Florida Department of Transportation

Analytical X-ray Radiation Safety Manual

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Chapter 1 - Introduction

1.1 Purpose

This manual describes the Department's radiation safety program (RSP) established to address analytical x-ray operations at the State Materials Office (SMO) authorized under Florida Radiation Machine Registration Number JR 34613000. It describes analytical x-ray machine related facilities, equipment, procedures and personnel qualification and responsibilities.

This manual provides information and instructions for safe and proper use of hand-held, benchtop, and large fixed analytical x-ray machines, and compliance with state and federal regulations applicable to the Department's analytical x-ray operations at the SMO.

1.2 Authority

Sections 20.23(3)(a), and 334.048(3), Florida Statutes (F.S.)
This manual conforms to requirements for a written RSP specified in Part III (Standards for Protection Against Radiation) of Chapter 64E-5, Florida Administrative Code (FAC), titled Control of Radiation Hazards Regulations.

1.3 Scope

The principal users of this manual are:

- Department and consultant personnel operating analytical x-ray machines possessed under Florida Radioactive Machine Registration Number JR 34613000; and

- Department personnel responsible for administration of the FDOT analytical x-ray RSP. These personnel are the State Radiation Safety Officer (SRSO), Chemistry Laboratory Manager and Bituminous Binder Laboratory Manager.

1.4 Training

The training requirements described in Table 1 below are mandatory for the Department's analytical x-ray machine operators and RSOs, which is covered in FDOT Course Number ST-06-0002, Safety and Control of Analytical X-ray Equipment. Chapter 3 of this manual describes the Department's training program.

Table 1: Training Requirements

Training Requirement	Regulation
Radiation awareness level training	Sec. 64E-5.902, FAC
Analytical x-ray machine operator training	Subsec. 64E-5.704(1), FAC

1.5 Acronyms and Abbreviations

Table 2: Acronyms and Abbreviations

Acronym	Abbreviation
ALARA	As low as reasonably achievable
ARSO	Alternate RSO
BRC	Bureau of Radiation Control (FL)
CFR	Code of Federal Regulations
FAC	Florida Administrative Code
FDA	Food and Drug Administration (U.S.)
FDOH	Florida Dept. of Health
FDOT	Florida Dept. of Transportation
I&M	Inspection and maintenance
kV	kilovolt
mA	milliamp
MOP	member(s) of the public
mR	milliroentgen
mrem	millirem
NRC	Nuclear Regulatory Commission
O&E	Operating & emergency (procedures)
OJT	On-the-job-training
OSHA	Occupational Safety & Health Admin.
PM	Personnel monitoring
PMI	Positive materials identification
RSC	Radiation Safety Consultant
RSM	Radiation safety manual
RSO	Radiation safety officer
RSP	Radiation safety program
SI	International System of Units
SMO	State Materials Office
SRSO	State Radiation Safety Officer
XRD	X-ray diffraction

Acronym	Abbreviation
XRF	X-ray fluorescence
XRS	X-ray spectrometer
XRSM	X-ray radiation safety manual

1.6 Posters and Forms

Poster notification and forms referenced in this manual are available in Appendices A and B.

1.7 Radiological Units

Additional reference material for radiological units can found in Appendix C.1.

Chapter 2 - Administrative Procedures

2.1 Purpose

This chapter provides information and instructions on administration of the Department's radiation safety program (RSP) for analytical x-ray operations authorized by Florida Radiation Machine Registration Number JR 34613000.

2.2 Authority

Sections 20.23(3)(a), and 334.048(3), Florida Statutes (F.S.)
This manual conforms to requirements for a written RSP specified in Part III of Chapter 64E-5, Florida Administrative Code (FAC).

2.3 Scope

The principal users of this chapter are FDOT personnel responsible for administration of the Department's RSP for analytical x-ray machines. These personnel are the State Radiation Safety Officer (SRSO), Chemistry Laboratory Manager, and Bituminous Binder Laboratory Manager.

2.4 Training

The State RSO is subject to the same training requirements as analytical x-ray machine operators, which are listed in Table 1. Chapter 3 of this manual describes the Department's analytical x-ray radiation safety training program.

2.5 Posters and Forms

Posters and forms referenced in this chapter are available in this manual's Appendices A and B.

2.6 FDOT Radiation Safety Program and Manual

2.6.1 General

The Department possesses portable, benchtop, and stand-alone analytical x-ray machines. As a registrant, the Department is required to establish and implement a formal RSP. The Department's program is described in this document, the Analytical X-ray Radiation Safety Manual (XRSM). The XRSM describes the administrative and operational aspects of the program in conformance with applicable state and federal regulations. Changes to the manual must be submitted to FDOH for review and approval.

2.6.2 Organizational Structure

The Department's x-ray RSP is led by the State Radiation Safety Officer (SRSO), based at the State Materials Office (SMO) in Gainesville. The SRSO may be supported by, and delegate program tasks to SMO staff and/or a radiation safety consultant. The contract consultant position is optional.

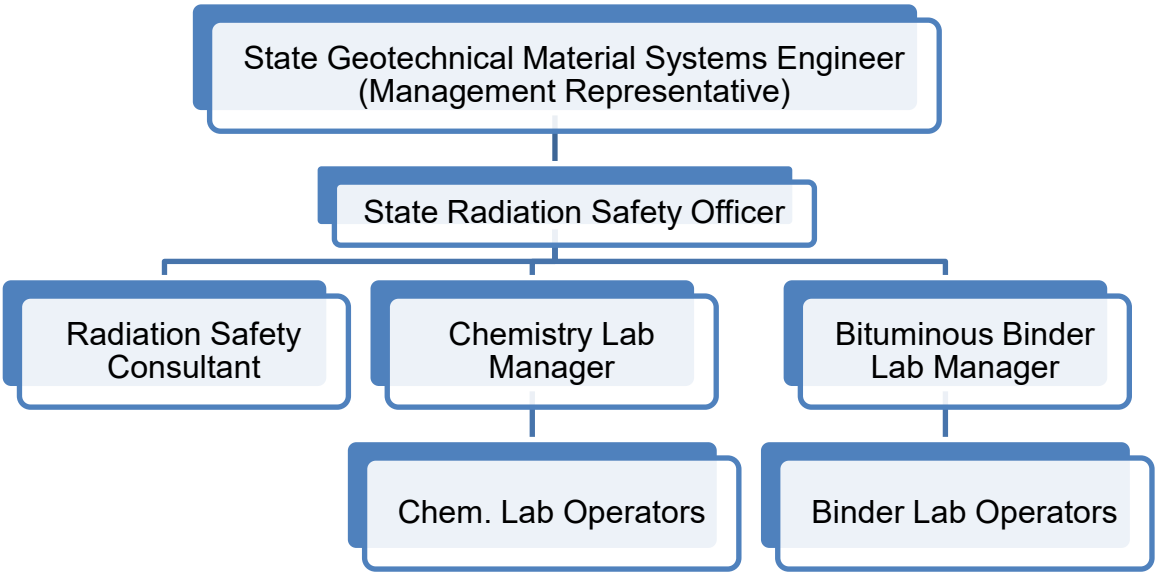


Figure 1: Radiation Safety Program Organizational Chart

2.6.3 Compliance

Department personnel are required to comply with all applicable provisions of the RSM. Personnel with repeated instances of noncompliance with RSM requirements may be denied the privilege of working with analytical x-ray equipment by the SRSO. Sections 112.311 – 112.326 of Chapter 112, FAC (Code of Ethics for Public Officers and Employees) describe conduct standards and the actions that may be taken for violations of the standards.

2.6.4 Format

The RSM is formatted in accordance with the Standard Operating System (Topic No. 025-020-002) established by the Department, Forms and Procedures Office. The RSM is available on the Department's website:

http://www.fdot.gov/materials/administration/resources/library/publications/rsamanual/index.shtm

To receive updates on the RSM, personnel can submit their email address through the SMO Publication RSM webpage on the Internet using this URL: http://www.fdot.gov/materials/administration/resources/library/publications/rsamanual/registration.shtm

2.7 Regulations

2.7.1 Chapter 64E-5, Florida Administrative Code

Possession and use of sources of ionizing radiation is regulated by the Florida Department of Health (FDOH), Bureau of Radiation Control (BRC) under the authority of Chapter 404, Florida Statutes, and implemented through Chapter 64E-5, Florida Administrative Code (FAC) – the Florida Radiation Control Regulations. These regulations are available on the agency's website:

http://www.floridahealth.gov/environmental-health/radiation-control/_documents/regs/64e-5tab.html

The parts listed in Table 3 below apply to the Department's analytical x-ray machines.

Table 3: Regulations Applying to the Department

Part	Description
I	General Provisions
III	Standards for Protection Against Radiation
V	Medical Uses of X-rays (registration requirements)
VII	Rad. Safety Requirements for Analytical X-ray Equipment
IX	Notices, Instructions, and Reports to Workers; Inspections

2.8 Registration Requirements and Procedures

FDOT is required to confine its possession of x-ray machines to the equipment, applications, and locations authorized by the registration certificate.

2.8.1 Compliance with Public Dose Limits

Florida radiation control regulations (section 64E-5.312, FAC) require the Department to conduct its operations in compliance with the public dose limits listed below:

- Doses in unrestricted areas do not exceed 2 mrem in any one hour.

- Doses to members of the public do not exceed 100 mrem in a year.

With respect to the Department's x-ray operations, anyone who is not a designated analytical x-ray machine operator is a member of the public, and subject to the public dose limits. The State RSO is responsible for evaluating radiation emissions from the Department's x-ray machines and verifying that radiation levels are kept within regulatory limits. Operators are responsible for controlling access to their equipment.

The Department may demonstrate compliance with the public dose limits by using area surveys, area monitoring and/or individual monitoring of operators. Historical data show that:

- Radiation levels associated with the SMO's x-ray machines are too low for the areas they are located within to be classified as restricted areas (where a person could receive > 2 mrem in any one hour).
- Annual radiation doses to analytical x-ray machine operators are less than the annual public dose limit, so by extrapolation, doses to members of the public are also below the 100-mrem annual limit.

As a security and ALARA measure, the Chem Lab's Room D111 is designated a Controlled Area; non-operators are only allowed inside when an operator is present, and the room is kept locked when operators are absent.

Note: Changes that potentially impact the Department's ability to comply with public dose limits (e.g., new equipment, relocation) may necessitate a reevaluation of x-ray operations by the SRSO. When appropriate, the SRSO will submit updated data to FDOH for approval.

2.8.2 Registration Process

Registration requirements are specified in Part V of Chapter 64E-5, FAC. The Department's x-ray machines are included in the "Educational or Industrial" classification. Such machines must be registered with the FDOH BRC X-ray Machine Section within 30 days of acquisition, using Form DH-1107 (available on the BRC website). The fee covering annual registration and inspection costs is due within 30 days after acquiring a machine, and by October 28th thereafter. If a machine is acquired within 120 days before the October 28th annual renewal date, the registration fee is due on October 28th and is the renewal fee. Registrants are instructed to submit their radiation safety program to the X-ray Machine Section for review and approval.

2.8.3 Change Reports

In accordance with subsection 64E-5.511(4), FAC, any changes to the contact information in the registration certificate must be reported in writing within 30 days. The receipt, sale, lease, transfer, relocation, assembly, installation or

disposal of any machine or major component must be reported within 15 days after such action occurs. FDOH Form DH-1114 is typically used for the reports

2.8.4 Vendor Registration

Vendors performing installations, repairs, maintenance, or other x-ray machine services must be registered with the FDOH BRC X-ray Machine Section before furnishing such services [subsection 64E-5.511(4), FAC]. A copy of each vendor's registration should be maintained on file.

2.8.5 Change of the State RSO

The FDOH BRC should be notified in writing within 30 days of a change of the State RSO. The notification should include documentation of the new RSO's qualifications (the same that apply to operators).

2.8.6 Vacating Premises

FDOH must be notified in writing no less than 30 days before vacating or relinquishing possession or control of the facility listed in the registration (see section 64E-5.349, FAC). The notification must be dated and signed by a certifying official and must describe the disposition of the x-ray equipment previously located at the facility. Documentation of x-ray machine transfer/disposal may be required.

2.8.7 Exemption Requests

FDOH may, upon application or its own initiative, grant exemptions or exceptions from regulatory requirements. The process for submitting an exemption request is described in section 120.542, Florida Statutes, and sections 28-104.001 – 28-104.006, FAC.

2.8.8 FDOH Inspections

The Department is subject to routine inspections of its activities conducted under the FDOT Radiation Machine Registration at 3-year intervals. Additional inspections may be conducted as FDOH deems necessary, or if prompted by an incident or allegation. Inspections may be announced or unannounced. All components of the Department's analytical x-ray RSP (facilities, equipment, procedures, and records) are subject to review.

2.9 Posting Procedures

Each location where analytical x-ray machines are used or stored must be posted with the documents listed below.

- Appendix A.1 - FDOH Notice to Employees, filled in to indicate where other required documents are maintained for review.

- Appendix A.2- FDOT X-ray Emergency Notification Poster
- FDOT emergency procedures (XRSM Chapter 5)

In addition, any FDOH BRC enforcement correspondence and FDOT responses must be posted within 5 working days after dispatch and must be kept posted for at least 5 working days or until corrective actions are completed.

2.10 Records Management Procedures

2.10.1 General Information

State and federal regulations mandate generation of numerous records relating to the Department's x-ray RSP, which must be maintained for specified intervals. Due to their importance from a legal perspective, some records are retained beyond required retention intervals.

Records can be originals or reproductions, hard-copy or digital, and must be legible throughout the retention period. When stored in electronic media, records with handwritten information, dates, signatures, and/or initials must be scanned to include that data, in a format capable of producing clear copies.

Records with limited retention intervals (e.g., 3 years) and no long-term value are typically not scanned, unless doing so facilitates their access by the SRSO. All records classified as "permanent" must be scanned and stored on the Department's network at the SMO Geotechnical network drive.

To safeguard against tampering and/or loss, access to RSP records should be restricted to authorized personnel. File cabinets or rooms used to store hard copies of RSP records should be kept locked when unattended. Measures to restrict access to computer directories with RSP records should also be in place.

2.10.2 Records Retention Procedure

Table 4: X-ray Radiation Safety Program Records

Document	Retention Interval/Rule	Format
Current copy of applicable parts of Chapter 64E-5, FAC (FL radiation control regulations)	Until termination of registration [64E-5.901]	Electronic
Active Radiation Machine Registration # JR 34613000	Until termination of registration [64E-5.901]	Hard copy & electronic

Provisions of X-ray RSP (i.e., FDOT Analytical X-ray RSM)	Permanent* [64E-5.335(2)]	Electronic
Correspondence with FDOH on FDOT x-ray systems	Permanent* [64E-5.502(1)(b)3.]	Hard copy & electronic
RSP annual reviews	Permanent* [64E-5.335(2)]	Hard copy & electronic
Radiation safety training & test records	Permanent* [64E-5.703(1)]	Electronic
X-ray machine receipt & transfer/disposal records	Permanent* [64E-5.103, .340(2)]	Electronic
X-ray machine manufacturer operations/maintenance manuals	As long as units are possessed*	Electronic
X-ray machine inventory records	3 years*	Electronic

* FDOT Policy

Table 5: SMO Radiation Monitoring Records

Document	Retention Interval/Rule	Format
Radiation survey reports [annual and when required by 64E-5.702(2)]	3 years [64E-.502(1)(b)2., 64E-5.702(2)]	Electronic
X-ray machine inspection, maintenance, and repair reports	As long as units are possessed* [64E-.502(1)(b)2.]	Electronic
Declared pregnancy (DP) forms, monitoring records for Declared Pregnant Workers (DPWs)	Permanent* [64E-5.339(4), (5)]	Electronic
Records of doses received during radiological incidents	Permanent [64E-5.339(1), (5)]	Electronic
Records showing compliance with public dose limits	Permanent [64E-5.313(5)]	Electronic

* FDOT Policy

2.11 Notification and Reporting Procedures

2.11.1 Reports of Stolen, Lost or Missing X-ray Machines

Telephone Reports. A stolen, lost or missing x-ray machine must be reported to FDOH BRC (407-297-2095) immediately after it becomes known.

Written Reports. Telephone reports of stolen, lost, or missing x-ray machines must be followed by a written report to FDOH BRC within 30 days after making the telephone report. Written reports must include the below information.

- Description of the equipment(s) (mfr., model, serial no., max. kV/mA).
- Description of the circumstances under which the loss/theft occurred.
- Statement of disposition/probable disposition of the equipment.
- Exposures of individuals to radiation, circumstances under which the exposures occurred, and possible doses received.
- Actions that have been or will be taken to recover the source.
- Procedures or measures that have been or will be adopted to prevent recurrence.

2.11.2 Incident Notifications

Reports may be made by phone or fax; names of individuals who have received radiation exposures must be stated in a separate and detachable portion of the report. Social security numbers and birth dates should not be included.

Immediate Notification. Required for any event that might have caused or threatens to cause a dose of 25 rem or more, an eye dose of 75 rem or more, or a skin, extremity or total organ dose of 250 rem.

24-Hour Notification. Required for any event that might have caused or threatens to cause an individual to receive in 24 hours a dose greater than 5 rem, an eye dose greater than 15 rem, or a skin, extremity or total organ dose greater than 50 rem.

2.11.3 Reportable Event Notifications

A written report must be submitted to the FDOH BRC within 30 days after learning of any incidents requiring immediate or 24-hour notification, or of a radiation dose in excess of the levels/limits listed below.

- Occupational dose limits for adults (5 rem) or minors (500 mrem).

- Embryo/fetus limits for a declared pregnant woman (500 mrem).
- Public dose limits (2 mrem in any 1 hour or 100 mrem in 1 year).
- Radiation levels greater than 20 mrem in unrestricted areas.

Reports must describe the extent of exposure of individuals, including (as appropriate) the information listed below.

- Estimates of each individual's dose.
- The levels of radiation involved.
- The causes of the elevated exposures, or dose rates.
- The corrective steps taken or planned to prevent recurrence, including a schedule for achieving compliance with license conditions.

2.11.4 Reports of X-ray Equipment Related Incidents

The FDOH BRC X-ray Section must be notified within 30 days of the failure of any component critical to safe operation to perform its intended function properly. The report must include:

- Description of equipment problem.
- Cause of incident (if known).
- Manufacturer name and model no. of equipment involved.
- Place, time, and date of incident.
- Actions taken to establish normal operations.
- Corrective actions taken or planned to prevent recurrence.
- Qualifications of the personnel involved in the incident

2.12 ALARA Policy

2.12.1 ALARA Philosophy

An important aspect of working with radiation-generating equipment is protection of operators and the public. Operations must be conducted cautiously, diligently, and with a respect for the x-ray hazard, following the philosophy of maintaining exposures as low as reasonably achievable (ALARA). A successful radiation safety program depends on the cooperation of all individuals involved. This includes management, radiation safety personnel, and operators.

Part III of Chapter 64E-5, FAC, establishes standards for protection against radiation hazards. The standards require the Department to employ, to the extent practical, procedures and engineering controls to achieve occupational and public doses that are as low as reasonably achievable (ALARA).

The concept of the ALARA philosophy is that unnecessary exposure to radiation should be avoided, even though occupational dose limits pose a very low risk of injury. The objective is to reduce radiation doses as far below regulatory limits as is reasonably achievable through good radiation safety planning and practice, and through a management commitment to policies that deter departures from good practices.

2.12.2 Management Commitment

FDOT management is committed to the philosophy of maintaining occupational and public radiation doses as low as reasonably achievable. Management will ensure that all personnel working with sources of ionizing radiation are made aware of this commitment to the ALARA philosophy and are instructed in ways to minimize doses. The State RSO has been delegated authority to ensure adherence to ALARA principles. Management is committed to making all reasonable modifications to procedures, equipment and facilities to reduce exposures, unless the costs are unjustified, and is prepared to describe the reasons for not implementing recommended modifications.

2.12.3 ALARA Policy Implementation

In accordance with this policy, the ALARA philosophy is integrated into the Department's analytical x-ray radiation safety program:

- ALARA principles are covered during operator training.
- Section 2.14 describes ALARA-related responsibilities of FDOT personnel.
- Chapter 3 includes instructions for applying ALARA principles.

Program audits. At least annually, the SRSO conducts a formal review of the RSP content and implementation. The reviews include an evaluation of equipment, procedures, dosimetry records for pregnant workers, inspection findings and incidents. The review also assesses trends in occupational exposures as an index of the program's success to determine if any modifications are needed. A summary of the results of each annual review, including a description of actions proposed and taken (if any) is provided to management.

2.13 Personnel Duties and Responsibilities

Personnel duties and responsibilities for implementation of the Department's analytical x-ray RSP are summarized. The listed duties may be delegated to qualified designees to ensure compliance.

2.13.1 State RSO

The State RSO is the individual delegated authority to fulfill the duties and responsibilities of the position as specified in the Florida radiation control regulations and listed below. The RSO must have sufficient training and experience to be a user of the equipment authorized by FDOT's license, with practical experience and knowledge of related procedures, facilities and equipment.

The SRSO is authorized to make legally binding statements on behalf of FDOT in all matters related to the Department's x-ray machine registration (i.e., the SRSO is designated as a certifying official). The duties and responsibilities of the SRSO are listed below:

- Ensure that FDOT's x-ray machines are always secured against unauthorized access or removal.
- Ensure compliance with the terms and conditions of the FDOT registration, and with applicable regulations.
- Ensuring timely payment of registration fees, timely revisions to the XRSM to address rule, policy, and operational changes.
- Ensure that radiation-generating devices are used only by qualified personnel.
- Ensure that personnel working with radiation-producing equipment read and understand the XRSM and are trained in accordance with the FDOT training program for analytical x-ray machine operators.
- Maintain all analytical x-ray RSP-related records required by the Department and applicable regulations and maintain a current copy of the XRSM on the Department website.
- Ensure that FDOT's x-ray machines are inventoried, inspected, and undergo preventive maintenance and safety device testing at least annually.
- Serve as a contact with FDOH BRC for radiological incidents and other communications.

- Ensure that the ALARA philosophy is emphasized to workers, and that workers are instructed on ways to minimize exposures.
- Monitor declared pregnant worker dosimetry data though timely reviews of dose reports to verify that exposures are being kept ALARA, that dosimetry data is accurate, and to investigate elevated doses or readings in a timely manner.
- Advise operators of the availability of their annual and termination dose reports upon request.
- Conduct an annual review of the Department's analytical x-ray RSP.

2.13.2 Radiation Safety Consultant

The radiation safety consultant (RSC) is an optional contract position. The RSC is an individual with extensive radiation safety training and experience applicable to the Department's radiological operations, serving an administrative support role to the State RSO. The duties and responsibilities for the RSC related to the Department's analytical x-ray operations are listed below:

- Assist with registration management.
- Assist with analytical x-ray RSP records maintenance.
- Assist with analytical x-ray RSP-related training and audits.
- Provide regulatory and technical support.

2.13.3 Chemical and Bituminous Binder Laboratory Managers

Analytical x-ray machines are used by personnel from two labs: the Chemical Lab and the Bituminous Binder Lab. Each lab has an individual delegated responsibility for their lab's x-ray equipment. At the Chemical Lab, it is the Chemical Operations Manager, and at the Bituminous Lab, it's the Bituminous Binder Laboratory Manager. These two individuals serve as extensions of the State RSO, fulfilling the applicable duties and responsibilities of the RSO within their respective labs. Specific duties and responsibilities are listed below:

- Ensure the security of their lab's analytical x-ray equipment and restrict access to the keys and passcodes for their x-ray units.
- Cooperate with the SRSO and SMO analytical x-ray machine operators in implementation of program requirements.
- Ensure that only qualified operators use SMO analytical x-ray equipment.
- Provide timely notification to the SRSO on any reports of analytical x-ray problems or any x-ray-related inquiries and assist with any responses.

- Emphasize the ALARA philosophy to operators, provide guidance on ways to reduce doses and take corrective actions as necessary.
- Assist the SRSO in developing, revising, and delivering initial and refresher radiation safety training to SMO analytical x-ray machine operators.
- Ensure compliance with requirements related to security and public dose limits for their x-ray equipment.
- Ensure that their x-ray equipment undergoes annual inventory, inspection, and maintenance in accordance with FDOT procedures.
- Maintain required postings in their labs and labels on their equipment.
- Assist with declared pregnancy requirements.
- Assist with response to x-ray incidents involving their equipment.
- Ensure that their lab's operators complete radiation safety training in accordance with the Department's training program.
- Ensure that personnel under their supervision comply with the operating and emergency procedures described in the FDOT RSM.
- Advise the SRSO of any unsafe conditions or practices related to their lab's x-ray operations.
- Respond to x-ray machine incidents in coordination with the SRSO and submit a written report to the SRSO following any x-ray machine incident.

2.13.4 Analytical X-ray Operators

Department personnel operating analytical x-ray machines are responsible for the duties listed below:

- Ensure the security of their lab's analytical x-ray equipment and restrict access to the keys and passcodes for their x-ray units.
- Be familiar with the FDOT Analytical X-ray Machine RSM and ensure that a current copy is available in their lab.
- Comply with all applicable provisions of the XRSM and all other pertinent instructions and requirements (e.g., manufacturer instructions) to ensure safe handling, transport and use of radiation-emitting equipment.
- Know and practice the ALARA philosophy to minimize radiation exposures.
- Maintain their x-ray machine diary according to RSM requirements.

2.14 Personnel Monitoring Program

The Department is not required to issue monitoring badges (dosimetry) to SMO analytical x-ray machine operators because their exposures are too low to meet

the criteria for personnel monitoring, as shown by years of dosimetry data. Therefore, the Department discontinued badging of personnel who routinely work with x-ray machines

2.14.1 Monitoring Requirement for Declared Pregnant Workers

Due to the elevated risk associated with radiation exposure to an embryo/fetus, Florida regulations limit the occupational dose of a declared pregnant woman to 500 mrem during the pregnancy. In addition, FDOH recommends that no more than 50 mrem be received in any one month of a pregnancy. These limits apply only if a worker elects to follow them by formally declaring her pregnancy in accordance with this procedure. A declared pregnant woman is defined as a female worker who has voluntarily informed her supervisor in writing of her pregnancy and the estimated date of conception. If by the time the woman declares pregnancy, the dose to the embryo/fetus has exceeded 500 mrem or is within 50 mrem of 500 mrem, the Department will be considered in compliance with the limit, provided the additional dose to the embryo/fetus does not exceed 50 mrem during the remainder of the pregnancy.

To initiate the process, a declared pregnant woman must submit a completed form shown in Appendix B.3, “Declaration of Pregnancy”, to her supervisor and comply with the form’s instructions. The worker’s supervisor must submit the form to the SRSO. Declared pregnant women will not be removed from working with analytical x-ray machines unless requested in writing by the individual. The supervisor must ensure that the employee wears her badge at waist level for the duration of the pregnancy.

Upon receipt of a “Declaration of Pregnancy” form (Appendix B.3), the SRSO must verify that the employee has not requested removal from x-ray work, ensure that the badge is worn properly, maintain records, and monitor compliance with the dose limit. Upon completion of the embryo/fetus monitoring, the SRSO will draft a memo describing how these instructions were implemented and noting the doses reported for the worker’s pregnancy. A copy of all relevant documentation will be maintained with the Department’s dosimetry files.

Note: Notwithstanding the above procedures, doses received by analytical x-ray machine operators typically range from 0 – 5 mrem per quarter.

2.14.2 Issuance and Processing of Dosimeters for Pregnant Workers

Each pregnant worker is assigned a dosimeter/participant number. The SRSO maintains a badge tracking system– a spreadsheet listing badge numbers and the names of the workers to whom each dosimeter has been assigned.

Prior to assigning a dosimeter, the SRSO must obtain the name (first, middle initial, last name), gender, and date of birth from the worker:

The SRSO or designee then contacts the dosimetry vendor by phone, email, or through the company's website to provide the above information and request that the pregnant worker be issued a badge imprinted with their name.

Dosimeters are exchanged on a quarterly basis. The vendor ships each batch of dosimeters to the SRSO. Each shipment includes a control dosimeter, which is used to monitor radiation doses received during transit and storage of the other dosimeters. The control badge must be stored in a protected area during the wear-period and returned to the dosimetry vendor with the other badges at the end of the quarter. The reading on the control dosimeter is subtracted from the dosimeter reading of each participant. Failure to include the control dosimeter will cause transit and storage doses to be reflected in the pregnant worker's doses. Dosimeters assigned to pregnant workers should be exchanged and processed in a timely manner by returning them to the vendor within 21 days of the end of the monitoring period.

2.14.3 Dosimetry Reports for Monitored Pregnant Workers

Quarterly Reports. The dosimetry vendor mails a copy of the dosimetry report to SMO and maintains the reports for all the monitored operators and radiation area zones. Electronic copies of dosimetry reports are available at the SMO and may be requested by the laboratory manager. The dosimetry badge user may request their personal dose data at any time.

The SRSO is responsible for timely reviews of the dosimetry reports, and for addressing any identified issues. As necessary, the SRSO will request the laboratory manager to respond to issues such as absent badges and assigned badges with elevated doses warranting special attention. If possible, absent badges must be located and processed. The operator's manager is responsible for investigating the cause of elevated doses on assigned badges (refer to the ALARA policy for additional instructions).

Annual Dose Reports. The Department issues an annual dose report for all monitored workers, which are available upon request. The reports are signed, dated, and issued by the SRSO using a vendor form.

Termination Dose Reports. The Department issues termination dose reports for all pregnant workers when monitoring has been discontinued, which are issued within 30 days after the individual's final dose total has been reported. The reports are issued by the SRSO using a vendor form and are available upon request.

2.14.4 Instructions for Lost/Damaged Dosimeters for Pregnant Workers

In the event of a lost or damaged dosimeter, the SRSO must estimate the pregnant worker's dose for the period the badge was worn and notify the dosimetry processor if the individual's dose total needs to be revised. A worker's dose is estimated by reviewing the individual's doses received during prior monitoring periods and their x-ray machine use for the time covered by the lost or damaged dosimeter. The SRSO must document the results of the review and describe how the dose for the monitoring period covered by the lost/damaged badge was estimated, then submit a memo to the individual for review and concurrence. If no objections to the estimated dose are received, and the worker's dose total needs to be revised, the SRSO will contact the dosimetry vendor and instruct the vendor to make the change. A record of the process is documented and retained on file.

If a lost/damaged badge requires that a replacement dosimeter be issued for the rest of the monitoring period, the SRSO must document the number of the assigned replacement badge. The SRSO will inform the dosimetry vendor to add the dose from the replacement badge to the worker's dose total. A record of the process is documented and retained on file.

2.14.5 Policy on Intentional Badge Exposures

Intentional exposure of any radiation badge is prohibited. If a pregnant worker believes she has accidentally exposed their personal dosimeter, they must notify the SRSO immediately. The SRSO will take appropriate actions to ensure the accuracy of dosimetry records.

2.14.6 Occupational Dose Limits for Minors

Florida regulations limit the occupational dose to a minor to 500 mrem/year. To ensure compliance, minors are prohibited from working with the Department's registered x-ray equipment.

2.14.7 Reports of Elevated Exposures

In the event that an elevated x-ray exposure is investigated and reported to FDOH BRC, a copy of the report will be provided to the exposed individual no later than when the report is sent out. A copy of the report, including a notation of the date a copy was provided to the exposed individual, will be maintained with the Department's dosimetry files.

2.15 X-ray Machine Receipt, Transfer and Disposal Procedures

State regulations impose stringent restrictions on the receipt, transfer, and disposal of licensed sources of radioactive material. Prior approval from the SRSO is required to purchase any radiation-generating equipment. The SRSO will take the

necessary steps to obtain regulatory approval for the acquisition and notify the personnel seeking the equipment once the authorization process has been completed. Any acquisition of x-ray emitting devices must include an evaluation of their impact on the Department's ability to comply with public dose limits and may require a revision to the public dose limit compliance study.

Documentation of the receipt, transfer, and disposal of x-ray machines must be maintained to identify each unit's origin and final disposition, and to ensure the accuracy of the site's x-ray machine registration. X-ray machine receipt/transfer/disposal records include the following:

- X-ray control manufacturer name, model, and serial number
- X-ray tube manufacturer name, model number, serial number, if available (also recommended: maximum kV and mA)
- Name, address, and phone number of the transferor and transferee
- State registration numbers of the transferor and transferee (if applicable)
- Date of the receipt/transfer
- Signatures of individuals shipping or receiving the machine

2.16 Radiation Detection Instruments

The SRSO maintains at least one radiation detection instrument (survey meter) for routine radiation surveys and for response to radiological emergencies. The meters are calibrated by the FDOH BRC Health Physics Lab in Orlando. Each meter bears a calibration label. Survey meter models may vary; all are low-range Geiger counters, such as the models listed below.

- Victoreen Model CD V-700 (0.1 – 50 mR/hr)
- Victoreen Model 493 (0.1 – 50 mR/hr)
- W.B. Johnson Model GSM-10S (0.1 – 20 mR/hr)

The meters may be equipped with an internal Geiger-Mueller (GM) detector (Model 493) or external "pancake" or side-window GM probes (Model CD V-700 and GSM-10S). The external probes and cables are delicate and cannot withstand abuse. The mylar window of the pancake probe is particularly fragile. When not in use, the cover on a pancake probe should be kept on and the window of a side-window probe should be kept closed.

Each SRSO is responsible for secure storage and routine checks on the status of their meters, keeping replacement batteries on hand, and ensuring that at least one calibrated and operable meter is available for their use.

Chapter 3 - Training Program

3.1 Purpose

Training is the principal means of ensuring safe use of radiation-producing equipment. Operation of x-ray machines is restricted to trained personnel – individuals that have completed appropriate radiation safety training and have been designated by the SRSO as qualified operators.

Training requirements are found in different sections of the Florida regulations. Awareness-level training requirements are in Part IX (64E-5.902, FAC), and analytical x-ray machine operator training is in Part VII (64E-5.704, FAC).

Part IX requires instruction in the below topics:

- Information on the Department's analytical x-ray equipment.
- Health risks associated with exposure to x-rays.
- Precautions and procedures for minimizing radiation exposures.
- Provisions of applicable regulations and the Department's registration.
- Operator responsibility to report any unsafe SMO x-ray operations.
- Response to x-ray incidents.
- Occupational dose reporting requirements.

Part VII requires personnel to demonstrate their understanding of:

- Radiation hazards associated with x-ray equipment, including symptoms of an acute localized overexposure.
- Radiation warning and safety devices.
- FDOT operating procedures and emergency procedures (including procedures for reporting an actual or suspected overexposure).

This chapter describes training requirements for qualification to operate the SMO's analytical x-ray equipment. It describes the Department's radiation safety training program for analytical x-ray machine operators and, as the position applies to FDOT x-ray operations, the SRSO.

The FDOT x-ray radiation safety training program is designed to provide the instructions necessary for compliance with x-ray procedures and regulatory requirements, and to minimize occupational x-ray exposures.

3.2 Authority

Sections 20.23(3)(a), and 334.048(3), Florida Statutes (F.S.)
This manual conforms to requirements for a written radiation safety training program specified in Parts III and XIII of Chapter 64E-5, FAC.

3.3 Scope

The principal users of this chapter are Department personnel responsible for administration of the FDOT radiation safety program (RSP) addressing analytical x-ray machines. These personnel are the State Radiation Safety Officer (SRSO), Chemistry Laboratory Manager, and Bituminous Binder Laboratory Manager.

3.4 Training Requirements for Analytical X-ray Machine Operators

Operation of analytical x-ray machines is restricted to individuals certified by the SRSO or the Department's Radiation Safety Consultant as having completed the Department's analytical x-ray machine operator training program.

There are two training components for qualification as an x-ray machine operator: radiation awareness level training, and function-specific (operator) training. Regulatory references for each training component are listed in Table 1.

3.4.1 Radiation Awareness Level Training

Prior to operating an analytical x-ray machine, personnel will receive instruction on the topics listed in subsection 64E-5.902(1), FAC, which are listed below. The topics are covered in the Department's in-house analytical x-ray radiation safety training course.

- Health risks associated with exposure to radiation to x-ray
- Precautions and procedures for minimizing x-ray exposures
- Provisions of applicable regulations and the Department's registration
- Worker responsibility to report unsafe conditions in the workplace
- Response to radiological incidents
- Occupational radiation exposure reporting requirements

3.4.2 Analytical X-ray Machine Operator Training

Qualification as an analytical x-ray machine operator requires SMO personnel to complete the following:

- Familiarize with the following manuals:
    - FDOT Analytical X-ray Radiation Safety Manual
    - X-ray equipment operation/maintenance manuals for units used

- Analytical x-ray machine operators must complete the Department's computer-based radiation safety course ST-06-0002, Safety and Control of Analytical X-ray Equipment. In class training may be provided by the SRSO or their designees (e.g., consultants, experienced analytical x-ray operators) if needed.
    - Prior to attending the analytical x-ray machine operator course, personnel are required to read the FDOT Analytical X-ray Radiation Safety manual (XRSM). The manual can be accessed on the website shown in section 2.6.4. In addition, read or familiarize with the x-ray equipment operation and maintenance manuals for the units to be used.
- Successful completion of the x-ray operator course requires a passing score (at least 70 out of 100 possible points) consisting of 25 multiple-choice questions, with each correct answer counting four points. Individuals failing the exam must review the course materials and retake the exam.
- Complete practical training under the supervision of the SRSO or an experienced operator and demonstrate competence to operate the equipment safely.
- X-ray operators must provide a copy of their certificate to their SRSO.

3.5 Radiation Safety Officer Training

The SRSO must have sufficient training and experience to be able to identify and control the hazards associated with the company's analytical x-ray equipment. The minimum qualification for the position is completion of the FDOT analytical x-ray machine operator training. Formal RSO training is not required, but is recommended, to gain insights into radiation safety program administration.

3.6 Refresher Training

Radiation safety refresher training is not required by rule but is recommended to maintain competencies. Operators should complete annual refresher radiation safety training, with the extent and duration of the training are left to the RSO's discretion. As a minimum, the training should include:

- A summary of the latest annual program audit findings
- A review of the past year's dosimetry data
- A question and answer session.

Refresher training may include a repeat of the initial training (or a shortened version to account for operators' experience), or may be in any format and cover any topics relevant to x-ray radiation safety and deemed appropriate by the RSO, such as lectures, guided discussions, demonstrations, or self-paced instruction,

including assigned readings and/or computer-based training (CBT). The training may be administered in-house or obtained through qualified third-party training providers (including web-based training).

Supplemental operator training will be conducted when:

- There is a significant change to x-ray radiation safety procedures;
- There is a significant change in risk or assigned tasks;
- New equipment is installed; and
- Observations or other information indicates a need for additional training.

RSO refresher training is recommended every 3-5 years; the intervals and extent of the training are left to the RSO's discretion.

3.7 Training Records

Documentation of training is maintained permanently, with the below information:

- Employee's name and date of most recent training completed
- Description, copy or location of training materials used
- Name and address of the person providing the training

Chapter 4 - Operating Procedures

4.1 Purpose

Exposure to x-rays is a health hazard, so it is important for SMO personnel operating x-ray machines to follow the Department's safety procedures and the manufacturer instructions for their equipment. Operators must maintain familiarity with these procedures and manuals.

This chapter provides instructions for FDOT personnel operating the Department's analytical x-ray machines, including two handheld devices (portable XRF analyzers), a benchtop unit and two fixed stand-alone systems. The purpose of these instructions is to ensure that workers using analytical x-ray equipment comply with applicable regulations, Department policies and procedures, and keep radiation exposures associated with analytical x-ray operations as low as reasonably achievable (ALARA).

4.2 Authority

Sections 20.23(3)(a), and 334.048(3), Florida Statutes (F.S.)
This manual conforms to requirements for written operating procedures specified in Part XIII of Chapter 64E-5, Florida Administrative Code (FAC).

4.3 Scope

The principal users of this chapter are Department personnel operating analytical x-ray machines and personnel responsible for administration of the FDOT analytical x-ray RSP.

4.4 Training

The training requirements shown in Table 1 are mandatory for the Department's analytical x-ray machine operators. Chapter 3 of this manual describes the Department's training program.

4.5 Posters and Forms

The required posters and forms referenced in this chapter are available in Appendices A and B.

4.6 Procedures

Complete and current copies of the below documents must be readily available for reference by analytical x-ray machine operators.

- The FDOT Analytical X-ray Radiation Safety Manual (XRSM).

- The operation/maintenance manuals for each model of x-ray equipment being in use.

4.7 Personnel

Operation of FDOT analytical x-ray equipment is restricted to qualified operators – personnel who have completed operator training described in Chapter 3.

4.8 Security

The fenced and gated SMO campus is secured during non-business hours. Additional security measures are described in Appendix B.

When not in use, the instrument must be secured by at least two independent means of preventing access by unauthorized personnel; security keys are controlled by authorized personnel.

- Each x-ray machine is equipped with a locking device or console passcode that prevents unauthorized or accidental production of radiation, and the instruments are kept locked (with the key removed and secured, and/or passcode-locked) except when under the direct surveillance of a qualified operator, maintenance technician, consultant or the SRSO.
- Unless the room (or storage container, in the case of the handheld XRF analyzers) is locked and equipped with an alarm system and/or entrance control while unattended by an operator, continuous surveillance by an operator is maintained during analytical operations to prevent unauthorized access.
- Systems able to automatically process samples may run in the absence of an operator provided the room is locked.

4.9 Prohibitions

Use of FDOT analytical x-ray equipment other than as specified by the manufacturer and these procedures is prohibited without prior written approval of the SRSO. Bypassing safety devices is prohibited. Except for minor part replacement (e.g., the XRF analyzer's measurement window), any disassembly, modification, repair, or non-routine maintenance is prohibited. Such work may only be performed by the manufacturer or other qualified vendors.

Any temporary alteration to safety devices, such as by-passing interlocks or removing shielding, must be approved in advance by the SRSO, specified in writing and posted at the scanner, and terminated as soon as possible. The process must be documented, and the record maintained for inspection, with the following information: date alteration was made, type of alteration, length of time unit remained in the altered condition, and signatures of the individual who made

the alteration, the individual who restored the unit to its original condition, and the SRSO.

4.10 Restrictions

Maintenance, modification, servicing, and repairs of x-ray scanners is restricted to FDOH-registered x-ray service vendors. Any person seeking to sell, install or service x-ray equipment to the Department must be registered with FDOH BRC, and supply documentation of their active registration to the SRSO in advance of providing such services.

No radiation-producing machine may be brought on site (even for a demonstration) without the prior notification and approval of the SRSO.

4.11 Protective Equipment

4.11.1 Area Monitoring Badges

The Chemistry Laboratory may use environmental (area) monitoring badges mounted on or near the x-ray equipment console to provide continuous tracking of radiation levels at the operator's workstation. The badges must not be disturbed or exposed to harmful agents (excessive heat, light, water, and chemicals). The SRSO processes area badges at least quarterly, and dose reports are generated and retained. Any elevated readings noted by the badges will be investigated and reported to the operators. Operators must promptly notify the SRSO of a lost, damaged, or accidentally exposed area badge. The RSO will investigate, and if necessary, provide a replacement badge.

4.11.2 Personnel Monitoring (PM) Badges

The Department is not required to issue whole body or extremity monitoring badges (dosimetry) to SMO analytical x-ray machine operators because their exposures are too low to meet the criteria for personnel monitoring. Therefore, the badging of Department personnel who routinely work with x-ray machines has been discontinue (with the exception of declared pregnant workers through the duration of the pregnancy – see Section 2.14.1).

4.11.3 Survey Meters

The SRSO maintains portable radiation monitoring instruments (survey meters) for performance of routine surveys and for emergency situations. The meters can measure the x-radiation energies and dose rates associated with SMO x-ray equipment. They are calibrated by the FDOH BRC in Orlando.

Prior to use, the SRSO verifies that the four checks described verify the instrument's calibration, condition, and proper operation. Meters failing any of

the tests should be removed from service and tagged/labeled as "Out-of-Cal", "Out-of-Service", etc.

- **Calibration Check:** Read the meter's calibration label to verify calibration within the last 12 months. If the calibration is past due, the meter can't be used, and a replacement must be obtained.
- **Visual Check:** Visually inspect the meter for damage. If any damage is noted that may compromise the instrument's ability to function properly, obtain a replacement.
- **Battery Check:** Turn the instrument's scale selection switch to the "battery check" setting and observe the battery strength indicator. If the indicator reads in the "Battery" range on the meter's scale, the battery has an adequate charge. If the test indicates weak, unsatisfactory battery strength; replace the batteries and repeat the test. If still below the acceptable range, obtain a replacement meter.
- **Radiation Response Check:** Test the meter's operation with a radiation check source (e.g., a Cesium-137 "button" source or a thorium lantern mantle). If the meter reads zero or significantly higher than the expected reading, obtain another meter and repeat the test.

The RSO is responsible for ensuring that any surveys by vendors are performed using appropriate, calibrated instruments that have undergone the above checks prior to use. Vendors must provide documentation of their instrument's calibration upon request of the SRSO.

4.11.4 Radiation Surveys

Radiation limits: X-ray emissions can't exceed 0.5 mR/hr at any point 5 cm from external surfaces. Radiation surveys are conducted to verify radiation levels post the following events:

- Installation of an x-ray machine and at least every 12 months thereafter, documented on form listed in Appendix B.5 – X-ray Machine Radiation Survey Report (or equivalent).
- Any change in the number of equipment components, location arrangement, or beam alignment that may increase radiation levels.
- Any change that decreases shielding effects
- Any maintenance/service requiring the disassembly or removal of system components.
- Any time a visual inspection reveals an abnormal condition.
- Whenever radiation monitoring devices indicate a significant increase over previous results.

If a required survey on an x-ray machine has not been performed, the machine cannot be operated until the required radiation survey has been completed and documented.

4.11.5 Interlocks

The design must include an electrical interlock (emergency stop). Interlocks cannot be used to de-activate the x-ray tube, except in an emergency or during testing of the interlock system. After shut-off, it must be possible to restore the machine to full operation only from the console.

Shall have an interlock system that prevents the operation of the unit unless the x-ray exit port is in contact with or in close proximity to the item being irradiated.

4.11.6 Indicators

Open-beam configuration devices must be equipped with a readily discernible indicator of the device's x-ray tube on-off status, located near the radiation source housing.

4.11.7 Safety Device

Subsection 64E-5.701(1), FAC requires open-beam configuration x-ray equipment to be equipped with a safety device that prevents entry of a body part into the primary beam path, or causes the beam to be shut off upon entry of a body part into its path.

Other than the handheld XRF analyzers, the SMO's analytical x-ray equipment comply with the safety device requirement. As permitted by 64E-5.704(1)(b), the SMO's portable XRF analyzer is exempted from the requirement because:

1. Such a device would defeat the instrument's ability to perform its intended function.
2. Alternative safety devices such as shielded stands and backscatter shields can't be used in all sample testing configurations.
3. The possibility of accidental exposures is minimized by informing operators and others in the area of the analyzer's lack of a safety device.
4. Radiological accident notification procedures are in place.

4.12 Posting and Labeling Requirements

4.12.1 Area Postings

Areas where analytical x-ray machines are used and/or stored are conspicuously posted with a signage bearing the radiation symbol and the

words "Caution – X-ray Equipment", "Caution – X-rays in Use" or similar wording.

Current and legible copies of the below documents are conspicuously posted in the two SMO labs to permit operators to observe them. Posted documents must be replaced if they become illegible and the documents may be posted in a clear plastic sleeve that allows them to be easily read.

- Department's x-ray machine registration certificate
- FDOH "Notice to Employees" poster (Appendix A.1).
- RSM Chapter 5 – FDOT Emergency Procedures
- FDOT X-ray Emergency Notification Poster (Appendix A.2)
- Enforcement correspondence: Any FDOH BRC notice of violations, proposed imposition of administrative penalties, and orders and responses to cited violations must be posted within 5 working days of receipt and for at least 5 working days, or until corrective actions have been implemented, whichever is later.
- Other required documents:
    - Parts III and IX of Chapter 64E-5, FAC
    - RSM Chapter 5 – FDOT Operating Procedures

Note: The "Notice to Employees" poster states where a copy of the regulations, this manual, and other x-ray RSP-related documents are maintained for review by operators. Due to the impracticality of posting the regulations and operating procedures, the "Notice to Employees" poster includes a note in the lower righthand corner that states where those documents are available for review.

4.12.2 Machine Labels

Analytical x-ray equipment must be labeled in accordance with state and regulations and national standards, as described below:

- Warning devices must be labeled so that their purpose is easily identified.
- The scanner must have an easily visible warning light label with the words "X-ray On" or similar wording, located near any switch that energizes an x-ray tube and the light must come on only when the tube is energized. Warning lights must have fail-safe characteristics.
- X-ray source housings must be labeled with a black or magenta radiation symbol and the warning "Caution – High Intensity X-ray Beam" or similar wording. The warning must be clearly visible to any person operating, aligning, or adjusting the unit.

- A label with a black or magenta radiation symbol and the warning "Caution – Radiation – This Equipment Produces Radiation When Energized", or similar wording must be affixed near each machine's control switch.

Example: The handheld XRF analyzer's screen displays a radiation warning that flashing lights indicate x-rays are being produced. An additional warning label is included on the device's ID plate.

4.13 General Rules of Use

Operators are required to follow the instructions listed below:

- Equipment checks – Prior to use, operators must perform a visual and operation check on the machine to ensure that it is in good general condition, all labels are present, all service panels and covers are closed and secured, and the system is functional. Any issues with safety interlocks, grounding or operating conditions must be promptly reported to the SRSO, and the equipment must be tagged as out-of-service until repaired.
- Operate their equipment in accordance with the manufacturer's instructions unless otherwise stated in a procedure approved by the SRSO. The equipment is only authorized for its intended purposes.
- Apply ALARA principles to minimize exposures: minimize time spent around x-ray generating equipment, maximize distance from them during operation; and make use of available shielding.
- For the handheld XRF analyzer:
  - Keep hands and body parts away from the front end of the analyzer when its shutter is open.
  - Consider use of shielded test stands or backscatter shields.
  - Use an inspection mirror to inspection or clean the front end of the analyzer
- Control access to x-ray equipment by members of the public.
- Report to the SRSO any condition which appears to be unsafe or a violation of FDOT procedures, or may lead to an unnecessary exposure, or cause an unsafe situation or violation of Department procedures or the regulations.

4.14 X-ray Machine Inspection and Cleaning

Operators perform routine inspection and cleaning of their equipment in accordance with manufacturer instructions. The manufacturer's manual should be referenced.

Any issues identified during inspections or routine x-ray operations must be promptly reported to the SRSO, who will assist in arranging for repairs. An

inoperable or malfunctioning instrument should be tagged to indicate its out-of-service status.

At least annually, the radiation safety components for benchtop and fixed x-ray machines must undergo preventative inspection and maintenance (I&M) in accordance with the manufacturer instructions. If I&M reveals damage to any radiation safety-related components, the machine must be tagged as out-of-service until repaired. Machine I&M must be documented using Appendix B.6 - X-ray Machine Inspection and Maintenance Report form or an equivalent form provided by the service representative.

4.15 Annual Inventory, Inspection, and Maintenance Procedure

The Department's x-ray machine inventory is verified by the SRSO each October during the FDOH re-registration process.

The annual analytical x-ray radiation safety program review is combined with an inventory, physical inspection, and preventive maintenance. The inspection includes an evaluation of the equipment's general condition and verification that all of the identification and warning labels are attached and legible. Safety devices such as interlocks, shutters and warning lights are tested for proper operation, and a radiation survey is conducted to measure x-ray emissions. Results are documented and retained.

If an inspection reveals damage, missing or illegible labels, or incorrect or missing information on the labels, the instrument must be removed from service until the problem is corrected. Any apparent damage or malfunction should be noted, and the unit tagged to indicate its condition.

Inventory information includes:

- Date of inventory
- Assigned location (lab)
- Present location (actual location at the time of inventory)
- Control manufacturer, model, and serial number
- X-ray manufacturer, model, serial number (if available), and maximum kV and mA (recommended)
- Signature of the SRSO

Chapter 5 - FDOT Emergency Procedures

5.1 Purpose

This chapter provides instructions for FDOT personnel responding to radiological incidents involving analytical x-ray machines possessed by the Department.

A radiological incident is defined as any situation involving a Department-owned x-ray machine where a radiation exposure has occurred, is suspected to have occurred, or has the potential to occur, including equipment damage, loss, or theft.

Examples of situations that are not radiological incidents include water damage to an x-ray machine and accidents involving a vehicle transporting a portable x-ray machine where no damage to the machine occurred or is suspected.

5.2 Authority

Sections 20.23(3)(a), and 334.048(3), Florida Statutes (F.S.)
This manual conforms to requirements for emergency procedures specified in Part VII (of Chapter 64E-5, Florida Administrative Code (FAC).

5.3 Scope

The principal users of this chapter are Department personnel operating analytical x-ray machines and personnel responsible for administration of the FDOT analytical x-ray RSP.

5.4 Posters and Forms

The required posters referenced in this chapter are in this manual's Appendix A. X-ray RSP forms are included in Appendix B.

5.5 Radiological Emergency Contacts

List of names and contact information can be found in Appendix A.2 "FDOT X-ray Emergency Notification Poster" in the event of a radiological emergency.

5.6 X-ray Emergency – Defined

An emergency exists when x-ray generation is not under the operator's control. Examples:

- Equipment malfunction:
  - "On" light will not turn off/emergency stop button fails
  - Electrical, fire, smoke, explosion, near location of use
- X-ray machine loss or theft

- Suspected or actual radiation injury indicates elevated radiation levels

5.7 Overexposure or Suspected Overexposure

If a worker believes that he/she has been overexposed, they must notify the SRSO immediately. The SRSO will investigate, implement corrective actions, estimate any exposures, document findings, make any required notifications, and submit any required reports.

5.8 Stolen, Lost or Missing X-ray Machine

Immediately notify the SRSO, who will notify the FDOH BRC and if appropriate local law enforcement agencies.

5.9 Damaged X-ray Machine

Fixed x-ray unit:

- Attempt to turn off power to the unit. If the main switch is inoperable, use the emergency stop button or shut off power to the lab at the breaker box.
- Secure the unit in a manner that prevents access, and ID the device's out-of-service status.
- Direct any individuals who suspect that they have been exposed to seek medical assistance.
- Notify the RSO, who will take corrective measures (e.g., perform a radiation survey, schedule an inspection by a qualified service technician) and make any required notifications.

Handheld XRF Analyzer:

- If the device is intact, but there is an indication of an unsafe condition (e.g., cracked case, shutter mechanism failure, or the lights remain flashing after a measurement is terminated), then take the following steps:
  - Stop using the instrument.
  - Remove the battery and wait until the device is completely powered off; the instrument is now safe to handle.
  - Place the instrument securely in the holster, then place it in its transport case.
- If the instrument is severely damaged, perform the same steps as described above, then place all components in a plastic bag. Immediately notify the SRSO, who will contact the manufacturer for additional guidance.

5.10 Action Plan

The SRSO will assess any x-ray incident or allegation, and if necessary, develop an action plan that may include:

- Collecting written statements from all involved personnel, to document the event as accurately and promptly as possible, in chronological order.
- Investigating the incident, implementing corrective actions, estimating any exposures that occurred, promptly processing any exposed badges, making required notifications, and submitting required reports to FDOH.
- Consulting with appropriate medical personnel and consultants. In cases involving a potential overexposure, the SRSO may need to refer exposed individuals to a physician. Such individuals will not be permitted to return to work without the SRSO's approval.

Appendix A: Poster Notification

A.1 FDOH Notice to Employees

FLORIDA DEPARTMENT OF HEALTH

NOTICE TO EMPLOYEES

STANDARDS FOR PROTECTION AGAINST RADIATION; NOTICES, INSTRUCTIONS AND REPORTS TO WORKERS; INSPECTIONS

POSTING REQUIREMENT:

THIS NOTICE MUST BE POSTED IN PLACES THAT PERMIT EMPLOYEES IN A RESTRICTED AREA TO SEE A COPY ON THE WAY TO OR FROM THEIR PLACE OF EMPLOYMENT.

The Department of Health has established standards for protection against radiation hazards in Chapter 64E-5, Florida Administrative Code (FAC).

YOUR EMPLOYER IS REQUIRED TO:

- Post or provide you a copy of the Department of Health rules and operating procedures that apply to your work and explain them to you.
- Apply the rules to work involving radiation sources.
- Post or provide you any Notice of Violation involving radiological working conditions, proposed civil penalties, and orders.

YOU ARE REQUIRED TO:

- Become familiar with the rules and the operating procedures that apply to your work.
- Observe the requirements to protect yourself and your coworkers.

WHAT IS IN THESE RULES:

- Limits on exposure to radiation and radioactive material in restricted and unrestricted areas
- Actions to take after accidental exposure
- Personnel monitoring, surveys, and equipment
- Caution signs, labels, and safety interlocks
- Exposure records and reports
- Options for workers about Dept. of Health inspections
- Related matters

REPORTS ON RADIATION EXPOSURE

Your employer must give you a written report if you receive an exposure above the limits in the rules or in the license. The maximum limits for exposure to employees are in Part III of the rules. However, your employer should keep your radiation exposure as low as reasonably achievable (ALARA).

If you work where personnel monitoring is required:

- Your employer must give you a written annual report of your radiation exposures.
- Your employer must give you a written report of your radiation dose when you terminate employment.

INSPECTIONS

Representatives of the Department of Health inspect all licensed and registered activities. Any worker or worker representative who believes that there is a violation of Chapter 404, Florida Statutes; Chapter 64E-5, Florida Administrative Code; or the terms of the employer's license or registration can request an inspection by contacting the Bureau of Radiation Control, Bin C21, 4052 Bald Cypress Way, Tallahassee, FL 32399-1741 (850) 245-4266. The request must state specific reasons for the inspection. During inspections, Department of Health inspectors can confer privately with workers and any worker can bring to the attention of the inspectors any past or present condition that they believe contributed to or caused any violation.

Copies of Chapter 64E-5, FAC, the company's x-ray machine registration, radiation safety procedures, any notice of violations about working conditions, penalty orders issued, and responses can be examined at:

Geotech Bldg. E
(Cubicle by the Exit Door/Near Printing Station)

A.2 FDOT X-ray Emergency Notification Poster

In the Event of a

RADIATION EMERGENCY

IMMEDIATELY NOTIFY:

Radiation Safety Officer:	Dino Jameson	(352) 955-2933
Chemical Ops. Mgr.:	Awilda Merced	(352) 955-6654
Radiation Safety Consultant:	Walt Cofer	(850) 519-5351

FOR STATE RADIATION EMERGENCY NOTIFICATION OR ASSISTANCE, CALL THE FLORIDA BRC:

(407) 297-2095
Monitored 24 hours a day

IN THE EVENT OF A RADIATION EMERGENCY:

1. EVACUATE AREA. ESTABLISH A SECURITY PERIMETER.
2. RESTRICT ACCESS TO EMERGENCY RESPONDERS; KEEP ALL OTHERS OUT!
3. TREAT INJURED PERSONNEL WITHOUT DELAY; THERE IS NO POTENTIAL FOR RADIOACTIVE CONTAMINATION FROM X-RAYS.
4. FOLLOW INSTRUCTIONS OF THE FDOT RSO & STATE/LOCAL AUTHORITIES.

Florida HEALTH

Florida Dept. of Health
Bureau of Radiation Control

Emergency Response (Orlando):	(407) 297-2095
HQ (Tallahassee):	(850) 245-4266
X-ray Section:	(850) 245-4888

Appendix B: Forms

B.1 Radiation Safety Program Audit Report

I. TABLE OF CONTENTS

II. INTRODUCTION

This form documents findings identified during a radiation safety program (RSP) audit conducted on MM/DD/YY at the Location by Auditor(s) for calendar year YYYY.

The audit evaluated the content and implementation of the FDOT Chem Lab RSP, as well as compliance with requirements specified in **FL Radiation Machine Registration No. JR-34613000** and applicable regulations, with emphasis on evaluation of the program's effectiveness in keeping occupational and public radiation doses ALARA.

III. AUDIT & INSPECTION HISTORY

1. **Last FDOT Audit:** YYYY
2. **Any concerns identified?** ☐ Yes ☐ No ☐N/A
3. **Any corrective actions taken?** ☐ Yes ☐ No ☐N/A
   Description of prior audit issues & corrective actions taken:
4. **Last FDOH inspection conducted date:** MM/DD/YY
5. **Violations noted during inspection:** ☐ Yes ☐ No ☐N/A
6. **Recommendations made by inspector:** ☐ Yes ☐ No ☐N/A
7. **Corrective actions taken:** ☐ Yes ☐ No ☐N/A
8. **Incidents since last audit:** ☐ Yes ☐ No ☐N/A
   a. **If yes, was the response appropriate**? (i.e., operator followed emergency procedures, required notifications/reports timely filed, cause of incident investigated, corrective actions taken & documented) ☐ Yes ☐ No ☐N/A
   b. **Description of violations/incidents since last audit:**
   c. **Description of corrective actions taken:**

IV. ORGANIZATION & SCOPE OF OPERATIONS

1. **Radiation Safety Personnel**

Position	Personnel
State RSO	
Management Support	
Rad. Safety Consultant	
X-ray Machine Operators	

2. **X-ray Machine Operations**

Office	Notes
Number of Analytical X-ray Machines	
Number of Locations	
Number of Operators	
Fixed XRF/XRD/XRS	
Portable XRF Analyzer	

3. **Other**
   a. **Address or physical location unchanged; facilities unchanged since the last audit** ☐ Yes ☐ No
   b. **Registered activities unchanged since the last audit, so current public dose limits compliance study remains valid [License Condition (LC), 64E-5.213(4)]** ☐ Yes ☐ No
   c. **If no to A or B, study was revised to demonstrate compliance with public dose limits, and registration was updated to approve change & revised study [64E-5.313(2)]** ☐ Yes ☐ No ☐N/A
   d. **Management provides adequate support to the Chem Lab radiation safety program (e.g., assistance, oversight, funding) [64E-5.303(1)]** ☐ Yes ☐ No
   e. **X-ray-related facility and/or equipment needs being met** ☐ Yes ☐ No
   Description of facility/equipment needs:

V. FACILITIES AND EQUIPMENT

1. **Chem Lab Facilities**
   a. **Facilities are as described in the manual (i.e., facility diagrams match current layout of facilities) [64E-5.213(4)]** ☐ Yes ☐ No
2. **Hand-held analytical x-ray devices are equipped with an interlock system preventing operation unless x-ray exit port is in contact with or close proximity to the item being irradiated [best practice]** ☐ Yes ☐ No

3. **Analytical X-ray Systems**
   a. **Warning light: Analytical x-ray machines equipped with easily visible warning light labeled "X-ray On," or similar words located near any switch that energizes the x-ray tube, & lights up only when tube is energized [64E-5.701(2)(a)]** ☐ Yes ☐ No
   b. **Analytical x-ray machine warning lights have fail-safe characteristics [64E-5.701(2)(c)]** ☐ Yes ☐ No
   c. **Unused ports on radiation source housings kept secured in the closed position to prevent inadvertent opening [64E-5.701(3)]** ☐ Yes ☐ No
   d. **Local components provide sufficient shielding or have access control to limit radiation does below public dose limits at any specified tube rating [64E-5.702(1)]** ☐ Yes ☐ No
4. **Enclosed-beam Analytical X-ray Systems**

a. **Radiation source, sample, detector & analyzing crystal (if used) enclosed in a chamber or coupled chambers that can't be entered by body parts during operation [good practice)]** ☐ Yes ☐ No
b. **Sample chamber closure is interlocked with x-ray tube high voltage supply or shutter in the primary beam so that no x-rays can enter sample chamber while it is open unless interlock has been defeated, & interlock has fail-safe design or adequate administrative controls to ensure operations will not continue without a properly functioning interlock [good practice]** ☐ Yes ☐ No

5. **Postings & Labeling**
   a. **Below documents are posted in conspicuous location(s) for workers to observe them on the way to/from x-ray work areas [64E-5.901]** ☐ Yes ☐ No
      i. FDOT emergency procedures
      ii. FDOH BRC radiological emergency notification poster
      iii. FDOH "Notice to Employees" form (3/01 ed.), with form filled in, listing location where regs, FDOT registration & procedures are available for review by workers
      iv. Any FDOH BRC Notice of Violations (NOV) letters, orders, etc., & FDOT responses to enforcement actions (NOV posted within 5 working days after receipt, & responses posted within 5 working days after dispatch; kept posted for at least 5 working days or until corrective actions have been completed, whichever is later) (recommendation: email all operators a copy of inspection reports)
   b. **Each area/room containing x-ray equipment posted with sign(s) bearing radiation symbol & "Caution – X-ray Equipment", "X-rays in Use", or similar wording [64E-5.702(3)]** ☐ Yes ☐ No
   c. **Each x-ray machine bears label(s) with rad. symbol & "Caution – Produces Ionizing Radiation When Energized" or similar language at each control used to generate x-rays & adjacent to each port [64E-5.322(3), .701(4)(b)** ☐ Yes ☐ No
   d. **Analytical x-ray source housings labeled "Caution – High Intensity X-ray Beam" or similar wording [64E-5.701(4)(a)]** ☐ Yes ☐ No ☐ N/A
   e. **Warning devices labeled so their purpose is easily identified [64E-5.701(2)(b)** ☐ Yes ☐ No
   f. **Additional info. provided on or near required signs/labels to make personnel aware of potential radiation exposures and to minimize exposures [64E-5.322(3)]** ☐ Yes ☐ No

6. **Storage/Use Areas(s)**
   a. **Radiation surveys performed & documented to verify the radiation levels are < 2 mR/hr [64E-5.313(1), LC (Chem Lab MOP study)]** ☐ Yes ☐ No
   b. **X-ray machines locked when in storage & not under direct surveillance [64E-5.320, .321]** ☐ Yes ☐ No
   c. **Extra precautions used to enhance security & deter theft [64E-5.320]** ☐ Yes ☐ No
      Description of extra security precautions:

7. **X-ray Equipment**
   a. **X-ray machines maintained in acceptable condition (i.e., no signs of poor maintenance or damage, and labels present & legible) [RSM]** ☐ Yes ☐ No

8. **Survey Meters**

a. **At least one calibrated (12 months) & operable survey meter available for use [64E-5.314]** ☐ Yes ☐ No
b. **Meters are checked before use: calibration, battery, visual, radiation response using a check source [good practice; RSM]** ☐ Yes ☐ No
c. **Radiation Detection Instruments**

Manufacturer	Model No.	Serial No.	Type	Range	Cal. Date

Comment:

VI. MONITORING OF PREGNANT WORKERS

This section is only applicable if there are pregnant workers that have chosen to declare their pregnancy using form B.3 in the RSM Appendix and are being monitored.

1. **Have any pregnant workers chosen to declare their pregnancy using Appendix Form B.3?** ☐ Yes ☐ No
2. **If yes to number 1, Personnel Monitoring (PM) records reviewed from (dates):** MM/DD/YY to MM/DD/YY
   Comment:

Description	Dose (mrem)	Quarter/Year
Highest Dose for a Quarter		
Highest Annual Dose		
Average Annual Dose		

   Results of review of PM badge reports (describe any issues & any corrective actions taken or planned):
3. **RSO investigates (in coordination with the Chem Lab Manager) any worker doses considered to be excessive or unnecessary [64E-5.303(2), RSM]** ☐ Yes ☐ No ☐ N/A
4. **Description of any worker dose investigation(s):**
5. **PM badges & control badges stored in locations isolated from radiation sources & protected from heat, light, moisture & chemicals [64E-5.314(4), RSM]** ☐ Yes ☐ No
6. **PM badges exchanged & promptly processed (i.e., within 21 days of end of monitoring period) [64E-5.314(4), RSM]** ☐ Yes ☐ No
7. **Adequate precautions being taken to prevent deceptive exposures to PM badges [64E-5.314 (4), RSM]** ☐ Yes ☐ No
8. **All badges accounted for (i.e., no lost or damaged badges)** ☐ Yes ☐ No
   a. **If no, RSO immediately notified & a record of worker's estimated dose made, provided to badge vendor & kept on file [64E-5.314(4), RSM]** ☐ Yes ☐ No ☐N/A

   Description of circumstances involving lost or damaged PM badge(s): N/A
9. **If any replacement badges were used, each replacement badge marked to ID worker it was assigned to, and badge vendor notified to add the replacement badge dose to the worker's occupational dose record [64E-5.314(4), RSM]** ☐ Yes ☐ No ☐N/A
10. **Dosimetry reports get timely reviews (within 7 days) by RSO [64E-5.314(4), RSM]** ☐ Yes ☐ No

11. **RSO issues annual dose reports for all monitored workers, and termination dose reports within 30 days of receipt of final dose report [64E-5.903, RSM]** ☐ Yes ☐ No

VII. TRAINING PROGRAM

1. **Analytical x-ray machine operators complete training per Chapter 2 provisions to address:**
   a. **Radiation awareness-level training ("instructions to workers") [64E-5.902, FAC]** ☐ Yes ☐ No
   b. **Operator training & testing, with practical training & testing per 64E-5.704(1) [.502(1)(a)2.]** ☐ Yes ☐ No
   Comment:
2. **Radiation Safety Officer (RSO)**
   a. **Qualified as an operator (required), & has RSO training (recommended)** ☒ Yes ☐ No
3. **Refresher Training**
   a. **Operators complete annual radiation safety refresher training (recommended)** ☐ Yes ☐ No

   b. **Comments**
      i.

VIII. INVENTORIES

1. **X-ray machines inspected & inventoried at least every 12 months [64E-5.1304, RSM]** ☐ Yes ☐ No
2. **X-ray machine inventory records document all required information and are maintained for 3 years. [64E-5.1303, RSM]** ☐ Yes ☐ No ☐N/A

IX. PREVENTIVE MAINTENANCE & RADIATION SURVEYS

1. **X-ray machines undergo annual inspection and preventive maintenance, including tests of safety devices, per mfr. instructions for each model [64E-5.902, FAC]** ☐ Yes ☐ No

2. **X-ray machines surveyed to test radiation emissions (leakage) per 64E-5.704(1) and documented on Form X-5 or equivalent [64E-5.502(1)(a)2.]** ☐ Yes ☐ No ☐N/A
   - Upon initial installation of the equipment.
   - Annually, during Q1, as part of annual equipment I&M and the annual RSP review (recommended).
   - Following any change in system components.
   - Following any maintenance requirement disassembly or removal of a local component.
   - During preventive maintenance/alignment procedures when a local component is disassembled or removed.
   - Any time an abnormal condition is identified.

X. GENERAL RULES OF USE

1. RSO emphasize to workers the importance of maintaining doses ALARA [64E-5.303(2)]
   ☐ Yes ☐ No
2. Good work practices used by workers to minimize doses [64E-5.303(2)]
   ☐ Yes ☐ No ☐N/A

XI. PROCEDURES AND RECORDS

1. FDOT X-ray Radiation Safety Manual is current with Dept. policies and operations
   ☐ Yes ☐ No

2. Regulations, License Documents & Related Correspondence
   a. Complete, current copy of FDOT X-ray registration certificate kept on file [64E-5.901(1)(b), RSM] ☐ Yes ☐ No
   b. Copies of the most recent FDOH enforcement-related correspondence maintained on file [64E-5.901(1)(d), RSM] ☐ Yes ☐ No
3. Training Records
   a. Radiation safety training records include all required information; records maintained until worker term. or 5 years [64E-5.1305(3)(d), .1307(3), RSM] ☒ Yes ☐ No
4. Additional Records
   a. Public dose limits compliance studies on file & submitted to/approved by FDOH BRC [64E-5.313, RSM] ☐ Yes ☐ No
   b. Inventory records: Document all required information & kept for 3 years [RSM] ☐ Yes ☐ No
   c. X-ray machine receipt/transfer records: Kept on e-file indefinitely [64E-5.103, RSM] ☐ Yes ☐ No
   d. Survey meter calibration records: Maintained for 3 yrs. [64E-5.336(1), RSM] ☐ Yes ☒ No
5. Annual Rad. Safety Program Audit
   a. RSO conducts annual review of x-ray radiation safety program's content & implementation, with emphasis on program's effectiveness in keeping doses ALARA [64E-5.313] ☐ Yes ☐ No
   b. Comment
6. Reports & Notifications
   a. RSO makes required notifications & submit required reports within specified timeframes in the event of changes to the program or an x-ray incident [64E-5 Parts III and IX; RSM) ☐ Yes ☐ No
   b. Comment:

XII. AUDIT FINDINGS/RECOMMENDATIONS

1. **Past Audit Issues:**
2. **RSP Organization/Scope of Operations**
    a.
3. **Facilities/Equipment:**
    a.
4. **Inventories:**
5. **Summary:**
6. **Recommended Action Items:**

B.2 Performance Audit – Analytical X-ray Machine Operator

Date: _____ Location: _____

Auditor: _____
Name Signature

Operator: _____
Name Signature

RSO Initials/Date: _____
(N/A if RSO is auditor)

	SAT.	UNSAT.
POSTINGS/RECORDS		
• Controlled Area access properly posted at all entry points with X-ray warning signage (ex.: "Caution – X-ray Equipment in Use")	☐	☐
• Copy of FDOH regulations (64E-5, FAC), the current Analytical X-ray Radiation Safety Manual, & machine manuals are available to the operator, who demonstrates knowledge of their contents	☐	☐
• Current rad. machine registration certificate posted in area	☐	☐
• Console is labeled w/ radiation symbol & "Caution-Radiation-This Equipment Produces Radiation When Energized" or similar warning near the power on switch	☐	☐
DOSIMETRY		
• Area radiation monitoring is properly mounted at the operator's workstation & is undamaged	☐	☐
• Operator is familiar with procedures for proper use of area & personal monitoring badges, their processing, storage, dealing with a lost or damaged badge & dosimetry reports	☐	☐
SURVEY METER(S)		
• Operator understands that the State RSO has access to calibrated & operable meters capable of making accurate x-ray measurements, if needed to perform required radiation surveys	☐	☐
• Operator is aware of the meter checks performed prior to taking survey readings: visual, calibration (12-months), battery & radiation response	☐	☐
• Meter bears legible calibration labels; radiation check source used to test meter function	☐	☐
OPERATIONS		
• Operator demonstrates knowledge of equipment's design, basic components, safety features, & x-ray & electrical hazards	☐	☐
• Operator demonstrates unit's operation principles	☐	☐
• Daily equipment checks are performed per mfr. instructions, including verification that all service panels & covers are closed & secured before starting powering-up	☐	☐
• Positive control of unit is maintained at all times during analytical x-ray operations	☐	☐
• Unit is kept locked & password-protected when not under direct surveillance of an operator	☐	☐
• X-ray console key is removed & secured by operator when not in use (if applicable)	☐	☐
• Operator demonstrates knowledge of emergency procedures	☐	☐

REMARKS:

B.3 Declaration of Pregnancy

DECLARATION OF PREGNANCY

To: _____
Employee Supervisor

In accordance with section 64E-5.311, Florida Administrative Code (FAC),

I, _____, am declaring that I am pregnant.

I believe that I became pregnant in: _____ _____
Month Year

I understand that the radiation dose to my embryo/fetus during my entire pregnancy will not be allowed to exceed 500 millirem unless that dose has already been exceeded between the time of conception and submitting this declaration. I understand that meeting the lower dose limit may require a change in job or job responsibilities during my pregnancy. I have been instructed to always wear my assigned PM badge at waist level to estimate the embryo/fetus dose. I will make every effort to maintain the fetal dose as low as reasonably achievable (ALARA), and I am aware that the Florida Department of Health (FDOH) and the U.S. Nuclear Regulatory Commission (NRC) recommend that an embryo/fetus not receive more than 50 mrem in any one month. I understand that records of fetal dose will be maintained with my dose records.

I have received verbal instructions on exposure monitoring requirements for declared pregnant women conducting activities involving sources of radiation, in accordance with the requirements of the Department's radiation safety program, the terms and conditions of the Department's radioactive materials license, and Chapter 64E-5, FAC.

I have received instructions concerning the potential risks involved for pregnant women exposed to radiation, including copies of NRC Regulatory Guide 8.13 "Instruction Concerning Prenatal Radiation Exposure", and NRC Regulatory Guide 8.13 "Radiation Dose to the Embryo/Fetus", which I have been encouraged to review. I understand that a declaration of pregnancy is voluntary, must be in writing, and must include the estimated date of conception.

I have been encouraged to request additional information if needed. I am aware that the State Radiation Safety Officer and District RSO are available to answer any questions I may have regarding declared pregnancies, and that radiation safety specialists from the FDOH Bureau of Radiation Control, and the U.S. NRC are also available to answer my questions.

_____
Signature

_____
Printed Name

_____
Date

B.4 Annual X-ray Machine Inventory

ANNUAL X-RAY MACHINE INVENTORY

FL Radiation Machine Certificate of Registration No. JR 34613000

Date of Inventory: _____

Inventory Performed by: _____

RSO (or designee) Signature: _____

No.	Mfr. & Model	Serial Number	Max. Output	Location	Condition /Notes
1					
2					
3.					
4.					
5.					

Notes: _____

_____

_____

B.5 X-ray Machine Radiation Survey Report

Survey Date: _____ Performed By: _____

X-ray Machine Data

Mfr. & Model No.: _____ Serial No.: _____

Max. Voltage: _____ Max. Current: _____

Survey Instrument Data

Mfr. & Model No.: _____ Serial No.: _____ Cal. Date: _____

Radiation Measurements (ID as mR/hr or uR/hr)

No.	Location	Reading
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		
Background reading: Location:		

Survey Locations

Notes: _____

B.6 X-ray Machine Inspection and Maintenance Report

Location: _____

Performed by: _____ Title: _____

Signature: _____ Date: _____

I. X-ray Machine/Scanner Mfr., Model and Serinal Number: _____	SAT	UNSAT
• Console label for *X-ray On* indicator	☐	☐
• Console lock (switch)	☐	☐
• Cables, connections & hoses (check for cracks/wear; clean & lubricate; verify proper grounding)	☐	☐
• Controller & generator circuit boards (check for dust/damage)	☐	☐
• System operation (test warm-up & cool down)	☐	☐
• Warning lights, indicators, controls, safety circuits (verify function)	☐	☐
• Radiation levels (test for leakage) – Use Appendix B.5 to record survey results	☐	☐
• System interlock(s)	☐	☐
• Interior interlock (emergency stop/kill button)	☐	☐
• Radiation alarm (visible/audible)	☐	☐
• Warning lights	☐	☐
• Radiation levels (test for leakage; report results on separate form)	☐	☐

Comments _____

_____

_____

_____

_____

_____

Appendix C: References

C.1 Radiological Units

1. Introduction to Radiological Units

SI (Système International) units (*aka* metric units) comprise the primary measurement system for most countries, and the system is gaining use in the U.S. Federal and state radiation control regulatory agencies have adopted SI units for radiation measurements, and most technical publications use them, however, U.S. industries continue to use traditional (English) units.

2. Common Radiological Unit Prefixes

Submultiples				Multiples			
m	milli	10^{-3}	thousandth	k	kilo	10^{3}	thousand
μ	micro	10^{-6}	millionth	M	mega	10^{6}	Million
n	nano	10^{-9}	billionth	G	giga	10^{9}	billion
p	pico	10^{-12}	trillionth	T	tera	10^{12}	trillion

3. Length

1 centimeter (cm)	=	0.3937 in	=	0.03287 ft			
1 meter (m)	=	100 cm	=	39.37 in	=	3.281 ft	
1 inch (in)	=	2.54 cm	=	0.254 m			
1 foot (ft)	=	30.48 cm	=	5.3048			

4. Radiation Exposure & Dose Units

- **Dosimetry reports** use the dose unit ***rem*** for occupational dose reporting
- **Survey meters** use the exposure unit **Roentgen (R)** to measure exposure rates (e.g., area radiation levels, x-ray leakage surveys), reporting them in uR/hr, mR/hr and R/hr
- **Units**
  - **Roentgen (R)**: Traditional unit for measuring the quantity of x-ray or gamma radiation by measuring the amount of ionization produced in air.

    The Roentgen does not account for biological effects of radiation on human tissue.

    1 R = Quantity of gamma or x-radiation that will produce ions carrying a charge of 2.58 x 10-4 coulombs per kg of air

    1 mR = 2.58 x 10-7 C/kg in air

    There is no SI unit of exposure; the closest conversion is Coulomb/kilogram (C/kg), with 1 R = 2.58 × 10-4 C/kg
  - **Rad:** Traditional unit for energy deposited in (absorbed) by an object per unit mass (amount of energy deposited per unit mass of absorbing material).

    The rad applies to all radiation types at all energies in all absorber materials.

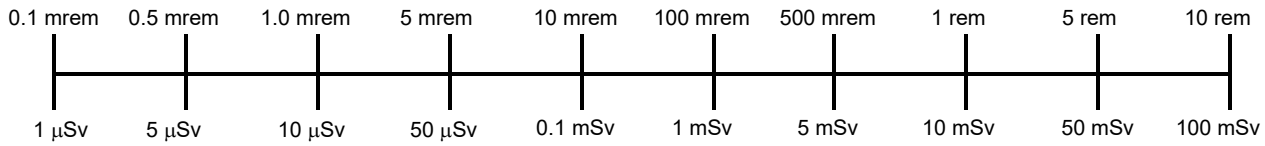
    1 rad = 100 ergs/g = 1 x 10-2 Joules/kg 1 rad = 0.01 Gy = 10 mGy

The SI unit of absorbed dose is the **Gray (Gy)** 1 Gy = 100 rad = 1 Joule/kg

- **Rem**: Traditional unit of radiation dose equivalent (rem = Roentgen equivalent man). It is the product of the absorbed dose in rad and a **quality factor (Q)**, which accounts for the effectiveness of the different types of radiation to cause biological damage.

  rem = rad x Q; for x-rays and gamma radiation, Q = 1, therefore, **1 R = 1 rad = 1 rem**

  The SI unit is the **Sievert (Sv)** 1 Sv = 100 rem 1 rem = 0.01 Sv = 10 mSv



5. SI Base Units

The SI is founded on **base units** for **base quantities** that are mutually independent.

Base Quantity	Name
length	meter (m)
mass	kilogram (kg)
time	second (s)
electric current	ampere (A)

6. SI Derived Units

Derived quantities are defined in terms of base quantities through a system of quantity equations. **SI derived units** for derived quantities are obtained from these equations and SI base units.

Derived Quantity	Derived SU Unit	Symbol
area	square meter	m^2
volume	cubic meter	m^3
speed, velocity	meter per second	m/s

Some SI derived units have been given special names and symbols; relevant units are listed below.

Name	Symbol	Derived Quantity	Quantity Equations
Becquerel	Bq	activity (of radioactive material)	s^{-1}
Gray	Gy	absorbed dose, specific energy (imparted), kerma	J/kg $m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
Sievert	Sv	dose equivalent	J/kg $m^2 \cdot s^{-2}$
Coulomb	C	electric charge, quantity of electricity	$s \cdot A$
Volt	V	electric potential difference, electromotive force	W/A $m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
Joule	J	energy, work, quantity of heat	$N \cdot m$ $m^2 \cdot kg \cdot s^{-2}$
Hertz	Hz	frequency	s^{-1}
Newton	N	force	$m \cdot kg \cdot s^{-2}$
Watt	W	power, radiant flux	J/s $m^2 \cdot kg \cdot s^{-3}$

7. **Units outside the SI**
   Certain units relevant to radiation protection are not part of the SI, but are widely used

Name	Symbol	Value in SI Units
minute	min	1 min = 60 sec
hour	hr	1 hr = 60 min = 3,600 sec
day	d	1 d = 24 h = 86,400 sec
electron volt	eV	1 eV = 1.60218 x 10^{-19} J
rad	rad	1 rad = 1 cGy = 10^{-2} Gy
rem	rem	1 rem = 1 cSv = 10^{-2} Sv
Roentgen	R	1 R = 2.58 x 10^{-4} C/kg

When working with x-rays:

1 R = 1 rad = 1 rem

8. **More SI Derived Units**
   SI derived units with special names and symbols may themselves be included in the names and symbols of other SI derived units. Examples with radiological applications are provided below.

Name	SI Derived Units	
specific energy	joule per kg	J/kg
exposure (x & gamma rays)	coulomb per kg	C/kg
absorbed dose rate	gray per second	Gy/s

9. **Units Relevant to X-ray Machines**
   - **Electron Volt (eV)**

     SI unit of energy for individual photons.

1 eV = amount of energy equal to the kinetic E an electron attains in falling through a potential difference of 1 V; 1 eV is a very small amount, so for x-rays, multiples are used:

keV 1 keV = 1,000 eV **MeV** 1 MeV = 1,000,000 eV

- **Volt (V)**

  SI unit for electric potential, electric potential difference and electromotive force.

  1 V = difference in electric potential across a wire when an electric current of 1 ampere (A, amp) dissipates 1 watt (W) of power; V = W/A.

  Voltage represents a source of energy (electromotive force); electrical potential difference between 2 pts. (ΔV – measured in volts, or J/C), or the difference in electric potential energy per unit charge between 2 pts. Voltage equals work done, per unit charge, against a static electric field, to move the charge between 2 pts.

  A **voltmeter** measures voltage (or potential difference) between 2 pts. in a system; usually a common reference potential, such as system ground, is used as one of the pts.

- **kVp vs. keV**

  kVp is the peak voltage applied to the x-ray tube; keV is the energy of the x-rays.

- **Ampere (A, amp, amperage)**

  SI unit of electric current; measure of the amount of electric charge passing a point per unit time. Ampere is a base unit, defined without reference to the quantity of electric charge. It is a measure of the current flowing between the cathode and anode in an x-ray tube; the output intensity of x-radiation is a function of current, measured in amperage.

  Current is the movement of electric charges from one place to another; its strength is measured in **amperes (A)** or **milliamps (mA)**; equates to the no. of electrons produced, which provides a means of controlling x-ray quantity.

  1 A = ~6.242 × 1018 electrons passing a given point each second.

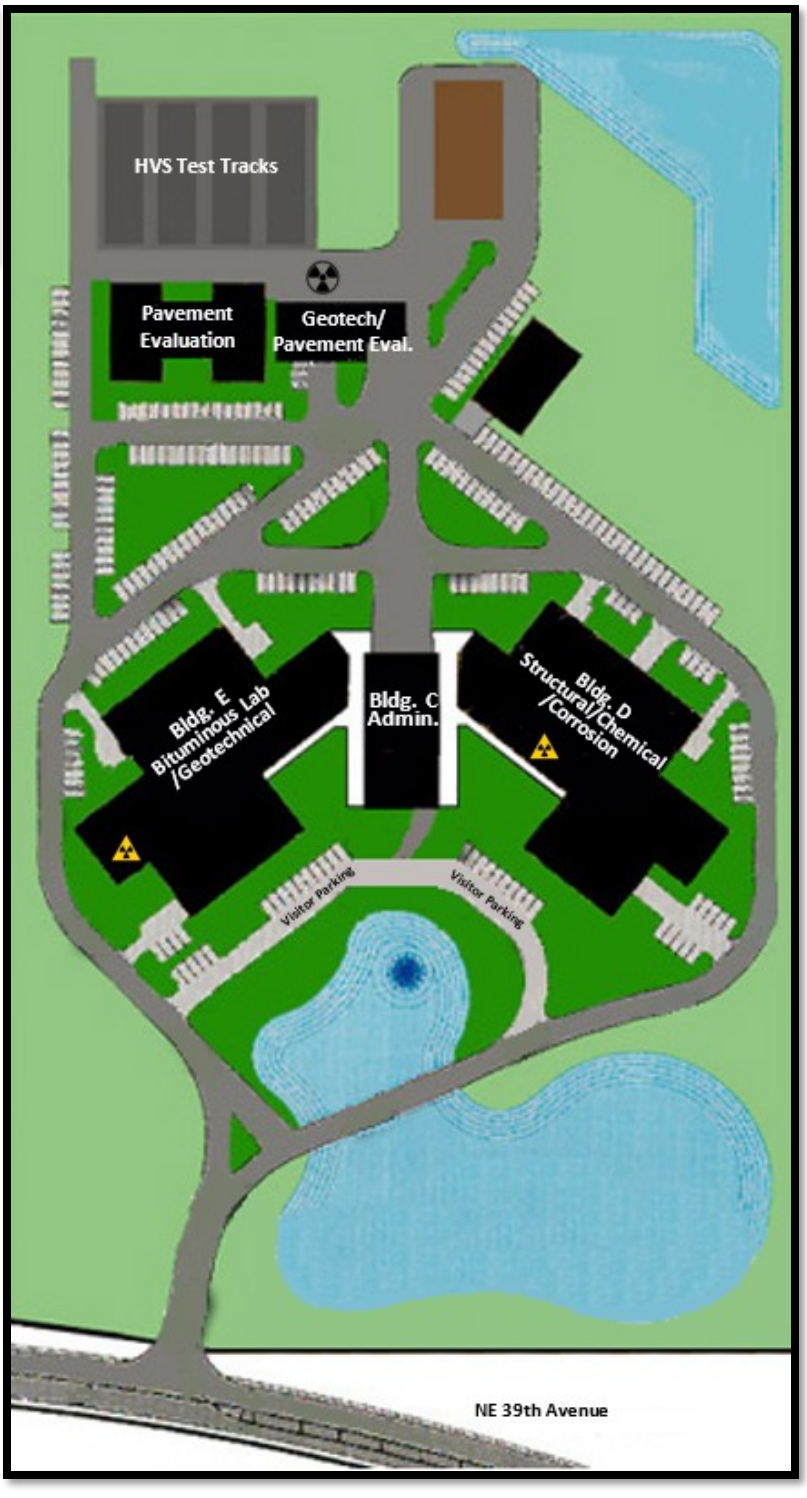
  1 A is a large amount, so a submultiple prefix is commonly used: **milliamp (mA)** – 0.001 amp.

- **Hertz (Hz)**

  Unit of frequency; 1 Hz = 1 cycle/sec.

C.2 Facilities and Equipment

Facility Information



The State Materials Office is located at the Materials Research Park, 5007 NE 39th Avenue, Gainesville, FL 32609. The campus consists of four major buildings: Administration (Bldg. C), Geotechnical & Bituminous (Bldg. E), Structures/Chemical/Corrosion (Bldg. D), and Geotech Test Pit and Pavement Evaluation.

The property is enclosed by fencing and has a security gate that is locked during non-business hours. There is a sign in/out log at the receptionist desk; visitors must be badged and escorted while on site.

The Chemical Lab (Bldg. D) houses all the x-ray units except a handheld XRF analyzer in the Bituminous lab (Bldg. E). Each x-ray machine is equipped with a key and/or passcode that is required for operation, and the keys/codes are restricted to authorized personnel.

The handheld XRF analyzer is stored in the Bituminous Lab (Bldg. E) at Row 7 of the Liquid Section

while in operation and locked up inside the Bituminous Binder Lab manager's office during non-operation.

X-ray Equipment at the SMO

The Florida Department of Transportation holds Florida x-ray machine Certificate of Registration No. JR 34613000 authorizing use of analytical x-ray machines at the State Materials Research Park in Gainesville.

Analytical x-ray equipment is used to look at the microscopic or elemental composition of a material. Examples include x-ray diffraction, x-ray fluorescence spectrometers, and electron microscopes.

The Department's current inventory of analytical x-ray machines consists of the following:

No.	Mfr. & Model	Serial Number	Max. Output	Location
1	Panalytical Zetium XRF analyzer	DY2110	60 kV 66 mA	Bldg. D, Room D104 (Chem Lab), Room D111 (X-ray Spec)
2	Panalytical Cubix Pro x-ray diffractor (XRD)	DY804	45 kV 40 mA	Bldg. D, Room D104 (Chem Lab), Room D111 (X-ray Spec)
3.	Panalytical Epsilon 1 benchtop EDXRF spectrometer	DY753	50 kV	Bldg. D, Room D104 (Chem Lab), Room D111 (X-ray Spec)
4.	Thermo Scientific Niton XL3 portable XRF analyzer	31095	50 kV 0.2 mA	Bldg. E, Row 7 Liquid Binder Section (Bituminous Lab)
5.	Thermo Scientific Niton XL5 portable XRF analyzer	501402	50kV 0.5mA	Bldg. D, Room D104 (Chem Lab), Room D111 (X-ray Spec)