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ORNL-6904/R4

OAK RIDGE NATIONAL LABORATORY

RADIATION EFFECTS TEST FACILITY OPERATIONS MANUAL

Protocols for Operating the Radiation Effects Test Facility

J. S. Bogard

February 2007

Managed and Operated by
UT-Battelle, LLC for the
United States
Department of Energy

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OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
managed by
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U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

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PREFACE

This manual is the primary instruction and operations manual for the Oak Ridge National Laboratory's Radiation Effects Test Facility (RETF, formerly called the Dosimetry Applications Research Calibration Laboratory, or DOSAR/CalLab). Its purpose is to (1) provide operating protocols for the RETF, (2) outline the organizational structure, (3) define the Quality Assurance plan, and (4) describe all the procedures, operations, and responsibilities for the safe and proper operation of all routine aspects of the calibration facility. Each person who works at RETF is required to read the latest revision of this manual and be familiar with its contents. Before being allowed to operate any equipment in or associated with the facility, the person must sign and date the last page of the manual's master copy indicating familiarity with it's contents. Each person is required to sign the manual after each revision to signify that the changes are understood. It is the responsibility of each individual to ensure a complete understanding of the proper operation of each piece of equipment used and to properly follow the instructions contained within this manual.

The instructions, protocols, and operating procedures in this manual do not replace, supersede, or alter the requirements contained in ORNL's Standards-Based Management System, including those of the Radiological Protection Management System, Management System Description: Radiological Protection, on the ORNL intranet at http://sbms.ornl.gov/sbms/SBMSearch/Msd/RPS/RPS_MSD.cfm, or any other official guidelines applicable to the operation of radiation sources and personnel safety.

The RETF Operations Coordinator (ROC) will review this manual in its entirety at least annually and certify that it is up to date with the existing equipment and procedures necessary for safe and proper operation of the facility by signing the approval sheet in front of the master copy. If it is not up to date, the ROC will initiate a revision. Changes to this manual will be made as necessary to ensure that it remains accurate and current. The manual and all of its revisions will be reviewed and approved by the BSD Dosimetry Applications Research Program Leader prior to its distribution to ensure that all precautions necessary for the safe operation of the facility are properly recorded in the manual in a manner that is clear and concise, and that it meets all applicable regulatory requirements. The procedures for operation of RETF sealed radiological sources will be reviewed by the BSD Radiation Safety Officer and approved on the approval page.

The master copy of the manual will be maintained in the office of the RETF Operations Coordinator. A copy of the manual will be available in each irradiation room in the RETF and in the control room. The ORNL Office of Nuclear and Facility Safety Services will receive a copy of the approved manual and of each revision. It is the responsibility of the ROC to ensure that all copies are properly updated and distributed.

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OAK RIDGE NATIONAL LABORATORY

Radiation Effects Test Facility Protocols

Approval Page

Reviewed and Updated ______________________________ J. S. Bogard ______________
RETF Operations Coordinator Date

Reviewed and Approved______________________________ J. S. Bogard ______________
Dosimetry Applications Research Program Leader Date

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Revision Distributed______________________________ J. S. Bogard ______________
RETF Operations Coordinator Date

Revision Distributed______________________________ J. S. Bogard ______________
RETF Operations Coordinator Date

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RETF Operations Coordinator Date

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1.0 Introduction

The RETF is operated under the management structure of the ORNL Biosciences Division. Its goal is to provide resources for performing a wide range of radiological experiments using calibrated radiation standards. The primary function of RETF is to provide facilities for dosimeter intercomparison studies and to perform standard tests for personal radiation dosimeters to ensure compliance with various national accreditation program requirements, such as those of the National Voluntary Laboratory Accreditation Program (NVLAP) and the Department of Energy Laboratory Accreditation Program (DOELAP). RETF will be available to users for low level radiobiological experiments, basic personal dosimeter research and radiation instrument calibration. The facility will also be used for training radiation dosimetrists and health physicists.

RETF will be operated as a *Radiological Facility*, and the total radiological material inventory will be maintained below **DOE Standard 1027** threshold quantities. Sources available at the facility include a medium-energy Pantak HF320 X-ray machine, a ^{60}Co and two ^{137}Cs gamma sources, a ^{90}Sr/^{90}Y beta source, a ^{238}Pu/Be neutron source and two ^{252}Cf neutron sources. The X-ray machine manufactured by Pantak Corporation has a stabilized constant current source with an operational range from 10 to 320 kV. The beta source is a 8.9×10^{8}-Bq (24-mCi) ^{90}Sr/^{90}Y beta particle source. Its beam intensity and quality have been characterized with a PTW extrapolation chamber. Two ^{137}Cs sources are used for gamma radiation work. A 2.7×10^{10}-Bq (0.73-Ci) source is mounted in a panoramic irradiator and a 2.5×10^{11}-Bq (6.7-Ci) source in a beam irradiator with a 20° circular beam port. The 2.7×10^{11}-Bq (7.2-Ci) ^{238}Pu/Be neutron source is in a panoramic irradiator. The two ^{252}Cf neutron sources are available to provide a variety of bare and moderated spectra.

Because the results of the irradiations and calibrations performed are the direct responsibility of the individual performing them, the operating staff shall be evaluated at least annually to ensure that their level of understanding both of the facility and of its associated operations is acceptable.

The instructions, protocols, and operating procedures in this manual do not replace, supersede, or alter the requirements contained in the ORNL Standards-Based Management System (including those of the Radiological Protection Management System, Management System Description: Radiological Protection, on the ORNL intranet at http://sbms.ornl.gov/sbms/SBMSearch/Msd/RPS/RPS_MSD.cfm), or any other official guidelines applicable to the operation of radiation sources and personnel safety.

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2.0 Organization

RETF is part of the Dosimetry Applications Research Program within the Biological and Nanoscale Systems Group of the Biosciences Division at Oak Ridge National Laboratory. The following is a list of personnel positions and responsibilities directly related to RETF.

Biosciences Division Director: Reviews and approves RETF goals and operations. Designates a divisional Radiation Control Officer to review operational procedures, radiation safety systems, and personnel training.

BSD Radiation Control Officer: Reviews RETF operations, procedures, safety systems, and personnel training to ensure compliance with divisional, laboratory, state, and federal policies and regulations and to promote safe, reliable operation of the facility. Coordinates safety reviews and inspections with the RETF Operations Coordinator.

Laboratory Space Manager: Creates and posts the Laboratory Space Posting (including lab access requirements and primary contacts for gaining entry). The Laboratory Space Manager reviews and updates each laboratory posting annually or when the hazards in the laboratory change.

DOSAR Program Leader: Overall responsibility for the daily activities associated with RETF. Responsible for funding, management, personnel assignments, review and approval of operating procedures, work contracts, purchase orders and facility modifications.

RETF Operations Coordinator: Responsible for equipment and facility design and operation. Coordinates and corrects deficiencies found in safety reviews and inspections. Responsible for ensuring facility meets applicable standards as set forth by NIST for Secondary Calibration Laboratories. Handles scheduling of activities at the RETF. Coordinates experimenters and operators with the operational schedule. Interfaces with ORNL Facilities and Operations Directorate and support personnel for work required involving the RETF. Reviews and updates the RETF Protocol Manual as necessary and oversees training.

RETF Operator: Interfaces with experimenters and operates sources as directed by the RETF Operations Coordinator. Responsible for full implementation of all procedures in the RETF Protocol Manual and for the safe and efficient operation of the facility. Responsible for keeping daily log of RETF Operations.

Experimenter: Responsible for experimental design and setup. Works with the operator to ensure proper execution of the experiments. Submits operational requirements to the RETF Operations Coordinator. Keeps log of all experimental parameters and data and provides complete records to the Operations Coordinator for the RETF file.

Radiological Support Services: Provides health physics support for the facility by ensuring that all personnel are assigned appropriate dosimetry and all radiation areas are properly surveyed and marked. Provides support for operators and experimenters during unusual events such as source transfers or emergency procedures.

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3.0 General Information

3.1 Safety

3.1.1 General Safety

It is the responsibility of each individual working in RETF to ensure that all operations are carried out in a manner that minimizes the risk to himself and others. Whenever proposing or planning any type of activity, personnel safety should be the first consideration. General safety practices are outlined in ORNL Standards-Based Management System. Radiation safety is covered in the Radiological Protection Management System, Management System Description: Radiological Protection, on the ORNL intranet at http://sbms.ornl.gov/sbms/SBMSearch/Msd/RPS/RPS_MSD.cfm). All personnel working in RETF should be familiar with the radiation sources used, the radiation fields they produce, and the hazardous radiation zones in and around the building.

3.1.2 Radiation Safety

All personnel present in the RETF during irradiations shall wear security badges and personnel radiation dosimeters. Personnel dosimeters shall be worn on the front chest area outside of the clothing with the front of the badge facing outward. Personnel involved in activities in which exposure to radiation is possible should also wear a pocket ionization chamber. Neutron dosimeters are required for work involving neutron sources.

The RETF Operator shall determine that exposed radiation sources are properly shielded after each exposure, or that electrically operated devices such as X-ray generators are de-energized, before personnel may enter the exposure room. The radiation environment shall be monitored with a portable dose-rate instrument by persons first entering an exposure room that day or after an exposure has concluded.

The safety of personnel during radiation-producing activities should be the primary concern of the operator. Operations involving bare source handling, transport, or repair will be done in the presence of an ORNL Radiation Control Technician (RCT) or by following approved written procedures. After a new source has been installed, the area will be surveyed by an RCT with the source in the raised or operating mode to determine radiation zones and safe distances. Drawings of the facility identifying radiation levels are included in **Appendix A**. The irradiation room shall be cleared of personnel and checked, entry doors closed and locked and the shield door closed as necessary prior to any irradiation in order to prevent accidental personnel exposure. Redundant interlocks are wired to the personnel door and the shield door so that operation of the source is not possible when either interlock is open. Opening an interlock during an irradiation causes the irradiation to terminate.

If an accident involving radiation contamination occurs, immediate action will be taken to ensure containment. All personnel will be evacuated and an RCT will immediately be notified. All personnel shall, unless injured, be required to remain at the evacuation location until released by the RCT.

If a source becomes jammed or stuck in the exposed position, the RETF Operations Coordinator will be notified and action will be taken as instructed in the section of the irradiation procedures which addresses equipment malfunctions.

3.1.3 Confined Space

The RETF neutron room contains two neutron sources stored at the bottom of a 1.2-m (4-ft) diameter × 1.2-m (4-ft) deep water-filled pit in the center of the room. This pit constitutes a confined space, as defined by the Occupational Safety and Health Administration and as reflected in the ORNL Standards-Based Management System. Entry into this confined space is allowed only under the provisions of a properly executed Safety Work Permit. The only part of a person's body that is allowed to break the horizontal plane of the pit at floor level without execution of a Safety Work Permit is the hand and arm up to the shoulder. Remote handling tools for retrieving items dropped into the pool are provided at RETF. Only a certified RETF Operator or someone under his direct supervision may break the horizontal plane of the pit at floor level with the hand or arm up to the shoulder without a Safety Work Permit in order to perform operations allowed within the context of this RETF Protocol Manual.

3.2 Facility Description

3.2.1 Location

RETF (Building 7735) is located south of the ORNL main plant site directly across the road from the DOSAR facility (Building 7710). The facility is at a remote location and has very low traffic, allowing operations at RETF to be carried out without interference from or danger to the general public. Front access to the main building is controlled by a locked door. Keys to the RETF are issued by ORNL Security Operations to staff, security, and emergency personnel only by approval of the RETF Operations Coordinator.

RETF is located away from sources of mechanical vibration, shock, and sources of electrical and electromagnetic interference and other potential sources of interference which might affect the accuracy and precision of the calibrations performed in the facility. All activities near the facility are screened for potential effects on RETF operations and services.

3.2.2 Construction

The RETF is a 260-m^2 (2800-ft^2) building constructed of 20-cm (8.0-in) thick concrete-filled block walls. The facility consists of three irradiation rooms, a control room, storage areas and a restroom (see Figure 1). The 6.4×7.0×4.3-m (21×23×14-ft) gamma irradiation room contains an Amersham beam irradiator and a J. L. Shepherd panoramic irradiator. The 6.4×7.0×4.3-m (21×23×14-ft) beta/X-ray room contains a beta-particle irradiator and an EG&G Astro-Physics Pantak HF320 X-ray machine. The low-scatter 9.1×9.1×5.8-m (30×30×19-ft) neutron room contains two neutron sources stored at the bottom of a 1.2-m (4-ft) water filled pit in the center of the room. The 6.1×2.4×4.3-m (20×8×14-ft) control room contains the control equipment from which all irradiations, except those involving the ^{238}Pu/Be source, are remotely controlled. Access to each of the irradiation rooms is through electrically controlled iron- and high-density-concrete shield doors and locked personnel access doors, both equipped with interlocks. A repeater radiation alarm, which flashes red when radiation is present in the room, is located at the shield door control switch for each respective room. The control room door across the hallway from the gamma irradiation room is also equipped with an electrically controlled iron and concrete shield door providing additional shielding for the operators in the control room. There is effectively a 0.4-m (16-in) concrete equivalent of shielding and attenuation between any of the irradiation rooms and the control room.

Electrical power to the control computer and critical equipment is protected from surges and line noise by a filtered uninterruptible power supply (UPS). Electrical power to the X-ray facility is through a line filter and voltage stabilizer unit.

The positioning of the instruments and dosimeters being calibrated is accomplished by the use of aluminum stands, either free-standing or suspended from rails attached to the ceiling. The height from the floor and the angle and distance from the source are manually adjustable and reproducible to any required degree of precision. The rail type of positioning system is used for the ^{137}Cs beam irradiator, X-ray machine and ^{252}Cf neutron irradiations. Phantom positioning for the ^{137}Cs irradiator is accomplished using a laser cross hair type of alignment system. The beam port of the Amersham ^{137}Cs beam irradiator is at a height of approximately 1.8 m (6 ft) from the lab floor. The shutter mechanism for the X-ray machine is approximately 2 m (6.5 ft) from the lab floor and the D_2O-moderated sphere for ^{252}Cf irradiations is suspended at approximately 3 m (10 ft) above the surface of the 1.2-m (4-ft) deep water-filled storage pit. Bare ^{252}Cf irradiations are accomplished by replacing the sphere with a source holder at that height. The size of the irradiation rooms and the material composition of support and placement rail systems provides a minimal-scatter environment.

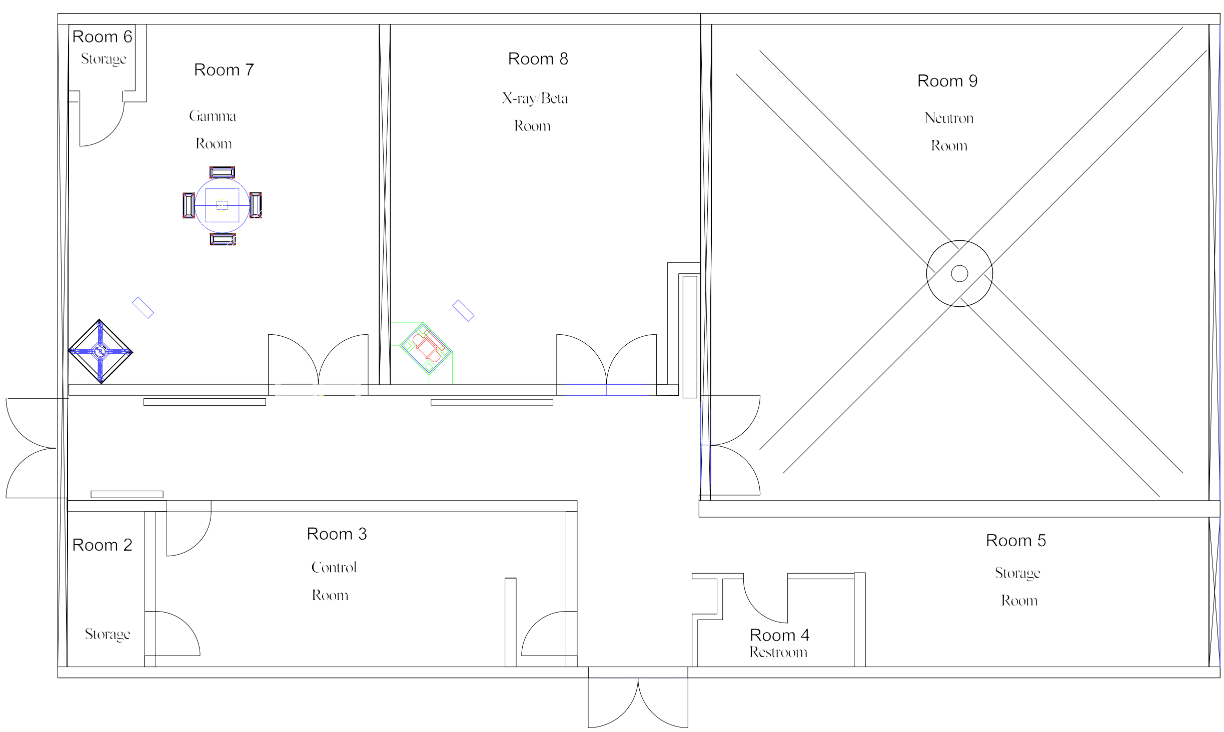

Figure 1 RETF Floor Plan

3.2.3 Environmental Monitoring

Environmental conditions within the laboratory are maintained by a central heating and cooling system. This allows relatively stable temperature control in the experiment rooms well within ±1 °C in any one-hour period. Environmental monitoring equipment continually provides indication of conditions such as temperature, atmospheric pressure, and humidity, which is recorded on the computer-generated Calibration Report when an irradiation or calibration is performed. Remote temperature detectors are located in each of the irradiation rooms. Thermometers calibrated to within ±0.5 °C are available when required to record the temperature at the exposure position. The electronic barometer and hygrometer are calibrated annually. A mercury Fortin-type barometer, factory calibrated by comparison with an National Bureau of Standards (NBS) certified barometer, is available for comparison and backup.

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4.0 Functional/Operational Considerations

4.1 Qualifications, Responsibilities, and Training

There are four personnel descriptions at RETF: Dosimetry Applications Research (DOSAR) Program Leader, RETF Operations Coordinator, RETF Operator, and Experimenter/User.

The qualifications for DOSAR Program Leader are determined by the Biosciences Division as part of the selection process for that position. The Program Leader is in an organizational position which allows operations to be carried out free from influences that might affect the quality or impartiality of the services.

The DOSAR Program Leader functions as the program manager both for RETF and for other DOSAR programs and initiatives. The Program Leader is responsible for maintaining up-to-date Research Safety Summaries identifying RETF hazards and mitigating controls and should be familiar with the RETF Protocol Manual, reviewing it as part of the approval process.

The qualifications for RETF Operations Coordinator (senior researcher) are determined by the DOSAR Program Leader, subject to approval by the BSD Biological and Nanoscale Systems Group Leader. The person should have a PhD, or equivalent experience, in radiation physics or a related field. In addition to familiarity with radiation dosimetry, his qualifications shall include a working and functional knowledge of all software associated with operation of the facility and an understanding of the basic concepts involved in the calibration of instruments.

The RETF Operations Coordinator (ROC) is responsible for the day-to-day operations of RETF. He is responsible for the development and implementation of the software and instrument control of the facility as well as the interlock system, positioning system and all other functional aspects of the facility. His responsibilities include submitting and updating the laboratory protocol and ensuring all aspects are enforced. He should, at least annually, evaluate staff competence and the need for training, and provide the required training for operators and experimenters as deemed appropriate. The ROC will submit training records to the group leader and make recommendations for operator certification. The ROC is also responsible for ensuring proper calibration of all equipment, routine maintenance, and certification by the appropriate agencies for operation.

The qualifications for RETF Operator are subject to the approval of the DOSAR Program Leader and the RETF Operations Coordinator. His qualifications should include the ability to operate all associated support equipment which he is required to operate, a working and functional knowledge of all software associated with operation of the facility, the ability to perform all irradiation types, and he should have thorough understanding of the basic concepts involved in the calibration of instruments. He must demonstrate the necessary understanding of all safety and fail-safe features of the irradiation control equipment and have the ability to troubleshoot problems. Operators will be trained by the ROC, who then recommends approval and certification to the DOSAR Program Leader.

The RETF Operator's responsibilities include calibration and documentation of scheduled or new instruments, QA/QC checks, the set-up of dosimeters and instruments for irradiation and calibration, performance of routine irradiations, and the documentation and filing of associated reports. Operators are responsible for accuracy and timely completion of the calibrations or measurements which they have been assigned.

The Experimenter/User may be anyone qualified to do basic or applied research using the equipment available at the RETF, or anyone associated with an approved project or job and whose involvement is appropriate as determined by the ROC and RETF Operator. Users will not be allowed to operate sources and associated equipment. They will receive an orientation to the facilities and associated equipment as well as basic radiation safety practices. Personnel assigned to the RETF Project for more than 30 days will receive formal orientation and instruction.

4.1.1 Training

All personnel working at the RETF will receive training commensurate with their assigned tasks and responsibilities. Training will be broken down into three categories: guest, experimenter/user, and operator.

A Guest is a person who is not assigned to work in the facility, but is performing some task within the building that may require from a few minutes to a few days. Such personnel include inspection teams, management visits, laborers, or engineering personnel. Training for these personnel will be limited to information pertaining specifically to hazards they are likely to encounter during their visit. Safety features such as radiation alarms and safety interlocks will be pointed out as well as conditions for restricted access. Personnel remaining for more than one hour within or immediately outside the building during radiation exposure operations will have the extent of the radiation fields explained to them. The level of guidance and training provided will be determined by the RETF Operations Coordinator (ROC). The ROC will decide if a visitor will be allowed unescorted access to RETF based upon the visitor's experience, knowledge of radiation physics, and familiarity with the RETF as well as the requirements for the visit. It is the operator's responsibility to ensure that each Guest is informed about the hazards present and is escorted within the building unless it is determined unnecessary by the ROC. No records are required for a Guest visit except those required by existing Radiation Work Permits issued by a Radiation Control Technician.

An Experimenter/User is defined in Section 4.1. Training for those personnel will be by basic orientation and a walk-through tour of the facility by the ROC. The orientation lecture will be according to the outline in **Appendix E**. The walk-through tour will include a brief description of the radiation fields and boundaries and the safety features built into the facility. A record of the training session will be made and approved by the DOSAR Program Leader, Biological and Nanoscale Systems Group Leader, BSD Radiation Control Officer, and the Biological & Environmental Sciences Directorate Operations Manager. A copy of the training record will be maintained by the BSD Training Officer and in the RETF Personnel Training Record File.

RETF operator training will be more rigorous and detailed. Actual training lectures and practice sessions will be scheduled by the RETF Operations Coordinator (ROC) in accordance with the individual needs of the prospective operators. As a minimum, training lectures will cover the material contained in **Appendix E**. The prospective operator will also be required to successfully complete Radiation Worker Training as provided by the Directorate of Environmental, Safety, Health and Quality. As part of the training, the prospective operator will be required to review the RETF Protocol Manual, any other appropriate manuals and guidelines that pertain to the RETF, and operating instructions for the equipment involved. The final portion of the training will involve direct operations under the guidance and supervision of the ROC. The ROC will evaluate the abilities of the prospective operator and when the ROC is confident of the person's expertise and ability, he will make a formal recommendation to the DOSAR Program Leader for approval as a certified Operator. A record of the training will be made and approved by the

DOSAR Program Leader, Biological and Nanoscale Systems Group Leader, BSD Radiation Control Officer, and the Biological & Environmental Sciences Directorate Operations Manager. A copy of the training record will be maintained by the BSD Training Officer and in the RETF Personnel Training Record File. When the approved records have been properly filed, the operator will be considered for certification. *No personnel will be allowed to remotely or manually operate any sources in the RETF without direct supervision of a certified Operator*.

4.2 Source and Irradiator Descriptions

Sources for use in the RETF will include, but not be limited to, the sources listed below. The transit time for source operation will be measured for all sources. The effects of the transit time on the deep and shallow dose measurements will be determined and compensation shall be made. The central axis of the radiation beam, both horizontal and vertical, for the ^{137}Cs beam irradiator and the X-ray machine shall be defined by a laser cross-hair projected on the front surface of the phantom.

4.2.1 ^{137}Cs Irradiators

Both ^{137}Cs sources at RETF are sealed sources which are surveyed routinely to assure the integrity of radioactive material encapsulation. The 2.3×10^{11}-Bq (6.2-Ci) source in the Amersham beam irradiator (ORNL Radiation Source Inventory identification number CS-137-3286) was calibrated by the Department of Medical Physics, University of Wisconsin, Madison on January 29, 1986 with an Exradin A5 ion chamber calibrated at NBS. The exposure rate at 0.75 m for this source was 112 mR/min on January 29, 1986[1]. The estimated error of this calibration is 2%. The 2.5×10^{10}-Bq (0.67-Ci) source in the J. L. Shepherd panoramic irradiator (ORNL Radiation Source Inventory identification number CS-137-3257) was calibrated on December 9, 1981 by MDH Industries, Inc. with a MDH Model 2025 detector traceable to NBS. The exposure rate of this source was 28.8 mR/min at 0.509 m on December 9, 1981 with an estimated error of 1%. Corrections to these values will be made as indicated in **Appendix D**, Section 3A. All calculations of intensity should be referenced to these calibrations.

Both ^{137}Cs sources are stored in a safe configuration in lead-shielded containments enclosed in steel. Exposure levels when the sources are in the safe position are less than 1.08×10^{-10} C/kg-s at 0.3 m (1.5 mR/hr at 1 ft) for the Amersham source and less than 1.44×10^{-10} C/kg-s at 0.3 m (2 mR/h at 1 ft) for the Shepherd source. The source in the Amersham irradiator is raised into the exposed position when power is applied to an electromagnet. When the power to the magnet is cut off for any reason, gravity returns the source to the safe position. The irradiator is positioned in the room such that in the event the source fails to return to the safe position, personnel may enter the room and manually return the source to the safe position without entering the direct path of the beam. The J. L. Shepherd source is pneumatically raised and held in the operate position. The air system contains appropriate filters and moisture separators to prevent contamination of the pneumatic system. Gravity returns it to the safe position once power to the irradiator is shut off. Each irradiator is equipped with indicator lights which communicate the status of the

[1] Calibration results are given only in the units of the calibration, although SI units are used elsewhere throughout this text with conventional units in parentheses. Nominal source activities given here without an explicit date are effective the date of this report and must be subsequently corrected for radioactive decay; calibration results correspond to the source activity on the calibration date.

irradiator: i.e., when the red light is on, the source is up and the irradiator operational; when the green light is on, the source is in the safe position.

The energy spectra of scattered radiation for the ^{137}Cs irradiators have been measured and the scattered contribution to the delivered dose is less than 5% on phantom.

4.2.2 ^{60}Co Source

A ^{60}Co source, ORNL Radiation Source Inventory identification number CO-60-3258 (also called “Big Blue” and “DOSAR #8”), is stored in the source cage of Building 7710, Room 114 for use at RETF. There is no permanent irradiator for use with this source; it must be transported from its storage location and manually removed from its shielded storage container for each exposure. The exposure rate from the unshielded source was measured on 05/21/2003 with a calibrated ion chamber to be 571 mR/h at 1 m. A Radiation Work Permit must be issued for each use of this source because of the potential for radiation exposure to the operator (see Section 7).

4.2.3 Beta Source

The Isotope Products Lab beta particle irradiator is supported by an aluminum stand. The top of the stand is shaped like the capital letter "D". The source is positioned in the center of the straight side of the "D". The semi-circle side allows multiple instruments or phantoms to be positioned equidistant from the center of the source at the same time. The beta particle energies at these points have been characterized using an extrapolation chamber. An extrapolation chamber may also be used at the time of irradiation to verify the delivered dose. The exposure rate of the encapsulated $^{90}Sr/^{90}Y$ beta source (ORNL Radiation Source Inventory identification number SR-90-3284) was measured to be 158 mrad/min when calibrated at 0.35 m by NBS on August 20, 1983. Exposure rates, however, are dependent on the position on the "D" where the measurement is made. Calibrations should be referred to extrapolation chamber measurements made at that position at the time of the exposure. In the safe position, the source is enclosed in a lead pig with a lead cap or lid fitting down over top of the source. When power is applied to engage the irradiator, an electro-magnetic relay to which the lid is attached closes and the lead lid is raised to expose the rotating source. When power to the relay is cut, gravity causes the lid to lower back over top of the source.

4.2.4 Pantak HF320 X-ray Generator

The X-ray generator consists of a Pantak HF 320 X-ray generator (ORNL Radiation Source Inventory identification number XG-3119) enclosed in a lead housing mounted approximately 1.8 m (6 ft) off the floor. The unit may be used for NIST beam code calibrations in the range of 10 to 300 kV. Control is by computer interface which may be either local by manual settings or remote by computer terminal. Two control shutters are provided on the beam port. The inner one is a high speed timing shutter used to deliver controlled doses. The second is a safety shutter which can be closed during operation such that necessary personnel can work within the X-ray facility without significant exposure. Delivered doses are determined by comparison with a calibrated ion chamber or (at energies below 50 kV) a calibrated extrapolation chamber. The X-ray beam is monitored during exposures with a transmission type ion chamber.

4.2.5 Neutron Sources: ^{252}Cf and ^{238}Pu/Be

Californium-252 neutron source serial number SRCF3045OR (ORNL Radiation Source Inventory identification number Cf-252-5542) had a neutron emission rate of 2.452×10^{9} s^{-1} as measured by NBS on May 8, 2006. It is contained in a stainless steel encapsulation. Screwed to the end of the encapsulation is a conical stainless steel end piece with a long thin rod attached which is used to raise the source into place. This source may be used in any one of three configurations. Used bare, the source delivered 23.9 mSv/h (2.39 rem/h) neutron dose equivalent at 1 m on the calibration date. The uncertainty in the neutron emission rate is estimated to be 1.3% (1σ) and the dose equivalent conversion factor has an error of about 4% giving an overall uncertainty in the dose rate of less than 5%.

Californium-252 neutron source serial number NSD-107 (ORNL Radiation Source Inventory identification number CF-252-3287) had a neutron emission rate of 7.63×10^{9} s^{-1} as measured by NBS on April 30, 1987. It is contained in a stainless steel encapsulation enclosed in a sealed, D_2O-filled tube. Screwed to the end of the tube is a conical stainless steel end piece with a long thin rod attached which is used to raise the source into the D_2O-filled sphere. The exposure rate calculated from the above emission rate is 11.7 μSv/min (117 mrem/min). The uncertainty in the emission rate is 1.5% and in the fluence to dose conversion about 4% giving an uncertainty in the delivered dose rate of less than 5%.

The 2.7×10^{11}-Bq (7.2-Ci) ^{238}Pu/Be source (serial number MRC-Pu8-Be-496; ORNL Radiation Source Inventory identification number PU8-BE-3285) was calibrated on March 22, 1982 by Monsanto Corporation by comparison with a NBS calibrated source. The neutron emission rate was 2.4×10^{7} s^{-1} with an unknown uncertainty. Conversion to dose equivalent rate yields 0.0424 μSv/min (0.424 mrem/min) at 1 m.

4.3 Irradiation Processing and Controlling Equipment

All equipment used shall be properly checked and, where appropriate, calibrated. Test and measurement equipment is periodically tested as part of a documented quality control program, as described in section 4.7.

Except for the ^{238}Pu/Be irradiator and the ^{60}Co source (which has no irradiator), all irradiators are operated by in-house developed control software written in QuickBasic and executed on a PC. The program that operates the irradiators may only be accessed by passing through a double layer of password protection. After the irradiation room has been secured, the operator will initialize the computer control system and select the proper operating parameters via a menu. **The operator will be prompted for information relating to the status and security of the irradiation room. Only after these conditions are met shall the operator respond to the inquiries in the affirmative, authorizing the computer to proceed with the exposure.**

In addition to the irradiator control computer, RETF is equipped with primary standard ion chambers calibrated by NIST, battery operated high voltage power supplies, two Keithley 617 programmable electrometers, one Keithley 614 electrometer, one Keithley 237 source measure unit, one Victoreen 550 electrometer, two Canberra 2071A Dual Counters, oscilloscope (pulse generator, current source, precision capacitors and resistors), and several polymethyl methacrylate phantoms (40×40×15 cm and 30×30×5 cm). Individual detectors can be positioned at points of interest in the irradiation rooms to verify the delivered doses.

4.4 Acceptance of Assignments (Calibration Policy)

The RETF provides calibrated radiation exposures in support of both U.S. Department of Energy programs and Work-for-Others clients (other government agencies and the private sector). Basic dosimetry research or calibration will be conducted subject to availability of sources, personnel, and other scheduling factors. Calibrated exposures are offered by RETF to governmental entities and to the private sector on a full-cost-recovery basis. Agreements under which services are provided to the private sector are coordinated by the U.S. Department of Energy Research and Technical Assistance Program (Work for Others Program) and are subject to approval by the Department of Energy.

4.5 Calibration Accuracy

Calibration accuracy will meet or exceed DOELAP or NVLAP requirements when requested and approved. Unless specified, the accuracy of each calibration will be evaluated and reported. Each calibration report will specify the source level and trace the radiation source calibration to a NIST standard, or detail the calibration procedure with reference to NIST criteria.

4.6 General Records Handling and Disposition (Source Records)

An equipment logbook will be kept with a complete record of all calibrations, modifications, repairs, or deficiencies found in the radiation sources and related equipment. All calibrations and calculations involving source intensities will be recorded and kept on file. Any discrepancies found in the operational capabilities of any instrument or source will result in the removal of that item from active use until repairs, calibrations or appropriate adjustments are made.

4.7 Source, Instrument and Equipment Reliability

The reliability, accuracy and stability of all equipment instrumental in the calibration process is essential to the operation of the calibration facility. Each critical piece of equipment will be recorded in a bound logbook kept in the RETF control room. The documentation will include model number, serial number, calibration date and, when appropriate, calibration certificate or reference to where such information is filed. The performance of each piece of equipment originally calibrated by comparison with a higher standard shall be tested routinely. The equipment shall be recalled and restricted from use when performance does not meet acceptable bounds as revealed by proficiency testing or routine quality control. The quality control guidelines for RETF are fundamental to ensure the highest caliber of calibration and irradiation services possible. Quality control checks will be performed and documented routinely. The calibration procedure for each piece of equipment is described in the equipment logbook.

An assessment of the uncertainty associated for each calibration, i.e., total, systematic, and random, shall be documented. The total systematic and total random uncertainties shall be determined from the estimated propagation of individual systematic or random uncertainties. The total uncertainty shall be determined for each calibrated exposure and reported in the calibration certificate.

4.8 Planned Maintenance/Safety Checks/Calibrations

Facility and equipment maintenance, operational tests of safety systems, and tests or re-calibration of calibrated equipment will be performed periodically. Specific actions and their frequencies are identified in **Appendix C**. Procedures for selected activities related to these actions are provided in **Appendix D**.

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5.0 Preparatory Operating Process

5.1 Irradiation Analysis

The irradiation time and corresponding radiation dose delivered to each dosimeter at its particular location will be determined by calculation (corrected for radioactive decay when the calculation is based on the activity of a NIST-calibrated isotopic source) prior to any irradiation. The actual exposure time and position after irradiation will be compared with those used in the initial calculations and appropriate corrections made to the report of delivered dose. A report shall be filed for each irradiation and appropriate information recorded in the RETF logbook.

An additional form will be filled out specifying the exposure category, as required by ANSI N13.11 for notification of the processor, when dosimeters are irradiated in order to test processor performance. This form will be included with the dosimeters when returned to the processor. Upon return of the processor's report, the values reported will be compared with the calculated value and the bias and standard deviation calculated according to ANSI N13.11 or the requested testing program criteria.

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6.0 Material Handling Pre/Post Irradiation

6.1 Dosimeter Handling

6.1.1 General Handling for DOELAP/NVLAP Irradiations

Each unit will , upon receipt of dosimeters for testing, be individually inspected, identified, and logged by supplier, type, serial number, and general condition. Units shall then be properly marked and may be stored in the shielded storage area in the RETF control room or in another secure low-background location until the scheduled irradiation time.

Scheduling of irradiations will be determined for each dosimeter to be tested under a single contract. The requested category will be chosen from the eight categories described in ANSI N13.11. Dose (or dose equivalent) assignments will be made randomly to each dosimeter as well as the category which may be assigned by a computer random number program called RANDOSE. From this, the distance and exposure time will be calculated for each irradiation. Irradiations will be performed in a timely manner as the restrictions of the facility such as schedule, personnel and source availability allow.

Each calibration or irradiation will be documented by a report generated by the controlling computer and recorded in the RETF daily logbook.

After testing is completed, the appropriate forms will be completed and each unit will be inventoried, packaged, and returned to the supplier/customer with a copy of the calibration or test report.

The institution for which the calibration or irradiation was performed will be notified within 24 hours, if possible, of the discovery of any error in the calibration report which would affect the accuracy of the calibration. A written report of the error will be sent within 72 hours, and either a corrected calibration report shall be sent or the dosimeter shall be recalibrated or irradiated to correct the error.

6.1.2 Handling for Research and Special Cases

Upon receipt of dosimeters for testing or irradiation, each unit will be individually inspected, identified, and logged by supplier, type, serial number, and general condition only when necessary to document the irradiation and provide information essential to reproduce it. Units properly marked may be stored in the shielded storage area in the RETF control room or in another secure low-background location until the scheduled irradiation time.

Appropriate reports will be generated and each unit will be inventoried, packaged, and returned to the supplier/customer with a copy of the calibration or test report after testing is completed.

6.2 Instrument Handling

Each instrument received for testing or calibration will be individually inspected, identified, and logged by supplier, type, serial number, and general condition as is necessary to document the irradiation and provide information essential to reproduce the irradiation. The instruments will then be properly marked and stored in the storage area in the RETF control room.

The scheduling of irradiations will be determined for each instrument to be calibrated under a single contract. The assignments will be made and irradiations performed in a timely manner as the restrictions of the facility such as schedule, personnel and source availability allow.

Each calibration or irradiation will be documented by a calibration irradiation report generated by the controlling computer and by a corresponding entry in the RETF daily logbook.

Appropriate reports will be generated and each instrument will be inventoried, packaged, and returned to the supplier/customer with a copy of the calibration or test report after testing is completed.

The institution for which the calibration or irradiation was performed will be notified within 24 hours, if possible, of the discovery of any error in the calibration report which would affect the accuracy of the calibration. A written report of the error will be sent within 72 hours, and either a corrected calibration report shall be sent or the instrument shall be recalibrated or irradiated to correct the error.

6.3 Biological and Miscellaneous Materials Handling

Irradiations are performed periodically on biological samples and various other materials. Live animals or biological samples with special handling and storage requirements must be brought to the RETF and accompanied during preparatory and post-irradiation handling by a suitably qualified individual.

These items will be inspected when received and identified as necessary to provide accurate descriptive information for irradiation record purposes and for reproducing the irradiation. The applicable information shall be recorded in the RETF logbook.

Each irradiation will be documented by a calibration irradiation report generated by the controlling computer and by a corresponding entry in the RETF daily logbook.

Appropriate reports will be generated after the exposure is completed and each item will be inventoried, packaged, and returned to or picked up by the supplier/customer along with a copy of the calibration/irradiation report.

The institution for which the irradiation was performed will be notified within 24 hours, if possible, of the discovery of any significant error in the calibration report. A written report describing the error will be sent within 72 hours, and either a corrected calibration report shall be sent or the irradiation redone to correct the mistake.

7.0 Irradiation Procedures

Procedures for routine operation of the Pantak HF320 X-ray machine, manually operated ^{60}Co and ^{238}Pu/Be sources, and the computer-controlled ^{137}Cs, ^{90}Sr/^{90}Y, and ^{252}Cf sealed sources are provided in the following sections. Also included are actions to be taken in the case that a source fails to return to a safe condition. A Radiation Work Permit (RWP) issued by Radiological Support Services is required in order to address any such failure.

7.1 ^{137}Cs Gamma Irradiations

These procedures meet the basic requirements for operation of the 2.7×10^{10}-Bq (0.73-Ci) ^{137}Cs panoramic gamma irradiator and the 2.5×10^{11}-Bq (6.7-Ci) ^{137}Cs gamma beam irradiator located in RETF. These procedures do not replace, supersede, or alter the requirements contained in ORNL's Standards-Based Management System (including those of the Radiological Protection Management System, Management System Description: Radiological Protection, on the ORNL intranet at http://sbms.ornl.gov/sbms/SBMSearch/Msd/RPS/RPS_MSD.cfm), or any other official guidelines applicable to the operation of radiation sources and personnel safety.

Pre-operation The radiation environment within the room will be verified with a portable dose rate survey instrument by the first person entering the room that day or after an irradiation. The room should be clean and orderly, and unused equipment should be stored, before setting up targets for a calibrated irradiation. Items such as tables and extra phantoms kept within the room should be moved against a wall away from the work area. Placement of the source and location of the phantoms should be carefully considered to minimize scattering effects and exposure from other sources that may be in use. The phantoms should be placed on a secure stand to prevent falling or movement during the experiment. The dosimeters should be mounted appropriately on the phantom according to guidelines such as those contained in ANSI N13.11. It is the operator's responsibility to (1) ensure that the setup is appropriate, that unused dosimeters are removed, and that no personnel remain in the room, (2) be the last to leave the room, and (3) ensure that the personnel door is locked after leaving and that the shield door is completely closed prior to performing the exposure.

Operation The source may only be operated by personnel who have demonstrated a knowledge of associated equipment, procedures, and safety regulations and who have been approved by the DOSAR Program Leader upon recommendation of the RETF Operations Coordinator. Conduct of experiments by other personnel requires the use of a qualified operator. It is the operator's responsibility to ensure proper experimental setup and adherence to these procedures.

The operator will, after the room has been secured, initialize the computer control system and select the proper operating parameters using the menu which appears on the computer screen. He will then certify that the room in which the exposure will take place is clear and locked by responding to the questions on the computer screen. After the operator is certain that all conditions for operation have been met, he may instruct the computer to proceed with the irradiation. The computer screen changes from blue to pulsing red while the source is exposed. The operator should verify proper operation of the alarm outside the gamma room while the source is exposed during the irradiation. He will make certain that no one tampers with the computer during operation and that the gamma room shield door remains shut until the computer screen returns to the normal blue color, indicating that the exposure is completed and that the source is shielded in its safe position.

Post-operation The operator will enter information requested by the computer program about the project and irradiation after the computer screen returns to the normal blue color. The resulting printout will then be verified, signed, and placed in the appropriate record binder. The radiation alarm outside the gamma room will be checked to ensure the absence of a radiation field prior to opening the shield door. The source position indicators will be checked visually to ensure the source has returned to the safe position after the shield door is open, but before entering the room. The radiation environment within the room will be verified with a portable dose rate survey instrument by the first person entering the room after an irradiation. Other personnel may be allowed to enter the room when all conditions are safe. All excess equipment should be stored and the room cleaned and prepared for the next operation after the last irradiation in an experimental series.

OPERATIONAL MALFUNCTIONS In the event of a problem during operation that has potential of interfering with an irradiation, the Operator should terminate the irradiation by pressing "s" on the keyboard. This should lead to a normal type termination with appropriate irradiation report. If this procedure's results are unsatisfactory, the operator should note the irradiation time and interrupt the irradiation by turning off power inside the control box and interrupting the control program by using control-C. The program EMER should be immediately executed. In the event of power loss to the building, the irradiation time should be noted and the backup power supply to the computer switched off. After conditions have returned to normal, the procedures should be followed again from the start. Unusual occurrences should be recorded in the RETF logbook. CalLab sources are designed to fail in a safe configuration. The Operator is required to verify the radiation environment after a malfunction in order to prevent personnel from entering the radiation room in the event that a source does not properly return to the safe position. The sources can be restored to the safe position for most circumstances using the following as a guide:

Panoramic Irradiator - The power to the panoramic irradiator should be turned off by turning off the AC power in the control cabinet. If the source is still not in a safe position, 1 to 2 hours should be allowed for the compressed air to bleed off. If, after two hours, the source still is exposed, the room should be secured and a Radiation Control Technician notified of the problem.

Beam Irradiator - Power should first be interrupted by turning off the switch inside the control cabinet. If the source still does not return to the safe position, **a Radiation Work Permit must be issued detailing the specific actions to be performed.** These may include entering the Gamma Room with a long pole to push the source rod down, using great care taken to stay out of the path of the main radiation beam and utilizing a handheld radiation survey instrument to verify that the primary beam is not traversed.

If a problem is experienced with the sources, action should be taken to correct the problem and prevent its recurrence. The RETF Operations Coordinator and DOSAR Program Leader should be notified of the problem and should be present during actions taken to correct an unsafe source situation. If the problem cannot be corrected immediately, the unit should be disabled to prevent operation and properly tagged as to the nature of the problem.

7.2 ^{60}Co Gamma Irradiations

The ^{60}Co source used for irradiations is Co-60-3258 (also called “Big Blue” and “DOSAR #8”). It is stored in a lead pig, and the pig is stored inside a larger shielded container in the source cage of Building 7710, Room 114 for use at RETF. There is no permanent irradiator for use with this source; it must be transported to RETF in the pig from its storage location and manually removed for each exposure. Exposure rates from the unshielded source, as measured on 05/20/1999with a calibrated ion chamber, are about 720 mR/h at 1 m.

Exposure rates at the surface of the lead pig with the source stored inside are 2 R/h at contact, 500 mR/h at 1 foot, and 100 mR/h at 3 feet. A Radiation Work Permit must be issued for each use of this source because of the potential for radiation exposure to the operator (see Section 7). A total exposure of about 25 mR can be expected to an operator who transports the pig from Building 7735 to the RETF gamma irradiation room, performs two exposures (each time removing the source with 3-foot tongs from its pig and placing it on a shelf at head height, leaving the room and closing the shield door, then re-entering the room at the exposure's conclusion and replacing the source in its pig), and then returns the pig and source to the larger shielded container in Building 7735. **An ORNL Radiological Work Permit is required each time this source is used for exposures at RETF.** These procedures do not replace, supersede, or alter the requirements contained in ORNL's Standards-Based Management System (including those of the Radiological Protection Management System, Management System Description: Radiological Protection, on the ORNL intranet at http://sbms.ornl.gov/sbms/SBMSearch/Msd/RPS/RPS_MSD.cfm), or any other official guidelines applicable to the operation of radiation sources and personnel safety.

Pre-operation The radiation environment within the room will be verified with a portable dose rate survey instrument by the first person entering the room that day or after an irradiation. The room should be clean and orderly, and unused equipment should be stored, before setting up targets for a calibrated irradiation. Items such as tables and extra phantoms kept within the room should be moved against a wall away from the work area. Placement of the source and location of the phantoms should be carefully considered to minimize scattering effects and exposure from other sources that may be in use. The phantoms should be placed on a secure stand to prevent falling or movement during the experiment. The dosimeters should be mounted appropriately on the phantom according to guidelines such as those contained in ANSI N13.11. It is the operator's responsibility to ensure that the setup is appropriate, that unused dosimeters are removed, and that no personnel are in the room, except as required or allowed by the Radiological Work Permit.

Operation The source may only be removed from its shielded container by personnel who have demonstrated a knowledge of associated procedures and safety regulations, who have been approved by the DOSAR Program Leader upon recommendation of the RETF Operations Coordinator, and who are explicitly named on the Radiological Work Permit applicable to the specific use of this source. It is the operator's responsibility to ensure proper experimental setup and adherence to these procedures.

The operator named on the Radiological Work Permit is responsible for taking the source from its pig and placing it in the exposure position in a manner that minimizes his own radiation dose. He should verify proper operation of the alarm outside the gamma room while the source is exposed during the irradiation and make certain that the gamma room shield door remains shut until the exposure is complete.

Post-operation The operator named on the Radiological Work Permit is responsible for re-entering the gamma room and replacing the source in its pig at the conclusion of the exposure, and for returning the source and pig to the larger shielded container in Building 7710. The operator will record information about the project and irradiation in the RETF daily logbook (see Section 8). Other personnel may be allowed to enter the room when all conditions are safe. All excess equipment should be stored and the room cleaned and prepared for the next operation after the last irradiation in an experimental series.

7.3 Beta Irradiations

These procedures meet the basic requirements for operation of the $^{90}Sr/^{90}Y$ beta irradiator located in the RETF. These procedures do not replace, supersede, or alter the requirements contained in ORNL's Standards-

Based Management System (including those of the Radiological Protection Management System, Management System Description: Radiological Protection, on the ORNL intranet at http://sbms.ornl.gov/sbms/SBMSearch/Msd/RPS/RPS_MSD.cfm), or any other official guidelines applicable to the operation of radiation sources and personnel safety.

Preliminary The area around the beta source shall be surveyed with a portable dose rate instrument to verify that the source is in a safe position prior to conducting any other activities around the source. Before irradiations are set up, the room should be clean and orderly. Equipment not in use should be stored. Items kept within the room such as tables and extra phantoms should be moved against a wall away from the work area. The necessary placement of the source and location of the phantoms should be carefully considered to prevent scattering effects and exposure from other sources that may be in use. The phantoms should be placed securely on the stand such that there is no danger of their falling or moving during the experiment. The dosimeters should be mounted in a manner appropriate to the phantom and according to guidelines such as those contained in ANSI N13.11. After the setup is complete, the room should be checked to ensure that the setup is proper, that unused dosimeters are removed, and that there are no personnel remaining in the room. It is the operator's responsibility to make the final check, to be the last to leave the room, and to ensure that the door is properly locked after leaving. The source is then ready for operation.

Operation The source may only be operated by personnel who have demonstrated a knowledge of the equipment, procedures, and safety regulations and who have been approved by the DOSAR Program Leader upon recommendation of the RETF Operations Coordinator. Conduct of experiments by other personnel requires the use of a qualified operator. It is the operator's responsibility to ensure proper setup of the experiment and adherence to these procedures.

After the room has been secured, the operator will initialize the computer control system and select the proper operating parameters. He will then certify that the room is clear and locked by responding to the questions on the computer screen. After the operator is positive that all conditions for operation have been met, he may instruct the computer to proceed with the irradiation. During the irradiation, the operator should check the source mechanism from outside the door (e.g. by using closed-circuit television) to ensure proper operation. He will make certain that no one tampers with the computer during operation and that the entry door remains shut. No further action will be taken until the computer screen returns to the normal blue color.

The beta source can also be operated using a manual override. Under these conditions, the operator should follow the same procedures outlined above, but using manual control instead of computer.

Post-operation After the computer screen returns to normal or the source is de-energized, the operator will enter or record the required information about the project and irradiation. The printout or log will then be checked, signed, and placed in the appropriate storage place. The room radiation alarm will be checked to ensure the absence of radiation and the source position will be checked to ensure the source has returned to the safe position prior to entering the room. The first person entering the room after an irradiation shall verify the radiation environment in the vicinity of the source using a portable dose rate instrument. If all conditions are safe, other personnel may be allowed to enter the room. After the last irradiation in the experimental series, all equipment should be restored and the room cleaned and prepared for the next operation.

OPERATIONAL MALFUNCTIONS In the event of a problem during an operation that has potential of interfering with an irradiation, the operator should terminate the irradiation by pressing the "s" key for the normal shutdown routine. If the source should fail to shut down, the operator should note the irradiation time and interrupt the irradiation by turning off power inside the control box and interrupting the control program by using control-C. The program EMER should be immediately executed. In the event of power loss to the building, the irradiation time should be noted and the backup power supply to the computer switched off. After conditions have returned to normal, the procedures should be followed again from the start. Unusual occurrences should be recorded in the RETF logbook.

In the event that a source does not properly return to the safe position, personnel should be prevented from entering the radiation room. The power to the irradiator should be turned off by turning off the AC power in the control cabinet. If the source is still not in a safe position, **a Radiation Work Permit must be issued detailing the specific actions to be performed.** These may include using a pole or meter-stick to push the source cover down after entering the room with great care not to approach the source too closely and using a portable dose rate survey meter to ensure minimal personnel exposure.

If a problem is experienced with the sources, action should be taken to correct the problem and prevent its recurrence. The RETF Operations Coordinator and DOSAR Program Leader should be notified of the problem and should be present during actions taken to correct an unsafe source situation. If the problem cannot be corrected immediately, the unit should be disabled to prevent operation and properly tagged as to the nature of the problem.

7.4 X-ray Irradiations

These procedures meet the basic requirements for operation of the Pantak HF320 X-ray beam generator located in RETF, Bldg 7735. These procedures do not replace, supersede, or alter the requirements contained in ORNL's Standards-Based Management System (including those of the Radiological Protection Management System, Management System Description: Radiological Protection, on the ORNL intranet at http://sbms.ornl.gov/sbms/SBMSearch/Msd/RPS/RPS_MSD.cfm), or any other official guidelines applicable to the operation of radiation sources and personnel safety, such as ANSI 543-1974. Note that additional training is required for operators and custodians of radiation generating devices such as the Pantak HF320.

Pre-Operation The radiation environment within the room will be verified with a portable dose rate survey instrument by the first person entering the room that day or after an irradiation. The area should be clean and orderly prior to operation of the X-ray machine. Unused equipment should be removed or placed out of the immediate work area. No obstructions should be placed in the room that would interfere with the operator immediately reaching the control panel or with an emergency evacuation. Equipment such as phantoms and detectors will be placed with careful consideration to beam alignment and scattering effects. Dosimeters should not be brought into the room until the pre-irradiation and warm-up sequence is complete and the beam is characterized and ready for exposure of the subject dosimeters. After the preparations are complete, the room shall be checked clear of unused dosimeters, extra personnel, and sensitive equipment. It is the operator's responsibility to make the final check, be the last to leave the room as appropriate, and to ensure the room is locked and the shield door closed in the case of a beam exposure. The cooler circulating pump can then be turned on by flipping the switch on the side of the control distribution box.

Warm-Up After the operator has ensured the machine and room are ready for operation, the warm-up sequence can begin. The operator will ensure that both shutters are closed by visually inspecting the safety shutter and by checking the indicator lamp on the timing shutter control on the control console. The breaker set 16-18-20 in electrical panel LP1 can then be turned on to supply power to the line regulator. The disconnect in the equipment room just above the line regulator can then be closed, providing power into the X-ray room. The cooler circulating pump should be checked to ensure proper operation. The disconnect above the control panel can now be closed to provide power to the control cabinet. Next, the operator will insert his key into the control panel and switch the unit to standby and then to operate. The panel should show all signs of normal operation and the interlock indicator should be off. If not, then corrective actions should be taken before proceeding. The operator may now activate the computer console if it is not already on. The warm-up mode should be selected and activated. The computer will now control the start-up and warm-up sequence. After power is applied to the X-ray tube as indicated on the control panel and the remote console, the operator should check to ensure that the 'X-ray On' signs are lit both inside the room and outside the door. Failure of either of these signs will require the shutdown of the machine until the problem is corrected. As long as the door to the room is unlocked, the operator must be aware of all activities taking place within the building. If it should become necessary for the operator to leave the area, he shall ensure that the entry door to the room is locked, that no personnel remain in the room, and that the shield door is closed. No attempt should be made to operate the shutters during the warm-up cycle.

Upon completion of the automatic warm-up cycle (about an hour from a cold start), the machine is ready for the experimental setup and operation. ***After completion of the warm-up cycle, the keys should NOT be removed or switched to the off position until the completion of the experiments for that day.*** If the operator should be required to leave the area, he will ensure that the doors to the X-ray room and, if appropriate, to the control room are locked.

Operational Limitations The X-ray machine can only be operated by the RETF Operations Coordinator until certification is approved for other operators. **The unit will be operated at a maximum tube potential of 250 kV during any type of measurement that requires opening both shutters, except under the direct supervision of a qualified Radiation Control Technician.** The X-ray tube current should be kept as low as possible commensurate with experimental needs.

Operation The operator shall be responsible for the safe operation of the X-ray machine and strict compliance with all applicable regulations and procedures. After the initial warm-up cycle, the settings can be set to the appropriate values for the exposure and the X-ray tube energized. Care should be taken that both shutters remain closed while personnel are within the room. If the inner shutter is to be opened with personnel in the room, the operator will ensure that no one approaches the machine in a manner that could result in exposure to leakage from the enclosure. The operator will make a final check of the experiment before leaving the room and will be the last to leave. The entry door will be locked and the shield door completely closed. The safety shutter may then be operated as necessary. The inner shutter may be used as a timing shutter or may be left open by the operator as he leaves the room. Personnel time within the neutron room, the hallway, and outside the building in the back shall be kept to a minimum to reduce unnecessary exposure. Data acquisition should be handled only from within the control room. When the X-rays are on and both shutters are open, the operator should check the radiation alarm, the 'X-ray On' lights, and the 'Beam On' lights for proper operation. The operator will then ensure that no one enters the room or tampers with the controls until normal termination of the exposure.

Post-Operation After the exposure is complete, the operator will close the safety shutter. The radiation environment within the room will be verified with a portable dose rate survey instrument by the first person entering the room after an irradiation. If open, the timing shutter should be closed as appropriate. The operator will shut down the system if no further operations are planned for that day. This is done by turning off and removing the 'Operate' key, opening the disconnect above the control console and above the line regulator, and then switching the breaker set off in the lighting panel.

OPERATIONAL MALFUNCTIONS In the event of a problem or malfunction which has the potential for personnel exposure or injury, equipment damage, or experimental difficulties, the operation should be terminated immediately. The safety shutter should be closed while experimental difficulties are corrected. Operation of the X-ray machine should be terminated in all other cases. Machine operation can be terminated by pressing (1) the ‘Escape’ key on the keyboard of the controlling computer, (2) the ‘Emergency Stop’ on the control console, or (3) the ‘Open’ switch on the shield door, or by breaking the electrical circuit either above the control console or above the line regulator in the Equipment Room. After power interruption to the system, the operator must ensure that conditions have returned to normal and that it is safe to operate before initializing the system from the start of the warm-up procedure. Problems should be reported to the RETF Operations Coordinator and the DOSAR Program Leader. If the system cannot be restored, it should be properly tagged to prevent operation until corrections are made and checked.

7.5 Neutron Irradiations

These procedures meet the basic requirements for operation of the ^{252}Cf neutron sources and the ^{238}Pu/Be neutron irradiator located in RETF. These procedures do not replace, supersede, or alter the requirements contained in ORNL’s Standards-Based Management System (including those of the Radiological Protection Management System, Management System Description: Radiological Protection, on the ORNL intranet at http://sbms.ornl.gov/sbms/SBMSearch/Msd/RPS/RPS_MSD.cfm), or any other official guidelines applicable to the operation of radiation sources and personnel safety.

Pre-operation The radiation environment within the room will be verified with a portable dose rate survey instrument by the first person entering the room that day or after an irradiation. Before irradiations are set up, the room should be clean and orderly. Equipment not in use should be stored. Items kept within the room such as tables and extra phantoms should be moved against a wall away from the work area. The necessary placement of the source and location of the phantoms should be carefully considered to prevent scattering effects and exposure from other sources that may be in use. The phantoms should be placed on a secure stand such that there is no danger of their falling or moving during the experiment. The dosimeters should be mounted in a manner appropriate to the phantom and according to guidelines such as those contained in ANSI N13.11. After the setup is complete, the room should be checked to ensure that the setup is proper, that unused dosimeters are removed, and that there are no personnel remaining in the room. It is the operator's responsibility to make the final check, to be the last to leave the room, and to ensure that the room is clear after leaving. The ^{238}Pu/Be source source is operated either from within the source room or from an adjacent room. The operator may unlock the source and remove any safety retainers after everyone else has left the room. The control cable is then reset in the release mechanism and checked to ensure that it is free to operate. The source is then ready for operation.

Operation The ^{238}Pu/Be source may be operated by personnel who have demonstrated a knowledge of its equipment, procedures, and safety regulations and who have been approved by the DOSAR Program Leader upon recommendation of the RETF Operations Coordinator. A qualified operator is required for ^{238}Pu/Be source irradiations in support of experiments conducted by other personnel and for irradiations using the ^{252}Cf sources. It is the operator's responsibility to ensure proper setup of the experiment and adherence to these procedures.

^{252}Cf operation - After the room has been secured, the operator will initialize the computer control system and select the proper operating parameters from the menu system. He will then certify the room clear and locked by responding to the questions on the computer screen. After the operator is positive that all conditions for operation have been met, he may enter "yes" to proceed with the irradiation. During the irradiation, the operator should check the alarm outside the neutron room to ensure proper operation. He will make certain that no one tampers with the computer during operation and that the neutron room shield and entry doors remain shut. No further action will be taken until the computer screen returns to the normal blue color. After the appropriate irradiation time, the cable will be released returning the source to the storage pit.

The ^{252}Cf sources can also be operated using a manual override. Under these conditions, the operator should follow the same procedures outlined above, but using manual control instead of computer.

^{238}Pu/Be operation - After the room is clear of all other personnel, the operator will initialize the irradiation by turning the handwheel to raise the source to the operate position. In the case of instrument measurements or other requirements, the operator may work within the room, but must ensure all personnel stay a safe distance from the source. The door(s) to the room will then be completely closed. The operator will ensure that the door remains closed and that no one enters the room until the end of the irradiation. At the end of the irradiation, the operator will lower the source to the safe position.

Post-operation After the irradiation, the operator will enter the required information about the project and irradiation and make the appropriate entry in the logbook. The entry will then be checked, signed, and placed in the appropriate storage place. The alarm will be checked to ensure the absence of radiation prior to re-entering the neutron irradiation room. The source position will be visually checked to ensure that the source has returned to the safe position after the shield door is opened, but before re-entering the room. The radiation environment within the room will be verified with a portable dose rate survey instrument by the first person entering the room after an irradiation. All equipment should be stored and the room cleaned and prepared for the next operation after the last irradiation in an experimental series. The operator will ensure that the ^{238}Pu/Be 'Source Safe' indicator shows that the source is properly stored before allowing entry by other personnel or before approaching the ^{238}Pu/Be source.

OPERATIONAL MALFUNCTIONS In the event of a problem which has the potential of interfering with an irradiation, the operator should terminate the irradiation by pressing the "s" key on the computer keyboard. If this fails to release the source, he should note the irradiation time and interrupt the irradiation by turning off power in the control cabinet. Irradiation procedures should be followed again from the start after conditions have returned to normal. Unusual occurrences should be recorded in the RETF logbook.

In the event that a source does not properly return to the safe position, personnel should be prevented from entering the radiation room. The sources can be restored to the safe position in most circumstances using the guidelines below, subject to provisions of an approved radiological work permit.

^{252}Cf Irradiations - If the source is lodged within the moderator or other mechanism, the operator should enter the room with caution and attempt to free the source from a distance greater than 2.4 m (8 ft) by using a 3-m (10-ft) pole (usually located behind the neutron room entrance door). If the source cannot be freed within approximately 1-2 minutes, the room should be secured and a Radiation Control Technician notified of the problem. If the source fails to enter the shield pool, the source can be raised a small distance by pulling the cable and then lowered into the pool. If this fails, the pole can be used to align the source with the opening to the pool. Operator exposure should again be limited to 1-2 minutes at 2.4 m (8 ft).

^{238}Pu/Be Irradiator - If the ^{238}Pu/Be source fails to indicate 'Safe', the operator may attempt to free it by operating the handwheel back and forth. If the cable has bowed outside the source pipe, it may be pushed back in using a long pole. Operator exposure times at 2.4 m (8 ft) should be less than 15 minutes.

Anytime anyone enters a room with potential for radiation exposure, a portable radiation survey meter shall be used by properly trained personnel to ensure minimal personnel exposure.

Actions should be taken to correct problems experienced with correct operation of sources and to prevent their recurrence. The RETF Operations Coordinator and DOSAR Program Leader should be notified of problems and should be present during actions taken to correct an unsafe source situation. If the problem cannot be corrected immediately, the source should be disabled to prevent operation and properly tagged as to the nature of the problem.

7.6 Calibration/Irradiation Reports

A calibration or irradiation report shall be issued, if requested by a client, for each irradiation performed. The report shall clearly describe any unusual or non-standard conditions of the irradiation. (Such conditions may include orientation of item – *i.e.* non-standard distance from the center of the source, elevation off the beam axis, or off-normal angle of incidence – or environmental conditions such as temperature, relative humidity or barometric pressure that are significantly different from those typically found in the laboratory.) Uncertainty associated with the calibration and any limitations of the calibration, such as maximum meter range calibrated (if less than the indicated range of an instrument), meter scales not calibrated, or application of calibration factors, shall be included.

Calibration reports shall be signed by the RETF Operator performing the calibration and reviewed and signed by the RETF Operations Coordinator or DOSAR Program Leader. The operator signature cannot be the same as the reviewer. A copy of each of the reports shall be maintained on file in the RETF control room. For an example of a completed report, see **Appendix B**.

In the event a mistake in the calibration report is discovered which would affect the accuracy of the calibration, the institution for which the calibration or exposure was performed will be notified within 24 hours of the discovery, if possible, and a written report of the mistake sent within 72 hours. A corrected calibration report shall be sent stating any corrected calibration factors.

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8.0 Records Keeping and Data Management

The RETF daily logbook shall contain a brief description of activities performed in or related to RETF. This description shall include the date, time (when appropriate), extent of activity, and personnel involved.

The irradiation records binder shall include all calibration and irradiation reports issued by RETF. These are maintained in three-ring binders labeled with the year covered in that volume.

The equipment maintenance logbook shall be maintained in the RETF control room and should contain appropriate entries concerning calibration and maintenance of equipment used in the RETF.

An up-to-date copy of the RETF Protocol Manual shall be maintained in each of the irradiation rooms, the front office of Building 7710 (master copy), and in the RETF control room.

All Calibration and Irradiation Reports shall be maintained electronically for a year on a removable medium, such as a diskette. This record shall be backed up quarterly and two copies archived at the end of one year. One copy shall be stored in the RETF control room and one in a storage location in a separate building (such as the RETF Operations Coordinator's office).

8.1 Distribution and Disposition of Records

A full history of calibration data for all standards and applicable equipment is maintained in the equipment maintenance logbook. A bound daily logbook is maintained in the RETF control room. It contains a sufficient description to identify every item of instrumentation calibrated, information essential to analyze and reconstruct a given calibration, detailed calibration report reference numbers of the specific calibrations, and names of individuals performing the calibrations.

The following information and records are also kept on permanent file:

1) a record of routine QC actions and control charts,

2) copies of all reports issued,

3) results of all proficiency testing, and

4) detailed education, experience and training records of all staff.

All records and reports related to calibrations are maintained for at least five years. Records of all standards used for calibration are maintained for at least fifty years. Routine back-up and archival is performed for all calibration records stored on the control computer.

8.2 Document Revision History and Approval

Significant changes to this Operations Manual are initiated by the RETF Operations Coordinator (ROC) and implemented in a Revision to the manual. Revisions are submitted for inclusion in the ORNL Comprehensive Publications and Presentations Registry and must be reviewed and approved by the ROC, the DOSAR Program Leader, the BSD Quality Representative and the BSD Radiation Control Officer.

8.3 Signature Record

Each person working within the RETF as an operator or experimenter/user is required to read and understand the current Operations Manual revision, as indicated by his signature on the Signature Record (**Appendix F**).

9.0 Calibration/Irradiation Report Review

9.1 Calibration/Irradiation Review Procedure

All irradiations for calibration shall be analyzed to determine their accuracy and precision. The uncertainty in delivered dose or exposure will be reported in terms of the deviation (in percent) from the NIST accepted value. Humidity, temperature, transit time, scatter, and systematic and random error will be factored into the analysis.

9.2 Report Review Procedure

Calibration Reports shall be reviewed to ensure their accuracy and correctness. The operator performing the calibration shall review, sign and submit each report to the RETF Operations Coordinator (ROC) for final review. The ROC or, in the case of the ROC being the operator, the DOSAR Program Leader will review and sign each report.

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10.0 Quality Assurance Plan Description

Operations at the Radiation Effects Test Facility conform to the ORNL Quality Assurance (QA) Program, which supports ORNL's quest for scientific and operational excellence within nuclear facilities, radiological areas, and within programs or activities that may impact nuclear safety. It also provides a structured framework for all other activities at the Laboratory. The program incorporates appropriate tools from a number of quality standards including the NQA-1 "Quality Assurance Requirements for Nuclear Facility Application", DOE O 414.1C, and DOE G 414.1-2A "Quality Assurance Management System Guide for use with 10 CFR 830 Subpart A, Quality Assurance Requirements, and DOE O 414.1C, Quality Assurance". The program is implemented through SBMS.

Complying with ORNL requirements in the development of this program ensures the delivery of a comprehensive, process- based, integrated Quality Program that meets the U.S. Department of Energy's requirements and programmatic needs. Effective application of the program begins with the Laboratory's Mission and Agenda.

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Appendix A: Health Physics Radiation Surveys

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Radiation survey reports are located in the RETF Control Room Copy of this manual only.

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Appendix B: Sample Irradiation Report

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DOSAR Report 01-95C

Radiation Calibration Laboratory
Dosimetry Applications Research Program
Oak Ridge National Laboratory
Oak Ridge, Tennessee 37831-6379

Report of Calibrated Exposure
May 8, 1995

A calibrated neutron exposure of ten sets of Harshaw neutron- and HBG-dosimeter pairs was provided for the Martin Marietta Energy Systems, Inc., Centralized External Dosimetry System (CEDS), on May 8, 1995. Exposure conditions were as specified in **ANSI N13.11-1994**, *American National Standard for Dosimetry - Personnel Dosimetry Performance - Criteria for Testing*, and **DOE/EH-0027**, *Department of Energy Standard for the Performance Testing of Personnel Dosimetry Systems*. Dosimeters were mounted on a standard 40×40×15-cm polymethylmethacrylate (PMMA) phantom at a distance of 50 cm from a bare (unmoderated) ^{252}Cf source[1]. The source emission rate was converted to dose equivalent rate using values reported by J. A. B. Gibson and E. Piesch in *Neutron Monitoring for Radiological Protection*, **IAEA Technical Reports Series No. 252**, p.22 (1985). Total uncertainty in the delivered dose equivalent is estimated to be about 3% (at the 95% confidence level). The scattered contribution to the neutron dose equivalent (not included in the delivered dose equivalent reported below) is estimated to be less than 2.6%.

The delivered dose equivalents and dosimeter identifiers are shown in the table below.

	Delivered Dose Equivalent (mrem)	
Dosimeter-Pair Serial Numbers (HBG/NEU)[2]	Neutron	Gamma
168068/900204, 169172/900269, 176235/901340, 176290/901487, 176642/901708	200	10
176735/902050, 176846/902195, 176870/902240, 176976/902355, 177111/902472	900	43

Questions about this report may be directed to J. S. Bogard, Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, Tennessee 37831-6379.

Submitted: ____________________
W. L. Robbins
RETF Operator

Approved: ____________________
J. S. Bogard, Ph.D., C.H.P.
DOSAR Program Leader

[1] Source number NDS-87, reference NIST Test No. 536-240107-87/2 for total neutron emission rate (September 24, 1987).
[2] Transit dosimeter-pair serial numbers 167920/902684 were returned unirradiated.

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Appendix C: Planned Maintenance/Safety Checks/Calibrations Schedule

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Planned Maintenance/Calibration Schedule

1. Operational Checks

   A. Verify source operation
   B. Verify radiation alarm operation
   C. Verify computer operation

2. Monthly Checks and Maintenance

   A. Verify radiation alarm operation with check source
   B. Verify correct operation of one interlock in each room.
   C. Back up computer record.
   D. Verify record entries.

3. Quarterly Checks and Maintenance

   A. Verify radiation alarm operation with check source
   B. Verify correct operation of all interlocks
   C. Test operation of emergency egress lighting
   D. Verify operation of lighted 'EXIT' signs
   E. Backup computer record
   F. Verify record entries
   G. Verify calibration of ion chamber and source

4. Additional Tests

   A. Verify half-value layers for X-ray machine operation
   B. Routine maintenance on the X-ray machine

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Appendix D: Planned Maintenance/Safety Checks/Calibrations – Selected Procedures

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Planned Maintenance/Calibration Procedures

1. Operational Checks

A. Verify source operation

Purpose: To verify proper operation of electrical control circuits and source operation mechanism.

Procedure: Upon entry of an affirmative reply to the computer control query to proceed with the irradiation, the operator should verify the change of the screen from blue to red and that the screen has a constant flickering. Failure of the screen to flicker red indicates a computer malfunction. Refer to operational procedures in Section 7.

After computer activation, the source should be verified to be in the operate position. This may be done visually via video monitor or by checking radiation alarm operation. For irradiations involving a measurement with a secondary standard or any other real time measurement, proper operation can be checked by the expected response on those instruments.

At the end of the irradiation, the computer monitor should return to a blue color. The return of the source to the stored position must be verified visually and by a radiation detector such as the radiation alarms.

Records: Any deviation from normal operation of the source or source control system should be noted in the RETF Operations Log. No further record is required for normal operation beyond that specified in Sections 7 and 8.

B. Verify radiation alarm operation

Purpose: To ensure proper operation of the radiation alarm devices.

Procedure: The radiation alarms in each room shall be verified to operate properly at least during the initial source operation in that room each day of operations. The alarm operation should be checked periodically during any day that involves repeated operations over an extended period. If a malfunction is noted, the operator will use a secondary method to verify source operation such as video monitors or other radiation detectors. If it has been verified that the alarm has failed, but the source operation is proper, the irradiation may be continued to its proper termination only under additional vigilance of the operator. It is the responsibility of the operator to ensure that no one attempts to enter the radiation room during operation of the source when the alarm is not functioning. Upon completion of the irradiation, the operator will investigate the cause of the malfunction and correct as necessary. Upon verification of proper functioning of the alarm system, the planned source operations may continue. The operator will make the appropriate log entries and notify the RETF Operations Coordinator (ROC) of the malfunction.

If the radiation alarm fails and cannot be repaired or replaced, the ROC should be immediately notified. Upon approval, the source operations may continue with additional restrictions placed on operational procedures. Personnel within the facility will be limited to only those directly involved in and required for the operations. The operator must remain in the vicinity of the access door, either in the hall outside the room or in the control room. The outside doors will be secured to prevent unauthorized entry. The operator will intercept anyone entering the building or attempting to enter the room. Prior to resumption of the source operation, all interlocks on the source to be used will be tested and the results recorded in the daily logbook. Operation of the X-ray facility will not be continued without an appropriate form of radiation monitoring.

Records: Log entries shall be made in the RETF Operational Log whenever a malfunction is noted in the response of the radiation alarms. This will include corrective actions taken and approvals for operation without proper alarms by signature. No entry is required for proper alarm operation beyond that specified in Sections 7 and 8.

C. Verify Computer Operation

Purpose: To verify and ensure proper operation of the computer control system and associated equipment.

Procedure: Computer maintenance is a daily task which is required to ensure proper performance during source operations. Initial checks of the computer include checking the power switch on in the control cabinet, power on on the UPS unit, printer power on, and a reading on the UPS power meter of less than 300 watts. The operation should ensure that the "scontrol" disk is in drive E (Bernoulli drive) and that the computer is properly booted. The computer should then be switched to drive E in the DOS system. After program initiation and log in, the menu system should guide the operator through selection of the operating parameters and some essential safety checks. Failure at this point in the program should result in program termination or lock-up. The operator should be vigilant to any unusual reading of display. If something is so noted, the program should be terminated and either retried or trouble shot. Failure of the program twice in the same manner should terminate operations until the problem has been corrected. When the source is operated by the computer, the screen will turn red and flicker constantly. Absence of the flicker indicates a program malfunction and therefore should be terminated by using "Control C" or by switching the computer off and back on with the cpu power switch. Upon routine completion of the irradiation, the computer will release the source and the screen will return to blue and indicate "SAFE". Proper source termination can be checked immediately by checking radiation alarms, visually checking the source with the video monitor, or by checking any active radiation detector in use and in position. After answering the computer's queries about the project, the operator may choose to continue with another irradiation or terminate the program. If there are any doubts about the proper functioning of the program or associated equipment, the program should be terminated and the problem investigated before continuing. The operator should also watch for proper report printout and for the computer to access drive E indicating proper storage of the irradiation parameters.

Records: Any deviation from normal operation should be noted in the RETF Operations Log. No other records are required beyond that specified in Sections 7 and 8.

2. Monthly Maintenance and QA/QC Checks

Monthly Maintenance and QA/QC Checks are performed during periods of facility use. If no irradiations are conducted during a given month in a particular irradiation room, then Maintenance and QA/QC checks may be postponed until activity resumes. Monthly Maintenance and QA/QC checks must be performed for an irradiation room within the 30-day period prior to conducting an irradiation within that room. The Monthly Maintenance and QA/QC Check for a RETF irradiation room must be performed prior to an irradiation if the 30-day period has been exceeded. These checks will be performed on at least a quarterly basis for each irradiation room, regardless of the level of activity in the facility.

A. Verify radiation alarm operation with check source.

Purpose: To verify proper operation of the radiation alarms used to monitor source operation and for radiation warning devices.

Procedure: Radiation alarms will be tested to show proper response to gamma radiation by use of the ^{137}Cs gamma source identified as DOSAR 13. The source pig will be held approximately 1 meter from the detector ion chamber and the top removed. Taking care not to turn the opening toward the operator's body, the pig should be oriented such that the opening is toward the detector and the source is clearly exposed. The detector alarm should flash red with the top of the pig removed and should stop flashing shortly after the lid is replaced. To test the repeater outside the shield door, the switch on the unit should be placed in audible mode such that the buzzer can be heard from inside the experiment room.

Records: Testing of the alarms should be recorded in the daily logbook in red ink and signed. Failure of an alarm should be detailed and the alarm replaced immediately.

B. Verify correct operation of one of the interlocks to each room.

Purpose: To verify the proper operation of the interlock system in shutting down source operations and terminating the control program sequence.

Procedure: In order to verify the operation of a source, the camera in that room will be positioned and directed such that it can directly monitor the source operation. For the gamma source, the beam irradiator will be selected. For the X-ray/beta room, the beta source will be selected. For the neutron room, the weighted bottle will be used without a source attached. The computer will be activated and the source brought to the exposed position. The shield door will then be opened approximately 15 cm (6 in.). The source will then be verified in the safe position using the video monitor and the computer will be checked to ensure the screen has indicated the source in the safe position. The irradiation report should state the completion of the test and the results. Malfunction of an interlock is sufficient to suspend use of that room until the problem is corrected.

Proper interlock operation may also be verified by demonstrating that the controlling computer will not allow the source to be brought to the exposed position if the entry door is closed, but the shield door is not closed.

Records: The type of interlock test and the results will be fully documented in the daily logbook in red ink.

C. Back up computer record

Purpose: To back up computer records on alternate media to insure that disk failure does not result in excessive loss of data.

Procedure: During the first week of each month, the computer record for the preceding month shall be copied onto two removable media, such as diskettes. One of these will be maintained in the RETF control room and the other will be stored in the RETF Operations Coordinator's office. The operator will verify the correct transfer of all data and ensure that each diskette is appropriately labeled.

Records: An entry will be made in the daily log in red indicating that the procedure has been completed. No other record is required.

D. Verify record entries

Purpose: To ensure that all records are complete and up to date.

Procedure: During the first week of each month at the time that the computer records are backed up, the printed or written records will be verified complete. The RETF operational log will be checked to ensure all numbered irradiations exposures are properly recorded. The log entries will be checked to ensure all required planned maintenance items are complete and recorded in red ink. Also, the computer printed records will be checked and missing reports found or replaced by regenerating them from the disk record.

Records: Completion of the procedure will be recorded in the log in red ink and any deficiencies noted.

3. Quarterly Maintenance and QA/QC Checks

A. Verify operation of all interlocks.

Purpose: To ensure proper operation of the interlock protection system and its ability to prevent accidental entry and exposure to the radiation sources that are remotely operated.

Procedure: The radiation interlock system consists of one switch located on each entry door and each shield door allowing access to the irradiation rooms. The shield door interlock will be first tested by activating one source in the subject room and then opening the shield door far enough to open the interlock switch. For the neutron room, the source does not need to be connected to the lifting mechanism. A small weight should be substituted. Termination of the source operation should be verified both by radiation alarm, if applicable, and by visually inspecting the source through the door window as appropriate. The procedure will be repeated for each source operating mechanism. Upon completion of shield door testing, the entry door interlock should next be tested. The source operating mechanism should be activated in the same manner with the shield and entry doors closed. The operator should position himself just outside the shield door. The shield door interlock can then be held by one hand while opening the shield door with the other. This may require use of a yardstick or similar device for the neutron room and a second person for the X-ray room. Under no circumstances should any alteration be made to the interlock switch (e.g., taping closed or rigging into a closed position by any mechanical means). After the shield door is sufficiently open, the source operating mechanism should be checked visually to ensure it is still operating. If still operating, the entry door should be opened. Correct operation can again be verified both visually and by radiation alarms. If the mechanism does not operate correctly and the source is still exposed, the door and shield door should be immediately reclosed without allowing entry by any personnel. The source operation should then be immediately terminated. Upon observation of any type of malfunction in the source operation or interlock functions, corrective action should be immediately taken and the malfunction reported to the RETF Operations Coordinator. No operations of the source should be allowed until the problem is fixed and verified.

Proper interlock operation may also be verified by demonstrating that the controlling computer will not allow the source to be brought to the exposed position if (1) the entry door is closed, but the shield door is not closed, and (2) the shield door is closed, but the entry door is not closed.

Records: The results of all interlock tests should be recorded in the daily logbook in red ink. All deficiencies should be recorded as well as the corrective action taken.

Reports: The results of all quarterly interlock tests shall be reported to the ORNL Nuclear and Radiological Protection Division as specified in SBMS Subject Area: Radiation Generating Devices.

B. Verify calibration of ion chamber and source

Purpose: To verify that the dose delivered to the target is within a specified limit of the required value.

Procedure: The verification of the delivered dose involves placing a detector at a position such that the measurement result from that detector is directly proportional to the dose delivered to the target. Ion chamber (NE type 2530/1 or Exradin model A2/A3) response is tested by determining its response to a well-characterized sealed radioactive source of ^{137}Cs and comparing this response with that expected from previous measurements. (This comparison tests both the ion chamber and the gamma photon source.) X-ray doses are confirmed by measurement with an ion chamber calibrated to the particular beam code, and by comparison to previously determined plots of exposure rate as a function of tube current.

Verification of beta irradiation will be done by use of an ionization chamber mounted at a position for which it has been calibrated with the phantom arrangement in use. Results will be evaluated using appropriate corrections and calibration factors.

Verification of neutron irradiations is not possible because of the lack of suitable primary and secondary standards. Consistency in irradiations will be demonstrated by use of a BF_3 detector mounted at a specific location that has been measured during previous experiments.

Records: The results of the verification measurement will be recorded in the daily logbook. Corrective actions (additional measurements, failure analysis) will be initiated if the observed value deviates more than 5% from the accepted true value.

4. Additional Tests

A. Verify half value layers for X-ray machine operation.

Purpose: To verify proper operation of the X-ray tube and ensure the output has not varied significantly from the calibrated conditions.

Procedure: The half value layer value will be measured for two National Institute of Standards and Technology (NIST) bremsstrahlung photon beam codes, M60 and H150, on a quarterly basis. Current settings will be made such that they correspond to the calibration conditions for the chambers. These values will be measured at 1 meter using the NE 2530/1 ion chamber and the aluminum plates provided for that purpose. The machine will be warmed up at the full operating voltage for at least 20 minutes prior to measurements. The X-ray beam will not be disrupted at any time during the measurements. When warmup has been completed, the PTW transmission chamber reading will be noted with both shutters open. The shutters will then be closed and the ion chamber positioned if not already in position. The output of the ion chamber will be measured at least 5 times along with the transmission chamber. The shutters will then be closed and an aluminum plate placed in the beam such that the chamber is shadowed and as much of the beam is covered as possible. The measurement will then be repeated as before and aluminum plates should be added until the data indicates that the total thickness of the added aluminum is greater than the second half value layer thickness. This procedure will then be repeated for the second beam code. First and second half value layers will be calculated along with the standard deviation for the measurements. These values will be compared with previous measurements and should vary no more that 2 standard deviations or 3%, whichever is less. If the values vary by more than 5%, the problem should be found and corrected. If the variation is 3-5%, the machine should be recalibrated.

Records: The procedure will be recorded in the equipment logbook and the data recorded in tabular form with previous data. Final results will be entered into the daily logbook in red ink.

B. Perform routine maintenance on the X-ray machine.

Purpose: To ensure proper operation of the X-ray machine by performing required maintenance on a regular schedule.

Procedure: The X-ray unit will be turned off and allowed to cool for at least one hour prior to servicing. The oil cooler unit will be turned off at least one half hour prior to servicing. The power switch on the console will be in the off position and the key removed. The three switches on the power feed will be switched off, one on the wall by the console, one on the wall by the power line filter unit, and one circuit breaker in the electrical panel next to the line filter unit. A tag will be placed on the circuit breaker indicating that the unit is tagged out. The lead enclosure will be opened and the inside checked for condition and cleanliness. Deficiencies should be corrected. The high voltage cable connectors will be removed one at a time and lubricated with the high-purity mineral oil provided for that purpose. After reconnecting, the connectors will be relocked and checked secure. The lead enclosure will then be reclosed. The connectors on the power supply end of the high voltage cables will be serviced in like manner. The fill cap on the oil cooler will then be removed and the calcium sulfate crystals should be replaced if saturated (blue in color). The unit should then be reassembled. The overall condition of the X-ray machine should be carefully noted and any problems corrected. The unit may then be returned to service by removing the lockout tag.

Records: The satisfactory completion of the procedure should be recorded in the daily logbook in red ink. Any deficiencies should be noted there and in the equipment maintenance logbook.

Appendix E: Training Lecture Outlines

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A. Outline for Experimenter/User Orientation Lecture

I. GOALS

a. ALARA
b. Environmental Protection

II. RESPONSIBILITIES

a. RETF Operation Coordinator
b. DOSAR Program Leader
c. Radiation Control Officer/Nuclear and Radiological Protection Division Representative

III. REQUIREMENTS FOR WORKING IN RETF

a. Properly monitored for radiation exposure
b. Properly trained in safety and to perform assigned task
c. An approved plan for completing work when required
d. Familiarity with the operating procedures

IV. TYPES OF HAZARDS

a. Radiological
b. Electrical
c. Mechanical

V. RADIATION HAZARDS

a. Neutron Sources
1 .Dose rates for storage pit - 0.1 mSv/h (10 mrem/h) at top of cover
2. Dose rate from large bare source - 0.15 mSv/min (15 mrem/min) at 1 meter
3. Dose rate from large source moderated - 0.04 mSv/min (4 mrem/min) at 1 meter
4. Dose rates from small source are about 1/3 of larger source
5. Dose rate from ^{238}Pu/Be source - 0.25 mSv/h (25 mrem/h) at 1 meter

b. Beta sources
1. Dose rate of 0.2 mGy/min (20 mrad/min) at 1 meter

c. Gamma sources
1. Panoramic irradiator - 3.2 (10^{-6}) C/kg-s (7.5 mR/min) at 1 meter
2. Beam irradiator - 2.57 (10^{-7}) C/kg-s (60 mR/min) at 1 meter

VI. SHIELDING

a. Walls
b. Doors
c. Distance

VII. PROCEDURES

a. Authorized operators
b. General safety
c. Written procedures
d. Housekeeping
e. Use of phantoms
f. Mounting of dosimeters or chambers
g. Pre-operational checks
h. Operators responsibilities
i. Post-operational procedures
j. Shutdown and lockup
k. Recordkeeping and logbooks

VIII. SPECIAL PROCEDURES FOR NEUTRON SOURCES

a. ^{238}Pu/Be source
    1. Source operation
    2. Emergency procedures
b. ^{252}Cf sources
    1. Source selection and setup
    2. Source operation
    3. Emergency procedures

IX. SPECIAL PROCEDURES FOR BETA SOURCES

a. Source timing options
b. Source operation
c. Emergency procedures

X. COMPUTER CONTROL SYSTEM

a. Basics of the control system
b. The control program
c. Program inputs and outputs
d. Emergency program interrupt

XI. SPECIAL PROCEDURES FOR GAMMA SOURCES

a. Gamma source selection
b. Source operation
c. Emergency procedures

B. Outline for RETF Operator Training Lectures

I. Facility Goals

a. Research objectives
b. Service functions
c. Certification

II.. Responsibilities

a. Management
b. Operator
c. Other personnel

III. Safety

a. References
b. Responsibilities
c. Radiation monitoring
d. General safety procedures
e. Application of RETF Protocol

IV. Gamma Source Operation

a. Source description
b. Radiation fields
c. Calibration
d. Safety systems
e. Operating controls
f. Emergency procedures

V. Beta Source Operation

a. Source description
b. Radiation fields
c. Calibration
d. Safety systems
e. Operating controls
f. Emergency procedures

VI. X-ray Machine Operation

a. Machine operation
b. Radiation fields
c. Calibration
d. Safety systems
e. Operating controls

f. Emergency procedures

VII. Neutron Source Operation

a. Source description
b. Radiation fields
c. Calibration
d. Safety systems
e. Operating controls
f. Emergency procedures

VIII. Computer Control

a. System description
b. Program function
c. Log-in procedures
d. Control operation
e. Operational checks
f. Maintenance
g. Emergency procedures

IX. Data Acquisition

a. Detector types
b. Electronic equipment
c. Detector setup
d. Calibrations
e. Operational checks
f. Data recording
g. Records and files
h. Storage

X. Requirements for Certified Calibrated Exposures

a. Exposure types
b. Associated equipment
c. Procedures during certified exposures
d. Proficiency tests
e. Annual calibration maintenance

XI. Work for Others

a. Solicitation of work
b. Charges
c. Handling of materials
d. Calibration reports

XII. Records

a. Computer files and records
b. Computer printouts
c. Calibration reports
d. Log entries
e. Experimenters log and data records

XIII. Planned Maintenance

XIV. Emergency Procedures

a. Operational procedures
b. Facility emergencies
c. Reporting malfunctions
d. Corrective actions

XV. QA/QC Procedures

XVI. Facility Modification Procedures

XVII. Unusual Events

Appendix F: Signature Record

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Each person working within the RETF as an operator or experimenter/user is required to read and understand the RETF Protocol and to follow the guidelines provided within. After reviewing the Protocol or the latest revision the person will sign below indicating they have read and understand the material contained within.

Date	Printed Name	Signature	Revision Date

ORNL-6904/R4

Internal Distribution

1-7. J.S. Bogard
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