body shall not exceed 3 rems; and

(2) The dose to the whole body, when added to the accumulated occupational dose to the whole body, shall not exceed 5 (N-18) rems where "N" equals the individual's age in years at his last birthday; and

(3) The licensee has determined the individual's accumulated occupational dose to the whole body on Form NRC-4, or on a clear and legible record containing all the information required in that form; and has otherwise complied with the requirements of § 20.102. As used in paragraph (b), "Dose to the whole body" shall be deemed to include any dose to the whole body, gonads, active blood-forming organs, head and trunk, or lens of eye.

§ 20.102 Determination of prior dose.

(a) Each licensee shall require any individual, prior to first entry of the individual into the licensee's restricted area during each employment or work assignment under such circumstances that the individual will receive or is likely to receive in any period of one calendar quarter an occupational dose in excess of 25 percent of the applicable standards specified in § 20.101(a) and § 20.104(a), to disclose in a written, signed statement, either: (1) That the individual had no prior occupational dose during the current calendar quarter, or (2) the nature and amount of any occupational dose which the individual may have received during that specifically identified current calendar quarter from sources of radiation possessed or controlled by other persons. Each licensee shall maintain records of such statements until the Commission authorizes their disposition.

(b) Before permitting, pursuant to § 20.101(b), any individual in a restricted area to receive an occupational radiation dose in excess of the standards specified in § 20.101(a), each licensee shall:

(1) Obtain a certificate on Form NRC-4, or on a clear and legible record containing all the information required in that form, signed by the individual showing each period of time after the individual attained the age of 18 in which the individual received an occupational dose of radiation; and

(2) Calculate on Form NRC-4 in accordance with the instructions appearing therein, or on a clear and legible record containing all the information required in that form, the previously accumulated occupational dose received by the individual and the additional dose allowed for that individual under § 20.101(b).

38 FR [illegible]

(c)(1) In the preparation of Form NRC-4, or a clear and legible record containing all the information required in that form, the licensee shall make a reasonable effort to obtain reports of the individual's previously accumulated occupational dose. For each period for which the licensee obtains such reports, the licensee shall use the dose shown in the report in preparing the form. In any case where a licensee is unable to obtain reports of the individual's occupational dose for a previous complete calendar quarter, it shall be assumed that the individual has received the occupational dose specified in whichever of the following columns apply:

25 FR 10914

Part of body	Column 1—Assumed exposure in rems for calendar quarters prior to Jan. 1, 1961	Column 2—Assumed exposure in rems for calendar quarters beginning on or after Jan. 1, 1961
Whole body, gonads, active blood-forming organs, head and trunk, lens of eye	3¾	1¼

41 FR 18300

(2) The licensee shall retain and preserve records used in preparing Form NRC-4 until the Commission authorizes their disposition.

25 FR 10914

If calculation of the individual's accumulated occupational dose for all periods prior to January 1, 1961 yields a result higher than the applicable accumulated dose value for the individual as of that date, as specified in paragraph (b) of § 20.101, the excess may be disregarded.

§ 20.103 Exposure of individuals to concentrations of radioactive materials in air in restricted areas.

(a)(1) No licensee shall possess, use, or transfer licensed material in such a manner as to permit any individual in a restricted area to inhale a quantity of radioactive material in any period of one calendar quarter greater than the quantity which would result from inhalation for 40 hours per week for 13 weeks at uniform concentrations of radioactive material in air specified in Appendix B, Table I, Column 1. [1] [2] [3] If

41 FR 52300

the radioactive material is of such form that intake by absorption through the skin is likely, individual exposures to radioactive material shall be controlled so that the uptake of radioactive material by any organ from either inhalation or absorption or both routes of intake [4] [5] in any calendar quarter does not exceed that which would result from inhaling such radioactive material for 40 hours per week for 13 weeks at uniform concentrations specified in Appendix B, Table I, Column 1.

(2) No licensee shall possess, use, or transfer mixtures of U-234, U-235, and U-238 in soluble form in such a manner as to permit any individual in a restricted area to inhale a quantity of such material in excess of the intake limits specified in Appendix B, Table I, Column 1 of this part. If such soluble uranium is of a form such that absorption through the skin is likely, individual exposures to such material shall be controlled so that the uptake of such material by any organ from either inhalation or absorption or both routes of intake [4] does not exceed that which would result from inhaling such material at the limits specified in Appendix B, Table I, Column 1 and footnote 4 thereto.

(3) For purposes of determining compliance with the requirements of this section the licensee shall use suitable measurements of concentrations of radioactive materials in air for detecting and evaluating airborne radioactivity in restricted areas and in addition, as appropriate, shall use measurements of radioactivity in the body, measurements of radioactivity excreted from the body, or any combination of such measurements as may be necessary for timely detection and assessment of individual intakes of radioactivity by exposed individuals. It is assumed that an individual inhales radioactive material at the airborne concentration in which he is present unless he uses respiratory protective equipment pursuant to paragraph (c) of this section. When assessment of a particular individual's intake of radioactive material is necessary, intakes less than those which would result from inhalation for 2 hours in any one day or for 10 hours in any one week at uniform concentrations specified in Appendix B, Table I, Column 1 need not be included in such assessment, provided that for any assessment in excess of these amounts the entire amount is included.

41 FR 52300

(b)(1) The licensee shall, as a precautionary procedure, use process or other engineering controls, to the extent practicable, to limit concentrations of radioactive materials in air to levels below those which delimit an airborne radioactivity area as defined in § 20.203(d)(1)(ii).

(2) When it is impracticable to apply process or other engineering controls to limit concentrations of radioactive material in air below those defined in § 20.203(d)(1)(ii), other precautionary procedures, such as increased surveillance, limitation of working times, or provision of respiratory protective equipment, shall be used to maintain intake of radioactive material by any individual within any period of seven consecutive days as far below that intake of radioactive material which would result from inhalation of such material for 40 hours at the uniform concentrations specified in Appendix B, Table 1, Column 1 as is reasonably achievable. Whenever the intake of radioactive material by any individual exceeds this 40-hour control measure, the licensee shall make such evaluations and take such actions as are necessary to assure against recurrence. The licensee shall maintain records of such occurrences, evaluations, and actions taken in a clear and readily identifiable form suitable for summary review and evaluation.

41 FR 52300

47 FR 16162

(c) When respiratory protective equipment is used to limit the inhalation of airborne radioactive material pursuant to paragraph (b)(2) of this section, the licensee shall use equipment that is certified or had certification extended by the National Institute for Occupational Safety and Health/Mine Safety and Health Administration (NIOSH/MSHA). The licensee may make allowance for this use of respiratory protective equipment in estimating exposures of individuals to this material provided that.

43 FR 29218

[1] Since the concentration specified for tritium oxide vapor assumes equal intakes by skin absorption and inhalation, the total intake permitted is twice that which would result from inhalation alone at the concentration specified for H 3 S in Appendix B, Table I, Column 1 for 40 hours per week for 13 weeks.

[2] For radon-222, the limiting quantity is that inhaled in a period of one calendar year. For radioactive materials designated "Sub" in the "Isotope" column of the table, the concentration value specified is based upon exposure to the material as an external radiation source. Individual exposures to these materials may be accounted for as part of the limitation on individual dose in § 20.101. These nuclides shall be subject to the precautionary procedures required by § 20.103(b)(1).

[3] Multiply the concentration values specified in Appendix B, Table I, Column 1, by 6.3×10^8 ml to obtain the quarterly quantity limit. Multiply the concentration value specified in Appendix B, Table I, Column 1, by 2.5×10^9 ml to obtain the annual quantity limit for Rn-222.

[4] Significant intake by ingestion or injection is presumed to occur only as a result of circumstances such as accident, inadvertence, poor procedure, or similar special conditions. Such intakes must be evaluated and accounted for by techniques and procedures as may be appropriate to the circumstances of the occurrence. Exposures so evaluated shall be included in determining whether the limitation on individual exposures in § 20.103(a)(1) has been exceeded.

[5] Regulatory guidance on assessment of individual intakes of radioactive material is given in Regulatory Guide 8.9, "Acceptable Concepts, Models, Equations and Assumptions for a Bioassay Program," single copies of which are available from the Office of Standards Development, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, upon written request.

47 FR 16162

(1) The licensee selects respiratory protective equipment that provides a protection factor greater than the multiple by which peak concentrations of airborne radioactive materials in the working area are expected to exceed the values specified in Appendix B, Table I, Column 1 of this part. The equipment so selected shall be used so that the average concentration of radioactive material in the air that is inhaled during any period of uninterrupted use in an airborne radioactivity area, on any day, by any individual using the equipment, does not exceed the values specified in Appendix B, Table I, Column 1 of this part. For the purposes of this paragraph, the concentration of radioactive material in the air that is inhaled when respirators are worn may be estimated by dividing the ambient concentration in air by the protection factor specified in Appendix A of this part. If the exposure is later found to be greater than estimated, the corrected value shall be used; if the exposure is later found to be less than estimated, the corrected value may be used.

(2) The licensee maintains and implements a respiratory protection program that includes, as a minimum: air sampling sufficient to identify the hazard, permit proper equipment selection and estimate exposures; surveys and bioassays as appropriate to evaluate actual exposures; written procedures regarding selection, fitting, and maintenance of respirators, and testing of respirators for operability immediately prior to each use; written procedures regarding supervision and training of personnel and issuance records; and determination by a physician prior to initial use of respirators, and at least every 12 months thereafter, that the individual user is physically able to use the respiratory protective equipment.

(3) A written policy statement on respirator usage shall be issued covering such things as: use of practicable engineering controls instead of respirators; routine, nonroutine, and emergency use of respirators; and periods of respirator use and relief from respirator use. The licensee shall advise each respirator user that the user may leave the area at any time for relief from respirator use in the event of equipment malfunction, physical or psychological distress, procedural or communication failure, significant deterioration of operating conditions, or any other condition that might require such relief.

(4) The licensee uses equipment within limitations for type and mode of use and provides proper visual, communication, and other special capabilities (such as adequate skin protection) when needed.

(d) Unless otherwise authorized by the Commission, the licensee shall not assign protection factors in excess of those specified in Appendix A of this part in selecting and using respiratory protective equipment. The Commission may authorize a licensee to use higher protection factors on receipt of an application (1) describing the situation for which a need exists for higher protection factors, and (2) demonstrating that the respiratory protective equipment will provide these higher protection factors under the proposed conditions of use.

47 FR 16162

(e) Where equipment of a particular type has not been tested and certified, or had certification extended, by NIOSH/MSHA, or where there is no existing schedule for test and certification of certain equipment, the licensee shall not make allowance for this equipment without specific authorization by the Commission. An application for this authorization must include a demonstration by testing, or on the basis of reliable test information, that the material and performance characteristics of the equipment are capable of providing the proposed degree of protection under anticipated conditions of use.

(f) Only equipment that has been specifically certified or had certification extended for emergency use by NIOSH/MSHA shall be used as emergency devices.

(g) The licensee shall notify, in writing, the Director of the appropriate Nuclear Regulatory Commission Inspection and Enforcement Regional Office listed in Appendix D at least 30 days before the date that respiratory protective equipment is first used under the provisions of this section.

25 FR 10914

§ 20.104 Exposure of minors.

(a) No licensee shall possess, use, or transfer licensed material in such a manner as to cause any individual within a restricted area who is under 18 years of age, to receive in any period of one calendar quarter from radioactive material and other sources of radiation in the licensee's possession a dose in excess of 10 percent of the limits specified in the table in paragraph (a) of § 20.101.

(b) No licensee shall possess, use or transfer licensed material in such a manner as to cause any individual within a restricted area, who is under 18 years of age to be exposed to airborne radioactive material possessed by the licensee in an average concentration in excess of the limits specified in Appendix B, Table II of this part. For purposes of this paragraph, concentrations may be averaged over periods not greater than a week.

41 FR 52302

(c) The provisions of §§ 20.103(b)(2) and 20.103(c) shall apply to exposures subject to paragraph (b) of this section except that the references in §§ 20.103(b)(2) and 20.103(c) to Appendix B, Table I, Column 1 shall be deemed to be references to Appendix B, Table II, Column 1.

25 FR 10914

§ 20.105 Permissible levels of radiation in unrestricted areas.

(a) There may be included in any application for a license or for amendment of a license proposed limits upon levels of radiation in unrestricted areas resulting from the applicant's possession or use of radioactive material and other sources of radiation. Such applications should include information as to anticipated average radiation levels and anticipated occupancy times for each unrestricted area involved. The Commission will approve the proposed limits if the applicant demonstrates that the proposed limits are not likely to cause any individual to receive a dose to the whole body in any period of one calendar year in excess of 0.5 rem.

(b) Except as authorized by the Commission pursuant to paragraph (a) of this section, no licensee shall possess, use or transfer licensed material in such a manner as to create in any unrestricted area from radioactive material and other sources of radiation in his possession:

(1) Radiation levels which, if an individual were continuously present in the area, could result in his receiving a dose in excess of two millirems in any one hour, or

(2) Radiation levels which, if an individual were continuously present in the area, could result in his receiving a dose in excess of 100 millirems in any seven consecutive days.

46 FR 18525

(c) In addition to other requirements of this part, licensees engaged in uranium fuel cycle operations subject to the provisions of 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operations," shall comply with that part.

29 FR 14434

§ 20.106 Radioactivity in effluents to unrestricted areas.

(a) A licensee shall not possess, use, or transfer licensed material so as to release to an unrestricted area radioactive material in concentrations which exceed the limits specified in Appendix B, Table II of this part, except as authorized pursuant to § 20.302 or paragraph (b) of this section. For purposes of this section concentrations may be averaged over a period not greater than one year.

(b) An application for a license or amendment may include proposed limits higher than those specified in paragraph (a) of this section. The Commission will approve the proposed limits if the applicant demonstrates:

(1) That the applicant has made a reasonable effort to minimize the radioactivity contained in effluents to unrestricted areas; and

(2) That it is not likely that radioactive material discharged in the effluent would result in the exposure of an individual to concentrations of radioactive material in air or water exceeding the limits specified in Appendix B, Table II of this part.

(c) An application for higher limits pursuant to paragraph (b) of this section shall include information demonstrating that the applicant has made a reasonable effort to minimize the radioactivity discharged in effluents to unrestricted areas, and shall include, as pertinent:

(1) Information as to flow rates, total volume of effluent, peak concentration of each radionuclide in the effluent, and concentration of each radionuclide in the effluent averaged over a period of one year at the point where the effluent leaves a stack, tube, pipe, or similar conduit;

29 FR 14434

(2) A description of the properties of the effluents, including:

(i) Chemical composition;

(ii) Physical characteristics, including suspended solids content in liquid effluents, and nature of gas or aerosol for air effluents;

(iii) The hydrogen ion concentrations (p^H) of liquid effluents; and

(iv) The size range of particulates in effluents released into air.

(3) A description of the anticipated human occupancy in the unrestricted area where the highest concentration of radioactive material from the effluent is expected, and, in the case of a river or stream, a description of water uses downstream from the point of release of the effluent.

(4) Information as to the highest concentration of each radionuclide in an unrestricted area, including anticipated concentrations averaged over a period of one year:

(i) In air at any point of human occupancy; or

(ii) In water at points of use downstream from the point of release of the effluent.

(5) The background concentration of radionuclides in the receiving river or stream prior to the release of liquid effluent.

(6) A description of the environmental monitoring equipment, including sensitivity of the system, and procedures and calculations to determine concentrations of radionuclides in the unrestricted area and possible concentrations of radionuclides.

(7) A description of the waste treatment facilities and procedures used to reduce the concentration of radionuclides in effluents prior to their release.

29 FR 14434

(d) For the purposes of this section the concentration limits in Appendix B, Table II of this part shall apply at the boundary of the restricted area. The concentration of radioactive material discharged through a stack, pipe or similar conduit may be determined with respect to the point where the material leaves the conduit. If the conduit discharges within the restricted area, the concentration at the boundary may be determined by applying appropriate factors for dilution, dispersion, or decay between the point of discharge and the boundary.

(e) In addition to limiting concentrations in effluent streams, the Commission may limit quantities of radioactive materials released in air or water during a specified period of time if it appears that the daily intake of radioactive material from air, water, or food by a suitable sample of an exposed population group, averaged over a period not exceeding one year, would otherwise exceed the daily intake resulting from continuous exposure to air or water containing one-third the concentration of radioactive materials specified in Appendix B, Table II of this part.

46 FR 18525

(f) The provisions of paragraphs (a) through (e) of this section do not apply to disposal of radioactive material into sanitary sewerage systems, which is governed by § 20.303.

(g) In addition to other requirements of this part, licensees engaged in uranium fuel cycle operations subject to the provisions of 40 CFR Part 190, "Environmental Radiation Protection Standard for Nuclear Power Operations," shall comply with that part.

25 FR 10914

§ 20.107 Medical diagnosis and therapy.

Nothing in the regulations in this part shall be interpreted as limiting the intentional exposure of patients to radiation for the purpose of medical diagnosis or medical therapy.

§ 20.108 Orders requiring furnishing of bio-assay services.

Where necessary or desirable in order to aid in determining the extent of an individual's exposure to concentrations of radioactive material, the Commission may incorporate appropriate provisions in any license, directing the licensee to make available to the individual appropriate bio-assay services and to furnish a copy of the reports of such services to the Commission.

PRECAUTIONARY PROCEDURES

§ 20.201 Surveys.

25 FR 10914

(a) As used in the regulations in this part, "survey" means an evaluation of the radiation hazards incident to the production, use, release, disposal, or presence of radioactive materials or other sources of radiation under a specific set of conditions. When appropriate, such evaluation includes a physical survey of the location of materials and equipment, and measurements of levels of radiation or concentrations of radioactive material present.

46 FR 53647

(b) Each licensee shall make or cause to be made such surveys as (1) may be necessary for the licensee to comply with the regulations in this part, and (2) are reasonable under the circumstances to evaluate the extent of radiation hazards that may be present.

§ 20.202 Personnel monitoring.

(a) Each licensee shall supply appropriate personnel monitoring equipment to, and shall require the use of such equipment by:

(1) Each individual who enters a restricted area under such circumstances that he receives, or is likely to receive, a dose in any calendar quarter in excess of 25 percent of the applicable value specified in paragraph (a) of § 20.101.

25 FR 10914

(2) Each individual under 18 years of age who enters a restricted area under such circumstances that he receives, or is likely to receive, a dose in any calendar quarter in excess of 5 percent of the applicable value specified in paragraph (a) of § 20.101.

(3) Each individual who enters a high radiation area.

(b) As used in this part,

(1) "Personnel monitoring equipment" means devices designed to be worn or carried by an individual for the purpose of measuring the dose received (e.g., film badges, pocket chambers, pocket dosimeters, film rings, etc.);

(2) "Radiation area" means any area, accessible to personnel, in which there exists radiation, originating in whole or in part within licensed material, at such levels that a major portion of the body could receive in any one hour a dose in excess of 5 millirem, or in any 5 consecutive days a dose in excess of 100 millirems;

(3) "High radiation area" means any area, accessible to personnel, in which there exists radiation originating in whole or in part within licensed material at such levels that a major portion of the body could receive in any one hour a dose in excess of 100 millirem.

52 FR 4601

(c) All personnel dosimeters (except for direct and indirect reading pocket ionization chambers and those dosimeters used to measure the dose to hands and forearms, feet and ankles) that require processing to determine the radiation dose and that are utilized by licensees to comply with paragraph (a) of this section, with other applicable provisions of 10 CFR Chapter I, or with conditions specified in a licensee's license must be processed and evaluated by a dosimetry processor:

(1) Holding current personnel dosimetry accreditation from the National Voluntary Laboratory Accreditation Program (NVLAP) of the National Bureau of Standards, and

(2) Approved in this accreditation process for the type of radiation or radiations included in the NVLAP program that most closely approximate the type of radiation or radiations for which the individual wearing the dosimeter is monitored.

Note: (c) effective 2/12/88.

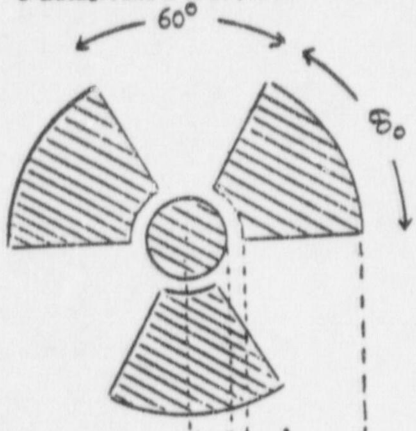
35 FR 5033

§ 20.203 Caution signs, labels, signals and controls.

(a) *General.* (1) Except as otherwise authorized by the Commission, symbols prescribed by this section shall use the conventional radiation caution colors (magenta or purple on yellow background). The symbol prescribed by this section is the conventional three-bladed design:

RADIATION SYMBOL

1. Cross-hatched area is to be magenta or purple.
2. Background is to be yellow.



(2) In addition to the contents of signs and labels prescribed in this section, licensees may provide on or near such signs and labels any additional information which may be appropriate in aiding individuals to minimize exposure to radiation or to radioactive material.

(b) *Radiation areas.* Each radiation area shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION[1]

RADIATION AREA

(c) *High radiation areas.* (1) Each high radiation area shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION[1]

HIGH RADIATION AREA

(2) Each entrance or access point to a high radiation area shall be:

(i) Equipped with a control device which shall cause the level of radiation to be reduced below that at which an individual might receive a dose of 100 millirems in 1 hour upon entry into the area; or

(ii) Equipped with a control device which shall energize a conspicuous visible or audible alarm signal in such a manner that the individual entering the high radiation area and the licensee or a supervisor of the activity are made aware of the entry; or

(iii) Maintained locked except during periods when access to the area is required, with positive control over each individual entry.

(3) The controls required by paragraph (c)(2) of this section shall be established in such a way that no individual will be prevented from leaving a high radiation area.

(4) In the case of a high radiation area established for a period of 30 days or less, direct surveillance to prevent unauthorized entry may be substituted for the controls required by paragraph (c)(2) of this section.

(5) Any licensee, or applicant for a license, may apply to the Commission for approval of methods not included in paragraphs (c)(2) and (4) of this section for controlling access to high radiation areas. The Commission will approve the proposed alternatives if the licensee or applicant demonstrates that the alternative methods of control will prevent unauthorized entry into a high radiation area, and that the requirement of paragraph (c)(3) of this section is met.

42 FR 64619

(6) Each area in which there may exist radiation levels in excess of 500 rems in one hour at one meter from a sealed radio-active source[2] that is used to irradiate materials shall:[3]

43 FR 2167

(i) Have each entrance or access point equipped with entry control devices which shall function automatically to prevent any individual from inadvertently entering the area when such radiation levels exist; permit deliberate entry into the area only after a control device is actuated that shall cause the radiation level within the area, from the sealed source, to be reduced below that at which it would be possible for an individual to receive a dose in excess of 100 mrem in one hour; and prevent operation of the source if the source would produce radiation levels in the area that could result in a dose to an individual in excess of 100 mrem in one hour. The entry control devices required by this paragraph (c)(6) shall be established in such a way that no individual will be prevented from leaving the area.

42 FR 64619

(ii) Be equipped with additional control devices such that upon failure of the entry control devices to function as required by paragraph (c)(6)(i) of this section the radiation level within the area, from the sealed source, shall be reduced below that at which it would be possible for an individual to receive a dose in excess of 100 mrem in one hour; and visible and audible alarm signals shall be generated to make an individual attempting to enter the area aware of the hazard and the licensee or at least one other individual, who is familiar with the activity and prepared to render or summon assistance, aware of such failure of the entry control devices.

(iii) Be equipped with control devices such that upon failure or removal of physical radiation barriers other than the source's shielded storage container the radiation level from the source shall be reduced below that at which it would be possible for an individual to receive a dose in excess of 100 mrem in one hour; and visible and audible alarm signals shall be generated to make potentially affected individuals aware of the hazard and the licensee or at least one other individual, who is familiar with the activity and prepared to render or summon assistance, aware of the failure or removal of the physical barrier. When the shield for the stored source is a liquid, means shall be provided to monitor the integrity of the shield and to signal, automatically, loss of adequate shielding. Physical radiation barriers that com-

[1] Or "Danger".

[2] This paragraph (c)(6) does not apply to radioactive sources that are used in teletherapy, in radiography, or in completely self-shielded irradiators in which the source is both stored and operated within the same shielding radiation barrier and, in the designed configuration of the irradiator, is always physically inaccessible to any individual and cannot create high levels of radiation in an area that is accessible to any individual. This paragraph (c)(6) also does not apply to sources from which the radiation is incidental to some other use nor to nuclear reactor generated radiation other than radiation from byproduct, source, or special nuclear materials that are used in sealed sources in non-self-shielded irradiators.

[3] These requirements apply after Mar. 14, 1978. Each person licensed to conduct activities to which this paragraph (c)(6) applies and who is not in compliance with the provisions of this paragraph on Mar. 14, 1978, shall file with the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, on or before June 14, 1978, information describing in detail the actions taken or to be taken to achieve compliance with this paragraph by Dec. 14, 1978, and may continue activities in conformance with present license conditions and the provisions of the previously effective § 20.203d until such compliance is achieved. For such persons compliance must be achieved not later than Dec. 14, 1978.

prise permenent structural components, such as walls, that have no credible probability of failure or removal in ordinary circumstances need not meet the requirements of this paragraph (c)(6)(iii).

42 FR 64619

(iv) Be equipped with devices that will automatically generate visible and audible alarm signals to alert personnel in the area before the source can be put into operation and in sufficient time for any individual in the area to operate a clearly identified control device which shall be installed in the area and which can prevent the source from being put into operation.

43 FR 21[illegible]

(v) Be controlled by use of such administrative procedure and such devices as are necessary to assure that the area is cleared of personnel prior to each use of the source preceding which use it might have been possible for an individual to have entered the area.

42 FR 64619

(vi) Be checked by a physical radiation measurement to assure that prior to the first individual's entry into the area after any use of the source, the radiation level from the source in the area is below that at which it would be possible for an individual to receive a dose in excess of 100 mrem in one hour.

(vii) Have entry control devices required in paragraph (c)(6)(i) of this section which have been tested for proper functioning prior to initial operation with such source of radiation on any day that operations are not uninterruptedly continued from the previous day or before resuming operations after any unintended interruption, and for which records are kept of the dates, times, and results of such tests of function. No operations other than those necessary to place the source in safe condition or to effect reparis on controls shall be conducted with such source unless control devices are functioning properly. The licensee shall submit an acceptable schedule for more complete periodic tests of the entry control and warning systems to be established and adhered to as a condition of the license.

(viii) Have those entry and exit portals that are used in transporting materials to and from the irradiation area, and that are not intended for use by individuals, controlled by such devices and administrative procedures as are necessary to physically protect and warn against inadvertent entry by any individual through such portals. Exit portals for processed materials shall be equipped to detect and signal the presence of loose radiation sources that are carried toward such an exit and to automatically prevent such loose sources from being carried out of the area.

43 FR 2167

(7) Licensees with, or applicants for, licenses for radiation sources that are within the purview of paragraph (c)(6) of this section, and that must be used in a variety of positions or in peculiar locations, such as open fields or forests, that make it impracticable to comply with certain requirements of paragraph (c)(6) of this section, such as those for the automatic control of radiation levels, may apply to the Director, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, for approval, prior to use of safety measures that are alternative to those specified in paragraph (c)(6) of this section, and that will provide at least an equivalent degree of personnel protection in the use of such sources. At least one of the alternative measures must include an entry-preventing interlock control based on a physical measurement of radiation that assures the absence of high radiation levels before an individual can gain access to an area where such sources are used.

25 FR 10914

(d) *Airborne radioactivity areas.* (1) As used in the regulations in this part "airborne radioactivity area" means (i) any room, enclosure, or operating area in which airborne radioactive materials composed wholly or partly of licensed material, exist in concentrations in excess of the amounts specified in Appendix B, Table I, Column 1 of this part; or (ii) any room, enclosure, or operating area in which airborne radioactive material composed wholly or partly of licensed material exists in concentrations which, averaged over the number of hours in any week during which individuals are in the area, exceed 25 percent of the amounts specified in Appendix B Table I, Column 1 of this part.

(2) Each airborne radioactivity area shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words

CAUTION [1]

AIRBORNE RADIOACTIVITY AREA

(e) *Additional requirements.* (1) Each area or room in which licensed material is used or stored and which contains any radioactive material (other than natural uranium or thorium) in an amount exceeding 10 times the quantity of such material specified in Appendix C of this part shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION [1]

RADIOACTIVE MATERIAL(S)

25 FR 10914

(2) Each area or room in which natural uranium or thorium is used or stored in any amount exceeding one hundred times the quantity specified in Appendix C of this part shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION [1]

RADIOACTIVE MATERIAL(S)

31 FR 10514

(f) *Containers.* (1) Except as provided in paragraph (f)(3) of this section, each container of licensed material shall bear a durable, clearly visible label identifying the radioactive contents.

(2) A label required pursuant to paragraph (f)(1) of this section shall bear the radiation caution symbol and the words "CAUTION, RADIOACTIVE MATERIAL" or "DANGER, RADIOACTIVE MATERIAL". It shall also provide sufficient information [2] to permit individuals handling or using the containers, or working in the vicinity thereof, to take precautions to avoid or minimize exposures.

(3) Notwithstanding the provisions of paragraph (f)(1) of this section labeling is not required:

(i) For containers that do not contain licensed materials in quantities greater than the applicable quantities listed in Appendix C of this part.

(ii) For containers containing only natural uranium or thorium in quantities no greater than 10 times the applicable quantities listed in Appendix C of this part.

(iii) For containers that do not contain licensed materials in concentrations greater than the applicable concentrations listed in Appendix B, Table I, Column 2, of this part.

(iv) For containers when they are attended by an individual who takes the precautions necessary to prevent the exposure of any individual to radiation or radioactive materials in excess of the limits established by the regulations in this part.

34 FR 19546

(v) For containers when they are in transport and packaged and labeled in accordance with regulations of the Department of Transportation.

31 FR 10514

(vi) For containers which are accessible [3] only to individuals authorized to handle or use them, or to work in the vicinity thereof, provided that the contents are identified to such individuals by a readily available written record.

(vii) For manufacturing or process equipment, such as nuclear reactors, reactor components, piping, and tanks.

[1] Or "Danger".

[2] As appropriate, the information will include radiation levels, kinds of material, estimate of activity, date for which activity is estimated, mass enrichment, etc.

(4) Each licensee shall, prior to disposal of an empty uncontaminated container to unrestricted areas, remove or deface the radioactive material label or otherwise clearly indicate that the container no longer contains radioactive materials.

§ 20.204 Same: exceptions.

Notwithstanding the provisions of § 20.203,

(a) A room or area is not required to be posted with a caution sign because of the presence of a sealed source provided the radiation level twelve inches from the surface of the source container or housing does not exceed five millirem per hour.

(b) Rooms or other areas in hospitals are not required to be posted with caution signs, and control of entrance or access thereto pursuant to § 20.203(c) is not required, because of the presence of patients containing byproduct material provided that there are personnel in attendance who will take the precautions necessary to prevent the exposure of any individual to radiation or radioactive material in excess of the limits established in the regulations in this part.

(c) Caution signs are not required to be posted at areas or rooms containing radioactive materials for periods of less than eight hours provided that (1) the materials are constantly attended during such periods by an individual who shall take the precautions necessary to prevent the exposure of any individual to radiation or radioactive materials in excess of the limits established in the regulations in this part and; (2) such area or room is subject to the licensee's control.

(d) A room or other area is not required to be posted with a caution sign, and control is not required for each entrance or access point to a room or other area which is a high radiation area solely because of the presence of radioactive materials prepared for transport and packaged and labeled in accordance with regulations of the Department of Transportation.

[3] For example, containers in locations such as water-filled canals, storage vaults, or hot cells.

§ 20.205 Procedures for picking up, receiving, and opening packages.

(a)(1) Each licensee who expects to receive a package containing quantities of radioactive material in excess of the Type A quantities specified in paragraph (b) of this section shall:

(i) If the package is to be delivered to the licensee's facility by the carrier, make arrangements to receive the package when it is offered for delivery by the carrier; or

(ii) If the package is to be picked up by the licensee at the carrier's terminal, make arrangements to receive notification from the carrier of the arrival of the package, at the time of arrival.

(2) Each licensee who picks up a package of radioactive material from a carrier's terminal shall pick up the package expeditiously upon receipt of notification from the carrier of its arrival.

(b)(1) Each licensee, upon receipt of a package of radioactive material, shall monitor the external surfaces of the package for radioactive contamination caused by leakage of the radioactive contents, except:

(i) Packages containing no more than the exempt quantity specified in the table in this paragraph;

(ii) Packages containing no more than 10 millicuries of radioactive material consisting solely of tritium, carbon-14, sulfur-35, or iodine-125;

(iii) Packages containing only radioactive material as gases or in special form;

(iv) Packages containing only radioactive material in other than liquid form (including Mo-99/Tc-99m generators) and not exceeding the Type A quantity limit specified in the table in this paragraph; and

(v) Packages containing only radionuclides with half-lives of less than 30 days and a total quantity of no more than 100 millicuries.

The monitoring shall be performed as soon as practicable after receipt, but no later than three hours after the package is received at the licensee's facility if received during the licensee's normal working hours, or eighteen hours if received after normal working hours.

(2) If removable radioactive contamination in excess of 0.01 microcuries (22,000 disintegrations per minute) per 100 square centimeters of package surface is found on the external surfaces of the package, the licensee shall immediately notify the final delivering carrier and, by telephone and telegraph, mailgram or facsimile, the appropriate Nuclear Regulatory Commission Inspection and Enforcement Regional Office shown in Appendix D of this part.

TABLE OF EXEMPT AND TYPE A QUANTITIES

Transport group [1]	Exempt quantity limit (in millicuries)	Type A quantity limit (in curies)
I	.01	0.001
II	0.1	0.050
III	1	3
IV	1	20
V	1	20
VI	1	1000
VII	25,000	1000
Special Form	1	20

[1] The definitions of "transport group" and "special form" are specified in § 71.4 of this chapter.

[Footnote 1 removed 49 FR 19623]

(c)(1) Each licensee, upon receipt of a package containing quantities of radioactive material in excess of the Type A quantities specified in paragraph (b) of this section, other than those transported by exclusive use vehicle, shall monitor the radiation levels external to the package. The package shall be monitored as soon as practicable after receipt, but no later than three hours after the package is received at the licensee's facility if received during the licensee's normal working hours, or 18 hours if received after normal working hours.

(2) If radiation levels are found on the external surface of the package in excess of 200 millirem per hour, or at three feet from the external surface of the package in excess of 10 millirem per hour,

the licensee shall immediately notify by telephone and telegraph mailgram, or facsimile, the director of the appropriate NRC Regional Office listed in Appendix D, and the final delivering carrier.

(d) Each licensee shall establish and maintain procedures for safely opening packages in which licensed material is received, and shall assure that such procedures are followed and that due consideration is given to special instructions for the type of package being opened.

§ 20.206 Instruction of personnel.

Instructions required for individuals working in or frequenting any portion of a restricted area are specified in § 19.12 of this chapter.

§ 20.207 Storage and control of licensed materials in unrestricted areas.

(a) Licensed materials stored in an unrestricted area shall be secured from unauthorized removal from the place of storage.

(b) Licensed materials in an unrestricted area and not in storage shall be

PART 20 • STANDARDS FOR PROTECTION AGAINST RADIATION

tended under the constant surveillance and immediate control of the licensee.

Waste Disposal

47 FR 57446

§ 20.301 General requirement.

No licensee shall dispose of licensed material except:

(a) By transfer to an authorized recipient as provided in the regulations in Parts 30, 40, 60, 61, 70 or 72 of this chapter, whichever may be applicable; or

(b) As authorized under § 20.302 or Part 61 of this chapter; or

46 FR 16230

(c) As provided in § 20.303, applicable to the disposal of licensed material by release into sanitary sewerage systems, or in § 20.306 for disposal of specific wastes, or in § 20.106 (Radioactivity in effluents to unrestricted areas).

36 FR 23138

§ 20.302 Method for obtaining approval of proposed disposal procedures.

(a) Any licensee or applicant for a license may apply to the Commission for approval of proposed procedures to dispose of licensed material in a manner not otherwise authorized in the regulations in this chapter. Each application should include a description of the licensed material and any other radioactive material involved, including the quantities and kinds of such material and the levels of radioactivity involved, and the proposed manner and conditions of disposal. The application should also include an analysis and evaluation of pertinent information as to the nature of the environment, including topographical, geological, meteorological, and hydrological characteristics; usage of ground and surface waters in the general area; the nature and location of other potentially affected facilities; and procedures to be observed to minimize the risk of unexpected or hazardous exposures.

47 FR 57446

(b) The Commission will not approve any application for a license for disposal of licensed material at sea unless the applicant shows that sea disposal offers less harm to man or the environment than other practical alternative methods of disposal.

28 FR 10914

§ 20.303 Disposal by release into sanitary sewerage systems.

No licensee shall discharge licensed material into a sanitary sewerage system unless:

(a) It is readily soluble or dispersible in water; and

(b) The quantity of any licensed or other radioactive material released into the system by the licensee in any one day does not exceed the larger of paragraphs (b)(1) or (2) of this section.

(1) The quantity which, if diluted by the average daily quantity of sewage released into the sewer by the licensee, will result in an average concentration equal to the limits specified in Appendix B, Table I, Column 2 of this part; or

(2) Ten times the quantity of such material specified in Appendix C of this part; and

(c) The quantity of any licensed or other radioactive material released in any one month, if diluted by the average monthly quantity of water released by the licensee, will not result in an average concentration exceeding the limits specified in Appendix B, Table I, Column 2 of this part; and

46 FR 16230

(d) The gross quantity of licensed and other radioactive material, excluding hydrogen-3 and carbon-14, released into the sewerage system by the licensee does not exceed one curie per year. The quantities of hydrogen-3 and carbon-14 released into the sanitary sewerage system may not exceed 5 curies per year for hydrogen-3 and 1 curie per year for carbon-14. Excreta from individuals undergoing medical diagnosis or therapy with radioactive material shall be exempt from any limitations contained in this section.

§ 20.305 Treatment or disposal by incineration.

No licensee shall treat or dispose of licensed material by incineration, except for materials listed under § 20.306 or as specifically approved by the Commission pursuant to §§ 20.106(b) and 20.302.

§ 20.306 Disposal of specific wastes.

Any licensee may dispose of the following licensed material without regard to its radioactivity:

46 FR 16230

(a) 0.05 microcuries or less of hydrogen-3 or carbon-14, per gram of medium, used for liquid scintillation counting; and

(b) 0.05 microcuries or less of hydrogen-3 or carbon-14, per gram of animal tissue averaged over the weight of the entire animal; provided however, tissue may not be disposed of under this section in a manner that would permit its use either as food for humans or as animal feed.

(c) Nothing in this section, however, relieves the licensee of maintaining records showing the receipt, transfer and disposal of such byproduct material as specified in § 30.51 of this chapter; and

(d) Nothing in this section relieves the licensee from complying with other applicable Federal, State and local regulations governing any other toxic or hazardous property of these materials.

47 FR 57446

§ 20.311 Transfer for disposal and manifests.

(a) Purpose. The requirements of this section are designed to control transfers of radioactive waste intended for disposal at a land disposal facility and establish a manifest tracking system and supplement existing requirements concerning transfers and recordkeeping for such wastes. The reporting and recordkeeping requirements contained in this section have been approved by the Office of Management and Budget; OMB approval No. 3150-0014.

(b) Each shipment of radioactive waste to a licensed land disposal facility must be accompanied by a shipment manifest that contains the name, address, and telephone number of the person generating the waste. The manifest shall also include the name, address, and telephone number or the name and EPA hazardous waste identification number of the person transporting the waste to the land disposal facility. The manifest must also indicate as completely as practicable: a physical description of the waste; the volume; radionuclide identity and quantity; the total radioactivity; and the principal chemical form. The solidification agent must be specified. Waste containing more than 0.1% chelating agents by weight must be identified and the weight percentage of the chelating agent estimated. Wastes classified as Class A, Class B, or Class C in § 61.55 of this chapter must be clearly identified as such in the manifest. The total quantity of the radionuclides H-3, C-14, Tc-99 and I-129 must be shown. The manifest required by this paragraph may be shipping papers used to meet Department of Transportation or

Environmental Protection Agency regulations or requirements of the receiver, provided all the required information is included. Copies of manifests required by this section may be legible carbon copies or legible photocopies.

(c) Each manifest must include a certification by the waste generator that the transported materials are properly classified, described, packaged, marked, and labeled and are in proper condition for transportation according to the applicable regulations of the Department of Transportation and the Commission. An authorized representative of the waste generator shall sign and date the manifest.

(d) Any generating licensee who transfers radioactive waste to a land disposal facility or a licensed waste collector shall comply with the requirements in paragraphs (d)(1) through (8) of this section. Any generating licensee who transfers waste to a licensed waste processor who treats or repackages waste shall comply with the requirements of paragraphs (d)(4) through (8) of this section. A licensee shall:

47 FR 57446

(1) Prepare all wastes so that the waste is classified according to § 61.55 and meets the waste characteristics requirements in § 61.56 of this chapter;

(2) Label each package of waste to identify whether it is Class A waste, Class B waste, or Class C waste, in accordance with § 61.55 of this chapter;

(3) Conduct a quality control program to assure compliance with §§ 61.55 and 61.56 of this chapter; the program must include management evaluation of audits;

(4) Prepare shipping manifests to meet the requirements of §§ 20.311 (b) and (c) of this part;

(5) Forward a copy of the manifest to the intended recipient, at the time of shipment; or, deliver to a collector at the time the waste is collected, obtaining acknowledgement of receipt in the form of a signed copy of the manifest or equivalent documentation from the collector;

(6) Include one copy of the manifest with the shipment;

(7) Retain a copy of the manifest and documentation of acknowledgement of receipt as the record of transfer of licensed material as required by Parts 30, 40, and 70 of this chapter; and,

(8) For any shipments or any part of a shipment for which acknowledgement of receipt has not been received within the times set forth in this section, conduct an investigation in accordance with paragraph (h) of this section.

(e) Any waste collector licensee who handles only prepackaged waste shall:

(1) Acknowledge receipt of the waste from the generator within one week of receipt by returning a signed copy of the manifest or equivalent documentation;

(2) Prepare a new manifest to reflect consolidated shipments; the new manifest shall serve as a listing or index for the detailed generator manifests. Copies of the generator manifests shall be a part of the new manifest. The waste collector may prepare a new manifest without attaching the generator manifests, provided the new manifest contains for each package the information specified in paragraph (b) of this section. The collector licensee shall certify that nothing has been done to the waste which would invalidate the generator's certification;

(3) Forward a copy of the new manifest to the land disposal facility operator at the time of shipment;

(4) Include the new manifest with the shipment to the disposal site;

(5) Retain a copy of the manifest and documentation of acknowledgement of receipt as the record of transfer of licensed material as required by Parts 30, 40, and 70 of this chapter, and retain information from generator manifests until disposition is authorized by the Commission; and.

47 FR 57446

(6) For any shipments or any part of a shipment for which acknowledgement of receipt is not received within the times set forth in this section, conduct an investigation in accordance with paragraph (h) of this section.

(f) Any licensed waste processor who treats or repackages wastes shall:

(1) Acknowledge receipt of the waste from the generator within one week of receipt by returning a signed copy of the manifest or equivalent documentation;

(2) Prepare a new manifest that meets the requirements of paragraphs (b) and (c) of this section. Preparation of the new manifest reflects that the processor is responsible for the waste;

(3) Prepare all wastes so that the waste is classified according to § 61.55 and meets the waste characteristics requirements in § 61.56 of this chapter;

(4) Label each package of waste to identify whether it is Class A waste, Class B waste, or Class C waste, in accordance with §§ 61.55 and 61.57 of this chapter;

(5) Conduct a quality control program to assure compliance with §§ 61.55 and 61.56 of this chapter. The program shall include management evaluation of audits;

(6) Forward a copy of the new manifest to the disposal site operator or waste collector at the time of shipment, or deliver to a collector at the time the waste is collected, obtaining acknowledgement of receipt in the form of a signed copy of the manifest or equivalent documentation by the collector;

(7) Include the new manifest with the shipment;

(8) Retain copies of original manifests and new manifests and documentation of acknowledgement of receipt as the record of transfer of licensed material required by Parts 30, 40, and 70 of this chapter; and

(9) For any shipment or part of a shipment for which acknowledgement is not received within the times set forth in this section, conduct an investigation in accordance with paragraph (h) of this section.

(g) The land disposal facility operator shall:

(1) Acknowledge receipt of the waste within one week of receipt by returning a signed copy of the manifest or equivalent documentation to the shipper. The shipper to be notified is the licensee who last possessed the waste and transferred the waste to the operator. The returned copy of the manifest or equivalent documentation shall indicate any discrepancies between materials listed on the manifest and materials received;

47 FR 57446

(2) Maintain copies of all completed manifests or equivalent documentation until the Commission authorizes their disposition; and

(3) Notify the shipper (i.e., the generator, the collector, or processor) and the Director of the nearest Commission Regional Office listed in Appendix D of this part when any shipment or part of a shipment has not arrived within 60 days after the advance manifest was received.

(h) Any shipment or part of a shipment for which acknowledgement is not received within the times set forth in this section, must:

(1) Be investigated by the shipper if the shipper has not received notification of receipt within 20 days after transfer; and

(2) Be traced and reported. The investigation shall include tracing the shipment and filing a report with the nearest Commission Regional Office listed in Appendix D of this part. Each licensee who conducts a trace investigation shall file a written report with the nearest Commission's Regional office within 2 weeks of completion of the investigation.

RECORDS, REPORTS, AND NOTIFICATION

25 FR 10914

§ 20.401 Records of surveys, radiation monitoring, and disposal.

(a) Each licensee shall maintain records showing the radiation exposures of all individuals for whom personnel monitoring is required under § 20.202 of the regulations in this part. Such records shall be kept on Form NRC-5, in accordance with the instructions contained in that form or on clear and legible records containing all the information required by Form NRC-5. The doses entered on the forms or records shall be for periods of time not exceeding one calendar quarter.

47 FR 57446

(b) Each licensee shall maintain records in the same units used in this part, showing the results of surveys required by § 20.201(b), monitoring required by §§ 20.205(b) and 20.205(c), and disposals made under §§ 20.302, 20.303, removed § 20.304,[1] and Part 61 of this chapter.

41 FR 18300

(c)(1) Records of individual exposure to radiation and to radioactive material which must be maintained pursuant to the provisions of paragraph (a) of this section and records of bioassays, including results of whole body counting examinations, made pursuant to § 20.108, shall be preserved until the Commission authorizes disposition.

(2) Records of the results of surveys and monitoring which must be maintained pursuant to paragraph (b) of this section shall be preserved for two years after completion of the survey except that the following records shall be maintained until the Commission authorizes their disposition: (i) Records of the results of surveys to determine compliance with § 20.103(a); (ii) in the absence of personnel monitoring data, records of the results of surveys to determine external radiation dose; and (iii) records of the results of surveys used to evaluate the release of radioactive effluents to the environment.

(next page is 20-11)

(3) Records of disposal of licensed materials made pursuant to §§ 20.302, 20.303, removed § 20.304,[1] and Part 61 of this chapter are to be maintained until the Commission authorizes their disposition.

(4) Records which must be maintained pursuant to this part may be the original or a reproduced copy or microform if such reproduced copy or microform is duly authenticated by authorized personnel and the microform is capable of producing a clear and legible copy after storage for the period specified by Commission regulations.

(5) If there is a conflict between the Commission's regulations in this part, license condition, or technical specification, or other written Commission approval or authorization pertaining to the retention period for the same type of record, the retention period specified in the regulations in this part for such records shall apply unless the Commission pursuant to § 20.501, has granted a specific exemption from the record retention requirements specified in the regulations in this part.

§ 20.402 Reports of theft or loss of licensed material.

(a)(1) Each licensee shall report to the Commission, by telephone, immediately after it determines that a loss or theft of licensed material has occurred in such quantities and under such circumstances that it appears to the licensee that a substantial hazard may result to persons in unrestricted areas.

(2) Reports must be made as follows:

(i) Licensees having an installed Emergency Notification System shall make the reports to the NRC Operations Center in accordance with § 50.72 of this chapter.

(ii) All other licensees shall make reports to the Administrator of the appropriate NRC Regional Office listed in Appendix D of this part.

(b) Each licensee who makes a report under paragraph (a) of this section shall, within 30 days after learning of the loss or theft, make a report in writing to the U.S. Nuclear Regulatory Commission, Document Control Desk, Washington, D.C. 20555, with a copy to the appropriate NRC Regional Office listed in Appendix D of this part. The report shall include the following information:

(1) A description of the licensed material involved, including kind, quantity, chemical, and physical form;

(2) A description of the circumstances under which the loss or theft occurred;

(3) A statement of disposition or probable disposition of the licensed material involved;

(4) Radiation exposures to individuals, circumstances under which the exposures occurred, and the extent of possible hazard to persons in unrestricted areas;

(5) Actions which have been taken, or will be taken, to recover the material; and

(6) Procedures or measures which have been or will be adopted to prevent a recurrence of the loss or theft of licensed material.

(c) Subsequent to filing the written report the licensee shall also report any substantive additional information on the loss or theft which becomes available to the licensee, within 30 days after he learns of such information.

(d) Any report filed with the Commission pursuant to this section shall be so prepared that names of individuals who may have received exposure to radiation are stated in a separate part of the report.

(e) For holders of an operating license for a nuclear power plant, the events included in paragraph (b) of this section must be reported in accordance with the procedures described in § 50.73 (b), (c), (d), (e), and (g) of this chapter and must include the information required in paragraph (b) of this section. Events reported in accordance with § 50.73 of this chapter need not be reported by a duplicate report under paragraph (b) of this section.

§ 20.403 Notifications of incidents.

(a) *Immediate notification.* Each licensee shall immediately report any events involving byproduct, source, or special nuclear material possessed by the licensee that may have caused or threatens to cause:

(1) Exposure of the whole body of any individual to 25 rems or more of radiation; exposure of the skin of the whole body of any individual of 150 rems or more or radiation; or exposure of the feet, ankles, hands or forearms of any individual to 375 rems or more of radiation; or

(2) The release of radioactive material in concentrations which, if averaged over a period of 24 hours, would exceed 5,000 times the limits specified for such materials in Appendix B, Table II of this part; or

(3) A loss of one working week or more of the operation of any facilities affected; or

(4) Damage to property in excess of $200,000.

(b) *Twenty-four hour notification.* Each licensee shall within 24 hours of discovery of the event, report any event involving licensed material possessed by the licensee that may have caused or threatens to cause:

(1) Exposure of the whole body of any individual to 5 rems or more of radiation; exposure of the skin of the whole body of any individual to 30 rems or more of radiation; or exposure of the feet, ankles, hands, or forearms to 75 rems or more of radiation; or

(2) The release of radioactive material in concentrations which, if averaged over a period of 24 hours, would exceed 500 times the limits specified for such materials in Appendix B, Table II of this part; or

(3) A loss of one day or more of the operation of any facilities affected; or

(4) Damage to property in excess of $2,000.

(c) Any report filed with the Commission pursuant to this section shall be prepared so that names of individuals who have received exposure to radiation will be stated in a separate part of the report.

(d) Reports made by licensees in response to the requirements of this section must be made as follows:

(1) Licensees that have an installed Emergency Notification System shall make the reports required by paragraphs (a) and (b) of this section to the NRC Operations Center in accordance with § 50.72 of this chapter.

(2) All other licensees shall make the reports required by paragraphs (a) and (b) of this section by telephone and by telegram, mailgram, or facsimile to the Administrator of the appropriate NRC Regional Office listed in Appendix D of this part.

§ 20.404 [Reserved]

§ 20.405 Reports of overexposures and excessive levels and concentrations.

(a)(1) In addition to any notification required by § 20.403 of this part, each licensee shall make a report in writing concerning any one of the following types of incidents within 30 days of its occurrence:

(i) Each exposure of an individual to radiation in excess of the applicable limits in §§ 20.101 or 20.104(a) of this part, or the license;

(ii) Each exposure of an individual to radioactive material in excess of the applicable limits in §§ 20.103(a)(1), 20.103(a)(2), or 20.104(b) of this part, or in the license;

48 FR 33850

(iii) Levels of radiation or concentrations of radioactive material in a restricted area in excess of any other applicable limit in the license;

(iv) Any incident for which notification is required by § 20.403 of this part; or

(v) Levels of radiation or concentrations of radioactive material (whether or not involving excessive exposure of any individual) in an unrestricted area in excess of ten times any applicable limit set forth in this part or in the license.

(2) Each report required under paragraph (a)(1) of this section must describe the extent of exposure of individuals to radiation or to radioactive material, including:

(i) Estimates of each individual's exposure as required by paragraph (b) of this section;

(ii) Levels of radiation and concentrations of radioactive material involved;

(iii) The cause of the exposure, levels or concentrations; and

(iv) Corrective steps taken or planned to prevent a recurrence.

46 FR 18525

(b) Any report filed with the Commission pursuant to paragraph (a) of this section shall include for each individual exposed the name, social security number, and date of birth, and an estimate of the individual's exposure. The report shall be prepared so that this information is stated in a separate part of the report.

48 FR 33850

(c)(1) In addition to any notification required by § 20.403 of this part, each licensee shall make a report in writing of levels of radiation or releases of radioactive material in excess of limits specified by 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operations," or in excess of license conditions related to compliance with 40 CFR Part 190.

(2) Each report submitted under paragraph (c)(1) of this section must describe:

(i) The extent of exposure of individuals to radiation or to radioactive material;

(ii) Levels of radiation and concentrations of radioactive material involved;

(iii) The cause of the exposure, levels, or concentrations; and

(iv) Corrective steps taken or planned to assure against a recurrence, including the schedule for achieving conformance with 40 CFR Part 190 and with associated license conditions.

(d) For holders of an operating license for a nuclear power plant, the incidents included in paragraphs (a) or (c) of this section must be reported in accordance with the procedures described in paragraphs 50.73 (b), (c), (d), (e), and (g) of this chapter and must also include the information required by paragraphs (a) and (c) of this section. Incidents reported in accordance with § 50.73 of this chapter need not be reported by a duplicate report under paragraphs (a) or (c) of this section.

(e) All other licensees who make reports under paragraphs (a) or (c) of this section shall, within 30 days after learning of the overexposure or excessive level or concentration, make a report in writing to the U.S. Nuclear Regulatory Commission, Document Control Desk, Washington, D.C. 20555, with a copy to the appropriate NRC Regional Office listed in Appendix D of this part.

43FR44827

§ 20.406 [Reserved]

49 FR 24513

§ 20.407 Personnel monitoring reports.

Each person described in § 20.408 of this part shall, within the first quarter of each calendar year, submit to the Director, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, DC 20555, the reports specified in paragraphs (a) and (b) of this section, covering the preceding calendar year.[1]

43 FR 44827

(a) A report of either (1) the total number of individuals for whom personnel monitoring was required under § 20.202(a) or § 34.33(a) of this chapter during the calendar year; or (2) the total number of individuals for whom personnel monitoring was provided during the calendar year: *Provided, however*, That such total includes at least the number of individuals required to be reported under paragraph (a)(1) of this section. The report shall indicate whether it is submitted in accordance with paragraph (a)(1) or (a)(2) of this section. If personnel monitoring was not required to be provided to any individual by the licensee under §§ 20.202(a) or 34.33(a) of this chapter during the calendar year, the licensee shall submit a negative report indicating that such personnel monitoring was not required.

(b) A statistical summary report of the personnel monitoring information recorded by the licensee for individuals for whom personnel monitoring was either required or provided, as described in paragraph (a) of this section, indicating the number of individuals whose total whole body exposure recorded during the previous calendar year was in each of the following estimated exposure ranges:

Estimated whole body exposure range (rems)[1]	Number of individuals in each range
No measurable exposure	
Measurable exposure less than 0.1	
0.1 to 0.25	
0.25 to 0.5	
0.5 to 0.75	
0.75 to 1	
1 to 2	
2 to 3	
3 to 4	
4 to 5	
5 to 6	
6 to 7	
7 to 8	
8 to 9	
9 to 10	
10 to 11	
11 to 12	
12+	

[1] Individual values exactly equal to the values separating exposure ranges shall be reported in the higher range.

The low exposure range data are required in order to obtain better information about the exposures actually recorded. This section does not require improved measurements.

§ 20.408 Reports of personnel monitoring on termination of employment or work.

(a) This section applies to each person licensed by the Commission to:

50FR34085

(1) Operate a nuclear reactor designed to produce electrical or heat energy pursuant to § 50.21(b) or § 50.22 of this chapter or a testing facility as defined in § 50.2 of this chapter.

43FR44827

(2) Possess or use byproduct material for purposes of radiography pursuant to Parts 30 and 34 of this chapter;

45 FR 13971

(3) Possess or use at any one time, for purposes of fuel processing, fabricating, or reprocessing, special nuclear material in a quantity exceeding 5,000 grams of contained uranium-235, uranium-233, or plutonium or any combination thereof pursuant to Part 70 of this chapter;

(4) Possess high-level radioactive waste at a geologic repository operations area pursuant to Part 60 of this chapter; or

46 FR 58281

(5) Possess spent fuel in an independent spent fuel storage installation (ISFSI) pursuant to Part 72 of this chapter; or

(6) Possess or use at any one time, for processing or manufacturing for distribution pursuant to Parts 30, 32, or 33 of this Chapter, byproduct material in quantities exceeding any one of the following quantities:

[1] A licensee whose license expires or terminates prior to, or on the last day of the calendar year, shall submit reports at the expiration or termination of the license, covering that part of the year during which the license was in effect.

43 FR 44827

Radionuclide[1]	Quantity in curies
Cesium-137	1
Cobalt-60	1
Gold-198	100
Iodine-131	1
Iridium-192	10
Krypton-85	1,000
Promethium-147	10
Technetium-99m	1,000

[1]The Commission may require, as a license condition, or by rule, regulation or order pursuant to § 20.502, reports from licensees who are licensed to use radionuclides not on this list, in quantities sufficient to cause comparable radiation levels.

47 FR 57446

(7) Receive radioactive waste from other persons for disposal under Part 61 of this chapter.

49 FR 24513

(b) When an individual terminates employment with a licensee described in paragraph (a) of this section, or an individual assigned to work in such a licensee's facility, but not employed by the licensee, completes the work assignment in the licensee's facility, the licensee shall furnish to the Director, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, DC 20555, a report of the individual's exposures to radiation and radioactive material, incurred during the period of employment or work assignment in the licensee's facility, containing information recorded by the licensee pursuant to §§ 20.401(a) and 20.108. Such report shall be furnished within 30 days after the exposure of the individual has been determined by the licensee or 90 days after the date of termination of employment or work assignment, whichever is earlier.

38 FR 22220

§ 20.409 Notifications and reports to individuals.

(a) Requirements for notifications and reports to individuals of exposure to radiation or radioactive material are specified in § 19.13 of this chapter.

(b) When a licensee is required pursuant to §§ 20.405 or 20.408 to report to the Commission any exposure of an individual to radiation or radioactive material, the licensee shall also notify the individual. Such notice shall be transmitted at a time not later than the transmittal to the Commission, and shall comply with the provisions of § 19.13(a) of this chapter.

25 FR 10914

EXCEPTIONS AND ADDITIONAL REQUIREMENTS

§ 20.501 Applications for exemptions.

The Commission may, upon application by any licensee or upon its own initiative, grant such exemptions from the requirements of the regulations in this part as it determines are authorized by law and will not result in undue hazard to life or property.

§ 20.502 Additional requirements.

The Commission may, by rule, regulation, or order, impose upon any licensee such requirements, in addition to those established in the regulations in this part, as it deems appropriate or necessary to protect health or to minimize danger to life or property.

ENFORCEMENT

48 FR 8774

§ 20.601 Violations.

An injunction or other court order may be obtained prohibiting any violation of any provision of the Atomic Energy Act of 1954, as amended, or Title II of the Energy Reorganization Act of 1974, or any regulation or order issued thereunder. A court order may be obtained for the payment of a civil penalty imposed pursuant to section 234 of the Act for violation of section 53, 57, 62, 63, 81, 82, 101, 103, 104, 107, or 109 of the Act, or section 206 of the Energy Reorganization Act of 1974, or any rule, regulation, or order issued thereunder, or any term, condition, or limitation of any license issued thereunder, or for any violation for which a license may be revoked under section 186 of the Act. Any person who willfully violates any provision of the Act or any regulation or order issued thereunder may be guilty of a crime and, upon conviction, may be punished by fine or imprisonment or both, as provided by law.

[Note removed 49 FR 19623]

APPENDIX A.—PROTECTION FACTORS FOR RESPIRATORS [a]

Description [b]	Modes [c]	Protection factors [d]: Particulates only	Protection factors [d]: Particulates (gases and vapors) [e]	Tested and certified equipment—National Institute for Occupational Safety and Health/Mine Safety and Health Administration tests for permissibility
I. Air-purifying respirators [f]				
Facepiece, half-mask [g]	NP	10		30 CFR Part 11, Subpart K.
Facepiece, full	NP	50		
Facepiece, half-mask, full, or hood	PP	1,000		
II. Atmosphere-supplying respirators				
1. Air-line respirator				
Facepiece, half-mask	CF		1,000	
Facepiece, half-mask	D		5	
Facepiece, full	CF		2,000	
Facepiece, full	D		5	30 CFR Part 11, Subpart J.
Facepiece, full	PD		2,000	
Hood	CF		(h)	
Suit	CF		(i)	(j)
2. Self-contained breathing apparatus (SCBA)				
Facepiece, full	D		50	
Facepiece, full	PD		[k] 10,000	30 CFR Part 11, Subpart H.
Facepiece, full	RD		50	
Facepiece, full	RP		[l] 5,000	
III. Combination respirator: Any combination of air-purifying and atmosphere-supplying respirators.			[m]	30 CFR Part 11, § 11.63(b).

[47 FR 19511]

[a] For use in the selection of respiratory protective devices to be used only where the contaminants have been identified and the concentrations (or possible concentrations) are known.

[b] Only for shaven faces and where nothing interferes with the seal of tight-fitting facepieces against the skin. (Hoods and suits are excepted.)

[c] The mode symbols are defined as follows: CF = continuous flow; D = demand; NP = negative pressure (i.e., negative phase during inhalation); PD = pressure demand (i.e., always positive pressure); PP = positive pressure; RD = demand, recirculating (closed circuit); RP = positive pressure, recirculating (closed circuit).

[d] (1) The protection factor is a measure of the degree of protection afforded by a respirator, defined as the ratio of the concentration of airborne radioactive material outside the respiratory protective equipment to that inside the equipment (usually inside the facepiece) under conditions of use. It is applied to the ambient airborne concentration to estimate the concentrations inhaled by the wearer according to the following formula:

$$\text{Concentration inhaled} = \frac{\text{Ambient airborne concentration}}{\text{Protection factor}}$$

(2) The protection factors apply:

(a) Only for trained individuals wearing properly fitted respirators used and maintained under supervision in a well-planned respiratory protective program.

(b) For air-purifying respirators only when high efficiency particulate filters (above 99.97% removal efficiency by thermally generated 0.3 μm dioctyl phthalate (DOP) test) are used in atmospheres not deficient in oxygen and not containing radioactive gas or vapor respiratory hazards.

(c) No allowance is to be made for the use of sorbents against radioactive gases or vapors.

(d) For atmosphere-supplying respirators only when supplied with adequate respirable air. Respirable air shall be provided of the quality and quantity required in accordance with NIOSH/MESA certification (described in 30 CFR Part 11). Oxygen and air shall not be used in the same apparatus.

[e] Excluding radioactive contaminants that present an absorption or submersion hazard. For tritium oxide, approximately one half of the intake occurs by absorption through the skin so that an overall protection factor of less than 2 is appropriate when atmosphere-supplying respirators are used to protect against tritium oxide. If the protection factor for a device is 5, the effective protection factor for tritium is about 1.4; for devices with protection factors of 10 the effective factor for tritium oxide is about 1.7, and for devices with protection factors of 100 or more the effective factor for tritium oxide is about 1.9. Air-purifying respirators are not suitable for protection against tritium oxide. See also footnote i concerning supplied-air suits.

[f] Canisters and cartridges shall not be used beyond service-life limitations.

[g] Under-chin type only. This type of respirator is not satisfactory for use where it might be possible (e.g., if an accident or emergency were to occur) for the ambient airborne concentration to reach instantaneous values greater than 10 times the pertinent values in Table 1, Column 1 of Appendix B of this part. This type of respirator is not suitable for protection against plutonium or other high-toxicity materials. The mask shall be tested for fit with irritant smoke, prior to use, each time it is donned.

[h] (1) Equipment shall be operated in a manner that ensures that proper air flow-rates are maintained. A protection factor of no more than 1000 may be used for tested-and-certified supplied-air hoods when a minimum air flow of 6 cubic feet per minute is maintained and calibrated air line pressure gauges or flow measuring devices are used. A protection factor of up to 2000 may be used for tested and certified hoods only when the air flow is maintained at the manufacturer's recommended maximum rate for the equipment, this rate is greater than 6 cubic feet per minute, and calibrated air line pressure gauges or flow measuring devices are used.

(2) The design of the supplied-air hood or helmet (with a minimum flow of 6 cfm of air) may determine its overall efficiency and the protection it provides. For example, some hoods aspirate contaminated air into the breathing zone when the wearer works with hands-over-head. This aspiration may be overcome if a short cape-like extension to the hood is worn under a coat or overalls. Other limitations specified by the approval agency shall be considered before using a hood in certain types of atmospheres, such as the design and its permeability to the contaminant under conditions of use.

[i] Appropriate protection factors shall be determined (see 20.103(c)), taking into account the design of the suit and its permeability to the contaminant under conditions of use. There shall be a standby rescue person equipped with self-contained breathing apparatus and communications equipment whenever supplied-air suits are used.

[j] No approval schedules are currently available for this equipment. Equipment shall be evaluated by testing or on the basis of reliable test information.

[k] This type of respirator may provide greater protection and be used as an emergency device in unknown concentrations for protection against inhalation hazards. External radiation hazards and other limitations to permitted exposure such as skin absorption shall be taken into account in these circumstances.

[l] Quantitative fit testing shall be performed on each individual and no more than 0.02% leakage is allowed with this type of apparatus. Perceptible outward leakage of gas from this or any positive pressure self-contained breathing apparatus is unacceptable because service life will be reduced substantially. Special training in the use of this type of apparatus shall be provided to the wearer (see footnote b).

[m] Protection factor for type and mode of operation as listed above.

Note 1.—Protection factors for respirators, as may be approved by the U.S. Bureau of Mines/National Institute for Occupational Safety and Health (NIOSH) according to applicable approvals for respirators for type and mode of use to protect against airborne radionuclides, may be used to the extent that they do not exceed the protection factors listed in this table. The protection factors listed in this table may not be appropriate to circumstances where chemical or other respiratory hazards exist in addition to radiological hazards. The selection and use of respirators for these circumstances should take into account applicable approvals of the U.S. Bureau of Mines/NIOSH.

Note 2.—Radioactive contaminants for which the concentration values in Table 1, column 1, Appendix B of this part are based on internal dose due to inhalation may, in addition, present external exposure hazards at higher concentrations. Under these circumstances, limitations on occupancy may have to be governed by external dose limits.

25 FR 10914

APPENDIX B

Concentrations in Air and Water Above Natural Background

[See notes at end of appendix]

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

APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See notes at end of appendix)

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

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See notes at end of appendix)

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

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

[See notes at end of appendix]

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

APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See notes at end of appendix)

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

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See notes at end of appendix)

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

APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

[See notes at end of appendix.]

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

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See notes at end of appendix)

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

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See notes at end of appendix)

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

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

(See notes at end of appendix)

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

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APPENDIX B

Concentrations in Air and Water Above Natural Background—Continued

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

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

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

40 FR 50704

** [4] These radon concentrations are appropriate for protection from radon-222 combined with its short-lived daughters. Alternatively, the value in Table I may be replaced by one-third (⅓) "working level." (A "working level" is defined as any combination of short-lived radon-222 daughters, polonium-218, lead-214, bismuth-214 and polonium-214, in one liter of air, without regard to the degree of equilibrium, that will result in the ultimate emission of 1.3 x 10^{5} MeV of alpha particle energy.) The Table II value may be replaced by one-thirtieth (1/30) of a "working level." The limit on radon-222 concentrations in restricted areas may be based on an annual average.

39 FR 23990

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

SA = 3.6×10^{-7} curies/gram U U-depleted
SA = $(0.4+0.38\,E+0.0034\,E^2)\,10^{-6}$ $E\geq0.72$

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

*Amended 37 FR 23319.
**Amended 39 FR 23990; footnote redesignated 40 FR 50704.
***Amended 40 FR 50704.
†Amended 38 FR 29314.
‡Amended 39 FR 25463; redesignated 40 FR 50704.

NOTE TO APPENDIX B

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

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

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

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

30 FR 15801

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

a. For purposes of Table I, Col. 1—6×10^{-13}
b. For purposes of Table I, Col. 2—4×10^{-7}
c. For purposes of Table II, Col. 1—2×10^{-14}
d. For purposes of Table II, Col. 2—3×10^{-8}

26 FR 11046

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

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

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

30 FR 15801

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

40 FR 50704

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

39 FR 23990

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

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

26 FR 11046

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

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

APPENDIX C

Material	Microcuries
Americium-241	.01
Antimony-122	100
Antimony-124	10
Antimony-125	10
Arsenic-73	100
Arsenic-74	10
Arsenic-76	10
Arsenic-77	100
Barium-131	10
*Barium-133	10
Barium-140	10
Bismuth-210	1
Bromine-82	10
Cadmium-109	10
Cadmium-115m	10
Cadmium-115	100
Calcium-45	10
Calcium-47	10
Carbon-14	100
Cerium-141	100
Cerium-143	100
Cerium-144	1
Cesium-131	1,000
Cesium-134m	100
Cesium-134	1
Cesium-135	10
Cesium-136	10
Cesium-137	10
Chlorine-36	10
Chlorine-38	10
Chromium-51	1,000
Cobalt-58m	10
Cobalt-58	10
Cobalt-60	1
Copper-64	100
Dysprosium-165	10
Dysprosium-166	100
Erbium-169	100
Erbium-171	100
Europium-152 9.2 h	100
Europium-152 13 yr	1
Europium-154	1
Europium-155	10
Fluorine-18	1,000
Gadolinium-153	10
Gadolinium-159	100
Gallium-72	10
Germanium-71	100
Gold-198	100
Gold-199	100
Hafnium-181	10
Holmium-166	100
Hydrogen-3	1,000
Indium-113m	100
Indium-114m	10
Indium-115m	100
Indium-115	10
Iodine-125	1
Iodine-126	1
Iodine-129	0.1
Iodine-131	1
Iodine-132	10
Iodine-133	1
Iodine-134	10
Iodine-135	10
Iridium-192	10
Iridium-194	100
Iron-55	100
Iron-59	10
Krypton-85	100
Krypton-87	10
Lanthanum-140	10
Lutetium-177	100
Manganese-52	10
Manganese-54	10
Manganese-56	10
Mercury-197m	100
Mercury-197	100
Mercury-203	10
Molybdenum-99	100
Neodymium-147	100
Neodymium-149	100
Nickel-59	100
Nickel-63	10
Nickel-65	100
Niobium-93m	10
Niobium-95	10
Niobium-97	10
Osmium-185	10
Osmium-191m*	100
Osmium-191	100
Osmium-193	100
Palladium-103	100
Palladium-109	100
Phosphorus-32	10
Platinum-191	100
Platinum-193m	100
Platinum-193	100
Platinum-197m	100
Platinum-197	100
Plutonium-239	.01
Polonium-210	0.1
Potassium-42	10
Praseodymium-142	100
Praseodymium-143	100
Promethium-147	10
Promethium-149	10
Radium-226	.01
Rhenium-186	100
Rhenium-188	100
Rhodium-103m	100
Rhodium-105	100
Rubidium-86	10
Rubidium-87	10
Ruthenium-97	100
Ruthenium-103	10
Ruthenium-105	10
Ruthenium-106	1
Samarium-151	10
Samarium-153	100
Scandium-46	10
Scandium-47	100
Scandium-48	10
Selenium-75	10
Silicon-31	100
Silver-105	10
Silver-110m	1
Silver-111	100
Sodium-24	10
Strontium-85	10
Strontium-89	1
Strontium-90	0.1
Strontium-91	10
Strontium-92	10
Sulphur-35	100
Tantalum-182	10
Technetium-96	10
Technetium-97m	100
Technetium-97	100
Technetium-99m	100
Technetium-99	10
Tellurium-125m	10
Tellurium-127m	10
Tellurium-127	100
Tellurium-129m	10
Tellurium-129	100
Tellurium-131m	10
Tellurium-132	10
Terbium-160	10
Thallium-200	100
Thallium-201	100
Thallium-202	100
Thallium-204	10
**Thorium (natural)[1]	100
Thulium-170	10
Thulium-171	10
Tin-113	10
Tin-125	10
Tungsten-181	10
Tungsten-185	10
Tungsten-187	100
**Uranium (natural)[2]	100
Uranium-233	.01
Uranium-234- Uranium-235	.01
Vanadium-48	10
Xenon-131m	1,000
Xenon-133	100
Xenon-135	100
Ytterbium-175	100
Yttrium-90	10
Yttrium-91	10
Yttrium-92	100
Yttrium-93	100
Zinc-65	10
Zinc-69m	100
Zinc-69	1,000
Zirconium-93	10
Zirconium-95	10
Zirconium-97	10
Any alpha emitting radionuclide not listed above or mixtures of alpha emitters of unknown composition	.01
Any radionuclide other than alpha emitting radionuclides, not listed above or mixtures of beta emitters of unknown composition	.1

35 FR 6425

Note.—For purposes of § 20.303, where there is involved a combination of isotopes in known amounts, the limit for the combination should be derived as follows. Determine, for each isotope in the combination, the ratio between the quantity present in the combination and the limit otherwise established for the specific isotope when not in combination. The sum of such ratios for all the isotopes in the combination may not exceed "1" (i.e., "unity").

45 FR 71761

[1] Based on alpha disintegration rate of Th-232, Th-230 and their daughter products.

[2] Based on alpha disintegration rate of U-238, U-234, and U-235.

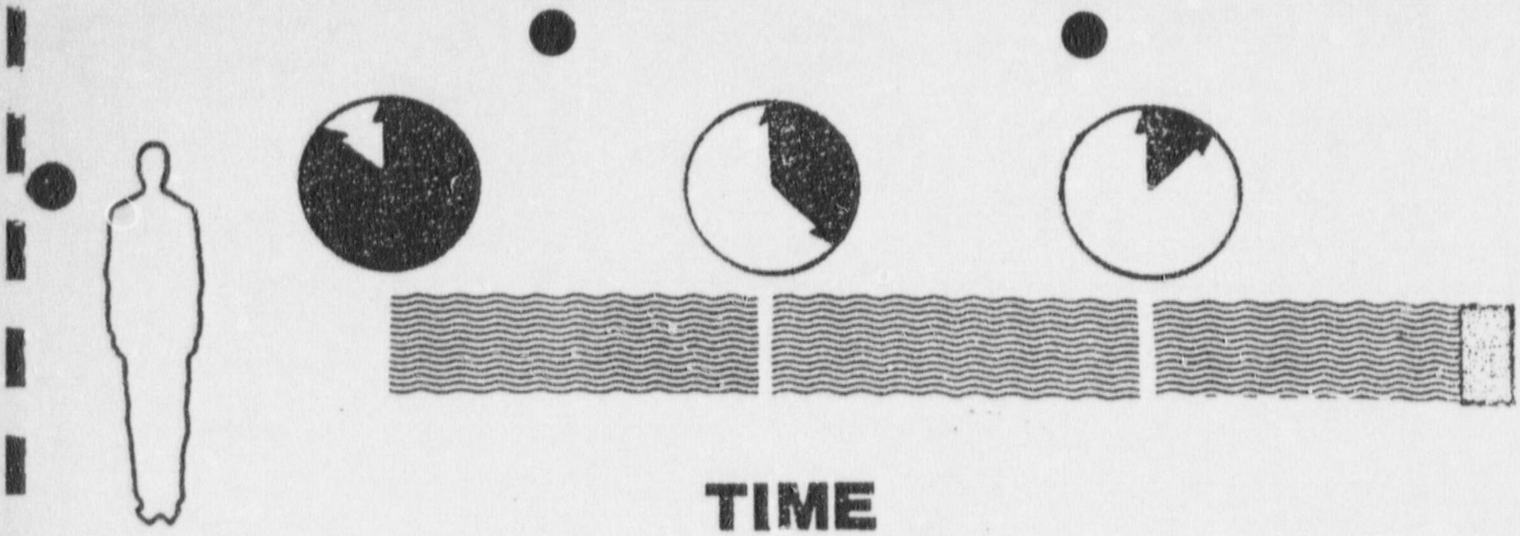
* Amended 36 FR 16898.

** Amended 39 FR 23990.

51 FR 35499

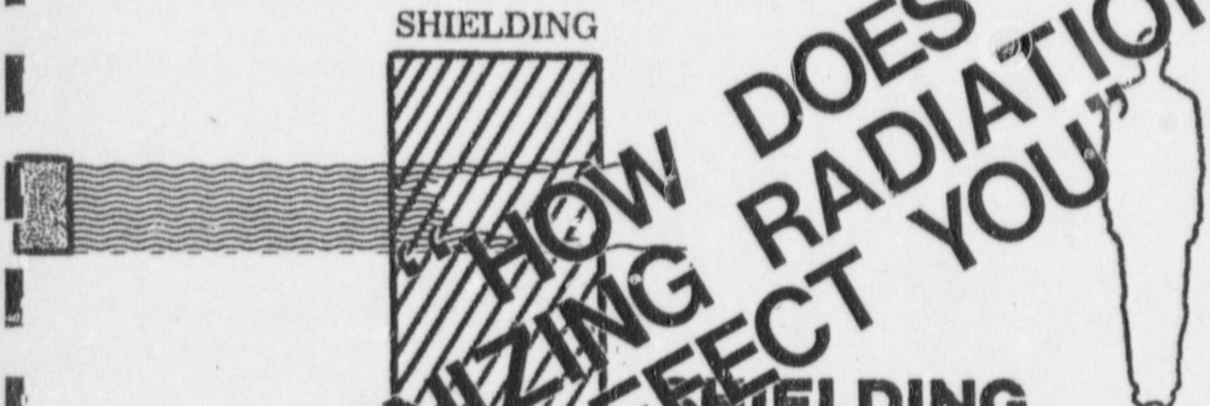
APPENDIX D.—UNITED STATES NUCLEAR REGULATORY COMMISSION REGIONAL OFFICES

	Addresses	Telephone (24 hours)
Region I: Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.	USNRC, 631 Park Avenue, King of Prussia, PA 19406.	(215) 337-5000 (FTS) 488-1000
Region II: Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, Puerto Rico, South Carolina, Tennessee, Virginia, Virgin Islands, and West Virginia.	USNRC, 101 Marietta Street, NW, Suite 2900, Atlanta, GA 30323.	(404) 331-4503 (FTS) 242-4503
Region III: Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin.	USNRC, 799 Roosevelt Road, Glen Ellyn, IL 60137.	(312) 790-5500 (FTS) 388-5500
Region IV: Arkansas, Colorado, Idaho, Kansas, Louisiana, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, and Wyoming.	USNRC, 611 Ryan Plaza Drive, Suite 1000, Arlington, TX 76011.	(817) 860-8100 (FTS) 728-8100
Region IV: Field Office	USNRC, Region IV Uranium Recovery Field Office, 730 Simms Street, P.O. Box 25325, Denver, CO 80225.	(303) 236-2805 (FTS) 776-2805
Region V: Alaska, Arizona, California, Hawaii, Nevada, Oregon, Pacific Trust Territories, and Washington.	USNRC, 1450 Maria Lane, Suite 210, Walnut Creek, CA 94596.	(415) 943-3700 (FTS) 463-3700



TIME

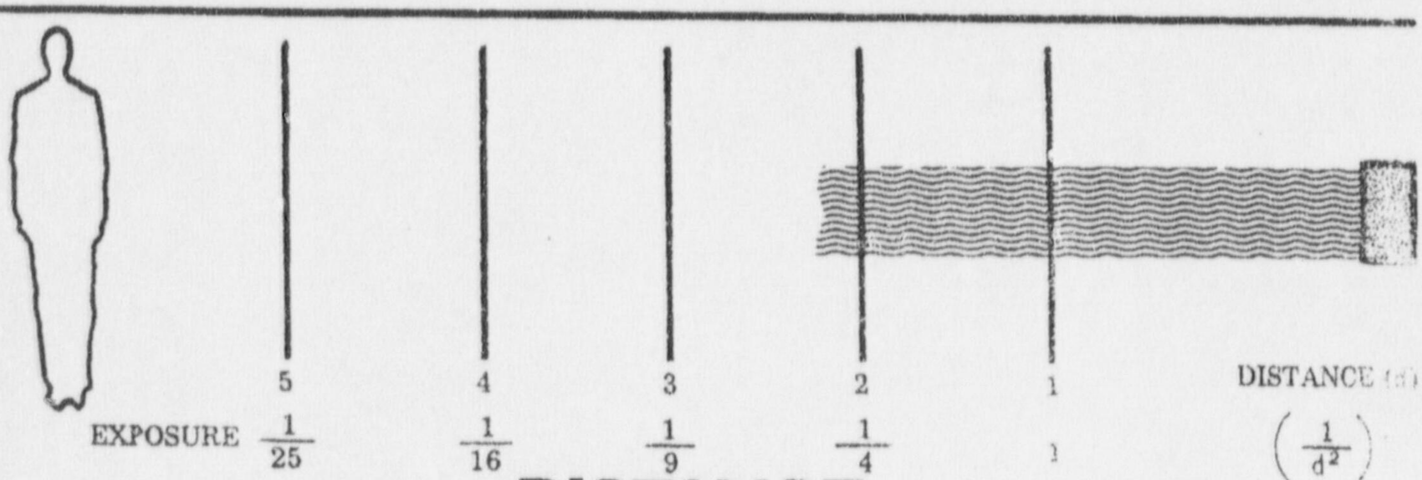
LIMIT THE TIME TO
REDUCE THE EXPOSURE



SHIELDING

USE SHIELDING TO
REDUCE THE EXPOSURE

"HOW DOES
IONIZING RADIATION
AFFECT YOU"



DISTANCE

INCREASE THE DISTANCE TO
REDUCE THE EXPOSURE

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FOREWORD

Packard Instrument Company, as a holder of Federal and State radioactive material licenses, has the responsibility of instructing affected employees in radiation safety. This discussion, "HOW DOES IONIZING RADIATION AFFECT YOU", is one method of instruction.

The primary goal of this training program is to minimize fear of radioactivity and to develop a profound respect for radioactivity and its uses.

The nature of the subject requires the inclusion of some technical material. As far as possible, the technical material has been restricted to Sections I and II, INTRODUCTION and RADIOLOGICAL UNITS. These sections can be omitted without losing any material which is necessary to achieve the goal of the program.

The program is designed to relate generally known and accepted experiences with the unknown quantity, radioactivity. This is achieved by examining medical uses of x-rays and radioactive pharmaceuticals and relying on human experiences with ionizing radiation in the twentieth century. The radiations discussed are twentieth century phenomena beginning with the discovery of x-rays in 1895 by Roentgen and the discovery of radioactivity in 1896 by Becquerel.

This program is also designed for study either with or without a discussion leader. Therefore, sufficient information has been included to help the reader achieve enough understanding to reduce the fear of radioactivity, the frightening unknown.

I. INTRODUCTION

What is RADIATION?

RADIATION is the emission and propagation of energy through space or through a material medium in the form of waves or particles.

Radiation defined as above includes *electromagnetic radiation* and *corpuscular emissions*. ELECTROMAGNETIC RADIATION is classified according to frequency and energy.

TABLE 1.1 ELECTROMAGNETIC RADIATION

Radiation	Frequency (hertz)	Energy (eV)
Radio, Television Radar	$10^4 - 10^{12}$	$4.1 \times 10^{-11} - 4.1 \times 10^{-3}$
Infrared	$10^{11} - 4 \times 10^{14}$	$4.1 \times 10^{-4} - 1.6$
Visible (light)	$4 \times 10^{14} - 7.9 \times 10^{14}$	$1.6 - 3.3$
Ultraviolet	$7.9 \times 10^{14} - 10^{17}$	$3.3 - 410$
X-rays	$2.5 \times 10^{15} - 7.3 \times 10^{24}$	$10 - 3 \times 10^{10}$
Gamma Rays	$2 \times 10^{18} - 2.5 \times 10^{21}$	$8 \times 10^3 - 10^7$
Cosmic Rays	$2.5 \times 10^{15} - 2.5 \times 10^{29}$	$10 - 10^{15}$

Several Kinds of Radiation

There are several kinds of radiation, and each behaves quite differently. Some procedures and materials give off only one kind of radiation while others may give off several different kinds. The following definitions apply to radiations which can arise from common procedures and radioactive materials.

ALPHA PARTICLE - [Symbol: α(alpha)] A doubly positively charged particle emitted by certain radioactive materials. It is made up of two neutrons and two protons bound together, hence it is identical with the nucleus of a helium atom. It is the least penetrating of the three common types of radiation (alpha, beta, gamma) emitted by radioactive material, being stopped by a sheet of paper.

BETA PARTICLE - [Symbol: β(beta)] An elementary particle emitted from a nucleus during radioactive decay. The beta particle has a single electrical charge and a mass equal to 1/1837 that of a proton. A <u>negatively</u> charged beta particle is identical to an electron; a <u>positively</u> charged beta particle is called a positron. Beta radiation can cause skin burns and beta emitters are harmful if they enter the body. However, beta particles have low penetrating power and are easily stopped by a thin sheet of metal.

GAMMA RAY - [Symbol: γ(gamma)] High energy, short-wavelength electromagnetic radiation originating in the nucleus of an atom. Gamma rays are very penetrating and are best stopped by dense materials, such as lead or depleted uranium. Gamma radiation frequently accompanies alpha and beta emissions and always accompanies fission.

X-RAY - [Symbol: x-ray] A form of electromagnetic radiation similar to gamma rays. X-rays are emitted from the extranuclear portion of the atom whereas gamma rays are emitted from the nucleus.

NEUTRON - [Symbol: n] A neutral particle emitted from a nucleus without an electrical charge.

BREMSSTRAHLUNG - Secondary radiation produced by charged particles passing through matter.

COSMIC RAY - Ionizing radiation which originates outside the earth's atmosphere. The energy of cosmic radiation can be as high as 10^{15}eV.

PROTON - [Symbol: p] An elementary nuclear particle with a positive electrical charge which is numerically equal to the charge of the electron. One proton constitutes the nucleus of the hydrogen atom of mass 1.

CORPUSCULAR EMISSIONS include alpha and beta radiation.

TABLE 1.2 CORPUSCULAR RADIATION

Radiation	Energy* (eV)
Beta Particle	1.8 E 04 to 8.1 E 06
Alpha Particle	1.8 E 06 to 1.2 E 07

Radiation does not actually exist in two neat compartments called *waves* and *particles*. Actually, all waves have some of the characteristics of particles and all particles have some of the characteristics of waves. Usually, however, the radiation is predominantly one or the other and little confusion will arise in our discussions if we speak of waves and particles as though they were separate phenomena.

*Computer notation is introduced to express exponents. E 03 = 10^3; E -03 = 10^{-3}. This notation will be used throughout this instructional material.

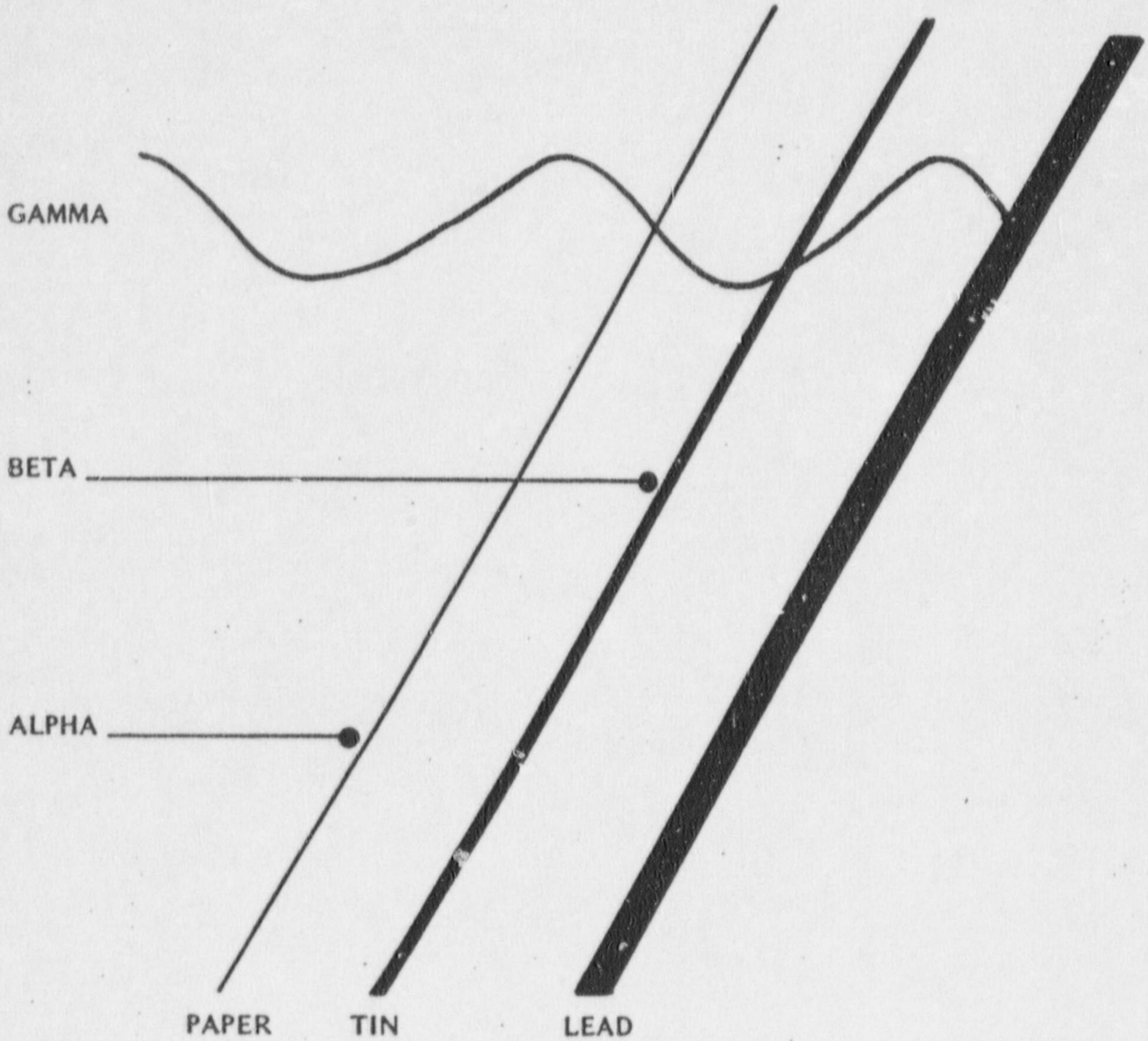


Figure 1.1. Penetrating Characteristics of Ionizing Radiation.

What is IONIZING RADIATION?

IONIZING RADIATION is any radiation which possesses sufficient energy to (1) strip electrons from an atom, producing two charged fragments called negative and positive ions, or (2) to cause molecules to be disrupted through molecular vibration to yield ions or free radicals. Typical examples of ionizing radiations are x-rays, gamma rays, cosmic rays, alpha particles and beta particles.

Other radiations can transfer energy to atoms or molecules thus increasing the energy of the receiving atom or molecule. Such radiations are called "exciting radiations" and the condition of increased energy is termed "excited state". Exciting radiations include radio waves, infrared, visible and ultraviolet radiations. These radiations have insufficient energy to effect ionization.

What is DIRECT ionizing radiation? INDIRECT?

The charged particles (protons, electrons and alpha particles) cause ionization or molecular fragmentation by direct interaction. Each interaction, or collision, results in a loss of energy and eventual disappearance of the particle by chemical reaction with surrounding molecules. The range of the charged particle in a medium such as water or tissue is very short:

TABLE 1.3 RADIATION AND RANGE

Radiation	Range
Alpha particle (4 MeV)	25 μm* in water (39.4 E -06 in)
Beta particle (E_{max} = 3 MeV)	1.5 cm in water (0.59 in)

*μm = micrometer = 10^{-6} meter

Therefore, the direct effects are predominantly restricted to thin layers of tissue.

Gamma rays and x-rays are penetrating radiations and may interact deep within the tissue. The interaction may produce electrons which can cause ionization or molecular fragmentation of surrounding matter. Through indirect interaction the interior of the body is affected. For example the gonads, liver or other internal organs are accessible to x-rays, gamma-rays and cosmic rays.

What is the energy unit of radioactivity?

We have said that radiation is the emission and propagation of energy through space or a material medium. This energy is measured in *electron volts* (eV). An electron volt is the energy acquired by an electron accelerated through a potential of 1 volt. The electron volt is a small unit and multiples are commonly used.

1 keV = 1000 eV

1 MeV = 1000 keV = 10^6 eV

The magnitude of 1 MeV can be visualized by recognizing that 2.62 E 13 MeV is necessary to raise the temperature of one gram of water 1°C! The energy per particle may be small but this is offset by the huge number of particles. One gram of hydrogen contains 6.023 E 23 electrons. Therefore, the total energy can be large.*

*1 gram calorie = 4.186 E 07 ergs.

1 MeV = 1.6 E 06 ergs.

Therefore, $\frac{4.186 \text{ E } 07}{1.6 \text{ E } 06}$ = 2.62 E 13 MeV/g-cal.

Chemical bonds are held together by only a few electron volts, whereas, ionization can be effected by ~32.5 eV, hence even a 1 keV particle can cause considerable ionization or molecular fragmentation.

RULES OF THUMB

I. IT REQUIRES AN ALPHA PARTICLE OF A LEAST 7.5 MeV TO PENETRATE THE PROTECTIVE LAYER OF THE SKIN, 0.07 mm THICK.

Alpha particles have short range in air.

MeV	Range cm	Range in
2.0	1.0	0.39
4.0	2.4	0.94
6.0	4.0	1.56
8.0	7.3	2.87

Alpha radiation has extremely low penetrating power and therefore causes most of its damage on the surface, e.g. burns. Deep tissue is not affected unless the radiation is internal. Adequate protection from alpha particles is achieved by the use of radiation shielding and by the interposition of distance between the source and you.

Internal effects of alpha radiation will be discussed later.

II. IT REQUIRES A BETA PARTICLE OF AT LEAST 70 keV TO PENETRATE THE PROTECTIVE LAYER OF THE SKIN, 0.07 mm THICK.

The range of beta particles in air is about 12 feet per MeV. The range of the beta particle from phosphorus-32 is approximately 1.71 x 12 = 20.52 feet, without shielding. Tritium beta particles (0.0186 MeV) have a range in air (unshielded) of approximately 2.7 inches!

Adequate protection from beta particles is achieved by the use of radiation shielding and the interposition of distance between the source and you.

III. GAMMA RADIATION (OR X-RADIATION) BEING WITHOUT MASS OR CHARGE IS HIGHLY PENETRATING. GAMMA AND X-RADIATION CAN EASILY REACH INTERNAL ORGANS.

The absorption of gamma or x-radiation by the interposition of matter is termed shielding. The amount of absorption by the shielding depends upon (a) the energy of the radiation and (b) the atomic number, mass and density of the absorbing medium. Gamma absorption is often described using the term "half-value layer" (HVL) which is defined as the distance of travel through an absorber required to decrease the intensity of a beam of gamma rays to one-half its initial value. Two HVL reduce the intensity 1/4, three 1/8, four 1/16, five 1/32, etc.

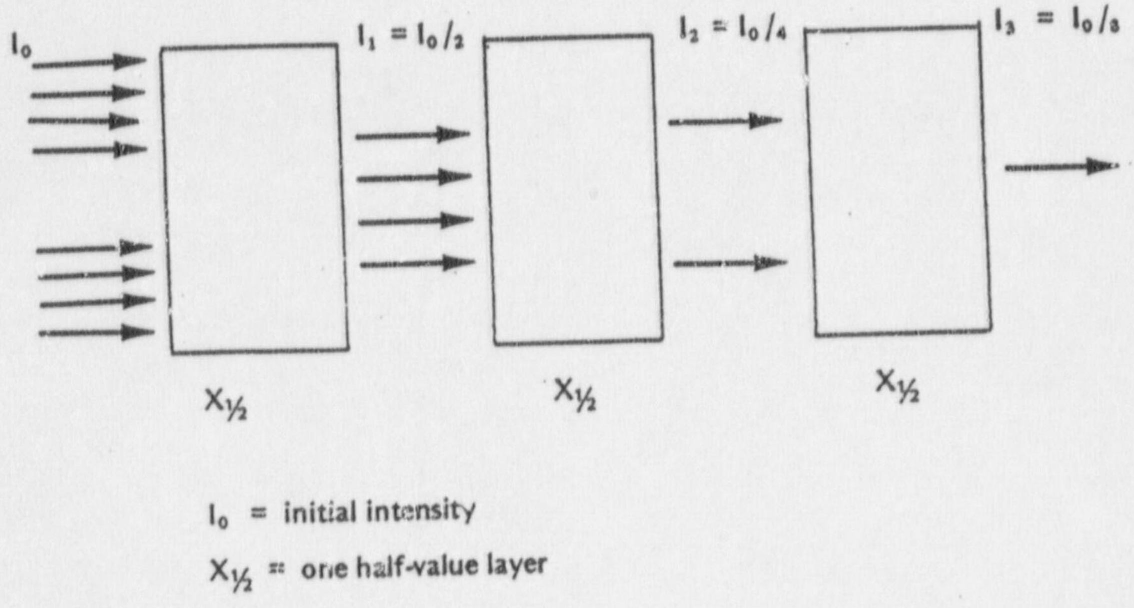


Figure 1.2. Absorption of Radioactivity

The half-value layer for cobalt-60 gamma rays (1.173 and 1.332 MeV) is about 1 centimeter of lead and for cesium-137 (0.662 MeV) HVL is about one-half centimeter of lead.

II. RADIOLOGICAL UNITS

What units are used with radioactivity?

There are several units commonly used with radioactivity and each has a specific meaning and application.

QUANTITY

The amount of radioactivity has long been expressed in curies (Ci). The current preferred unit is the becquerel (Bq).

1 curie = 3.7×10^{10} disintegrations/second
1 becquerel = 1 disintegration/second

DOSE - PHYSICAL

The unit for absorbed dose is the rad, which is an acronym for *r*adiation *a*bsorbed *d*ose. It is defined as that quantity of radiation that delivers 100 ergs of energy to 1 gram of substance (e.g. tissue). The rad is a physical unit.

Originally the roentgen (R) was the unit of radiation exposure. The roentgen is useful for x-rays and gamma rays but is inadequate for other radiations (e.g. neutrons). It is defined as 2.58×10^{-4} coulomb per kilogram of air. The rad and the roentgen are practically equivalent for tissue.

DOSE - BIOLOGICAL

The product of absorbed dose (rad) and certain modifying factors is termed the dose equivalent (DE). The unit of dose equivalent is the rem, (rem is an acronym for *r*oentgen *e*quivalent *m*an). The principal multiplier is the QUALITY FACTOR (QF) which varies with the type and energy of radiation.

TABLE 2.1 VALUES OF QUALITY FACTOR USED IN DEFINING DOSE EQUIVALENT

Radiation	QF
X-rays, gamma rays, electrons	1.0
Fast neutrons and protons up to 10 MeV	10
Alpha particles from radioactive decay (for internal exposure)	10
Heavy recoil nuclei	20

DOSE RATE

Dose rate means the dose absorbed per unit time and is commonly expressed in roentgens (or milliroentgens) per hour. For example, the portable personnel monitoring devices are commonly calibrated in mR/hr.

The dose rate of a gamma emitter, at a distance *d* from a "point source" of known activity can be calculated:

$$\text{Dose Rate} = \frac{A(\text{dis/hr})}{4\pi d^2} \times \frac{1}{(R)} \times \sum_i^n E_i\, n_i\, (\mu_a \rho_i)$$

For: $A = 1$ curie of ^{60}Co = 1.332 E 14 dis/hr

$d = 100$ cm

density of air = 1.293 E -03 g/cm³

$E_1 = 1.17$ MeV; $(\mu_a/\rho) = 0.0270\ cm^2/g$

$E_2 = 1.33$ MeV; $(\mu_a/\rho) = 0.0263\ cm^2/g$

$(R) = 5.24$ E 07 MeV/g air

$$\text{Dose Rate} = mR/(hr)(Ci)(m) = \frac{1.332\text{ E }14}{12.5664\text{ E }04} \times \frac{1}{5.24\text{ E }07} \times$$

$$[(1.17)(1)(0.0270)]+[(1.33(1)(0.0263)]$$

$$= 20.23 \times [0.0136 + 0.0350]$$

$$= 1.35\ R/(hr)\text{ at 1 meter/Ci}$$

(equivalent to 1.35 mR/hr at 1 meter/mCi

Using the inverse square law $\frac{1}{d^2}$ the dose from 1 mCi at <u>10 cm</u> = 135 mR/hr.

Table 2.2 lists the dose rates for selected gamma ray emitters. The dose rates at 100 cm and 10 cm illustrate the advantages of *distance between* the source and you.

SUB-UNITS

The units we have introduced are part of the International System of Units (SI) and are used with prefixes and symbols to form decimal multiples and submultiples of SI units. These are listed in Table 2.3.

TABLE 2.2. APPROXIMATE EXPOSURE RATES FOR SELECTED GAMMA RAY EMITTERS
(mR/hr/mCi at distance d)

During the passage of gamma rays through matter the rays undergo absorption by interaction with the atoms of the absorbing medium. The principle interactions are (a) the photoelectric effect, (b) the Compton effect and (c) pair production. The intensity of the radiation decreases with the distance traveled through the absorber. The intensities in air of the radiation from some commonly used gamma emitters is tabulated for distances of 1, 10 and 100 centimeters.

	mR/hr/mCi at distance d (cm)		
RADIONUCLIDE	d_1 = 1	d_2 = 10	d_3 = 100
Barium-133	2,400	24	0.24
Cerium-144	400	4	0.04
Cesium-137	3,300	33	0.33
Chromium-51	160	1.6	0.016
Cobalt-57	900	9	0.09
Cobalt-58	5,500	55	0.55
Cobalt-60	13,200	132	1.32
Copper-64	1,200	12	0.12
Gallium-67	1,100	11	0.11
Gold-198	2,300	23	0.23
Gold-199	900	9	0.09
Indium-113m	1,500	15	0.15
Iodine-125			
gamma ray only	13	0.13	0.0013
gamma ray & x-rays	230	2.3	0.023
Iodine-129			
gamma ray only	16	0.16	0.0016
gamma ray & x-rays	136	1.36	0.0136
Iodine-130	12,200	122	1.22
Iodine-131	2,200	22	0.22
Iron-59	6,400	6.40	0.64
Krypton-85	40	0.4	0.004
Manganese-52	18,600	186	1.86
Mercury-197	400	40	0.04
Mercury-203	1,300	13	0.13
Molybdenum-99	1,800	18	0.18
Potassium-42	1,400	14	0.14
Radium-226	8,250	82.5	0.825
Scandium-46	10,900	109	1.09
Scandium-47	560	5.6	0.056
Selenium-75	2,000	20	0.20
Sodium-22	12,000	120	1.20
Sodium-24	18,400	184	1.84
Strontium-85	3,000	30	0.3
Technetium-99m	600	6	0.06
Tin-113	1,700	17	0.17
Xenon-133	100	1	0.01
Zinc-65	2,700	27	0.27

TABLE 2.3 SI PREFIXES

Multiplication factor	Prefix	Symbol
10 E 18	exa	E
10 E 15	peta	P
10 E 12	tera	T
10 E 09	giga	G
10 E 06	mega	M
10 E 03	kilo	k
10 E 02	hecto	h
10 E 01	deka	da
10 E -01	deci	d
10 E -02	centi	c
10 E -03	milli	m
10 E -06	micro	μ
10 E -09	nano	n
10 E -12	pico	p
10 E -15	femto	f
10 E -18	atto	a

YET TO COME

In Section III we will discuss the exposure limits which have been established as the "maximum permissible dose limits". These limits are expressed in rems per calendar quarter and represent the sum of occupational exposures during the quarter.

III. RADIATION PROTECTION

Are there any guidelines regarding exposure to ionizing radiation?

The U. S. Nuclear Regulatory Commission has established limits which apply to the exposure of indivuals in a restricted area. These are called "Maximum Permissible Exposure Limits", (or Maximum Permissible Dose, MPD).

TABLE 3.1 MAXIMUM PERMISSIBLE EXPOSURE LIMITS (U.S.NRC)

Organ	Rems per Calendar Quarter
Whole body; head and trunk; active blood forming organs; lens of eyes; or gonads	1.25
Hands and forearms; feet and ankles	18.34
Skin of whole body	7.5

Are these precise limits?

These limits are based upon the best available evidence relating to the risk of adverse health effects due to ionizing radiation. The NRC based these limits on studies made by the National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR), the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP). The limits are estimates only and are continually under review.

At what exposure level can I be sure that the risk is zero?

There is no known "threshold" of exposure below which the risk estimate is zero. The best evidence is that radiation effects are cumulative. Society must accept some risk if it is to exploit the benefits of man-made radiation, (e.g., x-rays, diagnostic and therapeutic applications).

If radiation effects are cumulative, what should be done to manage one's exposure?

The NRC encourages the ALARA concept which was recommended by NCRP in 1954. The ALARA concept means that occupational radiation exposures should be maintained As Low As is Reasonably Achievable. NRC has determined that the occupational exposure at medical institutions is less than 10% of the maximum permissible dose and now requires medical licensees to report to the NRC any exposure which exceeds 10% of MPD.

All licensees are required, by regulation, to practice ALARA and nonmedical licensees are required to report any exposure which exceeds the MPD. The States which issue radioactive material licenses require a written report of a quarterly exposure to the whole body of 312 mRem or more (>¼ MPD).

How can I determine if I have been exposed to ionizing radiation?

The NRC requires each licensee to evaluate radiation hazards by physical survey of the workplace and by monitoring the exposure of each individual. Personnel monitoring can be accomplished using a variety of devices including film badges, thermoluminescent dosimeters (TLD), pocket-type exposure meters, etc. The devices used by Packard Instrument Company are the following:

1) A clip-on badge containing x-ray sensitive film. This badge monitors whole body exposure. It is recommended that this badge be worn in the front and in the area between the hips and the shoulders. This location is recommended so as to record the exposure of the critical organs.

   The badge exposure is determined by using a densitometer to measure the blackened area of the film.

2) A TLD ring badge, which contains an inorganic chemical (e.g., lithium fluoride) which stores energy upon irradiation. This badge monitors the exposure of hands and forearms and should be worn on the hand which is most often in closest contact with radioactive sources.

   The energy stored in the TLD is released as light when the TLD is heated. The amount of light released is a measure of the radiation exposure.

The film badge and TLD are integrating detectors in that they measure the total dose over a known period of time. Such devices provide the most accurate way of measuring exposure to low activity levels over the selected time interval.

What are pocket-type exposure meters?

Pocket-type exposure meters involve ionization of a gas, just as Geiger tubes do. The detector is usually a clip-on chamber which resembles a pocket pen. The condenser is charged to a prescribed voltage which sets its scale to zero. The scale is calibrated directly in terms of dose and is read by viewing through the eyepiece. The advantage of this dosimeter is the immediate reading capability plus accuracy up to dose rates of 100 R/hr. No permanent record is provided.

A variation of the pocket ionization chamber includes an alarm circuit. This pocket meter is useful where the radiation flux may be high and variable. The audible alarm indicates that a predetermined dose rate has been exceeded and appropriate action should be taken.

If radiation effects are cumulative, how much can I receive?

First, let us consider a familiar but nonradioactive radiation, namely the ultraviolet rays of the sun. Exposure to the sun rays causes the familiar "sunburn". Normally, an individual controls the exposure to sun rays so as to avoid discomfort. The damage done to tissue by sun rays is cumulative and long time exposure to the sun effects changes in unprotected tissue which may lead to skin cancer. Therefore, moderation is the logical course.

Likewise, with ionizing radiation an individual should practice moderation. This is the ALARA principle.

An additional factor must be included, i.e., the age of the individual. The evidence is that children are more radiosensitive than adults, therefore NRC limits the exposure of anyone under the age of 18 yrs. to 10% of MPD. For adults, the cumulative, or lifetime permissible dose has been set as 5(N-18) rems where "N" equals the individual's age in years at his last birthday. This equation indicates that an occupational exposure of 5 rems per year is permissible. Actual occupational exposures are much less.

Are radioactive materials toxic?

Toxicity generally refers to some reaction which occurs when a poisonous substance is introduced into body tissues. By this definition radioactive materials can be classified as having different levels of toxicity and the precautions to be taken when handling unsealed sources depends upon the degree of toxicity, quantity of the substance used and the nature of the operation. The classification according to radiotoxicity is given in Table 3.2.

TABLE 3.2 RADIONUCLIDES CLASSIFIED ACCORDING TO RELATIVE RADIOTOXICITY PER UNIT ACTIVITY

Group 1: very high radiotoxicity										
^{210}Pb	^{226}Ra	^{227}Th	^{231}Pa	^{233}U	^{238}Pu	^{241}Pu	^{243}Am	^{244}Cm	^{249}Cf	
^{210}Po	^{228}Ra	^{228}Th	^{230}U	^{234}U	^{239}Pu	^{242}Pu	^{242}Cm	^{245}Cm	^{250}Cf	
^{223}Ra	^{227}Ac	^{230}Th	^{232}U	^{237}Np	^{243}Pu	^{241}Am	^{243}Cm	^{246}Cm	^{252}Cf	
Group 2: high toxicity										
^{22}Na	^{56}Co	^{95}Zr	^{125}Sb	^{131}I	^{144}Ce	^{181}Hf	^{207}Bi	^{228}Ac		
^{36}Cl	^{60}Co	^{106}Ru	^{127}Te^{m}	^{133}I	^{152}Eu(13yr)		^{210}Bi	^{230}Pa		
^{45}Ca	^{89}Sr	^{110}Ag^{m}	^{129}Te^{m}	^{134}Cs	^{154}Eu	^{182}Ta	^{211}At	^{234}Th		
^{46}Sc	^{90}Sr	^{115}Cd^{m}	^{124}I	^{137}Cs	^{160}Rb	^{192}Ir	^{212}Pb	^{236}U		
^{54}Mn	^{91}Y	^{114}In^{m}	^{126}I	^{140}Ba	^{170}Tm	^{204}Tl	^{224}Ra	^{249}Bk		
		^{124}Sb								
Group 3: moderate toxicity										
^{7}Be	^{48}Sc	^{65}Zn	^{91}Sr	^{103}Ru	^{125}Te^{m}	^{140}La	^{153}Gd	^{187}W	^{198}Au	^{231}Th
^{14}C	^{48}V	^{69}Zn^{m}	^{90}Y	^{105}Ru	^{127}Te	^{141}Ce	^{159}Gd	^{183}Re	^{199}Au	^{233}Pa
^{18}F	^{51}Cr	^{72}Ga	^{92}Y	^{105}Rh	^{129}Te	^{143}Ce	^{165}Dy	^{186}Re	^{197}Hg	^{239}Np
^{24}Na	^{52}Mn	^{73}As	^{93}Y	^{103}Pd	^{131}Te^{m}	^{142}Pr	^{166}Dy	^{188}Re	^{197}Hg^{m}	
^{38}Cl	^{56}Mn	^{74}As	^{97}Zr	^{109}Pd	^{132}Te	^{143}Pr	^{166}Ho	^{185}Os	^{203}Hg	
^{31}Si	^{52}Fe	^{76}As	^{93}Nb^{m}	^{105}Ag	^{130}I	^{147}Nd	^{169}Er	^{191}Os	^{200}Tl	
^{32}P	^{55}Fe	^{77}As	^{95}Nb	^{111}Ag	^{132}I	^{149}Nd	^{171}Er	^{193}Os	^{201}Tl	
^{35}S	^{59}Fe	^{75}Se	^{99}Mo	^{109}Cd	^{134}I	^{147}Pm	^{171}Tm	^{190}Ir	^{202}Tl	
^{41}A	^{57}Co	^{82}Br	^{96}Tc	^{115}Cd	^{135}I	^{149}Pm	^{175}Yb	^{194}Ir	^{203}Pb	
^{42}K	^{58}Co	^{85}Kr^{m}	^{97}Tc^{m}	^{115}In^{m}	^{135}Xe	^{151}Sm	^{177}Lu	^{191}Pt	^{206}Bi	
^{43}K	^{63}Ni	^{87}Kr	^{97}Tc	^{113}Sn	^{131}Cs	^{153}Sm	^{181}W	^{193}Pt	^{212}Bi	
^{47}Ca	^{65}Ni	^{86}Rb	^{99}Tc	^{125}Sn	^{136}Cs	^{152}Eu(9.2h)		^{197}Pt	^{220}Rn	
^{47}Sc	^{64}Cu	^{85}Sr	^{97}Ru	^{122}Sb	^{131}Ba	^{155}Eu	^{185}W	^{196}Au	^{222}Rn	

(continued)

TABLE 3.2 (cont'd.)

Group 4: Low toxicity

^{3}H	$^{58}Co^{m}$	^{71}Ge	^{87}Rb	^{97}Nb	$^{103}Rh^{m}$	$^{131}Xe^{m}$	^{135}Cs	$^{191}Os^{m}$	^{232}Th	^{238}U
^{15}O	^{59}Ni	^{85}Kr	$^{91}Y^{m}$	$^{96}Tc^{m}$	$^{113}In^{m}$	^{133}Xe	^{147}Sm	$^{193}Pt^{m}$	^{Nat}Th	^{Nat}U
^{37}A	^{69}Zn	$^{85}Sr^{m}$	^{93}Zr	$^{99}Tc^{m}$	^{129}I	$^{134}Cs^{m}$	^{137}Re	$^{197}Pt^{m}$	^{235}U	

How can I protect myself from ionizing radiation?

The choice of protective measures begins with an understanding of the characteristics of the radiation to which an individual is exposed. The characteristics which must be considered are the following:

Radiation type,
Energy of the radiation, and
Quantity of radiation.

Radiation Type

Beta Particle - A radioactive atom can emit a negatively charged particle from its nucleus. This negatively charged particle is the beta particle and has mass and charge equal in magnitude to the electron. The emission of beta particles from an atom is a continuum of energies from zero to a maximum energy, E_{max}, which is a characteristic of the radionuclide. The range of maximum energies of beta emitters begins with a value of 0.018 MeV for tritium and ends with a maximum of 8.1 MeV for bromine-87.

The emission of beta particles is often accompanied by another type of radiation. However, several radionuclides decay by the emission of beta particles only, such radionuclides are called "pure beta emitters". A partial list of pure beta emitters is provided in Table 3.3 in the order of increasing energy.

TABLE 3.3 PURE BETA EMITTERS

Radionuclide	E_{max} (keV)	E_{av} (keV)
^{3}H	18.60	5.68
^{63}Ni	65.87	17.13
^{14}C	156.478	49.47
^{35}S	167.47	48.80
^{32}Si	213.0	64.7
^{33}P	249.0	76.6
^{45}Ca	256.9	77.2
^{64}Cu	578.2	190.3
^{115}In	859.0	290.0
^{95}Zn	905.0	320.9
^{89}Sr	1492.0	583.1
^{32}P	1710.4	695.0
^{90}Y	2284.0	934.8

The E_{max} for either tritium or nickel-63 is less than 70 keV. Therefore, neither consitutes a severe external hazard since approximately 70 keV of beta particle energy is required before the particle can penetrate the skin. However, sources composed of substances containing tritium or nickel-63 should be handled as carefully as any other radioactive source. This means radioactive sources should be handled with forceps if at all possible. Low energy sources may be handled with the hands only in the execution of an approved procedure, such as the assembly of iodine-129 sources in the Multi-Gamma Counter.

Will I become radioactive after exposure to radioactive material?

External exposure to radioactive materials will not make you radioactive. However, it is possible that exposure to radiation will cause biological damage due to chemical changes. The most knowledge we have concerning external radiation damage comes from the testing and use of nuclear weapons. One consequence is skin burns which appear to be the same as burns from a hot stove and are also temporary. The most extreme biological damage occurred with the bombing of Hiroshima and Nagasaki where heat accounted for a large number of fatalities and biological damage caused subsequent death due to cancer. There is no possibility that similar disastrous results can occur from your use of small quantities of nonfissionable radioactive material.

What can I do to reduce my exposure to radiations from radioactive material?

There are some simple principles by which you can reduce your exposure.

TIME

The exposure is reduced by limiting the time you are in the vicinity of the radioactive material. This simply means that the task you perform using radioactivity should be done carefully and efficiently so as to require the minimum amount of time.

SHIELDING

In Section I we learned that different radioactive particles showed varying abilities to penetrate matter.

Alpha particles - Very low ability to penetrate matter. A sheet of paper will stop the radiation from many alpha emitters. An alpha particle must have an energy of 7.5 MeV or more to penetrate the outer layer of the skin.

Beta particles - Small quantities of low energy beta emitters such as tritium and carbon-14 are effectively shielded by the containers in which they are stored or used. Large quantities (millicuries) of low energy beta emitters should be shielded due to the secondary x-rays formed when the walls of the container decelerate the beta particle (brehmstrallung).

Beta emitters which decay with the emission of high energies (e.g., phosphorous-32, E_{max} = 1.710 MeV) require shielding. Glass brick or Lucite are suitable shielding materials.

Gamma rays (or x-rays) have great penetrating power. Lead is the shielding material most commonly used for protection against gamma or x-rays. In Section I we became acquainted with the term Half-Value Layer, so let us tabulate HVL versus energy.

TABLE 3.4 HALF-VALUE LAYERS FOR LEAD

Energy (MeV)	HVL (cm)
0.03	0.0021
0.05	0.0078
0.1	0.011
0.5	0.38
1.0	0.86
1.5	1.18
2.0	1.34
3.0	1.46

NOTE: The lead brick commonly used for shielding is 2 inches thick. Since 2 inches is equal to 5.08 cm each thickness of lead brick is equivalent to 3.8 HVL for a 2.0 MeV gamma ray, which effects a reduction in intensity of about 1/14.

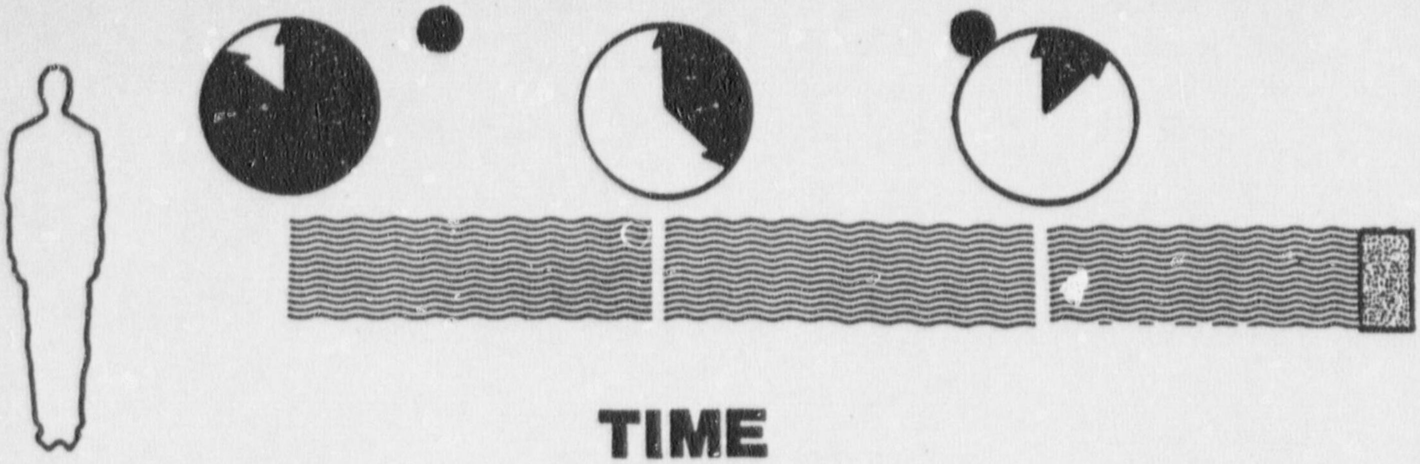
DISTANCE

As distance from the radiation source is increased, the exposure decreases. The intensity is inversely proportional to the square of the distance. Therefore doubling the distance reduces the exposure to ¼ the original intensity.

$$I_{d^1} = \frac{I_0}{(2)^2} = \frac{1}{4} \times I_0$$

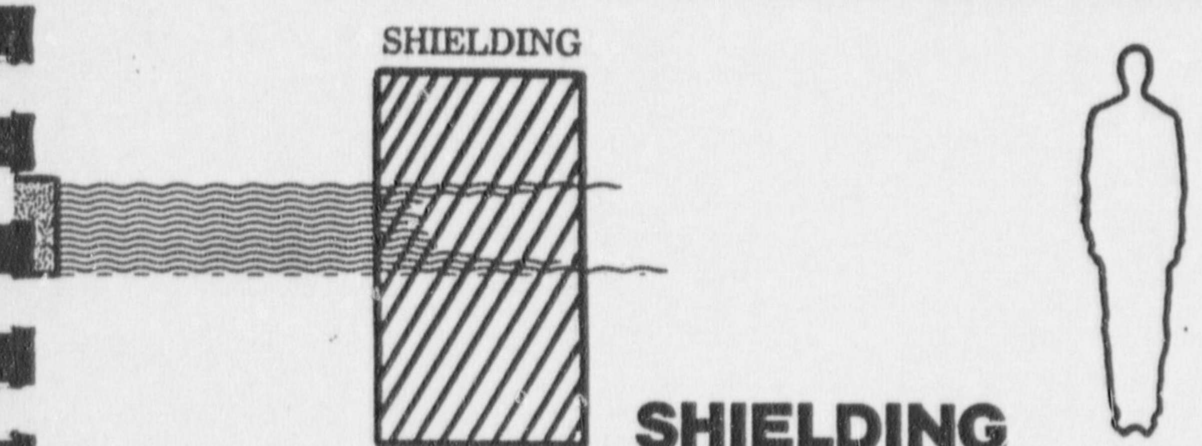
YET TO COME

In Section IV we will examine the radiation exposure of the general population of the United States.



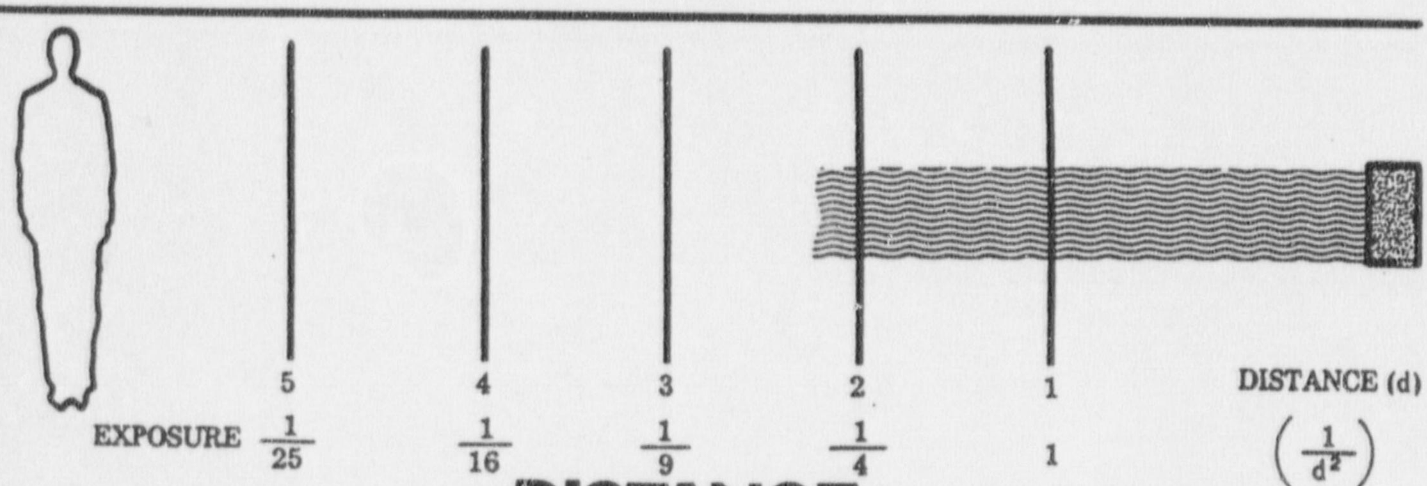
TIME

LIMIT THE TIME TO
REDUCE THE EXPOSURE



SHIELDING

USE SHIELDING TO
REDUCE THE EXPOSURE



DISTANCE

INCREASE THE DISTANCE TO
REDUCE THE EXPOSURE

IV. AVERAGE RADIATION EXPOSURES OF THE GENERAL POPULATION OF THE UNITED STATES

Radioactive materials and radiation are as old as the universe, however, mankind has recognized radioactivity only since 1896 -- less than one hundred years. Our everyday lives involve constant contact with naturally occurring radioactive materials.

What is the source of naturally occurring radiation?

Table 4.1 lists the estimated exposure of the general United States population.

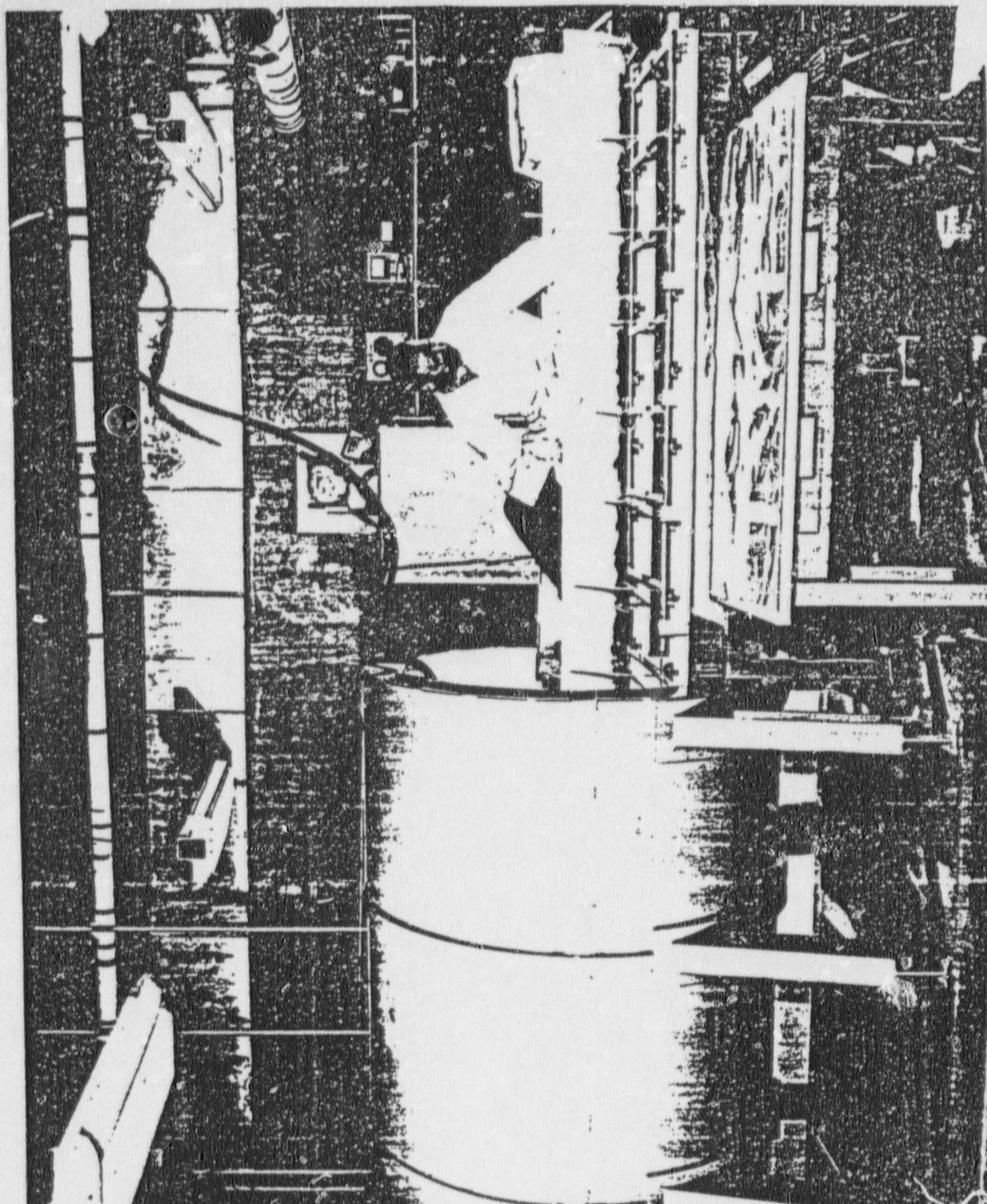
TABLE 4.1 U. S. GENERAL POPULATION EXPOSURE ESTIMATES (1978)

Source	Average Individual Dose (mrem/yr)
Natural background	100
Release of radioactive material by mining, milling, etc.	5
Medical	90
Nuclear weapons development (primarily fallout)	5-8
Consumer products (color TV)	0.03
Nuclear energy	0.28
Total	~200 mrem/year

(From U. S. NRC Draft Regulatory Guide, May 1980, "Instruction Concerning Risk from Occupational Radiation Exposure".)

The natural background consists of cosmic rays, and radioactive substances in the earth and in building materials. Cosmic rays originate in outer space and constantly bombard the earth. The exposure to cosmic radiation is increased as we go higher above sea level. Residents of Denver, Colorado (alt. 5,280 ft.) are exposed to more cosmic radiation than residents of Chicago, Illinois (alt. 595 ft.). Airline passengers receive increased exposure as a result of altitude and the thinning of the atmosphere at flight levels.

The earth is itself radioactive. Proof is that the Curies extracted polonium and radium from pitchblende mined in Golden, Colorado. The geologic radioactivity in Colorado is readily observed as an increased background count rate when one is using a Tri-Carb liquid scintillation counter in that area. One of the most intensely geologically radioactive areas is located in India where the population is exposed to approximately 1,300 millirems per year.



WHOLE BODY COUNTER - LOS ALAMOS SCIENTIFIC LABORATORY

Ordinary building materials, such as cement, brick, concrete, etc., contain radioactivity. In fact, special precautions are necessary when building a warehouse for photographic film or a laboratory for low level counting.

In addition to these natural radiations, we are exposed to radiations used in medicine for diagnosis and therapy. Clearly the decision has been made that the medical benefits outweigh the risks.

Nuclear energy contributes about one quarter of one percent of the total exposure of the general population. One diagnostic dose of radioactive iodine has been calculated to contain as much iodine radioactivity as the total cooling water in a Boiling Water Reactor.

Is it true that our bodies are radioactive?

Yes it is true that our bodies are radioactive. The level of radioactivity is usually low but it is there because each of the naturally occurring radioactive nuclides finds its way into the body. The principal ones are potassium-40, carbon-14 and hydrogen-3 (tritium). These three are important because of the relatively high percentages of these elements in the body.

In some areas there are natural concentrations of thorium and uranium, principally in the water and soil. Radium-226 is one of the daughters of uranium-238 and it tends to seek bones where it accumulates and adds to the radioactivity in the body.

Table 4.2 gives estimates of the internal radioactivity.

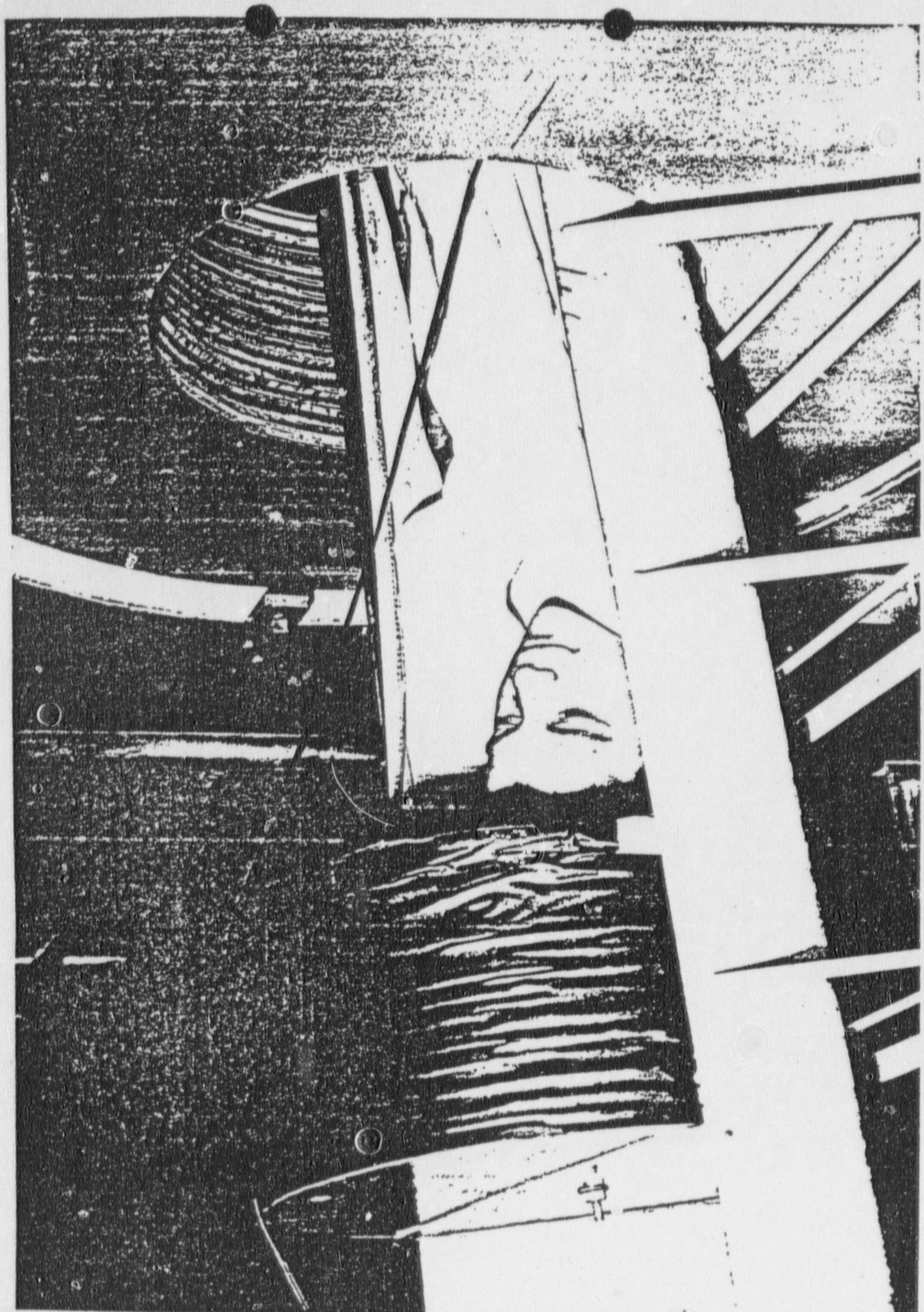
TABLE 4.2 INTERNAL NATURAL RADIOACTIVITY

Source	Dose rate (mR/yr)	Varies with
Thorium, uranium and daughters	40 - 400	Location and water supply
Potassium-40	20	Not very variable
Carbon-14	2	Not very variable
Tritium	2	Not very variable

The fact emphasized by this table is that our bodies contain a natural radioactivity in excess of 60 millirem per year! This internal dose rate exceeds the occupational exposure of 82% of Packard personnel who handled radioactive materials during 1978 and 1979! (See Table 4.3)

What is the purpose of discussing exposure to naturally occurring radioactivity?

It is hoped that we will be encouraged to place in perspective



WHOLE BODY COUNTER -- LOS ALAMOS SCIENTIFIC LABORATORY the dangers associated with radioactivity by developing an understanding that radioactive materials surround us in air, water, earth, building materials, etc., and yet we survive without loss of life or creation of monsters due to radioactivity.

The goal of this training is to minimize fear of radioactivity and to develop a profound respect for it and its uses.

How much more exposure do we receive due to our occupation?

The U. S. NRC required licensees to report occupational exposures for U. S. workers for the years 1978 and 1979. The Packard reports are combined in Table 4.2.

TABLE 4.3 STATISTICAL SUMMARY REPORT OF EXPOSURE OF PACKARD PERSONNEL (U.S. only)

Range of Exposure (Rem)	Number of Individuals 1978	1979
No Measurable Exposure	328	222
0.0 - 0.1	34	115
0.1 - 0.25	3	18
0.25 - 0.5	1	1
0.5 - 0.75		
0.75 - 1.0		
1.0 - 2.0	1	
2.0 - above		
Total No.	367	356
Rem	9.93	18.72
Average Exposure	0.027 R	0.053 R
Percentage of general exposure	0.014%	0.027%
Percentage of industry average (0.34 rem/yr)	7.9%	15.6%

It is clear from Table 4.2 that the occupational exposure of Packard employees is small. This reflects the use of low energy radioactive materials and the careful handling of radioactive materials.

YET TO COME

In Section V we will examine the biological effects of ionizing radiation.

V. BIOLOGICAL EFFECTS OF IONIZING RADIATION

The beneficial effects of ionizing radiation are universally accepted with scarcely a moment of concern. We routinely have X-rays made of our chests and teeth without worrying about danger. Ionizing radiation is used in the treatment of cancer with the clear understanding that the benefit exceeds the risk. Ironically, one of the most common fears associated with ionizing radiation is the general public's belief that radiation is a prime cause of cancer. In this section we will restrict the discussion to questions and answers which relate to this fear and other common fears of adverse effects of ionizing radiation. Each answer will emphasize practical information without stressing scientific details.

Section V may be studied alone if so desired.

Will radioactivity cause me to have cancer?

Probably not. About 97 percent of all cancers are caused by chemicals which alter the genetic material of the cell. Sunlight (ultraviolet radiation) causes a portion of the remaining 3% of cancers formed.

It is unethical to conduct experiments on humans so the answer to your question is really based on statistical examination of known facts.

Fact No. 1

Approximately 1 person in 4 develops cancer during a lifetime. The American Cancer Society offers these figures for adults in the 20-65 year age bracket. Thus for 10,000 workers <u>not exposed to radiation on the job</u> we expect 2,500 to develop cancer.

Fact No. 2

Three scientific bodies have independently estimated that cumulated exposure to 1 rem of radiation can be expected to cause 300 cancer cases per million individuals, or 3 cases per 10,000 people.

These two facts tell us that:

a)	of 10,000 people not exposed to radiation 2,500 will develop cancer	2,500
b)	of 10,000 radiation workers with a cumulated exposure of 1 rem, 3 additional people will develop cancer	3
c)	Total cancers	2,503
d)	Cancer development in percent	25.03
e)	Increased cancer development due to radiation in percent	0.03

For those of you who are poker players the following analogy can be drawn:

> The normal chance of developing cancer if you receive no occupational radiation is about equal to your getting a spade on a single draw from a full deck of playing cards, i.e., one chance in four.
>
> The chance of developing cancer from occupational exposure with the accumulation of 1 rem is about equal to your drawing three successive aces from a well-shuffled deck of cards if each card drawn is not replaced before the next card is drawn. (See APPENDIX II)

I have a neighbor who claims that atomic bombs, x-rays and nuclear power plants have caused new diseases never before seen by doctors. Is this true?

This is false. No new or unique diseases have been caused by radioactivity, whether it be man-made or naturally occurring. The harmful effects of radiation can all be caused by other means and the diseases have been known for years and years. Chemicals are a generally accepted cause of harmful effects and disease, chemically induced cancer is an example.

I heard on TV that the first nuclear reactor was in Africa. Is that true? I thought the first was in the United States.

Mother Nature produced the first nuclear reactor about 1.7 billion years ago. The natural uranium deposits in Africa occurred in rock structures through which water flowed. The uranium was highly reactive since it was "young" and perhaps had not passed through even one half-life ($T_{½}$ of U = 7.1×10^8y). Consequently, the uranium generated sufficient heat to turn the water to steam.

The first man-made nuclear reactor was built on the campus of the University of Chicago in 1942.

In assembling the multi-detector gamma counter it is necessary to thread the plastic capsule containing the activity onto a holder. Does the assembler receive a high dose of radiation during this operation?

The radiation dose is extremely small.

The source contains iodine-129 activity which gives off x-rays. The most energetic x-ray has an energy of 39.58 keV. The iodine-129 activity is bound to a resin and is contained in a plastic capsule. The capsule is delivered to the assembler in a plastic test tube. No measurable activity above background is observed when one or several tubes containing sources are placed close to a portable detector which has a sodium-iodide crystal.

How then does the source obtain a response in the Multi-gamma counter?

The Multi-gamma counter has one to four very sensitive sodium iodide detectors. The sensitivity is achieved by minimizing the amount of absorber between the source and the sodium iodide. In the Multi-gamma counter only a very thin (0.010 in.) aluminum sleeve separates the sodium iodide crystal from the iodine-129 source. On the other hand, the crystal of the portable detector is separated from the source by two layers of aluminum which total approximately 1/8 inch thick. This thickness is sufficient to reduce the x-ray intensity by approximately 50 percent. (See Appendix III.)

Now I understand that there is little danger from the iodine-129 source, but why are so many radiation labels required?

The Nuclear Regulatory Commission requires that all sources and containers of radioactivity be labeled. The label must identify the radioactive material and tell how much is present and it must also bear the international symbol for radioactivity and the words:

CAUTION RADIOACTIVE MATERIAL.

These labels are for the protection of the "unsuspecting public" who could be unknowingly exposed to radioactivity.

Will working with radioactivity make me sterile?

Occupational exposure to radioactivity at Packard will not make you sterile.

Knowledge about radiation induced sterility comes from therapeutic uses of radioactivity. Localized exposure, spread over a few weeks, of 500-800 rems to the gonads can produce permanent sterility in males or females. Note that this is localized exposure under conditions of therapy. A dose of 500-800 rems to the whole body would probably result in death within 30 days.

Temporary but measurable sterility can result from an acute dose of 20 rems to the testes.

Exposure of the magnitude to cause sterility are impossible with the levels of radioactivity used at Packard.

Can radiation produce monsters?

Monster formation (i.e., mutations) would be a result of genetic damage. Fortunately, there is no evidence of radiation induced mutations in humans. The descendants of survivors of the nuclear bombs at Hiroshima and Nagasaka do not show monsterism.

Studies involving the irradiation of fruit flies have produced evidence of mutation in this species. However, the rate of mutation is estimated as one gene out of 100,000. Dr. Hermann J. Muller was awarded a Nobel prize in 1946 for demonstrating that radiation can produce mutations in fruit flies.

Remember that no evidence is available to show that radiation exposure can transform human beings into monsters.

How does an overdose of radiation affect me and what effect does the overdose have on the individuals with whom I live?

This is a multifaceted question which we will separate into four parts:

1. External exposure without external contamination.
2. External exposure with external contamination.
3. Internal contamination.
4. What constitutes an overdose of radioactivity.

1. The first case is one in which an individual is exposed to a source of radiation but none of the radiation adheres to the individual's body or clothing. The most familiar example is a medical or dental x-ray procedure. Our experience over nearly 100 years confirms that there is no induced radiation and no residual radiation in an individual after obtaining a medical or dental x-ray. The same is true for the common radiations from radioactive materials. Irradiation by alpha or beta particles, or gamma rays, will not make you radioactive nor will a residue of radioactivity remain on your clothes or your body when the radioactive source has been removed.

   We can reach the same conclusion using another analogy. Gamma radiation is electromagnetic radiation just as light is. We all know that when the light is extinguished none of us glow.

   There is no effect on those who share your living quarters.

2. The second case is one in which external exposure is accompanied by contamination of the individual's clothing and body. External contamination can not occur with sealed sources. Typical of the sealed sources used at Packard are: cobalt-60, iodine-129, barium-133, cesium-137, radium-226 and americium-241.

   The manipulation of unsealed sources, whether liquid or solid, presents the possibility of external contamination. Typical unsealed sources used at Packard include:

   a) solutions of liquid scintillation standards in glass ampoules,

   b) standardized solutions of radioactivity used to prepare sealed standards, and

   c) solutions of radioactivity for use in research.

   The exercise of proper techniques for handling unsealed radioactive sources greatly diminishes the likelihood of external contamination. In addition, each individual and the protective clothing used should be monitored for radioactivity before leaving the area. If necessary, decontamination and re-inspection should follow.

There is no effect on those who share your living quarters.

3. The third case, internal exposure, becomes a concern when contamination control is absent. Radioactive materials can enter the body by three means: a) ingestion, b) inhalation and c) absorption.

   Ingestion - The concern here is accidental ingestion, which should be prevented by control of personal habits. Food, drink and smoking materials should be banned from the area where radioactivity is being handled, and nothing should be placed in the mouth while in the area.

   Ingested radionuclides can enter the blood stream by absorption through the gastrointestinal (GI) tract. How much is absorbed into the blood stream depends on the chemical and physical form of the ingested material. Insoluble material is excreted through the feces.

   Inhalation - Vapors from volatile liquids and airborne powders can enter the body by inhalation. Materials which can become airborne should be handled in a laboratory hood.

   Inhaled radionuclides can be absorbed into the blood stream through the lungs.

   Absorption - Radioactive materials can also enter the blood stream by absorption through the unbroken skin, or through abrasions, cuts and punctures. Any individual working with unsealed radioactive materials should wear protective clothing (e.g., gloves) and otherwise prevent contact with the skin. If skin contact does occur, the skin should be washed with soap and water and decontamination confirmed by means of a radioactivity monitor.

An individual with internal radioactivity, other than the naturally occuring materials potassium-42, carbon-14, hydrogen-3 (tritium) and daughters of thorium and radium, should be considered a source of radiation and radioactive contamination. It may be necessary to provide protection for those who come in contact with the contaminated individual.

Experience gained by the medical profession when treating patients with radioactive materials is useful in establishing some guidelines with respect to protective measures.

Low Level Contamination

Accidental internal contamination of Packard employees is very unlikely because unsealed sources are handled in the laboratory area only and this area includes the proper equipment for the safe handling of radionuclides. and the laboratory personnel use the necessary precautions. In addition, the unsealed sources used at Packard seldom contain millicurie amounts of radioactivity and are normally limited to microcurie quantities.

The Nuclear Medicine departments of hospitals routinely administer microcurie quantities of radioactivity in various diagnostic tests. Typical doses can range from 0.5 microcurie to 500 microcuries. Patients with such doses are not restricted, they mingle with the hospital staff, use public transportation and associate with family members without affecting them in any manner due to the radioactivity.

High Level Contamination

It is improbable that a Packard employee would ever get a high level occupational dose because the amounts of activity used are small. High level contamination can occur at plants which process nuclear fuel, synthesize radioactive compounds or perform other chemical operations on radioactive materials. A person so contaminated should be under medical supervision since the contamination is somewhat analagous to chemical poisoning.

What constitutes an overdose of activity?

The NRC has set 1.25 rems per calendar quarter as the Maximum Permissible Exposure. However, NRC recognizes the possibility of emergency situations in which a brief, high radiation exposure can occur. Such emergency exposure is allowable provided that:

a) the dose in any calendar quarter does not exceed 3 rems, and

b) the high dose plus the accumulated exposure does not exceed 5 (N-18) rems, where "N" equals the individual's age on the last birthday.

Let us accept 3 rems as the definition of "overdose" and relate that to the sources which we commonly handle.

a) Iodine-125: 1 mCi for iodination
At a distance of 10 cm (cf Table 2.2), 1300 hours of exposure would be required for a dose of 3 rems. (1300 hours - 32 work weeks of 40 hours)

b) Iodine-125: Insulin RIA kit which contains "not more than 10 microcuries".
At a distance of 10 cm and neglecting shielding and half life, 130,000 hours would be required for an exposure of 3 rems.
(130,000 hrs = 3,250 work weeks)

c) Iodine-129: 0.1 μCi
At a distance of 10 cm, and neglecting shielding and half life, 22×10^6 hours would be required for an

exposure of 3 rems.

d) Radium-226: 10 μCi and 20 μCi at a distance of 10 cm, and without shielding, a 20 microcurie source would require 1800 hours and a 10 microcurie source would require 3600 hours for an exposure of 3 rems.

These figures tell us that it is virtually impossible for a Packard employee to have an emergency exposure equivalent to what we have defined as "overdose".

Radium frightens me, but it is my job to add the source to the "ell-tube" when we assemble the TRI-CARB. I always use tweezers when handling the pellet. What are the possible effects on me and what other precautions should I take?

The use of tweezers is a good procedure. You are probably using other precautions such as:

1. storing the pellets in a labeled lead container in a specific place,

2. handling at your work station no more pellets than you need for the job,

3. working quickly and efficiently when loading the "ell" tube.

These three precautions plus the use of tweezers illustrate fundamental ways to limit exposure to radioactive material:

USE ONLY AS MUCH AS IS REQUIRED.

SHIELD THE ACTIVITY.

LIMIT THE TIME OF EXPOSURE.

USE DISTANCE AS A PROTECTION.

When these principles are followed, exposure will be low and the possibility of adverse effects will be minimal.

Your first statement was "radium frightens me". That is a perfectly normal reaction. We are all aware of frantic searches in hospitals whenever a radium needle was lost; we have heard horrible stories concerning radium watch-dial painters, and the movie story of Marie and Pierre Curie showed that they had leukemia ("blood cancer") after years of working with radium and other radioactive materials. How do we sort things out?

My mother used to say "enough is enough and too much hurts". This is the basic thought we should have in understanding how to safely handle radium.

Radium salts were the first radioactive materials used in the radiation treatment of cancer. The radium was encapsulated in needles so that a needle could be implanted and recovered. Recovery was desirable for two reasons: first, radium has a long half-life (1620 yrs) so if it was injected the patient would be contaminated for life; second, radium was and is very expensive so recovery was advisable as an economy measure. The frantic searches for lost needles was due to both factors, hazard and value.

When the doctor felt that the cancer had been irradiated sufficiently, the temporarily implanted radium needle was removed. This technique applied three fundamentals:

1. localization of irradiation or spatial control,

2. utilization of a small amount of quantity control, and

3. implantation for a definite period or time control.

These controls were absent in the experience of the Curies and the radium watch-dial painters. There was no understanding of the fact that some of the organs of the body are critically affected by radiation. For soluble radium compounds, the critical organ is bone and for insoluble radium compounds, the critical organ is the lung. Through years of working with radium and other radioactive materials, the Curies must have inhaled powders containing radium and these powders lodged in the lungs. Here the radium continually irradiated the blood, causing leukemia. The radium watch-dial painters had the habit of touching the tip of the paint brush to the tongue in order to maintain a fine tip. The soluble radium salt concentrated in the bone since radium seeks bone just as calcium does. Unfortunately, radium displaces the calcium in the bone consequently damaging the bone.

The Curies and the painters were victims of chronic exposure where chronic exposure refers to small doses received repeatedly over a long period of time. The precautions observed in assembling the ell tube are designed to control exposure to a minimum and to prevent ingestion of the activity. Handling the radium pellets is safe if these precautions are always observed.

I work with iodine-125 in one of two chemical forms: a) iodine-125 labeled tri-iodothyronine for the T-3 test and b) sodium iodide I-125 for the preparation of standards. The normal amount of T-3 (or T-4) purchased is 100 microcuries, likewise, a standardized solution of sodium iodide can be purchased containing 108 microcuries per milliliter. My question is how would I be affected if the full 100 microcuries was spilled on me or if it was totally oxidized?

Before we answer the question, let us review some facts about iodine-125.

Half-life	60.14 days*
Mode of Decay	Electron Capture

Principle Radiations	Energy	Emanations per 100 disintegrations
Auger-L	3.19 keV	156
Auger-K	22.7	20
ce-K 1	3.6781	80
x-ray L	3.77	15
x-ray $K_{\alpha 2}$	27.20170	39.8
x-ray $K_{\alpha 1}$	27.47230	74.2
x-ray K_{β}	31.	25.8
γ-1	35.4919	6.67

Compounds labeled with iodine-125 behave in the body in the same manner as compounds containing nonradioactive iodine. The labeled compounds are administered orally (thyroid function) or intra-venously (liver function, blood volume, etc.). The labeled compound can be detected and measured through the skin because of the x-rays and the gamma ray.

The quantity of radioiodine used varies with the test. Some quantities are as follows:

Test	Administered quantity
Thyroid iodine uptake	10 - 500 microcuries
Thyroid scanning	50 microcuries to "several" millicuries
Thyroid metastases	up to 100 millicuries

We immediately notice that the 100 microcurie shipment spilled approximates the <u>lower level</u> of activity administered for medical purposes. Reasoning by analogy, the accident can be no more dangerous than the medical procedure.

If we assume that the accidental spill results in complete ingestion of 100 microcuries of iodine-125, we become concerned only with long term effects since the quantity of radioactivity and the energy of the radiations will not produce acute effects.

Iodine compounds are primarily eliminated from the body in urine. Greater than 40% of the administered dose (accidental or intentional) is eliminated in 24 hours by individuals with a normally functioning thyroid.

*The International Atomic Energy Agency recommends 59.156 days.

We can compute the effective half-life (T_{eff}) of iodine from the following data and equation:

$$T_{eff} = \frac{T_r \times T_b}{T_r + T_b}$$

T_r = 60.14 days

T_b = 138 days = biological half-life of iodine

Therefore,

T_{eff} = 41.9 days

Roughly speaking, 50 microcuries will have been excreted in six weeks. The amount remaining in the body after 1 year will be approximately one-third of a microcurie.

Let us now respond to the question of what is the effect of spilling on ones self 100 microcuries of a compound containing iodine-125. Let us assume that little, if any, is ingested and that the contamination is 100% external. The problem is now much simpler and becomes an exercise in decontamination. The skin should be washed with soap and water; the contaminated clothing should be removed and the contaminated area rinsed with water. The skin and the clothing should be checked with a portable radioactivity detector to confirm that the decontamination was successful.

We have deliberately studied the effect of accidental exposure to 100 microcuries of iodine-125 as related to intentional medical exposure so that we could develop a perspective of the risk of the accident relative to medical procedures. It should be stated that the medical procedures represent a conscious acceptance of risk in the expectation of receiving desirable benefit. Although our analogy emphasizes the minimal risk caused by the accident, it does not alter the fact that proper care should be exercised to avoid the accident. After all, an accident involves risks without benefit.

I appreciate the discussion of the various questions. However, I am still skeptical. Exposure to radiation cannot fail to be harmful! We cannot see, feel, smell, hear or taste it! How can I be assured that it is truly safe for me to handle radioactivity?

The best way to reassure you may be to equate occupational exposure to radioactivity to another exposure to ionizing radiation with which we are familiar and comfortable. Perhaps we are most familiar with ionizing radiation as applied in medical diagnosis using x-rays. In a group of nations with highly developed medical technology, the annual exposure of the population to diagnostic x-rays has, as its upper limit, the following percentages:

General medical x-rays 40%

Mass chest surveys 17%

Dental x-rays 17%

In the United States the annual frequency of x-ray examinations is almost one x-ray per individual. Since we accept this wide-spread use of ionizing radiation without any public outcry, I propose that we examine the exposure to x-rays quantitatively so as to place in perspective the occupational exposure due to handling radioactivity.

The International Commission on Radiological Protection (ICRP) has summarized data on the average radiation dose received per examination for three tissues -- skin, gonads and bone marrow. The dose to the skin can range from 100 mrem for a chest x-ray to 10 rem for abdominal examinations of obese or pregnant patients. Dosage to the gonads and bone marrow varies with sex and age.

TABLE 5.2 EXPOSURE IN RADIOLOGICAL EXAMINATIONS

Examination	Adults: Bone Marrow Dose (mrem)	Adults: Gonad Dose (mrem) Male	Adults: Gonad Dose (mrem) Female	Children: Gonad Dose (mrem) Male	Children: Gonad Dose (mrem) Female
Head and neck	50	less than 10		less than 10	
Dental (full mouth)	20		"		"
Chest (heart & lung)	40		"		"
Upper back	200		"	30	30
Stomach & upper GI tract	300	30	150	75	150
Lower back	200	1000	400	200	200
Pelvis	100	700	200	300	150
Urinary tract	500	1200	700	500	200
Lower GI tract	600	200	800	400	500
Abdomen	100	500	500	150	50

How can we relate these data on radiological examinations to occupational exposure of Packard employees who handle radiation? A re-examination of Tables 4.3 and 5.2 will be helpful.

TABLE 5.3 EXPOSURE OF PACKARD PERSONNEL

Range (mrem)	1978 Individuals Per Range	1978 Individuals Cumulative	1978 % of Total	1979 Individuals Per Range	1979 Individuals Cumulative	1979 % of Total
No Measurable Exposure*	328	328	89.4	222	222	62.3
0.0 - 100	34	362	98.6	115	337	94.7
100 - 250	3	365	99.5	18	355	99.7
250 - 500	1	366	99.7	1	356	100
1000 - 2000	1	367	100			

*No measurable exposure means less than 10 mrem.

TABLE 5.4 EXPOSURE OF ADULTS IN RADIOLOGICAL EXAMINATIONS* (mrem)

Examination	Male	Female
Head and neck	50+	50+
Dental (full mouth)	20+	20+
Chest (heart and lung)	40+	40+
Upper back	200+	200+
Stomach & upper G.I. tract	330	450
Lower back	1200	600
Pelvis	800	300
Urinary tract	1700	1200
Lower G.I. tract	800	1400
Abdomen	600	600

*Exposures of gonads and bone marrow are summed.

Comparison of the exposures due to occupation and radiological examination shows that less than one-half of one percent of the Packard employees received more than 250 mrem during either year. Thus Packard employees experienced less exposure than occurs with x-rays of the GI tract (upper or lower), lower back, pelvis, urinary tract or abdomen!

Do we consider diagnostic x-ray examinations to be safe? Practically each individual U.S. citizen has an annual x-ray! It must be safe! Since the occupational exposure of Packard employees to ionizing radiation is lower than diagnostic x-ray exposure, it must be concluded that the applications of radioactivity at Packard are conducted with safety.

Do you really expect me to believe that there is no danger in handling radioactivity? Everyone knows better than that! You have failed to convince me!

To begin with, we are not trying to convince you that handling radioactivity is without danger. Let me repeat that our primary goal is to MINIMIZE FEAR of radioactivity and to develop a profound RESPECT for radioactivity and its uses. We also are stressing that proper care and protection REDUCES the danger which could result from handling radioactivity.

The technique used to achieve our goal has been to relate the potential danger from handling radioactivity to FAMILIAR and CONVENTIONAL DANGERS which we accept without hesitation. In Section IV we compared the average radiation exposures of the general population of the United States to the occupational exposures of Packard employees who work with radioactivity. Perhaps a comparison of the exposure of the general population to cosmic radiation and the exposure of Packard personnel to radioactive material would help prove our point.

Cosmic radiation originates in "outer space" from unknown sources either in or beyond our galaxy. Cosmic rays are very energetic with energies known to reach 10^{15} eV and possibly more. These rays interact with the earth's atmosphere and produce secondary radiations which include electrons, protons and other particles. Cosmic radiation enters the earth's atmosphere day and night and the amount at any location varies with the altitude above the earth's surface and the amount also varies with latitude. For our comparison, we will examine variations with altitude in the latitudes which include the United States.

Sea Level

The dose of cosmic radiation to the general population is 26 millirem per year. This includes Packard employees who do not handle radioactivity, such as secretaries, clerks, assemblers, switchboard operators, administrative officers, data processors, etc.

High Altitude Living

Data is available for two Colorado cities - Denver and Leadville.

Denver - If you live in Denver (the "Mile High City", altitude 5,280 feet) the cosmic ray dose is 50 millirem per year.

Leadville - If you live southwest of Denver, in Leadville (altitude 10,560 feet or 2 miles) your annual dose from cosmic radiation is 125 millirem per year.

Jet Plane Traveling

Jet airplanes cruise at altitudes up to 40,000 feet (approximately 7.5 miles). According to the National Council on Protection and Measurements, a transcontinental flight of 5 hours duration would result in an absorbed dose of 2.5 millirem (0.5 mrem per hour). A 10 hour flight from California to Europe over the polar route would result in a dose of 10 millirem. (The amount of cosmic radiation is greater at the poles.) With these figures available, let us calculate the exposure for pilots and flight attendants assuming a 20 hour work week. On this basis a transcontinental crew will absorb 10 millirem per week or 500 millirem per year and a transcontinental-transatlantic crew flying the polar route will absorb 20 millirem per week or 1000 millirem per year.

These data are illustrated in the bar graph of Figure 5.1.

What can we conclude from the graph?

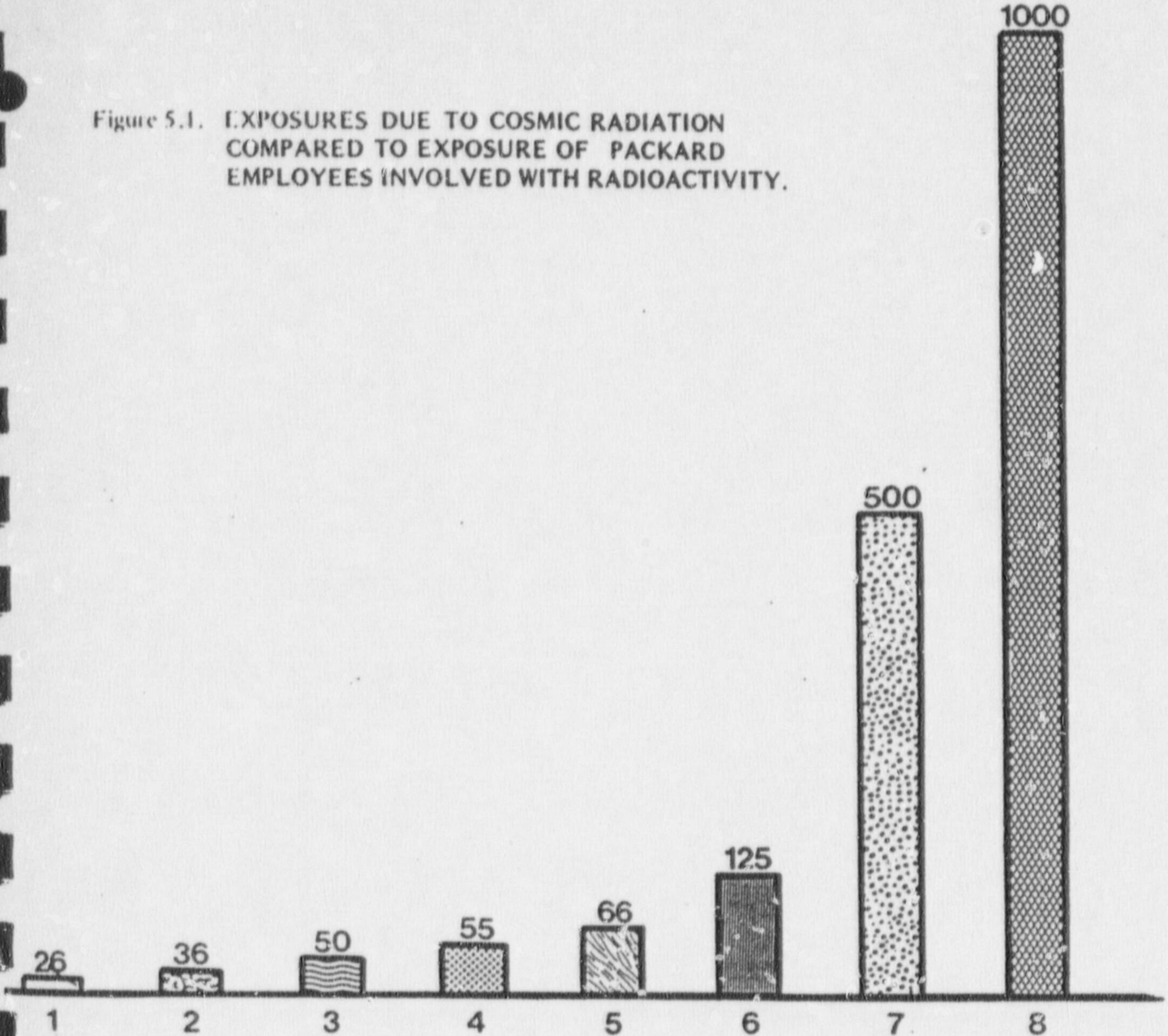
1. The exposure of Packard personnel involved with radioactivity is less than the cosmic ray dose absorbed by residents of Leadville, Colorado and by flight crews of jet airplanes.

2. The exposure of Packard personnel involved with radioactivity is approximately equal to the cosmic ray dose absorbed by residents of Denver, Colorado.

Would it be reasonable to stop living in the Colorado mountains or to stop flying jet aircraft? I would vote a resounding NO! How would you vote?

There is no more dramatic way to illustrate the safety which results when radioactivity is respected but not feared and when proper precautions are observed.

Figure 5.1. EXPOSURES DUE TO COSMIC RADIATION COMPARED TO EXPOSURE OF PACKARD EMPLOYEES INVOLVED WITH RADIOACTIVITY.



Legend (Dose in mrem per year).

1 (26) General population.
2 (36) Average exposure of 75% (550) of Packard Personnel involved with radioactivity.
3 (50) Residents of Denver, Colorado.
4 (55) Average exposure of 97% (699) of Packard personnel involved with radioactivity.
5 (66) Average exposure of all (723) Packard personnel involved with radioactivity.
6 (125) Residents of Leadville, Colorado.
7 (500) Transcontinental flight crew.
8 (1000) Transcontinental/transoceanic flight crew using polar route.

APPENDIX I

THE ROENTGEN UNIT

This appendix will illustrate the calculation of the value of 1 roentgen expressed in MeV per gram of air. This value of the roentgen was used in Section 2 in the calculation of the dose rate from 1 curie of cobalt-60.

When x-ray or gamma ray photons pass through air, the air is ionized into charged particles usually called "ion pairs". The roentgen is defined as that quantity of x- or gamma radiation which produces one electrostatic unit (1 esu) of electricity per 0.001293 g of air (1 cc at STP). Since the charge on the electron is 4.80 E -10 esu, the number of ion pairs equivalent to one roentgen can be calculated.

$$R = \frac{1 \text{ esu}}{4.80 \text{ E } -10 \text{ esu/ion pair}} = 2.083 \text{ E } 09 \text{ ion pairs per cc of air STP}$$

The formation of each ion pair requires 32.5 eV (or 32.5 E -06 MeV) of energy.

$$R = 2.083 \text{ E } 09 \times 32.5 \text{ E } -06$$

$$= 6.771 \text{ E } 04 \text{ MeV/cc air STP}$$

Converting to MeV/g air

$$R = \frac{6.771 \text{ E } 04}{0.001293}$$

$$= 5.24 \text{ E } 07 \text{ MeV/g air}$$

APPENDIX II

THE PROBABILITY OF DRAWING THREE SUCCESSIVE ACES

$$P(A_1, A_2, A_3) = \frac{4}{52} \times \frac{3}{51} \times \frac{2}{50}$$

$$= \frac{24}{132{,}600}$$

$$= 3 \text{ in } 16{,}575$$

(Estimate of radiation induced cancer is 3 in 10,000)

APPENDIX III

CALCULATIONS OF HVL FOR VARIOUS MATERIALS AT 40 keV

Iodine-129 decays by the emission of beta particles with a maximum energy of 150 keV and an average beta energy of 40 keV. There are simultaneous emissions of x-rays and gamma rays.

Rays	E(keV)	Intensity(%)
x-ray 1	4.1	8.2
x-ray 2	29.458	20.0
x-ray 3	29.779	37.1
x-ray 4	33.6	13.2
gamma ray	39.58	7.50

For the calculation of HVL we locate the mass absorption coefficient for various materials in the Radiological Health Handbook, pp. 137 - 139. The mass absorption coefficient is tabulated in units of cm^2/g and must be multiplied by density to yield HVL in cm.

$$I_1 = I_0 e^{(\mu/\rho)(\rho)(x)}$$

I = intensity
x = absorber thickness
$x_{1/2}$ = absorber thickness which reduces intensity by one-half
$x_{1/2} = 0.693/(\mu/\rho)(\rho)$

The HVL for eleven materials was calculated using the equation above. The last two columns show $x_{1/2}$ in centimeters and inches respectively.

(Chart on next page)

TABLE III-1

HVL AT 40 keV FOR TWELVE MATERIALS

	Material	(μ/ρ) cm^2/g	(ρ) g/cm^3	μ cm	$x_{1/2}$ cm	$x_{1/2}$ in
1.	Lead	14.0	11.34	158.76	0.0044	0.0017
2.	Tin	19.4	5.75	111.55	0.0062	0.0024
3.	Sodium iodide	19.3	3.667	70.7731	0.0098	0.0039
4.	Aluminum	0.567	2.70	1.5309	0.453	0.178
5.	Pyrex glass	0.431	2.35	1.0129	0.684	0.269
6.	Muscle	0.268	1.2	0.3216	2.155	0.85
7.	Lucite	0.234	1.19	0.27846	2.489	0.98
8.	Water	0.267	1.0	0.267	2.596	1.02
9.	Polystyrene	0.217	1.08	0.23436	2.957	1.16
10.	Polyethylene	0.226	0.965	0.21809	3.178	1.25
11.	Concrete	0.605	2.35	1.42175	5.325	2.1
12.	Air	0.248	1.293×10^{-3}	3.207×10^{-4}	2,160	850

Lead is obviously a good material for shielding and air is very poor. HVL for air is meaningless since distance between the source and the individual is one of the three factors for decreasing exposure. (See Note.)

NOTE: Radiation traveling through air loses intensity inversely proportional to the square of the distance (i.e., $1/d^2$). The reduction in intensity can be calculated for various distances from the source and some results are provided in Table III-2.
The calculations are based on the following equation and the assumption that $d_1 = 1$:

$$I_2 = I_1(d_1)^2 \times 1/(d_2)^2$$

TABLE III-2

REDUCTION IN INTENSITY OF RADIATION THROUGH AIR AS A FUNCTION OF DISTANCE

$d_1 = 1$

d_2	Percentage of Initial Intensity (%)
2	25
3	11
4	6.25
5	4
10	1
12	0.7
25	0.16
50	0.04
100	0.01

INVERSE SQUARE LAW

$$\frac{I_X}{I_o} = \frac{(d_o)^2}{(d_X)^2}$$

I	=	radiation intensity
d	=	distance
o	=	initial distance
X	=	multiplier
Xd_o	=	d_X

$$\frac{I_X}{I_o} = \frac{(d_o)^2}{(Xd_o)^2} = \frac{d_o^2}{X^2 d^2}$$

$$I_X = \frac{I_o}{X^2}$$

X	X^2
0.5	0.25
1.0	1.0
2.0	4.0
3.0	9.0
5.0	25.0
10.0	100.0

$\frac{I_o}{X^2}$

$1/0.25 \times I_o = 4\ I_o$

I_o

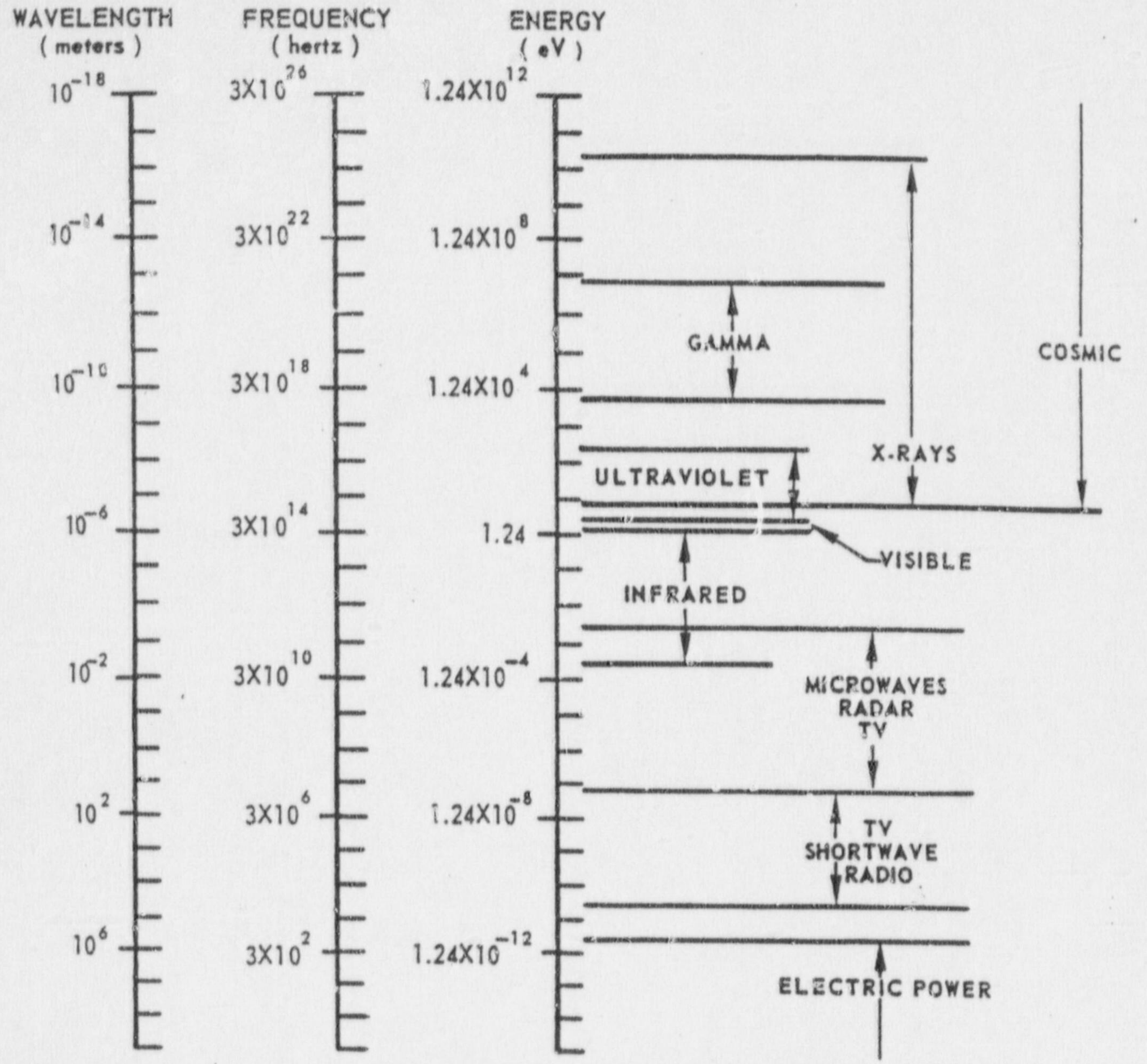
$1/4\ I_o = 0.25\ I_o$

$1/9\ I_o = 0.11\ I_o$

$1/25\ I_o = 0.04\ I_o$

$1/100\ I_o = 0.01\ I_o$

THE ELECTROMAGNETIC SPECTRUM



Type of Radiation	Wavelength Range* (meters)	Frequency Range (hertz)	Energy Range (eV)
Electric Power	∞ - 3×10^{5}	0 - 10^{3}	0 - 4.1×10^{-12}
Radio Waves	3×10^{4} - 3×10^{-4}	10^{4} - 10^{12}	4.1×10^{-11} - 4.1×10^{-3}
Infrared	3×10^{-3} - 7.6×10^{-7}	10^{11} - 4×10^{14}	4.1×10^{-4} - 1.6
Visible	7.6×10^{-7} - 3.8×10^{-7}	4×10^{14} - 7.9×10^{14}	1.6 - 3.3
Ultraviolet	3.8×10^{-7} - 3×10^{-9}	7.9×10^{14} - 10^{17}	3.3 - 410
X Rays	1.2×10^{-7} - 4.1×10^{-17}	2.5×10^{15} - 7.3×10^{24}	10 - 3×10^{10}
Gamma Rays	1.5×10^{-10} - 1.2×10^{-13}	2×10^{18} - 2.5×10^{21}	8×10^{3} - 10^{7}
Cosmic Rays	1.2×10^{-7} - ---	2.5×10^{15} - ---	10 - ---

*Ranges are approximate; no exact end points exist.

PHOTON ENERGY

Energy in electron volts = $\frac{1.240 \text{ E04}}{\text{wave length in angstroms}}$

$$1 \text{ eV} = \frac{h\,c}{e} \times \frac{1}{\lambda}$$

h = Planck's constant = 6.6256 E-34 joule second

c = speed of light = 3 E 10 cm/sec

e = electron charge = 1.6021 E-19 coulomb

λ = wave length in angstroms = 1E - 08 cm/A

$$1 \text{ eV} = \frac{6.6256 \text{ E-34} \times 3\text{E10}}{1.6021 \text{ E-19}} \times \frac{1}{1 \times \text{E-08}}$$

1 eV = 1.240 E04 per angstrom