RADIATION SAFETY HANDBOOK

5 PRIME -> 3 PRIME, INC.

JULY, 1987

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APPENDICES

PREFACE

This Handbook contains the official radiation health and safety regulations and procedures for the Company. All 5 Prime->3 Prime personnel who work, or are planning to work, with radioactive materials are required to comply with the provisions of those portions of this Handbook that are applicable to their work.

The regulations and procedures in this Handbook provide guidelines within which an investigator may conduct their work with radiation in a safe manner and in compliance with current Federal and Commonwealth Governmental requirements; for an effective safety program, each person must be fully cooperative and safety conscious.

Explanations of these provisions and/or additional information can be obtained from the Radiation Protection Officer (RPO) who also has responsibility for future additions to and revisions of this Handbook.

Submitted by:

Randolph J. Hellwig

Randolph J. Hellwig, Ph. D.
Radiation Protection Officer

July 30, 1987

Approved by:

Robert W. Morris

Robert W. Morris
President

July 30, 1987

EMERGENCY ASSISTANCE

In the case of any emergency or potential emergency situation in which radioactive materials are or may become involved, immediately notify the following personnel.

Randolph J. Hellwig
Radiation Protection Officer
644-4710 (work)
284-9309 (home)

Peter H. Zervos
Assistant Radiation Protection Officer
644-4710 (work)
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Robert W. Morris
644-4710 (work)
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I. Radiation Protection Program

A. Administration

The Radiation Protection Officer (RPO) has been appointed to oversee, from a health and safety point of view, all corporate activities which involve radioactive materials and/or radiation producing machines. All work with radiation is conducted with the expressed approval and under the supervision and guidance of the RPO. No radioactive material or radiation producing machine can be obtained or disposed of without his knowledge and consent.

B. Responsibilities

1. The Radiation Protection Officer is responsible for:

a) establishing a policy for the Radiation Protection Program that will provide adequate radiation protection and compliance with governmental regulations.

b) reviewing and approving proposals for new operations and procedures; specifying required safety and protective measures.

c) reviewing radiation safety rules for each laboratory.

d) implementing and maintaining radiation protective services.

e) maintaining all records and correspondence necessary to ensure compliance with Commonwealth and Federal Governmental Regulations.

f) providing adequate information and training to personnel relating to radiation protection procedures.

g) monitoring all laboratories to determine external radiation and contamination levels at quarterly intervals.

h) supervising radiation emergencies and special decontamination operations.

2. The President of the Company or his assignee is responsible for the overall approval of each project.

3. Each laboratory supervisor is responsible for:

a) the safe conduct of the work performed within their laboratory.

b) posting supplementary rules that are pertinent to their laboratory operations.

c) training of personnel under their supervision in safe practices and procedures related to the operations in their laboratory.

d) the assignment of duties to insure that their area of responsibility is properly secured at the close of each work period.

e) reporting all new operations and procedures related to radioactive experimentation to the RPO.

f) exercising disciplinary or corrective action, based on the recommendation of the RPO.

g) keeping an accurate radioisotope disposition record showing the amount of radioactive material used, date, amounts remaining in pure form solution or otherwise, disposal procedure, and amount.

h) reporting a radiation incident, spill, injury or other abnormality to the RPO, so that the necessary corrective action can be taken.

i) contacting the RPO prior to any maintenance, repair, or renovations involving equipment or facilities in which radioisotopes have been employed so that proper safety procedures can be instituted.

j) the safe packaging of radioactive waste.

4. Each individual employee is responsible for:

a) learning and complying with the Company's safety rules and required procedures.

b) learning and complying with the posted rules of their laboratory.

c) reporting to their immediate supervisor and to the RPO any incident involving known or suspected radiation exposure or contamination release that may result in any of the limits expressed in the Handbook being exceeded.

d) discipline in general radiological safety habits and implementation of appropriate techniques to minimize exposure and/or delays for time consuming decontamination operations.

e) reporting a radiation incident, spill, injury, or other abnormality to their immediate supervisor so that the necessary corrective actions can be taken.

f) taking precautions to limit or confine radiation contamination and to exclude all personnel, including themselves, from possible risk of unnecessary exposure.

C. Commonwealth and Federal Regulations

The usage of all radioactive byproduct material by the Company is done under the authority of the United States Nuclear Regulatory Commission (USNRC) through a specific license issued to 5 Prime -> 3 Prime, Inc. All work with radioactive byproduct material must be done under the direction and supervision of the Radiation Protection Officer. All work with radioactive byproduct material must be performed in compliance with the terms of the specific license issued to 5 Prime -> 3 Prime and in compliance with the general regulations relating to health and safety with radioactive materials listed in Title 10, U.S. Code of Federal Regulations, Part 19 and 20 (10 CFR 19 and 10 CFR 20).

Work with all radioactive materials (natural, byproduct, or accelerator produced) must in addition be in compliance with the regulations of the Commonwealth of Pennsylvania as listed in Title 25, Article V, "Radiological Health". All radiation producing machines and their usages must also meet the requirements listed in the above article.

Copies of the specific USNRC license and up-to-date revisions of 10 CFR 19 and 10 CFR 20 are available from the RPO for inspection. The penalties for non-compliance with the regulations are severe and could affect the Company. It is extremely important that each individual do their utmost to ensure that the procedures outlined in this Handbook are followed; only in this way can the Company fulfill its legal responsibilites.

II. Regulations For Use of Radioactive Materials

A. Obtaining usage approval

1. For new usage of a radioisotope or for changed usage (radioisotope, form, quantity, use, location, or user), approval must be sought from and granted by the RPO before any radioisotope can be acquired or put to use. In addition, overall approval for each project must also be granted by the President or his assignee if requested by the RPO. A protocol number will be assigned at this time.

2. Each request will be considered on the the basis of the appropriateness of the radiation training and experience of the personnel involved to the proposed operations, the locations and equipment to be employed, and the specific details of usage. This information is supplied to the RPO for review through the use of RPO Form #1, "Protocol for Radioisotope Experimentation", and an RPO form #2, "Radiation Training Experience and Exposure History", for each person (unless submitted previously for another project). See Appendix II for sample forms. It is important that the information submitted related to usage accurately reflect the processes that will actually be employed. All processes or determinations that will be conducted with the radioactive material should be included, even those operations that do not involve or concern themselves with the radioactivity that is present.

3. Prior to use of radioactive material, operational techniques must be developed and the entire procedure using all radionuclide(s) must be submitted to the RPO before the project can receive approval from them.

B. Procurement

1. For acquisition of all radioactive materials that have been approved for the user by the RPO, whether the materials are being purchased or being acquired free of charge from an outside supplier, an RPO Form #3, "Radioisotope Procurement Request" should be completed and sent to the RPO in advance of the expected receipt. See Appendix II. If the material is being purchased, the Form #3 should be accompanied by a completed and approved purchase requisition.

2. If the material is being purchased, the requisition will be approved by the RPO and then forwarded on to the Purchasing Department. No requisitions for radioactive material will be acted upon by Purchasing without the RPO or his designee's signature of approval.

3. All radioisotope shipments into 5 Prime -> 3 Prime should be addressed to the attention of the RPO and not the principal investigator or others working with the materials. Upon receipt of a package, the RPO will determine if the shipped material is what was ordered, if it has arrived intact, and to what extent the container is contaminated. The package will then either be delivered to the users or picked up from the RPO by the principal investigator or another user, depending on the isotope and the quantity involved. See Appendix II.

4. At the same time, a Radioisotope Receipt and Usage Report (RPO Form #6) will be issued to the user and will include a Radioisotope Number for the procured material.

a) All shipments must arrive during working hours and should be delivered to the RPO or designee.

Check in Procedure for Packages Containing Radioisotopes

1. Check the outside of the package for visible damage. If none is apparent note on procurement sheet or in isotope receipt logbook. If damaged, describe in written record and proceed with caution.

2. Check the contents, if written on the package exterior, against the order. Proceed if in agreement; if not, note the discrepancy and contact the supplier.

3. If isotope is a photon or high energy beta emitter, check the radiation level at the surface of the package, note it in the written record, and compare it with the information on the shipping label. If there is a discrepancy, enter it and proceed with caution.

4. Smear the outside of the package and count the smear in or with an appropriate nearby detection system after response and backaground checks. Enter all count data in the written record. If contamination in excess of 1000 dpm/100 cm^2 is found, notify the shipper and the supplier and proceed with caution. Notify the NRC if >20,000 dpm/cm^2 is found.

5. Open the package in an area set up for contamination control (in a hood for gases or potential volatiles and behind a shield for photon or high energy emitters).

6. Check the inner packing and isotope container for any signs of damage or leakage. If found, enter in the record, contact the supplier and user, and terminate the check-in procedure. Indicate to supplier that a replacement is required; dispose of damaged shipment by usual methods for radioisotopes. If none is found, proceed.

7. Smear the inner container, count the smear, and enter the data in the record.

a. If Ok, repack for delivery to user.

b. If contaminated to $\leq 10^5$ dpm, repack (with new inner wrapping) as in (a) and notify user so that extra caution might be taken (including disposal of inner wrappings as radioactive waste).

c. If contaminated to $> 10^5$ dpm, notify the user and take steps to remove or "fix" the contamination if the shipment is acceptable to the user.

8. Assign Radioisotope Number and issue Radioisotope Receipt and Usage Report (RPO Form #6).

C. Operational procedures and area rules

1. General

a. Only individuals who have completed an RPO Form # 2, "Radiation Training, Experience and Exposure History" may engage in the handling and use of radioactive materials.

b. Visitors and employees who are not authorized to handle radioactive material shall not be permitted to enter a radioisotope usage storage area unless permission has been granted by the RPO or his designee, who shall be responsible for the radiation protection of such persons.

c. All areas and equipment in which radioactive materials are used or stored must be posted or labeled as such using the standard radiation symbol and additional written information as appropriate.

d. The handling, use, or storage of radioactive materials shall only take place in areas that have been approved for such activities by the RPO.

e. Activities in the radioisotope usage area(s) during periods other than normal work hours, must have the prior and specific approval of the RPO.

f. Personal monitoring devices issued by the RPO must be worn during periods of radioisotope usage for which they were intended. For required monitoring, and labelling see Chapter IV "Precautionary Procedures"

2. Personal contamination and intake control

a. There shall be no eating, smoking, or use of cosmetics in radioisotope usage areas. Food, including candy and beverages shall not be carried into a radioisotope usage storage area, even for temporary storage.

b. Mouth pipetting is PROHIBITED in any region of a radioisotope laboratory.

c. Personal articles, such as briefcases and ladies handbags, should not be brought into a radioisotope usage storage area.

d. Disposable lab coats shall be worn at all times by all individuals working inside a radioisotope usage storage area. The lab coats shall be buttoned and the sleeves worn extended to cover the arms and wrists. All investigators working with radioactive materials must wear suitable disposable laboratory coats. These coats may not be worn outside the laboratory. Each disposable laboratory coat must be monitored for radioactive contamination after each use of radioisotopes. Uncontaminated disposable coats may be reused. Contaminated coats should be disposed of as appropriate for radioactive waste. All visitors or maintenance workers who enter a radioisotope usage storage area must wear disposable coats which may be obtained from the RPO. Disposable lab coats must be worn in any posted "Radiation" area. In addition, coats and other protective apparel as necessary must be worn in areas that have been temporarily posted as "Radiation" areas.

e. Used lab coats are not to be transferred from one individual to another. A lab coat shall not be worn if it is contaminated.

f. All disposable lab coats in use are to be monitored by survey meter for contamination after each use of radioisotopes. If lab clothing becomes contaminated or is suspected to be contaminated with ^{3}H or ^{14}C, discard the garment into the solid radioactive waste container.

g. Protective gloves shall be worn whenever radioactive materials are handled. This includes waste disposal operations. Surgical technique shall be used for putting on and removing gloves in order to avoid contaminating the inside surfaces. Gloved hands should be washed, if practical before the gloves are removed.

h. Personnel having open cuts or abrasions on the body must take additional safety measures to prevent contamination of those bodily areas before being permitted to work with radioisotopes.

i At all times, reasonable care must be taken to avoid and prevent cuts or puncture wounds, including accidental injection.

j. Additional care to avoid skin contact with radioactive materials must be taken when organic solvents are being used (they may increase the permeability of the skin).

k. Shoe covers must be used if there is radioactive contamination of laboratory floors (a temporary condition) or if such contamination is reasonably possible.

l. Before leaving a radioisotope usage area (for desk work, coffee breaks, cafeteria, rest rooms, etc.):

1. All contaminated or potentially contaminated protective clothing (labcoat, shoe covers, gloves) shall be removed, exercising care to avoid cross-contamination of other clothing;

2. Reusable protective clothing shall be stored in prescribed locations;

3. Hands shall be thoroughly washed;

4. The person shall thoroughly monitor themselves with appropriate external monitoring equipment when working with all isotopes other than tritium and carbon 14.

3. Laboratory and equipment contamination control

a. Contamination of laboratory notebooks from dust, splashing, spills, or glove contact shall be avoided. During the course of an operation in a radioisotope usage area, use a notepad for record keeping, then transfer the information to the permanent notebook.

b. Before the end of each work day (when radioisotopes have been used), work areas and equipment shall be inspected, surveyed, and cleaned as needed.

c. When it is necessary to postpone clean-up at the end of the work day, an appropriate sign shall be posted. Decontamination must be completed prior to starting a new operation.

d. For removal of radioisotopes or contaminated or potentially contaminated apparatus, supplies or clothing from a radioisotope usage area, see Chapter II, Section D.

4. Operations releasing or potentially releasing radioactivity

a. All operations that may give rise to airborne contamination (as determined by the RPO) shall be performed in a ventilated hood or ventilated enclosure approved by the RPO.

b. Operations which might produce airborne radioactive particulates, fumes, or vapors, even though conducted in a ventilated enclosure, should be designed to collect and contain the radioactivity rather than releasing it to the exhaust system.

c. Laboratory personnel are guided toward the principle that no radioactive materials are purposefully discharged into the sewerage systems on a random basis. For permitted sewerage disposal regulations see Chapter II Section D.

D. <u>Transfer or disposal of radionuclides and radiation laboratory equipment and supplies.</u>

1. Authorization from the RPO must be obtained before radionuclides or potentially contaminated supplies or equipment may be transferred from approved posted laboratory areas to other locations (whether previously approved or not).

a. Radioactive material shall not be removed from a radioisotope usage area unless:

1. It is totally enclosed in a non-contaminated shatterproof container;

2. It is properly labelled with a durable clearly visible label bearing the radiation symbol and the words - CAUTION RADIOACTIVE MATERIAL. The quantity, type of activity and the surface dose rate (if known) shall also be marked.

3. The exposure rate from the container is less than 200mR/hr at contact and 10 mR/hr at three feet; and

4. it is being transferred to an approved location or destination.

b. Unless authorized by the RPO, equipment, articles, or objects shall not be carried out of a radioisotope usage area until:

1. items exhibiting removable contamination are cleaned by the laboratory staff to below the limits of Chapter III, Section A, as verified by the Radiation Protection Officer;

2. items exhibiting fixed contamination (see Chapter III, Section A for limits) or any residual loose contamination are completely enclosed in packaging approved by the Radiation Protection Staff and are labelled to indicate their status: they may not be released for general usage;

3. items which may be internally contaminated (such as vacuum pumps) are labelled to indicate their status: they may not be released for general usage.

2. Origins of radioactive waste

Any operation involving work with radioactive materials generates radioactive waste. These may be classified as follows:

Type	Classification (level)	Concentration
liquid	low	microcurie/L (10^{-3} $\mu Ci/cm^3$)
	intermediate	millicurie/L (1 $\mu Ci/cm^3$)
	high	curies/L (1 mCi/cm^3)
solid	low	$10^{-3}\mu Ci/gm$
	intermediate	1 $\mu Ci/gm$
	high	1 mCi/gm

Limitation: These levels do not take into account the different radiotoxicities of the various radionuclides.

Most of the wastes that are encountered from biological research would be classified as low level radioactive waste, i.e. in the range of less than 10^{-3} μCi per cc (liquid) or 10^{-3} μCi per gm (solid).

3. Methods of radioactive waste disposal

a. An NRC licensed commercial disposal service is the only acceptable method of waste disposal for low, medium or high level specific activity materials. Types of waste material for which commercial disposal is recommended include:

Unused portions of mainstock radionuclides, unused preparations, e.g. solutions, suspensions, solid radioactive chemical wastes of high specific activity; scintillation counting materials, thin-layer chromatographic plates: and excessively contaminated articles. Procedures for disposal of isotopes by a commercial disposal service are listed on pages 10-13 . Each supervisor is responsible for the proper packaging of waste. Individuals reporting to the RPO will secure all disposal containers prior to shipment.

Radioactive Waste Packaging Criteria

The following packaging requirements are outlined according to the physical classification of the type of radioactive waste. In addition to these specific packaging requirements described herein, all radioactive waste must be packaged according to the following general requirements.

General Requirements

1. All radioactive waste must be packaged in Department of Transportation approved containers.

2. Isotope (s), activity, chemical form, company or institute, and radiation level must be completed on the front side of the radioactive waste disposal record affixed to the top of the container.

NOTE: Chemical form

The term "Chemical form" means a decription of the atomic or molecular composition of the substance containing the radionuclide. When the true detailed chemical description of the substance is burdensome, a general or other appropriate description may be used. The following are examples of descriptions which may be used (this list is not intended to be all inclusive, other similar descriptions are acceptable):

Protein	Carbohydrate	Scintillation Residue
Amino Acid	Sugar	Fatty Acid
Organic Salt	Enzyme	Inorganic Salt
Steroid		

3. No container shall contain in excess of those activities specified for "Type A" Packaging.

4. No container shall contain materials (radioactive or not) which would create a hazard because of potential explosive or pyrophoric characteristics.

5. The maximum radiation level on any container surface shall not exceed 200 mR/HR. For dose rates greater than 200 mR/HR, contact the NRC licensed commerical waste disposal dervice for requirements.

6. Each container must be wipe tested to assure that there is no significant removable contamination on the exterior surface of the container. This data shall be recorded on the radioactive waste disposal record (RPO Form #10)
(See Appendix II, RPO #).

7. The appropriate radioactive materials label must be completed and affixed to two sides of the container.

8. Each container must be securely closed and must incorporate a seal that is not readily breakable and which while intact, will be evidence that the package has not been illicitly opened.

9. After closing, the top of the container must be legibly marked either "Solid", "Vials" , or "Biological".

Liquid Scintillation Vials (All Isotopes except ^{14}C and ^{3}H)

1. Vials must be intact with tops securely in place.

2. Container must be lined with a minimum 4 mil plastic liner and long enough so that when the container is full, the liner may be twisted and taped securely.

3. Place 3 inches of approved absorbent at the bottom of the container. Vials and absorbent must be placed in the container in layers not exceeding 6 inches in depth. At least 1 inch of absorbent must be placed between each layer of vials.

4. The container must be filled with a 2 to 1 ratio of absorbent to liquid in the vials.

Absorbed Liquids (Large Volumes)

Solidification (see below) or sewerage disposal (^{14}C or ^{3}H only, p13-14) is preferred

1. The inner container must be lined with a minimum 4 mil polyethylene liner.

2. The inner container must be filled with a 2 to 1 ratio of absorbent to liquid, layered in approximately 1 foot layers to ensure even dispersion. There should be no free standing liquid at the top of the container.

3. Absorbed liquids should not be acidic or alkaline.

4. The inner container must be placed up-right in the outer container with absorbent on the bottom and around the sides of the outer container.

Solidified Liquids (small volumes)

1. Acceptable solidification media are:

   Dow Media
   Cement
   Delaware custom media
   Urea formaldehyde
   Asphalt

2. For small volumes of liquids (1 to 4 gallons) solidification kits utilizing Delaware Custom Media are available, with instructions from NRC licensed commercial disposal service.

Biological, Pathogenic or Infectious Material

This packaging procedure pertains only to biological, pathogenic or infectious material or equipment that is radioactive (e.g. syringes, test tubes, capillary tubes).

1. The inner container must be lined with a minimum 4 mil polyethylene liner which shall be sealed.

2. The inner container must be placed up-right in the outer container with absorbent on the bottom and around the sides of the outer container.

b. Aqueous waste - sewerage disposal (^{14}C or ^{3}H only)

1) No radioactive waste shall be discharged into the sewerage system unless:

a) it is readily soluble or dispersible in water; liquid wastes would include tissue homogenates, other biological preparations, and decontamination washes.

b) it has been extensively diluted with water before discharge so as to reduce the activity in a given volume; concentrations listed in (c) below can be used as a guide.

c) the discharge of the waste solutions is at a controlled rate. No more than 50μCi per day or 150μCi averaged over a week shall be flushed into sewerage with running tap water. Authorization from the RPO must be obtained to discharge more than 50μCi per day.

2) The following concentration limits should not be exceeded:

Radioisotope	Concentration, μCi/liter
^{3}H	10
^{14}C	10

3) Initial dilution of liquid waste is required to allow dispersal at the sewerage filtraton plant and to prevent "build-up" in the plumbing system at point of discharge (sink, trap, drain, pipe).

4) Avoid "splashing contamination" around the sink.

5) Accumulation of radioactive material in the traps of sink where waste has been poured may occur. The concentration of radioactive material waste disposed of by sewerage is specifically limited to very low levels by regulation. However, some can accumulate in the trap. The trap of any sink used for the above purpose should have a sign on it stating that monitoring for possible radioactivity is required before plumbing repairs can be made.

6) Water insoluble materials-evaporate solvent in ventilated hood system, seal vessel containing residue in a plastic bag, then use isotope disposal services.

c. A record identifying radioactive materials disposed of, method of disposal, amount and date must be kept by each investigator on forms supplied by the RPO. These records will be summarized quarterly by the RPO for the official Company records on disposition of licensed radioactive materials.

d. The RPO must be notified prior to the start of work which will produce radioactive waste materials not covered by the above regulations.

e. Each investigator will submit at the end of each calender quarter a summary of all amounts disposed (RPO Form #10) during that quarter. This information will also appear on the quarterly submission of the Radioisotope Receipt and Usage Form (RPO Form #6)

E. Procedures for Inventory Control

1. The radiation safety office will assign a Radioisotope No. for each labelled compound received at 5 Prime - 3 Prime.

a. New shipments of old orders will receive new Radioisotope No.

2. A Radioisotope Receipt and Usage Report (RPO Form #6) will be issued at the time of transfer from the RPO to the user.

a. The upper half of the report will be filled in by the RPO.

3. Quarterly updates on the status of each isotope will be sent on copies of the RPO Form #6 until the total inventory for the material (all forms) is zero. An isotope usage work sheet (RPO Form #4) may be helpful for the maintenance of each isotope disposition record.

4. Each investigator will also submit each calender quarter an accompanying summary report of the isotope inventory (RPO Form #7)

5. Quarterly reports for the disposition of an isotope for each investigator (RPO Form #7) and the total inventory of each isotope (RPO Form #8) will be compiled by the RPO.

F. Notification of Radiation Protection Officer

1. The investigator is responsible for the prompt notification of the RPO in case of any unusual or potentially hazardous incident involving radionuclides. Examples are:

a) Known or suspected "spills" of radioactive materials that are not contained by absorbent paper, trays and/or secondary containers (includes personal contamination);

b) Unintentional (not planned in experimental design) release or escape of radioactive material into the laboratory environment or beyond (via hoods, ventilation, sinks, etc.);

c) Known or suspected accidental ingestion or inhalation of radioactive materials in any quantity;

d) Operations that result in radiation exposure significantly in excess of that planned for or expected from experimental design;

e) External contamination of containers in which stock radioactive materials are stored;

f) Receipt of mislabelled materials or amounts of material in excess of that ordered which result in an investigator possessing materials for which he is not authorized (in kind and/or quantity).

2. In the event of a radiation incident the RPO will take appropriate action in one or more of the following ways:

a) Investigate and document the degree and cause of contamination and/or exposure;

b) Post and isolate any contaminated areas or equipment;

c) Evaluate the degree of exposure (internal and external) and/or contamination;

d) When indicated, suspend operations in a laboratory area and/or suspend work of an individual;

e) Schedule and supervise appropriate decontamination procedures;

f) Notify and report to regulatory agencies when required;

g) Arrange for any indicated medical attention.

III. Precautionary Procedures

A. Radiation measurements

1. personal monitoring

a) TLD badges, to measure external exposure

(1) A TLD (Thermoluminescent dosimeter) badge will be issued to individuals working with radioisotopes. The badges, which are distributed and picked up by the RPO on a monthly basis, should be worn on the chest or abdomen. They are processed and evaluated by the commercial supplier and serve as a indicator of skin and whole body dose.

(2) If the exposure of the hands or forearms can be significantly greater than that of the whole body, an additional hand or wrist film badge or other suitable monitor may be issued depending on the dosage levels.

(3) When a protective apron is worn, the film badge should be worn outside of the apron at the neckline position to serve as an indicator of exposure of the head and eyes.

b) At the discretion of the RPO, personnel working with radioisotopes may be asked to submit t direct external monitoring for detection of surface radioactive contamination and/or in order to detect the presence of those radioactive materials which may have been taken up into the body and which can be detected by external equipment.

c) Since all radioisotopes except tritium (hydrogen-3 and carbon-14) can be readily detected on body surfaces with suitable survey instruments (such as end-window Geiger counters), laboratory workers having such instruments available will monitor themselves on a frequent basis during the work day and whenever there is a question as to possible radioactive contamination.

d) In the case of workers using tritium, self monitoring can be accomplished through the use of moistened filter paper in conjunction with a liquid scintillation counter or windowless gas flow proportional counter. Consult the RPO when employing this method.

e) In order to detect and evaluate the presence of those radioactive materials that may have been taken up into the body and which cannot be detected by external equipment, personnel may be asked to submit urine and/or fecal samples for analysis. Such samples may also be requested to evaluate the elimination of radioisotopes of any kind from the body following known intakes. Urine samples will be required on a regular basis from those persons who are working with ten millicuries or more of tritium or carbon-14 at any one time in unsealed sources.

2. Area Surveys, including Air Sampling

a) The measurement and evaluation of external radiation levels in the laboratory will be conducted, when necessary, by the RPO. In certain situations where the radiation levels could change significantly during the course of an investigation or project, the RPO may direct the experimenter to make measurements (and record the results) in particular locations at specific times, such as whenever the experimental setup is appreciably altered.

b) Area surveying can also be used as a method for the detection and evaluation of surface contamination (except tritium and carbon-14). The routine monitoring of lab areas with a survey instrument by an investigator during the course of an experiment, or whenever contamination is suspected, is to be encouraged in those facilities where such equipment is available. The RPO may employ this method as a part of their routine surveillance of laboratories for radioactive contamination. (See Chapter III, Section A3).

c) The production of airborne radioactivity in occupied areas should be avoided whenever possible. In thos instances when airborne activity is present or suspected of being present, the air in the location will be sampled by the investigator using a method appropriate for the physical and chemical form of the radioactivity, and the concentration will be determined. Results of the air sampling will be supplied to the RPO on RPO form #5. On the basis of the results, the RPO may direct the experimenter to alter his setup and/or to submit to a determination of the extent of personal radioactivity intake.

d) Air sampling may also be used to determine the extent of releases of radioactivity to the environment through the laboratory hood ventilation system. Here, too, on the basis of the results, which will be recorded on RPO form #5, suggestions may be made for the alteration or modification of the experimental setup in order to limit releases.

3. Smear Surveys, including Contamination Limits

a) The measurement and evaluation of radioactive contamination in the laboratory will be conducted on a regular basis, at least once per quarter, by the Radiation Protection Staff. Removable contamination, including tritiumand carbon-14, will be determined using filter paper smears counted in an instrument appropriate to the radionuclides in use in the area. For health reasons and to avoid interference with experimental procedures, every attempt should be made to avoid the production of surface contamination. Experimenters can employ smear surveying during their laboratory work to check for possible removable surface contamination - this practice is to be encouraged.

b) A gross count rate of a filter paper smear which is twice the background count rate (with the appropriate instrument for counting the particular radionuclide) should be considered as indicative of removable surface contamination if an area of 100 cm^2 or less was sampled (smeared) with the moistened filter paper. If contamination is detected, the RPO should be notified and attempts made, under their direction, to decontaminate the involved areas.

4. Leak Testing of Sealed Sources

All sealed sources of radioactivity will be tested for leakage by the RPO on a periodic schedule. A source found to be leaking will be withdrawn from service for repair or disposal.

B. Caution Signs and Labels

1. It is extremely important that radioactive materials, radiation areas, high radiation areas, and regions of airborn radioactivity be properly marked so that they can be easily and readily recognized. For this purpose, the RPO has available a variety of signs, labels, and tags bearing the required official symbols and in some cases having space onto which additional information can be entered. See Appendix 5.

2. The RPO will affix the appropriate warning information at the beginning of work with radioactive materials in a particular area. (In some cases, to be in compliance with regulations, specialized devices may be required, such as flashing lights. In these instances, the RPO will indicate what is needed, but it is the responsibility of the user to acquire and install the equipment).

3. For radioactive materials, the following should have "Caution - Radioactive Material" labels.

a. All doors to rooms where radioactive material is used.

b. All large pieces of equipment in which radioactive materials are stored or used, examples being hoods, refrigerators, centrifuges, evaporators, cabinets.

c. All containers for radioactive waste materials.

d. All containers for radioactive material including packages of waste (here, additional information should be included to identify the content as to radionuclide and quantity).

4. "Caution - Radiation Area" signs are required in any area where the dose received could equal or be greater than 5 millirem in one hour.

5. After the initial setup by the RPO, it is the responsibility of the user to be sure all items are properly labelled.

C. Safety Equipment

1. It is the responsibility of the supervisor or investigator to be sure that safety and protective clothing and equipment appropriate to the work being carried out with radiation and/or radioactive materials is available to all those involved in such operations. In the case of projects presenting an unusual hazard, the RPO may direct that something specific be employed which goes beyond the normal apparel and devices.

2. All persons working with unsealed radioactive materials or potentially contaminated items must wear disposable laboratory coats and disposable protective gloves.

a) Protective gloves - long length, tight-fitting, surgical gloves made of thin latex are recommended.

b) The glove must cover the wrist and the lab coat sleeve should preferably be "tucked in".

c) While wearing protective gloves, do not directly touch objects (telephone) or surfaces (desk, notebooks, drawer pulls, door knobs) away from the restricted working area. The gloves should either be taken off, or some non-contaminated material (e.g. paper towel) interposed to cover the glove before touching items outside the work area; the cover should then be discarded as radioactive waste.

d) If convenient, wash gloved hands thoroughly-soap and water four times. Use paper towel to grip and turn water faucet knobs. Otherwise, carefully remove gloves (avoid contaminating the hands) and discard into radioactive waste.

e) A method of putting on and removing rubber gloves without contaminating the inside surface of the gloves should be used. This procedure is such that the inside of the glove is not touched by the outside, nor is any part of the outside allowed to come in contact with the bare skin. If you are unfamilar with this technique, consult the RPO.

3. Devices for pipetting radioactive solutions must be emplyed (including micropipetting). Mouth pipetting of radioactive solutions is STRICTLY PROHIBITED.

4. Optional items which may be required by the RPO include face shields, rubber aprons, shoe covers, respirators, external radiation shields, remote handling tools, and fume hoods or glove boxes. These should be employed as directed by the RPO.

IV. EMERGENCY PROCEDURES

In any radiation emergency, the primary concern must always be the protection of personnel from radiation hazards; the secondary concern is the confinement of any contamination to the local area of the accident if possible. The consequences of most radiation occurrences will be much less severe if the proper action is taken immediately.

A. Emergency Assistance

In case of any emergency situation involving or potentially involving radioactive material or radiation producing machines, notify the Radiation Protection Officer immediately.

If after hours or weekends, contact the RPO or his designeee at their home telephone number, which is posted in the area where radioisotopes are used. If possible, remain in the area for a return call from the Radiation Protection Officer or his representative.

B. Spills

Spills involve the unanticipated spread of radioactivity to areas beyond the confines of trays, secondary containers, absorbent paper covering, etc. which are meant to limit the spread of materials and to facilitate clean up efforts in the event of such an occurrence.

The clean up of confined spills shall be done under the supervision of the principal investigator (person responsible for the radioactive work in the lab) following appropriate procedures for personnel protection, waste disposal, and decontamination. The RPO may be consulted if desired. The following procedures, for radioactive materials which have spread beyond confines, are applicable for two cases, either involving or not involving significant external radiation hazard to personnel. The steps are arranged in order of their urgency and normally shall be followed in the order given.

1. Spills not involving significant external radiation hazard to personnel.

a) Confine the spill immediately

1) if the spill is a liquid, right the container and drop absorbent paper on the entire area (wearing waterproo gloves and labcoat). Avoid splashing.

2) If the spill is a dry material, dampen it thoroughly, water may be used except when chemical reaction would generate an air contaminant, wearing protective gloves and labcoat and being extremely careful not to raise a dust or in any other way spread the contamination.

b) verbally notify all persons within hearing distance that a spill has occurred, and caution them, if anywhere near the spill, not to move uncessarily until the RPO arrives and gives his approval.

c) permit only the minimum number of persons necessary to deal with the spill into the restricted area. Do not permit anyone to walk near the spill area.

d) notify the RPO (see "emergency assistance" in this handbook). If possibly contaminated, have someone else place the call for assistance, and proceed to Section 2.

e) after the RPO arrives, begin cleanup and decontamination according to their instructions.

1) decontamination and clean up shall be carried out by the person(s) responsible for the spill or others who work under the principal investigator.

2) protective clothing, as specified by the RPO, shall be worn during decontamination. This may include, but is not limited to rubber gloves, shoe covers, lab coats or overalls, and respirators.

f) persons may leave the spill area only after the RPO has monitored them and released them.

g) work in the area may resume after the RPO has conducted complete surveys and granted his approval. The person(s) who is responsible for the spill and the area will cooperate with the RPO in the preparation of a report on the incident.

2. Spills involving an external radiation hazard to personnel.

a) Verbally notify all persons in the area who are not involved in the spill to leave the immediate area at once but to remain in the vicinity until monitored by the RPO.

b) Move away from the spill area immediately and shut off any room fans.

c) if there is radioactivity on the skin, flush thoroughly with water taking care not to spread contamination.

d) if there is radioactivity on clothing, remove all such items at once, taking care not to spread contamination.

e) move to an area where there is no external radiation hazard. Maintain traffic control in the spill room, hallways where potentially contaminated people have walked, etc.

f) notify the RPO (See "Emergency Assistance" in this handbook). if potentially or actually contaminated, have someone else place the call for assistance, if possible.

g) while waiting for assistance from the RPO take steps to decontaminate personnel involved (see "Personal Decontamination", Chapter V, Section F.)

h) the RPO 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 or others who work under the principal investigator.

i) The RPO will monitor all persons and conduct a complete survey of the area to determine the adequacy of the decontamination.

j) Work may resume in the area only after the RPO grants his approval. The person(s) responsible for the spill and the area will cooperate with the RPO in the preparation of a report on the incident.

C. Accidents involving Radioactive Dust, Mists, Fumes, Organic Vapors and Gases

1. Notify all other persons to vacate the room immediately.

2. Hold breath and try to limit the release, close windows and shut off air circulating devices if time permits.

3. Vacate the room.

4. Be sure that all doors giving access to the room are closed.

5. Call the RPO (see "Emergency Assistance" in this handbook)

6. Post the closed doors with conspicuous warnings or guards to prevent accidental opening.

7. Attempt to shut off any externally controlled air circulating devices involving the sealed room.

8. Report to the RPO at once all known or suspected inhalations of radioactive materials.

9. The RPO will evaluate the hazard and the necessary safety devices for re-entry.

10. The cause of the condition must be rectified before decontamination procedure can begin. The RPO will recommend and/or supervise the decontamination and will monitor the air as required prior to and during these operations.

11. The RPO will monitor all persons suspected of either internal or external contamination. Urine and/or fecal samples may be requested.

12. Work in the area may not resume until approval has been granted by the RPO.

D. Personal Injuries Involving Radioactive Material

1. Wash minor wounds immediately under running water while spreading the edges of the opening in the skin. Attempt to avoid the spread of contamination to other body surfaces or laboratory areas. Notify the RPO (see "Emergency Assistance" in this handbook) and the Company physician whose telephone number is posted in the area where radioisotopes are used. before proceeding further. If possible, remove any contaminated clothing and flush any additional contaminated body surfaces with water, taking care not to spread contamination, before leaving the area (if directed to do so by the physician).

2. For major injuries to others, contact the Company physician and the RPO immediately. Attempt to limit the spread of contamination from the injured person by removing their contaminated outer clothing or wrapping him in an uncontaminated covering before transporting them, under the direction of the physician, from the area. If possible, also flush their wounds and other contaminated body surfaces with water as soon as possible, taking reasonable care to avoid the spread of contamination.

3. Permit no person sustaining an injury involving radioactive materials to return to work without the approval of the RPO and the Company physician.

E. Fires Where Radioactive Materials are Present

1. Large Fires

a) Evacuate the area, sound the fire alarm, and notify the RPO.

b) report after evacuation any radioactive material which was left unattended and which might prove hazardous to fire fighters.

c) Do not leave the general area until approval to do so has been granted by the RPO.

d) Do not re-enter the fire area after the fire has been brought under control and until approval to do so has been granted by the RPO.

2. Small Fires

a) Ask someone nearby to stand-by to sound the fire alarm if such action becomes necessary. Have the person contact the RPO immediately. If no one else is available, sound the alarm yourself and proceed as indicated below.

(1) If radioactive materials are not directly in the fire attempt to extinguish it in the usual manner noting the following precautions.

a. Do Not Disturb shielding around any radioactive material

b. Stay between fire and an exit

c. Keep all unnecessary personnel out of the room or area during and after the fire is extinguished

d. After the fire is extinguished, call the RPO and remain in the area until released by them.

(2) If the fire spreads to radioactive materials or filters which may contain radioactive materials, do the following.

a. Evacuate the room or area immediately
b. Sound the fire alarm and notify the RPO, indicating the extent of radioactivity involvement or possible involvement.

c. Do not leave the general area or re-enter the fire area after the fire has been extinguished and until approval to do so has been granted by the RPO.

F. Personal Decontamination

1. The RPO is to be notified immediately in the event of any personal external contamination or known or suspected intake (inhalation, ingestion, or injection) of radioactive material.

2. In the case of accidental ingestion the RPO may , for immediate action, suggest that vomiting be induced.

3. For external personal contamination, the RPO will direct the specific action to be taken to effect complete decontamination, but the immediate action which can be taken is to flood the affected area with water, followed by washing with soap and water. This is the best general method for decontamination of hands and other parts of the body regardless of the contaminant. If the contamination is localized and not of high level, it is often more practical to mask off the affected area and clean it with swabs before risking the danger of spreading the contaminant by general washing.

(a) For the hands, if the exact nature of the contaminant is known, it may sometimes be more effective to immerse them in a suitable reagent immediately after contamination. This should be followed by thorough washing in tepid water with a mild soap and thorough rinsing in clean water, taking care to avoid the spread of contamination to other body areas or to equipment. Detergents and wetting agents may also prove useful although sometimes a specific one may be required for a particular contamination problem in order to secure maximum cleaning efficiency.

(b) The skin may become sensitive following repeated application of detergents to the same area; care should be taken to avoid this practice. For any situation, one must avoid the use of organic solvents that may increase the probability of the radioactive materials penetrating through the skin barrier. Sweating techniques will sometimes prove useful. The affected area is covered with rubber or plastic sheeting or a glove. The area should be heated to promote sweating and then washed gently.

(c) The following are the recommended procedures for general hand washing. They should be employed following the recommended immediate action (see 3 above) in cases where the RPO is not immediately available to direct and supervise follow up procedures.

1. Wash for not less than 2 minutes nor more than 3 minutes by the clock with a mild pure soap in tepid water with a good lather covering the entire affected area thoroughly. Give special attention to the areas between the fingers and around the fingernails. The outer edges of the hands are readily contaminated and should not be neglected in the washing. Do not use highly alkaline soaps or abrasives. Rinse thoroughly and repeat, as monitoring indicates, but do not exceed three or four times.

2. If the above procedure is not sufficient to remove contamination, scrub the hands with a soft brush using a heavy lather and tepid water. This scrubbing is primarily to agitate the cleansing agent, so prolonged scrubbing with change of reagent is of questionable value. For this reason, at least 3 washes, including rinses, should be done within 8 minutes, and 6 of these 8 minutes should be devoted to scrubbing. Only light pressure should be applied to the brush (not sufficient to bend the bristles out of shape or to scratch or erode the skin). Rinse thoroughly and monitor. Do not repeat.

3. Apply lanolin or hand cream to prevent chapping.

(d) The level of seemingly fixed contamination which can be accepted for body surfaces depends on the degree of hazard associated with the radioisotope and on the nature and extent of the affected area. For isolated spots of moderately hazardous radioactive materials such as ^{14}C and ^{32}P which are not near body openings, levels of 100 counts per minute above background as measured with a thin-window GM tube placed directly over the area can be considered acceptable if measures to remove contamination have already been employed and if the number of such spots is low. In other situations decontamination efforts will continue under the direction of the RPO in an attempt to completely remove the contaminants or to reduce them by a factor of 10 below the above limit.

G. Area and Equipment Decontamination

1. The RPO is to be notified immediately in the event of any known or suspected "spills" of radioactive materials which are not contained or in the case of any unintentional release or escape of radioactive materials into the laboratory environment or beyond. This notification of the RPO should precede any attempts to decontaminate areas or involved equipment.

2. Decontamination shall be accomplished by personnel from the involved laboratory or area, working under the supervision of the RPO and using protective clothing as specified by the RPO. See Section IVB, "Emergency Procedures - Spills". In most instances, there should be no need to proceed with decontamination prior to the arrival of the RPO to direct the operations, so specific procedures are not included here in this section on emergencies.

3. The area or the equipment undergoing decontamination shall not be put back into use until approval has been received from the RPO. The limit for removable contamination is given in Section III, A3 -"Smear Surveys", and the limit for fixed contamination for areas or items which are to leave radioisotope usage areas and be released for general usage (including laboratory tools and glassware, and personal clothing) are given in Chapter IV, Section F3 (d), on external personal decontamination.

Appendix I.

Radioisotope Toxicity

In the following listing, a large number of radioisotopes are grouped according to relative overall hazard ranging from "low" to "very high". The quantities of radioisotopes in these four groups which could be considered as low to intermediate levels are given below.

Hazard Group	Low to Intermediate Quantity, microcuries
I. (very high hazard)	0.1
2. (high hazard)	10
3. (hazardous)	100
4. (low hazard)	1000

RADIONUCLIDE HAZARD GROUPING

(Alphabetical order within groups)

Group 1 (Very High Hazard)

227-Ac, 241-Am, 242m-Am, 243-Am, 249-Cf, 250-Cf, 251-Cf, 252-Cf, 254-Cf, 242-Cm, 243-Cm, 244-Cm, 245-Cm, 246-Cm, 248-Cm, 254-Es, 255-Es, 237-Np, 231-Pa, 210-Pb, 210-Po, 238-Pu, 239-Pu, 240-Pu, 241-Pu, 242-Pu, 223-Ra, 226-Ra, 228-Ra, 227-Th, 228-Th 230-Th, 230-U, 232-U, 233-U, 234-U.

Group 2 (High Hazard)

228-Ac, 110m-Ag, 242-Am, 211-At, 140-Ba, 207-Bi, 210-Bi, 249-Bk, 45-Ca, 115m-Cd, 144-Ce, 253-Cf, 36-Cl, 247-Cm, 60-Co, 134-Cs, 137-Cs, 253-Es, 254m-Es, 152y-Eu, 154-Eu, 255-Fm, 254-Fm, 181-Hf, 125-I, 126-I, 129-I, 131-I, 133-I, 135-I, 114m-In, 192-Ir, 54-Mn, 22-Na, 230-Pa, 212-Pb, 244-Pu, 224-Ra, 106-Ru, 124-Sb, 125-Sb, 46-Sc, 89-Sr, 90-Sr, 182-Ta, 160-Tb, 127m-Te, 129m-Te, 234-Th, 204-Tl, 170-Tm, 236-U, 91-Y, 95-Zr.

Group 3 (Hazardous)

105-Ag, 111-Ag, 244-Am, 41-Ar, 73-As, 74-As, 76-As, 77-As, 196-Au, 198-Au, 199-Au, 131-Ba, 7-Be, 206-Bi, 212-Bi, 250-Bk, 82-Br, 14-C, 47-Ca, 109-Cd, 115-Cd, 141-Ce, 143-Ce, 38-Cl, 57-Co, 58-Co, 51-Cr, 131-Cs, 136-Cs, 64-Cu, 165-Dy, 166-Dy, 169-Er, 171-Er, 152h-Eu, 155-Eu, 18-F, 55-Fe, 59-Fe, 254-Fm, 72-Ga, 153-Gd, 159-Gd, 197-Hg, 197m-Hg, 203-Hg, 166-Ho, 132-I, 134-I, 115m-In, 116m-In, 190-Ir, 194-Ir, 43-K, 85m-Kr, 88-Kr, 140-La, 177-Lu, 52-Mn, 56-Mn, 99-Mo, 24-Na, 93m-Nb, 95-Nb, 147-Nd, 149-Nd, 63-Ni, 65-Ni, 239-Np, 185-Os, 191-Os, 193-Os, 32-P, 223-Pa, 203-Pb, 103-Pd, 109-Pd, 147-Pm, 149-Pm, 142-Pr, 143-Pr, 191-Pt, 193-Pt, 197-Pt, 243-Pu, 86-Rb, 183-Re, 184-Re, 188-Re, 105-Rh, 220-Rn, 222-Rn, 97-Ru, 103-Ru, 105-Ru, 35-S, 122-Sb, 47-Sc, 48-Sc, 75-Se, 31-Si, 151-Sm, 153-Sm, 113-Sn, 125-Sn, 85-Sr, 91-Sr, 92-Sr, 96-Tc, 97m-Tc, 97-Tc, 99-Tc, 125m-Te, 127-Te, 129-Te, 131m-Te, 132-Te, 231-Th, 200-Tl, 201-Tl, 202-Tl, 171-Tm, 240-U, 48-V, 181-W, 185-W, 187-W, 135-Xe, 90-Y, 92-Y, 93-Y, 175-Yb, 65-Zn 97-Zr, 69-m-Zn.

Group 4 (Low Hazard)

37-Ar, 249-Cm, 58m-Co, 134m-Cs, 135-Cs, 71-Ge, 3-H, 113m-In, 114-In, 115-In, 116-In, 85-Kr, 97-Nb, 144-Nd, 59-Ni, 191m-Os, 193m-Pt, 197m-Pt, 87-Rb, 187-Re, 103m-Rh, 147-Sm, 85m-Sr, 96m-Tc, 99m-Tc, nat.-Th, 232-Th, nat.-U, 235-U, 238-U, 131m-Xe, 133-Xe, 133m-Xe, 91m-Y, 69-Zn, 93-Zr.

Appendix II. Standard Forms Used by the Radiation Protection Staff

APPENDICES

1. Standard forms used by the R.P.O.

The following forms (samples attached) are employed by the R.P.O. to aid them in carrying out their resposibilities. Their usage is explained in this manual.

R.P.O. 1 - Protocol for Radioisotope Experimentation

R.P.O. 2 - Radiation Training, Experience, and Exposure History

R.P.O. 3 - Radioisotope Procurement Request

R.P.O. 4 - Radioisotope Usage Work Sheet

R.P.O. 5 - Air Sample Record

R.P.O. 6 - Radioisotope Receipt and Usage Report

R.P.O. 7 - Radioisotope Inventory - Quarterly Report

R.P.O. 8 - Quarterly Summary/ Total Inventory.(by isotope) for all investigators

R.P.O. 9 - Summary Report - Method of Disposal of Radioactivity

R.P.O. 10 Commercial Isotope Waste Disposal - Individual Barrel

R.P.O 11 Commerical Isotope Waste Disposal - Summary

PROTOCOL FOR RADIOSOTOPE EXPERIMENTATION

1. Name:_____ Date:
   (person responsible to Radiation Protection Officer)

2. Radioisotope: Chemical Form:

3. Objective of Experiment:

4. Detailed description of the procedures to be used. (Attach as many pages as required) A reprint or copy of a reference can be attached as long as deviations from the method are indicated.

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

   b) Maximum amount of activity (mc) to be ordered per shipment:

   c) Maximum amount of activity (mc) to be ordered per calander Year:

6. Names of all persons to use isotope (all persons whose names are listed must submit RPO Form 2 if they have not already done so).

7. Rooms involved for each specific phase of the work, including isotope storage, sample counting, etc.

8. Arrangements for special problems such as liquid and solid waste storage and disposal, source shielding.

9. Arrangements for contamination control.

10. Monitoring and/or counting instruments available in the immediate area.

11. Expected duration of work:

12. Expected starting date:

13. Remarks and/or additional information.

_____ _____
(Signature)

RADIATION TRAINING, EXPERIENCE AND EXPOSURE HISTORY

1. Name_____ Age:_____

2. Soc. Sec. No._____ Date of Birth:_____

Occupational Exposure - Previous History

3. Previous Employments Involving Radiation Exposure. List Name and Address of Employer.	4. Dates of Employment (From-To)	5. Periods of Exposure	6. Previous Whole Body (REM)	7. Dose History Insert Record or Calculated

---

8. Type of Training	Where Trained	Duration of Training	Formal Course (give Title)	On the Job (yes/no)
(A) Principles and Practices of Radiation Protection				
(B) Radioactivity Measurement, Monitoring Techniques and Instruments				
(C) Mathmatics Basic to Use and Measurement of Radioactivity				
(D) Biological Effects of Radiation				

9. Experience: (Actual Use of isotopes)

	Isotope	Amount(μCi)	Location	Duration	Use
(A)					
(B)					
(C)					
(D)					

10. I Certify that the above information is correct and complete to the best of my knowledge and belief.

Date:_____ Signed:_____

DO NOT WRITE BELOW THIS LINE

Calculations - Permissible Dose Whole Body:

(A)Permissible Accumulated Dose = 5(N-18) _____REM

(B)Total Exposure to Date (From Item 7) _____REM

(C)Permissible Dose _____REM

5 Prime -> 3 Prime, Inc.

R A D I O I S O T O P E

RPO Form # 3

PROCUREMENT		CHECK-IN	
Chemical Form	Amount (MC)	Date Received	Volume or Weight
Supplier	Catalog No.	Lot Number	Specific Activity
Isotope		No. Vials or Ampules	Activity of Each
Physical Form			
Specific Activity			
Proposed Use			
Protocol No.	Requested by	Leak test & Remarks	
Users	Department		
	Isotope Storage Location		
Investigator (Approved Signature)	Date	Checked by	Date
RPO (Approved Signature)	Date	Radioisotope No.	

5 Prime -> 3 Prime, Inc.

RPO Form #4

RADIOISOTOPE USAGE WORK SHEET

DEPT._____ QUARTER _____ YEAR _____ USER _____ SUPERVISOR _____

Experiment (Notebook No. Pag & Date Operators Initials	dpm or μc used for dose or experiment (2.22×10^6 dpm/μc)	Amount (dpm) recovered (synthesis product, extraction, excreta, tissues, RIA fractions, etc.)	Disposition of radioactive compound, Specify date, amount and use.(e.g. specify counting aliquots, chromatography, storage(location) for future use, further use in experimentation, dialysis, electrophoresis, or other)	Disposal of radioactive compound; specify amount (dpm), date, method of disposal(sewerage, commericial, or other) and type of material disposed (extracts, remains of experiment, washes, etc.)

5 PRIME -> 3 PRIME
RPO Form 5

Air Sample Record

Location:_____ Date:_____

Investigator:_____

Air Sampler:_____ Type filter:_____

Expected isotope(s):_____

Flow Rate: Time:

Volume of Sample:

Counting Data:

counting instrument_____

Time and date counted_____

Filter # 1_____ _____ cpm gross Net cpm (a)_____

Filter # 2_____ _____ cpm gross Net cpm (b)_____

Background_____ _____ cpm

Standard: Isotope_____ Amount_____ uCi

Calib. date/Manuf._____

_____ cpm gross _____net cpm

Filter efficiency:

$$e = 1 - \frac{b}{a}$$

Activity on filter:

$$\frac{\text{Filter \#1 cpm}}{\text{Filter efficiency}} \times \frac{\text{uCi Std.}}{\text{cpm Std.}}$$

Airborne Concentration:

$$\frac{\text{Activity on filter uCi}}{\text{Volume in cc}}$$

% of occupational MPC_____ % of Environmental MPC_____

Remarks_____

_____

_____

_____

5 Prime -> 3 Prime, Inc. RPO Form #6

Labelled Coumpound	Amount	No. Vials or Ampules	Activity of Each
	Specific Activity		
Supplier	Date Rec'd		
Catalog No.			
Lot No.	Radioisotope No.		Isotope
Investigator			
Users	Storage Location		
Protocol No.			

Date	Amounts used (initial)	Outside shipment or in-hs	Disposal method	Disposed method	Remaining in other forms	Stock compound remaining	Total Activity

RADIOISOTOPE INVENTORY - QUARTERLY REPORT

INVESTIGATOR

DEPARTMENT DATE

ISOTOPES LISTED IN REPORT: Please circle

^{3}H, ^{14}C, ^{35}S, ^{32}P, ^{125}I, other________

(If more than two isotopes use more forms)

Amount (mCi) in Storage (all forms)

COMPOUND	RADIO ISOTOPE NO. RA	Sp. Act (mCi/mM)	3/31 Isotope		6/30 Isotope		9/30 Isotope		12/31 Isotope	
TOTAL										

5 Prime -> 3 Prime, Inc. RPO FORM # 8

QUARTERLY SUMMARY/TOTAL INVENTORY (by isotope) FOR ALL INVESTIGATORS

Quarter ____________ Year ________

			ISOTOPE				
INVESTIGATOR	^{14}C	^{3}H	^{125}I	^{35}S	^{32}P	OTHER	OTHER
TOTALS							

5 Prime -> 3 Prime, Inc. RPO Form #9

Summary Report
METHOD OF DISPOSAL FOR RADIOACTIVITY

Dept. _____ Quarter _____ Year _____ Name _____

	MONTH				
ISOTOPE					
METHOD					
SEWER					
LIQUID SINT. SOLVENT					
BARREL					
OUTSIDE SHIPMENT					
DECAY					
OTHER					

5 Prime -> 3 Prime, Inc. RPO Form #10

RADIOISOTOPE WAST DISPOSAL - COMMERCIAL

Barrel Number Location Exterior CPM

Labelled compound	Lot #	Supplier (Date Rec'd)	^{14}C	^{3}H	^{35}S	^{32}P	^{125}I	Other	Other	Physical Form	User (inital/date)
Total/Date											

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RPO FORM 11

COMMERCIAL WASTE DISPOSAL OF RADIOISOTOPES

Investigator	location	barrel #	size	assay	Contents Isotope - Amount Physical Form	Remarks

Appendix III. Preparation for Experimentation

1. To minimize potential wide area contamination with radioactivity, experimental work shall be done in an isolated non-congested area where enough working space is conveniently available to carry out the operation.

a) A sink should be accessible in every room where radioactive materials are used. Deep sinks are preferred over shallow ones since they provide better containment of contaminated liquids when laboratory glassware is washed.

b) The work area must include a fume hood or glove box if the use of such safety equipment has been specified by the RPO. Work with materials susceptible to atmospheric distribution, i.e. dusting, gaseous, dispersal, vaporizing, effervescence of solution, etc. must be carried out in an adequate enclosure.

2. All unnecessary equipment and objects shall be removed from the working area before labelled materials are handled.

3. The working surface must be covered with two-ply brown paper or plastic backed sheeting, Additional absorbent covering to soak up minor spills may be used. When absorbent material becomes contaminated, it shall be changed and treated as radioactive waste.

4. A supply of radioactive labels, industrial gloves, surgeons gloves, safety equipment as specified by the RPO, wipers, towels, Kimwips, Alconox, Radiac-Wash (or equivalent) and a two to three gallon pail must be on hand.

5. Polypropylene or stainless steel tray not only provides a "protective island" for small scale operations, but facilitates clean-up or spilled or scattered material. Such a tray should be employed if radioactive liquids are used in volumes which would not be absorbed by bench top covering if a spill occurred.

6. A large two-ply plastic bag receptor, top folded back, marked with a conspicuous "Caution - Radioactive Material" sign should be prepared to gather radioactive waste materials.

7. Estimated quantities of non-radioactive reagents required for the experiment must be placed within easy reaching distance of the worker. When the experiment has been completed, excess reagents will be discarded and the containers decontaminated.

8. Provisions for collecting contaminated equipment or equipment suspected of contamination on a tray or protected bench top, preferably in an isolated area of a fume hood, should be arranged and the area labelled with "Caution - Radioactive Material" signs or tape.

9. A large, non-porous pan or pail filled with Radiac-Wash (or equivalent) solution, placed off to one side, away from actual working area should be used for cumulative collection and storage of contaminated glassware and handling tools until decontamination can be performed.

10. Have all equipment and materials immediately accessible before initiating an experiment. Make absolutely certain that all supplies and materials required are present. This measure will prevent necessity for touching drawer pulls, door knobs, light switches, or stock reagent bottles when "glove-protected-hands" may be contaminated.

11. Warning signs, "CAUTION -RADIOACTIVE MATERIAL" must be placed conspicuously at entrances to laboratory and around all areas in which radioactive materials are to be used. See Section IV, B

12. CONTROLLED or RESTRICTED AREA - Any area set aside for radioisotpe use. All equipment within the area is under "quarantine" for the duration of radioisotope work and cannot be indiscriminately moved to other locations until it is monitored and found free of contamination. See Section II, D.

13. Containers of stock radioactive materials must be placed either in a tray or other protective vessel (lead shielded if gamma or energetic beta emitter) and stored in a location isolated from the general activity of the laboratory. All containers must be plainly marked with a RADIOACTIVE WARNING SIGN and properly identified (kind and amount of radioisotope).

14. Storage in fireproof metal containers is recommended.

15. Before using radioactive materials, it may be advisable to employ TRIAL RUN procedures to discover unexpected difficulties in handling techniques or to detect weakness in equipment, then modify procedures accordingly. Repeated performances may be required to eliminate all unforeseen difficulties. See Section II.A.

16. Caution to prevent contamination on the external surface of weighing vials will alleviate contamination of centrally located analytical balances.

a. Weigh paper or another vessel can be used to prevent contact of the weighing vehicle with the balance pan.

b. It is advisable for a second person to assist in weighing operations

c. Do not allow protective gloves to come in contact with balance control knobs.

d. Spatulas and other articles of equipment used in transfer oprations should be immersed in a washing agent, or wrapped carefully in paper and laid aside until decontamination can be performed.

17. The amount of radioactive stock material dispensed for a tracer study should always be kept to the lowest practicable level.

a. Remove from the storage container only the amount of radionuclide needed to perform the job.

b. Transfer manipulations of radioactive materials between storage container and working vessels must be done in such a manner as to prevent the posssiblity of airborne distribution and to avoid scattering by spillage or breakage.

c. Return unused quantities of stock material to the storage area before proceeding with the experiment.

18. In general, the inexperienced worker should take more stringent measures than may be required later as the actualities become apparent.

Appendix IV Routine Decontamination of Laboratory Equipment

1. The RPO will direct decontamination operations if major spread of contamination has occurred.

2. Personnel involved in decontamintion must be adequately protected. The recommendations of the RPO should be sought. Items to be considered: safety glasses, goggles, face masks, respirator, head cover, gloves (latex), shoe covers, apron, disposable lab coats or plastic suit.

3. A cleaning equipment kit for removing contaminants should include: handling tongs, forceps, labels, disposable towels, brushes, sponges, plastic bags, masking tape, decontamination tray for collecting equipment (e.g. polypropylene tray 14x18x4"), Radiac-Wash (or equivalent), Alconox, two 2-3 gallon plastic pails, brown paper, and plastic sheeting.

4. Provisions for safe accumulation and storage of all radioactive wastes are required - heavy duty plastic bags for solids , vessels for liquids.

5. Plan the decontamination operation thoroughly, considering the physical facilities and the chemical characteristics of the radioactive material to be removed. Dust raising methods such as dry sweeping must be avoided.

6. Operational Procedure:

a. Monitor contaminated area to determine the extent and amounts of radioactivity involved. Swab test with moistened filter paper discs and submit samples for radioactivity analysis or monitor surfaces directly with portable instruments if possible.

b. Outline contaminated areas with crayon or mask them off (covering unaffected areas to protect them from becoming contaminated).

c. Damp wiping with a decontamination agent is the usual first step for removal of the contaminant.

1) Use decontamination agents in which the chemical radioactive contaminant is soluble.

2) Guard against fixation of the contaminant to the surface.

3) Usually, Radiac-Wash (or its equivalent) in combination with detergent or soap cleansing is effective. Work on small areas and discard wiping towel often.

4) Take care not to spread contaminant to cleaner (lower activity) areas.

5) Always work towards the center of contamination.

d. Repeat Steps a. to c. above as required. Rough surfaces require more vigorous washing and scrubbing.

e. Completely monitor all articles before permitting their movement to clean areas. See Section II, D.

f. Post-operation Procedure:

1) Quarantine all equipment used for decontamination until it is monitored.

2) Monitor the area in which decontamination was performed.

g. All glassware and equipment must be decontaminated before it is sent to the central washing facility or returned to storage. Eight to ten rinses with water should be sufficient to remove water soluble materials. Further decontamination of apparatus can usually be achieved by ordinary washing procedure, as outlined above, using suitable solvents.

h. Instruments, e.g. scissors, syringes, forceps, spatulas, etc., may be washed with Radiac-Wash (or its equivalent) and then rinsed thoroughly in running tap water.

Appendix V Federal Regulations for Radiation Protection

The following is a copy of the Rules and Regulations of the U.S. Nuclear Regulatory Commission entitled "Standard for Protection Against Radiation" (Title 10, Code of Federal Regulations, Part 19 & 20). These rules apply to the usage of byproduct radioactive material at 5 Prime -> 3 Prime, Inc.; they are very similar to the Commonwealth regulations which apply to all radioactive materials in use by 5 Prime -> 3 Prime, Inc.

GLOSSARY OF TERMS

ABSORPTION - A process in which all or part of the energy of incident radiation is transferred to the matter through which it passes by various interactions with the basic particles (electrons, nuclei, etc.) of which the matter consists. This process results in a reduction of the radiation intensity or a reduction in the number of particles emerging from the absorbing material relative to the number of incident particles.

ACTIVITY -The strength of a radioactive source. In absolute units, it relates to the number of radioactive atoms decaying per unit of time; in relative terms, it is expressed in terms of the number of recorded counts per unit of time. Also a synonym for radioactivity. Absolute activity is usually expressed in curies or millicuries.

AIR MONITOR - A detecting device, used for control and warning purposes, to measure theamount of radioactivity present in the air.

ALPHA PARTICLE - A particle which is identical to the helium nucleus, consisting of two protons and two neutrons. It carries a positive charge of 2.

ALPHA RADIATION - The radiation consisting of alpha particles emitted by certain radioactive atoms.

BACKGROUND - In measurements of radioactivity, the observed count, in the absence of a sample, caused by cosmic radiation, instrument noise, power line fluctuations, etc. Also called background radiation.

BEAM - A unidirectional or approximately unidirectional flow of electromagnetic radiation or of particles.

USEFUL BEAM - (Radiology); Radiation which passes through the aperture, cone or other collimating device of the source housing. Sometimes called "primary beam".

BETA DECAY - The radioactive disintegration of a nucleus resulting in the emission of an electron (beta particle). If the beta is negative, the process results in an increase of stomic number by one unit, but the atomic mass remains the same. Positron decay results in a decrease in atomic numbe by one unit.

BETA EMITTER - Any radioactive nuclide that decays by beta decay with the emission of a beta particle.

BETA PARTICLE - An electron, either positive or negative. Positive beta particles are called positrons $\beta+$. Negative beta particles are sometimes called negatrons $\beta-$. The term beta particle and the symbol β are reserved for electrons originating in a nucleus.

BIOLOGICAL HALF LIFE - The time required for one-half of an administered substance to be excreted from the body or from an organ or section of living tissue.

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

CAPTURE, K-ELECTRON - Electron capture from the K shell by the nucleus of the atom. Also loosely used to designate any orbital electron capture process.

CARRIER - A quantity of non-radioactive or non-labelled material of the same chemical composition as its corresponding radioactive or labelled counterpart. When mixed with the corresponding radioactive labelled materials, soas to form a chemically inseparable mixture, the carrier permits chemical (and some physical) manipulation of the mixture iwth less label or radioactivity loss than would be true for the undiluted label or radioactivity.

CARRIER-FREE - An adjuective applied to one or more radioactive isotopes of an element in minute quantity, essentially undiluted with stable isotope carrier.

CERENKOV RADIATION - Visible light emitted by charged particles as theypass from a transparent medium of low refractive indix to a ransparent medim of high refractive index when their velocity in the first medium exceeds the velocity of light in the second.

CHAMBER, POCKET - A small, pocket-sized ionization chamber used for monitoring radiation exposure of personnel. Before use, it is given a charge and the amount of discharge is a measure of the radiation exposure.

CONTAMINATION, RADIOACTIVE - Deposition of radioactive material in any place where it is not desired, particularly where its presence may be harmful. The harm may be in vitiating an experiment or procedure, or in actually being a source of danger to personnel.

CONTROLLED AREA - A defined area in which the occupational exposure of personnel (to radiation) is under the supervision of the Radiation Protection Officer.

COSMIC RAYS - Radiation originating outside the earth's atmosphere, consisting of particles capable of producing ionizing events, primarily protons and nuclei, some of which have energies as high as 10^{15} ev. Secondary cosmic rays are produced by the interaction of primary cosmic rays with the earth's atmosphere.

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

SPURIOUS COUNT: In a radiaton counting device, a count caused by any agency other than radiation.

COUNTER, GAS FLOW - A device in which an appropriate atmosphere is maintained in the counter tube by allowing a suitable gas to flow slowly through the sensitive volume.

COUNTER, GEIGER - MUELLER - Highly sensitive, gas-filled radiation-measuring device. It operates at voltages sufficiently high to produce avalanche ionization.

COUNTER, PROPORTIONAL - Gas-filled radiation detection device: the pulse produced is proportional to the number of ions formed in the gas by the primary ionizing particle.

COUNTER, SCINTILLATION - The combination of phosphor, photomultimplier tube, and associted circuits for counting light emissions produced in the phosphors.

COUNTING RATEMETER - An instrument which gives a continuous indication of the average rate of ionizing events.

CURIE - The special unit of activity. One curie equals 3.700×10^{10} nuclear transformations per second. (Abbreviated Ci.) Several fractions of the curie are in common usage.

MICROCURIE - One-millionth of a curie (3.7×10^{4} disintegrations per second) Abbreviated μCi.

MILLICURIE - One-thousandth of a curie (3.7×10^{7} disintegrations per second) Abbreviated mCi.

PICOCURIE - One-millionth of a microcurie (3.7×10^{-2} disintegrations per second or 2.22 disintegrations per minute). Abbreviated pCi.

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

DECAY CONSTANT - The fraction of the number of atoms of a radioactive nuclide which decay in unit time. Symbol .

DECONTAMINATION FACTOR - The ratio of the amount of undesired radioactive material initially present to the amount remaining after a suitable processing step has been completed. Decontamination factors may refer to the reduction of some particular type of radiation, or to the gross measurable radioactivity.

DISINTEGRATION, NUCLEAR - A spontaneous nuclear transformation (radioactivity) characterized by the emission of energy and/or mass from the nucleus. When numbers of nuclei are involved, the process is characterized by a definite half-life.

EXPOSURE - A measure of the ionization produced in air by x or gamma radiation. It is the sume of the electrical charges on all ions of one sign produced in air when all electrons liberated by photons in a volume element of air are completely stopped in air, divided by the mass of the air in the volume element. The special unit of exposure is the roentgen.

ACUTE EXPOSURE - Radiation exposure of short duration.

CHRONIC EXPOSURE - Radiation exposure of long duration by fractionation or protraction.

FILM BADGE - A piece of photographic film contained in a lightproof holder and worn by an individual in order to measure the amount of radiation to which he is exposed

FLUOROGRAPHY (PHOTOFLUOROGRAPHY) - Photography of image produced on fluroescent screen by x or gamma radiation.

FLUOROSCOPE - A fluoroscent screen, suitably mounted iwth respect to an x-ray tube for ease of observation and protection, used for indirect visualization (by x-rays) of internal organs in the body or internal structures in apparatus or in masses of materials.

GAMMA RAY - Short wavelength electromagnetic radiation of nuclear origin (range of energy from 10 keV to 9 MeV) emitted from the nucleus.

HALF-LIFE, BIOLOGICAL - The time required for the body to eliminate one-half of an administered dosage of any substance by regular processes of elimination. Approximately the same for both stable and radioactive isotopes of a particular element.

HALF-LIFE, EFFECTIVE - The time required for a radioactive element in an animal body to be diminished 50 percent as a result of the combined action of radioactive decay and biological elimination.

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

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

HOT - A colloquial term meaning highly radioactive.

INTERLOCK - A device, usually electrical and (or) mechanical, to prevent activation of a control until a preliminary condition has been met, or prevent hazardous operations. Its purpose usually is safety.

LABELLED COMPOUND - A compound consisting, in part, of labelled moleculares. By observatons of radioactivity or isotopic composition, this compound or its fragments may be followed through physical, chemical, or biological processes.

PHANTOM - A volume of material approximately as closely as possible the density and effective atomic number of tissue. Ideally a phantom should behave in respect to absorption of radiation in the same manner as tissue. Radiation dose mearements made within or on a phantom provide a means of determining the radiation dose within or on a body under similar exposure conditions. Some materials commonly used in phantoms are water, Masonite, pressed wood and beeswax.

PHYSICS, HEALTH - A science and profession devoted to the protection of man and his environment from unnecessary radiation exposure.

RADIATION:

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

EXTERNAL RADIATION - Radiation from a source outside the body - the radiation must penetrate the skin.

MONOENERGETIC RADIATION - Radiation of a given type (alpha, beta, neutron, gamma, etc.) in which all particles or photons originate with and have the same energy.

PRIMARY RADIATION - The useful beam of an x-ray tube.

SCATTERED RADIATION - Radiation which during its passage through a substance, has been deviated in direction. It may also have been modified by a decrease in energy.

SECONDARY RADIATION - Radiation resulting from absorption of other radiation in matter. It may be either electromagnetic or particulate.

DOSE - A general form denoting the quantity of radiation or energy absorbed. For special purposes it must be appropriately qualified. If unqualified, it refers to absorbed dose.

ABSORBED DOSE - The energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest. The unit of absorbed dose is the rad. One rad equals 100 ergs per gram.

CUMULATIVE DOSE (RADIATION) - The total dose resulting from repeated exposures to radiation.

MAXIMUM PERMISSIBLE DOSE EQUIVALENT (MPD) - The greatest dose equivalent that a prson or specified part thereof shall be allowed to receive in a given period of time.

PERMISSIBLE DOSE - The dose of radiation which may be received by an individual within a specified period with expectation of no significantly harmful result.

TISSUE DOSE - Absorbed dose received by tissue in the region of interest expressed in rads.

DOSE EQUIVALENT (DE) - A quantity used in radiation protection. It expresses all radiations on a common scale for calculating the effective absorbed dose. It is defined as the product of the absorbed dose in rads and certain modifying factors. (The unit of dose equivalent is the rem.).

DOSE RATE - The dose of radiation received per unit of time.

DOSIMETER - A device (dose meter) used to measure the radiation dost to which an individual has been exposed.

EFFECTIVE DOSE - The amount of energy imparted to a tissue by each individual radiation from a radioactive source desposited in that tissue. For β-particles it is practically the average energy.

EFFECTIVE HALF-LIFE - The time taken for the radioactivity of a radioactive isotope in a living organism to decrease by one half.

EFFICIENCY (COUNTERS) - A measure of the probability that a count will be recorded when radiation is incident on a detector. Usage varies considerably, so it is well to ascertain which factors (window transmission, sensitive volume, energy dependence, etc.) are included in a given scase.

ELECTRON VOLT - A unit of energy equivalent to the energy gained by an electron in passiing through a potential difference of one volt. Larger multiple units of the electron volt are frequently used: keV for thousand or kilo electron volts; MeV for million or mega electron volts (Abbreviated: eV, 1 eV = 1.6×10^{-12} erg).

RADIOACTIVITY - The property of certain muclides of spontaneously emitting particles or gamma radiation or of emitting x radiation following orbital electron capture or of undergoing spontaneous fission.

ARTIFICIAL RADIOACTIVITY - Manmade radioactivity produced by particle bombardment or electromagnetic irradiation, as opposed to nature radioactivity.

INDUCED RADIOACTIVITY - Radioactivity produced in a substance after bombardment with neutrons or other particles. The resulting activity is "natural radioactivity" if formed by nuclear reactions occurring in nature, and "artificial radioactivity" if the reactions are caused by man.

NATURAL RADIOACTIVITY - The property of radioactivity exhibited by more than fifty naturally occurring radionclides.

RADIOGRAPHY - A process analogous to the making of an x-ray picture of an object by the selective absorption of radiation by the object, a radioactive source being used in place of an x-ray tube.

RADIOISOTOPE - Synonym for radioactive isotope. Any isotope which is unstable, thus undergoing decay with the emission of a characteristic radiation.

RELATIVE BIOLOGICAL EFFECTIVENESS (RBE) - The RBE is a factor used to compare the biolgoical effectiveness of absorbed radiation doses (i.e. rads) due to different ytpes of ionizing radiation, more specifically if is the experimentally determined ratio of an absorbed dose of a radiation in question to the absorbed dose of a reference radiation required to produce an identical biological effect in a particular experimental organism or tissue. NOTE: This term should not be used in radiation protection.

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

REP - An obsolete special unit of absorbed dose.

ROENTGEN - The quantity of x- or gamma radiation such that the associated corpuscular emission per 0.001293 grams of air (i.e., 1 ml at 0°C and 760 mm) produces, in air, ions carrying 1 electrostatic unit of quantity of electricity of either sign.

SEALED SOURCES - A radioactive source sealed in an impervious container which has sufficient mechanical strength to prevent contact with a dispersion of the radioactive material under the conditions of use and wear for which it was designed.

SHIELD - A body of material used to prevent or reduce the passage of particles or radiation. A shield may be designated according to what it is intended to absorb (as a gamma ray shield or a neutron shield), or according to the kind of protection it is intended to give (as a backgroumd, biological, or thermal shield). The shield of a nuclear reactor is a body of material surrounding the reactor to prevent the escape of neutrons and radiation into a protected area, which requently is the entire space external to the reactor. It may be required for the safety of personnel or to reduce radiaiton enough to allow us of counting instruments for research or for locating contamination or airborne radioactivity.

SICKNESS, RADIATION: (RADIATION THERAPY) - A self-limited syndrome characterized by nausea, vomiting, diarrhea, and psychic depression, following exposure to appreciable doses of ionizing radiation. particularly to the abdominal region. Its mechanism is unknown and there is no satisfactory remedy. It usually appears a few hours after irradiation and may subside within a day. It may be sufficiently severe to necessitate interrupting the treatment series or to incapacitate the patient. (GENERAL): The syndrome associated with intense acute exposure to ionizing radiations.

SOURCE - Any material which emits radiation

SPECIFIC ACTIVITY - (1) The activity or decay rate of a radioisotope per unit of mass of the sample. (e.g. microcurries per milligram, microcuries per millimole, disintegrations per second per milligrams). (2) The realtive activity per unit of mass (counts per minute per milligrams).

STANDARD RADIOACTIVE - A sample of radioactive materials, usually with a long half-life, in which the number and type of radioactive atoms at a definite reference time is known. It may be used as a radiation source for calibrating radiation measurement equipment.

SURVEY, RADIOLOGICAL - Evaluation of the radiation hazards incident to the productin, use, or existence of radioactive materials or other sources of radition under specific conditions. Such evaluation customarily includes a physical survey of the disposition of materials and equipment, measurements or estimates of the levels of radition that may be involved, and sufficient knowledge of processes using or affecting these materials to predict hazards resulting from expected or possible changes in materials or equipment.

TRACER - An isotopic tracer is an isotope used to tag or follow a chemical reaction or proces such that its location and concentration can later be determined.

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