

# Radiation Safety Manual



ENVIRONMENTAL HEALTH AND SAFETY  
THE WINIFRED MASTERSON  
BURKE MEDICAL RESEARCH INSTITUTE, INC.  
785 Mamaroneck Avenue, White Plains, New York 10605

## **Radiation Safety Mission**

The Radiation Safety program has been established to develop and implement a work place committed to the safe and proper use of radioactive materials with the policies set forth by the Radiation Safety Committee; in compliance with federal and state regulations; and in full support of the programs at participating institutions.

The program is structured to support all research activities, assist laboratories in safety practices and to help laboratories maintain compliance with regulating agencies.

In this manual are radiation safety practices, the policies and procedures that will govern work with radiation and radioactive materials at Burke Medical Research Institute.

## RADIATION SAFETY CONTACT NUMBERS

RADIATION EMERGENCY.....

**Peter Capitelli, RSO, mobile phone (718) 637- 4409**  
**RSO offices at Weill Cornell (212) 746 -5756, alt. (212) 746-6964**  
**Burke Radiation Safety Office (914) 368 -3145**  
**Weill Cornell EH&S Office (646) 962-7233**

EMERGENCY (off hours) ..... **RSO mobile (718) 637- 4409**  
Burke Security..... **(914) 597-2318**  
Weill Cornell Security ..... **(212) 746-0911**

Office of Environmental Health and Safety at Burke..... **(914) 368 -3156**

Radiation Safety Office..... **(914) 368 - 3145**

- Personnel Monitoring (radiation badges)
- Radioactive Waste Disposal Service
- Waste Container Pickup and drop-off Requests

Radiation Safety Officer..... **(914) 368 - 3145**  
**(212) 746 - 5756**

Environmental Health and Safety  
Main Office at NYC ..... **(646) 962 - 7233**

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## ***1. Administrative Commitment***

- i. The Administration is committed to the program described herein for keeping individual and collective doses from ionizing radiation as low as is reasonably achievable (ALARA). In accord with this commitment, we hereby describe an administrative organization for radiation safety and will develop the necessary written policy, procedures, and instructions to foster the ALARA concept within our institution.
- ii. To ensure safety, the Burke Radiation Safety Program is overseen by the Radiation Safety Committee (RSC). The members will perform an annual review of the radiation safety program. Taking into account ALARA considerations, operating procedures and past dose records, inspections, and consultations with the Radiation Safety Officer will be reviewed. .
- iii. Modifications to research protocols, maintenance procedures and to equipment and facilities will be made if they will reduce exposures unless the burden, in our judgment, outweighs the potential for dose reduction. We will be able to demonstrate, if necessary, that those improvements have been sought; that modifications have been considered, and that they have been implemented when reasonable. If radiological design modifications have been recommended but not implemented, we will be prepared to describe the reasons for not implementing them.
- iv. The goal of the program is to maintain doses to individuals and releases to environment as far below the limits as is reasonably achievable. The sum of the doses received by all exposed individuals will also be maintained at the lowest practicable level consistent with an expanding research program.

## ***2. Radiation Safety Committee***

The RSC is a Center-wide board comprised of scientists and administrators that establish the policies and regulations regarding the non-human use of ionizing radiation within BMRI. The members of the RSC are appointed by the administration at BMRI. The RSC reports to the Director of the institute.

- i. Review of Proposed Users and Uses:
  - During the authorization approval process, the RSC will review the qualifications of each applicant. The review will include evaluation of the types and quantities of

materials and methods of use for which application has been made to ensure that the applicant will be able to maintain exposure ALARA. The committee has the authority to grant, deny, or withdraw permission for the use of radioactive materials or any other radiation sources within Burke.

In its oversight role of the Radiation Safety Officer, the Committee is responsible for the following:

- Establishing policies,
  - Establishing training procedures and criteria,
  - Review and approve all requests for use of radioactive material within the institution,
  - Enforcing compliance with the program, including imposition of sanctions for noncompliance,
  - The RSC will ensure that the users document their procedures and will review the efforts of the applicants to maintain exposure ALARA,
  - The RSC will review incidents, accidents and results of hazard evaluations as well as corrective actions taken.
- ii. Delegation of Authority:
- BMRI will delegate authority to the RSO for management of the ALARA concept.
  - The RSO, or designee, conducts inspections, hazard evaluations and interviews to make recommendations that will include radiological planning which will contribute to dose reduction. The RSO is available for consultation with scientists and others university personnel concerning laboratory design, appropriateness of methods and alternatives. The RSO has the authority to prevent unsafe practices and stop work if necessary.
  - The RSO or designee performs facility and laboratory radiation surveys and inspects facilities to enhance contamination control and reduction of radiation exposure. The RSO has the authority to stop work if necessary when specific unsafe practices are identified.
  - The RSC will support the RSO when it is necessary for the RSO to assert authority. If the RSC has overruled the RSO, it will record the basis for its action in the minutes of its meetings.
- iii. Review of ALARA Program:

- During the authorization approval process, the RSO will encourage all users to review procedures and develop new or revised procedures as appropriate to implement the ALARA concept.
- The RSO will review the exposure records on at least a quarterly basis and initiate investigations where indicated.
- The RSC will perform an annual review of occupational radiation exposures. The principal purpose of this review is to assess trends in occupational exposure as an index of the ALARA program quality.
- The RSC will evaluate BMRI's overall efforts for maintaining doses ALARA on an annual basis. This review will include the efforts of the RSO, authorized users and ancillary groups as well as those of the administration.
- Violations of legal requirements or of the policies set forth in this manual will be brought to the attention of the responsible permit holder, who will be required to take appropriate corrective actions. Failure to properly resolve a violation will be brought to the attention of the RSC Chair and Administration. Instances of repeated violations will be reviewed by the Radiation Safety Committee and may result in suspension of approval to use radioactive materials.

### ***3. Radiation Safety Officer (RSO)***

The Radiation Safety Officer shall ensure that safe radiological working conditions are established and maintained for all BMRI personnel, students, visitors, and the general public and shall ensure compliance with all pertinent federal, state, and local regulations.

#### **a. Reviews by the RSO:**

- i. Review records of radiation surveys. The RSO will review radiation surveys to determine that dose rates, amounts of contamination, and releases to the environment were at ALARA levels during the previous quarter.
- ii. Annual Review of occupational exposures. The RSO will review at least annually the radiation doses of authorized users and workers to determine that their doses are ALARA in accordance with the provisions of Section 8 of this program.
- iii. Annual review of the radiation safety program. The RSO will perform an annual review of the radiation safety program for consistency with the ALARA philosophy.

#### **b. Educational Responsibilities for ALARA Program:**



- i. The RSO will inform authorized users of ALARA program initiatives in its educational and training sessions.
  - ii. The RSO will ensure that authorized users and ancillary personnel who may be exposed to radiation will be instructed in the ALARA philosophy and informed that the administration, the RSC, and the RSO are committed to implementing the ALARA concept
- c. Development of ALARA Procedures:
- i. Radiation workers will be given opportunities to participate in formulating the procedures that they will be required to follow.
  - ii. The staff of the Radiation Safety Section will be in close contact with Principal Investigators and authorized users in order to develop ALARA procedures for working with radioactive materials.
  - iii. The RSO will establish procedures for receiving and evaluating the suggestions of individual radiation users for improving health physics practices and will encourage the use of those procedures when deemed appropriate.
- d. Reviewing Instances of Deviation from ALARA philosophy:
- i. The RSO will initiate investigations of all known instances of deviation from the ALARA philosophy and, if possible, will determine the causes. When the cause is known, the RSO will implement changes in the program to maintain doses ALARA.

#### ***4. Establishment of Investigational Levels in Order to Monitor Individual Radiation Doses.***

BMRI has established investigational levels for radiation doses and releases to the environment which, when exceeded, will initiate review or investigation by the RSC and/or the RSO. The investigational levels that BMRI has adopted are listed in Table 4-1. These levels are based on fractions of the exposure limits. These levels apply to both internal and external exposure of individuals (except for pregnant workers). The RSO will review and record results of personnel monitoring. The following actions will be taken at the investigational levels as stated in Table 4-1:

- a. Personnel dose less than Investigational Level I: Except when deemed appropriate by the RSO, no further action will be taken in those cases where an individuals' dose is less than Table 4-1 values for the Investigational Level.

- b. Personnel dose equal to or greater than Investigational Level I: The RSO will investigate in a timely manner the causes of all personnel doses equaling or exceeding Investigational Level and, if warranted, will take action.
- c. Personnel dose equal to or greater than Investigational Level II: A report of the investigation, any actions taken, and a copy of the individual's exposure history will be presented to the RSC. The details of these reports will be included in the RSC minutes without identifying the specific individual.
- d. Re-establishment of Investigational Level: The RSC may, if appropriate, raise or lower the investigational levels to achieve a desirable level of review. Justification for new investigational levels will be documented. The RSC will review the justification for and must approve or disapprove all revisions of Investigational Levels.

Table 4-1. Radiation Safety Investigational Levels

	For a Given Quarter (mrem)		Cumulative for the Year (mrem)	
	Level I	Level II	Level I	Level II
Whole Body Deep	125	375	500	1500
Lens of Eye	125	375	1500	4500
Whole Body Shallow	1250	3750	5000	15000
Extremity	1875	5625	5000	15000
Blood forming Organ	125	375	5000	15000
Minors (Whole Body)	--	20	--	30
Embryo/Fetus	--	20	--	30

### 5. *Authorized Users*

Authorized users are trained individuals and investigators approved by the Radiation Safety Committee and licensed by the State of New York to use, possess, order and apply radionuclides in a safe, scientific manner. The authorized users may include physicians, scientists, and other personnel and are ultimately responsible for the safe and appropriate usage of all radionuclides in their possession.

- i. Principal Investigators will apply to the RSC for authorization to use radioactive materials.

- ii. Principal Investigators responsibility:
  - i. The Principal Investigators will explain the ALARA concept and the need to maintain exposures ALARA to all supervised individuals.
  - ii. The Principal Investigators will ensure that supervised individuals who are subject to occupational radiation exposure are trained and educated in good health physics practices and in maintaining exposures ALARA.
  - iii. The Principal Investigator is accountable for radiation safety practices in his/her laboratories.
  - iv. Adequate planning. Before an experiment is performed, the supervisor should determine the types and amount of radioactive material or radiation to be used. This will generally give an indication of the level of protection required. The procedure must be well outlined. In many cases, before the procedure is actually performed with radiation, it should be rehearsed so as to preclude mistakes or unexpected circumstances. In any situation where there may be an appreciable radiation hazard, the Radiation Safety Officer shall be consulted before proceeding.
  - v. Instructing those employees for whom they are responsible in the use of safe techniques and in the application of approved radiation safety practices and insuring attendance at required radiation safety courses.
  - vi. Furnishing the Radiation Safety Officer with information concerning individual workers and activities in their areas- particularly with regard to personnel changes.
  - vii. Contacting the Radiation Safety Officer whenever major changes in operational procedures, new techniques, alterations in the physical plant (e.g., the shutdown or removal of a radiochemical fume hood), or when new operations, which might lead to personnel exposure, are anticipated.
  - viii. Complying with the regulations governing the use of radioactive materials, as established by Part 16 of the Health Code of the State of New York and the BMRI Radiation Safety Committee, for:
    - A. Correct procedure for the procurement of radioactive materials by purchase or transfer.
    - B. Posting areas where radionuclides are kept or used, or where radiation fields may exist.

- C. Seeing that each sign carries the name of the personnel currently responsible for the associated area.
  - D. Recording the receipt, transfer, and disposal of radioactive materials in his area. This includes sealed sources such as ion sources in gas chromatographs and static eliminators. The authorized user must be prepared to submit the required inventory data upon request.
  - E. Assuring that all radioactive waste materials are consigned to the Radiation Safety Officer for proper disposal.
  - F. Taking steps to prevent the transfer of radioactive materials to unauthorized individuals. This includes the proper disposition of radioactive materials in the possession of terminating workers or authorized users.
- ix. Keeping stock of stored radioactive materials to a minimum within laboratory areas. This includes radioactive waste as well.
  - x. Maintaining laboratory security where radioactive materials are stored or used. These areas are restricted areas and are to be kept locked.
  - xi. Complying with proper procedure for closing down or moving a laboratory:
    - A. This includes notifying the Radiation Safety Officer.
    - B. A final contamination survey and proper removal and disposition of all radioactive waste and sources.
    - C. New York State Health Department and the Radiation Safety Officer shall be notified of the location of the new facility. This includes the submission of a drawing or schematic of the new area.

## ***6. Application for Non-Human Radioactive Material License***

- a. Applicants for nonhuman radioactive materials use must apply for licensure through the Radiation Safety Officer. The application form to be completed is: "Application for Radioactive Materials License Non-Human Use" copies of which are available from the Radiation Safety Officer.
- b. This application is to be filled out and submitted to the Radiation Safety Officer. It will then be reviewed and submitted to the Radiation Safety Committee for review and approval. The Radiation Safety Committee requires a final vote of approval.

- c. The application form includes the following:
  - i. Name, address, title, of the applicant.
  - ii. A list of isotopes, quantities, and physical and chemical form.
  - iii. A list of facilities for the storage and use of radioactive materials including hoods, refrigerators and shields.
  - iv. A description and diagram of the premises on which isotopes are to be used.
  - v. Experience and training of the responsible investigator as well as those authorized to use isotopes within the laboratory.
  - vi. A list of instruments available for the detection and quantification of radioactive isotopes.

## ***7. Supervised Individuals Who May Receive Occupational Radiation Doses***

- a. Supervised individual users will be instructed in the ALARA concept as it applies to work procedures and work conditions.
- b. Supervised individual users will be responsible for obeying all safety requirements and shall report any problems to his/her supervisor.

## ***8. Supervised Individual User Responsibility***

Each individual user at BMRI who has any contact with radioactive materials is responsible for:

- a. Keeping his or her exposure to radiation as low as possible, and specifically below the maximum permissible exposures listed in Table 12-1.
- b. Laboratory air and water concentrations shall be maintained below the levels specified in 10 NYCRR Part 16 Appendix 16-C of the New York State Department of Health Code and 6 NYCRR Subpart 380.11 of the New York State Department of Environmental Conservation (DEC). Note that there is no dumping of radioactive materials into the sewage system unless authorized by the RSO.
- c. Wearing the proper monitoring equipment such as film badges and other approved monitors in radiation areas. A variety of monitors are available including ring, wrist, whole body, and neutron badges. Personnel who work only with pure beta emitters having a maximum energy of 0.2 MeV (200 keV) or less are not required to wear film badges.
- d. Surveying his or her hands, shoes, and body for radioactivity, and removing all loose contamination before leaving the laboratory.

- e. Utilizing all appropriate protective measures such as:
- i. Wearing protective clothing whenever working with radioactive materials and if contamination is possible and not wearing such clothing outside of the laboratory area.
  - ii. Wearing gloves and respiratory protection when necessary.
  - iii. Using protective barriers and other shields whenever appropriate.
  - iv. Using mechanical devices whenever their use will assist in reducing exposure.
  - v. Using pipette-filling devices. *Never pipette radioactive solutions by mouth.*
  - vi. Performing radioactive work within the confines of an approved hood or glove box unless a careful evaluation has indicated the safety of working in the open.
  - vii. Never ever eat or smoke in laboratories where radioactive materials are used. It is recommended that eating be done in the cafeteria or other designated area whenever possible. Eating may be permitted in a separate, enclosed space such as an office area of a laboratory that has been demonstrated to be free of contamination. Refrigerators shall not be used jointly for foods and radioactive materials.
  - viii. Maintaining good personal hygiene.
  - ix. Do not work with radioactive materials if there is a break in skin below the wrist.
  - x. Wash hands and arms thoroughly before handling any object, which goes to the mouth, nose or eyes.
  - xi. Checking the immediate areas, e.g., hoods, bench tops, etc., in which radioactive materials are being used at least once daily for contamination. A log record should be maintained of these surveys including results, which are entirely negative. Any contamination observed should be clearly marked and the RSO should be notified.
  - xii. Keeping the laboratory neat and clean. The work area should be free from equipment and materials not required for the immediate procedure. Keep or transport materials in such a manner as to prevent breakage or spillage (double container), and to insure adequate shielding. Wherever practical, keep work surfaces covered with absorbent material. Work over a stainless steel tray or pan to limit and collect spillage in the event of an accident.
  - xiii. Labeling and isolating radioactive waste and equipment, such as glassware, used in laboratories for radioactive materials. Once used for radioactive substances,

equipment should not be used for other work, and shall not be sent from the area for cleaning, repair or disposal, until demonstrated and documented to be free of contamination.

- xiv. Requesting RSO supervision of any emergency repair of contaminated equipment in the laboratory by BMRI personnel or by commercial service contractors. At no time shall service personnel be permitted to work on equipment in radiation areas without the presence of a member of the laboratory staff to provide specific information.
- xv. Reporting accidental inhalation, ingestion, or injury involving radioactive materials to his supervisor and the RSO, and carrying out their recommended corrective measures. The individual shall cooperate in any and all attempts to evaluate his exposure.
- xvi. Carrying out decontamination procedures when necessary, and for taking the necessary steps to prevent the spread of contamination to other areas.
- xvii. Complying with requests from the RSO for bioassay measurements including urine specimens and thyroid uptake measurements.

## ***9. Record Keeping***

The NRC and other regulators require strict record keeping regarding the use and disposal of radioactive materials as well records of routine contamination checks, instrument calibration, and training. Records should be kept in a general location accessible to anyone working in the laboratory.

- a. The laboratory must be able to prove that the isotopes ordered and received have been used according to Federal Law and disposed according to institution policy. (See Appendix II and III: Opening packages containing radioactive materials and Radioactive Material Inventory sheet. These records must be kept for five years.)
- b. Wipe test records must be documented in the proper units of DPM and kept permanently.
- c. Survey instruments must be calibrated every year and the calibration record must be kept for at least two years.
- d. Training records should be kept in the laboratory.

## ***10. Security of Radioactive Materials***

The U.S. Nuclear Regulatory Commission, in the wake of recent incidents at other institutions, is closely scrutinizing the security practices of radioactive material users at all licensed institutions. The most common source of concern found by inspectors is unlocked and unattended laboratories containing radioactive materials.

BMRI and all of its users of radioactive materials are required to comply with NRC regulations and policy. The NRC's current policy requires that all radioactive material must be secured from unauthorized use by remaining either under the constant surveillance of an authorized person or locked away at all times. As applied to laboratories at BMRI, the NRC requirements include the following guidelines, **which must be followed**:

- a. Radioactive material must be secured from unauthorized use. If in an unsecured use area (e.g., an unlocked laboratory), when not in locked storage, the material must be maintained under "constant surveillance." This means that an authorized person must at all times be in the laboratory or surrounding area where he or she is in a position to monitor for unauthorized persons entering the laboratory and to intervene upon observing someone who could walk away with the material. This requirement applies to radioactive material in waste and experiments in progress as well as to stock solutions. There is no exempt quantity of material that does not require this level of security.
- b. BMRI must make certain that unauthorized persons are not able to leave the laboratories with radioactive material. Toward that end, the NRC expects that unknown or unauthorized persons encountered in the laboratory will be challenged as to their identity and intent. Persons without justification for being in the laboratory are not allowed to remain unaccompanied in the laboratory.
- c. A posted laboratory containing any amount of unsecured radioactive material must be locked at all times, except when an authorized person is present in the laboratory or in an immediately surrounding area which permits continuous monitoring of the entrance to the lab.

*The following hypothetical examples illustrate the current NRC policy:*

**Example 10.1:** The only laboratory member working on a weekend day is in an area outside her posted lab, but where the entrance to her lab is readily visible at all times. The lab contains radioactive material in the radioactive waste container. She remains aware of persons near the lab and challenges any unauthorized person attempting to enter the lab. A worker, whom the laboratory member had called, arrives to repair a light fixture. She allows him into the lab. This complies with the NRC policy.

**Example 10.2:** A laboratory member is in the posted lab or surrounding area. No other lab member is present. The laboratory contains radioactive materials in experiments in progress on the bench top in various parts of the lab. An unexpected visitor arrives whom the laboratory member does not know. The laboratory member asks the visitor who she is, and she tells him that she needs to inspect



the lab; he does not ask her for identification. The laboratory member then allows the visitor to roam the lab without monitoring her activities. This fails to comply with NRC requirements.

**Example 10.3:** A posted laboratory is not actively using radioactive material at the present time. The radioactive stock vial in storage in the laboratory is in a locked box in the freezer. There is neither radioactive waste in the laboratory nor experiments in progress. This meets NRC requirements because the radioactive material is stored in a locked box.

## 11. ALARA (As Low As Reasonably Achievable)

. The guiding principle of all radiation work is: the dose should be **As Low As Reasonably Achievable**; economic and social factors being taken into account. This is called the "ALARA Principle" and is central to all radiation safety. Any Radiation User whose annual or quarterly dose, as measured by external monitoring or calculated from the results of bioassay procedures, greatly exceeds the normal value is subject to investigation by the Permit Holder, in co-operation with the Radiation Safety Officer.

## 12. Occupational Dose Limits

A radiation worker means an individual engaged in work under a license issued by the NYS Dept. of Health. Any person who is exposed to ionizing radiation as a direct and necessary condition of his occupation, business or employment is "occupationally exposed" and is subject to the dose limits for this group set out in Table 12-1. The purpose of dose limits is to ensure that the radiation dose received by any person (other than an accidental exposure, or a deliberate exposure as in medical diagnosis) is such that:

- a. The dose is below the threshold for any biological effect (non-stochastic or deterministic) which requires a minimum dose for expression; and
- b. The probability of any effect of the all-or-nothing (stochastic) type is small enough to be acceptable to the individual and to society.

Table 12-1 Summary of annual occupational dose limits for adults and minors.

<b>ANNUAL EXTERNAL EXPOSURE LIMITS</b>	
<b>Total Effective Dose Equivalent (TEDE)</b>	<b>50 mSv (5 rem)</b>
<b>Deep Dose Equivalent and Committed Dose Equivalent (Summation)</b>	<b>500 mSv (50 rem)</b>
<b>Eye Dose Equivalent</b>	<b>150 mSv (15 rem)</b>
<b>Shallow Dose Equivalent to the Skin or Extremities</b>	<b>500 mSv (50 rem)</b>
<b>Total Effective Dose Equivalent to Embryo/Fetus</b>	<b>5 mSv (0.5 rem)</b>
<b>Total Effective Dose Equivalent to Minor</b>	<b>5 mSv (0.5 rem)</b>

- c. Federal regulations state that the dose to the embryo/fetus shall not exceed 10% of the TEDE (5.0mSv (0.5rem)) during the entire pregnancy (from conception to birth), and that monthly dose should not exceed 1% of the TEDE (0.5 mSv (50 mrem)). Ideally, the radiation would be

received at a uniform rate on a monthly basis. If the declaration of pregnancy is not offered until the embryo/fetus has exceeded the 5.0mSv (0.5rem) limit or is within 0.5 mSv (50 mrem) of the limit, the licensee is required to limit the dose to the embryo/fetus to 0.5 mSv (50 mrem) for the duration of the pregnancy.

- d. Personnel monitoring
  - i. Personal monitoring is required for minors expected to exceed 10% of the applicable TEDE limit, (or 0.5 mSv [50 mrem]).
  - ii. Personal monitoring is required for workers expected to exceed of 10% of the applicable TEDE limit, (5 mSv [500 mrem]).

### ***13. Declared Pregnant Worker Status***

On January 1, 1994, the new Title 10, Code of Federal Regulations, Part 20 law went into effect in the United States. This document describes the changes and requirements that BMRI and pregnant radiation workers must follow to assure that exposures or risks are maintained at or below the legal requirements.

Requirements are:

- a. The limit for radiation exposure for a declared pregnant radiation worker is 5mSv (0.5rem) for the entire gestation period.
- b. There is now a separate limit for the fetus of 5mSv (500mrem) for the entire gestation.
- c. Exposures to the fetus must be uniform, and will be maintained at or below 0.5 mSv (50 mrem) per month.
- d. Declaration of pregnancy is optional. Pregnant radiation workers must declare their pregnancy in writing to the Radiation Safety Office for the fetal and prenatal limits to take effect. If no written declaration is made, the limits remain at the occupational limit (5rem per year).
- e. If exposures have occurred between the time of conception and the declaration date, the exposures will be subtracted from the permitted exposure limits, and the balance will be prorated over the remaining months.
- f. A meeting will be scheduled with the pregnant worker and the Radiation Safety Officer to review the previous exposures, discuss any particular concerns and review any special precautions or particular concerns in radiation uses.
- g. Pregnant radiation workers will be supplied with two radiation dosimeters, one for the mother (whole body), and one for the fetus (abdomen). These badges will be exchanged

monthly in order to assure that an exposure spikes do not occur, and to document that exposures do not exceed the 50 mrem/month cap.

- h. Exposure records for the fetus will be tracked separately from the mother. This eliminates confusion and assures that the accumulated dose wraps into the next year if the pregnancy carries into that year.

There are relatively few research laboratories where radiation levels are high enough that a fetus would receive 500 mrem before birth. Most nuclides pose little risk of dose via external exposure to the worker. For those who work with  $^{32}\text{P}$ , the risk is also very small; although  $^{32}\text{P}$  is a high energy beta nuclide, it can only penetrate the tissue 7 - 10 millimeters, and thus not to the depth of the fetus. (Shallow doses typically occur with  $^{32}\text{P}$ , not deep doses.)

If you are pregnant, planning to become pregnant or simply would like more information, please call the Radiation Safety Officer **3145**, and we will arrange a meeting with you to review information and to answer questions.

#### ***14. Protection of the General Public***

- a. The legal dose limit for non-radiation workers and members of public is 1 mSv (100 mrem) per year. This limit covers radiation exposure of all types, except those arising from background radiation and medical procedures, whether received inside or outside university premises. Since BMRI has no control over radiation sources outside the Center, it should never be assumed that the radiation exposure at a given point is the only source of exposure of the staff concerned. Dose levels in university premises should be interpreted with this in mind.
- b. The ALARA principle applies to non-radiation workers as well as Radiation Workers. Every effort must therefore be made to reduce the doses received by "other personnel" and members of the public to a minimum level. This applies to any situation in which such persons are not directly involved in the work but may nevertheless be exposed to radiation to some extent. Such exposure may occur, for example, to clerical and other non-academic staff within a department using radiation sources, to members of adjoining departments and to members of the public in areas adjacent to buildings housing major radiation-emitting equipment. The public may also incur exposure when radioactive waste is disposed of via the sewers or into the atmosphere.
- c. The difference between a "Radiation Worker/User" and a non-radiation worker or member of the public lies in the circumstances in which each is exposed to radiation. The latter is exposed incidentally or randomly, because he/she happens to come into the vicinity of radiation sources, of which he/she has no direct knowledge, interest or control. In contrast,

the Radiation User is systematically exposed as a result either of his/her own work or of work carried out by colleagues in the same laboratory or department.

- d. A corollary of the definition of a Radiation User is that no person outside the department or laboratory in which sources are stored or used, for example a member of a neighboring department, should be subject to a level of exposure which would require him/her to be classified as a Radiation Worker/User. Shielding should therefore be sufficient to reduce the radiation levels in adjacent areas, which are outside the control of the Permit Holder concerned, to less than 0.02 mSv (2.0 mrem) in any one hour and to less than 1 mSv (100 mrem) per annum (excluding background), occupancy being taken into account. In most cases this is not only feasible but corresponds to present practice. Radiation levels in adjacent areas higher than 1 mSv per year, up to 5 mSv per year, are legal but not recommended. Where it is difficult or impossible to meet this recommendation, the matter should be referred to the Radiation Safety Officer.

## ***15. Emergency Procedures for Laboratories***

### ***TO BE FOLLOWED IN CASE OF RADIOACTIVE ISOTOPE LOSS OR SPILL***

**Radiation Safety Officer - RSO mobile phone (718) 637-4409, Office (212)746-5756**

**Burke Radiation Safety Office - (914) 368 -3145**

**Security – Burke (914) 368-2318; Weill Cornell (212) 637-0911**

All laboratory personnel should read these procedures prior to commencing work.

### **MINOR SPILLS – Less than 100 $\mu$ Ci**

**NOTIFY:** Notify all other persons in the room.

**PREVENT THE SPREAD:** Prevent the spread of contamination by covering the spill with absorbent paper.

**CLEAN UP:** Clean up the spill using disposable gloves and absorbent paper and remote handling tongs. Carefully fold the absorbent paper with the clean side out and place in a plastic bag for later disposal as radioactive waste. Also put contaminated gloves and other contaminated, disposable material in the bag.

**SURVEY:** Survey the area with an appropriate low-range radiation detection survey meter or by wipe tests for removable contamination, as appropriate. Check the area around the spill. Also check your hands, clothing and shoes for contamination.

**REPORT:** Report the incident to the Radiation Safety Office.

### **DRY SPILLS**

Wear rubber or plastic gloves.

Place damp absorbent paper over the spill. Take care not to spread the contamination.

Notify Radiation Safety Officer, Ext. 3145.

Decontaminate as necessary.

Permit no person to resume work in the area until the Radiation Safety Office has confirmed a survey.

### **Major Spills – Greater than 100 $\mu$ Ci**

**CLEAR THE AREA:** Notify all persons not involved to vacate the room at once.

**PREVENT THE SPREAD:** If a liquid spill, right the container (have hands protected with gloves). Prevent the further spread of contamination by covering the spill with absorbent paper, but

DO NOT attempt to clean up the spill. To prevent the spread of contamination, limit the movement of all personnel who may be contaminated.

**SHIELD THE SOURCE:** Shield the source, if possible. This should be done only without further contamination or significant increase in radiation exposure.

**CLOSE THE ROOM:** Leave the room and lock the door(s) to prevent entry.

**CALL FOR HELP:** Notify the Radiation Safety Office immediately.

Call the Radiation Safety Officer: ..... **RSO mobile (718) 637- 4409**

**PERSONNEL DECONTAMINATION:**

Contaminated clothing should be removed and stored for further evaluation by Radiation Safety Officer. If spill in on the skin, flush thoroughly with lukewarm water and then wash with mild soap. Do not rub hard!

If contamination remains, induce perspiration by covering the area with plastic then wash again.

**FOLLOW UP:** The Radiation Safety Office must monitor all persons involved in the spill. Only the Radiation Safety Office can permit work to resume in or personnel to enter the area of the spill.

**Radioactive Dusts, Mists, Fumes, Gases, etc.**

Notify other persons to evacuate the room

Hold breath, close valves, and turn off air-circulating devices as time permits.

Vacate room.

Close all doors and post area.

Notify Radiation Safety Officer, 3145. .... **RSO mobile (718) 637- 4409**

Report suspected inhalations of radioactive materials.

Detail all persons suspected of being contaminated.

Decontaminate as instructed by Radiation Safety Officer.

Radiation Safety Officer must perform an air survey before work can be resumed.

**Injuries Involving Radiation Hazards**

Wash minor wounds immediately, under running water, spreading edges of wound.

Report all radiation accidents and injuries to personnel to the Radiation Safety Officer **(718) 637- 4409**

Have employees proceed to Employee Health Service or Urgent care.

In the case of traumatic injury, call 911 for medical assistance.

**Fires Involving Possible Radiation Hazards**

Sound Alarm.

Call Security: 2318

Close all doors and windows.

Extinguish the fire, if possible.

Call the Radiation Safety Officer: ..... **RSO mobile (718) 637- 4409**

Decontamination may be necessary before work is resumed.



## ***16. General Radiation Safety Guidelines***

The following presents the guidelines that are required of all persons using radioactive materials within BMRI. Adherence to these rules is strictly required. Failure to observe these rules will place a licensee in jeopardy of losing their license.

- a. Mouth pipetting is never permitted. Remote pipetters, syringes or other pipetting aids are to be used.
- b. Eating or smoking in any laboratory using or storing any amount of radioactive materials is never permitted.
- c. Storage of food or beverages in any laboratory using or storing any amount of radioactive materials is never permitted. This includes all contiguous areas to the licensed laboratory.
- d. Gloves are to be worn at all times when working with radioactive materials. If there are breaks in the skin, rubber gloves should be used. Gloves are to be removed immediately after working with radioactive materials and hands should be checked for any contamination.
- e. Hands should be washed thoroughly before leaving the laboratory.
- f. Disposable items contaminated with radioactive materials should be placed in the containers provided. Laboratory equipment contaminated with radioactive materials should be decontaminated upon discovery. The equipment shall not be used until removable contamination is documented to be below specified limits.
- g. Radioactive materials are to be transported to prevent spillage or breakage. When liquids are in a glass container, the container should be kept within a second non-breakable vessel. This vessel should be large enough to contain all of the liquid from the glass container.
- h. All bench tops shall be covered with an absorbent material and periodically monitored and replaced upon contamination. Work could also be done within a tray that would contain any spills.
- i. All work with volatile compounds is to be done within an appropriate hood.
- j. Radioactive shipments are to be opened in a hood if there is any possibility of volatilization of the materials.
- k. When a package containing radioactive material is opened, a check is to be made to determine if there is any physical damage to the package, contamination of the package

material or the vial containing the material. If contamination is found contact the Radiation Safety Officer, Ext. 3145. See Appendix II for Package Opening Procedures.

- l. The doors to the laboratory, work, and storage areas, are to be posted with the appropriate “radiation precaution” tri-blade symbol. These signs are available from commercial suppliers and from the Radiation Safety Office.
- m. An area within the laboratory is to be provided for the proper storage of radioactive materials. This area shall provide sufficient shielding to maintain exposure levels “as low as reasonably achievable” (ALARA) and which prevents release of the materials.
- n. All laboratories containing radioactive materials are to be locked when personnel are not present.
- o. All containers no longer containing radioactive materials are to be checked for contamination before disposal. If free of contamination, signs and references to radioactive materials are to be defaced before disposal.
- p. Laboratories using high-energy beta or gamma radiation are to have a calibrated survey meter available. The survey meter is to be calibrated once a year as per Part 16 of the New York State Health Code.
- q. Emergency procedures are to be posted in each laboratory. It is the responsibility of the licensee/laboratory head to see that employees are familiar with these procedures. Radiation safety personnel are available for training upon request. Training seminars are scheduled bi-annually. Attendance is mandatory for all new laboratory employees working with radioactive materials.
- r. In case of emergency, contact the Radiation Safety Officer, **1-718-637-4409**.
- s. The “Notice to Employees” document of the New York City Department of Health is to be posted in every laboratory.
- t. Contamination checks of all working and storage areas shall be performed at monthly intervals using appropriate equipment and techniques.
- u. If personnel monitors are provided to the laboratory, they are to be worn at all times in the laboratory. Personnel monitors are to be stored in an area where radiation is not present. Care should be taken to prevent exposure to heat and high humidity. Personal monitors are to be returned as soon as new ones are distributed.

- v. Persons under the age of eighteen are not to be employed to work with radioactive materials unless permission is granted from the Radiation Safety Officer. Please contact the Radiation Safety Officer for details.
- w. Female employees who are pregnant or think they are pregnant should contact the Radiation Safety Officer for information and instruction about options available regarding working with radioactive materials.
- x. Inventory records of radioactive materials are to be maintained within the laboratory by the laboratory personnel. These records are to include each receipt, use, transfer and disposal of radioactive material.
- y. The amount of radioactive materials stored in the laboratory cannot exceed the maximum possession amount shown on the license. It is the laboratory's responsibility to know their storage limits and be able to provide documentation, (inventory control sheets), showing compliance with this regulation.
- z. Accidental introduction of radioactive materials into the body: ingestion, contaminated wounds, or injection, must be reported immediately to the Radiation Safety Officer. The laboratory must also file an incident report.

## ***17. Policies and Procedures for Radionuclide Areas***

The following policies and procedures shall apply to the BMRI license:

### **a. Proper Marking of Laboratories, Areas, and Equipment:**

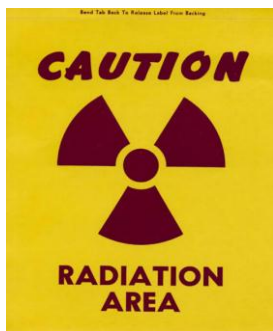
- i. A “**CAUTION RADIOACTIVE MATERIALS**” sign must be conspicuously posted on the doors to laboratory areas where radioactive materials are being stored or utilized. The supervisor shall be responsible for seeing that the posted information is current. Only the Radiation Safety Officer shall remove the signs from any room.
- ii. Storage areas shall be conspicuously marked with a “**CAUTION RADIOACTIVE MATERIALS**” sign. In addition, containers in which materials are transported or stored shall bear a durable, clearly visible label bearing the radiation caution symbol and the words “**CAUTION RADIOACTIVE MATERIALS.**” This label shall also state the quantities and kinds of radioactive materials in the containers and the date of measurement of the quantity. **This is an essential step in alerting the radiation hazard to personnel and the public.**
- iii. Radiation areas in the laboratory, i.e. areas where radiation levels might expose individuals to 5 millirem in any one hour at a distance of 30 cm; or in any five consecutive days, a dose in excess of 100 mrem, shall be posted with the sign “**CAUTION RADIATION AREA.**”

- iv. All equipment contaminated with radioactive material shall be marked with signs, decals, or other conspicuous means. Labeling shall not be required for laboratory containers such as beakers, flasks, and test tubes, used temporarily in laboratory procedures during the presence of the user.
- v. All signs referred to in this section are available from the Radiation Safety Officer, (X3145) located in Room Billings 02.

**b. Examples of Radiation Signs**



- i. “Caution Radioactive Materials” This is the most common sign encountered in a biological research institute, the trefoil symbol with the appropriate warning below. This sign specifically means there is a licensable quantity of ionizing radioactive material present in any form (> 500uCi) in the laboratory. This sign is required to be posted at the entrance of all laboratories licensed to possess and/or use radioactive materials.



- ii. “Caution Radiation Area” This sign specifically means that the area beyond may result in a dose to the individual of between 0.50  $\mu$ Sv, (5 mrem) and 0.1 mSv, 100 mrem).
- iii. “Caution High Radiation Area” is any area, accessible to individuals, in which there exist ionizing radiation levels that could result in an individual receiving a dose equivalent in excess of 1 mSv (0.1 rem) in one hour at 30 centimeters from the radiation source.

iv. A relatively new category of exposure level, which requires a still different sign, is the “Caution Very High Radiation Area.” This is an area, accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 5 grays (500 rads) in 1 hour at 1 meter from a radiation source or from any surface that the radiation penetrates.

**c. Posting Areas**

Authorized users must ensure that signs remain appropriately posted in all locations in which radioactive materials or radiation machines are stored or used. Such spaces include:

- i. Laboratories – Each entrance to all licensed laboratories shall have a proper “Caution Radioactive Materials” sign posted.
- ii. Cold rooms - All cold rooms where radioactive materials are used or stored shall have a proper “Caution Radioactive Materials” sign posted.
- iii. Animal rooms – All animal rooms where radioactive materials are used or stored shall have a proper “Caution Radioactive Materials” sign posted.
- iv. Refrigerators, freezers, cabinets, etc. – All locations where radioactive materials are stored shall have a proper “Caution Radioactive Materials” sign posted.
- v. Hoods – All hoods where radioactive materials are used and stored shall have a proper “Caution Radioactive Materials” sign posted.

**d. Labeling Containers and Equipment**

- i. All containers in which radioactive materials are stored for any purpose shall have a proper “Caution Radioactive Materials” label.
- ii. All laboratory equipment including containers, which are routinely used in conjunction with radioactive materials and therefore may become contaminated, shall be labeled with the “Trefoil” symbol.
- iii. All laboratory equipment including containers, which are contaminated, shall be labeled with the “Trefoil” symbol.
- iv. Labeling is not required if activities are less than the limits specified in Part 16, Appendix A, Table 9 list of typically used isotopes is listed in table 17-1.

**Table 17-1: Quantities of Licensed Material Requiring Labeling**

Hydrogen-3	37 MBq (1000 uCi)
Carbon-14	37 MBq (1000 uCi)
Flourine-18	37 MBq (1000 uCi)
Phosphorus-32	0.37 MBq (10 uCi)
Phosphorus-33	3.7 MBq (100 uCi)
Sulfur-35	3.7 MBq (100 uCi)
Chromium-51	37 MBq (1000 uCi)
Technetium-99m	37 MBq (1000 uCi)
Iodine-125	37 kBq (1 uCi)
Iodine-131	37 kBq (1 uCi)

- e. **Shielding of Sources:** Radioactive sources or stock solutions in the laboratory shall be shielded in such a manner that the radiation levels in any occupied area will not expose individuals in the area to more than 100 mrem in any five consecutive days. Use of thick-walled lead containers, L-shields, (either lead or Lucite depending on whether the emission is gamma or beta) is useful for this purpose.

**f. Aerosols, Dusts, and Gaseous Products**

- i. Procedures involving aerosols, dust, or gaseous products, or procedures, which might produce airborne contamination, shall be conducted in a hood, dry box, or other suitable closed system.
- ii. All releases from such systems shall not exceed the maximum permissible concentrations in air for the nuclide in question. Where practical, procedures should be carried out within a closed system (or with charcoal traps, if practical) to insure that environmental releases are as low as possible.
- iii. Radioactive gases or materials with radioactive gaseous daughters must be stored in gas-tight containers and must be kept in areas having approved ventilation.
- iv. Hoods to be used for radionuclide work should be tested by the Radiation Safety Office to insure that they meet the minimum flow requirements in terms of air velocity at the face of the hood (125 linear feet per minute).
- v. Iodination's are only to be performed in approved hoods.

**g. Sealed Radioactive Sources**

All sealed radioactive sources must be leak tested by the Radiation Safety Office personnel prior to initial use and at least every six months thereafter.

**h. Radioactive Materials in Gas Chromatography Equipment:**

All gas chromatography units in which radioactive materials are to be used are regulated as follows:

- i. Each cell containing a radioactive foil must have a label showing: The radiation cautions symbol with the words "CAUTION RADIOACTIVE MATERIAL"; and the identity and activity of the radioactive material. The radioactive foil shall not be removed from its identifying cell except for cleaning and shall not be transferred to other cells.
- ii. The following notice shall appear outside of each gas chromatography unit in a conspicuous location: "This equipment contains a radioactive source registered with the

Radiation Safety Office. Notify the Radiation Safety Office before removing the source from this room or area, or upon any change in custodial responsibility.”

- iii. Individuals using radioactive components in gas chromatograph equipment must vent the cell-exhaust through plastic tubing into a hood, room exhaust, or the Radiation Safety Office approved trap, to avoid contamination of work areas from the release of radioactive tagged samples introduced into the system or from the accidental overheating of radioactive foils in the cells.
- i. **Counting Equipment (that may contain a radioactive standard).** Certain counting equipment has a sealed source built into the detector system. Before disposing of this equipment, obtain clearance from the Radiation Safety Office. Do not give this equipment away. The radioactive material contained within is still YOUR responsibility.
- j. **Work Surfaces:** All work areas (bench tops, hood floors, etc.) as well as storage areas and areas adjacent to permanent set-ups and sinks should be covered at all times with stainless steel or plastic trays, uncracked glass plates, or other impervious materials. For some purposes, a plastic-backed absorbent paper (sometimes referred to as “blue-wipes”- or “blue chucks”) is satisfactory. When such paper is used, it should be discarded frequently to prevent radioactive materials from dusting off the surface.
- k. **11. Laboratory Monitors- [survey instruments]:** Each laboratory or area (other than those where H-3 is used exclusively or where only exempt quantities are used exclusively or where only exempt quantities of other radionuclides are handled) shall be equipped with a portable monitoring device to be used for personnel and area monitoring. This instrument shall be capable of detecting all types of radioactivity used in the laboratory. Typically, a GM (Geiger-Mueller) detector is optimal for pure beta emitters such as P-32, P-33, S-35 or C-14. A scintillation detector is optimal for gamma and X-ray emitters such as I-125, I-131, Cr-51 or Na-22. In certain cases, a scintillation detector can be used for P-32. Consult the Radiation Safety Officer regarding the selection and appropriateness of a particular instrument.
- l. **Removal of Equipment from the Laboratory:** Once used for radioactive substances, equipment shall not be used for other work, or sent for repair, cleaning, loan, or returned to the source of supply, until demonstrated to be free of contamination.
- m. **Repair, Maintenance and Disposal of Equipment in the Laboratory:** Equipment to be repaired either internally or under service contract shall be demonstrated to be free of contamination prior to servicing. If it becomes necessary to make emergency repairs on contaminated equipment, the Radiation Safety Office will assure that the necessary precautions are taken by supervising the work. It is the responsibility of the laboratory personnel to request this supervision from the Radiation Safety Office.

- n.* **House Vacuum Lines:** House vacuum lines are vulnerable to contamination. Traps must be used between the vacuum intake and the radioactive source. If house vacuum lines are to be used, the withdrawn gas must be demonstrated to the Radiation Safety Office to be free of radioactivity. It is advisable to use a separate vacuum system whenever possible, such as a separate vacuum pump exhausting into a hood.

## ***18. Personal Protections***

Protective clothing (or personal protective equipment, PPE) is worn in contaminated areas to prevent the contamination of personnel. It provides personnel with easily removed outer “skin” so that if contamination is present on the clothing, the wearer is no longer exposed after the clothing is removed. In addition, protective clothing may provide some shielding for beta radiation. The amount of protection gained by wearing protective clothing depends to a large degree on how the clothing is worn and used by personnel.

Description and Typical use of Protective Clothing in the Laboratory

- a. Lab Coats – standard cotton lab coats are worn in the laboratory for performing chemical analysis on radioactive samples, or for observation of a job in a slightly contaminated area.
- b. Gloves – cotton gloves are worn to provide some protection against dry contamination while rubber or plastic gloves are worn for protection against either dry or wet forms of contamination.
- c. Eye and face Shield – standard eye and face protection should be employed when performing chemical analysis of radioactive samples.
- d. Coverage of Legs and Feet – complete coverage of legs and feet prevent contamination from shattering beakers and test tubes. Only long pants, full length skirts and shoes that completely cover the feet are acceptable in the laboratory.

## ***19. Contamination Control***

Contamination control practices in research laboratories are under constant scrutiny from regulatory agencies as concerns are routinely surfacing that worker and public safety are being compromised. Whether or not this is in fact the case, contamination control requires a serious and structured program. All workers must practice contamination control techniques, as outlined in this document, regardless of the type of radioisotopes used, their activity, or their frequency of use.

In general, no radioactive contamination can be tolerated. Exceptions to this will include certain hood trays, dry boxes, stainless steel trays, surfaces covered with blue wipes, or other equipment which is used frequently for active work and which will be clearly marked with the standard radiation caution signs or stickers. Any contamination that is not confined to protected surfaces should be reported immediately to the Radiation Safety Office. The individual licensee is ultimately responsible for



cleanup of a contaminated area and for documenting that it is free of contamination with a final wipe test and/or survey.

- a. **Area Classification:** Areas should be classified according to their contamination and levels of isotope use. Typical designations include “controlled” area, “restricted” area, “contaminated” area, “highly contaminated” area, “airborne radioactivity area”, and “radioactive materials” area.
  - i. A **controlled area** refers to an individual’s ability to enter an area or building monitored by security personnel or accessible by identification card swipe access. Therefore, any building with security guards is considered a controlled building.
  - ii. A **restricted area** refers to an area, once in the building, is restricted to specific personnel for specific activities under specific conditions generally for the purpose of protecting individuals against undue risks from exposure to sources of radiation. Examples include the iodination rooms, radiological animal research facilities, radioactive waste storage areas, radioactive source storage areas, etc. Individual laboratories licensed to use radioactive materials are considered restricted areas due to the training requirements of the workers.
  - iii. A **contaminated area** refers to any area where the presence in or on any animal, food, water supply, building or premises, body of water, municipal sewage disposal system, chattel or thing of a solid, liquid or gas emitting ionizing radiation which may constitute a danger to human beings.
  - iv. A **highly contaminated area** refers to a contaminated area that has levels of either measured removable or total activity greater than the published radioactive surface contamination limits (Table 6).
  - v. A **radioactive materials area** refers to any location, or contiguous and adjacent locations, under a single license in which radioactive material is received, produced, used, possessed (stored), or transferred
- b. **Area posting:** Areas having (or likely to have) removable contamination or licensable quantities of radioactive material in use, in permanent or temporary storage, or in the form of waste, should be posted as noted above. Barriers and signs should be placed at entrances and perimeters around the area to warn personnel of any inherent hazards. In some cases, the requirements for entering an area should be posted.
- c. **Area preparation:** Two of the most common methods employed to prevent the spread of contamination in an area are **covering** and **confinement techniques**.
  - i. Covering those areas with materials such as plastic and absorbent lining materials can minimize contamination of clean areas. Slightly contaminated areas can be prevented from becoming highly contaminated areas through the use of protective coverings. Protective

coverings must be discarded as they become contaminated. The amount and type of preparation required to protect an area can vary greatly. Consideration of the type of work and degree of contamination already present or expected will determine the appropriate type of covering. Polyethylene materials become slippery when moist, flammability is an issue with cloth and polyethylene, and high traffic areas can promote tripping and slipping if coverage is not secured properly. Covering techniques, however, should be balanced against the volume of radioactive waste generated.

- ii. Confinement techniques should be considered in those cases when work is performed in areas with significant contamination, or could generate considerable airborne contamination. These techniques include (but are not limited to) the use of fume hoods, glove boxes, glove bags, tents, and portable ventilation systems.
- d. **Intake considerations.** Control of intake of radioactive materials into the body is a prime objective in the radiological research laboratory for several reasons. Assessing internal irradiation is a difficult process that is prone to inaccuracies. In addition, the analysis and interpretation of the results is time consuming due to process and regulatory requirements.
- i. To reduce the possibility of intake and subsequent internal irradiation, eating, drinking, and smoking are not allowed within any restricted area. All laboratories licensed to possess and use radioactive materials are considered restricted areas. Such areas **include** designated clean areas (permanent/temporary) within the restricted areas and all other areas contiguous to the restricted area.
  - i. Basic contamination control practices dictate that prior to eating, drinking or smoking an individual should:
    - 1. Remove his/her protective clothing;
    - 2. Perform a personal contamination survey and initiate decontamination efforts if necessary;
    - 3. Follow common personal hygiene practices (e.g. washing hands).
- e. **Air Contamination** and inhalation is a common pathway for radioactive particulates and gases to enter into the body. To control this pathway effectively, the design of the laboratory should include proper engineering controls such as ventilation systems, fume hoods, glove boxes, remote handling devices, and shielding should be employed as confinement and containment devices.
- i. Laboratories most at risk for air contamination include those using organic compounds of Sulfur-35 especially **cystine and methionine**. The following precautions should be adhered to when using these compounds:

1. Always open Cystine and methionine vials in a properly functioning chemical fume hood. Volatilization occurs out of the vial and can build up inside the “pig”.
  2. Always thaw Cystine and methionine in a properly functioning chemical fume hood.
  3. Vacuum lines should have separate desiccant/charcoal traps to avoid contamination.
  4. Cell culturing should not occur in recirculating fume hoods.
  5. When **incubating**, charcoal impregnated cotton filter fiber paper should be used in close proximity over the top of the samples. When opening incubators wait at least 15 seconds before retrieving the samples. The humidity should be kept as low as possible.
  6. **Contamination** will be most often found around hood sashes, micro-cracks in laboratory benches, centrifuges especially vacuum cavity types (screw top eppendorf tubes should be used), and impregnated into plastic lining and shielding.
- f. **Surface Contamination** found on floors, equipment and bench tops is of great concern especially when the material is transferable; it can be tracked to different locations, spreading the contamination and increasing the possibility of worker exposure. In certain instances floor contamination can become airborne through re-suspension. While a clear correlation between surface contamination levels and the resultant internal exposure does not exist, surface contamination is considered the primary suspect in most internal exposure incidents. Surface contamination limits for radioactive materials exist for laboratories and are published in the New York State Code Part 16. Surface contamination levels must be evaluated via wipe testing each month for every laboratory licensed to possess radioactive materials. Areas with surface contamination of any level must be clearly posted.

Table 19-1 Surface Contamination Limits and Actions

Type of Contamination	Removable Contamination Levels (dpm/100 cm <sup>2</sup> )		
	Low	Mid	High
Alpha	5 - 100	100 - 500	> 500
Gamma or High Energy Beta	100 - 250	250 - 1000	> 1000
Low or Intermediate Energy Beta	100 - 1000	1000 - 5000	> 5000
Decontamination Requirements	Should be decontaminated promptly, but may be tolerated in a particular work situation (Must be in a clearly marked radioactive work area)	Must be decontaminated promptly. A <i>Notice of Unsatisfactory Condition</i> will be sent to the Principal Investigator if decontamination is not completed within one week.	Requires immediate action. A <i>Notice of Unsatisfactory Condition</i> will be sent to the Principal Investigator. Depending on the extent of the contamination, further use may be suspended until decontamination is completed. The PI may be required to report to the Radiation Safety Office stating the reason for the incident and actions taken to minimize the risk of a repeat.

- g. **Equipment Protection:** Equipment used in or removed from radioactive laboratories should be prepared to minimize the creation and spread of contamination. The following methods should be employed: (1) screw caps should be used on all tubes used in centrifugation and tube speed rating should be matched to your experimental requirements to avoid collapsing; (2) charcoal filters should be used on all vacuum lines in contact with radioactive materials, especially organic compounds of S-35; (3) charcoal cotton fiber filter paper should be placed on top of radioactive samples being incubated; (4) secondary containment should be used in all heated water baths; (5) pipette tips which eliminate or reduce aerosolization should be used to avoid splattering ; and (6) pipette tips must be ejected directly into proper waste receptacle.

## 20. Decontamination

During the operation of any laboratory facility, contamination is inevitable; hence, the need exists to properly remove it from tools, equipment, laboratory surfaces, and personnel. Each decontamination effort must be evaluated on an individual basis and the techniques varied to meet the specific conditions. Preparations for decontamination should begin promptly. The Radiation Safety Officer will assist in this evaluation. The individual responsible for the contamination will be expected to do most of the cleanup under the supervision of the Radiation Safety Officer. In extreme cases, an outside commercial service may be called in to perform the cleanup. Charges for this service are the

responsibility of the licensed user. After decontamination, the area or equipment shall be considered contaminated until demonstrated otherwise by the Radiation Safety Officer.

- a. **Decontamination:** Steps to take immediately following the discovery of contamination.
  - i. Determine the extent and hazard of the contamination using your survey meter.
  - ii. Decontamination should start with the area of lower contamination and proceed towards the area of higher contamination.
  - iii. Intermittent decontamination surveys should be performed to determine both the degree of decontamination needed and the effectiveness of the decontamination method.
  - iv. The volume of solids and liquids used in decontamination should be minimized to reduce waste.
- b. **Decontamination of Equipment and Surfaces:** Decontamination of equipment and surfaces before work begins reduces both the potential for spreading contamination and the exposure to the worker. A typical scenario includes:
  - i. Frisking with an appropriate survey instrument. A common guideline value for determining a clean working area is less than 100 cpm above background.
  - ii. Determining whether the contamination is “fixed” or “loose” by wipe test technique.
  - iii. Applying “RAD CON”, detergents, or other agents to the area of interest and scrubbing with a hard bristle brush.
  - iv. Note: Some equipment, such as centrifuges, may need to be disassembled for decontamination.
  - v. If decontamination is unsuccessful equipment can either be discarded as radioactive waste or placed in a designated decay area by contacting the Radiation Safety Officer (x 3145).
  - vi. Surfaces that cannot be decontaminated must be covered and labeled with the isotope, amount of contamination, and release date
- c. **Personal Decontamination:** In cases of personal decontamination, the method should be chosen not only on the basis of the effectiveness of removing the contamination, but also on the effect the method will have on the individual.
- d. General principles of decontamination include the following:
  - i. Reduce radiation exposure

- ii. Minimize the absorption of radionuclides into the body
  - iii. Prevent localized contamination from spreading
- e. Removing Radioactive materials from the skin
- i. Survey over the skin, hair, clothing, etc., using an appropriate instrument.
  - ii. If the contamination is widespread, the individual should shower with soap and water. After drying off, the survey should be repeated, hopefully showing the contamination being reduced to a localized portion of the body.
  - iii. Localized areas can often be decontaminated by taping a surgeon's glove or plastic over the affected area. The contamination is removed by sweating through the skin.
  - iv. Flushing the areas with copious amounts of water and relying on trained medical professionals for further decontamination should handle contamination present in the eyes, mouth and wounds.
  - v. Decontamination should be repeated several times for a given procedure. If after up to four attempts, the contamination levels are not being reduced significantly, radiation safety or medical professionals should be notified.
  - vi. Note: Superficial contamination should always be removed by first washing the affected area with lukewarm water and mild soap. Hot water opens the pores allowing contamination to enter and cold water closes the pores trapping contamination. Scrubbing which causes excessive irritation can lead to a loss of integrity of the skin barrier.

## ***21. Radioactive Waste Management***

No radioactive wastes shall be disposed of in the ordinary waste stream. This means particularly that solid wastes may not be placed in the standard waste containers or red bag containers to be collected by housekeeping personnel, and that liquid wastes shall not be discharged into the sewer system through the laboratory sinks or drains. Liquid scintillation vials (LSV's) are to be disposed of in a separate container designated specifically for LSV's. These should be marked "LSV's ONLY". No other type of waste (liquid or solid) is to be placed in these containers. (To do so is a "mixed waste" violation). Radioactive animals must be disposed of separately in dedicated freezers and containers either for storage or for eventual pickup. Please email radiation safety to schedule liquid waste pickup.

No radioactive waste shall be released from a laboratory area for pickup and disposal prior to autoclaving or otherwise suitable deactivation of infectious agent(s). The addition of a bleach solution for deactivation of biologicals is obligatory. Radioactive waste disposal procedures used by the Radiation Safety Office may involve volume reduction and storage for decay. These procedures are not compatible with the proper handling of infectious agents. Similar considerations shall also be given to other highly toxic or hazardous substances.

**a. Waste Containers**

- i) To insure that solid and liquid wastes are kept separate, each laboratory having radioactive waste must be equipped with at least one container for solid dry waste and one for liquid waste. Due to the methods of ultimate disposal of waste by the Radiation Safety Office, short-lived isotope (P-32, S-35, I-125) waste must be stored separately in color-coded containers marked with the name of the isotope. Long half-lived waste (H-3, C-14) may be stored in a single container and separated by physical form- either liquid or dry. Additional waste containers shall be requested for this purpose and marked as to the radionuclides being used. (See Appendix IV for waste chart).
- ii) **Solid dry waste containers.** These may be obtained from the Radiation Safety Office. They must be fitted with a disposable waterproof plastic liner. Each drum is to be tagged indicating the isotope; the amount of activity and the date the radioactive material was placed in the drum. These numbers may be estimates. Tags are available from the Radiation Safety Office.
- iii) **Liquid waste containers.** Two sizes of polyethylene carboys are available: 5 gallon and 10 gallon. A means of secondary containment must be provided, i.e., having it set in a large pan. These are provided with covers that must be kept closed. In addition, they shall be conspicuously marked with appropriate “CAUTION RADIOACTIVE MATERIAL” radiation signs. Each carboy is to be tagged indicating the isotope; the amount of activity and the date the radioactive material was placed in the container. These numbers may be estimates. Tags are available from the Radiation Safety Office.
- iv) **Mixed Waste.** Mixed waste is defined as any radioactive material mixed with any EPA regulated waste. This waste **MUST** be labeled with the proper radioactive signs **AND** with the proper Chemical hazard signs. See Appendix V for a list of EPA regulated waste.
- v) **Animal carcasses.** Small radioactive animals should be placed in the standard polyethylene bags. Each unit must be conspicuously marked with a “CAUTION RADIOACTIVE MATERIAL” sign and in addition, the radionuclide(s), the date and amount remaining in the carcass shall be posted on the bag or label. If pickup cannot be arranged within 4 hours of sacrifice of animals, such animal carcasses must be refrigerated or preferably frozen for eventual pick-up.
- vi) **Liquid scintillation vials.** All LSV’s must be disposed of as radioactive waste in a separate container. Vials should remain tightly capped. No other form of waste- liquid or solid- is to be added.

- b. Decay in Storage Program:** BMRI license permits disposal of certain radioactive materials through a decay-in-storage program, provided that various conditions are met. Under the Decay-In-Storage (DIS) Program, wastes contaminated with certain short-lived isotopes can be stored in the laboratories generating the waste for a minimum of ten half-lives. The wastes are then rigorously surveyed, and if no activity distinguishable from

background levels is found, then the wastes are disposed of as non-radioactive medical wastes.

- i. Radioisotopes are permitted to be disposed of through the Decay-in-Storage Program but must have half-lives < 90 days. This includes radioisotopes such as P-32, P-33, S-35, Cr-51, and I-125.
- ii. Wastes contaminated with short-lived isotopes and intended for disposal through the DIS Program must be strictly segregated in the laboratory from all other radioactive wastes. DIS wastes themselves must be segregated by isotope to as large an extent as possible. Waste from an experiment with dual labeling, e.g., utilizing a short-lived isotope such as P-32 and a longer-lived isotope such as H-3 cannot be disposed of as DIS waste.
- iii. High activity (multi-millicurie) waste materials should be separated from lower activity materials in the laboratory to decrease the volume of wastes that must be stored in the DIS Facilities for more than ten half-lives.
- iv. Before an item is placed into a DIS solid waste container, radioactive materials labels must be removed, if possible, or thoroughly obliterated or covered. Wastes containing items with visible radioactive materials labels will not be accepted for storage in the DIS facilities.
- v. Liquid scintillation counting wastes contaminated with short-lived isotopes are not stored separately as DIS wastes. Due to low disposal costs for liquid scintillation counting wastes and the complexities of the DIS procedures, all liquid scintillation counting wastes, regardless of the contaminating isotope, are picked up and disposed of by the waste disposal service vendor.

**d. Unusual Waste Disposal Problems**

Plans for proper disposal of infectious agents and highly toxic or hazardous substances shall be made early in the design of the experiment. The Radiation Safety Committee will review proposed procedures involving unusual waste disposal problems on an individual basis.

## ***22. Lead Disposal and Safety***

- a **Handling Lead in the Laboratory:** Lead is commonly used (mostly in the form of bricks, sheets, and Pigs) as radiation shielding in many Labs and walls.
  - i All permanently installed lead must be covered whenever possible and practicable. Methods of covering can include painting, aluminum sheeting, plastic sheeting, or aluminum foil. To avoid problems that may be caused by the paint, Kapton tape may be used to cover lead that is being used as shielding close to detectors.



- ii Lead pieces not in use, but usable should be stored and labeled "LEAD SHIELDING FOR REUSE". Do not leave lead lying around unless you are using it. Pigs awaiting pickup should be in a bucket marked "lead for disposal."
- iii Consult the Radiation Safety Officer if you need to drill, mill or saw lead for any purpose.
- iv Lead bricks should NOT EVER be used as doorstops. When it is necessary to use a doorstop use a wooden wedge. (The doors to the labs should not be propped open at any time except to move heavy equipment in and out of those labs.)
- v Whenever possible and practicable, gloves should be worn when handling lead bricks, sheeting, or tape.
- vi Personnel should thoroughly wash their hands after handling lead

**b. Disposal of all Lead and Lead Pigs**

- i. All empty lead containers are to be checked for radioactive contamination by using both wipe tests and survey meters.
- ii. Any contamination found should be removed or the container should be held for decay.
- iii. All labels must be removed or defaced.
- iv. Plastic shields may be placed in the dry radioactive waste or in the regular trash if there is no contamination and the labels are defaced.
- v. Lead containers free of radioactivity and radioactive labels may be disposed of in a non-radioactive container provided by the Radiation Safety Officer.
- vi. The Radiation Safety Officer will remove all lead pots provided the steps above have been followed.

**NOTE: LEAD SHIELDING OR LEAD CONTAINERS SHALL NOT BE PLACED IN THE RADIOACTIVE WASTE OR THE REGULAR WASTE STREAM.**

## 23. Personal Dosimeters

- a. An individual can receive a dose from either an internal or external source of radiation.
  - i. Doses from internal sources can be evaluated by performing bioassay procedures, whole body counting, or calculating intake based on known air concentrations.
  - ii. Doses from external sources can be evaluated by calculating the length of time spent in a radiation field of known intensity through radiation monitoring and using personal dosimeters. The use of personal dosimeters is one of the most important aspects of an external dosimetry and personal monitoring program. Such a program is designed to detect, measure, and evaluate individual exposures to ionizing radiation.
- b. Currently regulations require personnel monitoring under certain conditions – typically when a defined percentage of a dose is likely to be received.
  - i. Adults likely to receive, in one year from sources external to the body, a dose in excess of 10 percent of the 50 mSv (5 rem) limit or 5 mSv (500 mrem);
  - ii. Minors likely to receive, in one year from sources external to the body, a dose in excess of 10 percent of any of the applicable limits; **\*\*NOTE: Minors should not be working directly with any radioactive materials\*\*** and
  - iii. Individuals entering a high or very high radiation area, including irradiator rooms.

Personnel dosimeter measurements are considered the preferred source of information for evaluating external doses. Examples of primary personal monitoring devices include: optically stimulated luminescence dosimeters (OSL), thermoluminescent dosimeters (TLD's), film, and track etch dosimeters. Audible alarm dosimeters, electronic dosimeters, and pocket ionization chambers are examples of supplemental dosimetry – devices often worn with or located near the primary dosimeter.

Optically stimulated luminescence dosimeters (OSL) and thermoluminescent dosimeters (TLD's) are the most popular type of primary personal dosimeters. Both OSL and TLD processes can be explained in generic terms for luminescent material. Luminescence arises from stimulation, either thermal or optical, of minerals that have been previously exposed to ionizing radiation. During exposure, radiation energy is accumulated and stored in the crystal lattice; this energy is stored in the form of electrons that have been trapped at defects in the lattice. During either optical or thermal stimulation, the trapped charge is released and as a result the luminescence signal goes to zero. The intensity of the released energy is proportional to the dose the material received.

- c. Limitations of the OSL (Luxel) dosimeters used at BMRI:
  - i. The dosimeter will only respond to beta energy above 150 keV. Therefore only P-32 dose can be determined within a limited degree of accuracy. Lower energy betas dose from P-33, S-35, C-14, and H-3 cannot be determined.

- ii. Information as to the dose received is available only after the exposure (retrospective determination) rather than prior to the exposure (prospective determination). In many cases the retrospective determination of a dose will be as long as 4 months.
- iii. A dosimeter that will adequately determine the effective dose equivalent to a worker requires a specific and fixed relationship to the body. This objective isn't generally met when dosimeters are worn on loose clothing, neck chains, or identification badges.

d. **Placement of Dosimeters**

- i. **Whole body dosimeter:** To determine the whole body dose, the dosimeters should be placed on the trunk of the body between the neck and the waist and positioned so that the front of the badge holder is facing the source of radiation.
  - ii. **Lens of the eye:** When the lens of the eye is of interest a measurement at the surface of the torso is sufficient when the exposure is uniform. For non-uniform exposures that include localized beams of radiation, x-ray machines, beta sources, etc., would require the placement of a dosimeter on the side of the head or forehead, close to the eye.
  - iii. **Embryo/fetus:** For dosimetry related to the embryo/fetus it is recommended that for declared pregnant workers an additional dosimeter –either a self-reading device or a second personal dosimeter be employed and placed closer to the waist or abdomen. For undeclared pregnant workers wearing a conventional personal dosimeter between the neck and waist is sufficient unless exposures approach 50 mrem in a month when an additional dosimeter is warranted.
  - iv. **Multiple dosimeters** should be considered when the worker might receive an exposure from a source(s) from multiple geometries relative to the front of the worker. The use of multiple dosimeters is warranted if the radiation field varies by more than 50% over the area of the whole body and the anticipated exposure is over 100 mrem. Multiple dosimeters should be placed where the highest dose equivalent is likely to be received. The head, chest, back, gonads, and top of arms and legs would be common candidates for dosimeters.
  - v. **Extremities:** In the case of extremities, personal dosimeters should be placed at the most exposed location on the extremities, that is, at or near the organ expected to receive the highest dose. Monitoring devices include ring badges, wrist badges, toe badges, and ankle badges.
- d. **Frequency of Wearing Dosimeters:** Personnel dosimeters should always be worn when the worker is being (or likely to be) exposed to radiation. Therefore, BMRI policy requires the wearing of dosimetry prior to the start of work in all laboratories designated as radiation laboratories.

- e. **Issuing of Dosimeters:** BMRI does not recommend that dosimeters be issued to all individuals in their laboratories unless a rationale for this action can be appropriately determined. Unnecessary issuance of dosimetry is discouraged, even in those cases where “concerned” individuals are involved, because information and training should come first. Once a dosimeter is appropriated to an individual, only the individual to whom it was issued should wear it.
- f. **Frequency of Reading Dosimeters:** The frequency of reading dosimeters varies with the type of dosimeter, and site-specific isotope usage. Laboratories receive dosimeters either each month or every two months. Fetal dosimeters are always distributed on a monthly basis. Used dosimeters must be returned as soon as possible after the individual receives the new dosimeter. ALARA, regulatory, and record keeping/report requirements cannot be satisfied when dosimetry is not returned to the radiation safety office in a timely manner.
- g. **Determination of Prior Exposure:** For those individuals for whom dosimetry is required, determination of prior exposure at other facilities is required. To document the determination of prior exposure, the individual to be monitored must provide an NRC Form 4 signed by the individual or a written statement that includes the names of all facilities that provided monitoring for occupational exposure to radiation during the current year and an estimate of the dose received. Consult the RSO for the appropriate forms. Although not required by the regulations, it is considered good radiation safety practice to verify the information provided by the individual. Verification may be documented with:
  - i. An NRC Form 5 for each listed monitoring period, or
  - ii. Electronic, telephone, or facsimile transfer of dose data provided by licensees listed on the written statement, or
  - iii. An NRC Form 4 countersigned by a licensee or current employer.
- h. **Determination of Lifetime Dose:** In addition, 10 CFR 20.2104(a) (2) requires that licensees attempt to obtain the records of lifetime cumulative occupational radiation dose. To demonstrate compliance with this requirement, the individual to be monitored may provide a written estimate of the cumulative lifetime dose or an up-to-date NRC Form 4 signed by the individual. This information need not be verified so long as the individual does not participate in a planned special exposure.
- i. **Dosimetry Reports:** Dosimetry reports are kept on file in the Radiation Safety Officer’s office. Copies without personal information such as SSN and DOB will be posted in the laboratories as they become available to the radiation safety office. The NRC Form 5 will be distributed annually to all individuals who have worn a dosimeter the previous year.

## 24. *Laboratory and Area Surveys*

- a. **Routine contamination surveys** are performed on a regular basis (daily, weekly, monthly, quarterly, etc.) as a good health physics practice to assure that contamination is not present in areas traversed by non-radiation workers, and members of the general public. These areas include hallways, bathrooms, offices and classrooms. Routine contamination surveys **MUST** be completed every month in a licenses radioactive material laboratory (e.g., hoods, bench tops). In addition, these areas should be inspected each and every time there is reason to suspect a contamination incident. Liquid scintillation counting (LSC), in units of DPM, is the only method accepted by regulatory agencies.
  - i. In all laboratories employing radioactive materials **routine contamination surveys must be performed at least once per month and those surveys must be in the form of a LSC survey**. The records generated must be maintained for a minimum of three years.
- b. **Suspect surveys** are instances where surveys are performed because we suspect contamination is present or known to exist. All laboratories licensed to use radioactive material fit into this category and as a result minimum routine survey standards may not be adequate. Laboratories routinely using radioactive materials **MUST** survey areas of use and storage before and after each and every use event. For tritium users this means frequent LSC surveys. For other isotopes a survey instrument can be used.
  - i. **Suspect surveys** must be conducted before and after any activity of radioactive materials is used in the laboratory. The method can be LSC or hand held survey meter in which case records need not be maintained.

## 25. *Portable Survey Instruments*

- a. **Geiger-Mueller detectors** are the most widely used portable survey meter for detecting ionizing radiation. These detectors, often referred to as Geiger counters or G-M counters, are a category of gas-filled detectors (ionization chambers and proportional counters are other gas-filled detectors) and are one of the oldest radiation detection devices in existence; the “modern” counter has remained essentially unchanged since Geiger and Mueller collaborated on an improved design in 1928. Geiger counters operate on the principle of gas ionization, i.e., the radiation interacting within the sensitive volume of the detector is of sufficient energy to “strip” or eject one or more electrons from the neutral gas molecule. The ionization process results in the formation of ion pairs: negatively charged electrons and positively charges gas molecules.
  - i. Each laboratory using unsealed radioactive material other than  $^3\text{H}$  should either have two portable radiation survey instruments/meters or possess one instrument and have access to a second. This is to ensure availability of a survey instrument if one is damaged, out of calibration, or otherwise unable to be used.

- ii. Survey instruments/meters must be calibrated to a National Institute of Standards and Technology (NIST) traceable  $^{137}\text{Cs}$  gamma source.
  - iii. While appropriate survey instruments must be available for activities involving radiation it is the responsibility of each laboratory to supply the instrument. Ideally, the instrument should read out in units of mR/hr and/or counts per minute (cpm) and the probe should be one that is most appropriate for the type of work performed in the laboratory. The Radiation Safety Office is available to assist with appropriate instrument selection. The Radiation Safety Office has a limited supply of loaner meters available for temporary use.
- b. **Geiger Counter Applications:** It is recommended that a "pancake" type Geiger Mueller (GM) probe be used for isotopes which emit beta particles and gamma radiation, except for  $\text{I}^{125}$ . A low energy gamma scintillation detector (solid crystal) should be used for  $\text{I}^{125}$ . **A standard lab survey meters cannot detect  $\text{H}^3$ .** Wipe test surveys must be performed to monitor for  $\text{H}^3$  contamination. Please contact the Radiation Safety Office for information on what type of instrument is best for specific applications, and for vendor information.

Figure 25-1 Probes used for laboratory surveys.



- c. **Meter Function Tests:** Each time the meter is turned on the batteries should be checked. There is a battery check position on the range switch of most quality units. Changing weak or dead batteries will greatly increase the life of your instrument as batteries can leak a corrosive liquid, which may destroy the unit or result in costly repairs. The cable connecting the probe to the electronics package is another element that should be checked. With prolonged use this cable may become defective, giving either no reading or false high readings sporadically, even in the absence of a radiation field. If you suspect there is a problem with the cable, switch cables with another meter that is working properly. If the meter response is normal, then you have a "bad" cable. If you need information on meter supplies, please contact the Radiation Safety Office. One should verify that an instrument does indeed respond to a radiation field. Using a "check source", or alternatively, a known source of radiation in your laboratory may accomplish this. A check source contains a very

small quantity of radioactive material, commonly in the form of a disk. This disk may be securely glued or epoxied to the side of a meter. A measurement should be taken at a constant distance. This reading should be recorded as an operational check.

d. **How to Perform a Meter Survey:**

- i. Once batteries have been checked and meter is confirmed to be operational, the range switch on the meter should be rotated all the way to the lowest number. This is the most sensitive scale. With the appropriate probe, a survey is conducted by slowly passing the probe over the area or object to be surveyed.
  - ii. Be certain that the pass is at a constant velocity (One probe width per sec is recommended) and sufficient time is allowed for the meter to respond. The distance from the contaminated object or area should also be constant. A distance of 1cm is suggested.
  - iii. Begin any survey by checking yourself first.
    1. Each finger should be checked with special attention paid to thumbs.
    2. Wrist and forearm areas should be surveyed.
    3. Lab coat sleeves, fronts and pockets.
    4. The bottoms of shoes. Shoe soles are an excellent indicator of the presence or absence of floor contamination.
    5. All readings should be recorded. When recording measurements, counts per minute (cpm) or milliroentgens per hour (mR/hr) should be used. The type of probe being used determines the correct unit. When a pancake or scintillation probe is used, cpm is the correct unit. When the energy compensated probe is used, mR/hr is the correct unit. Questions related to the correct use of units should be directed to the Radiation Safety Office.
    6. Please be certain that all readings are recorded as "net". To do this, determine the normal background reading by observing a meter reading in an area where radioactive materials are not used or stored. Subtract this reading from all other measurements taken, prior to recording them.
- e. **Frequency of Surveys:** Individuals should survey themselves and their work areas on an "as used" or "daily basis". The Radiation Safety Office recommends frequent surveys of hands and other skin areas to identify and rectify contamination, thus preventing significant doses and internal exposures. An operating survey meter should be within arm's reach whenever working with radioactivity. The Radiation Safety Office suggests that complete surveys of work areas (wipe tests and meter surveys) be performed at a frequency, which is commensurate with your isotope work and probability of contamination. **Such surveys**

**should be fully documented and should be performed at least monthly.** The frequency of surveys may need to be increased depending on the radioisotope use in your area. Situations or circumstances may dictate an increased frequency. Call the Radiation Safety Office for advice.

- f. **How to Document Surveys:** It is suggested that all documentation of lab surveys contain the following information:
- i. Room number and floor plan map;
  - ii. Location number, indicating on the map where the wipe test or meter reading was taken;
  - iii. Wipe test results (even if background), such as liquid scintillation counter printout;
  - iv. Survey meter results (even if background);
  - v. Name of person performing the survey;
  - vi. Date of survey;
  - vii. Model, serial number and manufacturer of the counting equipment.
  - viii. Reference standard.
  - ix. If applicable, list the monitoring results following decontamination to include:
    1. Wipe test
    2. Survey meter reading
- g. **Records shall be kept on both positive and negative survey results in a notebook, which is accessible to everyone in the lab.** Records should include output from the beta or gamma counter that was used for counting.

## ***26. Liquid Scintillation Counting (LSC)***

Wipe Tests or LSC surveys are designed to determine the level of removable contamination over a surface approximating 100 cm<sup>2</sup>, 10 cm x 10 cm or 4 in x 4 in. The rationale behind choosing this particular area is unclear. It may be that smear material becomes compromised at larger areas. It may also be the case that extending the smear beyond this area only serves to transfer contamination from place to place.

- a. **Performing Wipe Tests:** When performing a wipe test apply moderate pressure with dry medium to the potentially contaminated surface. The medium typically used is a white paper filter with a diameter of 47 mm numbered on one side. In practice the wipe medium can consist



of many different materials from cotton swabs, tissue material, dissolvable plastic, to small pieces of Styrofoam and carbon impregnated filter paper for low energy beta emitters such as tritium. In any case each wipe sample should be placed in a separate envelope or vial to prevent cross contamination and should be numbered to correspond with the laboratory diagrams.

- b. **Removable Activity:** To determine the extent of removable activity at a given smear location, the following equation may be used:

$$\text{dpm}/100\text{cm}^2 = \frac{\text{gross counts} - \text{background counts}}{\text{time (min)} \times \text{efficiency (cpm/dpm)}}$$

The equation assumes that an integrating device is used and no area correction is necessary because a  $100\text{cm}^2$  area was used.

**Example:** During a suspect survey after a labeling event using S35 a portable Geiger counter indicates a direct reading of 15,667 cpm on the rotor surface in a centrifuge. Since the Geiger counter records a total reading, (“fixed” plus “removable”) a smear taken at the highest point of activity will determine the removable fraction of activity. When the smear is taken and counted in a typical LSC instrument the printed result shows 3954 cpm. If the efficiency of the LSC instrument for S35 is 76%, then an estimate of the removable beta activity on the centrifuge rotor would be:

$$\frac{3954 \text{ net cpm}}{(.76 \text{ cpm/dpm})} = 5163 \text{ dpm}/100 \text{ cm}^2$$

Much of the contamination was transferable indicating this instrument has become a hazard in the laboratory. According to regulatory guidelines low energy beta contamination exceeding  $5000 \text{ dpm}/100\text{cm}^2$  on any laboratory surface or equipment must be decontaminated immediately. Use of this centrifuge must be suspended until contamination levels are reduced.

c. **Liquid Scintillation Cocktail**

(See Appendix VII for list of BMRI approved Liquid Scintillation Cocktail)

- i. **Fluors:** The purpose of the fluor is to convert the energy of the beta decay into light detectable by the photomultiplier tubes. The most efficient fluors do not emit light at detectable wavelengths. Therefore it is common to use two fluors:
1. Primary Fluor: to convert the energy deposited into the solvent by the radiation into visible light.
  2. Secondary Fluor: to absorb the light emitted from the primary fluor and re-emit it at a wavelength more readily detectable.
- ii. **Counting Errors:** Liquid scintillation systems are vulnerable to two major problems related to the emissions of light.

1. **Quenching:** The loss or absorption of light before it can be detected by the PMT; known as quenching, (false negative counts).
  - I. **Color Quenching** – Color quenching is the result of absorption of light of particular energies into the solution. This is most commonly associated with a colored sample. “Bleaching” the sample to remove as much color as possible can reduce color quenching. It can also be corrected by calibrating the LSC system to the color sample.
  - II. **Optical quenching** – Optical quenching is the physical blocking of light before it can reach the PMT and can be caused by dirt or fingerprints on the sample vials or by condensation if the vial has been chilled. For this reason the vials should be handled carefully to avoid materials on the outside.
  - III. **Chemical Quenching** – Chemical quenching is caused by impurities in the solution, which result in the inefficient transfer of energy in the solvent.
2. **Luminescence:** The emission of light from the liquid scintillation cocktail due to some other process other than radioactive decay in the sample, (false positive counts).
  - I. **Photoluminescence** – Photoluminescence is the production of light as the result of UV light or sunlight interactions. Photoluminescence typically decays in a few minutes so it can be avoided by storing the LSC vials in the dark before counting and by avoiding exposure of the vials to sources of UV or sunlight.
  - II. **Chemoluminescence** – Chemoluminescence is the production of light due to a chemical reaction in the LSC cocktail. It is often observed in samples of alkaline pH, samples containing peroxides, and samples containing fatty substances. Chemoluminescence can have a fairly slow decay time (30 minutes to a few days) depending upon the sample temperature so it should be avoided during sampling if possible.
  - III. **Static Luminescence** – Static luminescence is caused by static charge building up on plastic sample vials as a result of latex gloves.

iii. Avoiding Luminescence

1. Luminescence is a single photon event and it is discriminated against to a large extent by coincidence counting of the PMT. Also luminescence is primarily very low energy (approximately 6 KeV) and can be avoided by not counting the low energy channels when possible.
2. Alternatively, because many forms of luminescence decay away rapidly, it often can be avoided by counting the samples twice a few minutes apart. A significantly lower count the second time, which cannot be explained by a short half-life, indicates luminescence.

3. When sampling, keep in mind that chemoluminescence will likely occur if samples are very dusty or dirty.
4. Static luminescence is always a possibility when using plastic sample vials. Plastic sample vials should be wiped with an anti-static cloth before counting occurs.

Table 26-1 Isotopes Routinely Assayed by LSC

Isotope	H <sup>3</sup>	C <sup>14</sup>	S <sup>35</sup>	P <sup>32</sup>	P <sup>33</sup>	I <sup>125</sup>	Cr <sup>51</sup>
Approx. Counting Efficiency	50%	85%	85%	100%	90%	70%	25%
Beta E <sup>max</sup> (keV)	18.6	156	167	1710	249	NA	NA

## 27. Reportable Events: Laboratory

Report of stolen, lost, or missing licensed or registered sources of radioactive materials:

- i. Telephone reports. Each licensee or registrant shall report by telephone as follows:
  - 1 Immediately after its occurrence becomes known, stolen, lost, or missing radioactive material in an aggregate quantity equal or greater than 1,000 times the quantities specified in table 27-1.
  - 2 Within 30 days after its occurrence becomes known stolen, lost, or missing radioactive material in an aggregate quantity equal or greater than 10 times the quantities specified in table 27-1.
  - 3 Immediately after its occurrence becomes known, a stolen, lost, or missing radiation machine.

### a. Notification of Incidents:

- i. Immediate notification. Each licensee or registrant shall immediately report each event involving a source of radiation possessed by the licensee or registrant that may have caused or threatens to cause any of the following conditions:
  - 1 An individual to receive:
    - I. A total effective dose equivalent of 0.25 Sv (25 rem) or more; or
    - II. An eye dose equivalent of 0.75 Sv (75 rem) or more; or

- III. A shallow dose equivalent to the skin or extremities or a total organ dose equivalent of 2.5 Gy (250 rad) or more; or
    - 2 The release of radioactive material, inside or outside of a restricted area, so that, had an individual been present for 24 hours, the individual could have received an intake five (5) times the occupational ALI.
  - ii. Twenty-four hour notification. Each licensee or registrant shall, within 24 hours of the discovery of the event, report each event involving the loss of control of a licensed source of radiation possessed by the licensee that may have caused, or threatens to cause, any of the following conditions:
    - 1 An individual to receive in a period of 24 hours:
      - I. A total effective dose equivalent of 0.05 Sv (5 rem) or more; or
      - II. An eye dose equivalent of 0.15 Sv (15 rem) or more; or
      - III. A shallow dose equivalent to the skin or extremities or a total organ dose equivalent of 0.5 Sv (50 rem) or more; or
    - 2 The release of radioactive material, inside or outside of a restricted area, so that, if an individual been present for 24 hours, the individual could have received an intake in excess of one (1) occupational ALI.

Table 27-1 Quantities of Licensed or Registered Radioactive Materials

Isotope	Quantity (uCi)	Isotope	Quantity (uCi)	Isotope	Quantity (uCi)
H-3	1000	Kr-81m	1000	I-131	1
C-11	1000	Rb-82	1000	Xe-133	1000
C-14	1000	Sr-89	10	Cs-137	10
F-18	1000	Y-90	10	Sm-153	0.01
P-32	10	Sr-90	0.1	Ho-166	100
P-33	100	Mo-99	100	Lu-177	100
S-35	100	Tc-99m	1000	Ir-192	0.01
Cr-51	1000	Pd-103	100	Th-201	1000
Co-60	1	In-111	100	Bi-213	10
Ga-67	1000	I-125	0.01	Any Alpha	.001

END

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## Appendix I

### Pregnancy Declaration

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#### Memorandum

Date:

To:

From:

Subject: Pregnancy Declaration

This is to inform you of my pregnancy or my intention to become pregnant. This form also provides me with information concerning the effects of radiation exposure to the unborn child. The signing of this document and release of this information are done solely in the interest of protecting my unborn child.

The reason for informing you of my intention to become pregnant is to prevent an unwanted, exposure from occurring before I become aware that I am pregnant. I understand the possible effects of ionizing radiation exposure to the unborn child as stated in paragraphs A and B of this section. The following information comes from *Radiation Protection Guidance to Federal Agencies for Occupational Exposure Approval of Environmental Protection Agency Recommendations* Vol., 52 No. 17 Tuesday, January 27, 1987, and addresses the effects of radiation on children who were exposed while in the womb.

- A.** Not only may the unborn be more sensitive than adults to the induction of malformations, cancer, and hereditary effects, but recent studies have drawn renewed attention to the risk of severe mental retardation from exposure of the unborn during certain periods of pregnancy. The risk of less severe mental retardation appears to be similarly elevated. Although it is not yet clear to what extent the frequency of retardation is proportional to the amount of dose (the data available at occupational levels of exposure are limited), it is prudent to assume that proportionality exists.
- B.** The recommendations also incorporate guidance for limiting exposure of the unborn as a result of occupational exposure of the female workers. It has long been suspected that the embryo and fetus are more sensitive to a variety of effects of radiation than are adults. Although our knowledge remains incomplete, it has now become clear that the unborn are especially subject to the risk of mental retardation from exposure to radiation at a relatively early phase of fetal development. Available scientific evidence appears to indicate that this sensitivity is greatest during the period near the end of the first trimester and the beginning of the second trimester of pregnancy, which is the period of from 8 weeks to about 15 weeks after conception. Accordingly, when a worker has declared her pregnancy,

guidance recommends not only that the total exposure of the unborn be more limited than that of adult workers but that the monthly rate of exposure be further limited in order to provide additional protection. Due to the incomplete state of knowledge of the transfer of radionuclides from the mother to the unborn (and the resulting uncertainty in dose to the unborn), in those few work situations where intake of radionuclides could normally be possible it may also be necessary to institute measures to avoid such intakes by pregnant women in order to satisfy these recommendations.

I understand that the possible risks, my rights, possible limitations and responsibilities are as follows:

1. The health protection objectives of this guidance for the unborn should be achieved in accordance, with the health provisions of Title VII of the Civil Rights Act of 1964, as amended, with respect to discrimination in employment practices. The guidance applies only to situations in which the worker has voluntarily made her pregnancy known, in writing to her employer.

Protection of the unborn may be achieved through such measures as temporary job rotation, worker self-selection or use of protective equipment. The guidance recognizes that protection of the unborn is a joint responsibility of the employer and the worker. As a result, temporary arrangements necessary to modify exposures may be made. The responding organization will make such arrangements in a manner that allows minimization of the impact to the worker.

1. The responding organization further recognizes that while they share concern for the protection of unborn children of their employees, it is also the decision of the Supreme Court of the United States in *UAEW v. JOHNSON CONTROL, INC.*, U.S. 111S. Ct. 1 196, 113, 1 Ed.2d 158 (March 20, 1991) that: "Decisions about the welfare of future children must be left to the parents who conceive, bear, support and raise them rather than to employers who hire those parents."

2. The Civil Rights Act of 1964, as amended, provides that "It shall be an unlawful employment practice for an employer (1) to fail or refuse to hire or to discharge any individual, or otherwise to discriminate against any individual with respect to his compensation, terms, conditions, or privileges of employment, because of such individuals...sex...; or (2) to limit, segregate, or classify his employees or applicants for employment in any way which would deprive or tend to deprive any individual of employment opportunities or otherwise adversely affect his status as an employee, because of such individual's...sex..." [42 U.S.C. 2000e-2(a)]. The Pregnancy Discrimination Act. Or 1978 defines "because of sex" to include because of or on the basis of pregnancy, childbirth, or related medical conditions [42 U.S.C. 2000e (k)].

3. The radiation dose equivalent that my unborn child shall receive from conception until birth (the entire gestation period) shall be limited to 0.5 rem (500 mrem), unless pregnancy declaration occurs after this limit has been exceeded.

4. My unborn child is further limited to an equivalent radiation exposure rate of 0.05 rem (50 mrem) per month. This is to prevent further fluctuations above a uniform monthly exposure rate that would satisfy the limiting value.

5. I shall exchange my dosimeter on a monthly basis to ensure compliance to the monthly administrative limit.
6. If the radiation dose to my unborn child is determined to have already exceeded 0.5 rem by the time I notified you by signing this Declared Pregnancy Notification Form, I agree to be assigned to tasks where additional occupational exposure is unlikely.
7. Once the pregnancy is concluded, or at such time as I wish to revoke my pregnancy declaration, I shall notify you by signing a Pregnancy Condition Form, so I can resume my normal duties.

Employee:

\_\_\_\_\_  
Printed Name

\_\_\_\_\_  
Signature

\_\_\_\_\_  
SSN

**Privacy Act Statement:** *The information on this form is protected by the Privacy Act of 1974. The purpose of requesting this information is to minimize risks to unborn child/children in the womb. This information will be used by the Burke Medical Research Institute, and its contractors. Failure to provide this information could result in our inability to limit the exposure to the unborn child.*

Responding Organization Representative:

\_\_\_\_\_  
Printed Name

\_\_\_\_\_  
Signature



## Appendix II

### Recommended Procedures for Handling Packages Containing Radioactive Material

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#### Receiving the Package

1. Protective clothing (gloves, lab coat, safety glasses) should be donned before handling radioactive materials.
2. All radioisotope shipments should be opened immediately and surveyed (as directed below) by personnel in the receiving laboratory, and then stored in a locked, labeled radioisotope storage area.

Note: Only authorized, trained users of radioactive materials may accept and sign for radioactive packages.

#### Opening the Package

1. Place package in vented hood (if available) or other designated radioactive work area.
2. Take a measurement on the external surface of the package with a survey meter in a low background area. Compare this reading to similar packages previously received to insure the vendor has shipped the correct quantity of material.
3. If the package contains gamma or high-energy beta emitters, check dose rate on outside of package with an energy compensating probe or ionization chamber.
4. Open outer package and remove packing slip. Open inner package and verify that the contents agree in name and quantity with isotope and quantity ordered.
5. Check for possible breakage of seals or containers, loss of liquid or change in color of absorbent material.
6. If package appears to be tampered with, wipe test innermost container and count for activity. A wipe test is conducted over 100 cm<sup>2</sup> and measured in liquid scintillation counter.
7. Upon verification that package is contamination free, store material appropriately.
8. If contamination, leakage or variations in isotope, or quantity ordered are observed, notify the Radiation Safety Office (3145).

### **Discarding Packaging Materials**

1. Deface or destroy all radioactive labels on the empty container. Outer containers, which have had labels defaced and are free of contamination, may be disposed of as normal trash, once the cardboard container has been flattened.
2. All boxes must be left visibly empty for proper disposal. No containers may be discarded as closed boxes in the regular trash. Lids should be left ajar and dry ice should be removed prior to disposal. Cardboard containers must be torn or otherwise disassembled so as to make them useless.
3. Styrofoam boxes that are free of contamination may be recycled according to manufacturer's directions.
4. The isotope container may be lead lined. The lead must be separated from the plastic liner. The liner label must be defaced and should be discarded as regular trash. The lead portion of the container shall be stored in the lab until a routing waste pick-up by radiation safety.

### **Recording/Reporting Results**

1. NRC regulations dictate that each laboratory must be able to account for the whereabouts of all radioactive material received in the laboratory. Therefore, complete the top portion of a "Radioactive Material Use Log" (see sample on next page) for each vial received.
2. Post log in location convenient for completion as material is used.
3. Attach wipe test results to bottom of log sheet.
4. If contamination, leakage, or variations in isotope or quantity ordered are observed, notify the Radiation Safety Office immediately (3145).

# Appendix III

## BURKE RESEARCH INSTITUTE INVENTORY FORM

### RECORD OF RADIOACTIVE MATERIALS USE

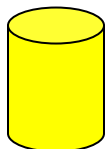
P.I./Authorized User: \_\_\_\_\_

Use/Storage Locations: \_\_\_\_\_

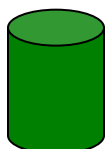
RECEIPT OF VIALS			WITHDRAWALS BY INDIVIDUALS				DISPOSAL		
Date Vial Received	Amount Received		Isotope/Chemical Form	Date Used	By (Initials)	Amount Used		Balance Remaining	Date Vial Disposed in Radiation Waste Bucket
	(μCi)	(cc)				(μCi)	(cc)		
<b>PACKAGE SURVEY (MUST COMPLETE)</b>  <b>Lot #:</b> _____ (Lot number found on container or vial label)  <b>Condition of Package:</b> OK    Not OK (notify radiation safety)  <b>Survey Meter Result @ 1 meter, (3 Ft.):</b> Background: Yes    No (notify radiation safety)  <b>Wipe Test (Survey Meter or LSC)</b> Background: Yes    No (notify radiation safety)   <b>Directions:</b>  a. Check condition of packaging. b. Perform survey at distance of 1 meter. c. Open package d. Perform wipe test on the source container using survey meter for all isotopes <b>except</b> H3. e. Attach LSC results for H3. f. Deface radiation labeling on all packing materials									

## Appendix IV

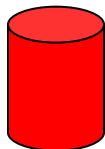
### Color Coding for Segregated Dry Waste



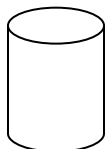
Yellow:  $^{35}\text{S}$



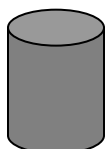
Green:  $^{14}\text{C}$  and  $^3\text{H}$



Red:  $^{32}\text{P}$ ,  $^{33}\text{P}$  and  $^{131}\text{I}$



White:  $^{125}\text{I}$



Gray:  $^{51}\text{Cr}$

All liquid wastes should be placed in appropriately sized containers.  
Labels must declare the date, isotope, activity and chemical content.

## Appendix V

### Guide to identifying EPA Mixed Waste

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The term *mixed waste* means a waste that contains both a hazardous chemical and a radioactive isotope. As a result, the Environmental Protection Agency (EPA) and the Nuclear Regulatory Commission (NRC) both regulate how mixed waste is handled and disposed. Having both agencies regulate the same material makes compliance more complicated, increases the cost of disposal, and limits the number of facilities allowed to accept the material for disposal. Depending on the chemical hazards and the isotope involved, disposal costs may approach \$2,000-\$3,000 per gallon. Even worse, disposal options may not be available for some mixed wastes.

Non-compliance with either EPA or NRC regulations can result in large fines. Simply having mixed waste on campus subjects Burke to more intense scrutiny by regulatory agencies. For these reasons, it is in our best interest to limit the amount of mixed waste generated and to have researchers receive prior approval from our office before generating mixed wastes.

The tables on the back list the types of wastes that are regulated by EPA. If the wastes you generate (or propose to generate upon approval of your project) contain an isotope, and are of the type regulated by EPA, then you may be producing mixed waste. Because of the issues described above, Burke encourages every Authorized User to eliminate to the extent possible the generation of any mixed waste.

Follow the tips listed here to help avoid generating mixed wastes:

- Use high flashpoint (>140°F) and biodegradable scintillation cocktails for counting purposes.
- Do not mix isotopes or different chemicals in collection containers unless you have received approval from the Radiation Safety Officer.
- Reduce the amount or toxicity of chemicals used in processes containing isotopes.
- Reuse chemicals if possible.
- Substitute non-hazardous chemicals for hazardous chemicals.
- Neutralize corrosive solutions to a pH level between 5 and 9.
- Use short half-life isotopes in place of long half-life isotopes, where possible.
- For long half-life isotopes ( $C^{14}$ ,  $H^3$ ), collect large enough quantities to make shipping as economical as possible.
- Do not use nitrocellulose films, as these can be classified as flammable solids. Substitute other types of films that are not flammable solids.
- If using x-ray or photographic-type films, use films that have already been through the development process. Undeveloped film contains silver at levels that are regulated by EPA.
- Also, be sure to tag all chemical and mixed waste for pickup by Laboratory Safety or Radiation Safety.

Please complete the radioactive waste record attached to the waste buckets, including the isotope, activity, and all chemical constituents by proper chemical name and approximate percentage.

**Pose one or more of the following hazards:**

Flashpoint < 140°F	Oxidizer
Water Reactive	Corrosive
Cyanide-Containing	Unstable
Flammable Solid	Pyrophoric
Air Reactive	Explosive
Sulfide-Containing	

**Or contain one or more of the following constituents above regulated levels:**

Acetone	Methyl Isobutyl Ketone
Arsenic	Methylene Chloride
Barium	Nitrobenzene
Benzene	2-Nitropropane
Butanol, n-	Pentachlorophenol
Cadmium	Pyridine
Carbon Disulfide	Selenium
Carbon Tetrachloride	Silver
Chlordane	Tetrachloroethylene
Chlorobenzene	Toluene
Chloroform	Toxaphene
Chromium	2,4,5-TP (Silvex)
Cresol, m-	1,1,2-Trichloro-1,2,2-
Cresol, Mixed	trifluoroethane
Cresol, o-	1,1,1-Trichloroethane
Cresol, p	1,1,2-Trichloroethane
Cresylic Acid	Trichloroethylene
Cyclohexanone	Trichlorofluoromethane
2,4-D	2,4,5-Trichlorophenol
Dichlorobenzene, o-	2,4,6-Trichlorophenol
1,4-Dichlorobenzene	Vinyl Chloride
1,2-Dichloroethane	Xylen
1,1-Dichloroethylene	
2,4-Dinitrotoluene	
Endrin	
2-Ethoxyethanol	
Ethyl Acetate	
Ethyl Benzene	
Ethyl Ether	
Heptachlor(and its Epoxide)	
Hexachlorobenzene	
Hexachlorobutadiene	
Hexachloroethane	
Isobutanol	
Lead	
Lindane	
Mercury	
Methanol	
Methoxychlor	
Methyl Ethyl Ketone	

## Appendix VI

### Guide to Approved Liquid Scintillation Cocktail

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#### MEMORANDUM

TO: Burke Medical Research Principle Investigators and Researchers

SUBJECT: **MANDATORY USE OF ENVIRONMENTALLY FRIENDLY  
LIQUID SCINTILLATION COCKTAIL**

The techniques of liquid scintillation counting continue to be of primary importance in dealing with low energy beta emitting isotopes, particularly  $^3\text{H}$  and  $^{14}\text{C}$ . Traditional scintillation cocktail formulations with their flammable, toxic, and hazardous solvents represent a significant hazard to laboratory workers. The resultant waste generated is radiological and hazardous chemical "mixed wastes" regulated by the U.S. Environmental Protection Agency (EPA) and the Nuclear Regulatory Agency (NRC). The generation of mixed waste created a disposal problem that places strains on the environment and often represents hidden disposal costs to the institution. Difficulties in storing or disposing of radioactive liquid scintillation waste are aggravated by the presence of this flammable or toxic hazard.

If you have any questions about radioactive material use in the laboratory, contact The Radiation Safety Office at 3145.

If you have any questions about the use of chemical hazards in the laboratory, contact EHS at (914) 368-3144.

**APPROVED LIQUID SCINTILLATION COCKTAILS FOR USE AT BURKE**

<b>Scintillation Cocktail</b>	<b>Manufacturer</b>	<b>Scintillation Cocktail</b>	<b>Manufacturer</b>
BCS	Amersham	Opti-Phase HiSafe 3	Wallac
BetaMax ES	ICN Radiochemicals	Opti-Phase HiSafe Polysafe	Wallac
Betaplate Scint	Wallac	Opti-Phase HiSafe Supermix	Wallac
Bio-Safe II	Research Products International	Optiscint HiSafe	Wallac
Bio-Safe NA	Research Products International	Optisolv Solubilizer	Wallac
CytoScint ES	ICN Radiochemicals	Pico-Safe	Packard Instruments
DPA	Packard Instruments	Poly-Flour	Packard Instruments
Ecolite +	ICN Radiochemicals	Ready Safe	Beckman
Ecolume	ICN Radiochemicals	ScintiSafe 30%	Fisher Scientific
Econo-Safe	Research Products International	ScintiSafe Econo 1	Fisher Scientific
Ecoscint	National Diagnostics	ScintiSafe Econo 2	Fisher Scientific
Ecoscint A	National Diagnostics	ScintiSafe Econo F	Fisher Scientific
Ecoscint O	National Diagnostics	ScintiSafe Gel	Fisher Scientific
Emulsifer Safe	Packard Instruments	ScintiSafe Plus 50%	Fisher Scientific
Flo Scint V	Packard Instruments	Scintiverse BD	Fisher Scientific
High Efficiency Mineral Oil Scintillator	Packard Instruments	Solvable	Packard Instruments
Irgasafe	Packard Instruments	Starscint	Packard Instruments
Irgasafe Plus	Packard Instruments	Ultima Gold	Packard Instruments
Microscint 20	Packard Instruments	Ultima Gold AB	Packard Instruments
Microscint 40	Packard Instruments	Ultima Gold F	Packard Instruments
Microscint AF	Packard Instruments	Ultima Gold LLT	Packard Instruments
Microscint O	Packard Instruments	Ultima Gold M	Packard Instruments
Mono-Flow 5	National Diagnostics	Ultima Gold XR	Packard Instruments
Omni-Flour	Packard Instruments	Ultima-Flo AF	Packard Instruments
Opti-Flour	Packard Instruments	Ultima-Flo AP	Packard Instruments
Opti-Flour O	Packard Instruments	Ultima-Flo M	Packard Instruments
Opti-Phase HiSafe	Wallac	UniverSol ES	ICN Radiochemicals
Opti-Phase HiSafe 2	Wallac		

If you are using a Liquid Scintillation Cocktail not on this list, you must contact EHS at (914) 368-3144 to arrange removal of this hazardous material.



## Appendix VII

### Procedures for Transporting and Shipping Radioactive Materials

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There are four types of transfers of radioactive materials and each transfer mechanism has specific requirements. These requirements are regulated by federal, state and international law and severe penalties may be levied on individuals not in strict compliance with these laws.

It is the **RESPONSIBILITY OF THE PRINCIPAL INVESTIGATOR** to comply with the guidelines provided in this appendix. The four types of radioactive materials transfers originating at BMRI are:

- I. Transfers within the workplace.
- II. Transfers within BMRI.
- III. Transfers between BMRI and other institutions within the United States.
- IV. International transfers.

Each of these transfer mechanisms is discussed below.

#### **I. Transfers within the workplace:**

This type of transfer involves the relocation of radioactive material from one authorized lab or area to another that is connected by corridors, overpasses, or tunnels, i.e., the material is **not** taken outside. The Radiation Safety Officer must be contacted (3145), in advance, and informed of radioactive transfers within the workplace, to confirm recipient Authorized User is licensed to possess isotope and quantity being transferred.

#### **II. Transfers within BMRI:**

Transfers within BMRI are defined as any amount of radioactivity being transported from one facility to another using city streets (as opposed to transport between BMRI buildings interconnected with overpasses or tunnels). To conduct such a transfer, please refer to the items below:

- A. Notify the Radiation Safety Office of your need to transfer radioactivity within the BMRI. Advance notice must be given to the Radiation Safety Office to allow for the required proper packaging of your material and for transportation planning.
- B. The Radiation Safety Office will confirm the recipient of your radioactive material is authorized for the type and quantity being transferred.
- C. Your radioactive material must be packaged under the Radiation Safety Office supervision. Certified shipping containers will be provided for this purpose. This is to ensure compliance with the United States Department of Transportation, the United States Nuclear Regulatory Commission, and the State of New York Department of Environmental Protection regulations concerning such transfers.
- D. The activity, in microcuries or millicuries, of radioactive material to be shipped must be accurately calculated when supplied to the Radiation Safety Officer.

- E. Radiation Safety will require signature(s) on certain provided document(s) recording the date, name of individual transporting the radioactive materials, the Authorized User sending the material, the receiving Authorized User, laboratory locations, and radioisotope name and quantity.
- F. Once transfer is complete, update your radioactive materials inventory to reflect change.

### **III. Transfers between BMRI and Other Institutions within the U.S.A**

Notify the Radiation Safety Office of all intended transfers of radioactive material to other institutions well in advance of the anticipated date of shipment. The Radiation Safety Office will provide the proper containers, packaging components, labels, and documents required to ship your radioactive material in compliance with government and university regulations.

1. Provide the following:
  - a. Your name, campus address, and phone number.
  - b. The radionuclide name.
  - c. The amount of activity (uCi or mCi) you plan to ship.
  - d. Chemical and physical form of the material.
  - e. Volume (in ml) or mass (in grams).
  - f. If the shipment requires dry ice or ice packs.
2. Contact the Radiation Safety Officer at the institution you intend to ship radioactive material to and:
  - a. Inform them of the name of the person you plan to send the material to and the isotopes and quantities to be sent.
  - b. Ask them to FAX, to your lab or office, an acceptance statement confirming their institution will receive and accept your material. This statement must include:
    - i. The radionuclide name.
    - ii. The activity amount (mCi or uCi), and
    - iii. The chemical form of the material they will accept upon arrival, plus
    - iv. The exact mailing address of the location where the radioactive package will be received.
    - v. Ask them to provide you with a copy of their NRC or agreement state license.

### **IV. International Shipments**

The Radiation Safety Office will provide procedures for international shipments of radioactive material. Such shipments generally require special consideration. Also, due to the transportation restrictions of some foreign countries, it may not be feasible to transfer radioactive material to all countries. Please contact the Radiation Safety Office prior to the completion of any plans to perform experiments that will result in the production of radioactive material you intend to ship outside the USA. We can make a prior determination if any transportation problems might be encountered that would prevent the transfer of your material.

## Appendix VIII

### Laboratory Decommissioning

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Any time a lab unit vacates a space where they were previously using radioactive materials, a decommission survey must be performed by the Radiation Safety Office. The decommission survey ensures that no contamination remains in the lab space upon arrival of the next occupant, confirms that all stock materials and wastes are handled appropriately, and confirms that equipment to be moved is decontaminated appropriately prior to the move.

When preparing to move, please adhere to the following steps to ensure the relocation gets handled as smoothly as possible:

1. Notify the Radiation Safety Office of intended move giving the following information:
  - a. Principal Investigator, Department, Contact Name, Phone and Fax Numbers
  - b. Time and Date of the projected move
  - c. Location of lab(s) being vacated
  - d. Location of new lab(s), if any (Are you leaving BMRI?)
2. Determine and set the last day of active isotope use. Notify the Radiation Safety Office of that date. When all radioactive material use ceases collect all radioactive waste and contact the Radiation Safety Office to have it removed. Consolidate all unwanted lead items (pigs, shields, sheets, etc.) into one area or container so they can be removed when radioactive waste is removed. All radioactive material not designated as waste must be removed from the lab either as:
  - a. An Inventory *transfer within the workplace* (the material is relocated but never taken outside); or
  - b. A Radioactive material *transfer within the University* (transported between University facilities using city streets); or
  - c. A Radioactive material *transfer to another institution*. See **appendix VII** for complete details related to these modes of transfer.
3. Lab staff must perform both meter and wipe test surveys on all items that currently are, or PREVIOUSLY HAD been, used with radioactive materials. This survey must be documented for future reference. Items found to be contaminated with radioactive material must be cleaned and resurveyed until all removable contamination is removed (< 100 CPM). Documentation of decontamination surveys must also be maintained. The Radiation Safety Office **must** confirm that all radiation-related items are officially decommissioned prior to being removed from a BMRI building. An official clearance will be issued for these items and should be made available to those concerned (movers, etc.)
  - a. After all equipment has been surveyed and removable contamination cleaned, lab staff must perform a routine monthly lab survey, which should include meter and wipe test surveys.

4. BMRI Custodial Services or “outside” professional movers are often used to move heavy/bulky items (freezers, centrifuges, etc.). Any such item that was also radiation related must be identified so Radiation Safety can check it before movers arrive. Special arrangements must be considered when transferring frozen or refrigerated materials. When a lab is relocating within a BMRI facility with no need to bring items outside of that facility, it is strongly recommended that responsible **lab** personnel survey and safely transport smaller radiation-related items such as pipettes, vortex mixers, glassware, etc.
5. Plans to clean, paint, or otherwise renovate vacated labs may be formulated. However, under no circumstances will this type of work be permitted to begin until the Radiation Safety Office grants an official clearance of the respective labs.
6. Be aware that the Radiation Safety Office often needs to be consulted prior to disposal of equipment. For example, **liquid scintillation counters** normally contain lead and a radioactive source that must be removed prior to disposal. Refrigerator/freezers contain Freon, which also needs to be removed prior to disposal. This will be removed by EHS once the Radiation Safety Office has issued a clearance for the refrigerator/freezer.

**Note:** Any equipment or instrument that may have contained a chemical or biological material must be emptied completely, and when necessary, decontaminated appropriately by laboratory staff. If a Biosafety label is affixed to a piece of equipment slated for disposal or repair, lab personnel must decontaminate it prior to the Radiation Safety staff performing any surveys on these items.

## Appendix IX

### Sealed Sources

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Sealed sources are those radioactive materials that have been encapsulated or double enclosed to prevent leakage of the source contents. Often the radioactive materials within these sources are in a solid form or are electroplated onto metal within the source. Sealed sources can be in the form of discs, foils, seeds, wires or welded capsules. NYS license states that the BMRI may not acquire a sealed source or device unless the source or device has been registered with the U.S. NRC pursuant to 10CFR 32.210 or equivalent regulations of an agreement state. When choosing a source for a purpose, Principal Investigators need to verify that the source is of a registered design.

#### **Testing of Purchased and Fabricated Sealed Sources**

Each sealed source obtained from a vendor and containing byproduct material (other than tritium) with the half-life greater than thirty days, in any form other than gas, shall be tested for contamination and/or leakage immediately prior to use. Each sealed source fabricated within the BMRI shall be tested for contamination and/or leakage immediately after fabrication. In addition to an initial test upon fabrication, the source will be stored for a period of seven days and retested prior to transfer to another Authorized User.

#### **New York State Department of Health Requirements (10 NYCRR Part 16.16(4))**

Each sealed source containing byproduct material, other than tritium, with a half-life greater than thirty days, and in any form other than gas, shall have the following:

1. Test for leakage and/or contamination at intervals not to exceed six months.
2. Tests shall be capable of detecting the presence of 0.005 microcurie of removable contamination.
3. Wipe test shall be taken from the sealed source or from the surfaces of the device in which the sealed source is permanently or semi-permanently mounted or stored and on which one might expect contamination to accumulate.
4. Alpha sources shall be tested at intervals not to exceed three months.
5. Results of tests shall be recorded and maintained for inspection by NYS Department of Health Inspectors. If the required tests reveal the presence of 0.005 microcurie or more of removable contamination the Radiation Safety Office shall notify the Authorized Use and immediately withdraw the source from use.
6. Only The Radiation Safety Officer is specifically authorized by the Department of Health to perform tests for leakage or contamination from sealed sources.

#### **Exceptions to Leak Test Requirements**

No leak tests are required for the following:

1. Sealed sources containing tritium.
2. Sealed sources containing only radioactive material as a gas.
3. Sealed sources containing byproduct material with a half-life or less than thirty days.
4. Sealed sources containing 3.7 MBq (100uCi) or less of beta or photon emitting material or 370 kBq (10uCi) or less of alpha emitting material.
5. Seeds of iridium-192 encased in nylon ribbons.

6. Sealed sources, except teletherapy and brachytherapy sources, in storage and identified as in storage. However, when these sources are removed from storage for use or transfer, they shall be tested before use or transfer.

**Principal Investigator Responsibilities**

It is the responsibility of the Authorized User to provide source specific information to the Radiation Safety Officer to ensure that leak tests are performed and that the Radiation Safety Officer is notified of all such sources requiring leak tests. Contact the Radiation Safety Office (3145) for details.

## Appendix X

CORNELL  
UNIVERSITY

BURKE MEDICAL  
RESEARCH INSTITUTE

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Joann and Sanford I. Weill  
Medical College

Radiation Safety Office  
785 Mamaroneck Avenue, Room B02  
White Plains, NY 10605

Telephone: (914) 368-3145  
Fax: (914) 798-4174

### RADIATION EXPOSURE PERSONAL MONITORING PROGRAM

#### REGISTRATION AGREEMENT

Name: \_\_\_\_\_ Department: \_\_\_\_\_

Position: \_\_\_\_\_ ss#/id#: \_\_\_\_\_

Date of Birth: \_\_\_\_\_ Lab room #: \_\_\_\_\_

Email address: \_\_\_\_\_ Phone #: \_\_\_\_\_

Dept. Badge Coordinator: \_\_\_\_\_ Badge Type: \_\_\_\_\_

Name of Department Supervisor/Principal Investigator: \_\_\_\_\_

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As part of New York State Department of Health Code requirements in order to assure employee exposure to radiation does not exceed legal safety standards, all employees who use and/or routinely come in contact with radioactive materials and/or ionizing radiation must participate in the personnel monitoring program.

In order to receive a badge, all information on this form must be filled out, signed by the user and department head/principal investigator, and submitted to the Radiation Safety Office, room B02, (914) 368-3145.

I have read the information above and agree to comply with the badge and monitoring program by wearing my radiation badge at all times when at work and routinely returning it to the Radiation Safety Department in a **TIMELY** manner, as instructed, so that accurate exposure records can be maintained by the institution.

Signature

Date

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_  
Signature – Principal Investigator/Department Supervisor

\_\_\_\_\_  
Date

Please note that the information you have supplied here is kept strictly confidential, stored in a restricted area, and not available for public use.

## **Appendix XI**

### **Guidance for Laboratory Self-Audit (optional)**

Authorized user:

Rooms where radioactive material are used and/or stored:

Approximate amounts radioactive materials used in lab per month:

P32    P33    S35    H3    C14    I125    Cr51    Other:

#### **INVENTORY CONTROL**

- Can you answer the question, "How many cc's of isotope do you have available for use in the lab?"
- Are there separate inventory sheets for each vial of isotope received?
- Are the inventory sheets current and reflect the number of vials and quantities present in the lab?
- Are the records known and easily accessible to every one in the lab?

#### **CONTAMINATION CONTROL**

- Have wipe tests been performed each month?
- Is there a printed record reported in DPM or a known efficiency for each month?
- Is there a survey meter available, working, and calibrated in the radiation use area?
- Are survey's performed before and after each procedure?
- Are the records known and easily accessible to every one in the lab?

#### **WASTE CONTROL**

- Is radioactive waste being held in proper containers, (proper color bucket)?
- Are the waste logs being filled out as people place waste in the buckets?
- Is the container labeled with radiation symbol and specific isotope present?
- Is there appropriate shielding around waste containers?
- Is decay in storage procedure being followed?
- Are waste containers over filled?

#### **PERSONAL PROTECTION**

- Are personnel monitors (dosimeters) assigned and worn if necessary?
- Are gloves and lab coats routinely worn?
- Are chemical hoods functional and flowing between 100 and 130 fpm?
- Is food being brought into the lab?
- Are legs and feet covered while working in the lab?

#### **SECURITY**

- Are there measures taken to prevent unauthorized entry into the lab?
- Are there measures taken to prevent unauthorized use of radioactive materials?

#### **TRAINING**

- Are certificates available for all people working with radioactive materials?
- Has everyone in the lab attended refresher training at least once during the year?

#### **POSTINGS**

- Are all doors to the laboratory posted with "Radioactive Material" sign?
- Is there a "Notice to Employees" posting near the radiation work area?
- Are there emergency procedures posted near the radiation work area?



**Appendix XII**  
Physical Properties of Laboratory Isotopes

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$^{32}\text{P}$ ,  $^{33}\text{P}$ ,  $^{35}\text{S}$ ,  $^{14}\text{C}$ ,  $^3\text{H}$ ,  $^{125}\text{I}$

## PHOSPHORUS-32 [<sup>32</sup>P]

### PHYSICAL DATA

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

### RADIOLOGICAL DATA

10. Critical organ (biological destination) (soluble forms): Bone
11. Critical organs (insoluble forms or non-transportable <sup>32</sup>P compounds): Lung (inhalation) and G.I. tract/lower large intestine (ingestion)
12. Routes of intake: Ingestion, inhalation, puncture, wound, skin contamination (absorption)
13. External and internal exposure from <sup>32</sup>P
14. Committed Dose Equivalent (CDE):  
32mrem/mCi (ingested)  
37mrem/mCi (puncture)  
96mrem/mCi (inhaled/Class W/lungs)  
22mrem/mCi (inhaled/Class D/bone marrow)
15. Committed Effective Dose Equivalent (CEDE):  
7.50mrem/mCi (ingested/WB)  
5.55mrem/mCi (inhale/Class D)  
13.22mrem/mCi (inhale/Class W)
16. Skin contamination dose rate:  
8700-9170 mrem/mCi/cm<sup>2</sup> (7 mg/cm<sup>2</sup> or 0.007 cm depth in tissue)
17. Dose rate to basal cells from skin contamination of 1.0 mCi/cm<sup>2</sup> (localized dose)  
9200 mrad/hr
18. Bone receives approximately 20% of the dose ingested or inhaled for soluble <sup>32</sup>P compounds.
19. Tissues with rapid cellular turnover rates show higher retention due to concentration of phosphorous in the nucleoproteins.
20. <sup>32</sup>P is eliminated from the body primarily via urine.
21. Phosphorus metabolism; see <sup>33</sup>P Fact Sheet.

## SHIELDING

22. 3/4 inch thick Plexiglas, acrylic, Lucite, plastic, or wood
23. Do not use lead foil or sheets! Penetrating Bremsstrahlung x-ray will be produced!
24. Use lead sheets or foil to shield Bremsstrahlung x-rays only **after** low density Plexiglas, acrylic, Lucite, wood shielding.

## SURVEY INSTRUMENTATION

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

## DOSE RATES (from unshielded 1.0 mCi isotropic point source)

Distance	rads/hr
1.00 cm	348
15.24 cm	1.49
10.00 ft	0.0015

28. 780,000mrad/hr at surface of 1.0 mCi  $^{32}\text{P}$  in 1 ml liquid.
29. 26,000mrad/hr at mouth of open vial containing 1.0 ml  $^{32}\text{P}$  in 1.0 ml liquid.

## REGULATORY COMPLIANCE LIMITS (10 CFR 20 / Appendix B)

- Derived Air Concentration (DAC): 4.0E-7 uCi/cc (all except phosphate)  
(Occupational) 2.0E-7 uCi/cc (phosphates)
- Airborne Effluent Release Limit:\* 1.0E-9 uCi/cc (all except phosphate)  
(Annual Average) 5.0E-10 uCi/cc (phosphates)  
\* Applicable to the assessment & control of dose to the public (10 CFR 20.1302). If this concentration were inhaled or ingested continuously over one year it would produce a TEDE of 50millirem.
- Urinalysis: Not required; however, may be requested by Radiation Safety Office personnel after a radioactive spill of P-32 or a suspected intake.
- Unrestricted Area Removable Contamination Limit: 1,000 dpm / 100 cm<sup>2</sup>
- Posting Areas or Rooms [10 CFR 20.1902(e)]: >100 uCi
- Container Labeling Requirement [10 CFR 20.1905]:  $\geq 10$  uCi
- Exempt Quantity [10 CFR 30.18]: 10 uCi
- Limited Quantity [DOT Limits / 49 CFR 173.425]:  $\leq 811$  uCi
- Type A Quantity [DOT Limits / 49 CFR 173.425]: > 811 uCi  
\* [Requires Certified Type A Transport Container]
- Reportable Quantity ["RQ" / DOT / 49 CFR 172.101] 100 mCi  
\* [Indicate "RQ" on transfer/shipping papers & package labels]

## GENERAL RADIOLOGICAL SAFETY INFORMATION

- Inherent Volatility (STP): Insignificant / Negligible
- P-32 is used as a tracer to study phosphorous-containing processes (nucleotide biochemistry).
- Skin (0.007 cm) & lens of the eye (0.3 cm) are primary dose concerns.
- Skin contamination (skin dose), lens of the eye dose, ingestion, inhalation, puncture, absorption through skin, and area contamination are primary radiological concerns.

- Drying can cause airborne P-32 dust contamination.
- Rapid boiling can cause airborne P-32 contamination.
- Expelling P-32 solutions through syringe needles and pipette tips can generate airborne aerosols.
- Never work directly over an open container of P-32. Avoid direct eye exposure from penetrating P-32 beta particles.
- **Always** wear a lab coat and disposable gloves when handling P-32.
- Monitor your hands, shoes, lab coat, work areas, and floors using a survey meter equipped with a thin-window G-M probe for gross contamination. Preferably, use a sensitive G-M pancake / frisker probe (15.5 cm<sup>2</sup> monitoring area).
- Monitor for removable surface contamination by smearing, swiping, swabbing, or wipe testing where P-32 is used. Count smears or swabs in a liquid scintillation counter (LSC).
- Use low-atomic (low Z) shielding material to shield P-32 and reduce the generation of Bremsstrahlung x-rays. The following materials are low Z materials: Plexiglas, acrylic, Lucite, plastic, wood, or water.
- **DO NOT** use lead foil, lead sheets, or other high-density (high atomic number) materials to shield P-32 directly. Penetrating Bremsstrahlung x-rays will be generated in lead and other high density shielding material.
- Percent of incident P-32 betas converted to Bremsstrahlung x-rays: 4.8% (lead), 0.5% (Lucite), and 0.3% (wood).
- Safety glasses or goggles are recommended when working with P-32.
- Typical liquid scintillation counter counting efficiency for P-32 (full window / maximum) > 85%.
- Typical detection limit of P-32 in urine specimens using a liquid scintillation counter = 1.08E-7 uCi/ml.

## PHOSPHORUS-33

[<sup>33</sup>P]

### PHYSICAL DATA

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

### RADIOLOGICAL DATA

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

### SHIELDING

20. Not required; however low density material is recommended, e.g., 3/8 inch thick Plexiglas, acrylic, Lucite, plastic or plywood.

### SURVEY INSTRUMENTATION

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

## PERSONNEL DOSIMETERS

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

## REGULATORY COMPLIANCE LIMITS (10 CFR 20 / Appendix B)

- Derived Air Concentration (DAC): 4.0E-6uCi/cc (Class "D")  
(Occupational) 1.0E-6uCi/cc (Class "W")
- Airborne Effluent Release Limit:\* 1.0E-8uCi/cc (Class "D")  
(Annual Average) 4.0E-9uCi/cc (Class "W")  
\* Applicable to the assessment & control of dose to the public (10 CFR 20.1302). If this concentration were inhaled or ingested continuously over one year it would produce a TEDE of 50millirem.
- Urinalysis: Not required; however, may be requested by Radiation Safety Office personnel after a radioactive spill of P-33 or a suspected intake.
- Unrestricted Area removable Contamination Limit: 1,000 dpm / 100 cm<sup>2</sup>
- Posting Areas or Rooms [10 CFR 20.1902(e)]: > 1000uCi
- Container Labeling Requirement [10 CFR 20.1905]:  $\geq 100\text{uCi}$
- Limited Quantity [DOT Limits / 49 CFR 173.425]:  $\leq 2.43\text{mCi}$
- Type A Quantity [DOT Limits / 49 CFR 173.425]:\* > 2.43 mCi  
\* [Requires Certified Type A Transport Container]
- Reportable Quantity ["RQ" DOT Limits]: 1.00 Ci

## GENERAL RADIOLOGICAL SAFETY INFORMATION

- Inherent Volatility (STP): Insignificant
- Skin dose, internal contamination, and area contamination are the primary radiological concerns.
- Drying can form airborne P-33 contamination.
- **Always** wear a lab coat and disposable gloves when handling P-33.
- Monitor work areas for removable surface contamination by smearing, swabbing, or wipe testing where P-33 is used. Count smears or swabs in a liquid scintillation counter (LSC).

SULFUR-35  
[<sup>35</sup>S]

**PHYSICAL DATA**

1. Beta energy:  
167 keV (maximum)  
53 keV (average) (100% abundance)
2. Physical Half Life:  
87.4 days
3. Biological Half Life:  
623 days (unbound <sup>35</sup>S)
4. Effective Half Life:  
44-76 days (unbound <sup>35</sup>S)
5. Specific Activity:  
42,400Ci/g
6. Maximum Beta Range in Air:  
26.00 cm. = 10.2 in.
7. Maximum Beta Range in Water or Tissue:  
0.32 mm. = 0.015 in.
8. Maximum Beta Range in Plexiglas or Lucite:  
0.25 mm. = 0. 01 in.
9. Fraction of <sup>35</sup>S betas transmitted through dead layer of skin = 12%

**RADIOLOGICAL DATA**

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

## SHIELDING

19. None required (  $\frac{3}{4}$  mm Plexiglas shields; shielding optional)

## SURVEY INSTRUMENTATION

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

## RADIATION MONITORING DEVICES

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

Distance	rad/hr
1.0 cm	1173.6
2.5 cm	93.7
15.24 cm	0.2
20.00 cm	0.01

## REGULATORY COMPLIANCE INFORMATION (10 CFR 20 / Appendix B)

- Derived Air Concentration (DAC): 6.0E-6 uCi/cc (S-35 vapors)  
(Occupational) 7.0E-6 uCi/cc (sulfide/sulfate)  
9.0E-7 uCi/cc (elemental sulfur)
- Airborne Effluent Release Limit: 2.0E-8 uCi/cc (S-35 vapors)  
[Annual Average] 2.0E-8 uCi/cc (sulfide/sulfates)  
3.0E-9 uCi/cc (elemental sulfur)
- Applicable to the assessment & control of dose to the public (10 CFR 20.1302). If this concentration was inhaled or ingested continuously over one year would produce a TEDE of 50 millirem.
- Urinalysis: Not required; however, may be requested by Radiation Safety after a radioactive spill involving S-35 or suspected intake. Recommended after working with > 10 mCi of S-35.
- Unrestricted Area Removable Contamination Limit:  $\leq 1,000$  dpm/100 cm<sup>2</sup>
- Posting Areas or Rooms [10 CFR 20.1902(e)]: > 1,000 uCi
- Container Labeling Quantity [10 CFR 20.1905]:  $\geq 100$  uCi
- Exempt Quantity [10 CFR 30.18] 100 uCi
- Limited Quantity [DOT / 49 CFR 173.425]:  $\leq 5.41$  mCi
- Type A Quantity [DOT Limits]: > 5.41 mCi  
\* [Requires Certified Type A Transport Container]
- Reportable Quantity ["RQ" / 49 CFR 172.101]: 1 Ci



## GENERAL RADIOLOGICAL SAFETY INFORMATION (S-35)

- Inherent volatility (STP): **SIGNIFICANT** for S-35 methionine & cysteine
- Radiolysis of S-35 amino acids (cysteine & methionine) during storage & use may lead to the release of S-35 labeled volatile impurities. Volatile impurities are small (< 0.05%).
- Metabolic behavior of organic compounds of sulfur (cysteine & methionine) differs considerably from the metabolic behavior of inorganic compounds.
- Organic compounds of sulfur (cysteine & methionine) become incorporated into various metabolites. Thus, sulfur entering the body as an organic compound is often tenaciously retained.
- The fractional absorption of sulfur from the gastrointestinal tract is typically > 60% for organic compounds of sulfur. Elemental sulfur is less well absorbed from the GI tract than are inorganic compounds of the element (80% for all inorganic compounds of sulfur and 10% for sulfur in its elemental form). Elemental sulfur is an NRC inhalation Class W.
- Inhalation of the gases SO<sub>2</sub>, COS, H<sub>2</sub>S, and CS<sub>2</sub> must be considered. Sulfur entering the lungs in these forms is completely and instantaneously translocated to the transfer compartment and from there its metabolism is the same as that of sulfur entering the transfer compartment following ingestion or inhalation of any other organic compound of sulfur.
- Contamination of internal surfaces of storage and reaction vessels may occur (rubber o-rings).
- Vials of S-35 labeled amino acids (cysteine & methionine) should be opened and used in ventilated enclosures (exhaust hoods). In addition, S-35 vapors may be released when opening vials containing labeled S-35 amino acids, during any incubating of culture cells containing S-35, and the storage of S-35 contaminated wastes.
- The volatile components of S-35 labeled cysteine & methionine are presumed to be hydrogen sulfide (H<sub>2</sub>S) and methyl mercaptan (CH<sub>3</sub>SH), respectively.
- Excessive contamination can be noted on the inside surfaces and in water reservoirs of incubators used for S-35 work. Most notable surface contamination can be found on rubber seals of incubators & centrifuges.
- Radiolytic breakdown may also occur during freezing process, releasing as much as 1.0 uCi of S-35 per 8.0 mCi vial of S-35 amino acid during the thawing process.
- S-35 labeled amino acids work should be conducted in an exhaust hood designated for radiolytic work.
- Vent S-35 amino acid stock vials with an open-ended charcoal-filled disposable syringe. Activated charcoal has a high affinity for S-35 vapors.
- Place an activated carbon or charcoal canister, absorbent sheet, or tray (50-100 grams of granules evenly distributed in a tray or dish) into an incubator to passively absorb S-35 vapors. Discard absorbers which exhibit survey meter readings of > 10-times facility background levels.
- **Always** wear a lab coat and disposable gloves when handling S-35.
- Monitor personnel (hands, clothing, shoes, etc), work areas, and floors using a G-M survey meter equipped with a G-M pancake / frisker probe for gross contamination. A urinalysis should be conducted by the Radiation Safety Officer after researchers have worked with > 10 millicuries of S-35 amino acids.
- Monitor for removable surface contamination by smearing, swiping, swabbing, or wipe testing where S-35 is used. Count smears or swabs in a liquid scintillation counter (LSC).
- Research personnel **must** maintain a current inventory of S-35 sources at all times.
- Expelling S-35 solutions through syringe needles and pipette tips can generate airborne aerosols.
- Drying can cause airborne S-35 dust contamination and rapid boiling can volatilize S-35 or cause airborne S-35 aerosol contamination.
- Skin contamination (dose), ingestion, inhalation, puncture/injection, absorption through skin, and area contamination are primary radiological safety concerns.

## CARBON-14 [<sup>14</sup>C]

### PHYSICAL DATA

1. Beta Energy:  
156 keV (maximum)  
49 keV (average) (100% abundance)
2. Physical Half-Life:  
5730 years
3. Biological Half-Life:  
12 days
4. Effective Half-Life:  
12 days (Bound)
5. Effective Half-Life:  
40 days (Unbound)
6. Specific Activity:  
4460 mCi/gram
7. Maximum Beta Range in Air:  
24.00 cm = 10 inches
8. Maximum Beta Range in Water/Tissue:  
\*0.28 mm = 0.012 inches
9. Maximum Range in Plexiglas/Lucite/Plastic:  
0.25 mm = 0.010 inches  
\*Fraction of <sup>14</sup>C beta particles transmitted through dead layer of skin: At 0.007 cm depth = 1%

### RADIOLOGICAL DATA

10. Critical Organ:  
Fat Tissue
11. Routes of Intake:  
Ingestion, Inhalation, Skin Contact
12. External exposure:  
Deep dose from weak <sup>14</sup>C beta particles is not a radiological concern
13. Internal exposure & contamination:  
Primary radiological concerns
14. Committed Dose Equivalent (CDE):  
2.08mrem/uCi (ingested)  
2.07mrem/uCi (puncture)  
2.09mrem/uCi (inhalation)
15. Committed Effective Dose Equivalent (CEDE):  
1.54mrem/uCi (ingested)
16. Annual Limit on Intake (ALI)\*:  
2 mCi (ingestion of labeled organic compound)  
2000 mCi (inhalation of carbon monoxide)  
200 mCi (inhalation of carbon dioxide)  
\*[1.0 ALI = 2 mCi (ingested C-14 organic compound) = 5,000 mrem CEDE]
17. Skin Contamination Dose Rate: 1090-1180 mrem per 1.0 uCi/cm<sup>2</sup> (7 mg/cm<sup>2</sup> depth)
18. Dose Rate to Basal Cells from Skin Contamination 1.0 uCi/cm<sup>2</sup> = 1400mrad/hour.
19. Immersion in <sup>14</sup>C Contaminated Air = 2.183E<sup>7</sup> mrem/year per uCi/cm<sup>3</sup> at 70 um depth of tissue and 4.07E<sup>6</sup> mrem/year per uCi/cm<sup>3</sup> value averaged over dermis.

## SHIELDING

20. none required ( 3/4 mm Plexiglas shields; shielding optional)

## SURVEY INSTRUMENTATION

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

## RADIATION MONITORING DOSIMETERS

24. Not Needed (beta energy too low)
25. <sup>14</sup>C Beta Dose Rate: 6.32 rad/hr at 1.0 in air per 1.0 mCi <sup>14</sup>C
26. Skin Contamination Dose Rate: 13.33mrad/hr per uCi on skin
27. Dose Rate from a 1 mCi isotropic point source of <sup>14</sup>C:

Distance	rad/hr
1.0 cm	1241.4
2.0 cm	250.4
15.2 cm	0.126
20.0 cm	0.0046

## REGULATORY COMPLIANCE INFORMATION (10 CFR 20 / Appendix B)

- Derived Air Concentration (DAC): 1.0E-6uCi/cc (labeled compound)  
(Occupational) 9.0E-5uCi/cc (carbon dioxide)  
7.0E-4uCi/cc (carbon monoxide)
- Airborne Effluent Release Limit: 3.0E-9uCi/cc (labeled comp'd)  
3.0E-7uCi/cc (carbon dioxide)  
2.0E-6uCi/cc (carbon monoxide)  
\* Applicable to the assessment & control of public doses (10 CFR 20.1302). If this concentration was inhaled or ingested continuously over 1-year would produce a TEDE of 50millirem.
- Urinalysis: Not required; however, may be requested by the Radiation Safety Office after a C-14 radioactive spill or suspected intake.
- Unrestricted Area Removable Contamination Limit: 1,000 dpm / 100 cm<sup>2</sup>
- Posting Areas or Rooms [10 CFR 20.1902(e)]: > 10,000 uCi
- Container Labeling Quantity [10 CFR 20.1905]: > 1,000 uCi
- Exempt Quantity [10 CFR 30.18]: 100 uCi
- Limited Quantity [DOT Limits / C-14 Liquids]: ≤5.41 mCi
- Type A Quantity [DOT Limits / C-14 Liquids]: \* > 5.41 mCi  
\* [Requires Certified Type A Transport Container]
- Reportable Quantity ("RQ" / 49 CFR 172.101) 10 Ci
- [Indicate "RQ" on transfer / shipping papers & package labels]

## GENERAL RADIOLOGICAL SAFETY INFORMATION

- Inherent Volatility (STP): Not Significant
- Possibility of organic C-14 compounds being absorbed through gloves.
- Care should be taken NOT to generate CO<sub>2</sub> gas that could be inhaled.
- Skin contamination, ingestion, inhalation, and puncture are primary concerns (potential internal doses).
- **Always** wear a lab coat and disposable gloves when working with C-14.
- Slowly monitor your hands, shoes, clothing and work area using a G-M survey meter for gross C-14 contamination, (3% counting efficiency).
- Monitor for surface contamination by smearing, swabbing, swiping, or wipe testing where used and counting in a liquid scintillation counter.
- Typical liquid scintillation counter counting efficiency for C-14 (full window / maximum) ~ 95%.
- The concentration of carbon in adipose tissue, including the yellow marrow, is about 3-times the average whole body concentration. No other organ or tissue of the body concentrates stable carbon to any significant extent.
- The fractional absorption of dietary carbon (uptake to blood) is usually in excess of 0.90.
- <sup>14</sup>C-thymidine are specifically incorporated into the DNA of dividing cells and tissues are irradiated much more uniformly from <sup>14</sup>C incorporated into DNA than they are from <sup>3</sup>H incorporated into DNA.
- There are three main classes of carbon compounds that may be inhaled: organic compounds, gases (CO or CO<sub>2</sub>), and aerosols of carbon containing compounds such as carbonates and carbides.

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

**Gases** - the inhalation of CO and its retention in body tissues has been studied extensively. Since gas has a relatively low solubility in tissue water, doses due to absorbed gas in tissues are insignificant in comparison with doses due to the retention of CO bound to hemoglobin. CO<sub>2</sub> in the blood exists mainly as bicarbonate.

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

## HYDROGEN - 3 [<sup>3</sup>H]

### PHYSICAL DATA

1. Beta Energy:  
18.6 keV (maximum)  
5.7 keV (average) (100%)
2. Physical Half-Life:  
12.3 years
3. Biological Half-Life:  
10 - 12 days
4. Effective Half-Life:  
10 - 12 days \*  
\* Forcing liquids to tolerance (3-4 liters/day) will reduce the effective half-life of H-3 by a factor of 2 or 3. (Relatively easy to flush out of system with fluids).
5. Specific Activity:  
9650 curies / gram
6. Maximum Beta Range in Air:  
5 mm = 0.5 cm = 1/4"
7. Maximum Beta Range in Water:  
0.005 mm = 0.0005 cm = 3/10,000"
8. Penetrability of Beta Particle in Matter or Tissue: Insignificant \*  
\* [0% of beta particle energy transmitted through dead layer of skin]

### RADIOLOGICAL DATA

9. Least radio-hazardous of all radionuclides
10. Critical Organ: Body Water or Tissue
11. Routes of Intake: Ingestion, Inhalation, Puncture, Wound, Skin Contamination (Absorption)
12. External exposure from weak H-3 beta energy - not a concern
13. Internal exposure & contamination are primary radiological concerns
14. Committed Dose Equivalent (CDE): 64 mrem / mCi  
(Inhalation, ingestion, or puncture)
15. Committed Effective Dose Equivalent (CEDE): 64 mrem / mCi  
(Inhalation and ingestion)
16. Annual Limit on Intake (ALI): 80 mCi (ingestion or inhalation) [H3O]  
\* [1.0 ALI = 80 mCi (H-3) ingested or inhaled = 5,000 mrem CEDE]
17. Skin Contamination Exposure Rate: 57,900 mrad/h per 1.0 mCi (contact)  
\* Exposure rate to 'dead layer of skin' (<0.007 cm depth) only.  
\* Skin contamination of 1.0 uCi/cm<sup>2</sup> = 0 mrad/h dose rate to basal cells
18. Rule of Thumb: 0.001 uCi/liter of H-3 in urine sample is indicative of a total integrated whole body dose of approximately 10millirem (average person) if no treatment is instituted (flush with fluids) [NCRP-65 / 1980]

### SHIELDING:

19. none required

### SURVEY INSTRUMENTATION:

20. H-3 CANNOT be detected using a G-M or NaI survey meter
21. Use Liquid scintillation counter (indirect) only to detect H-3 contamination on smears or swipes [LSC counting efficiency (max): 50% (full window)]

## PERSONAL RADIATION MONITORING DOSIMETERS

(Whole Body Badge or Finger Rings):

22. Not Needed (H-3 beta energy is too weak)

## RADIOACTIVE WASTE:

23. solid, liquids, scintillation vials, pathological materials (combine with C-14 contaminated objects only)

## REGULATORY COMPLIANCE INFORMATION (10 CFR 20 / Appendix B)

- Derived Air Concentration (DAC):  $2.0E-5$  uCi/cc (occupational)
- Airborne Effluent Release Limit:  
 $1.0E-7$  uCi/cc \* [Annual Average]  
\* [Applicable to the assessment & control of dose to the public (10 CFR 20.1302)]. If this concentration were inhaled continuously for over a one-year period the resulting TEDE would be 50millirem.]
- Unrestricted Area Removable Contamination Limit: 1,000 dpm/100 cm<sup>2</sup>
- Posting Areas or Rooms [10 CFR 20.1902(e)]:  $>10,000$  uCi
- Container Labeling Quantity [10 CFR 20.1905]:  $\geq 1,000$  uCi
- Exempt Quantity [10 CFR 30.18] 1,000 uCi
- Limited Quantity [DOT / 49 CFR 173.425]:  $\leq 108$  mCi
- Type A Quantity [DOT / 49 CFR 173.425]:  $> 108$  mCi  
\* [Requires Type A Container]
- Reportable Quantity ["RQ" / 49 CFR 172.101]: 100 Ci
- Urinalysis: license REQUIREMENT when handling  $\geq 100$  mCi H-3

## GENERAL RADIOLOGICAL SAFETY INFORMATION

- Inherent Volatility (at STP): SUBSTANTIAL
- Experimental uses include total body water measurements & in-vivo labeling of proliferatory cells by injection of tritium-labeled compounds (i.e.: thymidine). Tritium labeling is also used in a variety of metabolic studies.
- Oxidation of H-3 gas in air is usually slow ( $< 1\%$  per day)
- Absorption of H-3 inhaled in air is much less when it is present as elemental H-3 than as tritiated water (HTO).
- Tritium penetrates the skin, lungs, and GI tract either as tritiated water or in the gaseous form.
- As gaseous hydrogen, H-3 is not significantly absorbed into the body and does NOT exchange significantly with hydrogen in the body compounds.
- As water (HTO), the H-3 entering the lung or GI tract is completely absorbed and is rapidly dispersed throughout the body.
- Some H-3 is incorporated into cellular components and has a long turnover rate.
- Forcing fluid reduces internal exposures from H-3.
- Monitor for H-3 contamination using only smears, swabs, swipes, or wipe testing (bench tops, floors, refrigerator/freezer handles, phone, etc).
- Always wear a lab coat & disposable gloves when handling H-3.
- Skin contamination, ingestion, inhalation, and punctures involving H-3 are primary radiological concerns (internal doses).
- Tritiated water, taken into the body by inhalation, ingestion, or absorption through the skin is assumed to be completely and instantaneously absorbed and rapidly mixed with total body water.
- The volume of total body water (standard man) is 42,000 ml.
- The concentration of H-3 (uCi/ml) in urine is assumed to be the same as that in total body water. [urine concentration = body concentration]
- Detection Limit of H-3 in Urine:  $1.08E-5$  uCi/ml (approximately).

- For a continuous inhalation exposure at a rate of 1/365 of an ALI per day, the equilibrium concentration of H-3 in urine is 0.073 uCi/ml. [NOTE: 1/365 of 80 mCi (ALI) = 219 uCi]
- The predicted concentration activity normalized to unit intake from inhalation is 2.204E-5 uCi/ml per uCi of H-3 intake.
- Tritiated thymidine, if not catabolized, is taken up only by the nuclei of those cells synthesizing DNA.
- The ingestion ALI of tritiated thymidine is likely to be approximately 1/10 of that for tritiated water.
- The ALI for tritiated thymidine might be as much as 50-times smaller than the ALI for tritiated water.
- Ingested tritiated water is assumed to be completely and instantaneously absorbed from the GI tract and to mix rapidly with the total body water so that, at all times following ingestion, the concentration in sweat, urine, sputum, blood, insensible perspiration, and expired water vapor is the same.
- Tritiated water is instantaneously distributed uniformly among all the soft tissues of the body after inhalation.
- Organic compounds of H-3 are not very volatile under normal circumstances and the probability of their being inhaled as vapors is, therefore, small.
- Beta dose rates from 1.0millicurie H-3 point source:

<b>Distance</b>	<b>rad/hr</b>
0.25 cm	10,293
0.50 cm	28.12
0.56 cm	1.12

## IODINE-125 [<sup>125</sup>I]

### PHYSICAL DATA

1. Gamma Energies:  
35.5 keV (7% abundance/93% internally converted gamma)  
27.0 keV (113%, x-ray)  
27-32 keV (14%, x-ray)  
31.0 keV (26%, x-ray)
2. Specific Gamma Ray Constant:  
0.27 to 0.70mR/hr per mCi at 1 meter
3. Physical Half-Life:  
60.1 day
4. Biological Half-Life:  
120-138 days (unbound iodine)-thyroid elimination
5. Effective Half-Life:  
42 days (unbound iodine)-thyroid gland
6. Specific Activity:  
17,400 Ci/gm (theoretical/carrier free)
7. Intrinsic Specific Activity:  
22.0 Ci/millimole

### RADIOLOGICAL DATA

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

### SHIELDING

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

### SURVEY INSTRUMENTATION

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

### DOSE RATES (from unshielded 1.0 mCi isotropic point source)

**Distance                      mrads/hr**



1.00 cm	156 - 275
10.00 cm	15.5 - 27.5
100.00 cm	0.156 - 0.28
6.00 inches	6.5

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

## REGULATORY COMPLIANCE INFORMATION (10 CFR 20 / Appendix B)

- Derived Air Concentration (DAC): 3.0E-8 uCi/cc (occupational)
- Airborne Effluent Release Limit: 3.0E-10 uCi/cc<sup>\*</sup>  
(Annual Average)
- [Applicable to the assessment & control of dose to the public (10 CFR 20.1302).  
<sup>\*</sup> [If this concentration was inhaled continuously for > 1 year the resulting TEDE would be 50 millirem.]
- Unrestricted Area Removable Contamination Limit: 20 dpm / 100 cm<sup>2</sup>
- Posting Areas or Rooms [10 CFR 20.1902(e)]: > 10 uCi
- Container Labeling Quantity [10 CFR 20.1905]: ≥ 1 uCi
- Exempt Quantity [10 CFR 30.18]: 1 uCi
- Limited Quantity [DOT / 49 CFR 173.425]: ≤ 5.41 mCi
- Type A Quantity [DOT / 49 CFR 173.425]:<sup>\*</sup> > 5.41 mCi  
<sup>\*</sup> [Requires a Certified Type A Container]
- Reportable Quantity ["RQ" / DOT / 49 CFR 172.101]: 10 mCi  
<sup>\*</sup> [Initials "RQ" required on transfer/shipping forms & container label]
- Thyroid Bioassay: REQUIRED when handling ≥ 1.0 mCi of unbound (NaI) I-125 on a bench top or ≥ 10 mCi of I-125 in an exhaust hood; contact Radiation Safety Office (3145) for appointment.

## IODINATION PROCEDURES

- Iodinations must be conducted in a radiation safety approved exhaust hood.
- Iodinations must only be conducted using a radiation safety approved "closed" system (no pipetting and no open containers during iodination process). Only use rubber-septum sealed vials or containers and syringes.
- Initial cold run and hot run iodination procedures must be observed by a health physicist.
- Thyroid bioassays are required after each iodination using ≥ 1 mCi of unbound I-125 on a bench top or ≥ 10 mCi in an exhaust hood (Byproduct Material License / Regulatory Guide 8.20).
- Whenever possible, perform iodination reactions in the original sealed shipping vial when handling potentially volatile radioiodine.
- Vent the airspace of stock and reaction vials through an activated charcoal-filled syringe trap during iodination procedures.
- Remove contaminated syringe needles from stock and reaction vials through absorbent material (tissue paper, etc).
- Store I-125 contaminated objects (syringes, stock vials, waste, etc) in sealed containers (zip-lock bags, plastic containers, etc).
- Always have a solution of sodium thiosulfate on-hand during iodination procedures.
- Obtain iodination safety protocols from radiation safety officer.

## GENERAL RADIOLOGICAL SAFETY INFORMATION

- Inherent Volatility (STP): "SUBSTANTIAL" [volatilization is a very significant concern with I-125 especially in disassociated (free) form or in acidic solutions]
- Internal exposure and contamination represent the primary hazards for most I-125 applications. Iodine-125 is easily shielded using 1/16" - 1/8" lead sheets to reduce external radiation exposures.
- Acidic and frozen solutions enhance radioiodine volatility.
- Soluble iodide ion is oxidized to elemental (free) iodine that has low solubility in water and high vapor pressure. Acidic solutions enhance the oxidation of sodium iodide to elemental (free) iodine; thereby, increasing volatility.

- Alkaline sodium thiosulfate should be used to chemically stabilize I-125 prior to initiating decontamination of an I-125 spill (0.1 M NaI, 0.1 M NaOH, and 0.1 M Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>).
- Store at room temperature: DO NOT FREEZE (whenever possible)
- Radioiodine labeled compounds should be assumed to be potentially volatile since radiolytic decomposition can give rise to free iodine in solution. Radiolytic decomposition is minimized by maintaining solutions at low (dilute) concentrations.
- Addition of antioxidants (sodium thiosulfate) to either labeled or NaI solutions of I-125 will help reduce both decomposition & volatilization.
- Regulatory limits on personal intake and environmental releases of I-125 are quite restrictive because of the relatively high radiotoxicity relative to other common university-related radionuclides.
- Intakes of I-125 greater than 242 nanocuries over a 7-day period requires a health physicist and authorized user investigation, correction action, and documentation according to NRC Regulatory Guide 8.20 and the U-M Byproduct Material License (21-00215-04).
- Urine Bioassays - should be conducted 24-hours after a suspected intake of I-125.
- Thyroid bioassays conducted by the Radiation Safety Office must be conducted within 10-days after handling > 10 millicuries of free or unbound (NaI) form of I-125. Contact radiation safety for an appointment (3145).
- The urinary excretion rate decreases by about two orders of magnitude during the first 5-days after intake. Thus, uncertainties in interpretation of urinary excretion that arise because of the unknown time of intake in routine monitoring may be large.
- For continuous exposure at the rate of 1/365 ALI per day, the following equilibrium levels are attained: Inhalation Class "D" = thyroid activity (1.86 uCi) = 0.081 uCi/day (81 nCi/day).

## APPENDIX XIII

### Wipe Test Procedure

A wipe test is a check for any removable radioactive contamination from various surfaces. It must be performed after each use of tritium in the lab and if any contamination is suspected. Monthly wipe test are performed in several locations to locate and assess extent of any contamination that may be found.

Procedure:

- With a gloved hand, rub the cotton swab in an S – shaped movement over an area of 100 cm<sup>2</sup>.
- If using high energy beta isotopes, a quick assessment can be made by placing the cotton swab 1 cm from the surface of the GM pancake detector. Do this in a low background area. If anything above background is recorded, contact radiation safety.
- For all other isotopes and a more complete analysis use liquid scintillation counter.

Liquid Scintillation Counter Sample preparation:

- Place the cotton swab in a liquid scintillation vial (found under the LSC machine or in the radiation work area) with a sufficient quantity of environmentally-safe scintillation cocktail solution.
- Prepare a background sample by following the above procedure with an unused cotton swab.
- Place the vials into the blue rack with protocol number 1 listed on it. Place the standards in the white rack and the red stopper last.
- Hit the select button and then hit start. Please convert the units from CPM to DPM. For assistance contact radiation safety.

Any sample reading that is more than 100 CPM should be cleaned properly. The contamination limits presented below are guide values laboratories should use to ensure compliance with NYSDOH Rules and Regulations.

**RADIOACTIVE SURFACE CONTAMINATION LIMITS**

<i>Application</i>	<i>Alpha (dpm/100cm<sup>2</sup>)</i>		<i>Beta/Gamma</i>	
	<i>Total</i>	<i>Removable</i>	<i>Total (mR/hr)</i>	<i>Removable (dpm/100cm<sup>2</sup>)</i>
<i>Controlled area</i>				
Basic guide	25,000 Max. 5,000 Av.	500	1.0	5,000
Clean area	1,000	100	0.5	1,000
<i>Non-controlled area</i>				
Skin, personal clothing	500	N.D. <sup>‡</sup>	0.1	N.D. <sup>‡</sup>
Release of material or facilities	2,500 (Max.) 500 (Av.)	100	0.2	1,000

<sup>‡</sup> Measured at 1 cm from the surface.

<sup>‡</sup> N.D.—non-detectable.

## **Mark I Model 25 Irradiator**

### **EMERGENCY PROCEDURES**

**ALL INCIDENTS MUST BE REPORTED TO THE RADIATION SAFETY OFFICE**

**AFTER HOURS OR ON WEEKENDS, PLEASE CALL SECURITY AND THE RSO FOR ASSISTANCE**

#### **Emergency Numbers:**

**Radiation Safety Officer - 1-718-637-4409 (24 hours)**

**Radiation Safety Office - ext. 3145**

**Security - ext. 2318**

#### **Procedure for Emergency or Unusual Occurrence**

- 1. The following conditions are considered emergency or unusual Occurrences warranting immediate notification to the Radiation Safety Officer.**
  - a. Fire in the area.**
  - b. An exposure reading on a GM survey instrument exceeding five times background or greater than 5 mR/hr.**
  - c. C. Failure of the source to return to the off position for any reason.**
  - d. Timer malfunction.**
  - e. Power failure.**
  - f. Malfunction of any of the emergency interlock or safety control systems.**
  
- 2. In the event of any of the above conditions you should:**
  - a. Press the source off button on the front of the instrument to shield the source.**
  - b. Notify all personnel in the area of a possible malfunction.**
  - c. Vacate and lock the room.**
  - d. Notify the Director.**
  - e. Call the Emergency contacts listed above on this page**

**JL SHEPHERD & ASSOCIATES**

1010 ARROYO AVE., SAN FERNANDO, CALIFORNIA 91340-1822

818-898-2361 FAX 818-361-8095

**OPERATING MANUAL**  
**(INCLUDING INSTALLATION AND**  
**MAINTENANCE)**  
**FOR**  
***MARK I SERIES***  
**RESEARCH IRRADIATION FACILITY**

*OPERATING MANUAL FOR **MARK I** SERIES RESEARCH IRRADIATION  
FACILITY*

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COMPONENT AND ACCESSORY MANUALS



# OPERATING MANUAL FOR MARK I SERIES RESEARCH IRRADIATION FACILITY

**Model Mark I - 25**

**S.N. 1033**

## **I. INTRODUCTION**

The Mark I is a self-contained Cesium-137 irradiator with the source permanently installed in the shielded section of the unit. A full width door provides access to the entire irradiation chamber, where samples are rotated on turntables to receive an integrated dose, equivalent to cylindrical source geometry, for exposures over one minute. Source operation is via pneumatic cable cylinder; source travels from the fully shielded OFF position to the irradiation chamber in less than two seconds and returns in less than two seconds. Sample dose is determined by turntable position and irradiation time. The door and source drive system are fully interlocked so that the source cannot be raised if the door is not fully closed, and the door cannot be opened unless the source is fully shielded. During all installation procedures, the chamber door is locked in the closed position and there is no possibility of personnel exposure. Installation consists of location of the irradiator at suitable installation site, assembly, complete operational and safety check of the unit, and personnel training.

### **CAUTION:**

**Installation of this irradiator requires the services of manufacturer's qualified personnel, operating under a specific State of California License. A license to possess this unit does not permit the user to install the device or make repairs unless specifically authorized in this manual.**

**Moving or dismantling this unit is prohibited, unless user's license specifically (on a line item basis) authorizes the user to perform these functions.**

**Re-programming or re-wiring of the operating systems and interlocks to by-pass safety systems is expressly prohibited by regulation.**

**The physical security of this source/device from arrival until disposal is the sole obligation of the facility.**

**NOTICE TO USER: Your license to possess this irradiator includes performing leak test procedures. The USNRC or agreement state requires that leak tests be performed and documented at six month intervals. (Check your license, some states are more stringent.)**

## **I. INTRODUCTION (Concluded)**

### **Leak Test Procedures**

- A. Sources must be in the fully shielded OFF position ("SOURCE RETURN" indicator light on control panel illuminated, "SOURCE RETURN" button on control panel activated).
- B. Using an absorbent material (e.g., cotton swab or filter paper), wipe the area where the operating tower meets the top of the shield.

**NOTE:** If more stringent standards exist at your institution, and the wipe must be performed at the upper end of the source rod where it exits the shield, you must obtain prior, written permission from the manufacturer to remove the operating tower cover.

- C. These wipes should be measured on an instrument capable of detecting 0.005  $\mu\text{Ci}$  of Cesium-137.

**NOTE:** The 0.005  $\mu\text{Ci}$  level is that generally prescribed by licensing authorities; individual institutions may require more stringent standards.

***If contamination above this level is detected, immediately remove the irradiator from service and contact the manufacturer.***

### **RADIATION PROTECTION:**

The nature, severity and duration of the effects of radiation exposure depend on the dose and type of radiation, rate of exposure, portion of the body exposed and individual sensitivity to radiation (other factors may also contribute to the overall effect.) The external radiation levels for your device and the source strength may be found in the External Radiation Level Certificate and the Calibration Certificate, which are incorporated into this manual.

Personnel doses resulting from operating the irradiator or working in the vicinity of the irradiator should follow ALARA (As Low As Reasonably Achievable) principles. Unnecessary work should not be performed in the vicinity of an irradiator, nor should the irradiator be used as a work station. Maximum allowable personnel doses must be followed in accordance with the requirements of the US NRC's 10 CFR Part 20, Subpart C for occupational exposure, and Subpart D for members of the public, which is incorporated into Agreement State regulations. **NOTE:** Individual states or licenses may impose more stringent restrictions.

**NOTE:** Manufacturer's training following installation or specific training classes is only provided for the operation and selected maintenance of the Mark I Irradiator. The licensee is required to provide health physics training to the Irradiator users in accordance with license commitments.

**CAUTION:** Removal of the source from this irradiator will result in severe radiation exposure, injury and possibly death.

**CAUTION:** Removal of the source from this irradiator will result in severe radiation exposure, injury and possibly death.

## **II OPERATIONAL REQUIREMENTS**

### **A. Air**

For pneumatic units which do not utilize the optional noiseless air compressor, a clean air supply, rated at 80 psig, must be available within five (5) feet of the irradiator. A water trap must be provided.

### **B. Electrical**

A clean, low noise electrical circuit, 115VAC, 60Hz, single phase, rated at 15 amps, within five (5) feet of the irradiator is required. A circuit which has fluorescent lights, freezers, or other equipment which inject large inductive or capacitive pulses into the line will cause the timer of the Mark I to malfunction. If sporadic timer malfunctions are noted, this will be caused by "noisy" circuits and a computer-type surge suppresser will be required to ensure proper timer operation.

### **C. Weight**

Because of the weight of this irradiator, it is necessary for it to be placed in a location where the floor loading will bear its weight. Consult the Installation Specification Sheet, provided prior to order.

### **III. OPERATING INSTRUCTIONS AND EMERGENCY PROCEDURES**

**NOTICE: IF, AT ANY TIME, THIS IRRADIATOR MALFUNCTIONS, IMMEDIATELY REMOVE THE UNIT FROM OPERATION, PADLOCK THE DOOR LATCH AND CONTACT J.L. SHEPHERD & ASSOCIATES FOR INSTRUCTIONS.**

Although not related to radiation safety, the major hazard to be encountered in the use of this irradiator is the formation of spatulated finger tips. This will occur if the door is closed before the operator's hand is completely removed from the door/chamber interface. All users should be instructed in this regard.

#### **A. System Activation**

Plug the power cords (control panel, turntable, radiation area monitor, and compressor, as applicable) into a 115 VAC outlet, as specified in Section II. Turn control panel key switch to ON position. The control panel "POWER" light should be illuminated. Ascertain that the monitor is turned on, that the air supply is connected, and that incoming air pressure is a minimum of 60 psig. The control panel "LOW PRESSURE" light will go out when there is sufficient pressure to safely raise the source. The monitor will go through an initial power-up sequence, ending with display of the current radiation level detected.

The radiation area monitor is an integral part of the Mark I irradiator safety interlock system. A 2-wire cable from the Mark I control panel is attached to the 3 pin connector on the bottom of the terminal block. The monitor must be turned on ("ON/OFF" switch) and functioning properly for the source to be raised to the IRRADIATE position. If the external radiation levels exceed the preset limit on the monitor (see monitor manual), the source will remain or return to the fully shielded OFF position. If the monitor is not working properly, take unit out of operation and contact J.L. Shepherd & Associates.

**NOTE:** The radiation area monitor must be ON for the Mark I irradiator source to be operational.

**NOTE:** The source drive system and irradiation chamber door are locked by spring-loaded bolts. These bolts can only be actuated when power is supplied and the necessary interlock switches are activated; therefore, it is impossible to raise the source or open the door unless the power is on. It is also impossible to safely raise the source without air pressure or with low pressure, as indicated by the "LOW PRESSURE" light on the control panel.

### **III. OPERATING INSTRUCTIONS AND EMERGENCY PROCEDURES (Continued)**

#### **B. Door Operation**

The Mark I irradiation chamber door is equipped with a completely independent mechanical pressure switch in addition to the electro-mechanical interlock system. The mechanical pressure switch (200 lb. operating force) is actuated only when the chamber door is completely closed. In the event of catastrophic malfunction of the electro-mechanical interlock, this system will cause the source to immediately drop to the fully shielded OFF position if the door opens as much as 1/16" from the fully closed position, eliminating the possibility of radiation exposure.

##### 1. Opening the Door:

To open the door, the following procedures must be followed:

- a. Push the "DOOR SWITCH" button (mounted at the top left side of the chamber/door). A sharp click will indicate that the bolt has been actuated.
- b. While pushing the "DOOR SWITCH" button, operate the door handle. The door will now open normally.

**DO NOT OPERATE THE DOOR HANDLE UNLESS THE "DOOR SWITCH" BUTTON IS BEING PUSHED.** This will cause the door bolt to bind and fail to release.

If the door handle is inadvertently operated when the "DOOR SWITCH" button is not being pushed and the door bolt becomes jammed, proceed to **REMEDY** in the following sections to open the door.

**NOTE:** The roller section of the door strike is adjustable and may require adjustment after prolonged use. To adjust this roller, proceed as follows:

Loosen the 7/16" hex bolt on the top of the strike. The roller assembly is then adjusted by rotating the wheel (which has screwdriver slots) at the rear underside of the strike, clockwise to move the roller section out, or counter-clockwise to move it in. After adjustment, secure the hex bolt.

The roller section should be adjusted so that the tongue section of the latch is firmly engaged against the roller at full (or almost full) extension of the tongue when the door is firmly closed by pushing either the door or handle.

**WARNING:** Do not attempt to open the door with the red handled door closure assistance latch closed. You will damage the door opener. This red handled latch is located under the door pressure switch interlock assembly on the left side, facing the device.

### **III. OPERATING INSTRUCTIONS AND EMERGENCY PROCEDURES (Continued)**

#### **B. Door Operation, continued**

##### 2. Closing the Door:

When closing the door, do NOT grasp the handle. Push on the handle without grasping it and close the door firmly.

If your unit is provided with a U-shaped handle, use this handle only for closing the door.

**NOTE:** DO NOT PRESS THE "DOOR SWITCH" BUTTON (MOUNTED AT THE TOP LEFT SIDE OF THE CHAMBER DOOR) WHILE CLOSING DOOR. IF THE DOOR WILL NOT CLOSE WITHOUT PRESSING THIS SWITCH, THIS INTERLOCK IS MALFUNCTIONING. THE UNIT SHOULD IMMEDIATELY BE TAKEN OUT OF SERVICE AND THE MANUFACTURER CONTACTED.

The rationale for this is that the tongue on the door handle must be fully engaged against the roller on the strike or sufficient force (caused by the weight of the door) will not be exerted on the pressure switch to permit the locking bolt on the primary interlock to engage the hole in the door tang. If the bolt does not engage the tang, the source cannot be raised. There is also the possibility that the bolt will engage as the door is closed which will permit the source to be raised, but the door may rebound slightly, which will cause the bolt to bind so that the door cannot be opened after the exposure. Evidence of this is a buzzing sound when the "DOOR SWITCH" button is pushed, rather than the usual sharp click that the bolt has been retracted.

**REMEDY:** If this occurs, the remedy is to exert pressure on the door by pushing on it until the door bolt retracts when the "DOOR SWITCH" button is pushed. Evidence of this is a sharp click rather than a buzz when the button is pushed.

**WARNING/CAUTION:** Ensure that all fingers and/or objects are removed from the irradiator/chamber door interface before closing the door. Any object in this interface will cause the interlocks to malfunction beyond the point where "Remedy" above may not be adequate. Remove the irradiator from service and immediately contact the manufacturer, if door operation is not functioning properly.

### **III. OPERATING INSTRUCTIONS AND EMERGENCY PROCEDURES (Continued)**

#### **C. Selecting Timer Function**

Select either PRESET or MANUAL mode operation with the toggle switch below the timer on the control panel. Convert minutes and seconds into 10's: 15 seconds = .25 minutes, 30 seconds = .5 minutes, 45 seconds = .75 minutes.

##### **1. PRESET Mode Operation:**

In PRESET mode, after the completion of any exposure, it is necessary to press the "RESET" button before another exposure is initiated. If this is not done, the source cannot be raised.

Pressing the "RESET" button automatically resets the timer to the previously selected time. If the preset time is to be changed, the "RESET" button must be pressed after each change or the sample will be irradiated (one time only) for previous irradiation time.

The timer starts at 0000.00 minutes and counts up to the preset time. After the exposure is completed, the elapsed time (total irradiation time) is indicated on the LED readout (left illuminated set of digits).

##### **2. Inspecting a Sample during an Irradiation:**

In either PRESET or MANUAL mode, the LED time display starts at 0000.00 minutes and shows the elapsed irradiation time. If it is desirable to inspect an experiment during an irradiation, press the "SOURCE RETURN" button on the control panel to lower the source to the fully shielded OFF position and open the door. To continue the experiment, close the door and raise the source. The timer will continue timing as soon as the source has been raised and will return the source to the OFF position either at the end of the total preset time (PRESET mode) or by pressing the "SOURCE RETURN" button (either mode). The "OFF" indicator light will be illuminated when the source is in the fully shielded OFF position.

##### **3. MANUAL Mode Operation:**

To commence a MANUAL mode irradiation, the "SOURCE RAISE" button must be pressed. The control panel "ON" light will be illuminated when the source is fully raised. The elapsed timer will continue to show and add to the total elapsed irradiation time, no matter how many cycles are performed, until 9999.99 minutes. To reset the total elapsed irradiation time to 0000.00 minutes, press the "RESET" button.





### **III. OPERATING INSTRUCTIONS AND EMERGENCY PROCEDURES. (Continued)**

#### **D. Turntable Selection and Experiment Set-up**

Select the turntable position and corresponding turntable for sample irradiation, using the isodose curves provided as part of this manual, to determine dose rate and distribution.

Turn turntable drive to "OFF" position.

Place turntable with center hole in hub over the 1/4" diameter center rod on the turntable drive system.

Rotate until the drive pin holes in the hub slip over the drive pins in the drive system.

When the pins are in place the turntable will be lowered approximately 3/16" and all bearings in the turntable will be in contact with SS base plate of the Mark I cavity.

Turntable drive may now be activated.

#### **CAUTION**

Activating the turntable drive system until the turntable has been properly installed per the above instructions will damage the turntable. Damage to turntables caused by improper installation is NOT covered by Warranty. Turntables will be replaced at users expense.

Turntable operation is controlled by a switch mounted on the turntable drive box, located on the left side of the irradiator.

Ascertain that sample is rotating properly before closing door. **NOTE:** Samples must be rotated to achieve the integrated dose as shown on the isodose curves: 1 minute (minimum) for the standard 6 rpm turntable motor rotation speed or 1/2 minute (minimum) for the optional 12 rpm, dual speed turntable motor. Turntable motor speed is approximate, RPM's will differ slightly depending upon gearing.

### **III. OPERATING INSTRUCTIONS AND EMERGENCY PROCEDURES (Continued)**

#### **E. Sample Irradiation**

To expose the source, press the "SOURCE RAISE" button on the control panel. After a short delay (two to ten seconds), the source should raise smoothly to the IRRADIATE position. The control panel "SOURCE RAISE" indicator light will then illuminate. The irradiation chamber door must be fully closed to do this.

IN CASE OF ANY HANG-UP OF THE SOURCE OPERATING SYSTEM, THE SOURCE SHOULD IMMEDIATELY BE RETURNED TO THE *OFF* POSITION, THE IRRADIATOR IMMEDIATELY TAKEN OUT OF SERVICE, AND THE MANUFACTURER CONTACTED.

NOTE: IF THERE HAS BEEN AN ELECTRICAL FAILURE, YOU MAY HAVE TO RUN THE SOURCE THROUGH A IRRADIATE CYCLE TO BE ABLE TO OPEN THE DOOR.

#### **F. Source Return**

The source may be returned to the fully shielded OFF position by either of two methods: at the expiration of the preset time period (in PRESET mode) or by manually by pressing the "SOURCE RETURN" button, which overrides PRESET mode and also ends a MANUAL mode irradiation.

IN THE EVENT OF ELECTRICAL AND/OR AIR PRESSURE FAILURE, THE SOURCE AUTOMATICALLY RETURNS TO THE FULLY SHIELDED *OFF* POSITION. THIS ELIMINATES DAMAGE TO THE SAMPLE IN THE IRRADIATION CHAMBER DUE TO EXCESSIVE DOSE. ELECTRICAL POWER IS REQUIRED TO OPEN THE CHAMBER DOOR; THERE IS NO EMERGENCY PROCEDURE FOR OPENING THE DOOR MANUALLY.

**IN THE CASE OF ANY MALFUNCTION OF THE SOURCE DRIVE OR INTERLOCK SYSTEM, THE IRRADIATOR MUST BE IMMEDIATELY TAKEN OUT OF SERVICE AND THE MANUFACTURER CONTACTED.**



### **III. OPERATING INSTRUCTIONS AND EMERGENCY PROCEDURES (Continued)**

#### **G. Safety Precautions**

The control panel is equipped with the following lights: "POWER", "SOURCE RETURN", "SOURCE RAISE", and "LOW PRESSURE". Because of the design of the safety interlocks built into the irradiator, it is impossible to open the door when the source is totally or partially exposed, or to expose the source when the door is open, except in the case of a major mechanical failure. The possibility of such a failure is very slight, because of the safety margins built into the mechanical components of the system. As an added precautionary measure to insure the safety of personnel working with the irradiator, the manufacturer recommends that the radiation area monitor provided with the unit, or comparable instrument with an audio output or preset alarm level, be mounted in close proximity to the door of the irradiator.

#### **H. Optional Accessories**

##### **1. Attenuators:**

The set of 5 attenuators are identified as "X-2", "X-5", "X-10", "X-50", and "X-100". They are placed cumulatively (starting with the "X-2") against the source sleeve tube at the front of the irradiation chamber, and samples placed on turntable position number 3, to achieve the sample dose rate as described on the enclosed isodose curves. The larger turntable may be used with the X-100 attenuator set.

Each attenuator is provided with a threaded hole (near the top) in which a thumb screw may be attached for easy manipulation. The thumbscrew must be removed before the next attenuator is added.

##### **2. Model 302 Attenuator:**

The Model 302 Attenuator is placed against the source sleeve tube at the front of the irradiation chamber. Samples are placed in turntable position number 3 to achieve the dose rate described on the enclosed isodose curve.

**NOTE:** The Model 302 Attenuator is not used with the set of cumulative attenuators described in Section III.H.1 above.

### III. OPERATING INSTRUCTIONS AND EMERGENCY PROCEDURES (Concluded)

#### 3. Model 335 Collimator:

The Model 335 Collimator system consists of an adjustable collimator which fits into the irradiation chamber of the Mark I, and a rolling table for installation/removal and storage of the collimator when not in use.

The rolling table aligns with the door opening and base of the Mark I so that the table top plate is parallel with the irradiation chamber floor. The table is equipped with six rollers, of which the center two are slightly below the plane of the other four so that the table may be readily rolled and turned.

The collimator is attached to the rolling table with two locking arms (tightened/loosened by an Allen wrench). **CAUTION:** Do not move the rolling table unless the collimator is locked down. The collimator is also on rollers, weighs approximately 300 pounds, and is capable of seriously damaging anything it falls on.

To place the collimator in the irradiation chamber:

- a. Fully open the Mark I door.
- b. Remove the turntables from the irradiation chamber. Also remove any attenuators which may be installed.
- c. Place Model 335 into the chamber. Roll the table so that the front of the table plate abuts the irradiation chamber floor. Loosen the locking arms, and gently roll the collimator into the irradiation chamber, until the front of the collimator is snug within the irradiation chamber. Both sides of the adjustable collimator are hinged. They are moved to the desired width by loosening the wing nuts and moving collimator to the desired width and re-tightening. **NOTE:** The centerline of the opening (per the isodose curves) is scribed on the bottom plate of the collimator. Measurements for each side are made equidistant from this point.

## **IV. MAINTENANCE**

NEVER, UNDER ANY CIRCUMSTANCES, IS ANY LUBRICANT TO BE PLACED ON THE SOURCE ROD OR THE TUBE THROUGH WHICH IT PASSES - RADIATION POLYMERIZATION OF HYDROCARBONS WILL OCCUR. This will cause malfunction of the irradiator and require that it be sent to a hot cell facility for a complete overhaul. APPLICATION OF ANY LUBRICANT OR ACCIDENTAL SPILL OF OTHER MATTER (e.g., SODAS, JUICE, etc.) INTO THIS AREA IMMEDIATELY VOIDS ALL WARRANTIES.

**CAUTION:** A LICENSE TO POSSESS THIS UNIT DOES NOT PERMIT THE USER TO PERFORM MAINTENANCE OR REPAIRS ON SAFETY-RELATED SYSTEMS, UNLESS THE LICENSE SPECIFICALLY AUTHORIZES THE USER TO PERFORM THESE FUNCTIONS.

### **A. Electrical and Mechanical Maintenance/Repair**

Electrical and/or mechanical maintenance on all safety/interlock circuits, including the control panel, is strictly prohibited and must be performed by, or under direct supervision of, licensed manufacturer's personnel. Simple, specific maintenance or repairs, on the control panel or operating tower only, may be performed if user obtains *prior* written permission and instructions from manufacturer. Under no circumstances is the control panel or tower cover to be removed without express written permission of manufacturer.

Specifically authorized maintenance/repair procedures are as follows:

1. Control panel: replacement of fuses which are accessible without removing cover.
2. Turntable chain and drive assembly: as covered in this section.
3. Cavity clean-up: as covered in this section.
4. Door latch adjustment: as described in Section III.B, Door Operation.
5. Optional noiseless compressor: manufacturer's instructions and schematic provided as part of this manual, along with additional instructions in the following section.

## **IV. MAINTENANCE (Continued)**

### **B. Pneumatic System - Authorized Maintenance/Repair Permitted on Filter-Regulator-Lubricator System and Optional Noiseless Compressor, Outside of Operating Tower Only**

A weekly, visual inspection of the filter-regulator-lubricator (F-R-L) system (the transparent reservoirs or bowls on the side of the operating tower) is recommended. The outside bowl (away from the tower) is the filter reservoir, which collects water condensation present in the air lines. The other reservoir contains oil for the pneumatic source drive system.

It is very important that the filter reservoir be emptied before it overflows into the oil reservoir. Permitting water into the pneumatic system can damage the system and require major factory maintenance.

It is also important that the oil level and oil dispersion be maintained. For oil dispersion, a metering valve is located at the top of the lubricator assembly. This should be opened approximately 1/2 turn from the fully closed position and set so that a fine mist appears in the sight glass on top of the lubricator. Oil consumption should be one (1) bowl per every 6-12 month period, depending upon amount of use irradiation. If no oil is consumed, open metering valve slightly until a fine mist appears. Lack of oil can damage the pneumatic source drive system and require major factory maintenance. If oil consumption is greater, slightly close metering valve.

*Fill oil reservoir with #10 or #20 weight non-detergent or vacuum pump oil.*

**NOTE:** A nylon exhaust tube extends from the bottom of the tower. This prevents exhaust oil from entering the source drive mechanism. Do not remove this tube or exhaust oil could enter the source drive system, causing it to freeze (radiation polymerization of hydrocarbons) and the irradiator will need to be returned to a hot cell to effect repairs. Please reference the manufacturer's technical specifications, found in this manual, for further details.

Follow the manufacturer's instructions (located in Appendices) for maintaining the optional noiseless compressor. Of particular importance is emptying the receiver tank of water and other contaminants. This should be done at least once a week, and more frequently for humid locations. Also, the compressor's F-R has a filter reservoir which must be kept clear of water and other contaminants; it should be checked at the same time as the receiver tank. Do not operate the compressor without verifying that it has enough oil in it. Oil level is visible through the sight glass, and should be maintained about halfway up this sight glass. Use only SJ-27 synthetic oil to fill the compressor; other oils are not approved by the manufacturer and could damage the compressor.

## **IV. MAINTENANCE (Continued)**

### **C. Turntable Adjustment, Maintenance and Repair**

Please reference the turntable diagram in the appendices of this manual:

1. The turntable drive is set up using a .1475" pitch stainless steel roller chain. If the primary drive chain, which extends from the motor/gear head (which is located on the left side of the irradiator) to the turntable assembly inside becomes loose, remove the cover of the turntable drive assembly and readjust the motor/gear head assembly outward in the slots provided. This will increase tension on the primary drive chain. This chain should never be excessively taut, but should be tight enough so that slippage is not possible.
2. Lubrication of the turntable drive assembly should be made at three month intervals. The turntable drive sprockets, which turn on the steel pins, must be lubricated with DRY GRAPHITE only. Use of any organic lubrication will cause polymerization and seizure of the turntable assembly.

### **D. Cavity Clean-up**

1. Remove the bottom plate (chamber floor) by unscrewing the four flathead screws. During re-assembly, be careful to replace the standoffs or shims in their exact positions.
2. The turntable drive assembly is now fully exposed. If thorough clean-up cannot be achieved with the turntable drive in place, it may be removed as follows:
  - a. Remove the cover of the turntable drive box (on the left side of the device). Do not pull off any attached wires.
  - b. Loosen the bolts that hold the motor/gear head in place. Push the motor/gear head toward the unit and remove the primary drive chain from the sprocket.
  - c. Return to the inside of the chamber and lift all chains, sprockets, and idlers from the center rods on which they are mounted. Note the location and position of each component. The only chain not completely removable is the main drive chain. It must be cleaned by moving it through the tubes in the side of the irradiator.
  - d. After cleaning, reassemble with all the components in the exact positions that they were removed from.
  - e. Liberally lubricate all pins with DRY GRAPHITE only.



#### **IV. MAINTENANCE (Concluded)**

- f. Tighten the set screw(s) in primary drive sprocket hub (the sprocket which is attached to the gear head shaft).
- g. With the primary drive chain engaged on its sprocket inside the irradiation chamber, wrap this chain around the primary drive sprocket. Slide the motor/gear head away from the irradiator until the chain is tight. Tighten the bolts which hold the motor/gear head in place and replace the turntable drive box cover of the turntable motor.

**NOTE:** The manufacturer offers certified training classes for additional maintenance on non-safety related systems.

**V. NOTICE TO RSO CONCERNING LEAK TEST, SAFETY CHECK AND NON-SAFETY CHECK PROCEDURES**

YOUR LICENSE TO POSSESS THIS IRRADIATOR REQUIRES THAT YOU PERFORM AND DOCUMENT LEAK TESTS, SAFETY SYSTEMS AND NON-SAFETY SYSTEMS CHECK PROCEDURES AT SIX MONTH INTERVALS (CHECK YOUR LICENSE; SOME STATES AND INSTITUTIONS ARE MORE STRINGENT).

**VI. LEAK TEST PROCEDURES - TO BE PERFORMED AT SIX MONTH INTERVALS**

- A. Source must be in the fully shielded OFF position.
- B. Using an absorbent material (e.g., cotton swab or filter paper), wipe the area where the operating tower meets the top of the shield.

**NOTE:** If more stringent leak test standards exist at your institution, or are required by your license, and the wipe must be performed at the upper end of the source rod where it exits the shield, you must obtain prior, written permission from the manufacturer to remove the operating tower cover.

- C. These wipes should be measured on an instrument capable of detecting 0.005  $\mu\text{Ci}$  of Cs-137. The 0.005  $\mu\text{Ci}$  level is that generally prescribed by licensing authorities; individual institutions may require more stringent standards.

**IF CONTAMINATION ABOVE THIS LEVEL IS DETECTED, IMMEDIATELY REMOVE THE IRRADIATOR FROM SERVICE AND CONTACT THE MANUFACTURER.**

**VII. SAFETY SYSTEMS CHECKOUT PROCEDURES - TO BE PERFORMED AT SIX MONTH INTERVALS**

**A. Checkout of Source Interlock System**

1. With power on, and air turned off, open the door slightly so that the door tang is approximately 1/4" from the door interlock box.
2. Press the "SOURCE RAISE" button on the control panel.
3. If interlock is malfunctioning, items to be noted are:
  - a. A sharp click, in the lower tower section, will be heard if the source locking solenoid, which prevents the source from being raised, is actuated.

## **VII. SAFETY SYSTEMS CHECKOUT PROCEDURES - TO BE PERFORMED AT SIX MONTH INTERVALS (Concluded)**

- b. The control panel "SOURCE RETURN" light will be extinguished. This light is illuminated by proper functioning of a limit switch actuated by the source rod in the fully shielded OFF position and a second limit switch actuated by proper position of the locking solenoid.

**NOTE:** A time delay is built into this system, so that the source is raised two to ten seconds after the "SOURCE RAISE" button is pushed.

If interlock is malfunctioning, turn control panel key off and source will not be raised (in case the air supply has inadvertently been left on).

**IF ANY MALFUNCTION OF SOURCE INTERLOCK SYSTEM OCCURS, AND SOURCE CAN BE RAISED WITH THE DOOR OPEN, IMMEDIATELY TAKE UNIT OUT OF SERVICE AND CONTACT MANUFACTURER.**

### **B. Checkout of Door Interlock System**

With the door fully closed, press the "SOURCE RAISE" button.

A loud click will be heard in the lower section of the operating tower.

Immediately press the "DOOR SWITCH" button, to the left side of the door. There is a two to ten second delay before the source raises. Nothing should happen.

If a second click is emitted from the interlock box, this means that this door interlock system is not functioning properly. Do not attempt to open the door. **NOTE:** Door pressure switch will return source to the fully shielded OFF position if door is opened.

**VIII. NON-SAFETY SYSTEMS CHECKOUT PROCEDURES FOR  
SOURCE ROD OPERATION - TO BE PERFORMED AT SIX  
MONTH INTERVALS**

A. In MANUAL mode, with some time on the preset timer, press the "SOURCE RAISE" button. After a two to ten second delay, source should raise smoothly and the "SOURCE RAISE" light on the control panel should be illuminated when source rod reaches the top of the operating tower.

Press the "SOURCE RETURN" button.

Source should immediately and smoothly return to the fully shielded OFF position, the "SOURCE RETURN" light on the control panel should be illuminated, and a click should be heard in the lower section of the tower (as described in previous section).

B. In PRESET mode, set some time (e.g., 0000.10 minutes) on the timer, remembering to press the "E" button after the time change.

Press the "SOURCE RAISE" button. After a two to ten second delay, source rod should raise smoothly and the "SOURCE RAISE" light in the control panel should be illuminated.

At the end of the preset time, the source should move smoothly to the fully shielded OFF position, the "SOURCE RETURN" light on the control panel should be illuminated and a click should be heard in the lower section of the operating tower, as described in the previous section.

**IF THE UNIT DOES NOT OPERATE AS ABOVE, REMOVE THE UNIT FROM SERVICE AND CONTACT THE MANUFACTURER.**

**IX. DEVICE CERTIFICATION**

**DEVICE CERTIFICATION**  
**MARK I SERIES IRRADIATOR**

Model Mark I - 25

S.N. 1033

**J.L. SHEPHERD & ASSOCIATES CERTIFIES THAT THIS DEVICE MEETS ALL APPLICABLE D.O.T. SHIPPING REGULATIONS RELATED TO EXTERNAL RADIATION LEVELS FOR CONTAINERS OF RADIOACTIVE MATERIALS.**

**THIS DEVICE MEETS ALL UNDERWRITER'S LABORATORY SPECIFICATIONS, INCLUDING FIRE CODE REGULATIONS.**

**THIS DEVICE MEETS REQUIREMENTS FOR A STANDARD INDUSTRIAL FIRE WITHOUT RELEASING RADIATION OR RADIOACTIVE MATERIALS TO ENVIRONS.**

## **X.**

### **J.L. SHEPHERD & ASSOCIATES**

#### **PRODUCT WARRANTY**

##### **MARK 1 SERIES IRRADIATOR**

**A.** THIS WARRANTY CONSTITUTES THE ENTIRE UNDERSTANDING BETWEEN BURKE MEDICAL RESEARCH INSTITUTE, WHITE PLAINS, NY, HEREINAFTER REFERRED TO AS "BUYER", AND J.L. SHEPHERD & ASSOCIATES, HEREINAFTER REFERRED TO AS "SELLER", RELATING TO WARRANTIES, GUARANTEES, OR PROVISIONS IN BUYER'S TERMS AND CONDITIONS OF PURCHASE.

**B.** SELLER WARRANTS THAT ALL PRODUCTS DELIVERED UNDER PURCHASE ORDERS ISSUED BY BUYER, OR UNDER PURCHASE ORDERS ISSUED DIRECTLY BY BUYER'S CUSTOMERS, WILL CONFORM TO APPLICABLE SPECIFICATIONS AND DRAWINGS; WILL BE FREE FROM DEFECTS IN MATERIAL AND WORKMANSHIP; WILL BE FREE FROM DEFECTS ARISING FROM THE PROCESS OF MANUFACTURE, WHICH PROCESS IS DICTATED BY THE REQUIREMENTS OF THE BUYER'S DESIGN; AND WILL BE FREE FROM DEFECTS ARISING FROM SELLER'S ROUTINE SELECTION OF MATERIALS. BUYER AND SELLER RECOGNIZE THAT CERTAIN METHODS AND MATERIALS USED IN THE MANUFACTURE OF THE PRODUCTS ARE PROPRIETARY TO OR THE SOLE RESPONSIBILITY OF SELLER. SELLER THEREFORE WARRANTS THAT DEFECTS OR FAILURES ARISING FROM THE PROPRIETARY PROCESS OF MANUFACTURE AND THE SELECTION OF MATERIAL NOT CALLED OUT IN THE SPECIFICATIONS OR DRAWINGS, OR WHERE OPTIONAL MATERIAL REQUIREMENTS ARE ALLOWED, WILL BE THE RESPONSIBILITY OF THE SELLER.

THE WARRANTIES OF THIS SECTION SHALL BE APPLICABLE AS FOLLOWS:

1. FREE PARTS AND SERVICES WILL BE ALLOWED FOR THREE MONTHS.
2. FREE PARTS WILL BE ALLOWED FOR AN ADDITIONAL NINE MONTHS.

**C.** THERE SHALL BE NO WARRANTY BY SELLER FOR DEFECTS ATTRIBUTED IN WHOLE OR IN PART TO FACTORS BEYOND SELLER'S CONTROL, INCLUDING, BUT NOT LIMITED TO, BUYER'S DESIGN, FAILURE OF BUYER OR ITS CUSTOMERS TO PROPERLY PRESERVE, STORE, INSTALL, OPERATE OR MAINTAIN PARTS MADE BY SELLER.

SELLER ALSO DENIES LIABILITY FOR ANY FAILURE OR DETERIORATION OF PARTS ATTRIBUTABLE TO EXTENDED STORAGE UNDER CONDITIONS OF EXCESSIVE TEMPERATURE OR HUMIDITY, AND FOR MALFUNCTION OR DESIGN DEFICIENCY OCCURRING IN OTHER SYSTEMS OR INSTALLATIONS THAT WOULD IN TURN AFFECT THE PERFORMANCE OF THE PART.

**X.**

**J.L. SHEPHERD & ASSOCIATES**

**PRODUCT WARRANTY**

**MARK I SERIES IRRADIATOR**

**(CONCLUDED)**

SELLER FURTHER DENIES LIABILITY FOR PERFORMANCE OF THE PARTS WHEN ABNORMAL ENVIRONMENTAL OPERATING CONDITIONS ARE ENCOUNTERED.

**D.** ANY PART MADE BY SELLER WHICH BUYER CLAIMS TO HAVE FAILED OR TO BE DEFECTIVE AND COVERED BY THIS WARRANTY SHALL BE PRESENTED TO SELLER AT THE SELLER'S FACILITY, FOR EXAMINATION AND DISPOSITION BY SELLER.

**E.** THE WARRANTIES SET FORTH HEREIN ARE IN LIEU OF ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, AND THE LIABILITY OF SELLER UNDER THESE WARRANTIES SHALL BE LIMITED TO THE REPAIR OR REPLACEMENT OF NON-CONFORMING OR DEFECTIVE PARTS. OTHER THAN EXPRESSLY STATED ABOVE, SELLER SHALL ASSUME NO LIABILITY OF WHATSOEVER NATURE, INCLUDING LIABILITY FOR CONSEQUENTIAL DAMAGES, NOR MAKES ANY REPRESENTATIONS OR WARRANTIES, EITHER EXPRESS OR IMPLIED, AND SPECIFICALLY, THERE IS NO WARRANTY OF MERCHANTABILITY OR OF FITNESS, ARISING BY LAW OR OTHERWISE, WITH RESPECT TO THE MANUFACTURE OR USE OF SAID PARTS.

# JL SHEPHERD & ASSOCIATES

1010 ARROYO AVE., SAN FERNANDO, CALIFORNIA 91340-1822

818-898-2361 FAX 818-361-8095

## LEAK TEST / CONTAMINATION CHECK CERTIFICATION

TO: The Burke Medical Research Institute

JLS&A Ref #MK2553Tr

SOURCE: 20.366939 TBq (550.45783 Curies) Cesium-137, as of 5/25/2011  
J.L. Shepherd and Associates Model 6810 Source Capsule, S.N. JLS-2553  
NSTS ID # 142271

RESULTS:  $\leq 5 \times 10^{-3} \mu\text{Ci}$ .

INSTRUMENT: Ludlum Model 2200 Scaler/Ratemeter S.N. 106784

LEAK TEST TAKEN: June 29, 2011

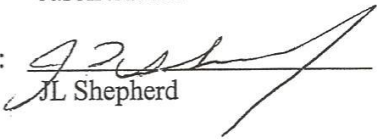
CERTIFICATE DATE: June 29, 2011

J.L. SHEPHERD AND ASSOCIATES

LEAK TEST PERFORMED BY:

  
Jason Breeze

CERTIFICATE APPROVED BY:

  
JL Shepherd



# JL SHEPHERD & ASSOCIATES

1010 ARROYO AVE., SAN FERNANDO, CALIFORNIA 91340-1822

818-898-2361 FAX 818-361-8095

## EXTERNAL RADIATION LEVEL CERTIFICATION

TO: The Burke Medical Research Institute JLS&A Ref #MK2553Tr

SOURCE: 20.366939 TBq (550.45783 Curies) Cesium-137, as of 5/25/2011  
J.L. Shepherd and Associates Model 6810 Source Capsule, S.N. JLS-2553  
NSTS ID # 142271

DEVICE: J.L. Shepherd and Associates Mark I, Model 25 Irradiator, S.N. 1033

INSTRUMENT: Ludlum 14C, S.N. 240212


SOURCE IN "ON" POSITION:	@ 2.5 cm from surface	@ 30 CM from surface
Tower:	≤ 0.1 mR/hr	≤ 0.1 mR/hr
Top of chamber:	≤ 0.4 mR/hr	≤ 0.1 mR/hr
Door (latch side)	≤ 0.1 mR/hr	≤ 0.1 mR/hr
Door (hinge side)	≤ 1.5 mR/hr	≤ 0.1 mR/hr
Scatter shield (plugs in)	≤ 0.3 mR/hr	≤ 0.1 mR/hr
Turntable box:	≤ 0.9 mR/hr	≤ 0.3 mR/hr
Rear:	≤ 0.5 mR/hr	≤ 0.1 mR/hr
Below chamber section:	≤ 0.1 mR/hr	≤ 0.1 mR/hr

SOURCE IN "OFF" POSITION:	@ 2.5 cm from surface	@30 cm from surface
Below chamber section:	≤ 0.15 mR/hr	≤ 0.1 mR/hr
Above chamber section:	≤ 0.3 mR/hr	≤ 0.1 mR/hr
Inside chamber		
At bottom of source tube	≤ 20 mR/hr	

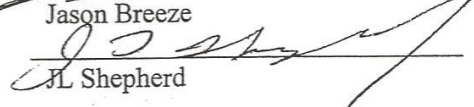
DATE: June 28, 2011

J.L. SHEPHERD AND ASSOCIATES

PERFORMED BY:

  
Jason Breeze

APPROVED BY:

  
J.L. Shepherd

# JL SHEPHERD & ASSOCIATES

1010 ARROYO AVE., SAN FERNANDO, CALIFORNIA 91340-1822

818-898-2361 FAX 818-361-8095

## CALIBRATION CERTIFICATION

TO: The Burke Medical Research Institute JLS&A Ref #MK2553Tr

SOURCE: 20.366939 TBq (550.45783 Curies) Cesium-137, as of 5/25/2011  
J.L. Shepherd and Associates Model 6810 Source Capsule, S.N. JLS-2553  
NSTS ID # 142271

DEVICE: J.L. Shepherd and Associates Mark I, Model 25 Irradiator, S.N. 1033

INSTRUMENT: All calibration is done with MDH Industries Model 2025 X-ray Monitor,  
S.N. 22580, with Converter S.N. 8701 and 0.18 cc probe, S.N. 22188.

This meter is calibrated by J.L. Shepherd and Associates for Cs-137 in Model 89-400  
Calibration Range, S.N. 8190, with NIST traceability by use of NIST Transfer Dosimeters,  
National Institute of Standards and Technology Report # DB1044/073, Dated April 11, 2011,  
DB1034/087, dated April 21, 2009, DB1015/013, April 27, 2004 and DB 917/144, dated March  
20, 1996.

Accuracy is  $\pm 5\%$ .

POSITION, DISTANCE & OUTPUT: Please see attached Isodose Curves

CAUTION: The user is responsible for selecting the correct radiation dose corresponding to the correct turntable position and ensuring that it has been delivered. The actual 100% area dose rates (R/min) for each turntable position and the source strength (Curies) are measured by J.L. Shepherd and Associates for the Mark I and their values are provided on Isodose Curves, which are a part of the Manual. The dose distribution functions are given as percentages of the 100% dose area. The dose rates are measured in air, and the point at which it is measured, with the above referenced NIST traceable instrument, corresponds to the geometrical center of the turntable volume. The 100% dose rate and Curie content are functions of time. The rate of Cesium-137 decay with respect to time is 30.17 years.

Note: All information provided on the radiation performance of the irradiator is for the "as designed" application. Therefore for the data to be applicable, the irradiator must be used with the turntable rotating. Turntables are removed for cryogenic chamber and collimator use.

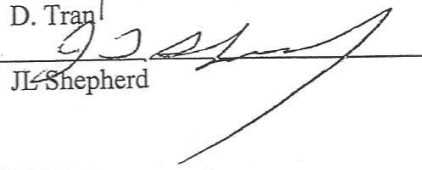
DATE: June 15, 2011

J.L. SHEPHERD AND ASSOCIATES

PERFORMED BY:

  
D. Tran

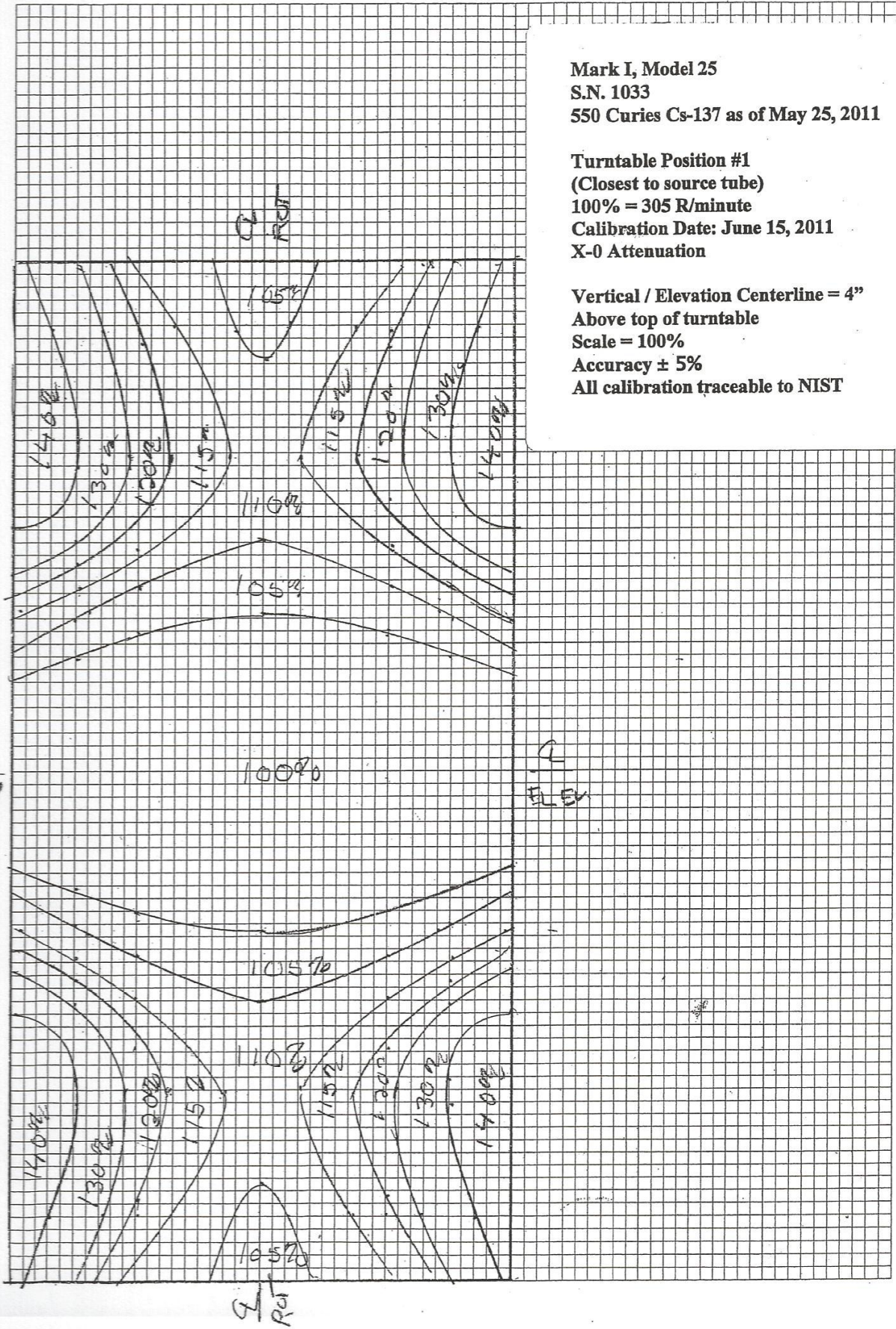
APPROVED BY:

  
J.L. Shepherd

46 0703

K&E 10 X 10 TO THE INCH .7 X 10 INCHES  
KRUEFFEL & ESSER CO. MADE IN U.S.A.

Q  
ELEV



Mark I, Model 25  
S.N. 1033  
550 Curies Cs-137 as of May 25, 2011

Turntable Position #1  
(Closest to source tube)  
100% = 305 R/minute  
Calibration Date: June 15, 2011  
X-0 Attenuation

Vertical / Elevation Centerline = 4"  
Above top of turntable  
Scale = 100%  
Accuracy  $\pm$  5%  
All calibration traceable to NIST

Mark I, Model 25  
 S.N. 1033  
 550 Curies Cs-137  
 As of May 25, 2011

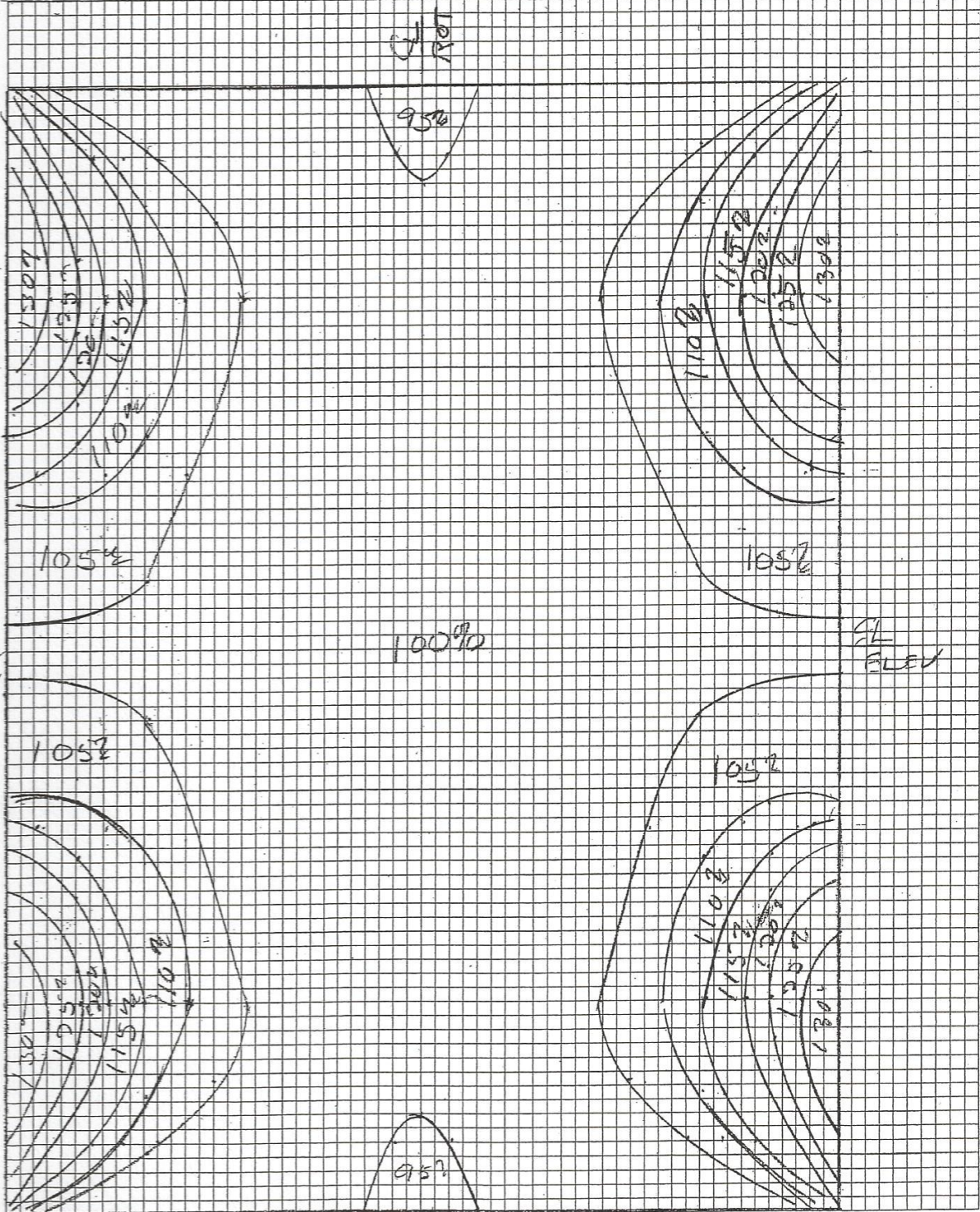
Turntable Position #2  
 (Center of chamber)  
 100% = 195 R/minute  
 Calibration Date:  
 June 15, 2011  
 X-0 Attenuation

Vertical / Elevation Centerline =  $6''$   
 Above top of turntable  
 Scale = 100%  
 Accuracy  $\pm 5\%$   
 All calibration traceable to NIST

46 0703

10 X 10 TO THE INCH, 7 X 10 INCHES  
 KEUFFEL & ESSER CO. MADE IN U.S.A.

9  
 ELEV



95%  
 Rot

Mark I, Model 25  
S.N. 1033  
550 Curies Cs-137  
As of May 25, 2011

Turntable Position #3  
(Closest to door)  
100% = 130 R/minute  
Calibration Date:  
June 15, 2011  
X-0 Attenuation

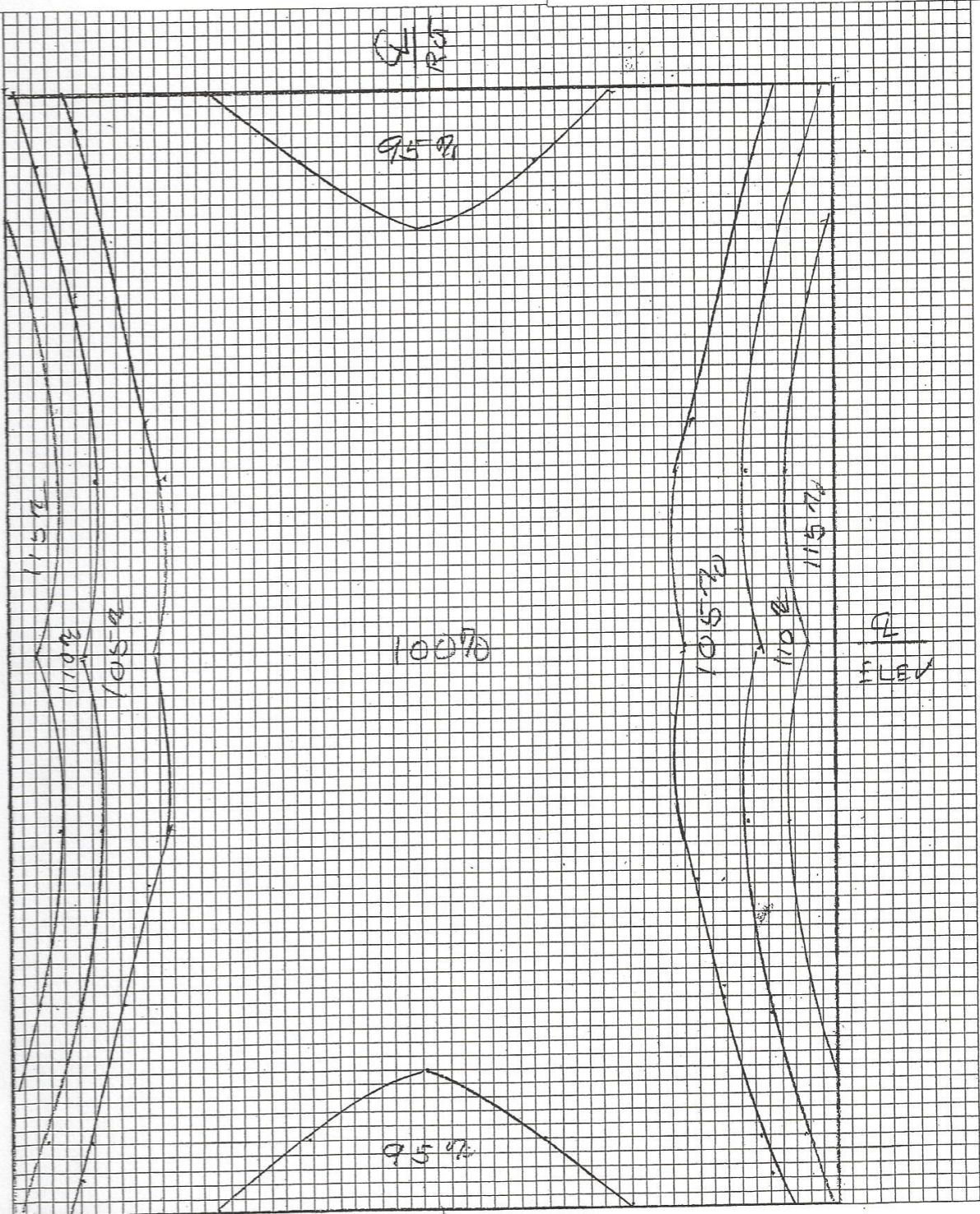
Vertical / Elevation Centerline = ~~4~~ 6" <sup>10</sup>  
Above top of turntable  
Scale = 100%  
Accuracy ± 5%  
All calibration traceable to NIST

46 0703

10 X 10 TO THE INCH • 7 X 10 INCHES  
KEUFFEL & ESSER CO. MADE IN U.S.A.



CL  
ELEV



CL  
R/

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## CESIUM -137 DECAY TABLE

HALF LIFE: 30 + 0.17 YEARS  
OUTPUT: CALIBRATED OUTPUT x DECAY FACTOR  
MONTHLY DECAY FACTOR= 0.99808  
QUARTERLY DECAY FACTOR= 0.99424  
SEMI-ANNUAL DECAY FACTOR= 0.98851

### DECAY TABLE BY YEARS

<u>YEARS</u>	<u>DECAY FACTOR</u>	<u>YEARS</u>	<u>DECAY FACTOR</u>
0.0	1.0000	15.5	0.6989
0.5	0.9885	16.0	0.6912
1.0	0.9772	16.5	0.6831
1.5	0.9659	17.0	0.6751
2.0	0.9548	17.5	0.6676
2.5	0.9439	18.0	0.6598
3.0	0.9330	18.5	0.6521
3.5	0.9223	19.0	0.6449
4.0	0.9117	19.5	0.6376
4.5	0.9012	20.0	0.6299
5.0	0.8908	20.5	0.6229
5.5	0.8806	21.0	0.6156
6.0	0.8705	21.5	0.6084
6.5	0.8605	22.0	0.6017
7.0	0.8506	22.5	0.5947
7.5	0.8408	23.0	0.5877
8.0	0.8312	23.5	0.5812
8.5	0.8216	24.0	0.5744
9.0	0.8122	24.5	0.5677
9.5	0.8029	25.0	0.5624
10.0	0.7936	25.5	0.5549
10.5	0.7845	26.0	0.5484
11.0	0.7755	26.5	0.5423
11.5	0.7666	27.0	0.536
12.0	0.7578	27.5	0.5297
12.5	0.7491	28.0	0.5238
13.0	0.7405	28.5	0.5177
13.5	0.7319	29.0	0.5116
14.0	0.7235	29.5	0.5060
14.5	0.7152	30.0	0.5000
15.0	0.707		