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OAK RIDGE NATIONAL LABORATORY

LOCKHEED MARTIN

RADCAL OPERATIONS MANUAL

Radiation Calibration Laboratory

PROTOCOL

J. S. Bogard

December 1, 1998

Life Sciences DIVISION ornl

MANAGED AND OPERATED BY
LOCKHEED MARTIN ENERGY RESEARCH CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
managed by
LOCKHEED MARTIN ENERGY RESEARCH CORP.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-96OR22464

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PREFACE

The Life Sciences Division (LSD) of Oak Ridge National Laboratory (ORNL) has a long record of radiation dosimetry research, primarily using the Health Physics Research Reactor (HPRR) and the Radiation Calibration Laboratory (RADCAL) in its Dosimetry Applications Research (DOSAR) Program. These facilities have been used by a broad segment of the research community to perform a variety of experiments in areas including, but not limited to, radiobiology, radiation dosimeter and instrumentation development and calibration, and the testing of materials in a variety of radiation environments. Operations of the HPRR were terminated in 1987 and the reactor was moved to storage at the Oak Ridge Y-12 Plant; however, RADCAL will continue to be operated in accordance with the guidelines of the National Institute of Standards and Technology (NIST) Secondary Calibration Laboratory program and will meet all requirements for testing dosimeters under the National Voluntary Laboratory Accreditation Program (NVLAP).

This manual is to serve as the primary instruction and operation manual for the Oak Ridge National Laboratory's RADCAL facility. Its purpose is to (1) provide operating protocols for the RADCAL facility, (2) outline the organizational structure, (3) define the Quality Assurance Action 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 RADCAL 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 RADCAL 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 LSD Health Physics and Radiological Protection 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 RADCAL sealed radiological sources will be reviewed by the LSD Radiation Safety Officer and approved on the approval page.

The master copy of the manual will be maintained in the office of the RADCAL Operations Coordinator. A copy of the manual will be available in each irradiation room in the RADCAL facility and in the control room. The ORNL Office of Nuclear Safety 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.

PROCEDURE TITLE: RADCAL OPERATIONS MANUAL

Approval Page

Reviewed and Updated J S Bogard J. S. Bogard 11/20/98
RADCAL Operations Coordinator Date

Reviewed and Approved J S Bogard J. S. Bogard 11/20/98
Health Physics & Radiological Protection Program Leader Date

Reviewed and Approved R. E. Rodriguez R. E. Rodriguez 11/20/98
LSD Radiation Safety Officer (Alt) Date

Revision Distributed J S Bogard J. S. Bogard 11/20/98
RADCAL Operations Coordinator Date

Reviewed without Revision _____

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RADCAL Operations Coordinator Date

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1.0 Introduction

The RADCAL facility is operated as part of the Dosimetry Applications Research (DOSAR) Program of the ORNL Life Sciences Division. Its goal is to provide resources for and to perform a wide range of radiological experiments using calibrated radiation standards. The primary function of RADCAL 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). RADCAL 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.

Sources available at the facility include a medium energy Pantak HF320 X-ray machine, 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 1.5×10^{9} Bq (40 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. The 4.4×10^{10} Bq (1.2 Ci) source is mounted in a panoramic irradiator and the 3.7×10^{11} Bq (10 Ci) source in a beam irradiator with a 20 degree circular beam port. The 3.1×10^{11} Bq (8.5 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.

2.0 Organization

RADCAL is part of the Dosimetry Applications Research Program within the Assessment Technology Section of the Life Sciences Division at Oak Ridge National Laboratory. The following is a list of personnel positions and responsibilities directly related to RADCAL.

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

LSD Radiation Control Officer: Reviews RADCAL 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 RADCAL Project Director/Operations Coordinator.

Health Physics & Radiological Protection Program Leader: Overall responsibility for the daily activities associated with RADCAL. Responsible for funding, management, personnel assignments, review and approval of operating procedures, work contracts, purchase orders and facility modifications.

RADCAL Project Director/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 RADCAL facility. Coordinates experimenters and operators with the operational schedule. Interfaces with ORNL Plant & Equipment Division and other support personnel for work required involving the RADCAL facility. Reviews and updates the RADCAL Protocol Manual as necessary and oversees training.

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

Experimenter: Responsible for experimental design and setup. Works with the operator to ensure proper execution of the experiments. Submits operational requirements to the

RADCAL Operations Coordinator. Keeps log of all experimental parameters and data and provides complete records for file with the DOSAR Group.

Health Physicist: 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.

3.0 General Information

3.1 Safety

3.1.1 General Safety

It is the responsibility of each individual working in RADCAL 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 the ORNL Safety Manual and radiation safety is covered in the ORNL Health Physics Procedures Manual. All personnel working in RADCAL 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 RADCAL facility 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 RADCAL 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 a laboratory health physicist (HP) or by following approved written procedures. After a

new source has been installed, the area will be surveyed by an HP 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 a health physicist will immediately be notified. All personnel shall, unless injured, be required to remain at the evacuation location until released by the health physicist.

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

3.1.2 Confined Space

The RADCAL 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 ORNL safety procedures. 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 RADCAL. Only a certified RADCAL 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 RADCAL Protocol Manual.

3.2 Facility Description

3.2.1 Location

RADCAL (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 RADCAL to be carried out without interference from or danger to the general public. Front access to the main building is controlled by a central computer connected to a local security badge reader. The RADCAL access list, which is controlled by the Building 7735 Facility Manager, is limited to staff, security, and emergency personnel.

RADCAL 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 RADCAL operations and services.

3.2.2 Construction

The RADCAL facility is a 260-m^2 (2800-ft^2) building constructed of 20-cm (8.0-in) thick concrete-filled block walls. The building is encircled in a chained-off area with appropriate signs designating the area inside the chains as a radiation area. 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 and, in the future, the X-ray machine 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.

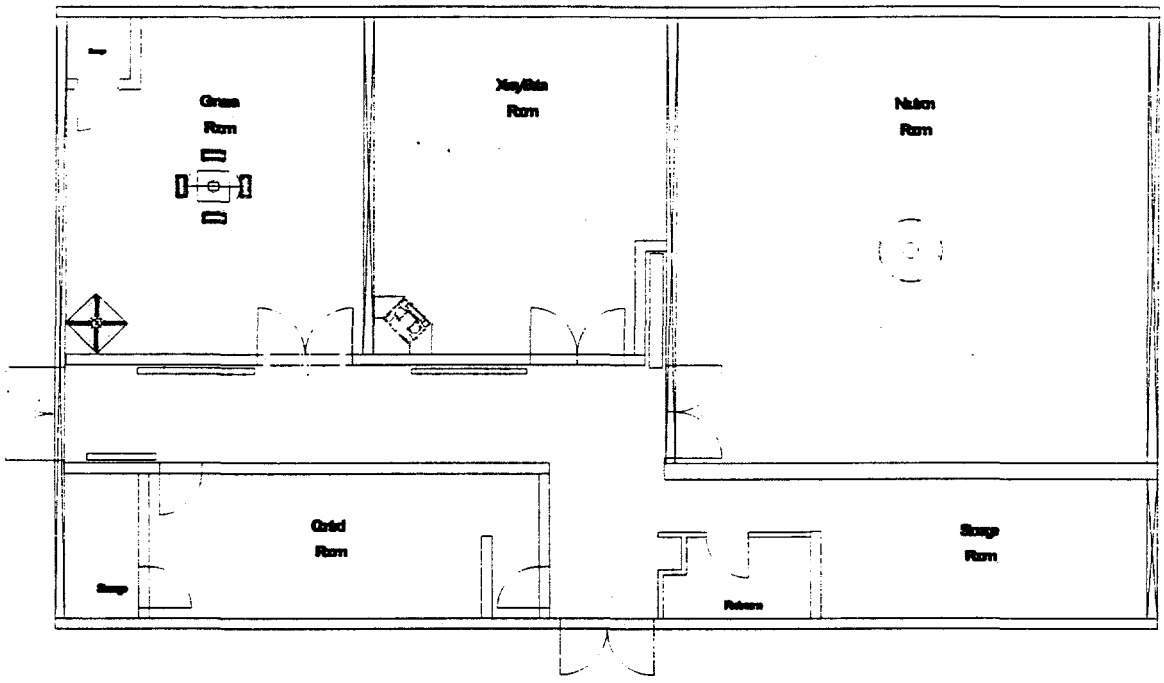

Figure 1 RADCAL Floor Plan

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.

4.0 Functional/Operational Considerations

4.1 Qualifications, Responsibilities, and Training

There are four personnel descriptions at RADCAL: Health Physics & Radiological Protection Program Manager, RADCAL Project Director/Operations Coordinator, RADCAL Operator, and Experimenter/User.

The qualifications for Health Physics & Radiological Protection Program Leader are determined by the Life Sciences 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 Program Leader functions as the program manager both for RADCAL and for other DOSAR programs and initiatives. He should be familiar with the RADCAL Protocol Manual and review it as part of the approval process.

The qualifications for RADCAL Project Director/Operations Coordinator (senior researcher) are determined by the Health Physics & Radiological Protection Program Leader, subject to approval by the LSD Assessment Technology Section

Head. The person should have a Ph.D., 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 RADCAL Operations Coordinator (ROC) is responsible for the day-to-day operations of RADCAL. 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 RADCAL Operator are subject to the approval of the Health Physics & Radiological Protection Program Leader and the RADCAL 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 Health Physics & Radiological Protection Program Leader.

The RADCAL 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 RADCAL facility, or anyone associated with an approved project or job and whose involvement is appropriate as determined by the ROC and RADCAL 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 RADCAL Project for more than 30 days will receive formal orientation and instruction.

4.1.1 Training

All personnel working at the RADCAL facility 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 ROC. The RADCAL ROC will decide if a visitor will be allowed unescorted access to RADCAL based upon the visitor's experience, knowledge of radiation physics, and familiarity with the RADCAL facility 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 the health physicist.

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 Health Physics & Radiological Protection Program Leader, Assessment Technology Section Head, LSD Radiation Control Officer, and the Life Sciences Division Director. A copy of the training record will be maintained by the Assessment Technology Section office and in the RADCAL Personnel Training Record File.

RADCAL operator training will be more rigorous and detailed. Actual training lectures and practice sessions will be scheduled by the 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, and Health Compliance. As part of the training, the prospective operator will be required to review the RADCAL Protocol Manual, any other appropriate manuals and guidelines that pertain to the RADCAL facility, 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 Health Physics & Radiological Protection Program Leader for approval as a certified Operator. A record of the training will be made and approved by the Health Physics & Radiological Protection Program Leader, Assessment Technology Section Head, LSD Radiation Control Officer, and the Life Sciences Division Director. A copy of the training record will be maintained in the Assessment Technology Section office and the RADCAL Personnel Training Record File. When the approved records have been properly filed, the operator will be considered for certification.

Until certification, no personnel will be allowed to remotely operate any sources in the RADCAL facility without direct supervision of a certified Operator. Sources which are operated manually, such as the ^{238}Pu/Be or ^{137}Cs source DOSAR 13, may be used by any personnel trained to do so at the Experimenter/User level. Sources configured for remote operation, but with manual capabilities, will only be operated manually by certified Operators with ROC approval.

4.2 Source and Irradiator Descriptions

Sources for use in the RADCAL facility 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 RADCAL are sealed sources which are surveyed routinely to assure the integrity of radioactive material encapsulation. The 3.7×10^{11}-Bq (10-Ci) source in the Amersham beam irradiator 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*. The estimated error of this calibration is 2%. The 4.4×10^{10}-Bq (1.2-Ci) source in the J. L. Shepherd panoramic irradiator 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

* Calibration values are given only in the units of the calibration, although SI units are used elsewhere throughout this text with conventional units in parentheses (as prescribed by Laboratory policy).

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 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 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 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.

4.2.3 Pantak HF320 X-ray Generator

The X-ray generator consists of a Pantak HF 320 X-ray generator 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 Nuclear Enterprises ion chamber or a calibrated extrapolation chamber at energies below 50 kV. The X-ray beam is monitored during exposures via a transmission type ion chamber.

4.2.4 Neutrons Sources: NSD-87, NSD-107 and ^{238}Pu/Be

The NSD-87 ^{252}Cf source had a neutron emission rate of 2.51×10^{9} s^{-1} as measured by NBS on May 6, 1987. 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 4.32 μSv/min (43.2 mrem/min) neutron at 1 m as of the above calibration date. When used inside the 30-cm diameter, D_2O-filled sphere, the dose rate was 3.84 μSv/min (43.4 mrem/min) at 0.5 m and

when used inside the 30-cm polyethylene moderator, the rate was 0.506 μSv/min (5.06 mrem/min) at 1 m as of the above reference date. The error in the neutron emission rate is estimated to be 1.4% and the dose equivalent conversion factors have an error of about 4% giving an overall uncertainty in the dose rate of less than 5% for the moderated irradiations. The uncertainty in the bare dose rate is essentially the same as the uncertainty in the moderated configuration.

The NSD-107 ^{252}Cf source 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 3.1×10^{10}-Bq (8.5-Ci) ^{238}Pu/Be source 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. All equipment in use calibrated prior to initial accreditation through the National Voluntary Laboratory Accreditation Program (NVLAP) and all subsequent replacement equipment is subjected to a documented program for quality control. The frequency, procedure and the equipment to be included in this program are addressed in section 4.7.

Except for the ^{238}Pu/Be 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, RADCAL 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 RADCAL facility provides calibrated radiation exposures in support of DOSAR programs and to clients from Energy Systems, 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 RADCAL 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 Energy Systems Central Work-for-Others (WFO) Office and are subject to approval by the Department of Energy. Instruments submitted to RADCAL for calibration or testing will be accompanied by a qualified service technician unless other arrangements are made in advance.

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 RADCAL 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 RADCAL 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.

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 RADCAL 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.

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 RADCAL control room or in the highly shielded counting room in DOSAR building 7710 until the scheduled irradiation time.

Preference will be given to dosimeters received for NVLAP type irradiations. 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 RADCAL 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 RADCAL control room or in the highly shielded counting room in DOSAR building 7710 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 RADCAL 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 RADCAL 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. 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 RADCAL logbook.

Each irradiation will be documented by a calibration irradiation report generated by the controlling computer and by a corresponding entry in the RADCAL 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

7.1 Gamma Irradiations

These procedures meet the basic requirements for operation of the 4.4×10^{10} Bq (1.2 Ci) ^{137}Cs panoramic gamma irradiator and the 3.7×10^{11}-Bq (10-Ci) ^{137}Cs gamma beam irradiator located in RADCAL at the DOSAR facility. These procedures do not replace, supersede, or alter the requirements contained in the ORNL Health Physics Procedure Manual, the ORNL Safety Manual, or any other 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 Health Physics Applications Program Leader upon recommendation of the RADCAL 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 RADCAL 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 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 health physicist notified of the problem.

Beam Irradiator - For the beam irradiator, the gamma room may be entered with great care taken to stay out of the path of the main radiation beam from the source. A handheld radiation survey instrument shall be utilized by the person entering the room to verify that he does not traverse the primary beam. 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 long pole may be used to push the source rod down. If this does not succeed, a health physicist should be notified of the problem.

If a problem is experienced with the sources, action should be taken to correct the problem and prevent its recurrence. The RADCAL Operations Coordinator and Health Physics & Radiological Protection 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 Beta Irradiations

These procedures meet the basic requirements for operation of the $^{90}Sr/^{90}Y$ beta irradiator located in RADCAL at the DOSAR facility. These procedures do not replace, supersede, or alter the requirements contained in the ORNL Health Physics Manual, the ORNL Safety Manual, or any other 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 Health Physics Applications Program Leader upon recommendation of the RADCAL 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 RADCAL 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, the room must be entered with great care taken not to approach the source too closely. A pole or meter stick may be used to push the source cover down. If this does not succeed, a HP should be notified of the problem. A portable dose rate survey meter shall be used 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 RADCAL Operations Coordinator and Health Physics Applications 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.

7.3 X-ray Irradiations

These procedures meet the basic requirements for operation of the Pantak HF320 X-ray beam generator located in RADCAL, Bldg 7735. These procedures do

not replace, supersede, or alter the requirements contained in the ORNL Health Physics Procedures Manual, the ORNL Safety Manual, or any other guidelines applicable to the operation of radiation sources and personnel safety such as ANSI 543-1974.

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 RADCAL Operations Coordinator until certification is approved for other operators. **The unit will be operated at a maximum tube potential of 150 kV during any type of measurement that requires opening both shutters, except under the direct supervision of a qualified health physicist.** 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 RADCAL Operations Coordinator and the Health Physics Applications Program Leader. If the system cannot be restored, it should be properly tagged to prevent operation until corrections are made and checked.

7.4 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 RADCAL. These procedures do not replace, supersede, or alter the requirements contained in the

ORNL Health Physics Procedure Manual, the ORNL Safety Manual, or any other 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 Health Physics Applications Program Leader upon recommendation of the RADCAL 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 RADCAL 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 following as a guide:

^{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 HP 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. If this does not succeed, a HP should be notified of the problem.

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 RADCAL Operations Coordinator and Health Physics Applications 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.

7.5 Calibration/Irradiation Reports

A calibration or irradiation report shall be issued for each irradiation performed. The report shall clearly describe the conditions of the irradiation including orientation of item, i.e., distance from the center of the source, elevation, and angle of incidence, and the environmental conditions (i.e., temperature, relative humidity and barometric pressure). Any limitations of the calibration such as maximum range calibrated if less than the indicated range of the instrument, scales not calibrated, application of calibration factors as well as the uncertainty associated with the calibration shall be included.

When there is a possible question of accreditation, the report form shall include the following statement with the appropriate box checked:

> "This calibration_ was_ was not performed using a procedure which is within the scope of accreditation."

Calibration reports shall be signed by the RADCAL Operator performing the calibration and reviewed and signed by the ROC or Health Physics & Radiological Protection 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 RADCAL 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.

8.0 Records Keeping and Data Management

The RADCAL daily logbook shall contain a brief description of activities performed in or related to RADCAL. 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 RADCAL. These are maintained in three-ring binders labeled with the year covered in that volume.

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

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

All Calibration and Irradiation Reports for a year shall be maintained on a removable Bernoulli cartridge. This cartridge shall be backed-up monthly and two copies archived at the end of one year. One copy shall be stored in the RADCAL control room and one in a storage location in DOSAR Building 7710 (ROC 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 RADCAL 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

When the need arises to alter or revise operational procedures, a formal revision process as determined by the divisional QA representative and outline in the Preface must be followed. Any significant alteration or revision affecting a service previously accredited by NIST must be approved by the accrediting body.

8.3 Signature Record

A signature record of all personnel required to read and fully understand the RADCAL Protocol Manual is maintained in 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 ROC for final review. The ROC or, in the case of the ROC being the operator, the Health Physics & Radiological Protection Program Leader will review and sign each report.

10.0 Quality Assurance Plan Description

10.1 Organization

Requirements: The organizational structure, functional responsibilities, levels of authority, and lines of communication for activities affecting quality shall be documented and controlled (1).

This requirement is addressed in this manual in section 2. *(Organization)*.

10.2 Quality Assurance Program

Requirements: ORNL management shall implement those QA requirements that are applicable to all projects and programs given by DOE in DOE Order 5700.6C, *Quality Assurance* (2), as interpreted in DOE-ER-STD-6001-92, "Implementation Guide for Quality Assurance Programs for Basic and Applied Research" (3), and by Oak Ridge National Laboratory in its Standard Practice Procedures (4) and GP-5, *Quality Assurance Program* (5).

All personnel performing operations in RADCAL shall receive training to acquire necessary skills to perform their responsibilities. Training is addressed in section 4.1 (Qualifications and Training). All key personnel responsible for operations at RADCAL shall have a qualified individual designated to serve as their replacement in the event of an extended absence. This organizational structure with designated replacement shall be on file in the front office of DOSAR (Building 7710). These shall be updated as necessary.

10.3 Design Control

Requirements: ANSI/ASME NQA-1, Sect.II-3 (6), requires that the design be defined, controlled, and verified.

RADCAL personnel shall have responsibility for initiating action to authorize conceptual design, providing technical criteria, and reviewing and approving design for RADCAL projects. The RADCAL personnel shall be responsible for performing design activities in accordance with the authorization and technical criteria.

RADCAL personnel shall also have primary responsibility for determining if the conceptual design is satisfactory for its intended use (7).

10.4 Procurement Document Control

Requirements: Requirements necessary to ensure adequate quality shall be included or invoked on documents (purchase requisitions, purchase orders, and specifications) for procurement of items. In addition, measures shall be established to ensure that purchased items conform to procurement documents (7).

All items and services procured by contract shall require the supplier to meet applicable specifications as stated by RADCAL personnel. The specifications shall be written into the ORNL Purchase Order Agreement. If needed to ensure the specifications are clearly understood by all parties concerned, specifications shall be discussed with the supplier at the time of the contract award by representatives of the RADCAL staff. Inclusion of appropriate specifications in the contracts shall be the shared responsibilities of the RADCAL Operations Coordinator, Health Physics Applications Group Leader, and the purchasing agent in Energy Systems Purchasing Department.

10.5 Instructions, Procedures, and Drawings

Requirements: ANSI.ASME NQA-1, Sect. II-5 (6), and DOE Order ORO 5700.6C (2), require that all activities affecting quality be prescribed by and performed in accordance with documented instructions, procedures or drawings of a type appropriate to circumstances. These documents shall include or reference appropriate quantitative or qualitative acceptance criteria for determining that prescribed activities have been satisfactorily accomplished (9).

All facets of RADCAL activities and operations, from general to specific, are either addressed directly or referenced in the Oak Ridge National Laboratory RADCAL Protocol and DOE Program documentation. These include all instructions, procedures, and drawing specifications as follows:

- Procedures to ensure dependability of calibration related equipment (QC checks etc.)

- Procedures describing set-up, alignment and positioning of items for calibration.
- Procedures to perform irradiations.
- Procedures to verify accuracy of calibrations and related irradiations.
- Procedures for logging and handling items for calibration.
- Procedures to ensure documentation of calibrations.
- Procedures for preparation, review and disposition of reports.
- Procedures to ensure document control.

All documents shall be reviewed by the ROC to ensure compliance with approved procedures. Approval shall be acknowledged by his signature on the transmittal letter.

10.6 Document Control

Requirements: The preparation, issuance, and change of documents that specify quality requirements for items or prescribed activities affecting quality (fitness for intended use) shall be controlled to ensure that correct documents are being employed and are available at the location where they are to be used. Such documents, including changes thereto, shall be reviewed for adequacy and approved for release by authorized personnel (10).

All documents related to RADCAL operations shall be reviewed and approved as detailed in section 8.2 (Document Revision, History and Approval).

10.7 Control of Purchased Items and Services

Requirements: Requirements necessary to control the procurement of items or services shall be invoked to assure conformance with specified requirements. As a minimum, procurement of special items and services for all ORNL projects and programs shall be controlled. Such control shall provide for source evaluation and selection, evaluation of objective evidence of quality furnished by the supplier, and examination of items or services upon delivery or completion (11).

The procurement of items and services is controlled by the RADCAL staff to assure conformance with specifications. The criteria on which to base compliance is specified in the contract purchase order prepared by the RADCAL staff. The

Purchasing Department of Energy Systems reviews the Purchase Order Agreement for completeness and then bids the contract to qualified bidders according to procedures approved by DOE, DOD, HSRD, and ORNL. Supplier bids are reviewed by the purchasing agent, and the lowest qualified bid is recommended to RADCAL personnel. The qualifications and bids are reviewed by the ROC or designated person for acceptance. All items, with the exception of routine office supplies, shall be visually inspected by the individual using them. Any nonconformances shall be reported, verified, and documented.

10.8 Identification and Control of Items

Requirements: Controls shall be established to ensure that only correct and accepted items are used or installed.

All equipment essential to calibration activities shall be controlled. All equipment shall be identified and documented in a manner providing traceability to documentation that verifies the acceptability of the item. No item shall be installed unless it has been approved and documented as acceptable. Any items improperly identified, defective in workmanship or otherwise failing to meet criteria for acceptability, shall be identified, marked and handled appropriately (12).

10.9 Control of Process

Requirements: Special processes that control or verify quality shall be performed by qualified personnel in accordance with specified requirements (13).

Operations affecting the quality of calibrations and irradiations shall be controlled. Calibration and QC checks of instrumentation are addressed in Sect. 4.7 (Source, Instrument, and Equipment Reliability).

10.10 Inspection

Requirements: Inspection activities required to verify conformance of an item or activity to specified requirements shall be planned and executed (14).

Inspections are required to verify conformance of items and activities to

specified requirements. The ROC assumes these inspection responsibilities. The ROC may delegate portions of the inspection responsibilities to appropriate qualified individuals. Specific inspection responsibilities are addressed in other sections of this document. Purchased equipment is inspected by Instrumentation & Controls and RADCAL personnel according to specified procedures as documented in the ORNL *Quality Assurance Manual.*

10.11 Test Control

Requirements: Tests required to verify conformance of an item to specified requirements and to demonstrate that items will perform satisfactorily in service shall be planned and executed. Characteristics to be tested and test methods to be employed shall be specified. Test results shall be documented, and their conformance with acceptance criteria shall be evaluated (15).

10.12 Control of Measuring and Test Equipment

Requirements: ANSI/ASME NQA-1, Sect. II-12 (6), requires that measuring and test equipment used during research, development, manufacturing, installation, construction, pre-operational testing, operation, and maintenance activities be controlled and calibrated as necessary to meet program objectives and ensure safe, reliable, cost-effective, and timely operation. As a minimum, measuring and test equipment relied upon for safe operation, acquisition of reportable experimental data, and inspection activities shall be calibrated before initial use and recalibrated in a timely manner during routine use. In addition, QA plans shall list all special calibration requirements.

Conformance testing on equipment shall be conducted on a routine basis (16). Section 4.7 (Source, Instrumentation, and Equipment Reliability) addresses this issue.

10.13 Handling, Storage, and Shipping

Requirements: Handling, storage, and shipping of items shall be conducted in accordance with established work and inspection instructions, drawings, specifications, shipment instructions, or other pertinent documents or procedures specified for use in conducting the activity (17).

Section 6 (Materials Handling Pre/Post Irradiation) addresses these issues.

10.14 Inspection, Test, and Operating Status

Requirements: The status of inspection and test activities shall be identified either on items or in documents traceable to the items to ensure that required inspections and tests are performed and to ensure that items which have not passed the necessary inspections or tests are not inadvertently installed, used, or operated (18).

The inspection, test, and operating status of all equipment is maintained on file in the RADCAL control room. Nonconforming equipment shall be tagged and stored to prevent inadvertent use. All equipment used in calibration and irradiations shall have the date of the last inspection and the date of the next inspection (defined by RADCAL requirements and procedures) indicated on an affixed sticker.

10.15 Control of Nonconforming Items

Requirements: ANSI/ASME NQA-1, Sect.II-15 (6), requires that nonconforming items be controlled to prevent inadvertent installation or use. Each ORNL division and program ensures prompt identification, control, and disposition of items that do not conform to drawings and specifications (19).

10.16 Corrective Action

Requirements: ANSI/ASME NQA-1, Sect. II-16 (6), requires that all significant quality problems be investigated and documented for management review and, when appropriate, corrective actions taken.

All conditions adversely affecting quality shall be promptly identified, documented, and corrected as soon as possible (20). Section 4.7 (Source, Instrument, and Equipment Reliability) addresses these issues.

10.17 Quality Assurance Records

Requirements: Records that furnish documentary evidence of quality (fitness for intended use) shall be specified, prepared, and maintained. Records shall be protected against damage, deterioration, or loss. Requirements and responsibilities for record

transmittal, distribution, retention, maintenance, and disposition shall be established and documented (21).

Records that furnish documentary evidence of quality, such as inspections, audits, and corrective actions, shall be prepared and maintained on file in the RADCAL control room, according to provisions outlined in *ORNL Standard Practice Procedures* (21).

10.18 Audits

Requirements: Planned and scheduled audits shall be performed to verify compliance with all aspects of the QA program and to determine its effectiveness. These audits shall be performed in accordance with written procedures and checklists by personnel who do not have direct responsibility for performing the activities being audited. Audit results shall be documented and reported to and reviewed by responsible management. Follow-up action shall be taken by the responsible line organization when necessary, and the corrective actions will be monitored by the ORNL Manager of Quality Audits (22).

All audits and surveillances conducted by the RADCAL QA Coordinator, or qualified designee, shall be performed according to written procedures as outlined in *ORNL Standard Practice Procedures* (22). Audit and surveillance results shall be documented and reported to and reviewed by responsible management. Follow-up action for discrepancies noted during the audit and surveillance shall be taken and implemented as needed. All follow-up actions shall be documented and filed in the RADCAL control room.

10.19 Software

Requirements: Verification is required for all computer codes acquired, modified, or developed during support of a RADCAL project. Validation is required at the responsible manager's option. This procedure is to be applied in a graded manner according to agreements reached between the responsible manager and the Quality Assurance Specialist (QAS) (23).

Verification of control software and interface programs shall be performed in a graded manner according to specifications identified by the ROC and the Quality

Assurance Specialist (23).

REFERENCES

1. *ORNL Standard Practice Procedures*, Y/QD-15, "Quality Program Plan," Oak Ridge National Laboratory, Oak Ridge, TN, Current Edition.

2. U.S. Department of Energy, DOE Order 5700.6C - *Quality Assurance*, U.S. Department of Energy Oak Ridge Operations Office, 1991.

3. U.S. Department of Energy, DOE-ER-STD-6001-92, "Implementation Guide for Quality Assurance Programs for Basic and Applied Research", U.S. Department of Energy Oak Ridge Operations Office, 1992.

4. *ORNL Standard Practice Procedures*, SPP X-QA-1, "Quality Assurance Program," Oak Ridge National Laboratory, Oak Ridge, TN, Current Edition.

5. *Policy Procedures Manual*, Martin Marietta Energy Systems, Inc., Oak Ridge, TN, Current Edition.

6. *Quality Assurance Program Requirements for Nuclear Facilities*, ANSI/ASME NQA-1, The American Society of Mechanical Engineers, 1986.

7. *ORNL Standard Practice Procedures*, ESS-QA-3.0, "Design Control," Oak Ridge National Laboratory, Oak Ridge, TN, Current Edition.

8. *ORNL Standard Practice Procedures*, SPP X-GP-16, "Procurement of Critical Applications/Safety-Class Items and Services at ORNL," Oak Ridge National Laboratory, Oak Ridge, TN, Current Edition.

9. *ORNL Standard Practice Procedures*, ESS-QA-5.0, "Instructions, Procedures, and Drawings," Oak Ridge National Laboratory, Oak Ridge, TN, Current Edition.

10. *ORNL Standard Practice Procedures*, SPP X-AD-9, "ORNL Document Management," Oak Ridge National Laboratory, Oak Ridge, TN, Current Edition.

11. *ORNL Standard Practice Procedures*, SPP X-QA-7.0, "Control of Purchased

Items and Services," Oak Ridge National Laboratory, Oak Ridge, TN, Current Edition.

12. *ORNL Standard Practice Procedures*, ESS-QA-8.0, "Identification and Control of Items," Oak Ridge National Laboratory, Oak Ridge, TN, Current Edition.

13. *ORNL Standard Practice Procedures*, ESS-QA-9.0, "Control of Processes," Oak Ridge National Laboratory, Oak Ridge, TN, Current Edition.

14. *ORNL Standard Practice Procedures*, ESS-QA-10.0, "Inspection," Oak Ridge National Laboratory, Oak Ridge, TN, Current Edition.

15. *ORNL Standard Practice Procedures*, ESS-QA-11.0, "Test Control," Oak Ridge National Laboratory, Oak Ridge, TN, Current Edition.

16. *ORNL Standard Practice Procedures*, SPP X-GP-8, "Control and Calibration of Measuring and Test Equipment at ORNL," Oak Ridge National Laboratory, Oak Ridge, TN, Current Edition.

17. *ORNL Standard Practice Procedures*, ESS-QA-13.0, "Handling, Storage, and Shipping," Oak Ridge National Laboratory, Oak Ridge, TN, Current Edition.

18. *ORNL Standard Practice Procedures*, ESS-QA-14.0, "Inspection, Testing, and Operating Status," Oak Ridge National Laboratory, Oak Ridge, TN, Current Edition.

19. *ORNL Standard Practice Procedures*, SPP-X-QA-9, "ORNL Non-Conformance Reporting," Oak Ridge National Laboratory, Oak Ridge, TN, Current Edition.

20. *ORNL Standard Practice Procedures*, SPP-X-QA-3, "ORNL Energy Systems Action Management System (ESAMS)," Oak Ridge National Laboratory, Oak Ridge, TN, Current Edition.

21. *ORNL Standard Practice Procedures*, SPP-X-AD-7, "ORNL Records

Management," Oak Ridge National Laboratory, Oak Ridge, TN, Current Edition.

22. *ORNL Standard Practice Procedures*, SPP-X-QA-7, "ORNL Quality Assurance Audits," Oak Ridge National Laboratory, Oak Ridge, TN, Current Edition.

23. *ORNL Standard Practice Procedures*, SPP-X-QA-8, "Quality Assurance for ORNL Computer Software," Oak Ridge National Laboratory, Oak Ridge, TN, Current Edition.

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Appendix A

Health Physics

Radiation Surveys

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Radiation survey reports are located in the RADCAL 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.

Dosimeter-Pair Serial Numbers (HBG/NEU)[2]	Delivered Dose Equivalent (mrem) 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
RADCAL Operator

Approved: _____
J. S. Bogard, Ph.D., C.H.P.
Dosimetry Applications
Research 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/

Calibration 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
   D. Verify dose delivered

2. Monthly Checks and Maintenance

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

3. Quarterly Checks and Maintenance

   A. Verify correct operation of all interlocks
   B. Verify calibration factor between primary and secondary standards

4. Annual Checks and Maintenance

   A. Calibrate primary standards as necessary at NIST
   B. Undergo proficiency test by NIST

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Appendix D

Planned Maintenance/

Calibration 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 RADCAL 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 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 RADCAL 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 RADCAL Operations Log. No other records are required beyond that specified in Sections 7 and 8.

D. Verify Dose Delivered

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. For gamma irradiations on a standard phantom, a miniature GM tube (labeled Phil Tube #1) will be placed on the phantom at a previously calibrated position. Similarly, an ion chamber (either a NE type 2530/1 or an Exradin model A2/A3) will be mounted on the phantom at a calibrated position for verification of an X-ray irradiation. In addition, the beam will be monitored using a PTW transmission chamber. The output of the transmission chamber will be recorded at regular intervals as well as monitored on a scope by the operator. The irradiation will be rejected if excessive noise is observed on the scope or excessive drift is observed on the recorder.

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 or on the radiation report. In the case where the recorded value exceeds 2 standard deviations from the calibration value (as measured during the calibration process), the calibration will be rejected.

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 RADCAL 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. A malfunction in the interlocks will be sufficient to suspend use of that room until the problem is corrected.

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 5.25 in. floppy diskettes. One of these will be maintained in the RADCAL control room and the other will be stored in the RADCAL ROC'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 RADCAL 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 RADCAL ROC. No operations of the source should be allowed until the problem is fixed and verified.

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 Office of Radiation Protection as specified in Radiological Protection Procedure RPP-365.

B. Verify calibration factor between primary and secondary standards.

Purpose: To ensure that radiation detectors used for routine QA/QC measurements are within the prescribed calibration range.

Procedure: For gamma detectors, the secondary standard will be the Phil tube labeled #1 or a second Exradin A2/A3 ionization chamber. It will be positioned on a standard phantom at a location 10 cm from the top and on the front vertical centerline. The primary standard, an Exradin A2/A3 type ionization chamber with a current calibration, should be located at the center of the front face of the phantom. The gamma beam source will be used with a source-to-phantom distance of 1.5 meters. Irradiation times should be 3 to 5 minutes as controlled by the timer units on the data acquisition units. The counts registered with the Phil tube will be divided by the calculated dose from the ion chamber. The measurement should be repeated a minimum of 5 times and the mean and standard deviation calculated. The phantom should then be positioned at 1 meter and the measurements repeated. Results will be recorded in the equipment maintenance log and the daily logbook. The resulting calibration factors will be used in the procedure for verifying the radiation dose delivered in normal operations. The dose rate calculated from the primary standard should be within 3% of the expected rate from the source calibration and previously acquired data. The measurement should be repeated and care should be taken to find the cause of any discrepancy exceeding 3%. No calibration will be accepted until the results agree within 3% consistently.

For X-ray detectors, the above procedure will be repeated using the NE type 2530/1 ion chamber or the PTW extrapolation chamber as appropriate for the primary standard and the PTW transmission chamber and another ion chamber for the secondary standard. The beam codes used will consist of all codes being offered as a service. Any codes not calibrated will be calibrated before use when necessary. The distance will be set at 1 meter and the data taken and compared as with the gamma detectors.

No secondary standards are available for the beta source. The PTW extrapolation chamber will be used for both the primary and secondary detector. Neither a primary nor a secondary standard is currently available for neutron exposures. A BF_3 tube will be used during multiple exposures to demonstrate consistency.

Records: Data and descriptions of the calibration transfer along with any deficiencies noted will be recorded in the equipment maintenance logbook. A record will be made in the daily logbook of the measurement, results, and deficiencies in red ink along with the calibration factor.

C. 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 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.

D. 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 checked to ensure they are not saturated. If saturated (blue in color), the cap should be taken to Building 7710 and the crystal dried in an appropriate oven. 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.

3. Annual Calibration and Test Requirements

A. Calibrate primary standards at NIST.

Purpose: To maintain up-to-date and accurate calibrations of detectors and sources by comparison of a set of primary standard detectors directly with NIST calibration standards.

Procedure: Arrangements for calibration of detectors will be made with personnel at NIST and detectors will be transported to NIST via personal transport when possible. The selection of detectors to use as primary standards will be made to ensure a calibrated standard for each type of radiation provided as a calibration service where possible. This should include as a minimum an ion chamber for gamma ray sources, ion chambers to cover all X-ray beam codes, and electrometers used with the ion chambers and extrapolation chambers. Calibration should also be maintained on all voltage/current sources that are used for calibration and testing of instruments.

Upon return of the calibrated detectors from NIST, the calibration of all sources should be checked to ensure that values used in the computer codes and other calculations are accurate. If the discrepancy is outside one standard deviation, the values should be updated to reflect the measurements made with the newly calibrated detectors. No primary standard detector currently exists for neutron sources, so no measurement corrections will be made for those sources.

Records: Two copies of the calibration reports will be made upon receipt. One will be filed in the RADCAL Operator's office (Building 7710) and the other will be taped into the equipment maintenance logbook in the RADCAL control room. The original will be filed in the RADCAL ROC's office. An entry will be made in the equipment maintenance logbook of all source measurements and an entry of each calibration completed shall be made into the daily logbook in red ink.

B. Undergo proficiency test by NIST

Purpose: To obtain and maintain certification as a secondary calibration laboratory by undergoing annual certification proficiency test administered by personnel at NIST.

Procedure: The nature of the proficiency test and the scheduled test dates will be determined by NIST. Prior to applying for the test, a review will be held to determine any deficiencies in the current calibration program and procedures. The RADCAL ROC will review all procedures, calibrations, and source characterization studies to ensure they are up to date and accurate. Action will be taken as appropriate to correct any deficiencies. If any deficiencies are identified during the proficiency testing or any safety or operational review, it will then be the responsibility of the ROC to ensure those deficiencies are corrected in a timely manner and that the certification is maintained.

Records: No records are required for this procedure beyond that outlined in other sections of this protocol.

Appendix E

Training Lecture

Outlines

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A. Outline for Experimenter/User Orientation Lecture

Ref: ORNL Radiological Protection Procedures

I. GOALS

a. ALARA

b. Environmental Protection

II. RESPONSIBILITIES

a. RADCAL Operation Coordinator

b. Health Physics & Radiological Protection Program Leader

c. Radiation Control Officer/Office of Radiation Protection Representative

III. REQUIREMENTS FOR WORKING IN RADCAL

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 RADCAL Operator Training Lectures

Ref: ORNL Radiological Protection Procedures

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 RADCAL 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

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

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Appendix F

Signature Record

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PROCEDURE TITLE: RADCAL OPERATIONS MANUAL

Each person working within the RADCAL facility as an operator or experimenter/user is required to read and understand the RADCAL 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

Internal Distribution

1-7. J.S. Bogard
8. B. D. Embleton
9. R.E. Rodriguez
10. R.E. Swaja
11. W.L. Robbins
12. Laboratory Records
13. Laboratory Records - RC
14. ORNL Office of Nuclear Safety
15. ORNL Patent Section