CAMECO RESOURCES
CROW BUTTE OPERATION

86 Crow Butte Road
P.O. Box 169
Crawford, Nebraska 69339-0169

(308) 665-2215
(308) 665-2341 – FAX

October 28, 2015

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

Attn: Document Control Desk, Director
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Request for Additional Information for Response to License Condition 9.12
Quality Assurance Program (QAP)
Crow Butte Resources, Inc., Crawford, Nebraska
Source Materials License SUA-1534
TAC No: L00766

Dear Director:

By letter dated August 10, 2015, (received August 17, 2015) the U.S. Nuclear Regulatory Commission (NRC) staff, upon review of Crow Butte's letter dated December 31, 2014, in response to License Condition 9.12 in renewed Source Material License SUA-1534 issued (November 2014) to Crow Butte Resources, Inc., (TAC J00555), has found deficiencies in Crow Butte's response and has requested additional information. The requests and Crow Butte's responses are summarized below.

Table of Contents

RAI 1:

Description of Deficiency

The staff cannot complete its evaluation of the QAP required by LC 9.12 due to missing information.

Basis for Request

NMSS01
Q004
NMSS

LC 9.12 requires the QAP to address topics recommended in Regulatory Guide 4.15 (as revised). There appears to be information that is recommended in Regulatory Guide 4.15 that NRC staff cannot find in the QAP.

Request for Additional Information

Please provide the following information:

A. Please address Section 8 of Regulatory Guide 4.15, Verification and Validation, or describe where this information can be found in the QAP.

Crow Butte Response

The QAP has been revised; Verification and Validation is described in Section 10.

B. Please address Section 10 of Regulatory Guide 4.15, Preventive and Corrective Actions, or describe where this information can be found in the QAP.

Crow Butte Response

The QAP has been revised; Preventive and Correction Actions is described in Section 11.

Section 5 Instrument Calibration

RAI 2:

Description of Deficiency

The staff cannot complete its evaluation of Section 5 of the QAP required by LC 9.12 due to the missing information

Basis for Request

Section 5.3 of the QAP introduces a staff position titled "designee" that is not described in either Section 2 or Section 3 of the QAP.

Request for Additional Information

Please provide information on the staff position or designee regarding where this position fits within the organizational structure, responsibilities, and qualifications and training related to the quality assurance program.

Crow Butte Response

Section 5.3 was revised by replacing "designee" with "HPT".

RAI 3:

Description of Deficiency

The NRC staff requires clarification of the formula used to calculate self-absorption of radiation on air filter collection media

Basis for Request

In Section 5.6.5 of the QAP, the licensee presents the following calculation to calculate self-absorption of radiation on air filter collection media:

$$\% \text{ Self Absorption} = \frac{C_2 - C_3}{2C_1+C_2-C_3} \times 100$$

where:
C_1 = cpm on front of filter
C_2 = cpm on back of filter
C_3 = cpm on front of filter covered by new filter of the same type

The NRC staff cannot confirm the origin of this formula.

Request for Additional Information

Please provide the NRC staff with a reference for this equation. In particular, please provide a reference that discusses the origin of the "$2C_1$" term in the denominator.

Crow Butte Response

The method is described in Appendix B of the Canadian Nuclear Safety Commission Regulatory Guide G-4, *Measuring Airborne Radon Progeny at Uranium Mines and Mills (June 2003).* The referenced document is attached to this submittal.

RAI 4:

Description of Deficiency

The staff cannot verify that all necessary radiation survey instrument calibrations and check are being performed at the required intervals.

Basis for Request

LC 9.7 requires the licensee to follow the guidance set forth in Regulatory Guide 8.30, "Health Physics Surveys in Uranium Recovery Facilities" (as revised).

Guidance in Section 8 of Regulatory Guide 8.30 recommends that survey instruments be checked for constancy prior to each usage with a radiation check source. An instrument should not differ from the reference reading by more than 20%.

The licensee discusses radiation survey checks in Section 5 of the QAP. Section 5.2.2.4 discusses what a response source check is, but provides on quantitative comparison as described in Regulatory Guide 8.30.

In Section 5.1.1.6 of the QAP, the licensee stated that the radiation survey instrument calibration frequency is annual or at the frequency recommended by the manufacturer, whichever is more frequent.

However, guidance in Section 8 of Regulatory Guide 8.30 recommends that alpha counting systems used for radon daughter measurements should be calibrated at least monthly by using a known standard alpha source.

Request for Additional Information

Please update Section 5 of the QAP as necessary to incorporate the guidance in Regulatory Guide 8.30.

Crow Butte Response

Section 5.1.2 was revised to include the calibration frequency for alpha counting systems for radon daughter measurements.

Section 5.2.2.5 was added to describe the constancy check for survey instruments.

Section 7 Occupational Sample Collection

RAI 5:

Description of Deficiency

In its discussion of using gross alpha counting of area air filters, the licensee provided a statement that is contradictory to a previous statement addressing the same procedure.

Basis for Request

In Section 7.1.1 of the QAP, the licensee stated:

> "Measurement of airborne uranium is performed by gross alpha counting of the area air filters using an alpha scaler such as a Ludlum L-2000 or equivalent. The analytical results are compared to the derived air concentration (DAC) for soluble (D classification) natural uranium of 5 E-10 μCi/ml from Appendix B to 10 CFR §§20.1001 – 20.2401. This is a conservative method because the gross alpha results include uranium-238 and several of its daughters (notably radium-226 and thorium-230) which are alpha emitters".

This statement contradicts a previous response from the licensee addressing an RAI for the North Trend Amendment (refer to RAI 5.7.3.2.c of Crow Butte Resources, Inc., 2009a) where the licensee found this method not to be conservative.

Request for Additional Information

Please correct the statement above to reflect the requirements of 10 CFR 20.1204 regarding mixtures of radionuclides in air.

Crow Butte Response

Section 7.1.1, third paragraph, was revised to reflect the requirements of 10 CFR 20.1204.

RAI 6:

Description of Deficiency
The licensee did not provide sufficient justification for the use of the survey detector proposed for performing beta dose rate surveys. In addition, the licensee did not address surveys for beta contamination levels.

Basis for Request

The requirements in 10 CFR 20.1501(a)(2)(iii) specify that licensees shall make surveys of areas that are reasonable under the circumstances to evaluate the potential radiological hazards of the radiation levels and residual radioactivity detected.

In Section7.3.3, the licensee proposed using the Ludlum Model 3 survey meter with Ludlum Model 44-6 G-M detector, or equivalent. However, the NRC staff observes that the Ludlum Model 44-6 G-M beta gamma survey detector has a beta cutoff energy of 200 keV in the open window configuration. According to Ludlum's technical information: "The detector incorporates a rotary shield, which when open, allows the detection of beta radiation for energies above approximately 200 keV".

See, for example, http://www.ludlums.com/images/stories/data sheets/M44-6.pdf

The NRC staff also observes that Th-234, a daughter product of U-238 and beta-emitter, decays by beta emission with energies significantly below the 200 keV cutoff energy of the Model 44-6 G-M detector, making it unlikely that these beta particles will be detected. Any detector equivalent to the Ludlum Model 44-6 will exhibit this same shortcoming.

Request for Additional Information

Please provide appropriate detectors for the beta dose rate surveys as well as beta contamination surveys.

Crow Butte Response

Sections 5.2.3.4 and 7.3.3 were revised to list an appropriate detector for the beta dose rate surveys as well as beta contamination surveys.

RAI 7:

Description of Deficiency

There appear to be typographical errors in the numbering of the sections.

Basis for Request

The table of contents lists "Section 7.4 Surface Contamination" and "Section 7.5 Bioassay Program". The Surface Contamination section is not enumerated in the text of the QAP and the Bioassay section is labeled as "7.4".

Request for Additional Information

Please review the table of contents and make the appropriate changes in the text of the QAP.

Crow Butte Response

The table of contents was revised to match the text of the QAP.

RAI 8:

Description of Deficiency

The NRC staff cannot verify that all topics recommended in Regulatory Guide 4.15 have been incorporated into the licensee's QAP.

Basis for Request

Section 5 of Regulatory Guide 4.15 recommends that:

> "Sampling of solids, liquids, and gases involves the measurement of sample masses, flow rates, or volumes. The ACCURACY of the instruments or containers used for this purpose should be determined and checked regularly to ensure that sampling performance criteria remain within the limits specified by the MQOs. The results of mass, flow rate, or volume calibrations and associated UNCERTAINTIES should be recorded".

In addition, Section 6 of Regulatory Guide 4.15 recommends that:

> "Performance criteria for radioanalytical measurements should be selected to provide a management tool for tracking and trending performance and to identify precursors to nonconforming conditions. Laboratories should satisfy program-specific criteria for all measurement processes, including necessary levels of PRECISION, acceptable BIAS, and applicable detection levels.

The NRC staff observes that Section 6.1 of Regulatory Guide 4.15 also provides recommendations for nonradiological instruments, measurements, and test equipment.

LC 11.1(D) requires the licensee to submit a semiannual report consistent with the terms of Regulatory Guide 4.14, "Radiological Effluent and Environmental Monitoring at Uranium Mills". Section 6 and 7 of Regulatory Guide 4.14 provide recommendations on the recording and reporting of results of effluent and environmental monitoring including error estimates.

Section 8 of the licensee's QAP discusses replicate and blank samples in general, and lower limits of detection for radiological and nonradiological parameters.

However, the NRC staff could not locate a discussion on the licensee's expectation on measurement uncertainties for reporting purposes and for the purpose of tracking and trending performance and to identify precursors to nonconforming conditions.

In its renewal application, the licensee stated that its airborne sampling procedures implemented the guidance in Regulatory Guide 8.25, "Air Sampling in the Workplace" (refer to Section 5.8.3.1 of Crow Butte Resources, Inc. 2009b). Regulatory position 5.3 of Regulatory Guide 8.25 provides recommendations on calculating the uncertainty in the volume of air sampled.

Request for Additional Information

Please provide a discussion on how the precision and accuracy of the licensee's monitoring processes are determined. The response should include a discussion on how errors are estimated for all pertinent measurement parameters including, for example, sample masses, flow rates, volumes, and sampling time for radiological and nonradiological analyses performed by the licensee.

Please also provide a description of activities that are implemented by the licensee for the purpose of tracking and trending performance and to identify precursors to nonconforming conditions.

Crow Butte Response

Sections 6 and 8 were revised to provide a discussion on how the precision and accuracy of Crow Butte's monitoring processes are determined and a description of activities that are implemented by Crow Butte for the purpose of tracking and trending performance to identify precursors to nonconforming conditions.

RAI 9:

Description of Deficiency

The proposed record storage duration does not appear to meet the requirements of 10 CFR Part 20, 10 CFR Part 40, and the conditions of License SUA-1534.

Basis for Request

In Section 11.4 of its QAP, the licensee stated:

> "The minimum storage duration for records containing the results of sampling, analysis, surveys and monitoring, reports of audits and inspections, and investigations and corrective actions is five years. Data used for determination of personnel exposures must be retained until termination of the NRC Source Materials License".

Various regulatory requirements in 10 CFR Part 20, 10 CFR Part 40 specify record retention periods significantly longer than five years. The following citations are examples of record retention requirements pertinent to those measurements discussed in Section 11 of the licensee's QAP:

- 10 CFR 20.1501(b)
- 10 CFR 20.2203(b)(4)
- 10 CFR 20.2107(b)
- 10 CFR 40.61(b)

Regulatory Position C.4 of Regulatory Guide 4.15 states, in part:

> "...The licensee should establish a retention time for records consistent with licensing conditions and in accordance with the licensee's overall QA program".

LC 9.10 states:

> "The results of the following activities, operations, or actions shall be documented: sampling; analyses; surveys or monitoring; survey/monitoring equipment calibrations; reports on audits and inspections; all meetings and training courses; and any subsequent reviews, investigations, or corrective actions required by NRC regulation or this license. Unless otherwise specified in a license condition or applicable NRC regulation, all documentation required by this license shall be maintained until license termination, and is subject to NRC review and inspection".

Various license conditions specify monitoring that results in records that are addressed by LC 9.10. For example:

- LC 11.3
- LC 11.4
- LC 11.5
- LC 11.6

Request for Additional Information

Please review all regulatory and licensing requirements for record retention requirements and revise Section 11 of the QAP as appropriate.

Crow Butte Response

Section 12.4 (Section 11.4 in prior submittal) was revised to indicate that all records required by CBO's license and permits will be maintained until all license and permits have been terminated.

RAI 10:

Description of Deficiency

The NRC staff cannot complete its evaluation of Section11 of the QAP as required by LC 9.12 due to missing information.

Basis for Request

Section 11 of the QAP introduces a staff position titled "designee" that is not described in either Section 2 or Section 3 of the QAP.
Request for Additional Information

Please provide information on the staff position of designee regarding where this position fits within the organizational structure, responsibilities, qualifications and training related to the quality assurance program.

Crow Butte Response

The reference to a "designee" was removed from Section 12.1 and 12.2 (Section 11.1 and 11.2 in prior submittal).

RAI 11:

Description of Deficiency

The NRC staff cannot complete its evaluation of Section 5 of the QAP required by LC 9.12 due to missing information.

Basis for Request

Section 12.4.1 and 12.4.2 of the QAP introduce staff position titled "qualified designated operator", "qualified designee", and Operations Manager that are not described in either Section 2 or Section 3 of the QAP.

LC 9.7 requires the licensee to follow guidance set forth in Regulatory Guide 8.31, "Information Relevant to Ensuring that Occupational Radiation Exposures at Uranium Recovery Facilities Will Be as Low as Is Reasonably Achievable" (as revised), with specific exception for the performance of daily inspections.
Regulatory Guide 8.31 recommends that the radiation safety officer (RSO) and the facility foreman should conduct a weekly inspection of all facility areas. Contrary to this recommendation, the licensee stated in Section 12.4.2 of the QAP that, in addition to the RSO and Operations Manager, qualified designees may conduct weekly inspections.

Request for Additional Information

Please provide information on the staff position of "qualified designated operator", qualified designees", Operations Manager regarding where these positions fit within the organizational structure, responsibilities, and qualifications and training related to the quality assurance program.

In addition, please revise the description of weekly inspections to be consistent with LC 9.7 regarding personnel performing the inspection.

Crow Butte Response

Section 2 and Sections 12.4.1 and 12.4.2 have been revised to be consistent with LC 9.7 and Regulatory Guide 8.31.

If there are any further questions or concerns feel free to contact me at (308) 665–2215 ext. 114.

Sincerely,

Larry Teahon

Larry Teahon
SHEQ Manager

Enclosure

cc: Deputy Director
Division of Decommissioning
Uranium Recovery and Waste Programs
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Mail Stop T-8F5
11545 Rockville Pike
Two White Flint North, Rockville, MD 20852-2738

CBO- File

ec: CR-Casper

CROW BUTTE RESOURCES, INC.
d/b/a
CAMECO RESOURCES
CROW BUTTE OPERATION

QUALITY ASSURANCE PROGRAM

Original
December 31, 2014

Revision #2
October 30, 2015

TABLE OF CONTENTS

1 OBJECTIVES AND ELEMENTS OF A QUALITY ASSURANCE PROGRAM

To define the objectives of a Quality Assurance (QA) program, it is important to first define what quality assurance is and its relationship to quality control.

Quality assurance comprises all those planned and systematic actions that are necessary to provide adequate confidence in the results of a monitoring program. Quality control comprises those quality assurance actions that provide a means to control and measure the characteristics of measurement equipment and processes to established requirements. Therefore, quality assurance includes quality control.

The overall objectives of a QA program are:

- To identify deficiencies in the sampling and measurement processes to those responsible for these operations so that corrective action can be taken, and
- To obtain some measure of confidence in the results of the monitoring programs in order to assure the regulatory agencies and the public that the results are valid.

To achieve these objectives, the QA plan contains the following elements:

- Designation of an individual within the organization as the QA Coordinator. The QA Coordinator should undertake activities such as quality planning, audits and programs to insure reliability and should have the responsibility to assure that the QA plan is being properly implemented.
- A systematic policy for selection and use of measurement and sampling methodology. Where available, this methodology should be approved by the appropriate agency.
- Procedures for the documentation and review of operating procedures and instructions.
- QA audits of acceptance criteria for a QA plan to determine on a systematic basis that all planned activities are being done.

2 ORGANIZATIONAL STRUCTURE AND RESPONSIBILITIES OF MANAGERIAL AND OPERATIONAL PERSONNEL

The structure of the organization as relating to the QA program is shown in Figure 1. The responsibilities of the key QA personnel are as follows:

2.1 BOARD OF DIRECTORS

The Board of Directors has the ultimate responsibility and authority for radiation safety and environmental compliance for Crow Butte Resources, Inc. (CBR) d/b/a Cameco Resources, Crow Butte Operation (CBO). The Board of Directors sets corporate policy and provides procedural guidance in these areas. The Board of Directors provides operational direction to the President of CBR.

2.2 PRESIDENT

The President is responsible for interpreting and acting upon the Board of Directors' policy and procedural decisions. The President directly supervises the General Manager of US Operations. The President is empowered by the Board of Directors to have the responsibility and authority for the radiation safety and environmental compliance programs. The President is responsible for ensuring that the operations staff is complying with all applicable regulations and permit/license conditions through direct supervision of the General Manager of US Operations.

2.3 GENERAL MANAGER OF US OPERATIONS

The General Manager of US Operations is responsible for managing all US Operations. The General Manager of US Operations is responsible for ensuring that Crow Butte personnel comply with Industrial Safety, Radiation Safety, Environmental Protection Programs, and all relevant state and federal regulations. The General Manager of US Operations has the responsibility and the authority to suspend, postpone or modify, immediately if necessary, any activity that is determined to be a threat to employees, public health, the environment, or potentially a violation of state or federal regulations. The General Manager of US Operations reports directly to the President.

2.4 MINE MANAGER

The Mine Manager is responsible for all uranium production activity at the project site. The Mine Manager is also responsible for implementing any industrial and radiation safety and environmental protection programs associated with operations. The Mine Manager is authorized to immediately implement any action to correct or prevent hazards. The Mine Manager has the responsibility and the authority to suspend, postpone, or modify, immediately if necessary, any activity that is determined to be a threat to employees, public health, the environment, or potentially a violation of state or federal regulations. The Mine Manager cannot unilaterally override a decision for suspension, postponement, or modification if that decision is made by the Manager of Safety, Health, Environment and Quality, or the RSO. The Mine Manager reports directly to the General Manager of US Operations.

2.5 MANAGER OF SAFETY, HEALTH, ENVIRONMENT AND QUALITY (SHEQ)

The Manager of SHEQ is responsible for all, safety, health, environmental and quality programs as stated in the Safety, Health, Environment, and Quality Management System (SHEQMS) and for ensuring that CBR complies with all applicable regulatory requirements. The Manager of SHEQ reports directly to the Mine Manager. This position assists in the development and review of radiological and environmental sampling and analysis procedures and is responsible for routine auditing of the programs. The Manager of SHEQ has no production-related responsibilities. The Manager of SHEQ also has the responsibility and authority to suspend, postpone, or modify any activity that is determined to be a threat to employees, public health, the environment or potentially a violation of state of federal regulations.

2.6 RADIATION SAFETY OFFICER (RSO)

The RSO is responsible for the development, administration, and enforcement of all radiation safety programs. The RSO is authorized to conduct inspections and to immediately order any change necessary to preclude or eliminate radiation safety hazards and/or maintain regulatory compliance. The RSO inspects facilities to verify compliance with all applicable requirements in the areas of radiological health and safety. The RSO works closely with all supervisory personnel to insure that established programs are maintained. The RSO is also responsible for the collection and interpretation of employee exposure related monitoring, including data from radiological safety. The RSO makes recommendations to improve any and all radiological safety related controls. The RSO has no production-related responsibilities. The RSO reports directly to the Mine Manager. As such, the RSO has a secondary reporting requirement to the General Manager of U.S. Operations.

2.7 HEALTH PHYSICS TECHNICIAN (HPT)

The HPT assists the RSO with the implementation of the radiological safety programs. The HPT is responsible for the orderly collection and interpretation of all monitoring data, to include data from radiological safety and environmental programs. The HPT reports directly to the RSO.

2.8 QUALIFIED DESIGNATED OPERATOR

The qualified Designated Operator is responsible for performing daily inspections in the occasional absence of the RSO and the HPT. A qualified Designated Operator will meet the minimum qualifications and perform only those duties as outlined for a qualified Designated Operator as specified in License Condition 9.7 of source Material License SUA-1534.

2.9 ENVIRONMENTAL LEADERSHIP COORDINATOR

The Environmental Leadership Coordinator is responsible for the development, administration, and enforcement of environmental protection programs. The Environmental Leadership Coordinator inspects facilities to verify compliance with all applicable requirements in the areas of environmental protection. The Environmental Leadership Coordinator is authorized to immediately order any change necessary to preclude or eliminate environmental harm and/or maintain regulatory compliance. The Environmental Leadership Coordinator works closely with all supervisory personnel to review and approve new equipment and changes in processes and procedures that may affect environmental protection and to ensure that established programs are maintained. The Environmental Leadership Coordinator makes recommendations to improve environmental protection-related controls. Responsibilities of the Environmental Leadership Coordinator include the maintenance of appropriate records to document compliance with the regulations and the SHEQMS. The Environmental Leadership Coordinator reports directly to the Manager of SHEQ.

2.10 PLANT FOREMAN

The Plant Foreman supervises plant operations, including the safe and efficient recovery and processing of uranium oxide while staying within regulatory and technical constraints. The Plant Foreman is responsible for carrying out any procedures or actions implemented by the Mine Manager, Manager of SHEQ, or the RSO to correct or prevent radiation safety hazards in the plant. The RSO and the Plant Foreman are responsible for conducting weekly inspections of all facility

areas to observe general radiation control practices and review required changes in procedures and equipment. The Plant Foreman reports directly to the Mine Manager.

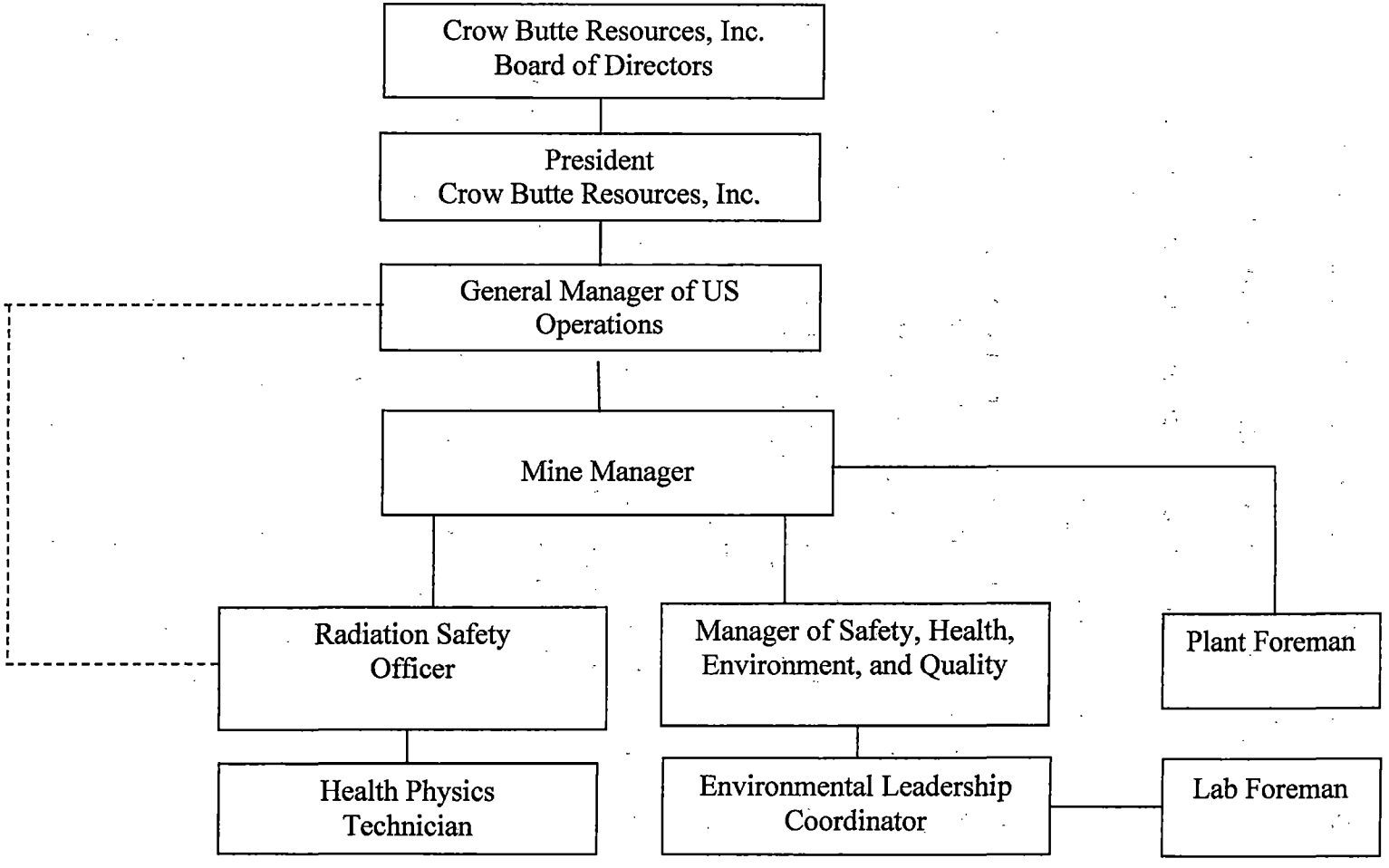
2.11 LAB FOREMAN

The Lab Foreman has direct oversight of the on-site analytical laboratory including implementing laboratory quality assurance procedures. The Lab Foreman is responsible for carrying out any procedures or actions implemented by the Mine Manager, Manager of SHEQ, or the RSO to correct or prevent radiation safety hazards in the laboratory. The Lab Foreman reports directly to the Environmental Leadership Coordinator.

2.12 QUALITY ASSURANCE COORDINATOR

CBR will conduct audits of the quality assurance program as discussed in Section 13. The Manager of SHEQ may conduct these audits while serving as the Quality Assurance Coordinator. Additionally, CBR may utilize an outside auditing service to provide assurance that all quality assurance procedures and regulatory requirements are being conducted properly at the Crow Butte Uranium Project. Any outside service used for this purpose will be qualified in quality assurance procedures as well as environmental aspects of solution mining operations.

Figure 1: Crow Butte Resources Quality Assurance Organizational Chart



3 QUALIFICATION AND TRAINING OF PERSONNEL

The minimum qualifications of operational personnel involved in the QA program are as follows:

3.1 PRESIDENT OF CBR

Bachelor's degree in engineering or science field and five (5) years' experience or equivalent in mine operations management or a related field.

3.2 GENERAL MANAGER OF US OPERATIONS

Bachelor's degree in engineering or science field and five (5) years' experience or equivalent in mine operations management or a related field.

3.3 MINE MANAGER

Bachelor's degree in engineering or science field and three (3) years' experience or equivalent in mine operations management or a related field.

3.4 MANAGER OF SAFETY, HEALTH, ENVIRONMENT, AND QUALITY

Bachelor's degree in science, industrial hygiene, environmental technology or engineering or an equivalent combination of training and relevant experience in uranium mill/solution mining radiation protection. A minimum of 3 years working in environmental protection or related regulatory experience in a similar field.

3.5 RADIATION SAFETY OFFICER

3.5.1 Education

A Bachelor's degree in the physical sciences, industrial hygiene, or engineering from an accredited college or university or an equivalent combination of training and relevant experience in UR facility radiation protection. Two years of relevant experience are generally considered equivalent to one year of academic study.

3.5.2 Health Physics Experience

A minimum of one year of work experience relevant to UR operations in applied health physics, radiation protection, industrial hygiene or similar work. This experience should involve actually

working with radiation protection and measurement equipment, not strictly administrative or "desk" work.

3.5.3 Specialized Training

At least four weeks of specialized classroom training in health physics specifically applicable to uranium recovery. In addition, the RSO should attend refresher training on UR facility health physics every 2 years.

3.5.4 Specialized Knowledge

A thorough knowledge of the proper application and use of all health physics equipment used in the UR facility, the chemical and analytical procedures used for radiological sampling and monitoring, methodologies used to calculate personnel exposure to uranium and its daughters, and a thorough understanding of the UR process and equipment used in the facility and how the hazards are generated and controlled during the UR process.

3.6 HEALTH PHYSICS TECHNICIAN

3.6.1 Education

An associate degree or two years or more of study in the physical sciences, engineering or a health related field.

3.6.2 Training

At least a total of four weeks of generalized training (up to 2 weeks may be on the job training) in radiation health protection applicable to UR facilities.

3.6.3 Experience

One year of work experience using sampling and analytical laboratory procedures that involve health physics, industrial hygiene, or industrial safety measures to be applied in a UR facility.

3.6.4 Alternate Qualifications and Training

The HPT may also possess the following alternate qualification and training:

- Education - A high school diploma
- Training - A total of at least three months of specialized training (up to 1 month may be on the job training) in radiation protection relevant to UR facilities.
- Experience - Two years of relevant work experience in applied radiation protection.

3.7 ENVIRONMENTAL LEADERSHIP COORDINATOR

Bachelor's degree in science or a closely related field. Minimum of 3 years working in environmental protection or related regulatory experience in a similar field.

3.8 LAB FOREMAN

The minimum qualifications for a Lab Foreman are two years of post-secondary education in Chemistry or Physical science and two years of inorganic laboratory experience. At least one year of this experience should be at a UR facility.

3.9 QUALIFIED DESIGNATED OPERATOR

The minimum qualifications for a qualified Designated Operator are described in Section 5.6.6.1 of the Source Material License Renewal (November 2014).

3.10 TRAINING

Personnel performing quality related activities will be trained in the principals and techniques of the activities performed. An on-the-job training program that will be administered by experienced professionals will achieve training of the field personnel.

3.11 TRAINING EVALUATION

On an annual basis, the Manager of SHEQ or a designated outside consultant will observe field and plant personnel in the sample collection and analysis process and evaluate the personnel performance on the basis of adherence to written procedures.

4 OPERATING PROCEDURES

4.1 ADMINISTRATIVE AND OPERATION PROCEDURES

The CBR Quality Assurance Program is implemented through the use of written Standard Operating Procedures (SOPs). These SOPs have been developed for all process activities, including those activities involving radioactive materials, for the Crow Butte Uranium Project. Where radioactive material handling is involved, pertinent radiation safety practices are incorporated into the SOP. Additionally, SOPs contain instructions for performing non-process activities including instrument calibration, environmental monitoring, health physics monitoring, and emergency measures.

Quality assurance and control objectives are met by including the requirements for performance of quality control measures in the appropriate SOP. In some instances, separate SOPs are developed to implement quality measures.

Written SOPs are kept electronically and in hard copy in the areas of the plant facility where they are used. This allows for easy access by employees. Employees are trained on the appropriate SOPs for their job description when they are initially hired and when any procedure revisions are made.

4.2 TYPES OF PROCEDURES

The SOPs developed by CBR are a critical step to insuring that quality assurance objectives are met. Current SOPs exist for a variety of areas, including but not limited to:

1. Environmental monitoring procedures.
2. Testing and calibration procedures.
3. Exposure control procedures.
4. Equipment operation and maintenance procedures.
5. Employee radiological health and safety procedures.
6. Incident response procedures.
7. Laboratory procedures.

The CBR Safety, Health, Environment, and Quality Management System (SHEQMS) are organized into eight volumes. The volumes are as follows:

Volume I, *Standard*
Volume II, *Management Procedures*
Volume III, *Operations Manual*
Volume IV, *Health Physics Manual*
Volume V, *Industrial Safety Manual*

Volume VI, *Environmental Manual*
Volume VII, *Training Manual*
Volume VIII, *Emergency Manual*

Specific SOPs that are used by CBR to implement quality measures are listed throughout this Quality Assurance Program. These SOPs may be revised and/or supplemented with additional SOPs to meet quality requirements as the need arises. The site also has a *Laboratory Procedures Manual* for a quality assurance/quality control program to determine the precision and accuracy of the laboratory analysis performed in the on-site laboratory.

4.3 PROCEDURE REVIEW AND APPROVAL

Written SOPs have been developed, reviewed and approved by the RSO and the responsible managers. The responsible manager ensures that the operational aspects of the SOP are correct and appropriate. All written SOPs are reviewed for radiological protection aspects and approved by the RSO prior to implementation.

SOPs are revised as necessary to meet changing operational and regulatory requirements. Any revisions made to the SOPs are reviewed and approved by the RSO and responsible manager prior to implementation. At a minimum, the SOPs are reviewed and, where necessary, revised, on an annual basis by the RSO. The annual review is documented by the RSO.

The personnel shown in Table 1 are responsible for approvals for each of the SHEQMS volumes.

Table 1
Procedure Approval Responsibility

SHEQMS Volume	Radiological Protection Approval	Final Approval
Volume I, *Standards*	RSO	Mine Manager
Volume II, *Management Procedures*	RSO	Mine Manager
Volume III, *Operations Manual*	RSO	Mine Manager
Volume IV, *Health Physics Manual*	RSO	RSO
Volume V, *Industrial Safety Manual*	RSO	Mine Manager
Volume VI, *Environmental Manual*	RSO	SHEQ Manager
Volume VII, *Training Manual*	RSO	SHEQ Manager
Volume VIII, *Emergency Manual*	RSO	SHEQ Manager
Laboratory Procedures Manual	RSO	Lab Foreman

5 INSTRUMENT CALIBRATION

CBR implements a routine maintenance and calibration program for all radiological survey instruments and samplers. This program is implemented through the use of appropriate SOPs. The CBR instrument maintenance and calibration program is based upon the recommendations contained in USNRC Regulatory Guide 4.15, *"Quality Assurance for Radiological Monitoring Programs (Inception through Normal Operations to License Termination) – Effluent Streams and the Environment,"* (Revision 2, 2007) and Regulatory Guide 8.30, *"Health Physics Surveys in Uranium Mills,"* (Revision 1, 2002).

5.1 INSTRUMENT CHECKS

CBR performs checks of radiation survey and counting equipment daily before use. The daily checks consist of a physical check and a response check. CBR also performs checks of counting instruments to determine instrument efficiency and sensitivity.

5.1.1 Vendor Calibration

The physical checks performed on a daily basis include verification that the instrument is properly calibrated, has sustained no physical damage that may interfere with accuracy, and that the instrument battery has adequate power (if appropriate).

The manufacturer or a qualified accredited vendor shall calibrate portable survey instruments, counter/scalers, mass flow meters and/or dry cell calibrators, and calibration sources. Calibration will be performed as recommended in ANSI N323 and ANSI N323A. The ANSI standard requires that radiation detection instruments be performance tested on an annual basis to verify that they continue to meet operational and design requirements. Instruments must be tested for range, sensitivity, linearity, detection limit, and response to overload. The specific calibration requirements for various types of instrument are given in the following sections.

5.1.1.1 Linear and Digital Readout Instruments

Linear readout instruments with a single calibration control for all scales shall be adjusted at the point recommended by the manufacturer. Instruments with calibration controls for each scale must be adjusted on all scales. After adjustment, the instrument must be checked near the end points (approximately 20% and 80% of full scale).

5.1.1.2 Logarithmic Readout Instruments

Logarithmic readout instruments normally have two or more adjustments. The instrument must be adjusted for each scale as recommended by the manufacturer. After adjustment, the instrument must be checked at a minimum of one point on each decade.

5.1.1.3 Surface Contamination Measurement Instruments

Alpha and beta-gamma detection instruments usually consist of a count rate meter and a separate detector. The electronics and the detector may be calibrated together or separately. The detector should be calibrated with the radionuclide to be detected, if possible, or with radionuclides of similar energies. When the instrument is calibrated as an integral unit, a minimum of one point on each scale is calibrated up to approximately 6×10^4 dpm/100 cm^2. When calibrated separately, the count rate meter is calibrated with an electronic pulser. Exchange of detectors is allowed if the response to a calibrated check source is within the range of acceptable counts for the original probe and check source.

5.1.1.4 Radioactive Calibration Sources

Calibration sources that are used to determine instrument operating parameters such as high voltage setting, reliability factor, and efficiency must be calibrated annually by the manufacturer. Depending on the half-life of the radionuclide used for the source, decay correction may also be necessary during use to ensure accuracy. All calibration sources are stored in the Radiation Safety Laboratory and are secured after hours by a locked door.

5.1.1.5 Calibration Records

The calibration vendor shall provide a record of all calibration, maintenance, repair, or modification. Calibration records will be filed with all previous records for the same instrument. In addition, each instrument will be labeled with the following information:

- Date of most recent calibration;
- Initials of calibrator;
- Date that primary calibration is again required;
- Special use or limitations (if applicable);
- Serial number of the instrument.

5.1.1.6 Calibration Frequency

Calibration frequency is annual or at the frequency recommended by the manufacturer, whichever is more frequent. Where instruments are subjected to extreme operational conditions, hard usage, multi-shift use, or corrosive environments, the RSO should consider increasing the calibration frequency. The calibration vendor should provide the as-found calibration condition for each instrument. If greater than 10% of the instruments are out of calibration when received by the calibration vendor, consideration should be given to increasing the calibration frequency.

5.1.2 On-Site Calibration

Regulated air samplers (Eberline RAS-1 or equivalent) and high volume air samplers are calibrated semiannually or at the manufacturer's recommended frequency, whichever is more frequent. Breathing zone samplers are calibrated daily during use. With the exception of breathing zone samplers, air samplers should be labeled with the date of calibration, correction factors (if applicable), and initials of the calibrator. This information is recorded on the daily calibration sheet for the breathing zone samplers. All alpha counting systems used for radon daughter measurements are calibrated at least monthly using a known standard alpha source.

5.2 FUNCTIONAL TESTS

Functional tests are performed at the mine site to ensure that an instrument is acceptable for use. The functional tests are checks that are often qualitative and consider the physical condition of the instrument (e.g., battery condition) and response of the instrument to a radioactive source.

5.2.1 Initial Instrument Checks

Initial instrument checks are performed initially after receipt of the instrument from the calibration vendor. The results of these initial instrument checks are recorded and are used to ensure that a system continues to operate in as-received condition until the next scheduled calibration. These functional tests are also performed after any repair or if the response of the instrument to a known source is questioned.

5.2.1.1 Instrument Reliability Factor

The instrument reliability factor (RF) will indicate whether an instrument is operating properly within the statistical limits of counter reliability. The reliability factor is determined initially after receiving the appropriate type of instrument from the calibration vendor. The reliability factor should also be determined for an instrument that has not been in service for an extended period or for an instrument that has a daily source check count that falls outside the acceptable range. The reliability factor should be between 0.64 and 1.22. This implies that the instrument is operating reliably. A reliability factor between 0.50 and 0.64 or 1.22 and 1.40 will be investigated by the

RSO. A reliability factor less than 0.50 or greater than 1.40 is unsatisfactory and the instrument will be removed from service.

5.2.1.2 Acceptable Range

The acceptable range will allow a quick determination that the daily source count performed for a specific instrument is within satisfactory limits. Note that the daily source count must be performed using the same calibrated source that was used to determine the reliability factor.

5.2.1.3 High Voltage Plateau

The instrument high voltage plateau will indicate whether or not the high voltage applied to the instrument detector is set at the appropriate point for maximum sensitivity with minimal influence from background radiation levels. The high voltage plateau is performed initially after receiving the appropriate type of instrument from the calibration vendor. The purpose of this high voltage plateau is to confirm the high voltage selected by the calibration vendor is appropriate. A secondary purpose is to ensure that the setting was not affected by shipment of the instrument. A high voltage plateau should also be performed on an instrument when a new detector is installed or when there is a noticeable degradation in instrument performance as indicated by the daily functional tests. Performance problems would include a decrease in the instrument efficiency over time or erratic results indicated by a daily source check count that falls outside the acceptable range.

5.2.1.4 Lower Limit of Detection (LLD)

The instrument lower limit of detection (LLD) is the smallest concentration of radioactive material that has a 95 percent probability of being detected. The LLD will determine whether the instrument and counting procedures are capable of detecting the presence of radioactive material below the allowable regulatory limits (i.e., allowable air concentrations or removable activity concentrations). The LLD is a determination of sensitivity for a measurement system and is not intended to be calculated for individual samples.

If the LLD is at or above the allowable limit, adjustments will be made to reduce it to an acceptable level. Typically, the counting system LLD should be 10 percent of the allowable limit. In no case should the LLD be above 50% of the allowable limit. Increasing the sample count time, increasing the sample volume, or reducing background levels will lower the LLD.

The LLD is determined initially after receiving the instrument from the calibration vendor. LLD should also be determined for an instrument that has not been in service for an extended period or for an instrument that has required repairs or a high voltage plateau.

5.2.1.5 Minimum Detectable Concentration (MDC)

The LLD is the determination of sensitivity for a measurement system and is not intended to be calculated for individual samples. Minimum detectable concentration (MDC) is a measurement of the detection sensitivity for a single sample based on sampling and counting parameters and should be calculated to ensure adequate sensitivity is achieved for each sample.

5.2.2 Instrument Checks

Regulatory Guide 8.30 specifies requirements for routine maintenance and calibration of radiological surveys instruments. Regulatory Guide 8.30 also references the standards contained in ANSI N323-1978, *Radiation Protection Instrumentation Test and Calibration.* ANSI is in the process of a major revision of this Standard that will result in three separate Standards that apply to radiological instrumentation. The first revision, ANSI-N323A-1997, *Radiation Protection Instrumentation Test and Calibration, Portable Survey Instruments*, was incorporated in this Chapter. Where conflicts arise between Regulatory Guide 8.30 and the ANSI Standard, the Regulatory Guide recommendations have been followed.

5.2.2.1 Calibration Verification

Any survey or counting equipment in use shall have a current calibration sticker in place. Calibration stickers shall be checked before use or daily when in use. Calibration date and due date will be recorded on the appropriate form.

Air samplers shall have a current calibration sticker in place. Calibration stickers shall be checked each day before use of these regulated air samplers. Breathing zone samplers do not require calibration stickers if they are calibrated before each use. Calibration results will be recorded on the appropriate form.

5.2.2.2 Physical Check

Before each use, all instruments and samplers shall be inspected for physical condition. The inspection should include determining whether there are any loose or damaged knobs, buttons, cables, or connectors. Meter movements or displays should be inspected for damage. Instrument cases should be inspected for dents or corrosion. Probes should be inspected for damage such as punctured or deformed probes or probe windows.

An instrument that has any physical damage should not be placed in service. Repairs shall be made and documented.

5.2.2.3 Battery/High Voltage Check

The battery check is performed to determine the condition of the instrument's batteries. This check is important to ensure that there is sufficient voltage being supplied to the detector and the instrument circuitry. The battery check will be performed in accordance with the instructions contained in the appropriate instrument technical manual. If the battery check is unsatisfactory, refer to the technical manual for instruction for replacement of batteries and repeat the check. If results are still not satisfactory, remove the instrument from service until repairs can be made. Repairs shall be made and documented.

High voltage checks shall be performed in accordance with the appropriate instrument technical manual. The purpose of the high voltage check is to ensure that the proper voltage is being applied to the detector. The high voltage setting is provided by the instrument calibration vendor on the calibration certificate or is determined by performing a high voltage plateau.

5.2.2.4 Response Source Check

The response source check is made to ensure that the instrument in use will respond to a known source of radiation. The response check does not result in determination of efficiency or the instrument correction factor. The response check is typically performed before each use and indicates that the instrument has not sustained damage that would prevent it from detecting radiation. An example of a response check would be checking an alpha contamination survey meter at a restricted area access point with a check source of Th-230.

5.2.2.5 Constancy Check

Survey instruments should be checked for constancy of operation with a radiation check source prior to each usage or at a minimum checked weekly. If the instrument response to the radiation check source differs from the reference reading by more than 20%, the instrument should be repaired if necessary and recalibrated. The constancy check should be supplemented by calibrations at 12 month intervals or at the manufacturer's suggested interval whichever is shorter.

5.2.2.6 Background Measurement

Background measurements for radiation survey instruments are performed daily or as required. Local background may need to be determined before a particular use, such as performing a gamma radiation survey for characterization of potential contamination.

Background measurements for scaler type instruments are used to evaluate the radiation level in the area where the instrument is located. High background radiation levels will affect the sensitivity of scaler type instruments and will adversely affect the lower limit of detection (LLD).

5.2.2.7 Determination of Efficiency and Correction Factor

Instrument efficiency (E) is determined to check instrument performance when measured with a source of known activity of a particular radioisotope. A correction factor (CF) is determined that allows conversion of instrument cpm to disintegrations per minute (dpm) and is the inverse of the known efficiency (i.e., 1/E).

The instrument dpm Factor may be determined for contamination survey instruments to correct the indicated cpm to dpm per 100 cm^2. This factor is typically determined for instruments that are used for performing total surface contamination surveys since the action levels and regulatory limits are expressed in units of dpm/100 cm^2.

5.2.3 Instrument Check Schedules

Routine checks of radiation survey and counting instruments are made to ensure that the instrument is responding accurately and is in proper condition for field use. The check schedule for each type of instrument based on the guidance contained in Regulatory Guide 8.30. Specific instructions for performing these checks on each instrument are contained in the appropriate instrument technical manual.

5.2.3.1 Radiation Survey Instruments

Radiation survey type instruments include the Ludlum Model 3 Gamma Survey Meter and the Ludlum Model 2224-1with a 43-93 probe or equivalent. These instruments require the following checks at the noted frequency:

- Physical check – Daily when in use;
- Battery Check (if applicable) – Daily when in use;
- Response source check – Daily when in use;
- Calibration verification – Daily when in use;
- Background measurement – Daily when in use, as required.

5.2.3.2 Surface Contamination Instruments

Surface contamination instruments are used to measure alpha and beta-gamma surface contamination levels and include the Ludlum Model 2241 Ratemeter/Scaler Survey Meter or equivalent. These instruments require the following checks at the noted frequency:

- Response source check – Before each use;
- Battery Check (if applicable) – Daily when in use;
- High Voltage Check (if applicable) – Daily when in use;
- Calibration verification check – Daily when in use;
- Background measurement – Daily when in use, as required;
- Determination of efficiency/correction factor – Daily when in use;
- Determination of instrument reliability factor – Initially after calibration.

5.2.3.3 Scaler Type Instruments

Scaler type instruments are used to analyze the alpha contamination on air filters and loose surface contamination ("smear") samples. These instruments consist of a detector and a scaler and include the Ludlum Model 2000 Scaler, Ludlum Model 3030P Scaler or equivalent. These instruments require the following checks at the noted frequency:

- Physical check – Daily when in use;
- Battery Check (if applicable) – Daily when in use;
- High Voltage Check (if applicable) – Daily when in use;
- Calibration verification check – Daily when in use;
- Background measurement – Daily when in use;
- Verification of efficiency/correction factor – Daily when in use;
- Determination of instrument reliability factor – Initially after calibration, after repair or if instrument response is questionable;
- Determination of lower limit of detection – Initially after calibration, after repair or if instrument response is questionable;

- High voltage plateau – Initially after calibration, after repair or if instrument response is questionable.

5.2.3.4 Alpha/Beta Survey Meters

Alpha/Beta survey meters are used to measure alpha/beta surface contamination levels on skin and equipment and include a ratemeter such as the Ludlum model 2224-1 with a 43-93 probe or Ludlum model 3030E with a 43-93 probe or equivalent. These instruments require the following checks at the noted frequency:

- Response source check – Before each use;
- Battery Check (if applicable) – Weekly;
- High Voltage Check (if applicable) – Weekly;
- Calibration verification check – Weekly;
- Background measurement – Weekly;
- Verification of efficiency/correction factor – Weekly;
- Determination of instrument reliability factor – Initially after calibration.

5.2.4 Beta Calibration

Periodic beta detector calibration checks should be performed using aged yellowcake (i.e., at least 4 months old). The calibration should be performed at the surface and at 2 cm (approximately one inch) from the surface of the yellowcake source.

5.3 POTENTIAL DETECTION PROBLEMS

In the course of performing instrument checks and reviewing records, the RSO or HPT will be aware of the following observations that may indicate a detection problem:

- Background drift in a continuous direction, either up or down;
- Alpha background rates greater than 1.0 cpm;

- A calculated LLD that is greater than 50 percent of the appropriate regulatory limit;
- A ratemeter instrument that does not zero;
- A battery check that does not respond;
- Reliability factors greater than 1.40 or less than 0.50;
- A daily response source check that does not fall within ± 20 percent of the calculated mean.

If any of the potential problems listed above are noted, the RSO or HPT will remove the instrument from service and investigate until the source of the problem can be determined and corrected.

5.4 RADIOLOGICAL INSTRUMENT CALIBRATION

CBR calibrates radiation survey and counting instruments after each repair. Routine calibration is performed annually or at the frequency recommended by the manufacturer, whichever is more frequent. A qualified instrument calibration vendor performs all calibration of radiation survey and counting instruments.

5.5 AIR SAMPLER CALIBRATION

Proper calibration of air sampling equipment is important to ensure that the total volume of air sampled is accurate. Air sampling is performed at the Crow Butte project and expansion areas to determine environmental and occupational levels of radioactivity in air.

Calibration of field flow rate measurement instruments (typically rotameters) is performed by comparing the flow rate measured by the field instrument with the flow rate measured by a primary standard instrument or a properly calibrated secondary standard instrument. Primary measurements generally involve a direct measurement of the volume based on the physical dimensions of an enclosed space, such as a "frictionless" piston meter (i.e., soap film flowmeter or dry cell calibrator). Secondary standards are reference instruments or meters that trace their calibration to a primary standard, such as a mass flow meter.

Calibration should be performed semiannually as recommended in Regulatory Guide 8.30 or at the manufacturer's recommended frequency, whichever is shorter. Calibration should be performed with air filters in place to properly account for the reduction in flow due to solid material deposited on the filter.

5.5.1 Calibration Using the Soap Film Technique

The soap film technique involves using a graduated buret and a soap solution to measure the volume of air drawn through the buret during a measured time. The pump is started and connected to the buret, which is then dipped into a soap solution to form a bubble. The bubble will move along the buret. The time that it takes the bubble to move between volume graduations is measured, resulting in an indicated flow rate that is corrected to liters per minute (LPM). This measurement is then compared to the volume indicated by the air meter on the sampler. The comparison results in a correction between the indicated and the actual flow rate.

5.5.2 Calibration Using a Dry Cell Calibrator

A dry cell calibrator is a primary air flow calibrator that is a variation on the wet cell technique. The calibrator consists of a flow cell using a near-frictionless piston to measure the volume of air pumped. The flow cell is made of dimensionally stable borosilicate glass with a sensing encoder. The cell dimensions and crystal timing device are NIST traceable which allows use of the unit as a primary standard. Depending on the design flow rates, these units may be used for low and high flow samplers.

5.5.3 Calibration Using a Linear Mass Flow Meter

Linear mass flow meters may be used to calibrate sampling pumps. The linear mass flow meter measures the differential temperature of a gas drawn through a heated capillary tube and is considered a secondary standard.

5.5.4 Adjustment for Pressure and Temperature

Many variables affect the accuracy of air sampling measurements. Two of these are temperature and pressure variations. USNRC Regulatory Guide 8.25 states that corrections to the measured flow rate should be made if there are differences exceeding five percent in either the absolute pressure or absolute temperature between the calibration situation and the sampling situation.

Differences in the absolute pressure are common when calibration is performed at a different altitude (and thus a different air pressure) than that at which the instrument will be used. An example of this would be the calibration of a secondary standard at sea level and then use to calibrate rotameters at a higher elevation. Differences in pressure may be evaluated by comparing the barometric pressure readings at the calibration location with those at the sampling location.

Similarly, differences in temperature between the calibration location and the sample location will adversely affect accuracy of flow meters. Since calibrations are generally made at room temperature

(i.e., approximately 72°F), corrections should be made to account for sampling conditions if the ambient temperature is expected to exceed the five percent limit. Based on absolute temperature, five percent of a calibration temperature of 72°F would correspond to an ambient temperature less than 45°F and greater than 98°F.

5.6 SAMPLE ANALYSIS PROCEDURES

5.6.1 Analyzing Area Airborne Uranium Samples

Uranium airborne particulate samples are determined by counting alpha emissions using a scaler ratemeter or equivalent. The scaler is used with an alpha detector such as a Ludlum 43-10, Ludlum 218, Eberline SAC-R5, or equivalent. Some detectors, such as the Eberline SAC-R5, require the use of scintillation paper to detect alpha activity. The analyst should review the specific manufacturer's instruction manual to ensure familiarity with the detector operating requirements.

NOTE: Samples must age for 24 to 48 hours after sampling to allow decay of short-lived radionuclides.

5.6.2 Analyzing Breathing Zone Samples

Because breathing zone samples are typically collected over relatively short durations (i.e., less than a full work shift) it is necessary to utilize longer count times for both background and the sample in order to achieve the desired LLD. It should be noted that Regulatory Guide 8.25 recognizes that breathing zone samples may not be able to detect 10% of the appropriate DAC but that such samples are still acceptable for measuring potential uranium exposure to workers.

5.6.3 Radon Daughter Counting Procedure (Modified Kusnetz)

Radon daughter samples are analyzed using the modified Kusnetz method. Samples are collected on fiberglass or membrane filters using a lapel sampler or equivalent pump pulling a minimum of 2 liters per minute. Samples are collected for exactly five minutes, resulting in a 10 liter sample.

The sample filter is allowed to decay between 40 and 90 minutes after the end of collection before counting. After 40 minutes, only alpha particles from the decay of Po-214 are counted because virtually all of the Po-218 (3.05 minute half-life) has decayed.

The sample is counted with a scaler rate meter and an alpha scintillation detector at a count time determined by the RSO as adequate to meet the LLD requirements of 0.03 WL. The resulting gross counts are divided by the count time to arrive at a count rate (cpm).

Working levels are derived by dividing the count rate, minus background, by the product of the counter efficiency, the volume of air sampled, and the time factor.

The time factor (TF) is dependent on the time elapsed between end of sampling and the beginning of counting. The time factor is based on the assumption that equilibrium existed between Po-218, Pb-214, and Bi-214 at the time of sampling. The time factor relates dpm per liter of air from 40 to 90 minutes after sampling to the decay activity that would be present from an initial concentration of 1 WL.

5.6.4 Analyzing Smear Samples

Smear samples are taken to quantify the amount of removable contamination present on a surface or object. Following sample collection, smears are analyzed using a scaler rate meter and an alpha scintillation detector.

5.6.5 Filter Self Absorption Calculation

Regulatory Guide 8.25 requires that counting results be corrected for self-absorption of radiation by the filter collection media would reduce the count rate by more than 5 percent. The following comparison should be made as necessary as determined by the RSO. The self-absorption is determined using the following formula:

$$\% \text{ Self Absorption} = \frac{C_2 - C_3}{2C_1 + C_2 - C_3} \times 100$$

where:

C_1	=	cpm on front of filter
C_2	=	cpm on back of filter
C_3	=	cpm on front of filter covered by new filter of the same type

The three counts should be performed as quickly as possible at a count time of one minute. The calculated uranium activity must be adjusted if the filter self-absorption is determined to be greater than 5 percent. For example, if the calculated activity is 5.0 E-11 µCi/ml and the filter self-absorption is 15 percent, the actual activity is (5.0 E-11)(1.15) = 5.75E-11 µCi/ml.

5.6.6 Regulated Air Samplers (RAS)

Regulated air samplers are used at the Crow Butte project for measurement of airborne concentrations of particulate radioactivity. CBR calibrates regulated air samplers on a semiannual

basis. Calibration is performed using a properly calibrated mass flow meter. As a result of this calibration, the correction factor for the air sampler is determined and is used to ensure accurate total flow determinations are available.

5.6.7 Breathing Zone Samplers

Breathing zone samplers are used at the Crow Butte project for area sampling to determine the concentration of radon daughters in air using the Modified Kusnetz Method. Breathing zone samplers are also used for measuring the concentration of airborne particulate radioactivity in the breathing zone of workers. These samplers are calibrated before each use using a bubbler tube and stopwatch to ensure accurate determination of total volume of air sampled.

5.7 RADIONUCLIDE REFERENCE STANDARDS

Crow Butte uses calibrated radionuclide reference standards (sources) to determine the counting efficiency of instrumentation for a given radionuclide. Non-calibrated check sources are also used to check the response of certain instruments.

5.7.1 Calibrated Standards

Calibrated radionuclide standards that have been certified as traceable to National Bureau of Standards (NBS, now known as the National Institute of Standards and Technology, or NIST) measurements are used for determination of instrument efficiency and correction factor. The instrument efficiency is used to convert the instrument indicated count rate to a concentration of radioactivity. These calibrated standards are used to determine counting efficiencies for all radioactivity measurements that require comparison to a specified concentration of radioactivity per unit volume or area, such as air samples and surface contamination level determinations.

5.7.2 Non-calibrated Standards

Certain radionuclide check sources that are not traceable to NBS measurements are used at the Crow Butte project to indicate that an instrument is responding properly. These non-calibrated check sources include sources that are maintained at restricted area boundaries near survey instruments. The sources are used before each use of the instrument to perform a response check. This response check is performed in addition to the daily determination of efficiency and correction factor.

6 ENVIRONMENTAL AND EFFLUENT SAMPLING

CBR performs environmental and effluent monitoring at the Crow Butte project as required by NRC regulations and CBR's source materials license. Measurements are performed for the following purposes:

- To allow CBR to estimate the maximum annual radiation dose to the public;
- To ensure that the regulatory requirements and license conditions for dose and release limitations and meeting "as low as reasonably achievable" objectives are met;
- To evaluate the performance of effluent controls;
- To evaluate the environmental impact of mining operations; and
- To establish baseline data to aid in decommissioning or remediation efforts.

CBR's environmental and effluent sampling program was prepared in accordance with the guidance contained in Regulatory Guide 4.14, *"Radiological Effluent and Environmental Monitoring at Uranium Mills"*, (Revision 1, 1980). Regulatory Guide 4.14 and 4.15 contain guidance for quality assurance and quality control measures to ensure the accuracy of effluent and environmental sampling and analysis activities. It has been CBR's practice, and will continue to be CBR's practice, to submit all samples collected to meet the requirements described in Regulatory Guide 4.14 to an independent third party accredited laboratory for analysis.

6.1 SAMPLE COLLECTION

The quality assurance program for environmental sampling is implemented in the following areas:

- Procedures are used which define the details of sample location, sample frequency, number of samples, duration of sampling, sample volume, sample collection methods, and equipment to be used for sample collection.
- Procedures have been prepared for calibration and maintenance of equipment used for measurement. These procedures provide details for the standardization, use and maintenance of the instruments.
- Taking duplicate samples and submitting these to a third party accredited analytical laboratory makes random control checks. These checks allow evaluation of the performance of the analytical laboratory and to some extent, the validity of sampling procedures. In the event that

the results of the duplicate samples do not agree within predetermined limits, an audit will be performed to determine whether the problem is in the sampling or analysis.

CBR collects samples of environmental media within the NRC license area. Samples are also obtained from the surrounding area. Specific CBR SOPs are used to provide instructions for obtaining each type of environmental sample.

6.1.1 Air Sampling

The airborne effluent and environmental monitoring program is designed to monitor the release of airborne radioactive effluents from the Crow Butte project. To evaluate the effectiveness of the effluent control systems, the results of the monitoring program are compared with the background levels and with regulatory limits.

The accuracy of monitoring data is critical to ensure that the air monitoring program precisely reflects air quality in each phase of the program. Regulatory Guide 4.14 specifies the following lower limits of detection (LLD):

Radionuclides	LLD (µCi/ml)
Natural Uranium	1×10^{-16}
Thorium-230	1×10^{-16}
Radium-226	1×10^{-16}
Radon-222	2×10^{-10}
Lead-210	2×10^{-15}

6.1.1.1 Radon Gas Sampling

The radon gas effluent released to the environment is monitored using Track-Etch radon cups provided by Landauer Corporation. The cups are exchanged on a semiannual basis. In addition to the manufacturer's quality assurance program, CBR exposes two duplicate radon Track Etch cups during each monitoring period.

Radon-222 is monitored continuously at the environmental monitoring locations. Monitoring is performed using Landauer RadTrak detectors. These detectors are an alpha-track radon gas detector using Landauer's Track-Etch® process and are designed to monitor radon exposure for three months to one year. Landauer service includes the RadTrak detector and a comprehensive analysis.

The RadTrak radon detectors are supplied in aluminum bags to prevent radon exposure before deployment. The detectors should not be stored or deployed in any area in which the temperature may exceed 160°F. There is no low temperature limit.

Note: Landauer does not provide the LLD on the analytical result report. The LLD for Track-Etch® detectors is a function of the exposure time and the area of the cup that is analyzed by Landauer. The LLD should be determined in consultation with Landauer before monitoring is performed. If the LLD is above the NRC requirements from Regulatory Guide 4.14, it may be reduced by either employing a longer sampling time or requesting that Landauer analyze a larger portion of the Track-Etch® cup.

6.1.1.2 Air Particulate Sampling

Airborne particulate sampling is performed at the locations specified in the NRC License. The CBO License requires monitoring for at least 2 weeks of every month that the yellowcake dryer is in operation. However, CBO has instituted continuous monitoring at these sites as a best management practice.

Filters are collected for two weeks and then composited for analysis on a quarterly basis. At the end of the calendar quarter, the composite filter samples are submitted to the contract laboratory for radiometric analysis using standard Chain of Custody Procedures. The filters are composited according to location. The composite samples are analyzed for the concentrations of natural uranium, radium-226, and lead-210. The actual volume of air filtered at each station for the quarter is also forwarded to the contract laboratory with the filters. The flow rate on the RAS-1 pumps is calibrated at six-month intervals in order to ensure the accuracy of the volume of air sampled. The uncertainties in the volume of air sampled should be less than 20% as described in Regulatory Guide 8.25.

6.1.2 Water Sampling

During operations at the Crow Butte project, a detailed water-sampling program is conducted to identify any potential impacts to water resources of the area. CBR's operational water monitoring program includes the evaluation of groundwater on a regional basis, groundwater within the permit or licensed area and surface water on a regional and site specific basis. To evaluate the effectiveness of the effluent control systems, the results of the groundwater and surface water monitoring programs are compared with the background levels and with regulatory limits.

6.1.2.1 Groundwater Monitoring

The groundwater-monitoring program is designed to detect impacts to the local and regional groundwater from mining operations. Potential sources of impacts to the groundwater could be excursion of mining solutions beyond the perimeter of the wellfields or a failure of evaporation pond lining systems. Monitor wells are installed around the wellfield boundaries and the

evaporation ponds to monitor for impacts to the local groundwater. Sampling all private wells within one kilometer of the wellfield area boundary monitors impacts to regional groundwater.

Groundwater samples obtained for preoperational, operational, and restoration purposes are critical to meeting environmental protection goals at solution uranium mines. The results of these samples are used to determine pre-mining conditions, to monitor operational environmental protection efforts, and to determine whether restoration activities are successful. In order to ensure the accuracy of these monitoring efforts, strict compliance with groundwater sampling procedures is necessary.

6.1.2.1.1 Water Level Determination

The accurate determination of the static water level in wells provides important information concerning aquifer conditions. Well static water levels are monitored using an electrical measuring line (an "e-line"). The sampler takes e-line readings of all monitor wells before sampling. Significant changes in the water level in overlying aquifers may indicate a vertical excursion of mining solutions. Similarly, changes in the production zone water levels may provide an early indication of the migration of mining solutions from the active wellfield. Water level measurements are also used to determine groundwater gradients in the mining zone to assist operating personnel in managing wellfield balancing.

6.1.2.1.1 Field pH Measurements

Field measurement of pH is used in conjunction with conductivity as an indication that well purging has successfully removed stagnant water from the well casing and formation water is being sampled.

Degasification (such as loss of carbon dioxide), precipitation (such as calcium carbonate), and other chemical and physical reactions may cause the pH of a water sample to change significantly within several hours after the sample is collected. Therefore, immediate analysis of a sample in the field is required.

pH measurements will be performed in accordance with manufacturer's recommendations. The probe should be swirled in the sample to remove any air bubbles adhering to the surface of the probe. A reading is not valid until the reading on the panel is stable for at least ten (10) seconds or bounces around a point for at least ten (10) seconds.

Standardization will be checked daily during regular use. For the range of water quality encountered in well sampling activities, standardization will be performed using a pH 7.00 buffer and a pH 10.00 buffer.

6.1.2.1.1 Field Conductivity Measurements

Field measurement of conductivity is used to indicate when well purging has successfully removed stagnant water from the well casing and formation water is being sampled. Specific conductance meters used in the field are battery operated, and read directly in micromhos (μmhos) or microsiemens (μS) per cm.

The conductivity cell is checked daily during regular use. A standard solution of known electrical conductance that falls in the range of samples to be measured is used to check the cell. For the range of water quality typically encountered, a standard solution of from 500 to 1500 micromhos/cm at 25°C will be used. Instrument calibration will be performed in accordance with the manufacturer's recommendations.

Measurements are performed in accordance with manufacturer's recommendations. The probe is swirled in the sample to remove any air bubbles adhering to the surface of the probe. Conductivity readings stabilize much more quickly than pH readings. The Sampler will ensure that the reading is stable before recording the results.

6.1.2.1.2 Well Purging

Water that remains in the well casing between samples may not be representative of the formation water quality. The quality of water left in the casing between samples may be changed by sorption or desorption from casing materials, oxidation, or biological activity. Purging is required to remove this stagnant water and allow formation water into the well screen.

Purging should be accomplished at a flowrate that is lower than the well development rate. The purge rate should approximate the natural groundwater flow rate (i.e., little change in the well water level during purging) while satisfying time constraints. Purging at too high of a flow rate can result in redevelopment of the well and increased turbidity. In no case should a well be purged at a flowrate high enough to cause the well to pump dry. Purging is deemed complete only when it is determined through field monitoring of pH and conductivity that the water quality is stable.

6.1.2.1.3 Well Sampling

The sample should be taken as soon as the well is adequately purged. If the well was pumped dry during purging, the sample should be obtained as soon as adequate formation water is present in the casing. Do not touch the sampled water with your hands as this could result in contamination of the sample.

Make sure that the water being sampled is very low in visible solids and any contamination that may show up in the analysis. Fill the sampling container(s) completely, so all air is excluded from the container.

Record the time of sample collection and include any remarks as to unusual conditions of the water quality (e.g., odor, color) on the data sheet.

Keep the sample cool and transport it to the laboratory as soon as possible for analysis or filtering, preservation and/or shipment.

6.1.2.2 Surface Water Monitoring

The surface water-monitoring program is designed to detect impacts to the regional surface water from mining operations. Potential sources of impacts to the surface water could be releases of mining solutions, drainage from potentially contaminated areas, or failure of evaporation pond embankments. Surface waters within one kilometer of the wellfield area boundary are sampled.

Samples are collected in the appropriate container(s) and field measurements for pH and conductivity are performed and documented. The sample bottle must be rinsed with the sample water. The bottle is then filled with the mouth of the sample bottle pointed downstream to prevent collecting debris. If samples involve analysis that requires filtration, collect water in a clean bucket for transfer to the filter apparatus. Treatment of sample containers, preservation techniques, holding times, and shipping techniques are identical to those used for groundwater.

6.1.3 Soil and Sediment Sampling

Samples of soil and sediment are collected at the Crow Butte project to monitor radioactivity concentrations in these media. To evaluate the effectiveness of the effluent control systems, the results of the soil and sediment monitoring program are compared with the background levels and with regulatory limits.

6.1.3.1 Soil Sampling

Preoperational surface soil has been sampled. Surface soil samples will be taken at the air monitoring locations following conclusion of operations and will be compared to the results of the preoperational monitoring program.

Preoperational subsurface soil has been sampled at the plant. Subsurface soil samples will be taken following conclusion of operations and will be compared to the results of the preoperational monitoring program.

Soil samples are obtained with a clean auger, spade, or shovel. At the sampling location, remove the vegetation and collect a grab soil sample of the top 15 cm (6 inches) of soil. Samples may also be collected at successive 15 cm intervals for comparison with the decommissioning criteria contained in 10 CFR Part 40 Appendix A, Criterion 6-(6). Samples are placed in appropriate plastic bags. The amount of sample should be sufficient to provide the laboratory with at least 50 grams of soil. This quantity of sample is necessary to meet the LLD requirements. Any non-soil material such as rocks, sticks, vegetation, and large amounts of roots should be removed from the sample. Remove the air in the bag and seal it.

The plastic bags must be clearly labeled at the time of sampling with a permanent marker, identifying the project location, sample site, the depth interval of the sample (e.g. 0-6"), and the sample date. It is important that the type of soil extraction method to be used for the various chemical analyses be clearly identified on the chain of custody to the independent third party accredited laboratory.

6.1.3.2 Sediment Sampling

Sediment in local surface water features was sampled on a semiannual basis for one year prior to any construction in the area. Operational samples are taken upstream and downstream of the Crow Butte project site to monitor for impacts to the sediments from mining operations.

At the sampling location, collect a grab sample of the stream or impoundment sediment. Remove any vegetation, rocks, or other debris that may be present; place the sample in a plastic bag and seal. After allowing the bag to set, pour off any liquid that has decanted, remove the air, and re-seal the bag. The laboratory requires at least 50 grams of sample to meet the LLD requirements.

The sample bag should be pre-labeled with the sample identification, sample location, sample analysis required, date, and company initials. Prepare a Chain of Custody form and submit the sample to the independent third party accredited laboratory.

6.1.4 Vegetation Sampling

Vegetation samples from Crow Butte project were collected on an annual basis in animal grazing areas in the direction of the prevailing wind through 1997. Sampling was normally performed during the summer months. In 1998, routine vegetation sampling was discontinued with NRC approval due to the determination that exposure from grazing animals was not a potentially significant pathway.

Vegetation sampling may be required at some time in the future. Circumstances that would indicate the necessity for vegetation sampling include land application for waste disposal or characterization of impacted areas.

When obtaining vegetation samples, select mainly grasses or leafy plants that would normally be used as forage by domestic and wild animals as opposed to woody plants such as sagebrush. Samples should be comprised mainly of stems, leaves, and fruit and should be representative of the current year's growth. Cut the plants with a trimmer within a few inches of the ground and place in the sample bag until the bag contains a minimum of 8-10 kilograms (wet weight) of vegetation. Do not include any root material. The sample should be representative of dominant vegetation present at the sample location.

The plastic bags must be weighed and clearly labeled at the time of sampling with a permanent marker, identifying the project location, sample site, and the sample date. It is important that the sample wet weight and type of analytical method to be used for the various analyses be clearly identified on the chain of custody to the contract laboratory. Vegetation samples should be submitted to the independent third party accredited laboratory as quickly as possible.

6.1.5 Direct Radiation Measurement

Environmental gamma radiation levels are monitored continuously at the air quality monitoring stations. Dosimeters that fully meet ANSI N545 performance, testing, and procedural specifications will be used.

The dosimeters are supplied by the vendor before the end of each quarter. Each shipment of dosimeters contains a control dosimeter that measures exposure rates during processing and shipping of the dosimeters and a deployment dosimeter that measures exposure rates while deploying the dosimeters. Before deployment of the dosimeters, the control dosimeter must be placed in a storage area with a low ambient background gamma dose rate. The deployment dosimeter is also placed in the storage area after the dosimeters are deployed.

The dosimeters are deployed at the beginning of each quarter. The dosimeters are clipped onto each survey location with the fastener provided with the dosimeter. Each dosimeter has a tag with an identification number. When exchanging the dosimeters, the dosimeter is replaced with the corresponding dosimeter identification number.

After the dosimeters are collected, care is taken to ensure that they are not exposed to any additional gamma radiation or x-rays. Once the dosimeters are collected, they are returned to the vendor in the original box with the provided shipping label. This label cautions against exposure to radioactive materials or x-rays while in transit.

6.1.6 Uncertainty Limits for Volume and Mass Measurements

Sample volumes are derived for each type of sample based on measurement requirements. For liquid or solid samples consideration is given for the density/composition of the matrix, counting efficiency of the instrumentation, laboratory specific MDLs, applicable analytical chemical recovery, preservation techniques, and homogeneity of the samples. Air particulate volumes are impacted by filter collection efficiency, filter dust loading, and flow rates of sampling equipment. Methods for reporting sample analysis and result are found in specified environmental sampling and analysis procedures and in agreement with regulatory requirements.

7 OCCUPATIONAL SAMPLE COLLECTION

CBR performs occupational monitoring at the Crow Butte project as required by NRC regulations and CBR's source materials license. Measurements are performed for the following purposes.

- To allow CBR to determine the annual internal and external radiation dose to employees;
- To ensure that the regulatory requirements and license conditions for dose limitations and meeting "as low as reasonably achievable" objectives are met; and
- To evaluate the performance of exposure controls;

CBR's occupational monitoring program was prepared in accordance with the guidance contained in Regulatory Guide 8.30. Regulatory Guide 4.15 was also consulted for guidance for quality assurance and quality control measures to ensure the accuracy of occupational monitoring activities.

7.1 AIRBORNE URANIUM SURVEYS

7.1.1 Area Samples

Area air samples should be collected during the performance of work duties. Area samples may be used to monitor concentrations in work areas or to determine the effectiveness of the confinement of radioactive materials. For work area monitoring, the location of air samples should be as close to the breathing zone as practical without interfering in the performance of duties. To determine confinement, samplers should be placed in the airflow path near the source of contamination.

At a minimum, airborne uranium samples will be collected as approved by NRC in the source materials license. The frequency of the airborne uranium sampling is weekly in Airborne Radioactivity Areas and monthly in areas not designated as Airborne Radioactivity Areas as recommended in Regulatory Guide 8.30, although this frequency may be modified by specific NRC license conditions. More frequent sampling may be advisable when starting new equipment or facilities. . During yellowcake packaging operations, sampling in the dryer room is continuous. Spot samples may also be collected to verify the adequacy of the sampling procedures or as determined necessary by the RSO

Measurement of airborne uranium is performed by gross alpha counting of the area air filters using an alpha scaler such as a Ludlum L-2000 or equivalent. The analytical results are compared to the derived air concentration (DAC) for soluble (D classification) natural uranium of 5 E-10 μCi/ml from Appendix B to 10 CFR §§20.1001 - 20.2401. Crow Butte has collected isotopic samples from seven locations throughout the Central Processing Plant. As per Regulatory Guide 4.14, airborne particulate samples from the in-plant sampling stations were analyzed for U^{-Nat}, Th^{230}, Ra^{226}, and

Pb^{210}. Sampling indicated that the concentrations of the isotopes analyzed were present in concentrations significantly below 10% of their respective DAC's. In addition, the sum of the DAC percentage from Th^{230}, Ra^{226}, and Pb^{210} combined is significantly less than 1%, meeting the criteria of less than 30%. Therefore, these three radionuclides can be disregarded from the determination of the internal dose under 10 CFR 20.1204(g). Solubility studies performed at the Crow Butte operation demonstrated that the Uranium is of Class D solubility. Uranium compounds that have no assigned inhalation classification, or for which no site-specific data is available, such as uranium carbonates, shall be assigned to inhalation Class W for radiation protection purposes.

Samples should be obtained using the following steps:

- Obtain an Eberline RAS-1 or Hi-Q or Staplex Hi-Vol Sampler or similar equipment and the appropriate glass fiber filters. Ensure that the air sampler has a current calibration as discussed in Section 5.

- Record data concerning sample location, start and end time, total time in minutes, flow rate, as found operating status of the air sampler, air sampler identification, location and calibration data on the sampling form.

- Place a filter in the filter holder taking care not to damage or contaminate the filter.

- Place the air sampler at a location where workers could be exposed to airborne particulates at 4 to 6 feet above the floor and at least 1 foot away from walls, cabinets, etc.

- Ensure that the sampling environment is representative of the conditions encountered by workers while performing assigned duties.

- Start the pump and record the start time and the initial flow rate on the sampling form. Ensure that an adequate volume of air is obtained to meet the lower limit of detection (LLD) for uranium (i.e., 10% of the applicable DAC).

- At the conclusion of sampling, record the flow rate, shut off the sampler and record the sampling stop time on the sampling form. Unless the sample period is extremely long, with resulting dust loading on the filter, there should be no change between the initial and final flow rate.

- Carefully remove the filter from the filter holder and place in the sample holding envelope, taking care not to touch or disrupt the particulate material collected on the filter.

7.1.2 Breathing Zone Air Samples

In the plant, breathing zone air samples may be collected periodically. The samples are representative of the air inhaled by the worker. Breathing zone samples for specific jobs are used to monitor the intakes of individual workers performing tasks that have the potential for high airborne exposures. Breathing zone samples may also be collected for an entire work shift, resulting in a composite sample for an employee performing his normal duties. The breathing zone sample, in the latter case, may be used as a means of judging the adequacy of the area air monitoring program. The RSO typically determines under which circumstances a breathing zone sample should be obtained.

Samples should be obtained using the following steps:

- Obtain a lapel sampler (Sensidyne BDX or equivalent). Ensure that it is fully charged and properly calibrated.
- Obtain a glass fiber filter(s), or equivalent, of the proper size and an appropriate filter holder. Place filter in holder and attach to sampler hose.
- Secure the pump to belt and the filter holder to the shirt collar or lapel. Make sure the pump is in the upright position at all times. Consolidate the tubing to minimize restriction of motion.
- Turn the pump on (recording the time and flow rate) and continue monitoring until the task is completed. Record the time and flow rate at which the job is completed.
- Lapel samplers are to be analyzed within two working days of sampling, where possible. Ensure that the SHEQ Department obtains the filter and information in a timely manner so analysis can be completed.

7.1.3 Natural Uranium Radiometric Analysis

Natural uranium air sample filter(s) must be aged a minimum of three (3) hours in order to eliminate the short-lived radon daughters. These include 214Pb (26.8 min), 214Bi (19.7 min), and 214Po (164 μsec) in the shorter-lived decay chain. A sample counted immediately after collection will not only contain possible uranium ore dust and a possible static charge, but it may also contain radon daughters. Counting the sample too soon after sample collection will result in an overestimation of airborne uranium.

Samples may also be sent as individual samples or as part of a composite sample, to an approved outside independent third party accredited laboratory for analysis for specific isotopes.

7.2 RADON DAUGHTER MEASUREMENT

Radon daughter samples are taken in various areas of the plant and offices. The sample locations are near areas where workers are most often present to ensure that the samples are representative of worker exposure. Sampling is performed at a monthly frequency, unless concentrations greater than 0.08 WL are discovered. When concentrations greater than 0.08 WL are discovered, the sampling frequency is increased to weekly. Weekly sampling continues until concentrations of less than 0.08 WL occur for four consecutive weekly samples.

Analysis of radon daughter samples is performed on-site using the Modified Kusnetz Method. Measurement of radon daughters on sample filters is performed by gross alpha counting using an alpha scaler such as a Ludlum L-2000 or equivalent.

In addition to the Modified Kusnetz Method, CBR uses the PRISM II continuous radon monitoring system, which allows "real time" analysis of atmospheres for radon daughter concentrations. The PRISM II is used as a diagnostic tool to allow evaluation of work practices and engineering controls and may not be used for routine monitoring or exposure determination purposes.

7.3 EXTERNAL RADIATION EXPOSURE

7.3.1 Personnel Dosimeters

Occupational exposure to external gamma and beta radiation is measured using personnel dosimeters such as Thermoluminescent Dosimeters (TLD) or Optically Stimulated Luminescence (OSL) dosimeters. With two exceptions, dosimeters must meet NRC requirements, which state that a contract vendor must be certified by the National Voluntary Laboratory Accreditation Program (NVLAP) of the National Institute of Standards and Technology (NIST). The exceptions to this requirement are direct and indirect reading pocket ionization chambers and dosimeters used to measure the dose to extremities. The dosimeters consist of a clip-on badge worn by workers. The badge contains a chip that is constructed of a material that senses total exposure to external radiation. When the chip is properly developed, the radiation dose received by an individual during the period of time that the badge was worn may be determined.

The RSO is responsible for determining the dosimetry requirements based on the facility radiation levels, worker job locations and tasks, and specific licensing requirements. For each category of workers, the RSO must determine whether it is likely that a worker's dose may exceed the criteria from § 20.1502(a). If it is determined that dosimetry is required, the RSO will determine the exchange frequency for the dosimetry (i.e., monthly or quarterly). Contractors, depending upon the task to be performed, may also be issued dosimeters at the discretion of the RSO.

The RSO is responsible for reviewing the dosimetry results and comparing them with past data and regulatory exposure limits. Upon receipt of the dosimetry results from the NVLAP laboratory, the individual exposure records are to be maintained on hard copy and/or a computer system.

The control personnel dosimeters used by the NVLAP processor to subtract background exposure from the personnel badges, are to be stored in areas away from areas where elevated gamma dose rates may be present. It is important that control badges are returned to the NVLAP processor with the personnel dosimeters. In the event that a control badge is damaged, any unused personnel dosimeter may be designated as a control badge as long as it has been stored away from areas where gamma activity is mostly likely to occur.

7.3.2 Gamma Surveys

Gamma surveys are conducted at various locations throughout the facility. Routine gamma surveys are performed as approved by NRC in the source materials license. In areas that meet the criteria for posting as "Radiation Areas", surveys should be performed at least quarterly as recommended in Regulatory Guide 8.30. NRC licensing requirements specific to the facility may require alternate survey frequencies. Gamma surveys are conducted on a semiannual basis at various locations through the plant. These results are used to insure plant areas are properly placarded in accordance with 10 CFR 20. Additional gamma surveys may be performed at the discretion of the RSO or HPT to further characterize gamma dose rates. These surveys can be random, in conjunction with RWPs, to assist in identifying Radiation Areas, or performed before or during routine work, during contaminated waste control, or during upset conditions. Regardless of the purpose of the survey, the same procedure will be utilized to perform gamma surveys.

7.3.2.1 Instruments

- Ludlum Model 3 Gamma Meter with Ludlum Model 44-38 G-M detector or equivalent, calibrated in MilliRoentgen per hour (mR/hr).

7.3.3 Beta Surveys

In addition to gamma surveys, beta surveys should be performed before specific tasks that involve direct handling of large quantities of aged yellowcake (i.e., older than four months) to ensure that extremity and skin exposures for workers performing these operations are not unduly high.

Extremity dosimetry is required by 10 CFR 20.1502 if a worker is likely to receive a dose to any extremity in excess of 1250 mR/qtr or to the eye in excess of 375 mR/qtr.

Beta surveys should be performed before any special maintenance or non-routine operational activity with aged yellowcake to determine protective clothing needs and what portion of the body may be most exposed. If appropriate protective clothing and equipment is used (e.g. heavy rubber gloves, eye protection, etc.) the beta dose rate may not be a significant factor to overall dose. However, the protective clothing and equipment used must be of sufficient density to ensure that significant beta radiation does not reach the skin or the lens of the eye.

7.3.3.1 Instrument

- Ludlum Model 2224-1 with a 43-93 probe or equivalent equipment.
- The detector must be equipped with a beta shield to perform this survey.
- Surface Contamination

The primary sources of potential surface contamination at in situ leach uranium mines are associated with precipitation, slurry transfer, drying and packaging activities, and filter press activities. The remaining recovery and elution portions of the process do not present a significant surface contamination problem except for dried spills or when special equipment maintenance is required. Any visible yellowcake or production fluid spills must be cleaned up as soon as possible to prevent the potential spread by contact or drying and possible suspension into the air that could pose an inhalation hazard. If contamination is detected in a designated clean area above specified limits, the RSO will be promptly notified and the area will be cleaned. An investigation into the source of the contamination will be performed.

Routine surveys in the process areas consist of both a visual inspection for obvious signs of contamination (i.e. visible yellowcake) and instrument surveys to determine total alpha contamination. If the total alpha survey indicates that contamination is greater than 200,000 dpm/100 cm^2, the area shall be cleaned and resurveyed. This level of contamination has been determined to be low enough to ensure little contribution to airborne radioactivity and is readily visible due to the low specific activity of uranium.

In designated clean areas, such as lunchrooms, offices, and respirator cabinets, the target level of contamination is nothing detectable above background. If the total alpha survey indicates contamination exceeds 250 dpm/100 cm^2 (25% of the removable limit) a smear survey must be performed to assess the level of removable alpha activity. If smear test results indicate removable contamination greater than 250 dpm/100 cm^2, the area must be cleaned promptly and resurveyed. The RSO will investigate the cause of the contamination and implement corrective action to minimize the potential for a recurrence.

Direct measurement of total contamination is performed using alpha scintillation detectors. Measurement of loose contamination is performed by gross alpha counting of the smears using an alpha scaler such as an Eberline MS-3 or equivalent.

7.4 BIOASSAY PROGRAM

CBR has implemented a bioassay program to monitor for internal exposure to natural uranium. The bioassay program has been prepared in accordance with the guidance contained in Regulatory

Guide 8.22, *"Bioassay at Uranium Mills"*, (Revision 2, 2014). All plant personnel are included in the bioassay program. The program is implemented by the RSO.

CBR routinely performs bioassay by urinalysis for natural uranium. A baseline urinalysis is performed on all employees prior to their initial assignment at the plant. Routine bioassay samples are collected at a frequency that is based upon the employee's work assignment. Diagnostic bioassays may be required by the RSO based upon specific work activities. Upon termination of employment, a final urinalysis will be performed on all employees.

Records of bioassay results are maintained to document the sample collection and analysis dates as well as the individual's record to allow the most recent results to be compared to the employee's previous history.

Analysis of bioassay samples is performed at an independent third party accredited analytical laboratory. CBR submits spike and blank samples with each batch of bioassay samples to monitor the laboratory for accuracy and sample contamination. Analytical results for spiked samples must be within 30 percent of the spiked value. Otherwise, the most recent batch of samples will be re-run. The RSO will conduct an investigation to determine whether the CBR spiking procedure or the analytical laboratory was the cause of the inaccurate results.

Duplicate samples are obtained for submission to a different laboratory to monitor precision. These samples are submitted by CBR on a periodic basis. These duplicate samples are in addition to the duplicate samples analyzed by the analytical laboratory.

8 SAMPLE MANAGEMENT AND QUALITY CONTROL

Performance indicators are used to determine if the laboratory's processes are in control. The accuracy of the instruments or containers are checked regularly to ensure that sampling performance criteria remain within the limits specified by the QAP. The results of mass, flow rate, or volume calibrations and associated uncertainties are tracked and recorded. Performance indicators are selected to provide a management tool for tracking and trending performance and to identify precursors to nonconforming conditions. Laboratories consider necessary levels of precision, acceptable bias, and applicable detection limits. Definitions are as follows:

- Precision is the closeness of agreement between independent test results and can be assessed using replicate samples. It may be expressed as the standard deviation.
- Bias of a measurement process is a persistent deviation of the mean from the accepted reference value of the quantity being measured. It does not vary if a measurement is repeated.
- Sensitivity is the capability of a method or instrument to discriminate between measurement responses representing different levels of the analyte of interest. An evaluation of sensitivity is included in the Strata and/or vendor laboratory analytical methods that are used to analyze samples.
- Representativeness is generally ensured through the use of standard sampling protocols.
- Accuracy is the nearness of a measurement or the mean of a set of measurements to the true value and is usually expressed as the relative percent difference.
- Comparability is the confidence with which one data set can be compared to another and is ensured by employing approved sampling plans, standardized field procedures, and experienced personnel using properly maintained and calibrated instruments.

8.1 SAMPLE HANDLING AND DELIVERY

Chain of Custody (COC) forms should accompany every sample sent to off-site laboratories. The chain of custody should contain at a minimum the type of sample, the sample identification number, the preservation techniques (if any), the name of the sampler, the date and time the sample was taken, the name(s) of individuals who handled the sample and when they passed it on to another person, and the required analysis. Once the laboratory is finished with the chain of custody, it is sent back to the SHEQ Department with the analytical package so it can be filed for future reference.

8.2 INDEPENDENT THIRD PARTY ACCREDITED LABORATORY QUALITY CONTROL

CBR has implemented a quality control program to determine the precision and accuracy of the monitoring processes. Quality control sampling includes replicate samples to determine precision, spiked samples with a known concentration to determine accuracy, and blank samples to detect and measure contamination of analytical samples.

Inter-laboratory duplicate samples are analyzed by a second laboratory to determine the precision of the original laboratory. In addition, intra-laboratory duplicate samples may be collected and sent to the primary laboratory to assure internal laboratory precision. The RSO selects the locations, media and number of inter-laboratory and intra-laboratory duplicate samples. A minimum of one duplicate sample is collected per sampling period.

In addition to the quality control samples prepared and submitted by CBR to contract analytical laboratories, each qualified laboratory will have an acceptable QA/QC program in place. The CBR QA Coordinator will review the vendors QA/QC Program and will be responsible for approving the use of the vendor. Qualified laboratories will submit verification of participation in the EPA's Quality Control Program and the laboratory certification programs for environmental waters.

8.3 ANALYTICAL SENSITIVITY

8.3.1 Lower Limits of Detection

The NRC in Regulatory Guide 4.14 recommends the lower limits of detection (LLD) for radiological samples. CBR has adopted these LLD values that are appropriate for the samples obtained at the Crow Butte project. The required LLD values are listed in Table 2.

Table 2
Radiological Lower Limits of Detection

Media	Radionuclide	Lower Limit of Detection
Air	Natural Uranium Thorium-230 Radium-226	1×10^{-16} µCi/ml
	Lead-210	2×10^{-15} µCi/ml
	Radon-222	2×10^{-10} µCi/ml
Water	Natural Uranium Thorium-230 Radium-226	2×10^{-10} µCi/ml
	Polonium-210 Lead-210	1×10^{-9} µCi/ml
Soil and Sediment (dry)	Natural Uranium Thorium-230 Radium-226 Lead-210	2×10^{-7} µCi/g
Vegetation, Food and Fish (wet)	Natural Uranium Thorium-230	2×10^{-7} µCi/kg
	Radium-226	5×10^{-8} µCi/kg
	Polonium-210 Lead-210	1×10^{-6} µCi/kg

8.3.2 Non-radiological Detection Limits

Minimum detection levels are necessary for non-radiological samples obtained at the Crow Butte project. CBR has adopted the detection levels listed in Table 3.

Table 3
Non-radiological Detection Limits

Analyte	Detection Level (mg/l)
COMMON IONS	
Calcium	1.00
Magnesium	1.00
Sodium	1.00
Potassium	1.00
Carbonate	0.10
Bicarbonate	0.10
Sulfate	1.00
Chloride	0.10
Ammonia-N	0.05
Nitrite-N	0.01
Nitrate-N	0.01
Fluoride	0.10
Silica	1.00
Total Dissolved Solids	1.00
Total Alkalinity	0.10
Conductivity	1.00 (µmho)
pH	± 0.02 (standard units)
ACCURACY CHECKS (acceptable range)	
Ion Balance	0.95 to 1.05
TDS Balance	0.90 to 1.10
Conductivity Balance	0.95 to 1.05
MINOR AND TRACE METALS	
Arsenic	0.001
Barium	0.100
Boron	0.100
Cadmium	0.010
Chromium	0.050
Copper	0.010
Iron	0.050
Lead	0.015
MINOR AND TRACE METALS (continued)	
Manganese	0.010
Mercury	0.001

Table 3
Non-radiological Detection Limits

Analyte	Detection Level (mg/l)
Molybdenum	0.100
Nickel	0.050
Selenium	0.001
Vanadium	0.100
Zinc	0.010

9 ON-SITE LABORATORY QUALITY ASSURANCE

CBR has implemented a quality assurance /quality control program to determine the precision and accuracy of the laboratory analysis performed in the on-site laboratory. Quality control in the on-site laboratory includes the use of appropriate analytical methods, quality control samples and other internal quality control activities including instrument calibration, analyst training, equipment maintenance, and external quality control.

9.1 ANALYTICAL METHODS

The use of approved standard analytical methods ensures that the quality objectives for operation of the laboratory are met. Table 4 lists the assays that are performed in the on-site laboratory and the analytical method that is used. Specific procedures for each method are described in the *Laboratory Manual* maintained in the laboratory for use by the analysts.

Table 4
On-Site Laboratory Analytical Methods

Parameter	Reference/Method
U_3O_8	"Spectrophotometric Determination of Uranium (VI) with Bromo-PADAP", DA Johnson and TM Florence "Standard Methods for Chemical and Atomic Absorption Analysis of Uranium-Ore Concentrate", Sections 9-16, Uranium by Ferrous Sulfate Reduction – Potassium Chromate Titrimetric ASTM C 1022-84. EPA 200.7 Inductively Coupled Plasma-Atomic Emission Spectrometry
Alkalinity as $CaCO_3$	EPA 310.1 Titrimetric
Chloride	Standard Methods, 17th Ed. 4500-Cl^- B. Argentometric

Table 4
On-Site Laboratory Analytical Methods

Parameter	Reference/Method
Sulfate	EPA 375.4 Turbidimetric EPA 200.7 Inductively Coupled Plasma-Atomic Emission Spectrometry
Total Dissolved Solids	EPA 160.1 Residue – filterable, Gravimetric, 180°C
pH	EPA 150.1 Electrometric
Sodium	EPA 273.1 Atomic Absorption, direct aspiration EPA 200.7 Inductively Coupled Plasma-Atomic Emission Spectrometry
Calcium	EPA 215.1 Atomic Absorption, direct aspiration EPA 200.7 Inductively Coupled Plasma-Atomic Emission Spectrometry
Vanadium	EPA 286.1 Atomic Absorption, direct aspiration EPA 200.7 Inductively Coupled Plasma-Atomic Emission Spectrometry

9.2 QUALITY CONTROL SAMPLES

CBR uses three types of quality control samples at the on-site laboratory. These samples are duplicate samples, spiked samples, and control standards. Although the quality control samples are primarily used to monitor and control systematic and random measurement errors, they are useful in detecting all types of laboratory error.

9.2.1 Duplicate Samples

Duplicates are taken of the original sample and analyzed in the same way as the original sample. These duplicate samples allow the analysts to determine the precision of the assay. The acceptable limit for the duplicate analysis is ± 10% over the range normally encountered in the laboratory. If the assay is very high or very low, criteria for limits will be determined on a case-by-case basis.

9.2.2 Spiked Samples

Standard addition spikes are the addition of a known amount of analyte to a duplicate sample aliquot. These samples are useful in estimating the accuracy of an assay and in identifying potential interferences. The acceptable limit for spikes is 95 to 105 percent recovery.

9.2.3 Control Standards

Control standards are certified standards whose chemical concentration values are known. They are used for spiking and standardizing reagents. For example, a chloride standard that is sodium chloride with a concentration of 1,000 ± 0.0005 moles per liter is used to standardize the $AgNO_3$ solution which is used in the analysis of chloride. The standard is certified traceable to National Institute of Standards and Technology Standard Reference Material. This standard is also used for preparing chloride spiked samples.

9.2.4 Internal Quality Control Activity Schedule

Analysts will perform a minimum of one duplicate and one spike quality control sample per week per parameter assay.

Reagent blanks will be analyzed whenever new reagents are used and as often as required in specific methods. A reagent blank is the reference base with which the analytical results are

compared under the same conditions as the samples to be analyzed, except deionized water is used in place of the sample.

For analysis of metals in water by atomic absorption and inductively coupled plasma-atomic emission spectrometry, calibration standards and blanks are analyzed with each batch of samples. Calibration standards are samples with a known concentration that are used to plot an absorbance versus concentration curve. This curve is used to determine the concentration of the samples being assayed. The standards that are used to prepare the calibration standards are certified and traceable to NIST Standard Reference Material.

9.3 INSTRUMENT CALIBRATION

9.3.1 pH Meter

The pH meter is calibrated daily with pH 7 and pH 4 (or pH 10) buffer solutions. Calibration results are recorded.

9.3.2 Conductivity Meter

The conductivity meter has a set of cell constant and automatic temperature compensation. In order to ensure the accuracy of the instrument, the conductivity of standardized 0.01 molar potassium chloride with a specific conductance of 1413 µmho/cm at 25°C is checked and recorded on a monthly basis.

9.3.3 Turbidimeter

The turbidimeter is calibrated with Formazin, the primary turbidity standard, at least semiannually. All calibration data is recorded.

9.3.4 Balance

The Mettler balance is cleaned and checked annually by a certified technician.

When in use, the balance is checked on a monthly basis with NBS Class S masses calibrated to within 0.025mg or better.
All calibration data is recorded.

9.3.5 Perkin Elmer Atomic Absorption Spectrophotometer Model 3100

The operator can determine whether instrumental parameters are optimized and if the instrument is performing to specifications by using the sensitivity check. The sensitivity check value (in mg/l) is the concentration of an element that will produce a signal of approximately 0.2 absorbance units under optimum conditions at the wavelength listed. This number can be found in the *Analytical Methods for Atomic Absorption Spectrophotometry.*

If the instrument develops a malfunction that cannot be corrected by operator maintenance, a trained specialist will service it.

9.3.6 Optima 8300DV ICP-OES

For daily operations the instrument is calibrated according to the manufacturer's recommended procedures, using mixed calibration standard solutions and the calibration blank. The calibration line should consist of a minimum of a calibration blank and a high standard. Replicates of the blank and highest standard provide an optimal distribution of calibration standards to minimize the confidence band for a straight-line calibration in a response region with uniform variance. If the instrument develops a malfunction that cannot be corrected by operator maintenance, a trained specialist will service it.

9.3.7 Automatic Pipettes

Based upon equating milligrams with milliliters, automatic pipettes will be checked for accuracy by weighing the contents of the pipette on a precision balance. This will be performed and documented periodically as deemed necessary by the Lab Foreman.

9.4 CROSS-CONTAMINATION CONTROL

All glassware used in the laboratory is washed in a solution of tap water with the addition of a low phosphate laboratory grade detergent. The glassware is then rinsed with tap water. The glassware is then final rinsed with deionized water.

A deionized water system consisting of one activated carbon unit and two mixed bed deionizers is used to provide quality deionized water for assay work and glassware final rinsing.

9.5 ANALYST TRAINING

9.5.1 Lab Foreman

The minimum qualifications for a Lab Foreman are two years of post-secondary education in science and two years of inorganic laboratory experience. At least one year of this experience should be at an in-situ uranium facility.

9.5.2 Laboratory Technician

The minimum qualifications for a Lab Technician are a High School Diploma or a minimum of two years of directly related work experience. The Lab Foreman will directly supervise the Laboratory Technicians in the performance of their duties.

9.6 EQUIPMENT PREVENTATIVE MAINTENANCE PROCEDURES

Analysts will become thoroughly acquainted with the instrument operation manuals and will use the proper maintenance procedures as specified by the manufacturers.

9.7 EXTERNAL QUALITY CONTROL

Samples from wellfield monitor wells will be split and analyzed for the excursion parameters (alkalinity, chloride, and conductivity) at the on-site laboratory on a quarterly basis. The sample splits will be sent to a contract laboratory for analysis of the same excursion parameters. The on-site laboratory results will be compared with the contract laboratory results for consistency. The Lab Foreman or QA Coordinator will review the results from each laboratory. If the results are not within 10 percent for all parameters that are greater than 50 ppm or within ± 5 ppm for those parameters with a concentration less than 50 ppm, an investigation will be performed and appropriate corrective action will be taken.

9.8 DATA HANDLING

Production zone and shallow monitor well data will be reviewed for accuracy and reported to the Restoration Supervisor and Environmental Leadership Coordinator. Results of monitor well analysis for excursion indicators will be checked by the analysts to determine whether they are within the range of the upper control limits (UCLs) for that well. Any discrepancies will be investigated. If the data for a particular well falls out of range, it will be immediately reported to the SHEQ Manager or designee.

All process analytical data will be reported to the Plant Foreman or his designee.

The Lab Foreman will maintain all original laboratory worksheets and instrument calibration data on file in the on-site laboratory. Records will be maintained for the appropriate duration as discussed in Section 12.4.

10 VERIFICATION AND VALIDATION (V &V)

The verification and validation (V&V) of certain aspects and support activities of radiological, environmental and effluent measurement processes or monitoring programs are essential to the QAP. These aspects and activities include data and computer software and spreadsheet V&V and project method validation.

The analytical data from the CBR radiological counting laboratory will be reviewed by the RSO. The RSO or the QA Coordinator will also review the environmental and effluent monitoring data from the on-site laboratory and contract laboratories. The RSO or the QA Coordinator will be responsible for evaluating the data, entering the data into the corporate data handling system, and distributing the data to the corporate files and specified personnel. Data review will be properly documented.

10.1 VALIDATION AND VERIFICATION FOR ACCURACY AND COMPLETENESS

The objective of verification is to ensure that data is collected and reported in a consistent manner with approved procedures and per time requirements. This involves the review of raw data for completeness, transcription errors, accuracy of calculations, and whether proper procedures are followed. The RSO is principally responsible for the validation and verification of activities whose failure could have an impact on the environment, health, or safety. The RSO, HPT, Lab Foreman, and Environmental Leadership Coordinator are responsible to review and initial logbooks, QC reports, and logs at least monthly for completeness and accuracy. Technical data is routinely verified and validated to ensure that the data is of sufficient quality and quantity. Computer programs and spreadsheets used in the implementation of radiological monitoring are documented, verified, and validated before initial routine use and after each modification of the computer program. Verification checks are performed on all routine data-transfer and data-entry.

The following sections discuss the criteria to be used during the technical evaluation of the data.

10.2 TECHNICAL REVIEW

Technical review involves reviewing screened data points to determine if the point is acceptable or corrective action is needed. This evaluation takes into consideration factors such as number of historical data points, analyte concentrations, magnitude of deviation, variability of historical data, and location of sample point in regards to other potentially interfering activities. If point is not acceptable corrective action is taken.

10.2.1 Detection Limit Review Criteria

The reviewer will determine that the detection limits specified in **Tables 2 and 3** have been met.

10.2.2 Accuracy Check Criteria

- The radionuclide content of the various matrices (soil, vegetation, water, and air) should be evaluated for consistency with published data normally found in government reports.
- The radionuclide content of matrices where one would expect radiological constituents to be in secular equilibrium (such as soil) should be evaluated for internal consistency.
- The gross alpha value (if available) should be compared to the sum of the individual alpha emitting nuclides such as natural uranium, radium 226, and thorium 230.
- The cation-anion balance should be between 0.95 and 1.05.
- The ratio of the measured total dissolved solids (TDS) at 180°C to the calculated TDS corrected for bicarbonate decomposition should be between 0.90 and 1.10.
- The ratio of the measured electrical conductance (dilute) with the calculated electrical conductance should be between 0.95 and 1.05.

If the data on a given sample does not meet the above accuracy checks, the RSO will investigate the laboratory and sampling procedures to determine the cause of the discrepancy.

10.2.3 Data Comparison Criteria

The data on a given sample or set of samples will be compared with the data from previous representative samples from the same population. If an individual result falls within the range obtained on previous samples, the result is considered acceptable. If the result falls outside of the range, the data is evaluated for trends or other unusual distribution. The laboratory will then be notified and asked to check all calculations and quality control checks. If no discrepancies are found a new analysis may be requested on the sample provided that the maximum holding time for the sample has not been exceeded. If the maximum holding time has been exceeded, the RSO may then request a re-sample. .

10.2.4 Anomalous Data

The determination of anomalous data is done through the validation process. It involves screening of the data, technical review, and corrective actions to determine if the data point is indeed anomalous.

10.2.5 Corrective Action

Corrective action allows for further investigation into the cause behind anomalous data. Corrective action may include requesting a laboratory check of calculations and dilutions, sample reanalysis, re-sampling, and comparison of data to the next sampling event. Based on the corrective action the RSO or QA Coordinator can then determine if the data point is acceptable or an anomalous point. Anomalous points are considered unusable.

10.2.6 Validation of Field Data

Field data verification ensures that data is collected in accordance with designated procedures and per required schedules. The data should be reviewed for completeness, transcription errors, compliance with procedure, and accuracy of calculations. The individual validating the data, in consultation with the RSO or QA Coordinator, may correct problems that are found or noted in the documentation by lining through the incorrect entry with a single line, correcting the information, then initialing changes made to the document. Care must be made not to obscure the erroneous information. The person validating the data must also ensure that erroneous data is not entered into the database.

10.2.7 Variance of Field Data

Changes from field protocols established in SHEQMS Volume IV, *Health Physics Manual* and SHEQMS Volume VI, *Environmental Manual* must be authorized by the RSO and Manager of SHEQ and fully documented by the initiator. Field variance will be reported immediately to evaluate the impact the variance has on the data. Examples of variance in the field would be the activity performed or sample collection technique did not follow proper protocols, the monitoring or measurement instrument used was out of calibration, or there is a loss or damage to the record that cannot be duplicated. In events of variance it may be necessary for **a** corrective action(s). Field variance will be recorded in field notebooks and log sheets.

11 PREVENTIVE AND CORRECTIVE ACTIONS

The preventive and corrective actions aspect of the QAP ensures continuous improvement processes are implemented, deficiencies and non-conformance on programs are defined and identified, and corrective or preventive actions are taken.

11.1 DEFICIENCIES AND NON-CONFORMANCE

Assessments, audits, inspections, and surveillance form the basis of the continuous improvement program. These methods allow for identification of deficiencies and non-conformance in programs, tasks, or performance as well as providing valuable information on areas of improvement. The information from these methods is reviewed by appropriate personnel, and these personnel have the authority to implement corrective actions to ensure the program, task or performance meets quality or regulatory acceptance criteria. Documentation of the deficiency or non-conformance is taken, tracked, and reported to appropriate management and regulatory agencies if required.

11.2 CORRECTIVE ACTIONS

In the event that a program, task, or performance does not meet regulatory or quality acceptance criteria, corrective action is taken to ensure the program or task meets the appropriate criteria. The corrective action process involves the basic elements:

- Identification and documentations;
- Classification;
- Cause analysis;
- Corrections;
- Follow-up; and
- Closure

Findings and corrective actions are documented, tracked, and reported to management and regulatory agencies as required. Follow-up reviews are performed to verify the effectiveness and adequacy of the corrective actions as required in SHEQMS Volume II, *Management Systems*. Management or appropriate personnel who review and implement the corrective actions(s) have sufficient authority to resolve the problem.

12 RECORDS

12.1 FIELD RECORDS

Radiological Monitoring Data Sheets and all environmental sampling data sheets will be retained at the plant site. It will be the responsibility of the RSO to assure that all sampling records are kept in an organized and secure manner.

12.2 ENVIRONMENTAL/RADIOLOGICAL ANALYTICAL RECORDS

Analytical data will be retained at the plant site and/or the corporate office. It will be the responsibility of the RSO to assure that all analytical reports are kept in an organized and secure manner.

12.3 ENVIRONMENTAL/RADIOLOGICAL AUDIT REPORTS

All audit reports shall be maintained at the site. The SHEQ Manager or designee will be responsible to see that all audit reports are kept in an organized and secure manner.

12.4 RECORD STORAGE DURATION

All regulatory required records of the following activities, operations or actions shall be documented and retained including; sampling analyses, surveys or monitoring, survey/monitoring equipment calibrations, reports on audits and inspections, all meetings and training courses, and any subsequent reviews, investigations or corrective actions.

All required records and documentation will be available for regulatory review and inspection. Upon termination of all regulatory license and permits, the President of CBR will have the final authority to authorize the disposal of records.

13 AUDITS AND INSPECTIONS

CBR conducts audits of various programs at the Crow Butte project to ensure the quality of the implementation of the programs. In addition, CBR personnel conduct routine inspections of work areas to check for compliance issues and any other problems. These audits and inspections are summarized in this section.

13.1 QUALITY ASSURANCE/QUALITY CONTROL AUDIT

The QA Coordinator will conduct tri-annually an audit of the radiological monitoring, sampling and analytical QA/QC programs. The QA Coordinator may designate qualified individuals who do not have direct responsibility in the areas being audited to perform the audits. Audit results will be reviewed by the RSO and corrective action taken where necessary.

A tri-annual audit of the water sampling and analytical QA/QC programs will be conducted. The QA Coordinator or a designated qualified consultant, who does not have direct responsibility in the areas being audited, will perform the audits. Audit results will be reviewed by the QA Coordinator and corrective action taken where necessary.

13.2 ALARA AUDIT

Annually a third party will perform a formal audit of the ALARA program and submit a detailed written report to the SHEQ Manager and RSO. 10 CFR §20.1101 (c) and CBR's source materials license require this audit of the occupational and effluent control ALARA programs. The audit will be performed in accordance with the guidance contained in USNRC Regulatory Guide 8.31, *"Information Relevant to Ensuring That Occupational Radiation Exposures at Uranium Mills Will Be As Low As Reasonably Achievable"*, (Revision 1, 2002) and will include a review of the results of the following operational data:

- Bioassay results, including any actions taken when the results exceeded action levels given in Table 1 of Regulatory Guide 8.22.
- Exposure records, both external and internal, showing the time-weighted calculations.
- Training program activities.
- Safety meeting minutes and attendance records.
- Daily inspection log entries and summary reports of the daily and monthly reviews.

- In-plant radiological survey and sampling data.
- Environmental radiological effluent and monitoring data.
- Surveys required by radiation work permits.
- Reports on overexposures submitted to NRC, and
- Reviews of operating and monitoring procedures completed or revised during this period.

Specific attention will be given to air sampling results as recommended in USNRC Regulatory Guide 8.25, *"Air Sampling in the Workplace"*, (Revision 1, 1992). This review will determine whether air sampling results for the previous year are accurate and whether changes should be made to the air sampling program. The review will include the purposes and amount of air sampling, locations, trends, posting, procedures, correction factors, representativeness, and any indicated changes to the air sampling program.

The written ALARA audit report shall be specific in addressing any noticeable trends in personnel exposures for identifiable categories of workers and types of activities. Recommendations to further reduce personnel exposures will be included. The report should also provide data to show that the equipment for exposure control and effluent control is properly used, maintained and inspected.

In addition to reviewing the results of the occupational ALARA program, the audit will review trends in radiological effluent data as recommended in USNRC Regulatory Guide 8.37, *ALARA Levels for Effluents from Materials Facilities"*, (1993). The audit report will include any recommendations to further reduce environmental releases of radioactive materials.

13.3 OTHER REVIEWS

13.3.1 Standard Operating Procedures

The RSO will perform an annual review of all Standard Operating Procedures for radiation safety and environmental protection issues. This annual review will be properly documented. Appropriate operations supervisory personnel will review process procedures in their area of responsibility to ensure that the instructions reflect current operating conditions.

13.3.2 Inspection Reviews

The RSO will perform a monthly review of the daily and weekly inspections and all monitoring and exposure data. The RSO will prepare a written summary of significant worker protection activities, including exposure data, bioassays, and survey data. A discussion of any trends or deviations from the radiation protection and ALARA programs, implementation of license conditions, and unresolved problems and corrective actions, will be included.

13.3.3 Respiratory Protection Program

The RSO or other similarly qualified individual will conduct an annual review of the implementation of the CBR Respiratory Protection Program. The review will include discussions with workers that use respiratory protection to solicit comments on the effectiveness of the program. The review will ensure that the program procedures reflect the requirements of current applicable regulations and accepted standards and that the program is implemented in accordance with the Standard Operating Procedures.

13.4 INSPECTIONS

13.4.1 Daily Inspections

The RSO, HPT or a qualified Designated Operator will conduct a daily visual walk-through inspection of the plant facility to check for compliance issues and any other problems. These inspections will be properly documented. The results of these inspections will be reviewed by the RSO.

13.4.2 Weekly Inspections

The RSO and the Mine Manager, or the RSO and the Plant Foreman will conduct a weekly walk-through inspection of the plant operating areas to observe general radiation safety practices and to review required changes in procedures and equipment. These inspections will be properly documented.

Appendix A

Containers, Preservation Techniques, and Holding Times

APPENDIX A

Parameter	Volume Required (mls)	Preservative	Holding Time	Container
Dissolved Metals	250	Filter (0.45 µm), then add HNO_3 to ph<2	6 months	Plastic or Glass
Total Metals	250	HNO_3 to ph<2	6 months	Plastic or Glass
Alkalinity	100	Cool, 4°C	14 days	Plastic or Glass
Chloride	50	None Required	28 days	Plastic or Glass
Conductance	100	Cool, 4°C	28 days	Plastic or Glass
Fluoride	50	None Required	28 days	Plastic or Glass
Ammonia as N	50	H_2SO_4 to pH<2, Cool, 4°C	28 days	Plastic or Glass
Nitrate + Nitrite	50	H_2SO_4 to pH<2, Cool, 4°C	28 days	Plastic or Glass
Nitrate	50	Cool, 4°C	48 hours	Plastic or Glass
Nitrite	50	Cool, 4°C	48 hours	Plastic or Glass
pH	25	None Required	Analyze immediately	Plastic or Glass
TDS	500	Cool, 4°C	7 days	Plastic or Glass
TSS	500	Cool, 4°C	7 days	Plastic or Glass
Sulfate	100	Cool, 4°C	28 days	Plastic or Glass
Lead-210	1000	HNO_3 to ph<2	6 months	Plastic or Glass
Polonium-210	1000	HNO_3 to ph<2	6 months	Plastic or Glass
Radium-226	1000	HNO_3 to ph<2	6 months	Plastic or Glass
Uranium	1000	HNO_3 to ph<2	6 months	Plastic or Glass
U_3O_8	N/A	N/A	N/A	Glass

Canadian Nuclear Safety Commission
Commission canadienne de sûreté nucléaire

REGULATORY GUIDE

Measuring Airborne Radon Progeny at Uranium Mines and Mills

G-4

June 2003

Canada

REGULATORY DOCUMENTS

The Canadian Nuclear Safety Commission (CNSC) operates within a legal framework that includes law and supporting regulatory documents. Law includes such legally enforceable instruments as acts, regulations, licences and orders. Regulatory documents such as policies, standards, guides, notices, procedures and information documents support and provide further information on these legally enforceable instruments. Together, law and regulatory documents form the framework for the regulatory activities of the CNSC.

The main classes of regulatory documents developed by the CNSC are:

Regulatory policy: a document that describes the philosophy, principles and fundamental factors used by the CNSC in its regulatory program.

Regulatory standard: a document that is suitable for use in compliance assessment and describes rules, characteristics or practices which the CNSC accepts as meeting the regulatory requirements.

Regulatory guide: a document that provides guidance or describes characteristics or practices that the CNSC recommends for meeting regulatory requirements or improving administrative effectiveness.

Regulatory notice: a document that provides case-specific guidance or information to alert licensees and others about significant health, safety or compliance issues that should be acted upon in a timely manner.

Regulatory procedure: a document that describes work processes that the CNSC follows to administer the regulatory requirements for which it is responsible.

Document types such as regulatory policies, standards, guides, notices and procedures do not create legally enforceable requirements. They support regulatory requirements found in regulations, licences and other legally enforceable instruments. However, where appropriate, a regulatory document may be made into a legally enforceable requirement by incorporation in a CNSC regulation, a licence or other legally enforceable instrument made pursuant to the *Nuclear Safety and Control Act*.

REGULATORY GUIDE

Measuring Airborne Radon Progeny at Uranium Mines and Mills

G-4

Published by the
Canadian Nuclear Safety Commission
June 2003

Measuring Airborne Radon Progeny at Uranium Mines and Mills
Regulatory Guide G-4

Published by the Canadian Nuclear Safety Commission

Cat. No. CC173-3/2-4E
ISBN 0-662-34396-4

Également publié en français sous le titre de
La mesure des produits de filiation du radon en suspension dans l'air dans les mines d'uranium et les usines de concentration d'uranium.

Document availability

This document can be viewed on the Canadian Nuclear Safety Commission website (www.nuclearsafety.gc.ca). To order a print copy of the document in English or French, please contact:

Communications and Information Management Directorate
Canadian Nuclear Safety Commission
280 Slater Street
P. O. Box 1046, Station B
Ottawa, Ontario K1P 5S9
CANADA

Telephone: (613) 995-5894 or 1-800-668-5284 (Canada only)
Facsimile: (613) 992-2915
E-mail: publications@cnsc-ccsn.gc.ca

TABLE OF CONTENTS

MEASURING AIRBORNE RADON PROGENY AT URANIUM MINES AND MILLS

1.0 PURPOSE

This regulatory guide is intended to help users measure and compute instantaneous concentrations of airborne radon progeny at uranium mines and mills.

2.0 SCOPE

This document describes a method that Canadian Nuclear Safety Commission (CNSC) inspectors use to assess concentrations of airborne radon progeny at Canadian uranium mines and mills. This method, or methods of comparable accuracy, may be used by uranium mine or mill licensees.

3.0 BACKGROUND

Radon–222 is a chemically inert element, a radioactive gaseous by-product of other naturally occurring radioactive elements. Radon gas is released into the atmosphere as a result of both natural processes and human activities. It continuously undergoes spontaneous radioactive decay. Four solid, short-lived radionuclides — polonium–218, lead–214, bismuth–214 and polonium–214 — form in sequence as radon–222 decays to create lead–210. These four short-lived products are the "radon progeny" referred to in this guide.

To protect workers and to comply with federal requirements, uranium mine and mill licensees monitor and record the exposure of their workers to radiation hazards, including radon progeny. Uranium mines and mills also monitor concentrations of radon and its progeny in support of engineering design and workplace planning.

Alpha, beta and gamma radiation are emitted during the decay of radon gas to create lead–210. Of these forms of radiation, alpha particles typically pose the most significant radiation hazard to workers because, over time, the inhalation of air containing elevated concentrations of alpha-emitting radon progeny may increase the incidence of lung cancers in humans.

Under natural conditions, radon gas and its progeny are typically encountered in relatively low concentrations. However, higher concentrations can occur under special conditions, including those associated with uranium mining and processing activities.

Although all uranium mines and mills encounter radon and its progeny during their operations, the significance of these elements as potential radiation hazards in a specific situation will depend upon case-specific factors. Examples of such factors include source characteristics, geologic and climatic factors, production technology and methods, plant and mechanical designs, air-exchange rates, work processes, and personnel protection provisions.

With or without special control measures, radon and radon-progeny concentrations in uranium mine or mill workplaces can vary significantly over time and space. Typically, uranium mines and mills maintain radon and radon-progeny concentrations at safe levels by ensuring that their workplaces are adequately ventilated. This may involve exhausting air that contains significantly elevated concentrations of radon and its progeny, or introducing outside air that contains lower or background concentrations of radiation.

4.0 OVERVIEW OF METHOD

Uranium mines and mills in Canada use various methods to determine instantaneous concentrations of airborne radon progeny (References 2, 5, 9, 10, 11, 12). The sample collection, counting and computational procedures that are used by CNSC inspectors rely on the modified Kusnetz method.

To accurately measure the airborne radon progeny in a specific atmosphere, one must first sample, on either an instantaneous basis or a continuous basis, a representative volume of air. Instantaneous samples are, typically, those collected over short, discrete intervals of a few minutes. Continuous samples are those collected over much longer time intervals, typically hours or days.

The measurement approach described in this guide involves:

- filtering a representative volume of air to collect a sample of airborne radon progeny;
- measuring the alpha emissions that occur during radioactive decay of the collected progeny; and
- using observed, measured and known data, and established formulae, to estimate the atmospheric concentration of radon progeny at the time of sampling.

Initially, a sample of airborne radon progeny is collected by using a portable air pump to draw air through a low-porosity filter. The radon progeny that are present in the air attach to the inlet face of the filter used. These progeny subsequently decay, emitting alpha particles and other forms of radiation in the process. During this decay, the emissions of-alpha particles are detected and counted, using an instrument (an alpha counter) designed and manufactured for that purpose.

The counting results obtained are then used along with other pertinent data and observations to estimate the concentration, in units called working levels (WLs) of airborne radon progeny originally present in the air sampled. A working level "means the concentration of radon progeny in 1 m^3 of air that has a potential alpha energy of 2.08×10^{-5} J" [*Radiation Protection Regulations*, subsection 1(1)]. The formula for estimating the concentration of radon progeny in a sample of air, in working levels, is provided in subsection 9(e) of this guide.

The concentration of radon progeny, expressed in working levels, is calculated from a formula that mathematically relates alpha disintegrations per working level over the interval between the end of sampling and the middle of alpha counting, the volume of air sampled, the alpha activity of collected and resultant radon progeny, the efficiency and radioactive background of the alpha counter, and the absorption characteristics of the filter used during sampling.

5.0 SELECTING EQUIPMENT

The equipment and supplies typically required to determine radon-progeny concentrations in accordance with the method described in section 4 include:

- a portable, battery-powered, constant-flow air pump rated at 0.001-5 L/min;
- hoses and fittings of 0.25 in (6.35 mm) inside diameter for use with the air pump;
- cellulose-ester or glass-fibre filters of 0.8 micron porosity and 25 mm diameter;
- open-faced filter holders suitable for use with the pump, lines and filters selected;
- a bubble tube, or a flow meter that is accurate to within ±5%;

- an alpha counter comprised of a radiation detector[1] and related electronics;
- an americium–241 calibration source[2] that is certified accurate to within ±5% and mounted on a stainless steel disc of area equal to that of the filter paper to be used for sampling;
- an accurate timing device, such as a stop watch or digital wrist watch;
- tweezers;
- a battery-powered calculator;
- recording supplies, such as a log or record book, pencils and pens.

6.0 PREPARING FOR SAMPLING

To prepare for sample collection and analysis, follow the steps below:

(a) Assemble the equipment and supplies listed in section 5 of this guide.

(b) Perform the following checks on the sample pump:
- Check the pump battery to verify that it is charged.
- Using the flow meter or bubble tube, measure the rate of air flow through the assembly — air pump, hose and filter holder containing an unexposed filter — that is to be used to collect samples of radon progeny. A constant flow rate of approximately 2 L/min is recommended. Follow the manufacturers' instructions provided with the flow meter, bubble tube and air pump. Note the reading registered on the flow-rate indicator of the air pump. If the flow rate measured by the calibrated flow meter or bubble tube is different than the air pump reading, adjust the calibration of the pump following the manufacturer's instructions. Record the equipment number or other identifying characteristics of the air pump, the date and details of its calibration, and its measured flow rate in litres per minutes, as *F*.

(c) Perform the following checks on the alpha counter, immediately before and after daily use:
- Perform any relevant checks of the alpha counter recommended by the manufacturer. Include a battery check.
- Determine the alpha counter background by measuring the alpha activity of an unexposed filter. If the measured activity exceeds 5 counts per minute (CPM), suspend use of the equipment until it has been cleaned or repaired. Record the background count rate.
- Determine if the alpha counter is performing consistently by conducting a Chi-Square test on a set of 10 successive measurements, following the method described in Appendix A of this guide. Compare the variability of the 10 successive measurements against the variability to be expected as a feature of radioactive decay. If the counter repeatedly fails the Chi-Square test, discontinue its use until it has been satisfactorily repaired.
- Determine the efficiency, *E*, of the alpha counter by dividing the mean (in CPM of alpha activity) of the results of the 10 one-minute measurements that were conducted for the Chi-Square test, by the nominal activity (in DPM of alpha activity) of the Am–241 source used for the 10 measurements. If the alpha counter has a zinc-sulphide radiation detector, the calculated efficiency, *E*, of the counter should lie between 0.35 and 0.50. Within this range, the calculated efficiency of the counter, using the same Am–241

[1] A scintillation detector that uses zinc sulphide as the phosphor is recommended.
[2] Am-241 is recommended as a suitable calibration source because the energy emitted by its alpha particle (5.5 MeV) is similar to the energies emitted by radon progeny (5.5 - 7.7 MeV).

source, should not vary significantly from one day to the next, if the counter is operating satisfactorily. For example, a difference of 0.02 (approximately 1 standard deviation) or so in the calculated efficiencies of the counter over successive days is considered acceptable. However, if the calculated efficiency of the counter is outside of the recommended range (0.35 to 0.50), or if it drops suddenly, discontinue using the counter until it has been satisfactorily repaired.

- When counting radon-progeny samples of high concentration, or when counting radon-progeny samples that have been collected under dusty conditions, check the background of the alpha counter more frequently to determine whether it is becoming contaminated.

7.0 SELECTING SAMPLING LOCATIONS

Select air-sampling locations that accurately reflect the conditions to be assessed. Avoid non-representative or adverse sampling conditions such as areas of turbulent air flow — duct exhausts, junctures or intersections of ventilation passageways, door or window openings.

When collecting radon-progeny samples for purposes of estimating or confirming radiation doses to workers, sample the actual atmospheres breathed by the respective workers. Where possible, sample at the individuals' workstations over a representative period. Alternatively, if concentrations of airborne radon progeny are similar over a large area, it may suffice to collect representative samples while moving through the area, or at appropriate points within the area. The latter approach may be particularly appropriate within uranium processing plants and in travel-ways and/or similar areas of mines.

Samples that are intended to aid in the planning, development and evaluation of engineering works and production processes must be representative of the conditions that they are intended to assess. Accordingly, these samples should be collected at appropriate locations and times. For example, to determine the impact of modifications to mine or building ventilation systems, or to guide the installation of such systems, it may be necessary to collect several air samples at multiple locations, before, after or during the changes.

8.0 COLLECTING SAMPLES

(a) Record the previously determined flow rate, F, of the air pump in litres per minutes; as well as the previously determined efficiency factor, E, and the previously determined background, in CPM, of the counter that is to be used to detect and record alpha emissions.

(b) Assemble the sampling equipment in the correct configuration for use. Mount an unexposed filter in the filter holder, handling the filter by its edge without touching either face. Connect this filter holder securely to the inlet hose of the air pump.

(c) Record the sampling location, the date and the identification number of the holder that contains the filter paper to be used to collect the sample.

(d) If a significant quantity of airborne particulate or moisture is likely to be present during sampling, ensure that the inlet of the sample filter holder faces slightly downwards in preparation for sampling. Maintain this position during sampling to help prevent dust or moisture from depositing on the inlet face of the sample filter, and possibly clogging or damaging it.

(e) Start the air pump and timing device. Record the time of day at the beginning of air sampling. Try to collect the air sample over a timed interval of exactly 5 minutes. If you operate the air pump for more than a 5-minute-and-3-second sampling interval, extend the sample collection and pump operating time to 6 minutes. Observe the flow rate, F, during sampling and suspend air sampling if the pump flow rate decreases by 20% or more. Periodically check the sampling equipment to ensure that the filter is not blocked or clogged, and that the pump hoses remain connected and free of constrictions or obstructions. Record the time of day when air sampling is completed. Record the actual duration of the sampling interval in minutes as t_s.

(f) Once collection of a sample of airborne radon progeny has been completed, turn off the pump and detach the filter holder that contains the exposed filter. Securely store the exposed filter assembly in a protective container. Do not touch or disturb the face of the exposed filter during handling. If filter holders containing unexposed filters and filter holders containing exposed filters are to be stored in the same container, place the assemblies containing unexposed filters in the case with their inlet faces up. After sampling, return the filter holder assemblies to the carrying case with their exposed (inlet) faces down.

(g) Repeat steps (a) to (f) to collect additional samples.

9.0 COUNTING SAMPLES AND COMPUTING RESULTS

To determine the concentrations of radon progeny present in sampled air, count the alpha emissions from the exposed filters and compute the results, in accordance with the following steps:

(a) Transfer the exposed filter from its holder to the fixed or removable sample holder of the alpha counter. Handle the filter by its edge, using tweezers. Ensure that the exposed surface of the filter faces the scintillant of the counter. This step should be performed as quickly as possible to ensure that the counter's photo-multiplier tube is not exposed to any more light than necessary.

(b) Initiate and complete the counting of alpha emissions from the exposed filter within strict time limits. Begin this counting not less than 40 minutes after the end of sampling, and ensure that the midpoint of the selected counting interval is reached not later than 90 minutes after collection of the sample.
Select an appropriate duration for the counting interval. The counting interval is the length of time over which the alpha emissions from an exposed filter are to be measured.
Although 5-minute counting intervals are typical, the selection of an appropriate interval may require that special case-specific considerations be taken into account. These considerations could include the concentration of radon progeny likely to be present in the air sampled, the volume of air sampled, and the counting precision desired. To select appropriate counting intervals, consult Appendix C, "Dependencies among radon-progeny sampling parameters, working level concentrations and the precision of alpha-counting results", which illustrates key relationships.
Operate the counter in accordance with the manufacturer's instructions. Observe and record the time of day at the start and end of the alpha-counting interval.

(c) Note and record the alpha-counting interval in minutes as t_c and the net number of counts — total number of counts minus the number of counts due to instrument background —

obtained during this interval as C. Calculate the elapsed time from the completion of air sampling to the midpoint of the selected alpha-counting interval for the active filter, and record it as t_k.

(d) Use Appendix D or other references to determine the Kusnetz factor, K, that corresponds to t_k or calculate K from the appropriate equation of the following set:

$$K = 230 - 2t_k \text{ when } 40 \leq t_k \leq 70$$

or

$$K = 195 - 1.5t_k \text{ when } 70 \leq t_k \leq 90$$

(h) Calculate the concentration of airborne radon progeny at the time of sample collection using the following equation:

$$WL = \frac{C(1+S)}{Ft_s t_c KE}$$

where:

WL is the concentration in working levels;
C is the total number of alpha counts recorded over the interval of t_c minutes, minus the background alpha counts over interval t_c;
S is any correction factor, as per Appendix B, that is necessary in order to compensate for the absorption of radon progeny on the sample filter;
F is the air sampling flow rate in litres per minute;
t_s is the air sampling interval in minutes;
t_c is the interval, in minutes, over which alpha emissions from the sample are counted;
K is the Kusnetz factor in disintegrations per minute per litre of air per working level; and
E is the efficiency factor of the alpha counter.

GLOSSARY

alpha counter
An instrument designed and manufactured for the purpose of detecting and counting alpha particle emissions.

binomial distribution
A frequency distribution of the possible number of successful outcomes in a given number of trials in each of which there is the same probability of success.

Chi-Square test (χ^2)
Described in Appendix A; an operational check of the counting equipment.

modified Kusnetz method
A method of determining and expressing atmospheric concentrations of radon progeny in terms of latent alpha energy; requires the use of an alpha counter equipped with an electronic scaler to measure the emission of alpha particles.

Poisson distribution
A discrete frequency distribution which gives the probability of events occurring in a fixed time; named after French mathematician, S.D. Poisson.

radon progeny
For purposes of this guide, four solid, short-lived radionuclides — polonium-218, lead-214, bismuth-214 and polonium-214, which form in sequence as radon-222 decays to create lead-210.

working level (WL)
The concentration of radon progeny in 1 m^3 of air that has a potential alpha energy of 2.08×10^{-5} J.

REFERENCES

1. Beckman, R.T. "Calibration Procedures for Radon and Radon Daughter Measurement Equipment." U.S. Department of the Interior, Informational Report 1005, Washington, DC: 1975.

2. American National Standards Institute Inc. "Radiation Protection in Uranium Mines." N13.8, New York: 1973.

3. "Code of Practice on Radiation Protection in the Mining and Milling of Uranium Ores." Commonwealth Department of Health, Canberra, Australia: 1975.

4. Knoll, Glenn F. *Radiation Detection and Measurement.* New York: John Wiley and Sons, 1989.

5. Kusnetz, H.L. "Radon Daughters in Mine Atmospheres — A Field Method for Determining Concentrations." *Industrial Hygiene Quarterly* (March 1956). Alexandria, VA: p. 85.

6. National Council on Radiation Protection and Measurements,"Measurement of Radon and Radon Daughters in Air." *NCRP Report* No. 97. Bethesda, MD: November 15, 1988.

7. Nuclear Energy Agency Organization for Economic Cooperation and Development. "Metrology and Monitoring of Radon, Thoron and their Daughter Products" Paris: 1985.

8. International Atomic Energy Agency. "Radiation Monitoring in the Mining and Milling of Radioactive Ores" *International Atomic Energy Agency Safety Series No. 95.* Vienna: 1989.

9. Rolle, R. "Improved Radon Daughter Monitoring Procedure." *American Industrial Hygiene Association Journal* (March/April 1969). Alexandria, VA: American Industrial Hygiene Association, p. 153.

10. Rolle, R. "Rapid Working Level Monitoring." *Health Physics,* Vol. 22 (March 1972). New York: Pergamon Press, p. 233.

11. Rolle, R. "Determination of Radon Daughters on Filters by Simple Liquid Scintillation Technique." *American Industrial Hygiene Association Journal* (November/December 1970). Alexandria, VA: American Industrial Hygiene Association, p. 718.

12. Thomas, J.W. "Modification of the Tsivoglou Method for Radon Daughters in Air." *Health Physics*, Vol. 19 (November 1970). New York: Pergamon Press, p. 691.

13. International Atomic Energy Agency, "Manual on Radiological Safety in Uranium and Thorium Mines and Mills." *International Atomic Energy Agency Safety Series No. 43.* Vienna: 1976.

14. Rock, R.L., R.W. Dalzell and E.J. Harris. "Controlling Employee Exposure to Alpha Radiation in Underground Uranium Mines." Washington, DC: *U.S. Department of the Interior, Bureau of Mines,* Vol. 2, 1971.

15. Loysen, P. "Errors in Measurement of Working Level." *Health Physics*, Vol. 16 (May 1969). New York: Pergamon Press, p. 629.

16. McGeath, J.D. *How to Use Statistics.* San Francisco: Canfield Press, 1975.

APPENDIX A
Using Chi-Square tests to evaluate the performance of alpha counters

Background

For the long-lived standards that are typically used to test whether alpha counters are operating correctly, the number of transformations that occur is quite small relative to the number of radioactive atoms that are present in the standard.

Statistically, when the probability of an event, such as radioactive decay by alpha emission of a long-lived standard that is used to test alpha counter operation, is quite small (very much less than 1), the binomial distribution approaches the Poisson distribution.

By taking a series of counts of the number of alpha emissions from a radioactive standard, one can compare the variation in counting results to that predicted for situations where the probability over time behaves similarly to what would be predicted by a Poisson distribution.

In the application described below, the Chi-Square test is a method that compares the variability of "successive counts" obtained with an alpha counter to the variability in alpha counts that is predicted by a Poisson distribution. The object of the comparison is to identify any inconsistencies in the respective variability that would not be consistent with the random nature of radioactive decay. If the results obtained with a counter for a series of counts from a given radioactive sample (under controlled conditions) are too consistent (demonstrate little variability), then it is likely that the counter is not performing properly. Similarly, if the observed variability in results is excessive, then the counter system is also likely to be performing incorrectly.

Method

To check the performance of an electronic counter with the Chi-Square test, do the following:

(a) Using the counter to be tested, count the alpha activity of an americium–241 source of known decay rate. Make 10 separate counts, each of one-minute duration. Note and record the total number of counts for each of the 10 measurements.

(b) To calculate the Chi-Square for the above:
- Sum the squares of the differences between the observed count rates for the individual one-minute measurement intervals and the mean count rate over the total (10-minute) measurement period.
- Divide the sum obtained above by the mean count rate over the 10-minute period. The result is the Chi-Square value for the situation tested.

Thus, the Chi-Square value for a given situation can be calculated according to the formula:

$$\chi^2 = \frac{\sum_{i=1}^{n}(X_i - \overline{X})^2}{\overline{X}}$$

(c) If $3.33 \leq \chi^2 \leq 16.92$, the results of the Chi-Square test are consistent with a counter that is performing well.

(d) If $\chi^2 < 3.33$ or $\chi^2 > 16.92$, repeat the Chi-Square test. If the Chi-Square results obtained are repeatedly outside these bounds remove the counter from service until it has been repaired.

APPENDIX B
A method to determine correction factors to compensate for the absorption of radon progeny on sample filters

To compensate for errors due to the absorption of alpha particles by glass-fibre or cellulose-ester filters, an appropriate correction factor must be applied during the associated calculations of radon-progeny concentrations. To determine this correction factor:

(a) Collect a sample of radon progeny; allow the sample to decay for at least 40 minutes, but not more than 90 minutes.

(b) Measure the alpha activity in CPM from the face of the sample filter; record this reading as *A*. Note the time of day.

(c) Measure the alpha activity in CPM from the back of the sample filter and record this reading as *B*. Note the time of day.

(d) With a duplicate, unused filter placed over the face of the sample filter as an absorber, measure the alpha activity in CPM and record this reading as *C*. Note the time of day.

(e) Repeat step (b) to get a repeat reading *D* and note the time of day.

(f) If D < 0.9A, repeat step (c) to obtain another reading *E*, and note the time of day.

(g) Use readings *A* and *D* to estimate a reading *F* at the time at which *C* was observed. Use readings *B* and E to estimate *G* at the time at which *C* was observed.

(h) Calculate the correction factor for absorption on the filter, *S*, using one of the following formulas:

$$S = \frac{B - C}{2A + B - C}$$

or

$$S = \frac{G - C}{2F + G + C}$$

For a cellulose-ester filter, *S* will probably be less than 0.02. For a glass-fibre filter, *S* may exceed 0.10.

APPENDIX C
Dependencies among radon-progeny sampling parameters, working level concentrations and the precision of alpha-counting results

The computed entries in the table below are calculated for $t_k = 65$ minutes, where t_k is the time interval, in minutes, between the end of sampling and the mid-point of the sample-counting interval. For other values of t_k, the data will be commensurately different.

Expected concentration of radon progeny in working levels	Flow rate in litres per minute	Sample volume in litres	Measurement interval in minutes for an alpha-counting precision of:		
			±2%	±5%	±10%
0.05	2	10	150	30	6
	5	25	60	10	4
	10	50	30	6	2
0.10	2	10	80	20	4
	5	25	30	6	2
	10	50	20	4	1
0.20	2	10	40	6	2
	5	25	20	4	1
	10	50	10	2	1
0.40	2	10	20	4	1
	5	25	10	2	1
	10	50	4	1	1
0.80	2	10	10	2	1
	5	25	4	1	1
	10	50	2	1	1

Note:
This chart illustrates the typical relationships among radon-progeny sampling parameters such as the concentrations of radon progeny in the air that has been sampled, the sample flow rates and volumes, the filter count times and precision of results. For example, the length of the counting intervals that are necessary to attain results of similar precision are inversely proportional to the volumes of air sampled and the concentrations of radon progeny in the air sampled. For samples of greater volume but similar concentration, shorter alpha-counting times will suffice to attain results of comparable precision. To shorten the necessary counting times for filters exposed to low concentrations of radon progeny, use pumps of greater capacity to sample larger volumes of air over the specified sampling interval. Or, when smaller samples of air with lower concentrations of radon progeny are collected, increase the precision of the results by adopting longer counting intervals. When concentrations of radon progeny are 0.05 WL or less, counting intervals that result in a precision of ±10% are adequate. Consult references 1 and 2 to determine appropriate flow rates for air sampling and effective sample-counting intervals.

APPENDIX D
Determining Kusnetz correction factors for use in calculations of radon-progeny concentrations

Delay time in minutes	40	41	42	43	44	45	46	47	48	49
Kusnetz correction factor	150	148	146	144	142	140	138	136	134	132

Delay time in minutes	50	51	52	53	54	55	56	57	58	59
Kusnetz correction factor	130	128	126	124	122	120	118	116	114	112

Delay time in minutes	60	61	62	63	64	65	66	67	68	69
Kusnetz correction factor	110	108	106	104	102	100	98	96	94	92

Delay time in minutes	70	71	72	73	74	75	76	77	78	79
Kusnetz correction factor	90	88.5	87	85.5	84	82.5	81	79.5	78	76.5

Delay time in minutes	80	81	82	83	84	85	86	87	88	89	90
Kusnetz correction factor	75	73.5	72	70.5	69	67.5	66	64.5	63	61.5	60

Note :
Kusnetz correction factors may be determined from the above tables or by calculations.

Using the tables above

For the given delay period (i.e., the time, in minutes, from the end of sampling to the middle of counting), select the Kusnetz correction factor that appears in the same column, directly under the delay time in minutes.

For example:

- For a delay time of 60 minutes, the corresponding Kusnetz correction factor is 110.
- For a delay time of 68 minutes, the Kusnetz correction factor is 94.

To calculate Kusnetz correction factors

Calculate the appropriate Kusnetz correction factor by solving the applicable equation of the following set:

$$K = 230 - 2t_k \text{ when } 40 \leq t_k \leq 70$$

or

$$K = 195 - 1.5t_k \text{ when } 70 \leq t_k \leq 90$$

where t_k is the time interval, in minutes, between the end of sampling and the mid-point of the sample-counting interval.