TENNESSEE STATE UNIVERSITY

RADIATION SAFETY MANUAL

2000 EDITION

RADIATION SAFETY SUBCOMMITTEE

OFFICE OF SPONSORED RESEARCH

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RADIATION SAFETY MANUAL

CHAPTER I: INTRODUCTION

1.0 General Overview

This manual applies to all personnel at Tennessee State University (TSU) who procure radioactive materials or use radiation producing machines. The purpose of this manual is to protect the user, coworkers and the general public from exposure to excessive levels of radiation and concentrations of radioactive materials. It provides the user of ionizing radiation sources with a reference guide to regulatory agency requirements. All authorized use of ionizing radiation sources on the TSU campus is in compliance with TSU policies, state, and Federal regulatory requirements.

1.1 Radiation Safety Subcommittee

Radiation safety for research and instruction at TSU is coordinated by the **Radiation Safety Subcommittee (RSS)**. RSS is a subcommittee of **TSU's Biosafety Committee**. The Subcommittee is comprised of qualified representatives appointed by the President with recommendations from the Director of Sponsored Research with approval from the Vice President for Academic Affairs. Membership is consistent with the provisions of 10 CFR 33 " Specific Domestic License of Broad Scope for By-Product Material." The Subcommittee normally meets once a month. However, special call meetings are scheduled when needed.

The Radiation Safety Subcommittee is responsible for the development of uniform radiation safety policies at all TSU facilities, ensuring compliance with TSU policies as well as state and federal regulations. The subcommittee advises the Vice President for Academic Affairs and the Director of Sponsored Research on important matters pertaining to radiation safety, and the surveillance of TSU activities involving the use of radioactive materials and radiation producing machines. The subcommittee seeks to maintain an environment for research and/or class activities with radiation levels **A**s Low **A**s **R**easonably **A**chievable (**ALARA**). In order to safely manage TSU's radiation program, all procurement or possession of radioactive materials,

operation of radiation producing machines, and plans for construction or alteration of building facilities that contain ionizing radiation must be approved by the RSS. RSS has the authority to approve, disapprove or modify all proposals or procurements involving radioactive materials or radiation producing machines for research, instruction or related activities. The RSS requires that

- Written records of radioactive waste storage and disposal information be maintained by the Radiation Safety Officer (RSO)

- All radiation laboratories be surveyed at least once every Month by the RSO

- All survey instruments be calibrated annually by a company certified to perform such activity

- Official list of authorized users and operators under current license be maintained by the RSO

- Training courses be given to laboratory technicians who are involved with radioactive materials

- Workshops be provided for all housekeeping, security, and receiving personnel

- Posting of proper regulatory caution signs be made by all users and operators who are in charge of a radiation laboratory

- Personnel occupationally exposed to radiation be required to wear TLD badges and ring /pocket dosimeters or use effective shields for certain machines

- Written operating and emergency procedures pertaining to radiation safety be established for each facility

- Official locations of radiation producing machines and radioactive materials be kept by the RSO

- Registration of radiation producing machines be made with SRPAR

1.3 Radiation Safety Officer

The Radiation Safety Officer (RSO) is a professional staff member at TSU who works closely with the Radiation Safety Subcommittee. The RSO does not make radiation policy, but seeks to enforce and execute policy established by the RSS. The RSO is responsible for the following:

- Conducting inspections and reviews to verify that authorized radioisotope users and radiation producing machine operators comply with the Tennessee SRPAR requirements, Federal regulations, and policies.

- Ordering radioactive materials and maintaining current inventory of radioisotopes at TSU

- Ensuring that TOSHA standards relevant to the use of ionizing radiation are not violated

- Coordinating the film badge service and dosimetric activities at TSU to maintain exposure records of personnel

- Addressing emergency situations and requests for action involving radioactive materials

- Supervising and coordinating the radioactive waste storage and disposal program

- Performing or arranging the calibration of survey instruments

- Supervising and coordinating radiological safety courses, seminars, and workshops for faculty, staff , and students

- Updating the RSS on changes of Tennessee SRPAR requirements and Federal regulations (NRC)

- Providing housekeeping, security, and receiving personnel with radiation safety courses

- Ensuring that regulatory signs and markings are posted in laboratories and areas of storage

1.4 License and Tennessee "State Regulations for Protection Against Radiation" (SRPAR)

Radioactive materials and radiation producing machines are used at TSU in compliance with "State Regulations for Protection Against Radiation" (SRPAR) under the authority of the Division of Radiological Health, Tennessee Department of Environment and Conservation (TDEC). This authority includes approval of license applications, issuance of notices of violations of State regulations or license provisions, modification, suspension or revocation of approvals for health and safety.

The Tennessee Department of Environment and Conservation is responsible for protecting Tennesseans and the environment from the hazards associated with ionizing radiation. This responsibility consists of regulating the use and possession of radioactive materials and radiation producing machines, as described above, within the state, as well as responding to accidents involving radiation.

1.5 Responsibilities of Radioactive Users and Radiation Producing Machine Operators

Radioisotope users and radiation producing machine operators are responsible and liable for all personnel who may be exposed to radiation, including visitors, and personnel in neighboring laboratories. Users and operators are also responsible for maintaining a safe work environment in the laboratory, keeping written records, and enforcing all safety procedures to comply with SRPAR requirements and the policies of the Radiation Safety Subcommittee and the Radiation Safety Officer.

In addition, users and operators are to arrange both film badge service and access to dosimeters with RSO as well as physical examination when appropriate. Routine surveying of the work area with calibrated instruments and maintaining proper temporary storage and preparing radioactive materials for disposal are the responsibilities of all users and operators.

Users and Operators are required to identify any problems in their area of work arising from the Radiation Safety Subcommittee, SRPAR and Federal regulations. It is critical that users and operators meticulously adhere to this regulation to avoid radiation accidents and major violations with Federal, SRPAR and TSU's Radiation Safety Subcommittee. Substantial changes in

experimental and/or radiation working conditions of research or instructional laboratories must be approved by the Radiation Safety Subcommittee.

All radiation producing machines must be registered with the Radiation Safety Subcommittee and SRPAR. Finally, users and operators are responsible for training of all personnel within their jurisdiction via RSO.

1.6 Radiation Dosimetry Units and Definitions

The amount of energy absorbed by irradiated tissue is an important variable in the assessment of radiation risk and damage. The absorbed dose is defined as the energy absorbed per unit mass of tissue. The classical unit for absorbed dose is the **rad (radiation absorbed dose)**.

$$\textbf{1 rad = 100 erg/gram} \quad \textbf{where an erg = dyne} \cdot \textbf{cm = g} \cdot \textbf{cm/s}^2 \cdot \textbf{cm}$$

The rad is being replaced by a new unit based on the International System (SI) of units (The Gray, Gy).

$$\textbf{1 Gray (Gy) = 1 joule/kg} \quad \textbf{where a joule = Newton} \cdot \textbf{m = kg} \cdot \textbf{m/s}^2 \cdot \textbf{m}$$

It can be illustrated with a little "physics of units" that a Gray is mathematically related to the rad by

$$\textbf{1 Gray = 100 rad}$$

The SI units have not found widespread use in the United States. The continents of Africa, Asia, and Europe have made remarkable progress.

Radiation comes in several types which includes neutrons, alpha particles, beta particles, and gamma/X-radiation. Each type of radiation differ in the damage produced for a given absorbed dose. Special units of **dose equivalent** are used to adjust to the absorbed dose for this difference. The classical unit for **dose equivalent** is the **rem (roentgen equivalent man).** The rem is related to the rad by

$$\textbf{1 rem = 1 rad} \cdot \textbf{Q}$$

The symbol Q is defined as the **quality factor** and is assigned to radiation type based on the relative risk for a given dose.

The table below provides the **Q** values for each type of radiation which includes X-rays, beta particles, alpha particles, neutrons, and gamma rays.

QUALITY FACTOR FOR RADIATION TYPE

Table 1

Radiation Type	Q
X & Gamma Rays	1
Beta Particles	1
Neutrons	2.3 to 10
Alpha Particles	20

The SI unit for **dose equivalent** is the Sievert. The Sievert is related to the Gray by the equation

$$\textbf{1 Sievert} = \textbf{1 Gray} \cdot \textbf{Q} = \textbf{100 rem}$$

The amount of radiation energy absorbed by tissue is rarely measured directly. Most radiation detection instrumentation used in radiation protection measures the number of ion pairs produced in a volume of gas. The classical unit used to measure ionization in air is the **roentgen:**

$$\textbf{1 Roentgen} = \textbf{2.58 x } 10^{4} \textbf{ coulombs/kg of air}$$

The roentgen is defined only for x-rays and gamma rays. It is not used for alpha, beta or neutron radiation. The exposure of 1 roentgen of radiation results in an absorbed dose to tissue of 0.97 rad (then 1 roentgen is approximately 1 rad). It is generally assumed that the **roentgen, rad** and the **rem** are numerically equivalent for x-rays and gamma rays. Organs and tissues in the body differ in their sensitivity to radiation. Blood forming tissue and bone marrow are much more sensitive to radiation than the skin. In an effort to quantify the risk from radiation exposure when the body is not irradiated uniformly (when different doses are delivered to different organs or tissues) a unit called effective dose equivalent (symbol H) has been developed.

$$\mathbf{H = \sum Di\ Wi = \sum (D_1 + D_2 + D_3 + \ldots D_n)\ (W_1 + W_2 + W_3 + \ldots W_n)}$$

The term Di is the dose equivalent received by the ith tissue or organ, and Wi represents a weighting factor which is assigned to the ith tissue or organ

depending on its sensitivity to radiation. The weighting factors currently in use are listed in the table below:

EFFECTIVE DOSE EQUIVALENT

Table 2

TISSUE	Gonads	Breast	Red Bone Marrow	Lung	Thyroid	Bone Surfaces	Remainder	Whole Body
WEIGHTING FACTOR	0.25	0.15	0.12	0.12	0.03	0.03	0.30	1.00

When radioactive materials are inhaled, ingested, or otherwise internalized, they may be retained in some tissues for long periods of time. The committed effective dose equivalent is the dose equivalent that will be received from an intake of radioisotopes by a person during a 50 year period following the intake.

The deep dose equivalent is the dose equivalent at a tissue depth of 1 cm. The shallow dose equivalent is the dose equivalent at a tissue depth of 0.0007 cm averaged over an area of 1 square cm (cm^2). The eye dose equivalent is the dose equivalent to the lens of the eye.

Finally, the total effective dose equivalent is the sum of the committed effective dose equivalent for all intakes of radioactive material and deep dose equivalent to the whole body resulting from exposure to external sources of radiation.

1.7 Radioactivity

Atoms with unstable nuclei undergo a process called disintegration forming different atoms and releasing radiation as alpha particles, beta particles or x-rays and gamma rays. Atoms that disintegrate are called radioisotopes or radionuclides. The radioactivity or activity is normally described as the number of disintegrations per unit time. The SI unit for radioactivity is the becquerel (Bq). The SI unit was recently named in honor of Lord Becquerel for his distinguished work with radioactive materials.

1 becquerel (Bq) = 1 disintegration per second (dps)

However, in the United States the use of the curie is still prominent. The curie came about as result of the pioneering work of Nobel Prize Laureate,

Marie Curie. The **Ci** is a very large radiation unit and continues to maintain extraordinary popularity in United States.

$$\textbf{1 curie (Ci) = 3.7 x } 10^{10} \textbf{ dps}$$

Other popular units in the United States are the millicurie (mCi) and the microcurie (μCi). Activities used at TSU is mainly in the microcurie (μCi) range. As a radioisotope disintegrates or decays into other isotopes, it loses mass and thereby a decrease in activity. The change in activity is proportional to the change in mass. The change in activity is given by

$$A_t = A_o e^{-\lambda t}$$ where A_t is the activity after the elapsed time, t and A_o is the initial activity at time, t =0

The **symbol λ is the decay rate.** It describes how fast a radioisotope is disintegrating. The time required for a radioisotope to lose half of its activity is called its **half-life,** $t_{1/2}$. The half-life, $t_{1/2}$ is related mathematically to the decay rate, λ by the equation below.

$$\lambda = 0.693 / t_{1/2}$$

1.10 ALARA Policy

The Radiation Safety Subcommittee supports and requires that all radiation personnel and principal investigators operate such that radiation doses will be **A**s **L**ow **A**s **R**easonably **A**chievable (**ALARA**). It is the responsibility of all radiation users, operators, and supervisors to make every effort to operate within the ALARA guidelines.

Due to the uncertainties that exist about health effects of exposure to doses of radiation, it is prudent to keep dose levels to personnel within the policy limits of ALARA. It is highly recommended that each radiation user or operator incorporate effective shielding and protective devices to keep doses at ALARA.

1.11 Classification of Radioisotopes Relative to Their Hazard Potential

Radioisotopes are classified according to their relative hazard potential. They are described as 1) **Class 1(very high toxicity), Class 2 (high toxicity, moderate toxicity) and Class 4 (slight toxicity).**

Class 1 (Very High Toxicity)
Sr-90 + Y-90, Pb-210 + Bi-21), Po-210, At-211, Ra-226, Ac-227, Th-228, Th-231, U-233, Pu-238, Pu-239, Am-241, Cm-242, Cf-252, and other transuranic isotopes

Class 2 (High Toxicity)
Ca-45, Ca-47, Fe-59, Co-60, Sr-85, Sr-89, Y-91, Ru-106 + Rh-106, Cd-109, Cd-115, I-125, Ba-140, La-140, Ce-144 + Pr-144, Sm-151, Eu-154, Tm-170, Hg-203, Bi-207, Th-232, natural thorium and natural uranium.

Class 3 (Moderate Toxicity)
Na-22, Na-24, P-32, P-33, S-35, Cl-36, K-42, Sc-46, Sc-47, Sc-48, V-48, Cr-51, Mn-54, Mn-56, Fe-55, Co-57, Co-58 Ni-59, Ni-63, Cu-64, Cu-67, Zn-65, Ga-67, Ga-68, Ga-72, As-74, As-76, Br-82,Kr-85, Rb-84, Rb-86, Y-90, Zr-95,Nb-95,Mo-99, Tc-99, Rh-105, Pd-103 + Rh-103, Ag-105, Ag-111, Sn-113, Te-127, Te-129, I-132, Xe-133, Cs-137 + Ba-137, La-140, Pr-143, Pm-147,Ho-166, Lu-177, Ta-182, W-181, Re-183, Ir-190, Ir-192, Pt-193, Au-198, Au-199, Tl-200, Tl-202, Tl-204, Pb-203, Hg-197.

Class 4 (Slight Toxicity)
H-3, Be-7, C-14, F-18, Cr-51, Ge-68, Ge-71, Sr-87, Tc-99, In-111, Tl-201, U-235, and U-238

1.12 Characteristics of Radioisotopes Used at TSU

TSU is permitted under license agreement with SRPAR to use ^{3}H, ^{32}P, ^{14}C, ^{35}S, ^{125}I, ^{51}Cr, and ^{65}Ni. The emission characteristics and rate of decay via half-life of several important radioisotopes are described below:

- ^{3}H is a long lived β^- emitter with energies as high as 18.6 KeV. Because the range of these β^- particles is less than 1 cm in air, ^{3}H is not considered as an external hazard unless deposited in the skin. An internal dose may develop if ingested. As a result, TLD badges are not needed. However, it is recommended that ring dosimeters be worn.

- ^{14}C is also a long lived beta emitter with energies as high as 156 KeV. The range of these β^- particles is approximately 30 cm in the air. It is because of this range that ^{14}C is considered to be both an external and

internal radiation hazard. It is highly recommended that users wear TLD badges and ring dosimeters at all times.

- ^{32}P is a short lived β^- emitter with energies as high as 1700 KeV. It has a range of 37.5 cm (15 ft.) in the air. With a 15 ft. range and the fact that phosphorus concentrates in the bone, ^{32}P is considered a radiation hazard. Fortunately, ^{32}P has an half-life life of 14 days.

CHAPTER 2: RADIOACTIVE MATERIAL USE AND OPERATING PROCEDURES

2.0 Application for Tennessee License

Tennessee State University policy on the safe handling of radioactive materials is based on the Tennessee SRPAR. The use of radioactive materials in Tennessee requires a license from the State, whereas the use of radiation producing machines requires a registration.

The Radiation Safety Subcommittee controls the use of radioactive materials through the Radiation Safety Officer according to the conditions contained in TSU's License Agreement with SRPAR requirements.

2.1 Procurement and Use of Radioactive Materials

Requests by authorized license users to procure and acquire radioactive materials are prepared on the **TSU Application for Procurement of Radioactive Materials.** The applicant (potential user) should submit an experiment protocol or describe those experimental procedures or actions that may affect or cause the inadvertent release or ingestion/inhalation of radioactive materials. The applicant should also name any hazardous chemicals that will be used. Material Safety Data (MSD) sheets should be provided as guides for their safe use.

All applications for purchase of radioactive materials must be approved by the Radiation Safety Subcommittee, and ordered by RSO through the Department of Purchasing. The RSO may perform an expedited approval and authorization of applications considered to be routine with little or no high risk. The Radiation Safety Subcommittee considers the following radioisotopes or activities to be major in nature and will require the full Committee for review and approval:

- Applications for acquisition of **hazard class I radioisotopes** in quantities greater than 100 μCi

- Applications for acquisition of **hazard class II radioisotope** in quantities greater than 1mCi

- Applications for experiments or projects which involve substantial Airborne radiation hazards arising from gases, fine powders or aerosols

- Applications for new installations, major repairs or modifications to existing facilities on the TSU campus involving the use of ionizing radiation sources

2.2 Amendments

A request for amendment to an approved application is submitted as described above. Amendment requests may be made only for changes in quantities of radioisotope, addition or deletion of users, or changes in the location where radioisotopes will be used. However, requests for new projects or uses, or different radioisotopes must be submitted on a new application.

2.3 Receipt, Shipment, and Delivery of Radioactive Materials

The Radiation Safety Committee does not allow radioactive materials to be brought onto or shipped from the campus without prior approval from the RSO. Inbound shipments must be received (by the RSO or his trained designee) in the Chemistry Stockroom of Boswell Science Complex, where they are **checked for damage**, **carrier packaging** and **labeling** by the RSO or his designee, and then released for delivery to the end user. This procedure is intended to provide protection to those individuals handling radioactive material as well as to comply with TSU requirements and Federal and SRPAR regulations.

2.4 Personnel Dosimetry for Radioactive Materials

The general policy of the RSS requires that all persons listed on the application for use of radioactive materials be listed on the TSU Dosimetry Program. The TSU Dosimetry Program is a personnel radiation monitoring program designed to protect radioisotope users, supervisors and workers from hazardous radiation.

2.40 TSU Dosimetry Program

The Dosimetry Program requires that each authorized user of radioactive materials wear a radiation monitoring device such as a **thermoluminescent dosimeter badge (TLD badge) or a ring dosimeter.** It further requires that a certified radiation monitoring service be used by the RSO to supply and evaluate all TLD badges and/or ring dosimeters every 90 days for all radioactive material users and x-ray machine operators.

2.41 External Dose

TLD Badge/TLD Ring: The Tennessee SRPAR regulation specifies strict occupational radiation limits for various organs of the body and are given below in table 4.

The TLD badge measures the deep dose equivalent from external sources of radiation. **SRPAR regulations require a user to be monitored provided he/she will receive or likely to receive 10 % of the occupational limit**. The TLD badges are measured every 90 days (quarter) by a monitoring service company to ensure that the user may not approach the 5 rem/yr. limit.

Every 90 days the RSO provides a summary of personnel exposures to the supervisor of each laboratory using radioactive materials. However, any user may contact the RSO at any time concerning his or her exposure. Users are required to wear the TLD badge on his/her collar, shirt pocket or waist. TLD badges must be exchanged every three months.

The TLD rings are required for users who have prolonged handling of radioactive materials with the hands. These TLD rings are also read quarterly to ensure the occupational limit is not approached. In order to minimize the amount of external exposure to radiation, the rules and regulations below must be followed:

- Always wear TLD badges when working around radioactive materials
- Do not store TLD badges in a radiation area
- Do not share TLD badges

- Do n
- ot expose TLD badges to excessive heat
- Spend as little time as necessary in a radiation field or near a radiation source
- Obtain new TLD badges when lost or damaged
- Do not stand any closer to a radiation source than absolutely necessary
- Use protective shielding techniques from sources of radiation when needed to keep dose levels at **ALARA**

2.42 Internal Dose

Bioassay Section: An internal dose is possible when radioisotopes are taken into the body by ingestion, inhalation or absorption. Absorption via an open wound is particularly hazardous. Contamination in the laboratory is the most probable cause for increasing the internal dose.

The spread of contamination can result if a spill occurs or if protective clothing, including shoes, protective lab coats, and gloves are not worn. Some contamination is inevitable in a radiation work area. However, the limit of 100 dpm per 100 cm^2 of surface area has been set.

To inhibit the spread of contamination, survey instruments or liquid scintillation counters are employed to monitor areas where radioactive materials are used. For non-work areas such as desks, chairs, phones and door knobs, the limit is background. **THESE SURVEYS ARE MANDATORY!** The laboratory work areas and non-work areas must be made by annually calibrated instruments. A Daily Laboratory Survey Form must be completed every day radioisotopes are used in the laboratory. These forms must be submitted to the Radiation Safety Office every 90 days or on a quarterly basis. The quarterly report to the Radiation Safety Office will reflect the use of the laboratory facility and the adherence of the principal investigator and users to policy and operating procedures.

Daily Laboratory Survey Form

Building:_____ Room:_____ PI:_____

Isotope & Activity (μCi)	Areas Surveyed	External Background Level (mR/hr)	Action Taken

Signature:_____ Date:_____

Some mandatory rules that can be used to limit the amount of radioactive material taken into the body are listed below:

- Perform required daily laboratory surveys
- Do not eat, drink, apply cosmetics or use tobacco around radioactive materials
- Use fume hoods with volatile radioactive materials
- Do not store food in a place used to store radioactive material such as a freezer or refrigerator
- Wear protective clothing such as gloves, shoes, and lab coats
- Properly dispose of radioactive waste
- Follow instructions when a spill occurs
- Do not allow open wounds to come in contact with radioactive materials
- Participate in the Bioassay Program to protect yourself from hazardous doses of radioactive materials

Users exposed to unsealed sources of radioactive material with activities greater than the levels set by RSS are required to participate in the Bioassay

Section of the Dosimetry Program. Users working with or exposed to 100 mCi or more of ^{3}H must notify the RSO and submit a urine specimen for analysis. Users exposed to 1 mCi or more of volatile or dispersible radioiodine or 10 mCi or more of non-volatile radioiodine must call RSO for a thyroid check (Thyroid Counting).

Radiation Dose Limits: Allowable occupational radiation dose levels are established and set by 10 CFR 20. The levels are based on recommendations by the International Committee on Radiation Protection (ICRP), the National Council on Radiation Protection and Measurements (NCRP) and by NRC and Tennessee SRPAR regulations. The 10 CFR 20 regulatory limits are established to protect users of radioactive materials. The regulatory limits are provided in the table below:

ANNUAL ADULT* DOSE LIMITS

Table 3

Category	Dose
Total Effective Dose Equivalent (TEDE)	**5 rem/year**
Total Organ Dose Equivalent (TODE)	**50 rem/year**
Eye Dose Equivalent (EDE)	**15 rem/year**
Shallow Dose Equivalent (SDE)	**50 rem/year**

*The radiation doses for minors, persons under the age of 18, are limited to 10 percent of the limits for adults

The average annual background radiation (radiation from the environment) in the United States is approximately 300 – 500 millirem/year.

Prenatal Dose Limits: The effects on the human embryo or fetus during the first trimester can be catastrophic. As a result, the RSS and the RSO want to have an occupationally safe environment to ensure the proper development of the embryo or fetus. The dose limit to the embryo or fetus of a declared pregnant woman is 0.5 rem. This limit is strictly enforced by the RSO.

The Biosafety Committee and the Radiation Safety Subcommittee require that all women doing research or laboratory class activities in agriculture, allied health, art, biology, chemistry, engineering and technology, nursing,

or physics be given an opportunity to voluntarily declare their state of pregnancy or non-pregnancy.

A declared pregnant woman is a woman who voluntarily informs the RSO by completing the Safety Information Data (SID) form. The SID form, along with an array of other safety data, informs the RSO of her pregnancy and the approximate date of conception.

The dose to an embryo or fetus is the sum of the **deep-dose equivalent** to the declared pregnant woman and the dose from internally deposited radioisotopes in the embryo or fetus and the woman.

Delivery of Badges/Dosimeters: All TLD badges and ring dosimeters must be hand delivered by each authorized laboratory supervisor (principal investigator) to the RSO at least 7 days before the end of the quarter (90 day period). Failure to submit the radiation monitoring devices to the RSO on time may result in the suspension of the user's authority to use radioactive materials in research or laboratory classes at TSU.

It is not permitted for users to deliver TLD badges or ring/pocket dosimeters by campus mail. Delivery of such radiation monitoring devices by campus mail may affect the accuracy of the amount of radiation dose absorbed by a user over the 90 day period and would also be in violation of the ALARA guidelines.

2.5 Orientation and Training

All **new radioactive material users** must attend an orientation session with the RSO. The orientation is normally scheduled three times a year (Twice during the academic year and once during the summer). The orientation training course is designed for new users of radioactive materials and covers the following topics:

- Safe Use of Laboratory Equipment and Materials including Protective Clothing
- Experimental Procedures and Protocols, including Operating Procedures
- Safe Handling, Storage, and Disposal of Radioactive materials on the TSU campus

- Proper Maintenance of Required Records
- Emergency Procedures
- Methods to Control and Measure Radiation Levels and Contamination in all radiation laboratories

A **special refresher training course** is provided annually for **experience users** of radioactive materials to keep them up-to-date with latest Federal and state regulations and TSU policies.

2.6 Storage and Disposal of Radioactive Materials

Users of radioactive materials must make inventory of all radioisotopes on the **Radioactive Waste Disposal Report** which provides accountability for receipt and disposal of such material in each laboratory. The form must show the radioisotopes and activity levels on hand on a quarterly basis (90 days). The report must be returned every 90 days to the RSO. The official form is shown below:

Radioactive Waste Storage/Disposal Report

Reporting Period:_____ **Principal Investigator:**_____

	TSU Approved Radioisotopes											
Information/Action	^{3}H		^{14}C		^{32}P		^{51}Cr		^{63}Ni		^{125}I	
	ml	µCi	ml	µCi	ml	µCi	ml	µCi	ml	µCi	ml	µCi
Original Quantity on Hand												
Quantity Received												
Total Quantity Available												
Amount Lost to Decay												
Liquid Disposed to Sewer												
Liquid Disposed to RSO												
Solids Disposed to RSO												
Lost to Air or Transferred												
Subtotal Disposed of												
Ending Quantity on Hand												

Signature:_____ **Date:**_____

2.60 Rules and Regulations

The storage and disposal of radioactive waste is a very complex and important process. **Waste transporters, waste site managers, principal investigators, and the Radiation Safety Officer** are the key players involved with this process.

It is critical that **specific information** on each **waste container** be documented once it has left the laboratory in addition to the documented information provided on the **Radioactive Storage/Disposal Report**. All parties named above must have information on and know the following about the radioactive materials to be stored or disposed of:

- Physical form
- Chemical Form
- Activity (mCi or μCi)
- Half-life

Radioactive waste is treated according to its properties as described above. The **Tennessee SRPAR** impose specific regulations regarding waste categories and corresponding rules for separating radioactive materials into specific waste containers.

Dry Solids

The operating procedures at TSU are in compliance with Federal, state, and local regulations. The TSU operating procedures for handling solid waste are listed below:

- Dry solids must be separated from liquid waste

- Less than 90 day half-life dry solid material is to be disposed of separately from greater than 90 day half-life dry solid material

Solid radioactive waste with half-lives less than 90 days will at least lose more than half of their activity or concentration in a 90 day period or a quarter. In six months, the radioisotopes will at least lose more than 75% of their original activity or concentration. As can be seen, radioisotopes with short half-lives or fast decay rates can be allowed to essentially decay into background levels of radioactivity.

DRY SOLID WASTE
<90 HALF-LIFE

Building:_____ Room:_____ PI:_____

Date	Radioisotope	Activity (µCi)	Chemical Form	Volume (ml)	PI Initial

Signature:_____ Date:_____

DRY SOLID WASTE
>90 HALF-LIFE

Building:_____ Room:_____ PI:_____

Date	Radioisotope	Activity (µCi)	Chemical Form	Volume (ml)	PI Initial

Signature:_____ Date:_____

Aqueous Bulk Liquids
The TSU rules for handling aqueous bulk liquids are also in compliance with Federal, state, and local regulations and are summarized below:

- Separate 5 gallon containers must be used for less than 90 day half-life aqueous liquids and greater than 90 day half-life aqueous liquids

- Call the RSO when the 5 gallon containers are full (**DO NOT OVER FILL THE CONTAINERS WHICH MAY RESULT IN SPILLS)**

- State Regulations (SRPAR) allow principal investigators to dispose of aqueous liquids into the sewer with approval of the Radiation Safety Officer under the following regulatory conditions:

  > The liquid must be readily soluble in water (See RSO)

  > PI may dispose no more than 20 μCi per day of waste into the sewer

Non-Aqueous Bulk Liquids

Non-aqueous liquid waste cannot be disposed into sewer under no condition. Use 5 gallon container for disposal. The specific rules are:

- Separate 5 gallon containers must be used for less than 90 day half-life non-aqueous liquids and greater than 90 day half-life non-aqueous liquids

- Call the RSO when the 5 gallon containers are full (**DO NOT OVER FILL THE CONTAINERS WHICH MAY RESULT IN SPILLS)**

Mixed Waste

Mixed waste materials must be kept separate. They usually consist of radioactive materials as well as hazardous waste. Liquid scintillation vials are important examples of mixed waste.

Separate containers must be used for less than 90 day half-life mixed waste (specifically scintillation vials) and greater than 90 day half-life mixed waste.

Animal Waste
Animal waste containing short-lived radioisotopes is typically stored in 35 gallon drums. The purpose of this storage is to allow the radioisotope to decay essentially to background level in the radiation safety storage room.

Once the radioisotope has decayed to background level, it can be released to regular trash.

Animal Carcasses
Laboratories must store animal carcasses in a freezer until time for packaging and removal by the RSO for delivery to waste site. The PI is encouraged to notify the RSO well in advance of the freezers becoming full.

Syringes
Radioactive syringes are to be stored in containers approved by the Radiation Safety Officer. Call Radiation Safety Office to pick up radioactive containers.

2.7 Posting Requirements
The principal investigator is responsible for posting rooms, areas, cabinets, fume hoods, lab benches, and etc. involved in the use and/or storage of radioactive materials. These are warning signs to ensure that proper procedures are adhered to and appropriate steps be taken to minimize internal dose. The RSO will provide the warning sign to each authorized PI.

2.8 Emergency Procedures
Written **emergency procedures** pertaining to radiation safety are established for each work area containing radioactive materials by the RSO and posted in a conspicuous location. These procedures list the telephone number of the RSO and provide the following actions to be taken in case of a known or suspected accident involving radiation exposure:

Emergency Numbers

Radiation Safety Office	963-5336
Campus Safety and Security	963-5171

Minor Spills
- Notify other persons in the lab and secure the area.
- Confine the spill
  Wear gloves and use absorbent materials on wet spills. Do not spread contamination

- Call the RSO if assistance is needed
- Monitor all persons involved with survey instruments
- Decontaminate the "spill area"
- The spill event must be reported within 24 hours

Major Spills

- Instruct non-laboratory persons to leave the area and secure it
- Prepare to evacuate the spill area
  All equipment must be shut off. The skin should be flushed with water, and clothing should be discarded
- Vacate the spill area and prohibit personnel access
- Call the RSO

Radioactive Dusts, Gases, and Organic Vapors

- Instruct non-laboratory persons to leave the area and secure it
- Vacate the area and prohibit personnel access
- Call the RSO

CHAPTER 3. RADIATION PRODUCING MACHINE USE and OPERATING PROCEDURES

3.0 Introduction

A radiation producing machine is any device capable of producing ionizing radiation such as **x-ray diffraction and radiography units, particle accelerators, electron microscopes, and high voltage rectifiers** operating above 10kV.

Analytical x-ray machines produce intense beams of ionizing radiation that are used for diffraction and fluorescence studies. The most intense part of the beam is that corresponding to the K emission of the target material. X-ray diffraction wavelengths (ν) are selected so as to roughly correspond to the inter-atomic distances within the sample, and to minimize fluorescence. Wavelengths commonly used are 1.54 A (Cu targets), 0.71 A (Mo targets), 0.56 A (Ag targets), and 2.3 A (Cr targets).

3.1 Biological Effects of X-Ray Hazards

X-rays produced by radiation producing machines such as analytical x-ray diffractometers are readily absorbed in the first few millimeters of tissue, and therefore do not contribute any dose to the internal organs of the body.

However, the lens of the eye can receive a dose from x-rays of this energy. Overexposure of lens tissue can lead to the development of lensopacities and cataracts.

Absorbed doses of a few hundred rad may produce a reddening of the skin which is transitory in nature. Higher doses, on the order of 10^4 rad and greater, may produce significant cellular damage resulting in pigment changes and chronic radiation dermatitis. X-rays used for medical diagnosis are about one order of magnitude shorter in wavelength. Diagnostic x-rays are designed for tissue penetration and are carefully filtered to avoid x-ray damage to the skin.

3.2 Regulation

The use of radiation producing machines is regulated by Tennessee "State Regulations for the Protection Against Radiation" (SRPAR). SRPAR requires written operating procedures and emergency procedures pertaining to radiation safety be established for each radiation producing machine and be conspicuously posted near each machine (SRPAR 1200-2-6-07(2)(c)). SRPAR 1200-2-5-.71 requires that personnel occupationally exposed to radiation wear monitoring devices such as film badges, pocket or ring dosimeters.

3.3 Registration

All radiation producing machines at TSU must be registered with Tennessee SRPAR. Registration will be in the name of TSU, with the RSO as the point of contact. Registrants must be a full time faculty, academic professional or staff of TSU. Analytical x-ray equipment and other radiation producing machines are registered by submitting the appropriate form to the RSO. Registration forms are available in the Radiation Safety Office. The Radiation Safety Officer must be notified immediately of the acquisition, transfer, or disposal of any radiation producing machine within 30 days.

3.4 Operating Procedures for Radiation Producing Machines

Principal investigators who wish to operate a radiation producing machine must submit an application for radiation producing machine form to the RSS via RSO. Each application must be completed in sufficient detail for RSS evaluation. The applications include a description of the machine, description of proposed use, and for machines operating above 100kV, a description of the facility.

3.41 Authorized Users

Principal investigators are responsible for ensuring that only authorized users are allowed to operate their machines. Authorized users are those individuals listed on the TSU Dosimetry Program or the original application, as well as individuals added as new personnel.

3.42 Training for Operators

New personnel must be trained by a trained operator designated by the principal investigator, and must demonstrate knowledge of operating and safety procedures before independently operating a radiation producing machines.

Operators of these machines must receive training by the Radiation Safety Officer or his/her designee on the following topics:

- Limits of Exposure Types and Amounts to Workers
- Health Effects of Exposure to Low Doses of Ionization.
- Caution and Procedures to Minimize Exposure to Radiation
- Responsibilities of Personnel Using Radiation Producing Machines
- Rights of Radiation Workers to Have Access to Exposure Records
- Response in the Event of Exposure to Radiation
- Applicable Provisions of ALARA Rules and Regulations

3.43 Regulatory Dose Limits

SRPAR has imposed limits on the dose of ionizing radiation which may be received by individuals working with radiation producing machines. SRPAR rules and regulations are discussed in chapter 2. These limits are shown in table 3 of chapter 2 of this manual (page 15).

3.44 Limits for Declared Pregnant Workers

Due to concerns about prenatal radiation exposure, separate limits are set for embryo-fetus of declared pregnant workers. The limit is 0.5 rem dose equivalent to the embryo-fetus during pregnancy.

As described in chapter 2 of this manual, this is a voluntary process designed to protect the embryo-fetus and pregnant worker from exposure to hazardous radiation

3.45 Members of the General Public

The regulatory limit for members of the general public is 0.1 rem total effective dose equivalent per year (see chapter 2). This limit applies to all individuals who are not trained to work with sources of ionizing radiation.

3.46 Posting Warning and Information Signs

A sign bearing the words **CAUTION X-RAYS** must be posted at the entrance to each laboratory containing a radiation producing machine. The sign must include the name and **"after hours"** phone number of the PI.

A label containing the words **CAUTION: THIS EQUIPMENT PRODUCES RADIATION** must be affixed to the control device of each machine.

A label with the words **CAUTION: HIGH INTENSITY X-RAY BEAM** must be affixed on or near the tube of the x-ray unit. An x-ray warning light labeled as to its meaning, shall be located on or near an x-ray tube.

3.48 Machine Operating Procedures

Operating procedures for each machine must be available near the machine. For open systems, these procedures must specifically include:

- Means to control and limit exposures to individuals, within an access area
- Use of survey instruments, TLD badges, and ring/pocket dosimeters
- Use of protective barriers and/or shielding with an open x-ray system to ensure exposure rates in accessible areas are less than 2mR/hr at 5 cm from the exterior surface. It is important to avoid cracks and gaps in the shielding
- Unused x-ray ports must be permanently blocked or interlocked so that x-ray production is stopped if the port is opened. Material used to block unused ports must be of sufficient density and thickness to attentuate the primary beam to acceptable levels.
- The general policy of the Radiation Safety Subcommittee (RSS) requires that all personnel listed on the application to operate a radiation producing machine be also listed on the TSU Dosimetry Program. The TSU Dosimetry Program is described in chapter 2 of this manual (pages

12-13). It is advisable to consult with the RSO on any particular issue pertaining to radiation producing machines.

- For open systems, a log book must be kept with records containing the following information:

Log Book

1. **Operator** 2. **Date** 3. **Voltage** 4. **Current** 5. **Exposure Time** 6. **Radiation Survey Results**	

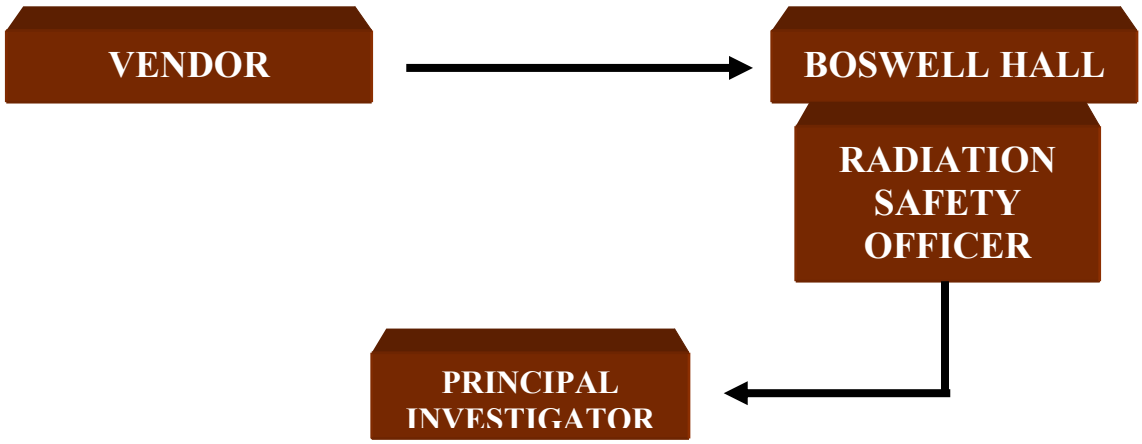
3.5 Emergency Procedures for Radiation Producing Machines

It is the responsibility of the PI and all workers within a radiation laboratory to make every effort to avoid accidents or unusual incidents. However, in the event of an accident or unusual incident involving radiation producing machines, the following actions should be taken:

- Turn off the machine and unplug or shut off the circuit breaker for the machine
- In the case of a serious injury, call the Main Campus Safety and Security Office at **963-5171** and request paramedics and/or the Fire Department
- Notify the Radiation Safety Officer (**963-5336**) or his/her designee
- Notify the laboratory supervisor or principal investigator
- Record information pertaining to the incident, such as information contained in the **log book** illustrated above.

RECEIPTS, SHIPMENT, and DELIVERY of RADIOACTIVE MATERIALS

The Radiation Safety Subcommittee does not allow radioactive materials to be brought onto or shipped from the campus without prior approval from the RSO. Inbound shipments must be received (by the RSO or his trained designee) in the Chemistry Stockroom of Boswell Science Complex, where they are **checked for damage**, **carrier packaging** and **labeling** by the RSO or his designee, and then released for delivery to the end user. This procedure is intended to provide protection to those individuals handling radioactive material as well as to comply with TSU requirements and Federal and SRPAR regulations.



TENNESSEE STATE UNIVERSITY
Radiation Safety Subcommittee

Radiation Producing Machines

Name of Machine:_____ **Registration No:**_____
Building:_____ **Room/Lab No:**_____
Authorized Operators:_____

Operating Procedures

Principal investigators who wish to operate a radiation producing machine must submit an application for radiation producing machine form to the Radiation Safety Subcommittee (RSS) via Radiation Safety Officer. Each application must be completed in sufficient detail for RSS evaluation. The applications include a description of the machine, description of proposed use, and for machines operating above 100kV, a description of the facility.

Authorized Users
Principal investigators are responsible for ensuring that only authorized users are allowed to operate their machines. Authorized users are those individuals listed on the TSU Dosimetry Program or the original application, as well as individuals added as new personnel.

Training for Operators
New personnel must be trained by a trained operator designated by the principal investigator, and must demonstrate knowledge of operating and safety procedures before independently operating a radiation producing machines.

Operators of these machines must receive training by the Radiation Safety Officer or his/her designee on the following topics:

- Limits of Exposure Types and Amounts to Workers
- Health Effects of Exposure to Low Doses of Ionization.
- Caution and Procedures to Minimize Exposure to Radiation

- Responsibilities of Personnel Using Radiation Producing Machines
- Rights of Radiation Workers to Have Access to Exposure Records
- Response in the Event of Exposure to Radiation
- Applicable Provisions of ALARA Rules and Regulations

Regulatory Dose Limits
SRPAR has imposed limits on the dose of ionizing radiation which may be received by individuals working with radiation producing machines. SRPAR rules and regulations are discussed in chapter 2 of the Radiation Safety Manual along with the limits are shown in table 3.

Limits for Declared Pregnant Workers
Due to concerns about prenatal radiation exposure, separate limits are set for embryo-fetus of declared pregnant workers. The limit is 0.5 rem dose equivalent to the embryo-fetus during pregnancy.

As described in chapter 2 of this manual, this is a voluntary process designed to protect the embryo-fetus and pregnant worker from exposure to hazardous radiation.

Members of the General Public
The regulatory limit for members of the general public is 0.1 rem total effective dose equivalent per year (see chapter 2). This limit applies to all individuals who are not trained to work with sources of ionizing radiation.

Posting Warning and Information Signs
A sign bearing the words **CAUTION X-RAYS** must be posted at the entrance to each laboratory containing a radiation producing machine. The sign must include the name and **"after hours"** phone number of the PI.

A label containing the words **CAUTION: THIS EQUIPMENT PRODUCES RADIATION** must be affixed to the control device of each machine.

A label with the words **CAUTION: HIGH INTENSITY X-RAY BEAM** must be affixed on or near the tube of the x-ray unit. An x-ray warning light labeled as to its meaning, shall be located on or near an x-ray tube.

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Operating procedures for each machine must be available near the machine. For open systems, these procedures must specifically include:

- Means to control and limit exposures to individuals, within an access area

- Use of survey instruments, TLD badges, and ring/pocket dosimeters

- Use of protective barriers and/or shielding with an open x-ray system to ensure exposure rates in accessible areas are less than 2mR/hr at 5 cm from the exterior surface. It is important to avoid cracks and gaps in the shielding

- Unused x-ray ports must be permanently blocked or interlocked so that x-ray production is stopped if the port is opened. Material used to block unused ports must be of sufficient density and thickness to attentuate the primary beam to acceptable levels.

- The general policy of the Radiation Safety Subcommittee (RSS) requires that all personnel listed on the application to operate a radiation producing machine be also listed on the TSU Dosimetry Program. The TSU Dosimetry Program is described in chapter 2 of this manual (pages 12-13). It is advisable to consult with the RSO on any particular issue pertaining to radiation producing machines.

- For open systems, a log book must be kept with records containing the following information:

Log Book

7. Operator **8. Date** **9. Voltage** **10. Current** **11. Exposure Time** **12. Radiation Survey Results**	

TENNESSEE STATE UNIVERSITY

Radiation Safety Subcommittee

Radiation Producing Machines

Name of Machine:_____ **Registration No:**_____
Building:_____ **Room/Lab No:**_____
Authorized Operators:_____

Emergency Procedures

It is the responsibility of the PI and all workers within a radiation laboratory to make every effort to avoid accidents or unusual incidents. However, in the event of an accident or unusual incident involving radiation producing machines, the following actions should be taken:

- Turn off the machine and unplug or shut off the circuit breaker
- In the case of a serious injury, call the Main Campus Safety and Security Office at **963-5171** and request **paramedics** and/or the **Fire Department**
- Notify the Radiation Safety Officer (**963-5336**) or his/her designee
- Notify the laboratory supervisor or principal investigator
- Record information pertaining to the incident, such as information contained in the **log book** illustrated below:

Log Book

13. Operator **14. Date** **15. Voltage** **16. Current** **17. Exposure Time** **18. Radiation Survey Results**	