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Powertech files Part2 from Varughese

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QUALITY ASSURANCE FOR RADIOLOGICAL MONITORING PROGRAMS (INCEPTION THROUGH NORMAL OPERATIONS TO LICENSE TERMINATION) — EFFLUENT STREAMS AND THE ENVIRONMENT

A. INTRODUCTION

This regulatory guide describes a method that the U.S. Nuclear Regulatory Commission (NRC) considers acceptable for use in designing and implementing programs to ensure the quality of the results of measurements of radioactive materials in the effluents from, and environment outside of, facilities that process, use, or store radioactive materials during all phases of the facility's life cycle. QUALITY ASSURANCE[1] (QA) is a fundamental expectation of Title 10, "Energy," of the *Code of Federal Regulations* (10 CFR) for items and activities that are relied on to protect the health and safety of the public and the environment.

This guide specifically applies to facilities for which NRC regulations require routine monitoring of radioactive effluents to the environment, and particularly those facilities licensed under the following regulations:

- 10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities" (Ref. 1)
- 10 CFR Part 52, "Licenses, Certifications, and Approvals for Nuclear Power Plants" (Ref. 2)

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[1] Special terms used in this guide are marked in SMALL CAPITALS the first time they are used, and are defined in the glossary provided in this regulatory guide.

- 10 CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste" (Ref. 3)
- 10 CFR Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste" (Ref. 4)
- 10 CFR Part 76, "Certification of Gaseous Diffusion Plants" (Ref. 5)

The guide also may apply to other facilities licensed by the NRC, for which the agency may impose specific license conditions for effluent or environmental monitoring, as deemed necessary to ensure the health and safety of the public and the environment, including those licensed under the following regulations:

- 10 CFR Part 30, "Rules of General Applicability to Domestic Licensing of Byproduct Material" (Ref. 6)
- 10 CFR Part 40, "Domestic Licensing of Source Material" (Ref. 7)
- 10 CFR Part 70, "Domestic Licensing of Special Nuclear Material" (Ref. 8)

Finally, radiological standards for occupational workers and members of the public are codified in 10 CFR Part 20, "Standards for Protection Against Radiation" (Ref. 9).

Although the specific regulations provide the actual requirements, the following presents an overview of applicable NRC regulations addressing limits on radioactive effluents, environmental levels of radioactivity, requirements for effluent and environmental monitoring, and associated QA.

In accordance with 10 CFR 20.1301, "Dose Limits for Individual Members of the Public," the TOTAL EFFECTIVE DOSE EQUIVALENT (TEDE) to individual members of the public from licensed operation must not exceed 1 milliSIEVERT [1 mSv, or 100 milliREM (mrem)] per year. Uranium fuel cycle facilities (excluding transportation and disposal) also must comply with the provisions that the U.S. Environmental Protection Agency (EPA) established in 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operations" (Ref. 10). In addition, 10 CFR 20.1101(d) requires licensees (other than those subject to 10 CFR 50.34a, "Design Objectives for Equipment to Control Releases of Radioactive Material in Effluents — Nuclear Power Reactors," discussed below) to restrict releases of airborne radioactive materials so that the highest individual dose to the public will not exceed 0.1 mSv (10 mrem) per year.

In addition, under 10 CFR 20.1101(b), licensees must apply AS LOW AS REASONABLY ACHIEVABLE (ALARA) concepts to doses to occupational workers and members of the general public. In accordance with 10 CFR 20.1302, "Compliance with Dose Limits for Individual Members of the Public," licensees must survey radiation levels to demonstrate compliance with the dose limits, and 10 CFR 20.1101, "Radiation Protection Programs," requires licensees to develop, document, and implement radiation protection programs commensurate with the scope and extent of licensed activities and sufficient to ensure compliance with the provisions of 10 CFR Part 20 (Ref. 9).

In 10 CFR Part 20, Subpart E, "Radiological Criteria for License Termination," the NRC provides the radiological criteria for license termination under unrestricted and restricted use scenarios. The NRC considers a site acceptable for unrestricted use if the residual radioactivity that is distinguishable from background radiation does not exceed 25 mrem/year (0.25mSv/year) TEDE to an average member of the critical group, including contributions from groundwater sources. A site can be released under restricted use if the residual radioactivity that is distinguishable from background dose not exceed a yearly dose of 25 mrem (0.25mSv) TEDE with site use restrictions in place.

For nuclear power reactors, 10 CFR 50.34a and 10 CFR 50.36a, "Technical Specifications on Effluents from Nuclear Power Reactors," require ALARA concepts for operations to maintain releases of radioactive materials in effluents consistent with the guidelines of Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low As Is Reasonably Achievable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents," to 10 CFR Part 50. Licensees must also establish appropriate SURVEILLANCE and monitoring programs to provide QA with respect to (1) areas of equipment operation and (2) data on the quantities or concentrations of radionuclides released in liquid and gaseous effluents. These programs will help to ensure accurate projection of the levels of radiation and radioactive materials found in the environment. Section III.B of Appendix I addresses requirements concerning estimates of radioactive iodine in water and food pathways if land use changes occur after plant construction.

The regulations in 10 CFR 30.34, "Byproduct Material," 10 CFR 40.41, "Source Material," 10 CFR 50.50, "Production and Utilization Facilities," and 10 CFR 70.32, "Special Nuclear Material," provide that the NRC may incorporate in any governed license such terms and conditions as it deems appropriate or necessary to protect health.

For land disposal of radioactive waste, 10 CFR 61.53, "Environmental Monitoring," requires measurements and observations to be made and recorded to provide data to evaluate potential health and environmental impacts, including long-term effects, as well as the need for mitigating measures. The monitoring system must be capable of providing early warning of releases of radionuclides from the disposal site. A postclosure monitoring program is also required to detect the release of radionuclides.

According to 10 CFR 70.59, "Effluent Monitoring Reporting Requirements," licensees authorized to possess and use special nuclear materials for processing and fuel fabrication, scrap recovery, conversion of uranium hexafluoride, or in a uranium enrichment facility shall report to the NRC the quantity of each of the principal radionuclides released to unrestricted areas in liquid and gaseous effluents, and other information as the Commission may require to estimate maximum potential annual radiation doses to the public resulting from effluent releases.

Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50 includes several applicable general design criteria (GDC) affecting nuclear power plant designs. GDC 60, "Control of Releases of Radioactive Materials to the Environment," requires suitable means to control the release of radioactive materials in gaseous and liquid effluents. GDC 64, "Monitoring Radioactivity Releases," requires means for monitoring effluent discharge paths and the plant environs for radioactivity that may be released from normal operations, including anticipated operational occurrences, and from postulated accidents. GDC 1, "Quality Standards and Records," requires the establishment of a QA program for those structures, systems, and components that are important to safety to provide adequate assurance that they will satisfactorily perform their safety functions. Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," to 10 CFR Part 50 establishes the QA requirements for power plants.

The requirements in 10 CFR 72.104, "Criteria for Radioactive Material in Effluent and Direct Radiation from an ISFSI [Independent Spent Fuel Storage Installation] or MRS [Monitored Retrievable Storage]," mandate operational restrictions for maintaining effluents and direct radiation levels in accordance with ALARA concepts, with limits so as not to exceed annual DOSE EQUIVALENTS of .25 mSv (25 mrem) to the whole body, 0.75 mSv (75 mrem) to the thyroid, and 0.25 mSv (25 mrem) to any other critical organ of any real individual beyond the controlled area.

For gaseous diffusion uranium enrichment facilities, 10 CFR 76.87, "Technical Safety Requirements," requires licensees to establish technical safety requirements with procedures and equipment to address (among other things) building and process ventilation and off-gassing, radioactive waste management, and environmental protection. In addition, 10 CFR 76.93, "Quality Assurance," requires a QA program satisfying the applicable provisions of the American Society of Mechanical Engineers (ASME) standard QA-1-1994, "Quality Assurance Program Requirements for Nuclear Facilities (with Addenda)" (Ref. 11).

Generic Letter 79065 (Ref. 12), regarding the NRC's Radiological Assessment Branch Technical Position on Radiological Environmental Monitoring, provides guidance on the appropriate type of, and location for, sampling and monitoring the environment surrounding nuclear power plants.

This regulatory guide presents more complete and extensive guidance on QA for facilities where radiological effluent or environmental monitoring is required by NRC regulations.[2] However, this guidance does not address all topics and elements that a facility's QA program may require (such as requirements of Appendix B to 10 CFR Part 50 for nuclear power plants or 10 CFR 76.93 for gaseous diffusion uranium enrichment facilities).

The NRC issues regulatory guides to describe to the public methods that the staff considers acceptable for use in implementing specific parts of the agency's regulations, to explain techniques that the staff uses in evaluating specific problems or postulated accidents, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations, and compliance with regulatory guides is not required.

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2 While not specific to QA, other regulatory guides that address measurements of radioactive materials in effluents and the environment include the following:

- Regulatory Guide 1.21, "Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water-Cooled Nuclear Power Plants" (Ref. 13)
- Regulatory Guide 4.1, "Programs for Monitoring Radioactivity in the Environs of Nuclear Power Plants" (Ref. 14)
- Regulatory Guide 4.14, "Radiological Effluent and Environmental Monitoring at Uranium Mills" (Ref. 15)
- Regulatory Guide 4.16, "Monitoring and Reporting Radioactivity in Releases of Radioactive Materials in Liquid and Gaseous Effluents from Nuclear Fuel Processing and Fabrication Plants and Uranium Hexafluoride Production Plants" (Ref. 16)

B. DISCUSSION

As used in the context of this guide, QA comprises all those planned and systematic actions that are necessary to provide adequate confidence in the ASSESSMENT of monitoring results. QUALITY CONTROL (QC) comprises those QA actions that provide a means to measure and control the characteristics of measurement equipment and processes to meet established standards; QA includes QC. This guide makes no further effort to distinguish those elements that may be considered QC from those composing QA.

Quality assurance is necessary to ensure that all radiological and nonradiological measurements that support the radiological monitoring program are reasonably valid and of a defined quality. These programs are needed (1) to identify deficiencies in the sampling and measurement processes and report them to those responsible for these operations so that licensees may take CORRECTIVE ACTION and (2) to obtain some measure of confidence in the results of the monitoring programs to assure the regulatory agencies and the public that the results are valid. All steps of the monitoring process should involve QA (e.g., sampling, shipment of SAMPLES, receipt of samples in the laboratory, preparation of samples, radiological measurements, data reduction, data evaluation, and reporting of the measurement and monitoring results) .

An effective overall management system for quality must precede the design of a QA program. A document by the International Organization for Standardization (ISO/IEC 17025-2005, Ref. 17) is available for use by laboratories in developing their management system for quality, administrative, and technical operations. Once a quality management system is in place, a DIRECTED PLANNING PROCESS can be used to define the data objectives for the specific monitoring program. The DATA QUALITY OBJECTIVE (DQO) process (EPA QA/G-4-2006, Ref. 18) provides one example of how to develop and define acceptance and performance criteria for a sample collection, measurement, and data analysis program. The QUALITY ASSURANCE PROJECT PLAN (QAPP), which documents how data will be collected, assessed, and analyzed, can form the basis of a QA program (EPA QA/G-5-2002, Ref. 19). The QAPP provides a blueprint of where, when, why, and how a particular project will achieve data of the type and quality needed and expected.

NUREG-1576, "Multi-Agency Radiological Laboratory Analytical Protocols Manual" (Ref. 20, hereafter referred to as MARLAP), contains guidance for developing DQOs for risk-informed decisions, and their consequent MEASUREMENT QUALITY OBJECTIVES (MQOs), in the context of radiochemical analyses of environmental samples. The same methodology can be applied in other environmental monitoring contexts. An example of a key MQO is the REQUIRED METHOD UNCERTAINTY at a specified radiation dose or radionuclide concentration. The specific dose may be a fractional amount of a radiation dose limit. The specific concentration may be a fractional amount of an effluent release or environmental radionuclide concentration. For either case, the fractional amount of the limit should be sufficiently small so that a licensee may take reasonable operational actions before the limit is exceeded. MARLAP recommends a PERFORMANCE-BASED APPROACH for selecting methods used to analyze samples or measure dose rates that meet the MQOs. Under this approach, the licensee's QA program should incorporate the initial (project METHOD VALIDATION) and continued [internal and external PERFORMANCE EVALUATION (PE) PROGRAMS] assessment of a method's capability to meet the MQO specifications. Process-radiation monitoring equipment and instrumentation need to have the desired sensitivity to provide both real-time and data-trend values that can correlate to the actual measurements of process streams before release. The radiological environmental measurements program may be used to confirm the adequacy of the process-monitoring equipment.

C. REGULATORY POSITION

The QA program of each organization performing radiological effluent or environmental monitoring of nuclear facilities using, processing, or storing radioactive materials during all phases of the facility's life cycle should be documented by written policies and procedures. Licensees should have sufficient RECORDS of program conduct and performance to demonstrate program adherence. In addition to its own program, a licensee should require any contractor or subcontractor performing support program activities (e.g., sampling, analysis, evaluations, and records) retain records sufficient for the licensee to develop and maintain a QA program covering the applicable program elements.

The following presents the QA program elements that should be developed and implemented to ensure the quality of data/results for radiological effluent and environmental monitoring programs.

1. Organizational Structure and Responsibilities of Managerial and Operational Personnel

The structure of the organization as it relates to the management and operation of the monitoring programs, including QA policy and functions, should be defined and documented. The authorities, duties, and responsibilities of the positions within this organization, down to the first-line supervisory level, should be described. This should include responsibilities for review and approval of written procedures and the preparation, review, and evaluation of monitoring data and reports.

Persons and organizations performing QA functions should have sufficient authority and organizational freedom to identify quality problems; to initiate, recommend, or provide solutions; and to verify implementation of solutions. Reporting should be at a management level that is independent of activity performance, costs, and schedule.

Section 2.1.1 of ANSI/ASQC E4-1994 (Ref. 21) and Section 5.2.1 of ANSI N42.23-2003 (Ref. 22) provide additional guidance on management structure and organizational responsibilities for radiological effluent and environmental monitoring programs.

2. Specification of Qualifications of Personnel

The qualifications of individuals needed to carry out assigned radiological monitoring functions should be defined and documented (e.g., as in a job description). Individuals with responsibility for performing quality-related activities should be trained and qualified in the principles and techniques of the activities to be performed. These individuals should maintain proficiency by retraining, reexamining, and recertifying or by periodic performance reviews, as appropriate. Continual training should be conducted as needed to ensure that personnel maintain awareness of events and issues that could affect the quality of program performance.

Section 2.3.1 of ANSI/ASQC E4-1994 (Ref. 21) provides additional guidance and criteria for developing personnel training and qualification specifications for radiological effluent and environmental monitoring programs.

3. Operating Procedures and Instructions

Monitoring programs should have written procedures for all activities that generate data, such as dose calculations and measurements, sample collection, sample management and CHAIN OF CUSTODY, sample preparation and analysis, data reduction and recording, data assessment and reporting, and final sample disposal. Procedures are also needed for addressing support functions, such as operation of process monitors, training, preparation of QUALITY CONTROL SAMPLES, collection of meteorological data, corrective actions, AUDITS, and records. Individuals satisfying the qualifications described in Section C.2 of this regulatory guide should write, review, and revise these procedures.

Instructions, procedures, or schedules should be prepared for the functions associated with the QA program, such as the following:

- ancillary laboratory functions (including cleaning of glassware, contamination control, and storage of standards and chemicals)
- CALIBRATION and QC of instrumentation (including range of activity, range of energy, and frequency of calibration)
- internal QC and external PE programs (including frequency, types, acceptance criteria for the laboratory PERFORMANCE TESTING samples, and individual analyst qualifications)
- timetable for VERIFICATION and VALIDATION (V&V) of data

Chapters 9, 11, and 12 of MARLAP (Ref. 20) provide guidance on the radioanalytical laboratory activities for which procedures are used. MARLAP Chapters 12 – 16 provide technical information that can be used to write or revise procedures. Section 5.4 of ISO/IEC 17025-2005 (Ref. 17) provides additional guidance regarding the content and quality aspects of procedure and method technical content. Section 2.5.2 of ANSI/ASQC E4-1994 (Ref. 21) identifies procedures that should be documented and may need control.

4. Records

licensees should maintain a system that produces unequivocal, accurate records that document all monitoring activities. Licensees should maintain records of implementation or ongoing activities, such as the following:

- procedure revision
- personnel training and qualification records
- analytical results
- audits
- corrective actions
- intermediate activities or calculations (as may be needed to validate or substantiate final results)
- records of tracking and control (chain of custody) throughout all processes from sample collection through analysis and reporting of results, including unique identifiers, descriptions, sources, dates/times, packaging/preparation/shipping, and required analyses
- field logs with sufficient information describing environmental conditions and recording related information and data documenting the nature of the sample and where and how it was taken
- laboratory notebooks recording related information and data, observations of analysts, and laboratory or other conditions potentially affecting the measurement process
- electronic data collection and algorithms and QA documentation
- calculations (including data reduction, analysis, and verification)

- QC records for radiation monitoring equipment, including the results of RADIOACTIVE SOURCE checks, calibrations, INSTRUMENT BACKGROUND determinations, and maintenance activities affecting equipment performance
- notifications to qualified staff that procedural changes affecting data quality have been made
- QC records for laboratory counting systems and support instrumentation and equipment, including calibrations, maintenance or repair, QC sample results, and traceability of standards used for instrument calibration

Records should be legible and identifiable, retained in predetermined locations, and protected against damage, deterioration, or loss. Records should be maintained in a format that is easily retrievable. If the media for storage is electronic (as opposed to paper or microfilm/fiche), the licensee should maintain the equipment necessary to read and present the data in an uncorrupted form. The document retention system should allow reconstruction of all activities associated with the generation of analytical results. The licensee should establish a retention time for records consistent with licensing conditions and in accordance with the licensee's overall QA program.

Section 2.5 of ANSI/ASQC E4-1994 (Ref. 21) provides guidance on specific types of documents that should be maintained, while Basic Requirement 17 of ASME NQA-1-1994 (Ref. 11) details the administrative criteria that should be considered for inclusion in a program for records and their retention. Section 4.13 of ISO/IEC 17025-2005 (Ref. 17) also provides guidance on the control of records. Chapters 4 and 11 of MARLAP (Ref. 20) discuss documents that should be retained as records. Nuclear Information and Records Management Association (NIRMA) TG11-1998 (Ref. 23), TG15-1998 (Ref. 24), TG16-1998 (Ref. 25), and TG21-1998 (Ref. 26) provide additional information addressing issues in developing and maintaining electronic records programs.

5. Quality Control in Environmental Sampling

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. The frequency of these calibrations should be specified and should be consistent with the DQOs of the measurement program. The collection efficiencies of the sampling equipment used should be documented; often such documentation is available from the manufacturer. HPS/ANSI N13.1-1999 (Ref. 27) provides guidance on QA and QC for air sampling instruments. Chapter 19 of MARLAP (Ref. 20) discusses measurement uncertainties in general and volume and mass measurements in particular.

Sampling or measurements should be performed using equipment and methods that yield a result that is representative of the population in the particular environmental media. FIELD DUPLICATES are co-located spatially or temporally and should be collected periodically to check REPRODUCIBILITY. Chapter 10 of MARLAP (Ref. 20) discusses the field and sampling issues that affect laboratory measurements, including packaging, shipping, and storage of samples.

Some individual environmental samples are collected simply to confirm that radioactivity levels are below a specified (small) fraction of an established concentration limit. In those cases, the MINIMUM DETECTABLE CONCENTRATION of the method used should be below that specified fraction of the limit. Chapter 20 of MARLAP (Ref. 20) discusses detection limits, while Appendix C to MARLAP covers the relationship between the desired fraction of the limit that is important to detect and the uncertainty of the measurement method. In some cases, a series of measurement results will be averaged for comparison with BACKGROUND LEVELS or a regulatory limit. For such measurements, an appropriate MQO would be the MINIMUM QUANTIFIABLE CONCENTRATION (see Chapter 20 of MARLAP).

For an isolated, well-mixed population, a single sample or measurement may be sufficient. It is more common, however, for spatial or temporal variations to exist. In that case, the frequency of sampling and number of samples and locations will depend on the level of variability and amount of radioactivity (compared with an established risk-informed limit). NUREG-1575, "Multi-Agency Radiation Survey and Site Investigation Manual" (Ref. 28, hereafter referred to as MARSSIM), discusses the effect that such variability has on the number of samples that may be appropriate for SURVEYS. In general, the DQO process may be used together with specific statistical designs (EPA QA/G-9S-2006, Ref. 29) to optimize the sampling. Continuous sampling or integrated measurements may be used to mitigate temporal variability.

Part 1, Sections II-11 and II-12, of ASME NQA-1-1994 (Ref. 11) discuss test control and control of measuring and test equipment. Part II, Subpart 2.20, of ASME NQA-1-1994 discusses QA standards for subsurface investigations for nuclear power plants.

6. Quality Control in the Radioanalytical Laboratory

The output of the directed planning process includes DQOs that encompass both sampling and analysis activities for a project or program. From the DQOs, a set of MQOs are developed for radioanalytical measurements (see Chapter 3 of MARLAP, Ref. 20). In a performance-based approach, MQOs are critical criteria used for the selection and validation of analytical methods and protocols (see Regulatory Position 8, below) and subsequently form the basis for the ongoing and final evaluation of the analytical data. The type, frequency of, and evaluation criteria for QC samples are developed during the directed planning process and are incorporated into ANALYTICAL PROTOCOL SPECIFICATIONS (APSs) for a project (see Chapter 3 of MARLAP, Ref. 20).

Chapter 18 of MARLAP provides guidance on monitoring key laboratory PERFORMANCE INDICATORS to determine whether a laboratory's measurement processes are in control. The chapter also provides information on likely causes of excursions for selected laboratory performance indicators, such as chemical yield, instrument background, and QC samples. Appendix C to MARLAP provides the rationale and guidance for developing MQOs for select method performance characteristics and gives guidance on developing criteria for QC samples.

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.

6.1 Calibration and Quality Control of Instruments, Measuring Devices, and Test Equipment

Instruments, devices, and test equipment used for measuring radioactivity should be operated, calibrated, and maintained to ensure that analytical specifications are met. All equipment should be operated, calibrated, and maintained in adherence to any applicable standards and methods and as specified in the laboratory's quality manual and standard operating procedures. Instrument configurations during calibration should match those used for subsequent analytical measurements of samples.

Calibrations of instruments should be made using CERTIFIED REFERENCE MATERIALS of known and documented value and stated uncertainty and should be traceable to a national standards body, such as the National Institute of Standards and Technology (NIST) in the United States. CALIBRATION SOURCES should be prepared in a manner that provides comparability to TEST SOURCES with respect to source geometry, positioning relative to the detector, source composition, and distribution of the test-source material within a container or on a source mount (see Section 15.2 of MARLAP, Ref. 20).

The frequency of calibrations should be consistent with the stability and performance of the instrument. Complete system calibration should be performed before initial use or following system maintenance, repair, or any other changes in environment or operating conditions that could affect performance (ASTM D7282-2006, Ref. 30). In addition, Sections 15.2 and 15.3 of MARLAP (Ref. 20) present general guidance regarding calibrations of instruments. Chapter 15 of MARLAP also presents guidance specific to calibrations of different instrumentation types.

The continuing validity of calibrations should be checked periodically as specified in a laboratory's quality manual (see Chapter 18 of MARLAP, Ref. 20). Quality control checks of radioanalytical instrument calibration parameters, such as detector response or energy and resolution calibrations for spectrometers, should be performed by measuring the response of each radiation detection system to appropriate CHECK SOURCES. Instrument QC frequencies are generally performed daily for systems used continually or before use for those systems periodically employed, but frequencies may vary by instrument type. Instrument QC checks should meet predefined acceptance criteria for the respective calibration parameter and should ensure that conditions have not significantly changed since initial calibration (ASTM D7282-2006, Ref. 30).

Instrument-calibration QC check results should be tracked, trended, and compared with predetermined ranges of acceptable performance. For example, if a monitor's response to a daily check source showed a trend that may lead to a condition outside of established acceptance criteria, a calibration may be needed to reestablish acceptable operation. Section 18.5 of MARLAP (Ref. 20) and ASTM D7282-2006 (Ref. 30) discuss radioanalytical instrument-calibration QC parameters.

Additional method-specific quality controls (e.g., chemical yield, spectral quality, resolution) may apply to certain methods and should be tracked and trended using control or tolerance charts to identify conditions that could be adverse to quality.

The laboratory quality manual and standard operating procedures should address the use, calibration, maintenance, and QC of all nonradiological instruments, measuring devices, and test equipment used for measuring or quantifying other necessary data (e.g., sample masses or volumes, temperatures). All measurement and test equipment should be calibrated before use and adjusted to maintain accuracy within established limits. Quality control checks should be performed at specified frequencies and should verify that instruments are operating to specified performance levels.

Nonradiological instruments, measurement, and test equipment should be operated according to manufacturers' instructions, according to established standards, or as specified in the laboratory quality manual and procedures. Section 18.6.7 of MARLAP (Ref. 20) provides guidance on control, calibration, and maintenance of calibration of apparatus used for mass and volume measurements. ISO/IEC 17025-2005 (Ref. 17) provides general guidance on establishing quality controls for nonradiological instruments. Items that do not conform to specified criteria should be controlled to prevent inadvertent use. These items should be tracked through the corrective action program.

Careful control of contamination and routine monitoring of instrument background are integral parts of a measurement QC program. Determination of the background counting rate should be performed on a regular, predefined frequency for systems in routine use and should ensure that analytical specifications for applicable programs can be met. Instrument backgrounds used to determine a net count rate should replicate actual sample measurement conditions as closely as possible (i.e., using appropriate sample containers and geometries).

Section 18.5.1 of MARLAP (Ref. 20) provides guidance on measurement and control of instrument backgrounds. Section 18.3 and Attachment 18A of MARLAP contain guidance on the statistical evaluation of performance indicators and on using control and tolerance charts.

Sections 10-13 and 20-25 of ASTM D7282-2006 (Ref. 30) and Section A.5.2 of ANSI N42.23-2003 (Ref. 22) provide additional guidance on instrument response source checks, background checks, and the use of control charts. ASTM MNL 7A-2002 (Ref. 31) provides guidance on setting up and using control charts.

6.2 Internal Quality Control Samples and Analysis

The use of QC samples should be an integral element of a laboratory QA program. Chapter 18 of MARLAP (Ref. 20) defines the different types of laboratory QC samples and provides guidance on evaluation techniques for QC samples. The laboratory should have as part of the normal operational sample load the following QC samples:[3]

- BLANK
- MATRIX SPIKE
- LABORATORY CONTROL SAMPLE
- LABORATORY DUPLICATE

Analysis of QC samples should be performed as a part of the routine operation of a laboratory to verify that laboratory operations are consistent with applicable specifications. The QC program should specify the type of and minimum frequency for processing QC samples. For example, this frequency may be defined as a minimum percentage of the total number of samples analyzed, a certain number per operational time interval (e.g., once per shift) or per sample batch, or a licensee-specified frequency based on laboratory-specific parameters. As part of its QC program, the laboratory may prepare and analyze BLIND SAMPLES, provided the individuals responsible for preparing the samples are not directly responsible for conducting the laboratory analysis. For example, the laboratory's assigned QC specialist may have the responsibility for preparing and submitting blind samples (blank, duplicate, laboratory control sample, and matrix spike). Blind samples are used primarily as a tool for evaluating the performance of individuals rather than as part of the laboratory QC load.

Acceptability of QC sample results should be evaluated based on criteria from the QC program, which include specific equations based on METHOD UNCERTAINTY. Chapters 7 and 18 of MARLAP (Ref. 20) provide guidance on the evaluation of QC samples.

Quality control sample results should be tracked, trended, and compared with predetermined ranges of acceptable performance to identify conditions that are in, or may lead to, nonconformance with program specifications. Such conditions should be tracked through the corrective action program.

6.3 Performance Evaluation Program (Interlaboratory Comparison)

Participation in an external PE program is an important independent check on the accuracy, possible bias, and precision of some radioanalytical or measurement methods used in a radiological monitoring program. Internal and contract radioanalytical laboratories used in the monitoring program should participate in one or more applicable PE programs that are administered by organizations that have an active measurement assurance (traceability) program with NIST (ANSI N42.22-1995, Ref. 32). Chapter

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[3] Note that this list does not include field duplicate samples that are part of the QC requirement for sampling.

5 of MARLAP (Ref. 20) recommends incorporating the criteria for a radioanalytical laboratory to participate in a PE program into the statement of work for services. Several external PE programs administered by government agencies or commercial radioactive-source suppliers are available for radionuclides and matrices germane to radiological monitoring programs. The PE program should provide fundamental sample types (e.g., solid, liquid, gas) and radionuclides (e.g., alpha-, beta-, and gamma-emitting nuclides) of interest at the facility. When available, laboratories should analyze samples as offered by a PE program on a frequency stipulated by the monitoring program's QA criteria, with all types of samples and analyses repeated at least biennially. Chapter 18 of MARLAP (Ref. 20) provides information on organizations that administer PE programs.

Acceptable performance criteria for results of performance-testing samples should be established that are consistent with the MQOs for the radiological monitoring project or program. For certain monitoring activities, the acceptance criteria of the PE program may be satisfactory. The performance in a PE program should be tracked and trended as one of the performance indicators for the laboratory and evaluated as part of the corrective action program.

7. Quality Control for Radioactive Effluent Monitoring Systems

7.1 Radioactive Effluent Process Monitors

An initial, primary radiation monitor calibration that meets the specifications of ANSI N42.18-2004 (Ref. 33), should be performed with radioactive sources traceable to a national standards body (such as NIST). Calibrations should be repeated periodically using (1) STANDARD REFERENCE MATERIALS or (2) certified reference materials that can be directly traced to the initial, primary calibration. Complete system calibration — including electronics, detector, and any support functions (such as alarm, display, and recording devices) — should be performed at a frequency that ensures system reliability and accuracy or after repair or maintenance that may affect instrument calibration. Unless otherwise specified in license requirements, the licensee should verify and validate the complete effluent monitoring system every 12 months. This frequency may be extended to longer time periods coinciding with facility maintenance schedules, such as refueling for nuclear power plants, if the licensee has verified proper system operation through established system reliability and more frequent source checks and functional checks.

Detectors should be response-checked periodically[4] for continuous effluent release points (e.g., ventilation systems and secondary water systems) and before release for batch discharges (e.g., primary boundary or containment purges and liquid waste tank releases). Licensees should ensure that check sources are of sufficient radiochemical purity so that the activity of the source may be corrected for decay to the date of measurement. These check sources need not be traceable to a national standards body (e.g., NIST). Whenever practicable, check sources should be an integral part of the monitoring system and should be remotely actuated. The functionality of isolation or alarm functions should be verified periodically, preferably by use of a radiation source.

Trends of process radiation monitor readings versus total radionuclide concentrations in the monitored release path should be performed routinely. These trends should be based on the results of analyses for specific radionuclides in samples taken from the release path that will yield a monitor response. Deviations in the trend may occur if concentrations or the mixture of radionuclides changed significantly (for example, during a fuel cycle in which significant fuel defects exist). The licensee should define the monitor-response parameter for all radiation monitors. The monitor-response constant should be adjusted to maintain this correlation between effluent radionuclide concentration and monitor response.

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[4] Frequencies should be appropriate to the instrument under consideration and may be dictated by license conditions.

7.2 Flow Monitoring Instrumentation

Continuous sampling of liquids and gases involves the measurement of sample flow rates and/or sample volumes. The accuracy and associated uncertainty of the devices used for this purpose should be determined on a regularly scheduled basis, and adjustments should be made as needed to bring the performance of the devices within specified limits. The results of these calibrations should be recorded. The frequency of these calibrations should be specified and should be based on the necessary accuracy, purpose, degree of usage, stability characteristics, and other conditions affecting the measurement.

Any flow-rate measuring devices associated with the system should be calibrated to determine actual flow rates at the conditions of temperature and pressure under which the system will operate. These flow rate devices should be recalibrated annually, but the frequency may be extended to that established for the radiation detector system, provided sufficient operating experience exists and an accelerated measurement check frequency gives sufficient data to ensure reliable performance.

Flow measuring devices should be checked periodically on an established frequency, considering the variability of the instrument, and recalibrated when established control limits are exceeded. HPS/ANSI N13.1-1999 (Ref. 27) provides additional guidance on QA and QC measures for the use, maintenance, and calibration of airborne sampling instrumentation. ANSI N42.18-2004 (Ref. 33) provides additional guidance on the calibration of liquid flow monitors.

7.3 Grab Sampling of Effluent Process Streams

Whenever practicable, effluent releases should be batch-controlled and released when the volume to be released has been mixed sufficiently to ensure uniform concentration. Sampling and analysis for each batch should be performed, and release conditions set, before release. A certain percentage of all batch releases should have field duplicates taken either before or during the release to assess the reproducibility of sampling and the effectiveness of the mixing process before release. Where possible, samples that are spatially or temporally separated should be collected periodically to verify representativeness.

For continuous-effluent discharges, composite samplers should be employed. However, periodic grab samples may be used when composite sampling of a continuous discharge point is not feasible. When grab samples are collected instead of composite samples, licensees should design the sampling program to sample at the time, location, and frequency that ensures each sample is representative of the radioactive materials released.

7.4 General Quality Control Considerations

The QC plan should address the following items:

- Sampling should be performed using calibrated instruments and equipment when taking a composite sample.
- Collection efficiencies based on the physical configuration of the sampling point and the type of collector should be documented. Vendor-supplied data may be used where adequate documentation exists to ensure the reliability and accuracy of data.
- Volumes of tanks and containers should be established during initial installation and should be verified again following any physical changes that could alter the system configuration.

- The frequency of duplicates and REPLICATES[5] should be established based on time (for continuous discharges) or number of batches (for batch discharges).
- Sample integrity should be maintained through chain of custody procedures.

Procedures for continuous sampling should use methods that are designed to ensure that the sample is representative of the volumes being discharged.

8. Verification and Validation

The V&V of certain aspects and support activities of the radiological measurement process or monitoring program are essential to the QA program. These aspects and activities include data and computer software V&V and project method validation.

Project method validation is the demonstration that a method (radioanalytical or radiation measurement) using performance-based method selection is capable of providing analytical results to meet a project's MQOs and any other criteria in the analytical protocol specification (APS). Acceptable method validation is necessary before the radiological analysis of samples or the taking of measurements in a monitoring program. Chapter 6 of MARLAP (Ref. 20) presents detailed guidance on project method validation for radioanalytical methods. In addition, Section 5.2.7 of ANSI N42.23-2003 (Ref. 22) and Section 5.4.5 of ISO/IEC 17025-2005 (Ref. 17) provide limited guidance for radioanalytical method validation.

Chapter 8 of MARLAP (Ref. 20) gives detailed guidance and applicable tools for the radioanalytical data V&V evaluation process as well as information for developing a data V&V plan, determining acceptable criteria and tests, and applying data qualifiers for radioanalytical data validation, as related to MQOs. EPA QA/G-8-2002 (Ref. 34) provides guidance for nonradioanalytical data V&V.

Computer programs used in the implementation of the radiological environmental monitoring program should be documented, verified, and validated before initial routine use and after each modification of the program. As described in Section 5.4.3.2 of MARLAP (Ref. 20), the laboratory's quality manual should include the criteria for computer software V&V and documentation. The software data reduction and reporting functions should be verified to perform as expected.[6]

9. Assessments and Audits

Assessments, audits, and surveillances are elements used to evaluate the initial and ongoing effectiveness of the QA program to monitor and control the quality of a radiological monitoring program. Management having responsibility in the area being reviewed should document and review the results of these activities. Assessments that are independent of the day-to-day operations should be performed routinely, including management surveillance, peer reviews, and READINESS REVIEWS for new or revised systems and methods. Key performance indicators should be tracked and trended, with periodic management reporting. The QA program or project plan should outline the scope, frequency, and schedule of assessments, audits, and surveillances. A plan should be developed for each assessment audit or

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5 Replicate samples may be prepared by removing separate ALIQUANTS from the same grab sample.

6 The Institute of Electrical and Electronics Engineers (IEEE) Standard 1063, "IEEE Standard for Software User Documentation" (Ref. 35); EPA Directive 2185, "Good Automated Laboratory Practices" (Ref. 36); Subpart 2.7 of ASME NQA-1-1994 (Ref. 11); Regulatory Guide 1.168, "Verification, Validation, Reviews, and Audits for Digital Computer Software Used Safety Systems of Nuclear Power Plants" (Ref. 37); and Section 8 of ANSI N42.14-1999, "Calibration and Use of Germanium Spectrometers for the Measurement of Gamma-Ray Emission Rates of Radionuclides" (Ref. 38), also provide guidelines on software V&V.

surveillance for each area of the monitoring program being evaluated. A report of these activities should be generated according to the outline, format, and content established in the plan.

Only qualified QA staff (see Regulatory Position 2, above), supported as needed by experts in the technical areas under evaluation, should conduct assessments, audits, and surveillances. (See ASME NQA-1-1994, Supplement 2S, Ref. 11.) Deficiencies, areas for improvement, and observations noted should be incorporated into the corrective action program and tracked. Section 18 of ASME NQA-1-1994 (Ref. 11) and Section 4.10 of ISO/IEC 17025-2005 (Ref. 17) provide guidance on establishing and conducting an audit program.

When the monitoring program will depend upon the services of a radioanalytical laboratory, prior onsite audits of the laboratory may be conducted to ensure that the laboratory is capable of fulfilling the project criteria in accordance with the APS (including MQOs) outlined in a statement of work (MARLAP Chapter 5 and Appendix E). The ongoing evaluation of the laboratory's QUALITY SYSTEM and operations is accomplished through onsite audits and desk audits. These audits are focused more on whether the laboratory is meeting project or program specifications than whether the laboratory has the capability to meet monitoring program or project criteria. Chapter 7 of MARLAP provides guidance and statistical tests to determine whether a laboratory is meeting the MQOs, especially the REQUIRED METHOD UNCERTAINTY. Section 5.2.10 of ANSI N42.23-2003 provides additional guidance for radioanalytical laboratory assessments.

Audits of the QA programs of contractors providing materials, supplies, or services affecting the quality of the laboratory's operations should be performed periodically (Section 4.6 of ISO/IEC 17025-2005, Ref. 17).

10. Preventive and Corrective Actions

Integral components of a QA program include identifying areas for improvement, defining performance or programmatic deficiencies, and initiating appropriate corrective or preventive actions. The QA program for radiological effluent and environmental monitoring programs should contain both a continuous-improvement program and a program for implementing corrective actions when conditions adverse to quality have been identified. In addition, needed improvements and potential sources of nonconformance should be identified and reported as part of a preventive action initiative of the continuous-improvement program (ISO/IEC 17025-2005, Sections 4.10–4.12) — for example, a condition-reporting program. Investigations should be initiated for degrading conditions, and corrective actions should be taken when conditions fall outside quality or regulatory acceptance criteria. For conditions that are adverse to quality, the corrective action process includes the following basic elements:

- identification and documentation
- classification
- cause analysis
- corrections
- followup
- closure

Findings and corrective actions should be documented, tracked, and reported to management. Followup reviews should be performed to verify the effectiveness and adequacy of the corrective actions. Section 2.10 of ANSI/ASQC E4-1994 (Ref. 21) provides specifications and guidelines for developing the process, programs, and procedures necessary to detect and correct items of nonconformance and for implementing continuous quality improvement.

When conducting an audit or surveillance of laboratory services, a prime area of review should be the effectiveness of the laboratory's corrective action program (Section 7.4.2 of MARLAP, Ref. 20). Section 4.11 of ISO/IEC 17025-2005 (Ref. 17) provides general guidance on preventive and corrective action programs for laboratories. Annex C of ANSI N42.23-2003 (Ref. 22) provides additional guidance that should be considered in developing a corrective action program, including root cause analysis for radioanalytical services.

D. IMPLEMENTATION

The purpose of this section is to provide information to licensees regarding the NRC staff's plans for using this regulatory guide. No backfit is intended or approved in connection with its issuance.

Non-nuclear power reactor applicants and licensees may continue to use Revision 1 of Regulatory Guide 4.15, dated February 1979, or may adopt other procedures or practices that reflect generally accepted standards for ensuring quality in environmental data collected for effluent monitoring purposes. Except in those cases in which a nuclear power reactor applicant or licensee proposes or has previously established an acceptable alternative method for complying with specified portions of the NRC's regulations, the methods and practices described in this guide will be used in evaluating QA practices for environmental radiological monitoring programs.

GLOSSARY[7]

accuracy—The closeness of a measured result to the true value of the quantity being measured. Various recognized authorities have given the word "accuracy" different technical definitions, expressed in terms of bias and imprecision. Following the Multi-Agency Radiological Laboratory Analytical Protocols (MARLAP) Manual (Ref. 20), the U.S. Nuclear Regulatory Commission (NRC) avoids all of these technical definitions and uses the term "accuracy" in its common, ordinary sense, which is consistent with the definition established by the International Organization for Standardization (ISO) in the "International Vocabulary of Basic and General Terms in Metrology" (Ref. 39).

aliquant—A representative portion of a homogeneous SAMPLE removed for the purpose of analysis or other chemical treatment. The quantity removed is not an evenly divisible part of the whole sample. An aliquot, by contrast, is an evenly divisible part of the whole.

analyte—See TARGET ANALYTE.

analytical protocol specification (APS)—The output of a DIRECTED PLANNING PROCESS that contains the project's analytical data needs and criteria in an organized, concise form. The level of specificity in the APS should be limited to those criteria that are considered essential to meeting the project's analytical data criteria to allow the laboratory the flexibility of selecting the protocols or methods that meet the analytical criteria.

as low as reasonably achievable (ALARA)—"As low as is reasonably achievable taking into account the state of the technology and the economics of improvements in relation to benefits to the public health and safety and other societal and socioeconomic considerations, and in relation to the use of atomic energy in the public interest" [10 CFR 50.34a(a)].

assessment—A planned and documented activity performed to determine whether various elements within a quality management system are effective in achieving stated quality objectives (ANSI N42.23-2003, Ref. 22).

audit—A planned and documented activity performed to determine by investigation, examination, or evaluation of objective evidence the adequacy of, and CONFORMANCE with, established procedures, instructions, drawings, and other applicable documents as well as the effectiveness of implementation. An audit should not be confused with surveillance or inspection activities performed for the sole purpose of process control or product acceptance (after ANSI N42.23-2003, Ref. 22).

background, instrument—Radiation detected by an instrument when no SOURCE is present. The background radiation that is detected may come from radionuclides in the materials of construction of the detector, its housing, its electronics, and the building as well as the environment and natural radiation.

background level—A term that usually refers to the presence of radioactivity or radiation in the environment. From an analytical perspective, the presence of background radioactivity in samples

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7 Certain terms included in this glossary are not used in the main body of this regulatory guide, but are included because they are used within other definitions.

needs to be considered when clarifying the radioanalytical aspects of the decision or study question. Many radionuclides are present in measurable quantities in the environment.

bias (of a measurement process)—A persistent deviation of the mean measured result from the true or accepted reference value of the quantity being measured, which does not vary if a measurement is repeated.

blank (analytical or method)—A SAMPLE that is assumed to be essentially free of the TARGET ANALYTE (the "unknown"), that is carried through the radiochemical preparation, analysis, mounting, and measurement process in the same manner as a routine sample of a given matrix.

blind sample—A SAMPLE with a concentration not known to the analyst. Blind samples are used to assess analytical performance. A double-blind sample is a sample whose concentration and identity as a sample is known to the submitter, but not to the analyst. The analyst should treat the double-blind sample as a routine sample, so it is important that the double-blind sample is identical in appearance to routine samples.

calibration—The set of operations that establish, under specified conditions, the relationship between values indicated by a measuring instrument or measuring system, or values represented by a material measure, and the corresponding known value of a parameter of interest.

calibration source—A prepared SOURCE, made from a CERTIFIED REFERENCE MATERIAL OR STANDARD REFERENCE MATERIAL, that is used for calibrating instruments.

certified reference material—A reference material, accompanied by a certificate, with one or more property values certified by a procedure that establishes its traceability to an accurate realization of the unit in which the property values are expressed, and for which each certified value is accompanied by an UNCERTAINTY at a stated level of confidence (ISO Guide 30, Ref. 40). See STANDARD REFERENCE MATERIAL.

chain of custody—Procedures that provide the means to trace the possession and handling of a sample from collection to data reporting.

check source—A material used to validate the operability of a radiation measurement device, sometimes used for instrument quality control. See TEST SOURCE and SOURCE, RADIOACTIVE.

condition adverse to quality— an all-inclusive term used in reference to any of the following: failures, malfunctions, deficiencies, defective items, and nonconformances. A significant condition adverse to quality is one which, if uncorrected, could have a serious effect on safety or operability.

conformance—An affirmative indication or judgment that a product or service has met the criteria of the relevant specifications, contract, or regulation; also the state of meeting the criteria (ANSI/ASQC E4-1994, Ref. 21).

corrective actions—Those measures taken to prevent, rectify, or eliminate conditions adverse to quality or detected nonconformities and — as necessary — to preclude repetition of those conditions.

data quality objective (DQO)—Qualitative and quantitative statements that clarify the study objectives, define the most appropriate type of data to collect, determine the most appropriate conditions from which to collect the data, and specify tolerable limits on decision error rates. Because DQOs will be used to establish the quality and quantity of data needed to support decisions, they should encompass the total UNCERTAINTY resulting from all data collection activities, including analytical and sampling activities.

directed planning process—A systematic framework focused on defining the data needed to support an informed decision for a specific project. Directed planning provides a logic for setting well-defined, achievable objectives and developing a cost-effective, technically sound sampling and analysis design that balances the data user's tolerance for UNCERTAINTY in the decision process and the available resources for obtaining data to support a decision. Directed planning helps to eliminate unnecessary, poor, or inadequate sampling and analysis designs.

dose equivalent—Quantity that expresses all radiations on a common scale for calculating the effective absorbed dose. This quantity is the product of absorbed dose (GRAYS (Gy) or rads) multiplied by a quality factor and any other modifying factors (MARSSIM, Ref. 28). The quality factor adjusts the absorbed dose because not all types of ionizing radiation create the same effect on human tissue. For example, a dose equivalent of one SIEVERT (Sv) requires 1 Gy of beta or gamma radiation, but only 0.05 Gy of alpha radiation or 0.1 Gy of neutron radiation. Because the sievert is a large unit, radiation doses often are expressed in milliSIEVERTS (mSv). See TOTAL EFFECTIVE DOSE EQUIVALENT.

duplicate, field—Two samples of the same material, collected at the same location at the same time and under the same conditions, which are used to verify representativeness of the sampled material.

duplicate, laboratory—Two ALIQUANTS of a SAMPLE, which are prepared and analyzed separately as part of the same batch, used in the laboratory to measure the overall PRECISION of the sample measurement process, beginning with laboratory subsampling of a field SAMPLE.

field duplicate—See DUPLICATE, FIELD.

graded approach—A process of basing the level of management controls applied to an item or work on the intended use of the results and the degree of confidence needed in the quality of the results. The NRC follows a graded approach to project planning and QUALITY ASSURANCE because of the diversity of environmental data collection activities. This diversity in the type of project and the data to be collected impacts the content and extent of the detail to be presented in the project planning documents.

gray (Gy)—The International System of Units (SI) unit for absorbed radiation dose. One Gy is 1 joule of energy absorbed per kilogram of matter, equal to 100 RAD. See SIEVERT.

laboratory control sample—A standard material of known composition or an artificial SAMPLE (created by fortification of a clean material similar in nature to the sample), which is prepared and analyzed in the same manner as the sample. In an ideal situation, the result of an analysis of the laboratory control sample should be equivalent to (give 100 percent of) the TARGET ANALYTE concentration or activity known to be present in the fortified sample or standard material. The result normally is expressed as percent recovery. See also QUALITY CONTROL SAMPLE.

laboratory duplicate—See DUPLICATE, LABORATORY.

matrix spike—See SPIKE.

measurement quality objective (MQO)—The analytical data criteria of the DATA QUALITY OBJECTIVES, which are project- or program-specific and can be quantitative or qualitative. These analytical data criteria serve as measurement performance criteria or objectives of the analytical process. MARLAP (Ref. 20) refers to these performance objectives as MQOs. Examples of quantitative MQOs include statements of required analyte detectability and the UNCERTAINTY of the analytical protocol at a specified radionuclide concentration, such as the action level. Examples of qualitative MQOs include statements of the required specificity of the analytical protocol (e.g., the ability to analyze for the radionuclide of interest (or TARGET ANALYTE) given the presence of interferences).

method uncertainty—Reference to the predicted UNCERTAINTY of the result that would be measured if the method were applied to a hypothetical laboratory SAMPLE with a specified analyte concentration. Although individual measurement uncertainties will vary from one measured result to another, the REQUIRED METHOD UNCERTAINTY is a target value for the individual measurement uncertainties and is an estimate of uncertainty before the sample is actually measured. See also UNCERTAINTY and REQUIRED METHOD UNCERTAINTY.

method validation—The demonstration that the method selected for the analysis of a particular analyte in a given matrix is capable of providing analytical results to meet the project's MEASUREMENT QUALITY OBJECTIVES and any other criteria in the ANALYTICAL PROTOCOL SPECIFICATIONS. Compare with data and software VALIDATION.

minimum detectable concentration—The minimum detectable value of the analyte concentration in a sample. The smallest (true) value of the net state variable that gives a specified probability that the value of the response variable will exceed its critical value (i.e., that the material analyzed is not blank).

minimum quantifiable concentration—Minimum quantifiable value of the analyte concentration, defined as the smallest concentration of analyte whose presence in a laboratory SAMPLE ensures that the relative standard deviation of the measurement does not exceed a specified value, usually 10 percent.

nonconformance—a deficiency in characteristic, documentation, or procedure that renders the quality of an item or activity unacceptable or indeterminate

performance-based approach—Definition of the analytical data needs and criteria of a project in terms of measurable goals during the planning phase of a project. In a performance-based approach, the project-specific data objectives that are determined during a DIRECTED PLANNING PROCESS serve as measurement performance criteria for selections and decisions regarding the conduct of the laboratory analyses. The project-specific analytical data objectives are also used for the initial, ongoing, and final evaluation of the laboratory's performance and the laboratory data. In method selection, a performance-based approach is the process wherein a validated method is selected based on a demonstrated capability to meet defined quality and laboratory performance criteria.

performance evaluation (PE) program—A laboratory's participation in an internal or external program of analyzing performance-testing samples appropriate for the analytes and matrices under consideration (i.e., PE program traceable to a national standards body, such as the National Institute of Standards and Technology (NIST) in the United States). Reference-material samples used to evaluate the performance of the laboratory are called performance-evaluation or performance-testing samples or materials. See CERTIFIED REFERENCE MATERIAL and STANDARD REFERENCE MATERIAL.

performance indicator—Instrument- or protocol-related parameter routinely monitored to assess the laboratory's estimate of controls such as chemical yield, instrument background, UNCERTAINTY, PRECISION, and BIAS. See BACKGROUND, INSTRUMENT.

performance testing—See PERFORMANCE EVALUATION PROGRAM.

precision—The closeness of agreement between independent test results obtained by applying the experimental procedure under stipulated conditions. Conversely, imprecision is the variation of the results in a set of REPLICATE measurements. Precision may be expressed as the standard deviation (IUPAC, Ref. 41).

quality assurance (QA)—An integrated system of management activities involving planning, implementation, assessment, reporting, and quality improvement to ensure that a process, item, or service is of the type and quality needed and expected. Quality assurance includes QUALITY CONTROL.

quality assurance project plan (QAPP)—A formal document describing in detail the necessary QUALITY ASSURANCE, QUALITY CONTROL, and other technical activities that must be implemented to ensure that the results of the work performed will satisfy the stated performance criteria. The QA project plan describes policy, organization, and functional activities and the DATA QUALITY OBJECTIVES and measures necessary to achieve adequate data for use in selecting the appropriate remedy.

quality control (QC)—The overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated objectives established by the project; operational techniques and activities that are used to fulfill objectives for quality. This system of activities and checks is used to ensure that measurement systems are maintained within prescribed limits, providing protection against out-of-control conditions and ensuring that the results are of acceptable quality.

quality control (QC) sample—An uncontaminated SAMPLE matrix spiked with known amounts of analytes from a source independent of the calibration standards.

quality system—A structured and documented management system describing the policies, objectives, principles, organizational authority, responsibilities, accountability, and implementation plan of an organization for ensuring quality in its work processes, products (items), and services. The quality system provides the framework for planning, implementing, and assessing the work performed by an organization and for carrying out required QUALITY ASSURANCE and QUALITY CONTROL activities (ANSI/ASQC E4-1994, Ref. 21).

readiness review—The formal process of performing a written or verbal assessment of key attributes of a program or project measured against defined minimum criteria, standards, or quality metrics before initiation of activities under that project or program.

record—A retrievable document that furnishes objective evidence of the quality of products, services, or activities and that has been verified and authenticated as technically complete and correct.

rem—The common unit for the effective or equivalent dose of radiation received by a living organism, equal to the actual dose (in rads) multiplied by a factor representing the danger of the radiation. Rem is an abbreviation for roentgen equivalent man, meaning that it measures the biological effects of ionizing radiation in humans. One rem is equal to 0.01 Sv. See SIEVERT and DOSE EQUIVALENT.

replicates—Two or more ALIQUANTS of a homogenous SAMPLE whose independent measurements are used to determine the PRECISION of laboratory preparation and analytical procedures.

reproducibility—The closeness of the agreement between the results of measurements of the same parameter carried out under changed conditions of measurement. A valid statement of reproducibility depends upon specification of the conditions changed. The changed conditions may include principle of measurement, method of measurement, observer (or analyst), measuring instrument, reference standard, location, conditions of use, and time. Reproducibility may be expressed quantitatively in terms of the dispersion characteristics of the results. Results are usually understood to be corrected results.

required method uncertainty (u_{MR})—METHOD UNCERTAINTY at a specified concentration. This is a key MEASUREMENT QUALITY OBJECTIVE.

sample—(1) A portion of material selected from a larger quantity of material, or (2) a set of individual samples or measurements drawn from a population whose properties are studied to gain information about the entire population.

sievert (Sv)—The Système International (SI) unit for the effective dose of radiation received by a living organism. This unit represents the actual dose received (GRAYS in SI or rads in traditional units) times a factor that is larger for more dangerous forms of radiation. One Sv is 100 REM. Radiation doses are often measured in mSv. An effective dose of 1 Sv requires 1 GRAY of beta or gamma radiation, but only 0.05 Gy of alpha radiation or 0.1 Gy of neutron radiation.

source, radioactive—A quantity of material configured for radiation measurement.

spike—A known amount of TARGET ANALYTE added to the environmental sample to establish whether the method or procedure is appropriate for the analysis of the particular matrix and how the TARGET ANALYTE responds when the environmental sample is prepared and measured, thereby estimating the bias introduced by the sample matrix. Also termed MATRIX SPIKE.

standard reference material—A CERTIFIED REFERENCE MATERIAL issued by NIST in the United States. NIST certifies a standard reference material for specific chemical or physical properties and issues it with a certificate that reports the results of the characterization and indicates the intended use of the material.

surveillance—Continual or frequent monitoring and verification of the status of an activity and the analysis of records to ensure that specified requirements are being fulfilled. A surveillance is less extensive and more frequent than an AUDIT and concentrates on a single item or activity.

survey—A systematic evaluation and documentation of radiological measurements with a correctly calibrated instrument or instruments that meet the sensitivity required by the objective of the evaluation.

target analyte—A radionuclide on the list of radionuclides of interest or a radionuclide of concern for a project.

test source—The final radioanalytical processing product or matrix (e.g., precipitate, solution, filter) that is introduced into a measurement instrument. A test source is prepared from laboratory sample material for the purpose of determining its radioactive constituents. See CALIBRATION SOURCE, CHECK SOURCE, and SOURCE, RADIOACTIVE.

total effective dose equivalent (TEDE)—The sum of the effective dose equivalent (for external exposure) and the committed effective dose equivalent (for internal exposure), expressed in units of Sv or rem (MARSSIM, Ref. 28). See DOSE EQUIVALENT.

uncertainty—A parameter, usually associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurement of interest (Chapter 19 of MARLAP, Ref. 20).

validation—(1) *Data validation,* the evaluation of data to determine the presence or absence of an analyte and to establish the UNCERTAINTY of the measurement process for contaminants of concern. Data validation qualifies the usability of each datum (after interpreting the impacts of exceptions identified during data VERIFICATION) by comparing the data produced with the MEASUREMENT QUALITY OBJECTIVES and any other analytical process criteria contained in the ANALYTICAL PROTOCOL SPECIFICATIONS developed in the planning process. (2) *Software validation,* the confirmation by examination and provision of objective evidence that the particular criteria for a specific intended use are fulfilled. Validation for a system is the set of activities ensuring and gaining confidence that the system is able to accomplish its intended use, goals, and objectives (ISO/IEC 15288-2002, Ref. 42).

verification—(1) *Data verification*, a process that ensures that laboratory conditions and operations were compliant with the statement of work, sampling and analysis plan, and QUALITY ASSURANCE PROJECT PLAN and that identifies problems, if present, that should be investigated during data validation. Data verification compares the material delivered by the laboratory to these criteria (compliance) and checks for consistency and comparability of the data throughout the data package and for completeness of the results to ensure that all necessary documentation is available. (2) *Software verification*, the confirmation by examination and provision of objective evidence that specified criteria have been fulfilled. A set of activities compares a system life cycle product against the necessary characteristics for that product. The system life cycle products may include, but are not limited to, specified criteria, design description, and the system itself (ISO/IEC 15288-2002, Ref. 42).

REFERENCES

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3. 10 CFR Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste," U.S. Nuclear Regulatory Commission, Washington, DC.[8]

4. 10 CFR Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel, High-Level Radioactive Waste, and Reactor-Related Greater Than Class C Waste," U.S. Nuclear Regulatory Commission, Washington, DC.[8]

5. 10 CFR Part 76, "Certification of Gaseous Diffusion Plants," U.S. Nuclear Regulatory Commission, Washington, DC.[8]

6. 10 CFR Part 30, "Rules of General Applicability to Domestic Licensing of Byproduct Material," U.S. Nuclear Regulatory Commission, Washington, DC.[8]

7. 10 CFR Part 40, "Domestic Licensing of Source Material," U.S. Nuclear Regulatory Commission, Washington, DC.[8]

8. 10 CFR Part 70, "Domestic Licensing of Special Nuclear Material," U.S. Nuclear Regulatory Commission, Washington, DC.[8]

9. 10 CFR Part 20, "Standards for Protection Against Radiation," U.S. Nuclear Regulatory Commission, Washington, DC.[8]

10. 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operations," U.S. Environmental Protection Agency, Washington, DC.[9]

11. ASME NQA-1-1994, "Quality Assurance Program Requirements for Nuclear Facilities (with Addenda)," American Society of Mechanical Engineers, New York, NY, 1994.[10]

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[8] All NRC regulations listed herein are available electronically through the Public Electronic Reading Room on the NRC's public Web site, at http://www.nrc.gov/reading-rm/doc-collections/cfr/. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room at 11555 Rockville Pike, Rockville, MD; the PDR's mailing address is USNRC PDR, Washington, DC 20555; telephone (301) 415-4737 or (800) 397-4209; fax (301) 415-3548; email PDR@nrc.gov.

[9] This regulation is available electronically through the U.S. Environmental Protection Agency's public Web site, at http://www.epa.gov/epacfr40/chapt-I.info/.

[10] Purchase information is available through the American Society of Mechanical Engineers (ASME) Web site at http://catalog.asme.org/Codes/PrintBook/NQA1_1994_Quality_Assurance.cfm.

12. Generic Letter 79065, "Radiological Assessment Branch Technical Position on Radiological Environmental Monitoring," Revision 1, U.S. Nuclear Regulatory Commission, Washington, DC, November 27, 1979.[11]

13. Regulatory Guide 1.21, "Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water-Cooled Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Washington, DC.[12]

14. Regulatory Guide 4.1, "Programs for Monitoring Radioactivity in the Environs of Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Washington, DC.[12]

15. Regulatory Guide 4.14, "Radiological Effluent and Environmental Monitoring at Uranium Mills," U.S. Nuclear Regulatory Commission, Washington, DC.[12]

16. Regulatory Guide 4.16, "Monitoring and Reporting Radioactivity in Releases of Radioactive Materials in Liquid and Gaseous Effluents from Nuclear Fuel Processing and Fabrication Plants and Uranium Hexafluoride Production Plants," U.S. Nuclear Regulatory Commission, Washington, DC.[12]

17. ISO/IEC 17025-2005, "General Requirements for the Competence of Testing and Calibration Laboratories," International Standards Organization/International Electrotechnical Commission, Geneva, Switzerland, May 2005, Correction 1, August 2006.[13]

18. EPA QA/G-4-2006, "Guidance on Systematic Planning Using the Data Quality Objectives Process," U.S. Environmental Protection Agency, Washington, DC, EPA 240/B-06/001, February 2006.[14]

19. EPA QA/G-5-2002, "Guidance for Quality Assurance Project Plans," U.S. Environmental Protection Agency, Washington, DC, EPA/240/R-02/009, December 2002.[14]

20. NUREG-1576 (MARLAP), "Multi-Agency Radiological Laboratory Analytical Protocols Manual," Volumes 1–3, U.S. Nuclear Regulatory Commission, Environmental Protection Agency, Department of Energy, Department of Defense, Department of Homeland Security, National

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11 Generic Letter 79065 is available electronically through the NRC's public Web site at http://www.nrc.gov/reading-rm/doc-collections/gen-comm/gen-letters/1979/gl79065.html.

12 All regulatory guides listed herein were published by the U.S. Nuclear Regulatory Commission or its predecessor, the U.S. Atomic Energy Commission. Most are available electronically through the Electronic Reading Room on the NRC's public Web site, at http://www.nrc.gov/reading-rm/doc-collections/reg-guides/. Active guides may be purchased from the National Technical Information Service (NTIS). Details may be obtained by contacting NTIS at 5285 Port Royal Road, Springfield, Virginia 22161, online at http://www.ntis.gov, by telephone at (800) 553-NTIS (6847) or (703) 605-6000, or by fax to (703) 605-6900. Copies are also available for inspection or copying for a fee from the NRC's Public Document Room (PDR), which is located at 11555 Rockville Pike, Rockville, Maryland; the PDR's mailing address is USNRC PDR, Washington, DC 20555-0001. The PDR can also be reached by telephone at (301) 415-4737 or (800) 397-4209, by fax at (301) 415-3548, and by email to PDR@nrc.gov.

13 Copies of all ISO publications cited in this document may be purchased from ISO in Geneva, Switzerland. Purchase information is available through the ISO Web site at http://www.iso.org/iso/en/ISOOnline.frontpage.

14 Copies of all EPA quality system publications are available for download free of charge from the EPA public Web site at http://www.epa.gov/quality/qa_docs.html.

Institute of Standards and Technology, U.S. Geological Survey, and Food and Drug Administration, Washington, DC, July 2004.[15]

21. ANSI/ASQC E4-1994, "Specifications and Guidelines for Quality Systems for Environmental Data Collection and Environmental Technology Programs," American National Standards Institute/American Society for Quality Control, New York, NY, 1994.[16]

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23. NIRMA TG11, "Authentication of Records and Media," Nuclear Information and Records Management Association, Inc., Windham, NH, 1998.[17]

24. NIRMA TG15, "Management of Electronic Records," Nuclear Information and Records Management Association, Inc., Windham, NH, 1998.[17]

25. NIRMA TG16, "Software Configuration Management and Quality Assurance," Nuclear Information and Records Management Association, Inc., Windham, NH, 1998.[17]

26. NIRMA TG21, "Electronic Records Protection and Restoration," Nuclear Information and Records Management Association, Inc., Windham, NH, 1998.[17]

27. HPS/ANSI N13.1-1999, "Sampling and Monitoring Releases of Airborne Radioactive Substances from the Stacks and Ducts of Nuclear Facilities," Health Physics Society (HPS), McLean, VA, 1999.[18]

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29. EPA QA/G-9S-2006, "Data Quality Assessment: Statistical Tools for Practitioners," U.S. Environmental Protection Agency, Washington, DC, EPA/240/B-06/003, February 2006.[14]

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[15] Copies are available electronically through NRC's public Web site at http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1576/ and from EPA's public Web site at http://www.epa.gov/radiation/marlap/links.htm.

[16] Copies of all ANSI publications cited in this document may be purchased from the American National Standards Institute, 1819 L Street, NW, 6th floor, Washington, DC 20036. Purchase information is available through the ANSI Web site at http://webstore.ansi.org/ansidocstore/default.asp.

[17] Copies of all NIRMA Technical Guidance documents cited herein may be purchased from the Nuclear Information and Records Management Association, Inc., 10 Almas Road, Windham, NH; telephone (603) 432-6476; fax (603) 432-3024; see the NIRMA Web site at http://www.nirma.org/member/publications.htm.

[18] Copies of this standard are available for purchase from the HPS Web site at http://hps.org/hpssc/n13standards.html.

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31. ASTM MNL 7A-2002, "Manual on Presentation of Data and Control Chart Analysis," 7th Edition, American Society for Testing and Materials, West Conshohocken, PA, 2002.[19]

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34. EPA QA/G-8-2002, "Guidance on Environmental Data Verification and Data Validation," U.S. Environmental Protection Agency, Washington, DC, EPA/240/R-02/004, November 2002.[14]

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36. EPA Directive 2185, "Good Automated Laboratory Practices," U.S. Environmental Protection Agency (EPA), Office of Information Resources Management, 1995.[21]

37. Regulatory Guide 1.168, "Verification, Validation, Reviews, and Audits for Digital Computer Software Used in Safety Systems of Nuclear Power Plants," U.S. Nuclear Regulatory Commission, Washington, DC.[12]

38. ANSI N42.14-1999, "Calibration and Use of Germanium Spectrometers for the Measurement of Gamma-Ray Emission Rates of Radionuclides," American National Standards Institute, New York, NY, 1999.[16]

39. International Organization for Standardization (ISO), "International Vocabulary of Basic and General Terms in Metrology," 2nd Edition, Geneva, Switzerland, 1993.[13]

40. ISO Guide 30, "Terms and Definitions Used in Connection with Reference Materials," International Organization for Standardization, Geneva, Switzerland, 1992.[13]

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19 Copies of all ASTM standards cited herein may be purchased from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959; see the ASTM International Web-based standards search tool at http://www.astm.org/cgi-bin/SoftCart.exe/NEWSITE_JAVASCRIPT/index.shtml?L+mystore+qkyo3147+117461063.

20 Copies of this standard are available for purchase from the IEEE Web site at http://standards.ieee.org/db/status/index.shtml.

21 Copies of this directive are available electronically from the EPA's public Web site at http://www.epa.gov/irmpoli8/archived/irm_galp/.

41. International Union of Pure and Applied Chemistry (IUPAC), "Nomenclature for Radioanalytical Chemistry," *Pure and Applied Chemistry*, 66:12, pp. 2513–2526, 1994.[22]

42. ISO/IEC 15288-2002, "System Engineering — System Life Cycle Processes," International Organization for Standardization, Geneva, Switzerland, 2002.[13]

[22] Copies are available electronically through the IUPAC public Web site at http://www.iupac.org/publications/pac/1994/6612/index.html.

U.S. NUCLEAR REGULATORY COMMISSION June 1982

REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 3.46
(Task FP 818-4)

STANDARD FORMAT AND CONTENT OF LICENSE APPLICATIONS, INCLUDING ENVIRONMENTAL REPORTS, FOR IN SITU URANIUM SOLUTION MINING

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INTRODUCTION

A Nuclear Regulatory Commission (NRC) source and byproduct material license is required under the provisions of Title 10, Code of Federal Regulations, Part 40, "Domestic Licensing of Source Material," to recover uranium by in situ solution mining techniques (in situ leaching). An applicant for a research and development or commercial-scale license or for the renewal or amendment of an existing license is required to provide detailed information on the facilities, equipment, and procedures to be used and an environmental report that discusses the operation's impact on the health and safety of the public and on the environment. This information is used by the Commission to determine whether the applicant's proposed activities will, among other things, result in undue risk to the health and safety of the public or adversely affect the environment. General guidance for filing an application and an environmental report is provided in § 40.31, "Applications for Specific Licenses," of 10 CFR Part 40 and in 10 CFR Part 51, "Licensing and Regulatory Policy and Procedures for Environmental Protection," respectively. The purpose of this guide is to provide specific guidance on the format* and content of an application, including an environmental report, for an in situ uranium solution mining facility license. Applications for licenses authorizing research and development studies are treated in a similar but less comprehensive manner than commercial-scale operations since such activities are not considered to be major Federal actions.

This guide is intended to provide instructive guidance. It should not be considered as a substitute for a careful evaluation of a program proposed by an applicant. Information not specifically discussed in this guide should be included in the application if it is a part of an applicant's proposed or existing operations or health and safety or environmental protection program. In some cases, information discussed in this guide may not be appropriate or necessary depending on site-specific characteristics and circumstances. In those cases, an applicant should describe why the information is not necessary or appropriate. An incomplete application will result in processing delay and may result in the rejection of a license application.

Changes to existing licensed activities and conditions require the issuance of an appropriate license amendment. An application for such an amendment should describe the proposed changes in detail and should discuss the potential environmental and health and safety impacts, using the appropriate sections of this document for guidance.

Filing an Application

The National Environmental Policy Act (NEPA) of 1969 (83 Stat. 852), implemented by Executive Order 11514 and the Council on Environmental Quality

*In cases where an applicant is also required to file an application with the licensing or permitting agency of a non-Agreement State, the applicant should consult with the NRC and the State agency prior to preparing the application so that a format agreeable to both agencies can be developed. This will provide the applicant with an opportunity to prepare a single application document and/or environmental report that would satisfy both State and Federal agencies.

regulations of July 30, 1979 (44 FR 55978), requires all agencies of the Federal Government to prepare detailed environmental statements on proposals for legislation and other major Federal actions significantly affecting the quality of the human environment. The principal objective of the NEPA is to build into the agency decisionmaking process an appropriate and careful consideration of the environmental impacts of the proposed actions. The NRC licensing and regulatory policies and procedures for the preparation and processing of environmental impact statements and related documents such as environmental impact appraisals in accordance with the NEPA are set forth in 10 CFR Part 51.

The provisions of paragraph 40.31(f) of 10 CFR Part 40 and of 10 CFR Part 51 require the submittal of both a license application (Form NRC-2) and a separate environmental report for certain activities requiring an NRC source and byproduct material license, including in situ uranium solution mining operations. In view of the nature of an in situ uranium solution mining operation, where the major consideration of both an applicant's submittal and the staff's review is the assessment of environmental impacts of the proposed activity, it appears reasonable that an application and environmental report for an in situ uranium solution mining license should consist of a single document (hereinafter referred to as the application) containing the information discussed herein.

An application for a new commercial-scale license should be filed at least 12 months prior to planned construction for the proposed operation. An application for a new research and development license should be filed at least 6 months prior to planned construction for the proposed operation. An application for a renewal of an existing license should be filed at least 30 days prior to the expiration date of the existing license. An application for an amendment to an existing license should be filed with sufficient lead time to permit a detailed assessment by the NRC staff and issuance of the required authorization before the proposed modification is scheduled to be implemented. All applications must be accompanied by a remittance in the full amount of the fee specified in § 170.31 of 10 CFR Part 170, "Fees for Facilities and Materials Licenses and Other Regulatory Services Under the Atomic Energy Act of 1954, As Amended." Applications may be filed with the Director, Office of Nuclear Materials Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, or may be filed in person at the Commission's offices at 1717 H Street NW., Washington, D.C., or 7915 Eastern Avenue, Silver Spring, Maryland.

Section 51.40 of 10 CFR Part 51 requires an applicant for a license authorizing commercial-scale in situ uranium solution mining to submit to the Director of Nuclear Materials Safety and Safeguards 15 copies of the application described above. The applicant is also required to retain an additional 85 copies of the application for distribution to Federal, State, and local authorities in accordance with written instructions issued by the Director of Nuclear Materials Safety and Safeguards. An applicant for a license authorizing research and development in situ uranium solution mining or for amendments or renewals for any in situ uranium solution mining operation should submit 10 copies of the application and/or environmental report to the Director, Office of Nuclear Materials Safety and Safeguards.

In situ uranium solution mining licenses are generally issued for 5-year periods and are renewable over the life of the project. License renewal applications are processed in a manner similar to that used for new applications. Operational experience, site-specific data, and proposed continuing activities are the primary factors considered by the NRC staff in processing renewal applications.

Presentation of Information

The applicant should strive for clear, concise presentation of the information in the license application. Each subject should be treated in sufficient depth and with sufficient documentation* to permit the Commission to independently evaluate the information presented. An evaluation of information or data should clearly state the conclusions of the evaluation and should present the analyses and supporting data in sufficient detail to permit an independent reviewer to verify this result. Tables, line drawings, and photographs should be used wherever they contribute to the clarity and brevity of the application. The number of significant figures stated in numerical data should reflect the accuracy of the data. Descriptive and narrative passages should be brief and concise. In cases where test results to support conclusions are presented, the procedures, techniques, and equipment used to obtain the test data should be included.

Information previously submitted to the Commission may be incorporated into the application by reference. Each reference should be clear and specific, i.e., the reference should indicate by document, date, page, and paragraph the information the applicant wishes to reference and how such information is pertinent.

Pertinent published information relating to a proposed site or facility and its surroundings should be referenced. Where published information or assumptions may be essential to evaluate specific aspects of the proposed activities, they should be included in summary or verbatim form or as an appendix to the application.**

An in situ uranium solution mining operation may include one or more ore bodies or well fields in the same general area plus an associated processing plant. An applicant should address all projected activities to the extent

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*Documentation as used in this guide means presentation of information, supporting data, and statements and includes (1) references to published information, (2) citations from the applicant's experience, and (3) references to unpublished information developed by the applicant or the applicant's consultants. Statements not supported by documentation may be acceptable provided the applicant identifies them as such or as expressions of belief or judgment.

**The distinction between pertinent and essential hinges on the effect that the information may have on the review of potential impacts to public health and safety and the environment. Useful information that is not likely to impact public health and safety or the environment is pertinent, whereas information that may reasonably be necessary for the review to ensure protection of public health and safety and the environment is essential.

possible over the anticipated lifetime of operations. If the proposed operation is at the site of other licensed uranium recovery activities, an applicant should consider the cumulative or synergistic effects of directly associated activities.

All pages of the application should be numbered and dated. Any changes to the original license application or environmental report made prior to issuance of a source material license should be submitted to the NRC in the form of replacement pages, figures, charts, graphs, or tables. The date of the change should be included on each page of replacement material. The applicant should review the entire application and related documents to eliminate any contradictory statements or proposals that may result from changes to a particular chapter or section.

Contents of an Application

The application should contain the information specified in items 1 through 8 of Form NRC-2. The information required in items 9 through 14 of Form NRC-2 should be incorporated into the various items identified in the chapters of this Standard Format that primarily address processing, in-plant radiation safety, and environmental considerations. Particular attention should be given to the information requested in Chapter 5, "Operations," of this Standard Format. Compliance with the specifications delineated in Chapter 5 is normally made a specific condition of the NRC operating license. The written specifications to be presented in the application in accordance with Chapter 5 (these written specifications are required by paragraph 40.31(h) of 10 CFR Part 40) are related to information in other chapters. Accordingly, Chapter 5 of this Standard Format should be reviewed in connection with other information throughout the total application. The following environmental concerns must also be fully addressed in these chapters:

1. The environmental impact of the proposed action,

2. Any adverse environmental effects that could not be avoided if the proposal were implemented,

3. Alternatives to the proposed action,

4. The relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity, and

5. Irreversible and irretrievable commitments of resources involved in the proposed action if it were implemented.

1. PROPOSED ACTIVITIES

This chapter of the application should summarize the overall proposed activities for which a license is requested in sufficient detail to permit the reviewer to obtain a basic understanding of the proposed activities and potential environmental impact. Review of the chapters that follow can then be accomplished with a better perspective and with recognition of their relative importance to the overall operations. The following subjects should be addressed: the corporate entities involved; the location of the proposed activities; land ownership; ore-body locations and estimated U_3O_8 content; proposed solution mining method and recovery process; operating plans, design throughput, and anticipated annual U_3O_8 production; estimated schedules for construction, startup, and duration of operation; plans for project waste management and disposal; plans for ground-water-quality restoration, decommissioning, and land reclamation; and surety arrangements covering eventual facility decommissioning, ground-water-quality restoration, and site reclamation. Applications for licenses authorizing commercial-scale operations should rely heavily on results from research and development operations as a basis for the proposed processes, operating plans (including plans for ground-water-quality restoration), and assessment of potential environmental impact.

2. SITE CHARACTERISTICS

This chapter should present the basic relevant information concerning those physical, ecological, demographic, and social characteristics of the environs that might be affected by the proposed operations. To the extent possible, the information presented should reflect observations and measurements made over a sufficient period of time to allow defensible conclusions to be reached.

2.1 Site Location and Layout

Provide a map showing the site and its location with respect to any Federal land and to State, county, and other political subdivisions. On detailed maps, show the location of the proposed in situ uranium solution mining operations; well fields and all principal structures (e.g., waste ponds, evaporation ponds, recovery plant); exclusion area boundaries and fences; applicant's property; adjacent properties, including water bodies, wooded areas, and farms; nearby settlements; and transportation links (e.g., railroads, highways, waterways). Indicate total acreage owned or leased by the applicant and that part occupied or modified by the proposed activity. Also indicate other existing and proposed uses of the applicant's property and the acreage devoted to these uses. A contour map of the site should be supplied with elevation contours of an interval suitable to show significant variations of the site environs and drainage gradients. For clarity, this information should be supplied on separate maps.

2.2 Uses of Adjacent Lands and Waters

Indicate, within a 3.3-km (2-mi) radius [0.8 km (0.5 mi) for research and development operations], the nature and extent of present and projected land use (e.g., agriculture, sanctuaries, hunting, grazing, industry, recreation, roads) and any recent trends of changes in population or industrial patterns. In addition, for commercial-scale operations, identify any other nuclear fuel cycle facilities located or proposed within an 80-km (50-mi) radius of the site.

Provide in tabular form for each of the 22-1/2-degree sectors centered on each of the 16 compass points, i.e., north, north-northeast, etc., the distances (to a distance of 3.3 km (2 mi)) from the center of the site to the following:

1. Nearest residence.

2. Nearest site boundary.

Identify the location, nature, and amounts of present and projected surface- and ground-water use (e.g., water supplies, irrigation, reservoirs, recreation, and transportation) within 3.3 km (2 mi) of the site boundary [0.8 km (0.5 mi) for research and development operations] and the present and projected population associated with each use point, where appropriate.

Data on both present and projected future water use(s) should be summarized and tabulated; users should be located on maps of legible scale. Tabulations should include:

1. Location: Include symbols shown on maps identifying the location of water users. Provide map coordinates if appropriate.

2. Distances from proposed uranium solution mining well fields.

3. Withdrawal Rate: Provide present and projected withdrawal rate for each water use. For ground-water uses, indicate depth of wells, ground-water elevations, flow rates, interval(s) screened, drawdown, and aquifers from which water is withdrawn, and characterize the uses of the aquifers.

4. Return Rates: Provide present and projected return rates if appropriate.

5. Type of Water Use: Provide the type of water use for each location, e.g., municipal, industrial, irrigation, stock and game watering.

6. Source and Projection of Water-Use Estimates: Where use rates are anticipated to change over the life of the project and beyond, indicate projections and the source of the projection information. Sources for such projections may be available from users or planning agencies at different levels of government.

7. Abandoned Wells: Furnish a tabulation of all abandoned wells and drill holes giving the location, depth, type of use, condition of closing, plugging procedure used, and date of completion for each well or drill hole within the site area and within 0.4 km (0.25 mi) of the well-field boundary. This information is generally available from public records and from inspection of the area.

For items 3 and 4 above, indicate monthly values if seasonal use varies significantly.

2.3 Population Distribution

Population data presented should be based on the most recent census data. On a map of suitable scale that identifies places of significant population grouping such as cities and towns within an 80-km (50-mi) radius [3.2 km (2 mi) for research and development operations] from the approximate center of projected activities, concentric circles should be drawn, with the site at the center point, at distances of 1, 2, 3, 4, 5, 10, 20, 30, 40, 50, 60, 70, and 80 km. The circles should be divided into 22-1/2-degree sectors with each sector centered on one of the 16 compass points, i.e., north, north-northeast, northeast, etc. A table appropriately keyed to the map should provide the current residential population within each area and for census years through the anticipated life of the operation. The table should provide separate and cumulative population totals for each sector and annular ring. Distance to the nearest residence should be noted for each sector. The basis for population projections should be described.

In addition, for commercial-scale operations, descriptive material should include tables giving significant population and visitor statistics of neighboring schools, plants, hospitals, sports facilities, residential areas, parks, etc., within 3.3 km (2 mi) of the solution mining operations. The material should also include appropriate available food production data in kg/yr for vegetables (by type and totals), meat (all types), and milk and any available future predictions by local governmental, industrial, or institutional organizations within 3.3 km (2 mi) of the site boundary.

2.4 Regional Historic, Archeological, Architectural, Scenic, Cultural, and Natural Landmarks

The application should include a brief discussion of the historic, scenic, archeological, architectural, cultural, and natural significance, if any, of the proposed site and nearby areas with specific attention to the site and nearby areas listed in the National Registry of Natural Landmarks and properties included in or eligible for inclusion in the National Register of Historic Places.

The National Registry of Natural Landmarks appears in the Federal Register (37 FR 1496). The National Register of Historic Places also appears in the Federal Register (44 FR 7416) where additions are published annually. General guidance on the treatment of historic, archeological, architectural, and cultural features can be obtained from the National Park Service publication entitled "Preparation of Environmental Statements: Guidelines for Discussion of Cultural (Historic, Archeological, Architectural) Resources," August 1973.*

The application should identify those properties included in or eligible for inclusion in the National Register of Historic Places located within the area of the proposed project. The applicant should also consult with the appropriate State Historic Preservation Officer (SHPO) concerning the identification of properties included in or eligible for inclusion in the National Register of Historic Places. The application should contain evidence of contact with the appropriate SHPO. A copy of the SHPO's comments concerning the effect of the facility on historic, archeological, architectural, and cultural resources should be included in the application.

State whether new roads, pipelines, and utilities for the proposed activity will pass through or near any area or location of known historic, scenic, cultural, natural, archeological, or architectural significance.

2.5 Meteorology

This section should provide a description of the meteorological diffusion characteristics of the site and its surrounding area. The description should be based on data collected on site and/or at nearby local meteorological stations. Sufficient data should be included to permit independent evaluations and assessments of atmospheric diffusion characteristics. Based on past application reviews of research and development operations, detailed meteorological data (other than basic wind speed and direction and precipitation/evaporation data) are not needed.

The following data concerning site meteorology from meteorological measurements taken on site and/or at nearby representative stations should be provided:

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*Copies may be obtained from Chief Historian, Room 1226, National Park Service, 18th and C Streets NW., Washington, D.C. 20240.

1. Joint frequency data

   a. National Weather Service (NWS) station data

      (1) Locations of all NWS stations within an 80-km (50-mi) radius

      (2) Available joint frequency distribution data by wind direction, wind speed, and stability class (3-dimensional numerical array)

      (3) Period of record by month and year

      (4) Height of data measurement

   b. Onsite meteorological data

      (1) Locations and heights of instrumentation

      (2) Description of instrumentation

      (3) Minimum of 1 full year of onsite joint frequency distribution data broken down by wind direction, wind speed, and stability class (3-dimensional array) with a joint data recovery of 90 percent or more

2. Miscellaneous data

   a. Annual average mixing layer heights

   b. Description (general) of regional climatology, particularly including frequencies and durations of extreme wind speeds

3. Total precipitation and evaporation by month

This information should be fully documented and substantiated as being representative of expected long-term conditions at and near the site.

The joint wind speed-stability-direction frequencies should be presented in tabular form, giving the frequencies as fractions when using 5-year NWS summaries or as the number of occurrences when using only 1 or 2 years of onsite data. The data should be presented for each of the 16 compass directions, and the stability categories should be established to conform as closely as possible with those of Pasquill. In addition, the annual average inversion height should be provided from other nearby weather stations.

Guidance on acceptable onsite meteorological measurements and data format is presented in Regulatory Guide 1.23 (Safety Guide 23), "Onsite Meteorological Programs."

In addition, this section should provide a discussion of general climatology, existing levels of air pollution, the relationship of the meteorological data gathered on a regional basis to local data, the impact of the local terrain and large lakes and other bodies of water on meteorological conditions in the area, and the occurrence of severe weather in the area and its effects. Data on diurnal and monthly averages of temperature and humidity should also be provided.

2.6 Geology and Seismology

A description of the geology of the site and establishment of the continuity of the geologic environs represented in the strata at the site should be included in the application. The discussion should note local and regional stratigraphy, structure, and tectonic history and should include geologic features such as dips, faulting, fracturing, and continuity of geologic strata at the site and in nearby regions. Structural and stratigraphic maps and cross sections, with representative core and geophysical well-log data, of the site and its environs should be included. Also include an isopach map of the intended zone of injection or production and confining beds. Conclusions concerning the geology, particularly the lateral continuity and vertical thickness of the ore zone(s), surrounding lithologic units, and confining zones, should be based on lithologic logs from core and drill cuttings, geophysical data, remote-sensing measurements, and the results of other appropriate investigations that are needed to define the geology. Geologic and geophysical logs and other data should be furnished in an appendix. Proprietary data should be so designated and kept separate from the remainder of the application.

An inventory of economically important minerals and energy-related deposits, in addition to the uranium ore, should be included in the discussion. Data defining the geochemistry of the ore zone and the geologic zones immediately surrounding the ore zone that will or could be affected by injected lixiviant should be included. Unique minerals (including those that might be affected by fluid movement associated with the proposed project such as bentonite) or paleontological deposits of particular scientific interest should also be identified. Any effect that planned operations might have on the future availability of other mineral resources should be noted.

Discuss the seismicity (including its history) of the region. Where possible, associate seismic events with tectonic features identified above. Furnish a regional earthquake epicenter map showing site location.

2.7 Hydrology

The effects of well construction and well-field operation on adjacent surface and ground waters and the effective control and monitoring of subsurface process fluids are of prime importance. The applicant should describe in quantitative terms the physical, chemical, biological, radiological, and hydrological characteristics; the typical seasonal ranges and averages; and the historical extremes for surface-water bodies and aquifers associated with the proposed project. Ranges, averages, and extremes should be evaluated to the extent that such characteristics can be distinguished from possible excursions during operations. Water-quality data should include measurements made both at and in close proximity (within 200-400 feet) of the proposed in situ uranium solution mining areas (well fields). NRC staff Technical Position Paper* WM-8102, "Groundwater Monitoring at Uranium In Situ Solution Mines," should be reviewed in connection with this section. The position paper provides specific guidance for obtaining both surface- and ground-water-quality baseline data.

2.7.1 Ground Water

The hydrology of both regional and local ground-water systems should be described. The description of the ground-water setting should include identification of the average thickness, lateral extent, general flow direction, average yield, and premining water elevation maps of the regional aquifer, the ore zone aquifer, and surrounding aquifers that might be affected.

Within the local ground-water systems, all aquifers that may be affected by the proposed in situ uranium solution mining operations should be identified. The hydrologic properties of the local aquifers, including aquifer thickness, distribution of potentiometric levels, flow gradients, flow directions, flow velocities, directional permeabilities, transmissivities, storage coefficients, and porosities, should be described in detail. Confining beds or other lithologic units separating the ore zone(s) from other aquifers should be described. Vertical permeabilities, horizontal permeabilities, competence, lateral extent, and other data sufficient for evaluation of the confining properties of the beds with respect to preventing excursions should also be defined. A description of soil types and near-surface material, including hydrologic properties, should be presented in sufficient detail to permit evaluations of the effects of surface activities related to the proposed uranium mining operations. Conclusions concerning the hydrologic characteristics of site aquifers and confining beds and soil types should be based on well borings and cores, aquifer pumping tests, laboratory permeability tests, soil surveys, and the results of other appropriate investigations needed to define the hydrology.

Descriptions of local ground-water wells, including well location, uses, amounts used, depth, screened intervals, yield, static water level, and preoperational water quality used, should be presented in the application. The descriptions should be in sufficient detail to fully define the uses and sources of ground water in the project environs.

All project-related wells, including well location, elevation, depth, screened intervals, static water level, and preoperational water quality, should be described in the application.

The preoperational water quality of all aquifers that might be affected by the proposed operations, as well as the changes expected in quality due to the solution mining activities, should be described.

Data and analysis of pumping tests, water-quality measurements, and other tests should be furnished to verify all hydrologic interpretations and conclusions. Methods of testing and analysis should also be described.

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*NRC staff technical position papers that are referenced in this Standard Format may be obtained from the Director, Division of Waste Management, Office of Nuclear Materials Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

2.7.2 Surface Water

Describe the location, size, shape, and hydrologic characteristics and uses of surface-water bodies in the environs of the site.

Include a description of upstream and downstream river control structures, and provide a topographic map showing the major hydrologic features. Water-quality analysis and flow rates from U.S. Geological Survey gaging stations in nearby environs should be included.

In the vicinity of evaporation ponds near drainage courses or where surface runoff is rerouted, the drainage areas of the water courses should be delineated. Where an embankment prevents surface runoff from entering or threatening an impoundment, stream cross sections in the impoundment vicinity should be provided to clearly show the vertical and horizontal relationships of the channel and the pond embankments.

2.8 Ecology

In this section, the applicant should describe the flora and fauna in the vicinity of the site, their habitats, and their distribution. This inventory should identify species that may require specific attention because of their importance to the community. A species is important (for the purposes of this guide) if a specific causal link can be identified between the facility and the species and if one or more of the following criteria applies: (1) the species is commercially or recreationally valuable, (2) the species is threatened or endangered,* (3) the species affects the well-being of some important species within criterion (1) or (2), or (4) the species is critical to the structure and function of the ecological system or is a biological indicator of radionuclides or chemical pollutants in the environment.

The inventory should establish the identity of the majority of the terrestrial and aquatic organisms on or near the site and their relative (qualitative) abundance. The applicant should identify the important species from this list and should discuss in detail their quantitative abundance. This discussion should include species that migrate through the area or use it for breeding grounds. Special attention should be given to the relative importance of the proposed site environs to the total regional area for the living resources (potential or exploited).

For commercial-scale operations and for research and development operations involving drying of yellowcake, the applicant should provide data on the count and distribution of important domestic fauna, in particular, cattle, sheep, and other meat animals that may be involved in the exposure of man to radionuclides. Important game animals should receive similar treatment. A map showing the distribution of the principal plant communities should be provided.

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* In the writing and reviewing of environmental reports, specific consideration should be given to possible impact on any species (or its habitat) that has been determined to be endangered or threatened with endangerment by the Secretary of the Interior and the Secretary of Commerce. New terminology defining "endangered or threatened with endangerment" has been issued in Public Law 93-205, 87 Stat. 884.

The discussion of species-environment relationships should include descriptions of area usage (e.g., habitat, breeding) for important species; life histories of important regional animals and aquatic organisms, their normal seasonal population fluctuations, and their habitat requirements; and identification of food chains and other interspecies relationships, particularly when these are contributory to predictions or evaluations of the impact of the facility on the regional biota.

Any definable preexisting environmental stresses from sources such as pollutants, as well as pertinent ecological conditions suggestive of such stresses, should be identified. The status of ecological succession should be described.

The information should be presented in two separate subsections: "Terrestrial Ecology" and "Aquatic Ecology." The sources of information should be identified. As part of this identification, a list of pertinent published material dealing with the ecology of the region should be presented. All ecological or biological studies of the site or its environs currently in progress or planned should be referenced and described.

2.9 Background Radiological Characteristics

Report site-specific radiological data, including both natural background radiation levels and results of measurements of concentrations of radioactive materials occurring in important biota, in soil, in air, and in surface and ground waters that could be affected by the proposed activities. These data, whether determined during the applicant's preoperational surveillance program or obtained from other sources, should be referenced. NRC staff Technical Position Paper WM-8102 should be reviewed in connection with background (baseline) surface- and ground-water-quality monitoring programs.

2.10 Background Nonradiological Characteristics

Site-specific nonradiological characteristics, particularly those that are related to expected site-related effluents, should be reported. Data should include such indicators as heavy metals and other potentially toxic substances in surface and ground waters, atmospheric pollutants, dusts, etc., that could affect water or air quality. Other regional sources of these same materials should be noted along with a discussion of the possible incremental contribution to the existing levels found at the site. NRC staff Technical Position Paper WM-8102 should be reviewed in connection with background (baseline) surface- and ground-water-quality monitoring programs.

2.11 Other Environmental Features

Some relevant information on the environs may not clearly fall within the scope of the preceding topics. Additional information may be required with respect to some environmental features in order to reflect the value of the site and site environs to important segments of the population. Such information should be included in this section.

Much of the information from the preceding topics will be used by the NRC to perform an independent assessment of offsite radiological impacts. Detailed computer assessments are performed for commercial-scale operations. Suggested formats for supplying much of the information necessary for an independent assessment of offsite radiological impacts resulting from the operation of a proposed commercial-scale facility are included as Appendix A to this guide.

3. DESCRIPTION OF PROPOSED FACILITY

The in situ uranium solution mining operation should be described in this chapter. Since environmental effects are of primary concern, the combined effects of mining effluents and related systems that interact with the environment should be described in sufficient detail to permit an independent evaluation by the NRC of the proposed project.

3.1 Solution Mining Process and Equipment

The entire in situ solution mining process should be described in sufficient detail to permit evaluation of all operations and processes involved. This description would include data about the ore bodies, the feasibility of processing defined well-field areas, well construction techniques and integrity testing procedures to ensure that well installations will not result in hydraulic communication between production zones and overlying or underlying aquifers, how wells and ponds will be completed, injection/production rates and pressures, proposed operating plans and schedules, details of the proposed uranium recovery facility and its operation, plant material balances and flow rates, lixiviant makeup and recovery efficiency, and major constituents and their concentrations in the gaseous, liquid, and solid wastes and effluents that will be generated in the process. The following should also be provided:

1. A map or maps showing the proposed sequence and schedules for the in situ uranium solution mining well-field area(s) and well-field ground-water-quality restoration operations,

2. A flow diagram of the process and/or circuit,

3. A material balance diagram,

4. A description of any chemical recycle systems,

5. A water balance diagram for the entire system, and

6. A map or maps showing the proposed sequence and schedules for land reclamation of the well-field areas.

3.2 Recovery Plant Equipment

A physical description and operating characteristics for the proposed major items of process equipment should be provided. A diagram of the proposed plant layout, indicating areas and points where dusts, fumes, or gases would be generated, should be included. The diagram should also show the locations of all ventilation, filtration, confinement, and dust collection systems, as well as the location of the radiation monitoring equipment identified in Chapters 4, "Effluent Control Systems," and 5, "Operations."

3.3 Instrumentation

A description of proposed process instrumentation and control systems relevant to safety and radiation safety sampling and monitoring instrumentation, including their minimum specifications and operating characteristics, should be provided. This includes well-field process control equipment for monitoring injection pressures and rates and production rates. Sufficient information should be included to permit an evaluation of the interrelationship between instrumentation systems and the operations or processes to be controlled or monitored.

4. EFFLUENT CONTROL SYSTEMS

4.1 Gaseous and Airborne Particulates

Provide a description of all proposed ventilation, filtration, and confinement systems that are to be used during operations to control the release of radioactive materials to the atmosphere. Include an analysis of equipment as designed and operated to prevent radiation exposures to employees and to limit such exposures to as low as is reasonably achievable (ALARA). The definition and operating philosophy for ALARA are contained in paragraph 20.1(c) of 10 CFR Part 20 and in Regulatory Guide 8.10, "Operating Philosophy for Maintaining Occupational Radiation Exposures As Low As Is Reasonably Achievable." Also include a physical description of discharge stacks, types and estimated composition and flow rates of atmospheric effluents, and proposed methods for controlling such release levels ALARA.

4.2 Liquids and Solids

To the extent that information is not provided in Section 3.1, provide a realistic estimate of the quantities and composition of all waste residues expected, along with proposed procedures for their management. Where retention systems such as ponds are to be used to prevent the release of liquid or solid wastes containing radioactive material, provide the information specified in Regulatory Guide 3.11, "Design, Construction, and Inspection of Embankment Retention Systems for Uranium Mills," and describe the type of liner and leak detection system proposed, as well as the quality assurance program to be used for installation of the liner and leak detection system. Also provide descriptions and design details for all temporary and permanent surface-water diversion facilities. NRC staff Technical Position Papers WM-8101, "Design, Installation, and Operation of Natural and Synthetic Liners at Uranium Recovery Facilities"; WM-8201, "Hydrologic Design Criteria for Tailings Retention Systems"; and "Explorations for Design and Evaluation of Uranium Mill Tailings Retention Systems," should be consulted in addition to Regulatory Guide 3.11 to provide design criteria acceptable to the NRC staff. Describe contingency plans to mitigate any environmental impact in the event that leakage occurs from impoundments containing potentially harmful materials. (See § 20.301 of 10 CFR Part 20.)

If effluents are to be released into waters of the United States, provide a discussion of the status of efforts to obtain a water-quality certification under Section 401 and discharge permits under Section 402 of the Federal Water Pollution Control Act, as amended, or submit copies of these items if already issued.

4.3 Contaminated Equipment

Provide a description of the methods for disposing of contaminated waste solids (e.g., ion exchange resins, filters, filter presses, obsolete or worn-out equipment) that are generated in the uranium recovery process.*

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*See Branch Technical Position, "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material," dated November 1976. Copies may be obtained from the Director, Division of Waste Management, Office of Nuclear Materials Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

5. OPERATIONS

Compliance with the statements, representations, and procedures provided in this chapter will normally be made a specific condition of the NRC source material license. Thus, the sections of this chapter should be considered as specific commitments on the part of the applicant for conducting operations, radiological protection programs, and all monitoring programs. In addition, the bases for all programs addressed in this chapter, as well as the demonstration of their adequacy, should be provided. In order to facilitate administration of the license by the licensee and NRC, this chapter should be complete in itself, insofar as possible, without references to other submittals.* The requirements of 10 CFR Part 20 are an integral part of this chapter. Specific sections of 10 CFR Part 20 are referenced where appropriate.

5.1 Corporate Organization and Administrative Procedures

Provide a detailed description of the applicant's proposed organization, including authority and responsibility of each level of management and supervision with regard to development, review, approval, implementation, and adherence to operating procedures, radiation safety programs, environmental and ground-water monitoring programs and associated quality assurance programs, routine and nonroutine maintenance activities, and changes in any of the above.

5.2 Management Control Program

Describe the proposed management control program and administrative procedures to ensure that all activities are conducted in accordance with written operating procedures that will be approved and reviewed at specified frequencies by the applicant's radiation safety staff. This program should provide a method for ensuring that any nonroutine work or maintenance activity not covered by an effective operating procedure will be conducted in accordance with a special work permit reviewed and approved by the applicant's radiation safety staff.

5.3 Management Audit and Inspection Program

Describe the proposed management audit and internal inspection program, including frequencies and types and scopes of reviews and inspections, action levels, and corrective action measures. Identify by management position the person responsible for each phase of the audit and inspection program. Also

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*Draft Regulatory Guides OH 941-4, "Information Relevant to Ensuring That Occupational Radiation Exposures at Uranium Mills Will Be As Low As Is Reasonably Achievable," OH 710-4, "Health Physics Surveys in Uranium Mills," and Regulatory Guide 8.22, "Bioassay at Uranium Mills," should be reviewed in connection with this chapter. Although these guides are for uranium mills, some of the guidance may be applied to solution mining recovery plants since the basic processes and potential for exposing workers to uranium and its daughters in a recovery plant are similar to those of certain milling operations.

provide a detailed description of the program for ensuring that employee exposures (to both airborne and external radiation) and effluent releases are as low as is reasonably achievable (ALARA program). (See paragraph 20.1(c) of 10 CFR Part 20.)

5.4 Qualifications

Provide a description of the minimum qualifications and experience required for personnel holding positions in the applicant's proposed organization who will be assigned the responsibility for developing, conducting, and administering the radiation safety program. Describe in an appendix the qualifications of the persons currently proposed for these positions. (In cases where specific individual appointments may not have been made when an application was filed, minimum specifications will suffice.)

5.5 Training

Provide a description of the proposed employee radiological protection training program, including the content of the initial training or indoctrination, testing, on-the-job training, and extent and frequency of retraining. In an appendix in conformance with § 19.12 of 10 CFR Part 19, provide a copy of the proposed written radiological safety instructions to be provided to employees. These instructions should include provisions for personal hygiene (including washing), for contamination surveying prior to eating or leaving the operating area, for wearing personnel monitoring devices and respirators, for good housekeeping requirements, for cleaning up spills within the site boundary, and for emergency action in the event of accidents.

5.6 Security

Provide a description of the proposed method for preventing unauthorized entry into the controlled area. (See § 20.203 of 10 CFR Part 20.)

5.7 Radiation Safety Controls and Monitoring

Paragraph 20.1(c) of 10 CFR Part 20 states that "... persons engaged in activities under licenses issued by the Nuclear Regulatory Commission pursuant to the Atomic Energy Act of 1954, as amended, and the Energy Reorganization Act of 1974 should, in addition to complying with the requirements set forth in this part, make every reasonable effort to maintain radiation exposures, and releases of radioactive materials in effluents to unrestricted areas, as low as is reasonably achievable." Regulatory Guide 8.10 provides the NRC staff position on this important subject. License applicants should give consideration to the ALARA philosophy, as described in Regulatory Guide 8.10, in the development of plans for work with licensed radioactive materials. The following material should be provided.

5.7.1 Effluent Control Techniques

Describe the proposed systems and procedures designed to minimize in-plant and environmental emissions at each step of the process where releases might occur. Provide the minimum performance specifications such as filtration or scrubber efficiency and airflow for operating the ventilation, filtration, and confinement systems throughout the recovery plant and associated laboratories at their reasonably expected best performance and the frequency of tests and inspections to ensure that these specifications are being met. Include descriptions of the contingency plans to be implemented in the event of equipment failures or spills.

5.7.2 External Radiation Exposure Monitoring Program

Describe the proposed methods, instrumentation, and equipment for determining exposures of employees to external radiation, in conformance with § 20.101 of 10 CFR Part 20, during routine and nonroutine operations, maintenance, and cleanup activities. Also describe the type of surveys to be conducted, criteria for determining survey locations, frequency of surveys, action levels, management audits, and corrective action requirements. For personnel monitoring devices such as film badges, indicate the number and category of personnel involved in the program and the sensitivity and range of the devices. For survey instruments, provide instrument sensitivities, ranges, calibration methods (in an appendix), and frequency of calibration. (See §§ 20.201 and 20.202 of 10 CFR Part 20.)

5.7.3 Airborne Radiation Monitoring Program

Describe the proposed sampling program to determine concentrations of airborne radioactive materials (including radon) during routine and nonroutine operations, maintenance, and cleanup activities. (See §§ 20.103, 20.201, and 20.203 of 10 CFR Part 20.) In the description of the sampling program, include:

1. The criteria for determining sampling locations with respect to process operations and personnel occupancy; and

2. The frequency of sampling, type of analyses, sensitivity of overall sampling and analyses, action levels, management audits, corrective action requirements, and instrumentation calibration frequency. Procedures for sample analyses and instrument calibration should be included in an appendix.

5.7.4 Exposure Calculations

Describe the proposed procedure, in conformance with § 20.103 of 10 CFR Part 20, to determine the intake of radioactive materials by personnel in work areas where airborne radioactive materials could exist. Include those exposures incurred during nonroutine operations, maintenance, and cleanup activities as well as during routine activities.

5.7.5 Bioassay Program

Describe the proposed bioassay program to confirm the results derived from the programs identified in Sections 5.7.3 and 5.7.4. Indicate the number and category of personnel involved in the program, the types and frequencies of bioassays performed, and action level criteria to be applied to bioassay results. (See §§ 20.103 and 20.108 and Appendix B to 10 CFR Part 20.)

5.7.6 Contamination Control Program

Describe the proposed occupational radiation survey program to determine that employees (plus their workclothes or coveralls, etc.) entering clean areas (lunchrooms, offices, etc.) or leaving the site are not contaminated with radioactive materials. The description should include proposed housekeeping and cleanup requirements and specifications in process areas to control contamination; frequency of surveys of clean areas; survey methods; and minimum sensitivity, range, and calibration frequency of survey equipment. Provide proposed contamination criteria or action levels for clean areas and for the release of materials, equipment, and workclothes to clean areas or from the site. Procedures for instrument calibration should be included in an appendix. (See §§ 20.201 and 20.202 of 10 CFR Part 20.) See also Branch Technical Position, "Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material," dated November 1976.

5.7.7 Airborne Effluent and Environmental Monitoring Programs*

Describe in detail the proposed effluent and environmental monitoring programs, including methods and procedures for measuring concentrations and quantities of both radioactive and nonradioactive materials released to and in the environs. The description of the proposed monitoring programs should include the technical basis used to determine environmental concentrations to show conformance with §§ 20.103, 20.105, and 20.106 of 10 CFR Part 20.

For both effluent and environmental monitoring, the frequency of sampling and analysis, the types and sensitivity of analysis, action levels and corrective action requirements, and the minimum number and criteria for locating effluent and environmental monitoring stations should be provided. Proposed locations should be indicated on a topographic map of the site and surrounding area.

5.7.8 Ground-Water and Surface-Water Monitoring Programs

Describe the monitoring programs to be used to determine if the lixiviant and/or contaminants are in hydrologic communication with other lithologic zones or with ground-water or surface-water supplies or have migrated laterally outside the well-field area. This description should include the technical basis for the monitoring programs, including the number and location of monitoring stations, the criteria used for locating sampling stations and determining sampling frequency, the excursion indicators and criteria used in determining them, and upper control limits for excursion indicators and corrective action requirements. Provide the procedures for sample collection and analyses in an appendix. See NRC staff Technical Position Paper WM-8102 regarding excursion indicator sets, upper control limits, and operational ground-water monitoring. (See §§ 20.103, 20.105, and 20.106 of 10 CFR Part 20.)

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*Regulatory Guide 4.14, "Radiological Effluent and Environmental Monitoring at Uranium Mills," should be reviewed in connection with this section.

5.7.9 Quality Assurance*

Describe the quality assurance programs for all radiological and nonradiological in-plant, effluent, and environmental (including ground-water) monitoring programs.

*Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring Programs (Normal Operations) - Effluent Streams and the Environment," should be reviewed in connection with this section.

6. GROUND-WATER-QUALITY RESTORATION, SURFACE RECLAMATION, AND PLANT DECOMMISSIONING

The applicant should describe in detail proposed plans for ground-water-quality restoration, surface reclamation, and plant decommissioning.

Detailed discussions should be provided for the following:

1. Plans and schedule(s) for ground-water-quality restoration, including:

a. An estimate of the quantities, concentrations, and lateral and vertical extent of those chemicals that may persist in leached-out well-field production zones after termination of in situ mining operations and prior to restoration activities;

b. A description of proposed methods and techniques to be used to achieve ground-water-quality restoration, including identification of in situ chemical reactions that may hinder or enhance restoration. The applicant should provide an analysis of the methods and techniques to be used to achieve restoration in terms of fluids to be used during restoration and the hydraulic and geochemical properties of the receiving stratum. For commercial-scale operations, the restoration methods and techniques should be based on results obtained from research and development operations. In addition, for commercial-scale operations, a schedule for sequential restoration of mine units should be included;

c. A description of the expected postreclamation conditions and quality of restored ground waters, compared with the preoperational land and water-quality characteristics;

d. An assessment of the proposed water-quality restoration operations with respect to adversely affecting ground waters outside production zones; and

e. The procedures to be used for plugging, sealing, capping, and abandoning all wells associated with the in situ solution mining operations.

2. Plans and schedule(s) for reclaiming disturbed lands, including;

a. A contour map showing the approximate postreclamation surface contours for affected lands and immediate surrounding area(s);

b. Procedures for the reclamation of any temporary diversion ditches and impoundments;

c. Procedures for reestablishing any surface drainage that may be disrupted by the solution mining operations;

d. Procedures for mitigating or controlling the effects of any subsidence; and

e. Procedures for ground surface preparation, depth of topsoil replacement and revegetation plans, erosion control and water conservation practices, and proposed postoperational land use.

3. Procedures for removing and disposing of structures used in conjunction with the in situ solution mining operations, including procedures for managing all toxic and radioactive materials. In the discussion pertaining to the disposal of wastes produced by in situ solution mining operations, procedures for removal and disposal of byproduct material to an existing uranium mill tailings disposal site or licensed burial site should be included.

4. Procedures for conducting postreclamation and decommissioning radiological surveys to ensure that sufficient potential radioactive contamination has been removed from the site to permit its release for unrestricted use. Include plans for postoperational ground-water monitoring to ensure that restored water quality is stabilized. See NRC staff Technical Position Paper WM-8102 regarding postoperational ground-water monitoring programs.

5. Financial arrangements to be made to ensure that adequate funds will be available for the ground-water-quality restoration, facility decommissioning, land reclamation, offsite disposal of byproduct waste material, and monitoring described above. Such arrangements should be based on a financial assessment of estimated costs, which should also be included.

7. ENVIRONMENTAL EFFECTS

The construction of facilities and well drilling will inevitably affect the environment; some of the effects may be adverse and others beneficial. Effects are considered adverse if environmental change or stress causes a valuable or otherwise important biotic population or natural resource to be less safe, less healthy, less abundant, less productive, less esthetically or culturally pleasing; if the change or stress reduces the diversity and variety of individual choice or the standard of living; or if the change or stress tends to lower the quality of renewable resources or to impair the recycling of depletable resources.

The applicant's discussion of adverse environmental effects should distinguish between those that are considered unavoidable and subject to later amelioration and those that are regarded as unavoidable and irreversible. Those effects representing an irreversible and irretrievable commitment of resources should receive detailed consideration. (In the context of this discussion, "irretrievable commitment of resources" refers to natural resources and means their permanent impairment, e.g., loss of wildlife habitat; destruction of nesting, breeding, or nursing areas; interference with migratory routes; loss of valuable or esthetically treasured natural areas; and expenditure of directly used resources.)

7.1 Site Preparation and Construction

The applicant should organize the discussion in terms of the effects of site preparation and construction on both land use and water use. The applicant should consider the consequences to both human and wildlife populations and should indicate which are unavoidable, irreversible, etc., according to the categorization set forth above.

A description of how construction activities may disturb the existing terrain and wildlife habitats should be included in the land-use discussion. Consider the effects of such activities as building temporary or permanent roads, bridges, or service lines; disposing of trash; excavating; and land filling. Provide information bearing on such questions as how much land will be disturbed and for how long, and will there be dust or smoke problems. Indicate proximity of human populations, and identify undesirable impacts on their environment arising from noise, disruption of stock grazing patterns, and inconvenience due to the movement of men, material, and machines, including activities associated with any provision of housing, transportation, and educational facilities for workers and their families. Describe any expected changes in accessibility of historic and archeological sites in the region. Discuss measures designed to mitigate or reverse undesirable effects such as erosion control, dust stabilization, landscape restoration, control of truck traffic, and restoration of affected habitats.

The discussion should also include any effects of site preparation and construction activities the consequences of which may be beneficial to the region.

The discussion of water use should describe the impact of site preparation and construction activities on area water sources. The applicant should describe the effects of these activities on fish and wildlife resources, water quality, water supply, esthetics, etc., as applicable. Describe measures such as pollution control and other procedures for habitat improvement to mitigate undesirable effects.

7.2 Effects of Operations

The impacts of operation of the proposed activity should be, to the fullest extent practicable, quantified and systematically presented in this section. In the discussion of each impact, the applicant should make clear whether the supporting evidence is based on theoretical, laboratory, onsite, or field studies undertaken for this or for previous operations. The source of each impact (the plant subsystem, waste effluent) and the population or resource affected should be made clear in each case. The impacts should be distinguished in terms of their effects on surface-water bodies, ground water, air, land, land use, ecological systems, and important plants and animals, etc.

7.3 Radiological Effects

In this section, the applicant should consider the radiological effects of operations on man. Estimates of the radiological impact on man via various exposure pathways should be provided.

7.3.1 Exposure Pathways

The various possible pathways for radiation exposure of man should be identified and described in textual and flow-chart format. Discuss any exposure pathways, if they exist, involving radionuclide accumulation in specific components of the environment. Suggested formats for supplying information necessary for the NRC independent evaluation of offsite radiological impacts resulting from the operation of a proposed commercial-scale facility are outlined in Appendix A to this guide.

7.3.2 Exposures from Water Pathways

Estimate the expected annual average concentrations of radioactive nuclides in receiving water at locations where water is consumed or is otherwise used by human beings or where it is inhabited by biota of significance to human food chains. Specify the dilution factors used in preparing the estimates and the locations where the dilution factors are applicable. Consideration should be given to the absence of mixing and dilution because of factors such as channeling.

Estimate the expected radionuclide concentrations in aquatic and terrestrial organisms significant to human food chains. Use bioaccumulation factors as necessary.

Using the above information and any other necessary supporting data, calculate the total annual body and significant organ doses (in millirems) to individuals in the population from all receiving-water-related exposure pathways, i.e., all sources of internal and external exposure. Provide an appendix describing details of the models and assumptions used in these calculations.

7.3.3 Exposures from Air Pathways

From release rates of airborne radioactivity and meteorological data, estimate total annual body and significant organ doses (in millirems) to individuals exposed at the point of maximum ground-level concentrations off site, individuals exposed at the site boundary in the direction of the prevailing wind, individuals exposed at the site boundary nearest to the sources of emission, and individuals exposed at the nearest residence in the direction of the prevailing wind. Assume annual average meteorological conditions. Identify locations of points of release (e.g., stack, roof vent) used in these calculations.

Estimate deposition of radioactive materials on food crops and pasture grass. Estimate total annual body doses (in millirems) and significant annual doses received by other organs via such potential pathways.

Provide an appendix describing the models used in these calculations.

7.3.4 Exposures from External Radiation

Provide an estimate of the maximum annual external dose (in millirems) that would be received by an individual from direct radiation at the nearest site boundary.

7.3.5 Total Human Exposures

Provide estimates of the maximum annual doses (in millirems) that could be received via all pathways described above by an individual at the site boundary and at the nearest residence.

For commercial-scale operations, the applicant should also present a table that summarizes the estimated radiation dose to the regional population (within 80 km) from the uranium recovery plant and well-field-related sources using values calculated in previous sections. The tabulation should include the total annual 100-year environmental dose commitment (person-rems) to the population from all pathways.

7.3.6 Exposures to Flora and Fauna

From considerations of the exposure pathways and the distribution of radioactivity released into the environs, the applicant should estimate the maximum radionuclide concentrations that may be present in important local flora and local and migratory fauna. Values of bioaccumulation factors used in preparing the estimates should be based on site-specific data if available; otherwise, values from the literature may be used. Tabulate and reference the values of bioaccumulation factors used in these calculations.

7.4 Nonradiological Effects

In this section, the specific concentrations of nonradioactive wastes in effluents at the points of discharge should be compared with natural ambient concentrations without the discharge and should also be compared with applicable standards. The projected effects of the effluents for both acute and chronic exposure of the biota (including any long-term buildup in soils and sediments and in the biota) should be identified and discussed. Dilution and mixing of discharges into the receiving environs should be discussed in detail, and estimates of concentrations at various distances from the point of discharge should be provided. The effects on terrestrial and aquatic environments from chemical wastes that contaminate ground water should be included.

Also discuss any potential effects of the proposed operation that do not clearly fall under any specific topic delineated above. These may include changes in land and water use at the project site; sanitary and other recovery plant waste systems; interaction of the facility with other existing or projected neighboring facilities; effects of ground-water withdrawal on ground-water resources in the vicinity of the well field(s) and recovery plant(s); effects of construction and operation of roads, transmission corridors, railroads, etc.; effects of changes in surface-water availability on biotic populations; and disposal of solid and liquid wastes other than those already discussed.

7.5 Effects of Accidents

Discuss the environmental effects of possible accidents that may occur, whether or not those accidents may produce an impact on the site or its environs. Analyses should be based on relevant experience and accident statistics from similar operating facilities. Accidents due to both human causes and natural phenomena should be addressed. See §§ 20.403 and 20.405 of 10 CFR Part 20 regarding reporting requirements.

7.5.1 Accidents Involving Radioactivity

The applicant should provide realistic analyses of accidents involving radioactivity for a spectrum of accidents that might occur ranging in severity from trivial (essentially no release of radioactivity to the environment) to large releases. Each class within the spectrum should be characterized by an occurrence rate or probability and its potential consequences, if any. Examples of accidents resulting in large releases would be an undetected lixiviant excursion or the failure of a waste retention system resulting from an act of nature, faulty design, or misoperation. Examples of accidents resulting in small releases would be failure of a pumping circuit with ground surface lixiviant release or failure of the ventilation system serving the chemical makeup area. An example of a trivial accident would be the leakage of a vessel containing barren lixiviant solution. Also describe measures to be taken to prevent accidents, and provide a discussion of proposed contingency plans to be implemented in the event that accidents occur.

7.5.2 Transportation Accidents

The potential environmental effects from transportation accidents involving radioactive and other hazardous materials should be evaluated.

7.5.3 Other Accidents

In addition to accidents that could release radioactivity to the environs, there might be accidents that, although radioactive materials would not be involved, would have consequences that could affect the environment. Such accidents as chemical explosions or fires, steam boiler failures, and leakage or rupture of vessels containing toxic materials could have significant environmental impacts. These possible accidents and associated effects should be identified and evaluated.

7.6 Economic and Social Effects of Construction and Operation

The purpose of this section is to provide guidance on the information needed to assess the economic and social effects of the proposed operations. There are, of course, limitations on the extent to which the social and economic benefits and costs of a project can be evaluated. The wide variety of benefits and costs are not only difficult to assess, but many are not amenable to quantification or even to estimation in commensurable units. Some primary benefits such as the quantity of uranium recovered are, to a degree, measurable as are the capital costs and operating and maintenance costs of the proposed facility. On the other hand, numerous environmental costs and their economic and social consequences are not readily quantifiable. All potential significant social and economic benefits and costs should be addressed in the application and, to the extent possible, should be discussed in quantitative terms.

Based on past reviews of research and development operations, the economic and social effects of construction and operation are usually minimal. However, the applicant should consider these to determine if there are any unique circumstances that could result in significant economic or social effects.

7.6.1 Benefits

The primary benefits of the proposed facility are those inherent in the value of the uranium to be recovered and the kilowatt-hours of electricity the uranium represents.

There are other social and economic benefits that affect various political jurisdictions or interests to a greater or lesser degree. Some of these reflect transfer payments or other values that may partially, if not fully, compensate for certain services as well as external or environmental costs, and this fact should be reflected in the designation of the benefit. Some examples are:

- Tax revenues to be received by local, State, and Federal governments.
- Temporary and permanent new jobs created and payroll (value-added concept).
- Incremental increase in regional product.
- Enhancement of recreational values.
- Environmental enhancement in support of the propagation or protection of wildlife and the improvement of wildlife habitats.
- Creation and improvement of local roads, waterways, or other transportation facilities.
- Increased knowledge of the environment as a consequence of ecological research and environmental monitoring activities associated with

plant operation and technological improvements from the applicant's research programs.

Discuss significant benefits that may be realized from construction and operation of the proposed facility. Where the benefits can be expressed in monetary terms, they should be discounted to present worth. In each instance where a particular benefit is discussed, the applicant should indicate, to the extent practical, who is likely to be affected and for how long. In the case of esthetic impacts that are difficult to quantify, the applicant should provide pictorial drawings of structures or environmental modifications visible to the public.

7.6.2 Costs

The economic and social costs resulting from the proposed operations are complex and need to be appraised.

The primary internal costs are (1) the capital costs of land acquisition and improvement, (2) the capital costs of facility construction, (3) other operating and maintenance costs, including license fees and taxes, (4) groundwater-quality restoration, surface reclamation, and plant decommissioning, and (5) research and development costs, including postoperational monitoring requirements. As in the case of benefits, the applicant should discount these costs to present worth.

There are also external costs. Their effects on the interests of people need to be examined. The applicant should supply, as applicable, an evaluation, including supporting data and rationale, regarding such external social and economic costs. For each cost, the applicant should describe the probable number and location of the population group adversely affected, the estimated economic and social impact, and any special measures to be taken to alleviate the impact.

Temporary external costs include housing shortages; inflationary rentals or prices; congestion of local streets and highways; noise and temporary esthetic disturbances; overloading of water supply and sewage treatment facilities; crowding of local schools, hospitals, or other public facilities; overtaxing of community services; and disruption of people's lives or of the local community caused by acquisition of land for the proposed site.

Long-term external costs include impairment of recreational values (e.g., reduced availability of desired species of wildlife and sport animals, restrictions on access to land or water areas preferred for recreational use); deterioration of esthetic and scenic values; restrictions on access to areas of scenic, historic, or cultural interest; degradation of areas having historic, cultural, natural, or archeological value; removal of land from present or contemplated alternative uses; reduction of regional products because of displacement of persons from the land proposed for the site; lost income from recreation or tourism that may be impaired by environmental disturbances; lost income attributable to environmental degradation; decrease in real estate values in areas adjacent to the proposed facility; and increased costs to local governments for the services required by the permanently employed workers and their families. In discussing the costs, the applicant should indicate, to the extent practical, who is likely to be affected and for how long.

7.6.3 Resources Committed

Any irreversible and irretrievable commitments of resources due to the operation should be discussed. This discussion should include both direct commitments such as depletion of uranium resources and irreversible environmental losses such as destruction of wildlife habitat.

In this discussion, the applicant should consider lost resources from the viewpoints of both relative impacts and long-term net effects. As an example of relative impact assessment, the loss of a few animals of a given species could represent quite different degrees of significance, depending on the total population in the immediate region. Such a loss in the case of a small local population, however, could be less serious if the same species were abundant in neighboring regions. Similarly, the loss of a given area of highly desirable land should be evaluated in terms of the total amount of such land in the environs. These relative assessments should accordingly include statements expressed in percentage terms in which the amount of expected resource loss is related to the total resource in the immediate region and in which the total in the immediate region is related to that in surrounding regions. The latter should be specified in terms of areas and distances from the site.

8. ALTERNATIVES TO PROPOSED ACTION

In this chapter, the applicant's choice of the particular mining and recovery processes for the ore body must be supported through a comparative evaluation of available alternatives. To the extent possible, discuss realistic alternatives for the various processing stages. Discussion of alternatives should include a description of the ground-water-quality restoration program to be applied for each alternative. The NRC will consider all those alternatives that may reduce or avoid significant adverse environmental, social, and economic effects expected to result from construction and operation of the proposed activity. The NRC will not preselect the alternatives that should be considered by the applicant; rather, the applicant should make this determination for this specific case and should also make clear the bases and rationales for the choices in regard to number, availability, suitability, and factors limiting the range of alternatives that might avoid some or all of the environmental effects identified in Chapter 7, "Environmental Effects." For commercial-scale operations, the comparative evaluation of available alternatives should include results obtained from research and development operations.

In the discussion of waste management alternatives, consideration should be given to the following siting, design, and operational performance objectives developed by the NRC staff in addition to the plans for final disposal discussed in Chapter 6, "Ground-Water-Quality Restoration, Surface Reclamation, and Plant Decommissioning."

1. Locate the liquid impoundment area(s) at sites where disruption and dispersion by natural forces are eliminated or reduced to the maximum extent reasonably achievable.

2. Design the impoundment area(s) so that seepage of toxic materials into the ground-water system would be eliminated or reduced to the maximum extent reasonably achievable.

9. BENEFIT-COST ANALYSIS

In this chapter, the applicant's benefit-cost statement should be summarized. The presentation should be made in the form of a narrative with accompanying tables and charts. It should clearly discuss the important benefits and costs of the proposed operations to justify the issuance of the license.

The applicant will have to develop criteria for assessing and comparing benefits and costs where these are expressed in nonmonetary or qualitative terms. The rationales for the selection of process alternatives as well as subsystem alternatives should be presented. In any case, the applicant should describe potential cumulative effects and should discuss in detail the tradeoffs that were made in order to warrant licensing of the proposed operation. The rationale for omitting apparent benefits or costs from the applicant's analysis should be explained. Key all the terms used in the benefit-cost analysis to the relevant sections of the application.

10. ENVIRONMENTAL APPROVALS AND CONSULTATIONS

List all licenses, permits, and other approvals of construction and operations required by Federal, State, local, and regional authorities for the protection of the environment.* List those Federal and State approvals that have already been received, and indicate the status of pending approvals. For general background, submit similar information regarding approvals, licenses, and contacts with local authorities. Indicate whether or not an environmental assessment or a full environmental impact statement has ever previously been prepared for the proposed mining site area or surrounding area. If so, cite the document.

Discuss the status of efforts to obtain a water-quality certification under Section 401 and discharge permits under Section 402 of the Federal Water Pollution Control Act, as amended, if required. If not already obtained, indicate when certification is expected. If certification is not required, explain.

In view of the potential effects of a proposed commercial-scale operation on the economic development of the region in which it would be located, the applicant should also note the State, local, and regional planning authorities contacted or consulted. Office of Management and Budget Circular A-95** identifies the State, metropolitan, and regional clearinghouse that should be contacted, as appropriate.

Describe meetings held with environmental and other citizen groups with references to specific instances of the applicant's compliance with citizen group recommendations.

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*This list should be updated bimonthly until final action is taken by the NRC.

**Copies of this circular are available from the Office of Management and Budget, Washington, D.C. 20503.

11. REFERENCES

The applicant should provide a bibliography of all sources used in preparing the application. References cited should be keyed to the specific sections and page numbers to which they apply. The applicant should also list the names, together with their qualifications (expertise, experience, professional disciplines), of the persons who were primarily responsible for preparing the application.

APPENDIX A

INFORMATION NEEDED BY NRC STAFF TO PERFORM RADIOLOGICAL IMPACT EVALUATIONS FOR COMMERCIAL-SCALE IN SITU URANIUM SOLUTION MINING FACILITIES

1. Detailed site plot plan (overlaid on topographic map, with scale and true north arrow) clearly identifying all locations of:

   a. Site property boundaries

   b. Restricted area boundaries, if different from site property boundaries

   c. All radiological effluent release points (or areas) such as

      (1) Production wells

      (2) Yellowcake drying and packaging area emission stacks or vents (if applicable)

      (3) Evaporation, settling, or any other solid/liquid disposal pond areas

      (4) Any other release points of emission to the atmosphere, e.g., surge tanks, process building vents

   d. Lands owned, leased, or otherwise controlled (including mill site claims) by the applicant

   e. Lands usable and available for grazing

   f. Private residences or other structures used by the general public

   g. Vegetable or other crops, identified by type and growing season

   h. Milk animals (cows or goats)

2. Locations of sources and receptors

   All locations should be given in terms of distances from a central release point. Coordinates relative to this release point should be given as follows:

   a. x kilometers east of the central release point

   b y kilometers north of the central release point

   c. z meters elevation from the base of the central release point

   (Note: Locations to the south and/or west should be denoted by a negative value. Any recognizable facility will suffice as a central frame of reference.)

Table 1 lists the types of sources and receptors and the format suggested for reporting the locations requested.

Table 1

Sources		East (km)	North (km)	Elevation (m)
1.	Yellowcake dryer	0	0	--
2.	Center of ore bodies (at ground surface level)	--	--	--
3.	Solid/liquid disposal areas	--	--	--
4.	Production wells	--	--	--
5.	Other sources, if applicable	--	--	--
Receptors				
1.	Nearest resident	--	--	--
2.	Nearest resident in prevailing wind direction	--	--	--
3.	Ranch	--	--	--
4.	Farm	--	--	--
5.	Orchard	--	--	--
6.	Grazing location 1	--	--	--
7.	Grazing location 2	--	--	--
4.	Garden	--	--	--
5.	Ranger bunk house	--	--	--
6.	Mine camp	--	--	--
7.	Town 1	--	--	--
8.	Town 2	--	--	--
9.	City 1	--	--	--
10.	Other nearby residents, industrial (or recreational) facilities	--	--	--
11.	Restricted area boundaries (N, S, E, W, NE, SW, SE, NW)	--	--	--

3. Time-sequenced bar graph describing various stages of the facility's operational and postoperational life. This should include any alterations relating to the sources of emission such as source location, operation, restoration, termination. Changes in exposed areas in evaporation ponds should also be indicated.

4. The following parameter values should be provided (if there are changes in Part 3 above, multiple corresponding values for each stage should be reflected here):

Parameter	Value
Average ore quality, U_3O_8, in ore body	______ %
Ore activity, U-238, U-234, Th-230, Ra-226, and Pb-210	______ pCi/g
Operating days per year (plant factor)	______ days
Dimensions of the ore body or bodies	
• Acres per year to be mined	______ acres
• Average thickness of body (bodies)	______ meters
Average production flow rate	______ gpm
Formation porosity	______ %
Process recovery	______ %
Leaching efficiency	______ %
Rock density	______ g/cm^3
Restoration flow rate	______ gpm
Production cell parameters	
Residence time	______ days
Type of cell pattern (5, 7 spot, or other)	______
Radius	______ m
Average cell flow rate	______ gpm
Annual Rn-222 emission from production	______ Ci/yr
Annual Rn-222 emission from restoration	______ Ci/yr

(Note: If the Rn-222 is not measured, indicate the complete calculational methodology, providing all assumed parameter values and references.)

Yellowcake drying and packaging data (if applicable)

Processing rates for drying and packaging if different	______________MT/hr
Estimated annual yellowcake production rate	______________MT/yr
Expected yellowcake purity, U_3O_8 by weight	______________%
Any measured airborne effluent concentrations	______________Ci U-238/yr
	______________Ci Th-230/yr
	______________Ci Ra-226/yr
	______________Ci Pb-210/yr
Stack heights and airflows	Drying_______________m, m^3/s
	Packaging____________m, m^3/s
	Other________________m, m^3/s
Anticipated release rates for dryer stack, the packaging area ventilation exhaust, and any yellowcake storage area ventilation exhausts	Dryer Stack__________kg/hr
	Packaging Stack______kg/hr
	Other________________kg/hr
Drying and packaging operations are carried out	______________hr/d and d/yr
Description of all ventilation air filtration equipment with design, expected, and minimum efficiencies (if applicable)	(Attach sheet)
Filtration equipment testing procedures and frequencies	(Attach sheet)
Solid/liquid disposal impoundments, e.g., evaporation ponds	(Attach sheet)

Complete physical, chemical, hydrological, and radiological description of disposal impoundment system.

Total area of each impoundment area and surface areas expected to be under water, saturated, moist, and dry (indicate surface moisture contents used as basis of estimates).

Anticipated Rn-222 release rates for surface areas under water, saturated, moist, and dry, Ci/yr per m^2.

If not included above, please provide the following:

Total dissolved solids in liquid waste	________________ g/l
Activity of solids in impoundments	________________ pCi U-238/g
	________________ pCi Th-230/g
	________________ pCi Ra-226/g
	________________ pCi Pb-210/g
Activity in liquids in impoundments	________________ pCi U-238/l
	________________ pCi Th-230/l
	________________ pCi Ra-226/l
	________________ pCi Pb-210/l
Density of solids	________________ g/cm^3

5. Meteorological Data

Annual joint relative frequency distributions of wind direction and wind speed by atmospheric stability class (see Table 2 on page 3.46-37).

a. Wind direction to be given in the 16 compass directions.

b. Wind speed to be given in knots in the indicated classes (i.e., 0-3, 4-6, 7-10, 11-16, 17-21, over 21)

c. Atmospheric stability to be given in the following manner:

A - Extremely unstable

B - Moderately unstable

C - Slightly unstable

D - Neutral

E - Moderately stable

F - Very stable

Further information is available in Regulatory Guide 1.23 (Safety Guide 23), "Onsite Meteorological Programs." For each atmospheric stability class, provide the data in the format indicated in Table 2.

Table 2

Stability Class Wind Direction	0-3	Wind Speed Class (knots) 4-6	7-10	11-16	17-21	Over 21
N						
NNE						
NE						
ENE						
E						
ESE						
SE						
SSE						
S						
SSW						
SW						
WSW						
W						
WNW						
NW						
NNW						

d. Regional Data (Within 80 km) (Attach sheet)

(1) Population distributions by direction (12) and radius (1, 2, 3, 4, 5, 10, 20, 30, 40, 50, 60, 70, and 80 km) for a recent year (no earlier than 1970) and for the last year of expected operations (see Table 3 on page 3.46-39 for reporting table format).

(2) Available county food production data, in kg/yr, for vegetables (by type and totals), meat (all types), and milk; if available, include any future predictions by local governmental or industrial or institutional organizations.

6. Miscellaneous

If not included above, please provide:

Fraction of year during which cattle graze locally ______________%

Fraction of cattle feed obtained by grazing ______________%

Fraction of stored cattle feed grown locally ______________%

Acreage required to graze 1 animal unit (450 kg) for one month (AUM)	______________ha
Length of growing season	______________mo/yr
Fraction of locally produced vegetables consumed locally	______________%
Fraction of locally produced meat consumed locally	______________%
Fraction of locally produced milk consumed locally	______________%

Table 3

	Population Distribution															
Kilometers	N 0.0	NNE 22.5	NE 45.0	ENE 67.5	E 90.0	ESE 112.5	SE 135.0	SSE 157.5	S 180.0	SSW 202.5	SW 225.0	WSW 247.5	W 270.0	WNW 292.5	NW 315.0	NNW 337.5
1.0- 2.0																
2.0- 3.0																
3.0- 4.0																
4.0- 5.0																
5.0-10.0																
10.0-20.0																
20.0-30.0																
30.0-40.0																
40.0-50.0																
50.0-60.0																
60.0-70.0																
70.0-80.0																

VALUE/IMPACT STATEMENT

An NRC source and byproduct material license is required in order to process uranium solutions extracted from in situ uranium solution mining operations. General guidance for filing an application is provided in § 40.31 of 10 CFR Part 40, "Domestic Licensing of Source Material." Regulatory Guide 3.46 (Task FP 818-4) provides specific guidance on the format and content of applications, including environmental reports, for licenses to authorize in situ uranium solution mining operations. The guide conforms to NRC regulations and reflects experience gained over the past several years in actual licensing cases.

Basic detailed guidance is essential to applicants for the efficient preparation of applications, including environmental reports, for in situ uranium solution mining facility licenses and for their review by the NRC staff. Such detailed guidance is not presently delineated in NRC regulations or in regulatory guides. Based on experience gained in the issuance of such licenses, the NRC staff has identified information that should be contained in applications, including environmental reports, to reflect present needs and practices. Such information provided in a regulatory guide will be helpful to both applicants and the NRC staff in reducing the cost and time involved in preparing and processing license applications. It should result in a significant reduction in the number of questions and requests for clarification submitted by the NRC staff to applicants, should improve the consistency in application reviews because of more uniform application submittals, should reduce the amount of NRC staff review effort in license processing, and should expedite licensing actions.

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555

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U.S. NUCLEAR REGULATORY COMMISSION

Revision 1
September 1989

REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 3.50
(Task CE 402-4)

STANDARD FORMAT AND CONTENT FOR A LICENSE APPLICATION TO STORE SPENT FUEL AND HIGH-LEVEL RADIOACTIVE WASTE

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INTRODUCTION

Subpart B, "License Application, Form, and Contents," of 10 CFR Part 72, "Licensing Requirements for the Independent Storage of Spent Nuclear Fuel and High-Level Radioactive Waste," specifies the information to be covered in an application for a license to store spent fuel in an independent spent fuel storage installation (ISFSI) or to store spent fuel and high-level radioactive waste in a monitored retrievable storage facility (MRS). However, Part 72 does not specify the format to be followed in the license application. This regulatory guide suggests a format acceptable to the NRC staff for submitting the information specified in Part 72 for a license application to store spent fuel in an ISFSI or to store spent fuel and high-level radioactive waste in an MRS.

The need for this revision of Regulatory Guide 3.50 arose from changes made to 10 CFR Part 72. The final rule was published on August 19, 1988 (53 FR 21651) and became effective September 19, 1988.

Part 72 provides for a single-step licensing procedure. The smooth functioning of this one-step licensing procedure requires that the license application be essentially complete when it is initially submitted. Thus, the final design details of those ISFSI or MRS components, systems, and structures that are important to safety should be made available for review and evaluation with submittal of the license application. Part 72 also requires that a site evaluation be provided to ensure that the natural characteristics of the site and its environs are sufficiently known and have been factored into the engineering design of the installation. The document in which this information is presented is a safety analysis report (SAR).

Although an applicant may plan to contract with another organization for the design, construction, and possibly the operation of the proposed ISFSI or MRS, a licensee under Part 72 cannot delegate to a contractor the responsibility for meeting applicable regulatory requirements. This means that the applicant must make a commitment that, as the licensee, it will have an adequate staff to ensure that regulatory requirements are met at each stage of the proposed project. If the applicant plans to contract with another organization for the operation of the proposed ISFSI or MRS, the contractual arrangements must be described in the license application. Any subsequent changes in such contractual arrangements may require an amendment to the application.

This regulatory guide represents a standard format that is acceptable to the NRC staff for the license application. Conformance with this guide, however, is not mandatory. License applications with different formats will be acceptable to the NRC staff if they provide an adequate basis for the findings required for the issuance of a license. However, because it may be more difficult to locate needed information, the staff review time may be longer, and there is a greater likelihood that the staff may regard the license application as incomplete.

As experience is gained in the licensing of spent fuel and high-level radioactive waste storage, the Commission's requirements for information needed in its review of applications for licenses to store radioactive material in an ISFSI or MRS may change. Revisions of the Commission's needs for information in connection with such licensing actions will be conveyed to the industry and the public by (1) amendments to NRC regulations, (2) revisions to this regulatory guide, (3) issuance of new or revised regulatory guides, and (4) direct communications, as needed, with the applicant by the NRC staff.

Prospective applicants are encouraged to meet with representatives of the Fuel Cycle Safety Branch, Division of Industrial and Medical Nuclear Safety, Office of Nuclear Material Safety and Safeguards, during the development of a license application to resolve any problems that may arise. An early resolution of potential problems is beneficial to all concerned with the licensing process.

Any information collection activities mentioned in this regulatory guide are contained as requirements in 10 CFR Part 72, which provides the regulatory basis for this guide. The information collection requirements in 10 CFR Part 72 have been cleared under OMB Clearance No. 3150-0132.

Contents of the License Application

The license application is the basic document that must address each of the requirements of Part 72 and must be complete in itself. The following should be submitted as separate documents as enclosures to the license application. The contents of each should be briefly summarized in the license application.

1. Safety Analysis Report
2. Decommissioning Plan
3. Emergency Plan
4. Environmental Report
5. Quality Assurance Program
6. Physical Security Plan (including guard training)
7. Safeguards Contingency Plan
8. Personnel Training Program
9. Proposed License Conditions, including Technical Specifications
10. Design for Physical Security

Format and Style

The applicant should strive for clear, concise presentation of the information provided in the application.

Abbreviations should be consistent throughout the license application and its enclosures. Any abbreviations, symbols, or special terms unique to the proposed activity or not in general use should be defined when they first appear.

A title page identifying key individuals responsible for the preparation of the license application and the oath or affirmation as required by paragraph 72.16(b) should be included. A table of contents should also be included.

Physical Specifications

1. Paper size: 8½ x 11 inches

2. Paper stock and ink. Suitable quality in substance, paper color, and ink density for handling and reproduction by microfilming or image-copying equipment.

3. Paper margins. A margin of no less than 1 inch should be maintained on the top, bottom, and binding side of all pages.

4. Printing

a. Composition: Text should be single or 1½ spaced.
b. Type face and style: Suitable for microfilming or image-copying equipment.
c. Reproduction: Either mechanical or photographic. Text should be printed on both sides of the paper with the image printed head to head.

5. Binding. Pages should be punched for a standard 3-hole loose-leaf binder.

6. Chapter and page numbering. Each requirement of the regulation addressed should be shown as a separate chapter with the same number as the chapter given in this guide, e.g., Chapter 7, "Operator Training." Pages should be numbered sequentially in each chapter, e.g., 7-1, 7-2, etc. Do not number the entire document sequentially.

Procedures for Updating or Revising Pages

All pages submitted to update, revise, or add to the license application should show the date of change and a change or amendment number. The changed or revised portion of each page should be highlighted by a "change indicator" mark consisting of a bold vertical line drawn in the margin opposite the binding side.

Referenced Materials

Caution should be used in references to information previously filed with the NRC. Such references must be pertinent to the subject discussed, must contain current information, and must be readily obtainable or extractable from the referenced documents. It may be more efficient in some cases to repeat, or at least summarize, information furnished in the previously submitted document.

1. GENERAL AND FINANCIAL INFORMATION

The license application should address the requirements of § 72.22, "Contents of Application: General and Financial Information," of 10 CFR Part 72 regarding details on the identity of an applicant. If the applicant is other than the owner and planned operator of the proposed independent spent fuel storage installation (ISFSI) or monitored retrievable storage facility (MRS), details of the working and contractual arrangements between all parties involved should be set forth. Any information on such matters considered as proprietary information by the applicant should be identified and submitted under separate cover. The procedures in paragraph 2.790(b) of 10 CFR Part 2 should be followed for such information.

If the proposed ISFSI or MRS is to be built on the site of another licensed activity or facility such as a nuclear power plant, details of the working arrangements and responsibilities of the licensees involved should be stated. Similarly, if unlicensed activities are carried out at the proposed site, any potential interactions between the proposed ISFSI or MRS and these other site activities should be explained.

Paragraph 72.22(e) specifically addresses the required financial information that must be submitted with the application. If the applicant is a corporation organized for the specific purpose of owning and operating the proposed ISFSI, details of its organizational structure, including the responsibilities of its members to meet the financial requirements of the proposed ISFSI throughout its proposed operating life and ultimate decommissioning, must be stated. This requirement is applicable even if the proposed ISFSI is to be owned and operated by a consortium of utilities.

2. TECHNICAL QUALIFICATIONS

Paragraph 72.40(a)(4) requires a finding by the NRC that the applicant is qualified by training and experience to operate an ISFSI or MRS. Section 72.28, "Contents of Application: Applicant's Technical Qualifications," sets forth information that must be included in the application for this purpose.

Although spent fuel storage in an ISFSI or spent fuel and high-level radioactive waste storage in an MRS is generally considered a relatively low-risk operation compared to some other types of nuclear activities, the design, construction, and operation of an ISFSI or MRS require certain skills and an understanding of the requirements involved to ensure that the objective of a relatively low-risk operation is achieved in practice. The license application should contain a commitment that the applicant will staff the project with an adequate cadre of personnel possessing the required skills throughout all phases of the project.

The licensee is responsible for the execution of the proposed project as described in the license application. This means that, even though much of the actual work involved during the site selection, design, procurement, construction, and even the operating phases of the project may be performed by a contractor, the licensee must have a staff that is knowledgeable in all aspects of the project. If such a staff does not actually exist, the applicant should describe the staffing plans in sufficient detail to support the finding required by paragraph 72.40(a)(4).

3. TECHNICAL INFORMATION -- SAFETY ANALYSIS REPORT

As required by § 72.24, "Contents of Application: Technical Information," the technical information is presented in the safety analysis report (SAR), which should be submitted as an enclosure to the license application. A summary statement identifying the type of installation proposed (e.g., a water-basin ISFSI, a storage-cask MRS), its design capacity, any unique features incorporated in its design, and its mode of operation is adequate for the license application document.

The SAR required for an ISFSI or MRS differs from the SARs for some other nuclear facilities in that the initial SAR is expected to be complete and comparable in scope and detail to the final SAR for facilities licensed under 10 CFR Part 50. Section 72.24 identifies the minimum information that is required to be included in the SAR. Although § 72.70 provides for the subsequent updating of the SAR, such changes during the design and construction phases of the project are expected to be of minor importance. Any of these changes deemed significant by the NRC staff may cause delay in the granting of the final clearance to receive spent fuel or high-level radioactive waste.

Guidance on the preparation of the SAR for an ISFSI of the water-basin type is contained in Regulatory Guide 3.44, "Standard Format and Content for the Safety Analysis Report for an Independent Spent Fuel Storage Installation (Water-Basin Type)." For the dry storage ISFSI that is not colocated at another nuclear facility site or for a dry storage MRS, guidance on the preparation of the SAR is being developed in the proposed Revision 1 to Regulatory Guide 3.48, "Standard Format and Content for the Safety Analysis Report for an Independent Spent Fuel Storage Installation or Monitored Retrievable Storage Installation (Dry Storage)." Guidance for preparing the SAR for the use of dry storage casks at the site of another nuclear facility is contained in Regulatory Guide 3.62, "Standard Format and Content for the Safety Analysis Report for Onsite Storage of Spent Fuel Storage Casks."

4. CONFORMITY TO GENERAL DESIGN CRITERIA

Subpart F of 10 CFR Part 72 contains the general design criteria for an ISFSI or MRS. The subject of conformity to the general design criteria is discussed in detail in the SAR. It is sufficient that the license application contain a summary discussion of each criterion and reference where more detailed information on a specific subject can be found in the SAR.

5. OPERATING PROCEDURES -- ADMINISTRATIVE AND MANAGEMENT CONTROLS

Paragraph 72.40(a)(5), "Issuance of License," requires a finding by the staff that the applicant's proposed operating procedures to protect health and to minimize danger to life or property are adequate. Essential to these operating procedures are the applicant's proposed administrative and management controls. Guidance on this subject is available in ANSI N299-1976, "Administrative and Managerial Control for the Operation of Nuclear Fuel Reprocessing Plants."* Although ANSI N299-1976 is designed for the much more complex operating requirements of a fuel reprocessing plant, the basic principles set forth for administrative and managerial controls are considered applicable to the operation of an ISFSI or MRS.

If the proposed ISFSI or MRS is to be operated by the owner, a relatively brief explanation of how ANSI N299-1976 will be followed may be adequate. However, if the proposed ISFSI or MRS is to be operated by a contractor, considerable detail may be required on the working arrangements between the parties involved. Particular attention should be placed on the description of the administration of the Independent Review and Audit Program that is identified in ANSI N299-1976.

*Copies may be obtained from the American National Standards Institute, Inc., 1430 Broadway, New York, NY 10018.

6. QUALITY ASSURANCE PROGRAM

The quality assurance (QA) program required by Subpart G of Part 72 must be submitted as an enclosure to the application and is briefly described in Chapter 11 of the SAR. It is sufficient that the license application contain a commitment that the QA program described is (or will be) understood by all involved in its execution and that the program will be implemented, as applicable, for all phases of the project, including any activities important to safety that have been carried out prior to submittal of the license application.

This program should cover the engineering aspects of the site investigation, facility design, procurement, shop fabrication, onsite construction, preoperational testing, conduct of operations, and ultimate decommissioning. The emphasis of this program should be on those activities and items that are identified as being important to safety. The planned QA effort should be commensurate with the importance to safety of the identified activities and items.

A QA program that has been approved by the NRC as meeting Appendix B to 10 CFR Part 50 or Subpart G of 10 CFR Part 72 may be applied to the spent fuel storage system.* The applicant should state the intent to implement this QA program for the ISFSI or MRS, the date on which the QA program was submitted to the NRC, the docket number, and the date of NRC approval.

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*Note that 10 CFR 72.140(d) states "A Commission-approved quality assurance program which satisfies the applicable criteria of Appendix B to Part 50 of this chapter and which is established, maintained, and executed with regard to an ISFSI will be accepted as satisfying the requirements of paragraph (b) of this section."

7. OPERATOR TRAINING

Subpart I, "Training and Certification of Personnel," of 10 CFR Part 72 requires that a personnel training program be established and that the program be submitted for NRC approval. A brief summary of the program should be included in the application. Applicants who have an approved training program in effect may modify this program to cover spent fuel storage operations. A description of the proposed changes should be provided.

ISFSI and MRS operators are not required to be licensed. However, they must have successfully completed an established training program. Appropriate documentation of training activities and certifications of proficiency should be included in the ISFSI or MRS records.

In addition to the specific operating requirements of the planned facility, the training program should include the nuclear engineering principles, NRC regulations, regulatory guides, and national standards applicable to ISFSI or MRS operations. Information on the content of the required training program is available from the Fuel Cycle Safety Branch, Division of Industrial and Medical Nuclear Safety, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

8. INVENTORY AND RECORDS REQUIREMENTS

A description of the inventory and records system for the stored spent fuel and high-level radioactive waste should be included in the license application. Section 72.72 identifies the inventory and record requirements for radioactive material stored at an ISFSI or MRS. The records on the identity of each fuel assembly or high-level radioactive waste container should be complete. As a minimum, these records should include:

1. For Spent Fuel

   a. Fuel manufacturer,
   b. Date of manufacture,
   c. Reactor exposure history,
   d. Burnup,
   e. Calculated special nuclear material content,
   f. Inventory control number,
   g. Pertinent data on discharge and storage at the reactor, transfer to the ISFSI or MRS, and storage at the ISFSI or MRS,
   h. For consolidated spent fuel, the records should show how the fuel rods can be traced to the original fuel assembly.

2. For High-Level Radioactive Waste

   a. Origin of waste,
   b. Calculations of isotope and curie content whenever they are necessary,
   c. Waste form,
   d. Thermal output,
   e. Inventory control number,
   f. Pertinent data on waste stabilization operations, transfer to the MRS, and storage at the MRS.

9. PHYSICAL PROTECTION

Subpart H, "Physical Protection," of 10 CFR Part 72 requires that a physical security plan and guard training plan (§ 72.180), a design for physical protection (§ 72.182), and a safeguards contingency plan (§ 72.184) be submitted. Since the details of the provisions for physical protection are withheld from public disclosure, these reports should be submitted separately. The license application should contain only a reference to the identity of the reports and when they were submitted.

Specific guidance on these submittals for an MRS or an ISFSI not located on a nuclear power reactor site may be obtained from the Safeguards Licensing Branch, Office of Nuclear Material Safety and Safeguards, U.S. Nuclear Regulatory Commission, Washington, DC 20555. Reactor licensees may obtain guidance on these topics from the Reactor Safeguards Branch, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

If the applicant has a physical security plan and a safeguards contingency plan that have been approved by NRC, modifications may be made to cover spent fuel storage operations. A description of, and a schedule for, changes related to the spent fuel storage installation should be provided.

10. DECOMMISSIONING PLAN

Section 72.30, "Decommissioning Planning, Including Financing and Recordkeeping," requires submittal of a proposed decommissioning plan, including a proposed funding plan that contains information on how funds will be available to decommission the ISFSI or MRS. The application should contain a description of the practices and procedures for decommissioning and an explanation of how the costs of decommissioning will be financed. Applicants who have previously submitted proposed decommissioning plans (i.e., nuclear power reactor licensees) may show how these plans will include the spent fuel storage installation.

11. EMERGENCY PLAN

The applicant should submit a plan for coping with emergencies as a separate document. If the ISFSI is located on the site of a nuclear power reactor, the emergency plan required by § 50.47 of 10 CFR Part 50 satisfies the requirements of § 72.32 of 10 CFR Part 72.

12. ENVIRONMENTAL REPORT

Section 72.34 requires that an environmental report be provided as part of the license application. Guidance on the format and content of an environmental report for an ISFSI may be found in Subpart A of 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions."

In the interest of keeping the size of this report within reasonable bounds and its structure and language keyed to the general public, it is recommended that a prospective applicant confer with the NRC staff to obtain definitive guidance on the scope and content of this report.

13. PROPOSED LICENSE CONDITIONS

License conditions proposed by an applicant constitute a commitment by the applicant to take the actions specified therein. License conditions can be considered in two broad categories: (1) administrative and management organization and controls and (2) technical specifications. Those addressing administrative and management subjects should be included in the license application; those addressing technical specifications should be described briefly in the license application with appropriate references to the detailed analyses in the SAR. Care should be taken to ensure that such references are clear and explicit.

Proposed license conditions should address such subjects as:

1. Administrative and management organization, procedures, controls (including review and approval activities), and auditing and reporting requirements. In particular, the subject of interfaces between the licensee and its contractors should be discussed.

2. Verification of design features that are important to safety. Those quality assurance activities that confirm that design and construction are being carried out in accordance with plans, e.g., inspection hold points, should be discussed. In particular, identify who is responsible for performing this verification.

3. Test procedures. Such subjects as conditions applicable to site evaluation, component testing during design and construction, preoperational testing prior to startup, and conditions applicable to tests that may be desirable after the commencement of operations should be discussed.

4. Functional and operating limits, monitoring instruments and limiting control settings. The operating limits necessary for (a) protecting the integrity of the spent fuel or solidified high-level radioactive waste, (b) protecting employees against radiation exposure, and (c) preventing uncontrolled release of radioactive material should be discussed. Radiation monitoring instruments and their limiting control settings should be described.

5. Limiting conditions of operation. The functional capabilities or performance levels of equipment and systems that are important to safety should be addressed. The subject includes setpoint limits on monitoring instruments and any controls that may need to be imposed on personnel access to any part of the installation.

6. Surveillance requirements. Such items as the periodic inspection of cranes and storage structures and, for water pools, water purity and evidence of corrosion should be covered.

VALUE/IMPACT STATEMENT

A draft value/impact statement was published with the proposed Revision 1 to Regulatory Guide 3.50 (Task CE 402-4) when the draft guide was published for public comment in September 1986. No changes were necessary, so a separate value/impact statement for the final guide has not been prepared. A copy of the draft value/impact statement is available for inspection and copying for a fee at the Commission's Public Document Room at 2120 L Street NW., Washington, DC, under Task CE 402-4.

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REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 3.56
(Task CE 309-4)

GENERAL GUIDANCE FOR DESIGNING, TESTING, OPERATING, AND MAINTAINING EMISSION CONTROL DEVICES AT URANIUM MILLS

A. INTRODUCTION

Regulations applicable to uranium milling are contained in 10 CFR Part 20, "Standards for Protection Against Radiation," and in 10 CFR Part 40, "Domestic Licensing of Source Material."

Paragraph 20.1(c) of 10 CFR Part 20 states that licensees should make every reasonable effort to keep radiation exposures, as well as releases of radioactive material to unrestricted areas, as low as is reasonably achievable. Paragraph 20.105(c) of 10 CFR Part 20 requires that licensees engaged in uranium fuel cycle operations subject to the provisions of 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operations," comply with that part. Part 190 of Title 40 requires that the maximum annual radiation dose to individual members of the public resulting from fuel cycle operations be limited to 25 millirems to the whole body and to all organs except the thyroid, which must be limited to 75 millirems. Criterion 8 of Appendix A to 10 CFR Part 40 requires that milling operations be conducted so that all airborne effluent releases are reduced to levels as low as is reasonably achievable.

Air in the immediate vicinity of such uranium milling operations as ore crushing, ore grinding, and yellowcake drying and packaging frequently contains radioactive materials in excess of that permissible for release to unrestricted areas. Emission control devices are installed in ventilation systems of uranium mills to limit releases of these radioactive materials to the environment.

General guidance for filing an application for an NRC source material license authorizing uranium milling operations is provided in § 40.31 of 10 CFR Part 40. An applicant for a new license or renewal of an existing license for a uranium mill is required by § 40.31 to provide detailed information on the proposed equipment, facilities, and procedures at the installation. This information is used by the NRC to determine whether the applicant's proposed equipment, facilities, and procedures are adequate to protect the health and safety of the public and to determine if they will significantly affect the quality of the environment. Calculations by the NRC of the environmental impact from the proposed uranium milling operations are based on the estimated rate of production of radioactive airborne particulates adjusted to reflect the removal efficiency of the emission control devices installed in the plant ventilation systems. This requires reliable information on the efficiency of these devices. It also requires reliable information on the production of airborne radioactive particulates during the proposed operations.

Section 40.65 of 10 CFR Part 40 requires mill operators to submit semiannual reports to the NRC specifying the quantity of each of the principal radionuclides released to unrestricted areas in gaseous effluents. This information may be used by the NRC to estimate maximum potential annual radiation doses to the public resulting from effluent releases and thereby determine compliance with paragraphs 20.1(c) and 20.105(c) of 10 CFR Part 20 and with Criterion 8 of Appendix A to 10 CFR Part 40. The quantity of radionuclides released is based on scheduled sampling of effluents discharged into exhaust stacks. The reliability of these data for estimating radiation exposures depends on maintaining uniform operation of the emission control devices during the reporting time interval because these effluents are not continuously sampled.

All emission control devices used in uranium mill ventilation systems need to perform reliably under expected operating conditions to meet the objectives discussed above. This guide describes procedures acceptable to the NRC staff for designing, testing, operating, and maintaining these emission control devices to ensure the reliability of their performance.

Any information collection activities mentioned in this regulatory guide are contained as requirements in 10 CFR Parts 20 or 40, which provide the regulatory basis for this guide. The information collection requirements in 10 CFR Parts 20 and 40 have been cleared under OMB Clearance Nos. 3150-0014 and 3150-0020, respectively.

B. DISCUSSION

The milling of uranium ores results in the production of airborne particulates containing uranium and its daughters in several areas of a typical uranium mill. These areas encompass (1) ore storage, handling, and crushing; (2) ore grinding, leaching, and concentrating processes; (3) yellowcake precipitation, drying, and packaging, and (4) miscellaneous mill locations such as maintenance shops, laboratories, and general laundries. Milling operations must be conducted so that all airborne effluent releases are reduced to levels as low as is reasonably achievable (ALARA). The primary means of accomplishing this is the control of emissions at the source.

The most significant sources of radioactive airborne particulates occur in ore handling and crushing areas and in yellowcake drying and packaging areas. These sources are generally controlled by separate ventilation systems in each area that remove these airborne particulates through local hoods, hooded conveyor belts, etc., into emission control devices where they are removed from the air streams. The cleaned air is then discharged by fans into the atmosphere through local exhaust stacks.

Emission control devices are available in a wide range of designs to meet variations in air cleaning requirements. Degree of removal required, quantity and characteristics of the contaminant to be removed, and conditions of the air stream all have a bearing on the device selected for any given application. Emission control devices used at ore crushing and grinding operations include bag or fiber filters (baghouses), orifice or baffle scrubbers, and wet impingement scrubbers. Water spray systems are also used at these operations to minimize the generation of dust. Wet impingement scrubbers or venturi scrubbers are generally employed at yellowcake drying and packaging areas.

All emission control devices used in a uranium mill ventilation system need to be designed for reliable performance under the expected operating conditions. Initial testing and proper maintenance are primary factors in ensuring the reliability of these components. Periodic testing during operation to verify the efficiency of these components is another important means of ensuring reliability. Built-in features that will facilitate convenient in-place testing of these devices are important in ventilation system design.

Emission control devices used in a uranium mill ventilation system need to be sufficiently instrumented to measure and monitor their operating characteristics. Frequent checks of all significant operating parameters are necessary to determine whether or not conditions are within a range prescribed to ensure that this equipment is operating consistently near peak efficiency. When checks indicate that the equipment is not operating within this range, it is necessary to take action to restore parameters to the prescribed range. To ensure that timely actions are taken, instrumentation is often supplemented by audible alarms that are preset to signal when prescribed operating range limits are exceeded. When the required actions cannot be taken without shutdown and repair of this equipment, it will be necessary to suspend milling operations that are the source of the emissions until corrective actions have been taken. Criterion 8 of Appendix A to 10 CFR Part 40 requires suspension of yellowcake drying and packaging operations as soon as practicable when shutdown and repair of the emission control system is necessary. The installation of automatic shutdown instrumentation on processes and systems at which operating parameters on emission control devices may exceed acceptable limits could prevent excessive releases that may result from continuous operations under these circumstances, e.g., those associated with the production of yellowcake. The installation of backup or redundant emission control systems would permit continuous operation during repair and maintenance of the primary system.

A preventive maintenance program is important for emission control devices used in uranium mill ventilation systems. A program designed to identify deficiencies in operation of these devices so that corrective action can be taken to reduce the frequency of off-normal operation can provide a measure of confidence in the operating characteristics of these devices. This program may require periodic updating to reflect actual in-plant experience, equipment manufacturers' guidelines, and NRC guidance. For example, a preventive maintenance program can consist of the equipment supplier's recommendations supplemented by provisions derived from the licensee's own routine inspection and maintenance records.

The key to proper maintenance of emission control devices is frequent inspection. It is important that a regular program of inspection be established and followed and records be kept of all inspections and the resulting maintenance. Inspection intervals will depend on the type of emission control device, the manufacturer's recommendation, and the process area where the unit is installed. These inspections need to be performed as frequently as experience shows to be necessary but not less than annually.

Considerable maintenance time can be expended on trouble shooting and correction of malfunctions of emission control devices. The ability to locate and correct malfunctioning components of these devices requires a thorough understanding of the system.

Throughout the manufacturing industry, there are many models of each type emission control device used at uranium mills. These models range in size in order to meet the different air capacity needs at the mills. In addition, some design features of each manufacturer are unique. Accordingly, the specific design and the testing, operating, and maintenance procedures for each model are beyond the scope of this guide. General guidance is presented, however, for each type of emission control device based on typical models in present-day use. Background information for this guidance can be found in the Bibliography. The licensee may substitute procedures based on specific operating parameters of the model in use at the facility for those described in this guide.

1. DESIGN AND OPERATION

1.1 Bag or Fabric Filters (Baghouses)

Bag or fabric filters, usually in the form of baghouses, remove particulates from a gas stream by filtering the airborne particulates (by impaction or diffusion) through a porous flexible fabric made of a woven or felted material. These collected particles form a structure of their own, supported by the filter, and have the ability to intercept and retain other particles. The increase in retention efficiency is accompanied by an increase in pressure drop through the filter. The baghouses are equipped with one of several automatic cleaning mechanisms for periodically dislodging collected material from filter components to prevent excessive resistance to the gas flow (i.e., excessive pressure drop) that would otherwise develop. The dislodged material settles in storage hoppers before the filter components are placed back on stream. The automatic cleaning cycle can be initiated by either a differential pressure switch or a timer, which may be interlocked with the main fan motor for the baghouse.

The cleaning mechanisms employed in baghouses are based on either mechanical shaking of the filter components or pneumatic vibration of these components by high-pressure air applied in reverse flow, reverse jet, or reverse pulse modes. The effectiveness of these compressed air systems depends on maintaining a sufficient reservoir of compressed air at the pressure specified by the baghouse manufacturer. Higher pressures than specified could cause failure of the filter fabric, while lower pressures can result in poor filter cleaning. These problems are minimized by pressure-regulating devices used in the compressed air systems.

The most critical parameter to be observed during baghouse operation is the pressure drop. Proper operation of the baghouse requires, at a minimum, maintaining the differential pressure of this device in the correct range specified by the manufacturer. A manometer or a differential-pressure gauge and transmitter are usually provided for this purpose. This instrumentation is often supplemented by an audible alarm system designed to signal and alert mill operators when prescribed differential-pressure ranges are exceeded. Lower differential pressures indicate potential deficiencies such as damaged filters or other air bypass channels that should be corrected. Higher differential pressures indicate that cleaning operations are inadequate. This can be corrected by increasing the frequency of the automatic cleaning cycle through adjustment of the differential-pressure switch or timer of the baghouse installation.

1.2 Wet Scrubbers

Wet scrubbers remove particulates from a gas stream by effecting intimate contact between the gas stream and a scrubbing liquor, usually water. The basic operations that take place within a wet scrubber are (1) saturation of the incoming gas, (2) contacting and capture of the particulates in the scrubbing liquor, and (3) separating the entrained particulate-laden liquid from the gas stream. The basic types of wet scrubbers are distinguished by the mechanisms used for transfer of particulates from the gas stream to the liquid stream. Most scrubber systems require some type of treatment and disposal of the particulate-laden scrubbing liquor.

Several water spray systems may be used in wet scrubber operations. Water from the main water spray system is directed either into a screen or throat to contact the particulate-laden gas stream. In applications where inlet gas temperatures are inordinately high, preconditioning of the incoming gas to the scrubber may be necessary to provide adequate humidity and thereby maintain particulate collection efficiency. This may be accomplished by use of an auxiliary water spray system upstream of the scrubber particulate scavenging area. Where particulate buildup is likely to occur in the entrainment separator, a wash system may be necessary to avoid this condition. The wash system is usually composed of low-pressure spray nozzles using recycled scrubbing liquor or fresh water for cleansing.

Orifice, wet impingement, or venturi wet scrubbers are generally used in uranium mill ventilation systems. In orifice-type wet scrubbers, the gas stream is made to impinge upon a surface of scrubbing water and is then passed through various constrictions where its velocity may be increased and where greater liquid-particulate interaction may occur. The gas stream finally discharges through a chamber section where entrained droplets are disengaged. In wet impingement scrubbers, the gas stream is wetted with water from low-pressure spray nozzles in the scrubber inlet and then passed through perforated plates at high velocity to impinge on baffle plates or vanes where liquid droplets containing particulate matter coalesce and drain to a sump. Solid particles are washed to the sump by either intermittent or continuous sprays. Prior to exiting from the scrubber, the gas stream passes through an entrainment separator to remove entrained liquid droplets. In a venturi scrubber, the gas stream flows through a throatlike passage where the gas is accelerated in velocity. The scrubbing liquor is added at or ahead of the venturi throat and is sheared into fine droplets by the high-velocity gas stream, resulting in liquid-particulate interaction. The gas and liquor droplets then pass through a cyclone separator where entrained droplets containing particulate matter are removed from the gas stream.

Although each type of scrubber discussed above has unique design features, their collection efficiencies are influenced in similar ways by incremental changes in certain common operating parameters, principally gas and liquid flow as well as pressure drop. A decrease in either the gas or liquid flow rate could result in insufficient gas cleaning. Collection efficiency can also diminish if the liquid-to-gas flow rate ratio falls below design values. An increase in pressure drop across the scrubber will enhance the collection efficiency for the same size distribution and concentration of particulates in the gas stream. Proper operation of these wet scrubbers requires monitoring of these parameters to determine that they are within ranges prescribed to ensure equipment performance consistently near optimum collection efficiency. Instrumentation used to monitor these parameters is often supplemented by audible alarm systems designed to signal and alert mill operators of the need for corrective action when prescribed operating ranges are exceeded. In some cases automatic control systems with interlocks may be necessary. For example, the scrubber fan could be interlocked to shut down in the event of an indication of water flow failure. These circumstances would require suspending particulate-producing processes in the ventilation zone serviced by the scrubber until corrective action could be taken or switching to a redundant scrubber unit.

Daily operational data summaries on baghouse and wet scrubber performance are useful in providing a continuous record of performance of these devices. Other formats that contain equivalent information such as recorder charts can also be used for this purpose. Criterion 8 of Appendix A to 10 CFR Part 40 requires that checks of all parameters that determine the efficiency of yellowcake stack emission control equipment operation be made and logged hourly. In addition, data from checks made of all operating parameters necessary to enable timely identification of malfunctions can be of value in ensuring proper operation of baghouses and wet scrubbers and in updating preventive maintenance programs for these devices to reflect actual operating experience.

2. MAINTENANCE

2.1 Bag or Fabric Filters (Baghouses)

The frequency of needed maintenance for baghouses can be determined from manufacturers' recommendations and operating experience. In order of decreasing frequency, the principal baghouse components requiring maintenance are (1) filter bags, (2) flow controls, (3) hoppers, and (4) cleaning mechanisms. Symptoms of potential operating problems requiring corrective maintenance are almost always one of the following: (1) excessive emissions, (2) short filter bag life, and (3) high pressure drop. These symptoms may indicate malfunctioning in more than one component. For example, high pressure drop may be attributable to difficulties with the filter bag cleaning mechanism, low compressed air pressure, high humidity, weak shaking action, loose filter bag tension or excessive reentrainment of dust. Many other factors can cause excessive pressure drop, and several options are usually available for appropriate corrective action.

2.2 Wet Scrubbers

The major maintenance problems with wet scrubbers are (1) excessive buildup of solids in the wet/dry zones and entrainment separator, (2) plugged water spray nozzles, (3) abrasion in areas of high velocity such as throats and orifices, and (4) corrosion on scrubber vessel internal surfaces. A buildup of solids often occurs around the wet/dry interfaces of ducts where the gas stream contacts the wetted scrubber housing. Instrumentation such as liquid and gas pressure indicators can exhibit rapid solids buildup and therefore require regular cleaning to ensure proper system operation and performance. Increased pressure drop, reduced gas flow, and subsequent system malfunction are all possible consequences of a buildup of solids in the entrainment separator. Water spray nozzles frequently wear or clog, which produces an uneven liquid pattern and requires their replacement. Venturi and impingement scrubbers tend to show signs of abrasion in areas downstream of gas and liquid acceleration. Corrosion can occur from the high moisture and airborne liquid incident on components, in particular where protective liners may have deteriorated.

A regular schedule of routine inspection of key components and operating parameters is an essential ingredient of a maintenance program for ensuring the reliability of performance of typical baghouses and wet scrubbers. Examples of some typical maintenance activities for baghouses and wet scrubbers used at uranium mills are presented in Appendices A and B, respectively. These activities are in addition to those procedures recommended by manufacturers for routine lubrication, inspection, and replacement of component parts.

3. TESTING

To ensure proper selection of emission control devices, it is necessary for potential users to supply manufacturers with a list of specifications for the given application, including gas flow rates, liquid flow rates (where scrubbers are under consideration), temperature, pressure, pressure drop, concentration of particulates, particle size distribution, emission levels, and collection efficiency. The manufacturers, in turn, should design and supply these devices based on test data already available for prototype equipment used under similar circumstances.

If relevant test data are not available, it is generally advisable for the manufacturer and potential user to run mutually agreed-upon pilot plant or prototype tests with a gas stream typical of the gas stream to be cleansed to ensure that proper equipment is supplied to meet the desired collection efficiency. After installation of the device, it may be tested in place to confirm its particulate removal efficiency. Periodic in-place testing will ensure continued effectiveness of the device. In this way, reliable data will be available to the licensee for estimating the environmental impact of uranium milling operations before and after the commencement of operations.

Collection efficiency for baghouses and wet scrubbers used in uranium mills is usually based on inlet and outlet particulate concentrations in a dry gas corrected to standard temperature and pressure. Inlet and outlet particulate concentrations are preferably sampled simultaneously if practicable. The procedure of choice for determination of particulate concentrations is described in Method 5, "Determination of Particulate Emissions From Stationary Sources," of Appendix A to 40 CFR Part 60, "Standards of Performance for New Stationary Sources." In this procedure, particulate matter is withdrawn isokinetically from the gas stream and collected on a glass fiber filter maintained in a prescribed elevated temperature range. The particulate mass, which includes any material that condenses at or above the filtration temperature, is determined gravimetrically after removal of uncombined water. If a preoperational in-place determination of collection efficiency is desired, a procedure mutually acceptable to the user and manufacturer may be used.

4. QUALITY ASSURANCE

Components of uranium mills do not require a formal quality assurance program; however, particular quality assurance requirements may be imposed by the NRC as license conditions if deemed necessary to protect health. A quality assurance program for emission control devices need only be an extension of the overall quality assurance program usually submitted by an applicant for a license to ensure that the emission control devices are designed and the testing, operating, and maintenance procedures are implemented to maintain uniform operation of these devices within prescribed ranges under expected operating conditions.

C. REGULATORY POSITION

Emissions from milling operations must be controlled so that all airborne effluent releases are reduced to levels as low as is reasonably achievable. An important means of accomplishing this is by means of emission control devices in mill ventilation systems. The design and the testing, operating, and maintenance procedures for these emission control devices should ensure that these devices are operating consistently near peak operational efficiency.

1. DESIGN AND OPERATION

In addition to the requirement in Criterion 8 of Appendix A to 10 CFR Part 40 that requires checks to be made and logged hourly of all parameters that determine the efficiency of yellowcake stack emission control equipment operation, other emission control devices should be sufficiently instrumented to monitor all operating parameters necessary to enable timely identification of malfunctions. Consideration should be given to centralizing equipment instrumentation and controls, where feasible, to facilitate ease of changing and evaluating operating parameters.

Instrumentation may be supplemented by audible alarms that are preset to signal when prescribed operating range limits are exceeded.

Consideration should be given to installation of automatic shutdown instrumentation on processes and systems so that, when operating parameters on emission control devices exceed preset limits, operations would cease.

Equipment used in the emission control system should be clearly marked to allow easy identification. Up-to-date system drawings should be available to identify the location of valves and instruments. A record of system modification or changes should also be available.

Consideration should be given to keeping records of operating data in order to evaluate system performance and to provide a basis for establishing or modifying a preventive maintenance program.

Written procedures should be available for equipment operation and for operator actions if malfunctions occur. Checkoff lists should be considered for complex or infrequent modes of operation. Some operational procedures that may be considered for typical baghouses and wet scrubbers used at uranium mills are presented in Appendix C.

Equipment operators should be instructed in the function of each device and its operating characteristics. They should also be made aware of consequences of malfunctions and misoperation as well as of corrective measures that may be taken by the operator.

Equipment operators should be made aware of modifications to the equipment, changes in procedures, and problems encountered during system operation.

2. MAINTENANCE

A preventive maintenance program should be developed and implemented to sustain proper equipment performance and to reduce unscheduled repairs. Inspections should be performed at least annually, more frequently if necessary, on all components.

In the development of the maintenance program, consideration should be given to the type of emission control device, the manufacturer's recommendations, and the process at which the unit is installed. This program may require periodic updating to reflect onsite maintenance experience.

Schedules and written procedures should be available for maintenance work. Maintenance personnel should be trained in the implementation of maintenance procedures. They should be trained to recognize the symptoms that indicate potential problems, to determine the cause of the difficulty, and to remedy it with the help, if necessary, of the manufacturer or other outside resource.

3. TESTING

Emission control devices should be tested in place at least annually to verify collection efficiency. Collection efficiency for baghouses and wet scrubbers used in uranium mills should be based on inlet and outlet radioactive particulate concentrations in a dry gas corrected to standard temperature and pressure. Inlet and outlet (radioactive or uranium) particulate concentrations should be sampled simultaneously, if practicable.

The test should be performed in accordance with Method 5 of Appendix A to 40 CFR Part 60 or an acceptable equivalent.

If a preoperational in-place determination of collection efficiency is desired, a procedure mutually acceptable to the user and manufacturer may be used.

4. QUALITY ASSURANCE

The overall quality assurance program submitted by an applicant for a license should include provisions for (1) documentation, review, and evaluation of design, testing, operating, and maintenance data for emission control devices and (2) timely initiation of corrective actions necessary to maintain uniform operation of these devices within prescribed ranges under expected operating conditions.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this regulatory guide.

Except in those cases in which an applicant or licensee proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the methods described in this guide will be used by the NRC staff in evaluating procedures for designing, testing, operating, and maintaining emission control devices used at uranium mills.

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*Available from the Industrial Gas Cleaning Institute, Inc., 700 N. Fairfax Street, Alexandria, VA 22314.

APPENDIX A

TYPICAL MAINTENANCE ACTIVITIES FOR BAGHOUSES

COMPONENT	ACTIVITIES
Baghouse Housing	• Inspect exhaust from filters for visible dust. • Inspect gasketing on filter housing to ensure against leakage.
Compressed Air System	• Inspect for air leakage (low pressure) and check valves.* • Check alignment of air pulse holes with center of bag filters.*
Dust Collection Hopper	• Inspect for dust and debris buildup in ducts to hopper. • Rod out dust buildup on all accessible hopper surfaces. • Check operation of the discharge mechanism.
Manometer	• Inspect for blockage.
Filter Bags	• Inspect individual filter bags and attachment hardware.

*Activities applicable to pulse or jet baghouses. The remainder are applicable to all baghouses.

APPENDIX B

TYPICAL MAINTENANCE ACTIVITIES FOR WET SCRUBBERS

COMPONENT	ACTIVITIES
Scrubber Body	• Inspect for wear, particularly in areas downstream of gas and liquid acceleration.
	• Inspect for corrosion on all scrubber internal surfaces.
	• Inspect for excessive buildup, in particular in the wet/dry zone.
Nozzles	• Inspect for buildup and damage.
Entrainment Separator	• Check operation.
	• Inspect structural supports for integrity.
Pumps	• Inspect pumps for wear, seal water, packing, and smooth operation.
Instruments	• Inspect the condition of all instruments with regard to solids buildup.

APPENDIX C

TYPICAL OPERATIONAL SURVEILLANCE PROGRAM FOR EMISSION CONTROL DEVICES

EMISSION CONTROL DEVICE	SURVEILLANCE ACTIVITY
Baghouses	• Monitoring differential pressure. Adjusting timer or differential-pressure switch to adjust frequency of automatic cleaning cycle as needed.
	• Monitoring differential-pressure alarm lights in control area.
	• Monitoring compressed air pressure gauge on high-pressure air system.
	• Monitoring air flow instrumentation in control area.
Wet Scrubbers	• Monitoring differential pressure.
	• Monitoring differential-pressure alarm lights in control area.
	• Monitoring air flow instrumentation and alarm lights in control area.
	• Monitoring water flowmeters.
	• Monitoring water pressure alarm lights in control area.
	• Monitoring control area process control indicator lights for possible process shutdown in the event of water flow failures at preconditioning sprays or at the scrubber.

VALUE/IMPACT STATEMENT

The NRC staff performed a value/impact assessment to determine the proper procedural approach for providing guidance on designing, testing, operating, and maintaining emission control devices at uranium mills. The assessment resulted in a decision to develop a regulatory guide describing procedures for designing, testing, operating, and maintaining emission control devices at uranium mills. The results of this assessment were included in a draft regulatory guide on this subject, CE. 309-4, that was issued for public comment in May 1985. Comments received from the public and additional NRC staff review have shown no need to change the value/impact statement published with the proposed regulatory guide. Therefore, the value/impact statement published with the proposed guide is still applicable. A copy of the draft regulatory guide (identified by its task number, CE 309-4) and its associated value/impact statement is available for inspection and copying for a fee at the NRC Public Document Room at 1717 H Street NW., Washington, DC.

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March 1987

REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 3.59
(Task WM 407-4)

METHODS FOR ESTIMATING RADIOACTIVE AND TOXIC AIRBORNE SOURCE TERMS FOR URANIUM MILLING OPERATIONS

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A. INTRODUCTION

Each licensee who processes or refines uranium ores in a milling operation is required by § 20.1 of 10 CFR Part 20, "Standards for Protection Against Radiation," to make every reasonable effort to maintain radiation exposures and releases of radioactive materials in effluents to unrestricted areas as low as is reasonably achievable, taking into account the state of technology and the economics of improvements in relationship to benefits to the public health and safety. In accordance with 10 CFR Part 40, "Domestic Licensing of Source Material," mill operations are to be conducted so that all airborne effluent releases are reduced to levels as low as is reasonably achievable. In addition, 40 CFR Part 190, "Environmental Radiation Standards for Nuclear Power Operations," requires that the maximum annual radiation dose to individual members of the public resulting from fuel cycle operations be limited to 25 millirems to the whole body (radium and its daughters excepted) and to all organs except the thyroid, for which the dose must be limited to 75 millirems.

40 CFR Part 192, "Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings," is also pertinent to this guide. Subpart D of 40 CFR Part 192 governs the management of uranium byproduct materials under Section 84 of the Atomic Energy Act of 1954, as amended, during and following the processing of uranium ore. After the closure period, this regulation limits releases of radon-222 from uranium byproduct materials to the atmosphere so as not to exceed an average release rate of 20 picocuries per square meter per second (paragraph 192.32b(ii)). In addition, 40 CFR Part 61, "National Emission Standards for Hazardous Air Pollutants (NESHAPs); Standards for Radon-222 Emissions from Licensed Uranium Mill Tailings," establishes work practices that limit the total size and area of new impoundments. Conditions are also provided for continued operation of existing impoundments.

This regulatory guide provides guidance to applicants and licensees in preparing environmental reports and environmental impact statements and to the NRC staff in reviewing those reports. The guide addresses methods, models, data, and assumptions acceptable to the NRC staff for estimating airborne emissions of radioactive and toxic materials from various steps in uranium milling. The emissions and the methods for estimating the source terms for these emissions were identified from NRC licensing actions on uranium mills, evaluations and monitoring of mill operations, research programs conducted to identify and improve on methods for retention and stabilization of mill tailings, and methods and practices used by the NRC staff to generate the estimates. If alternative methods, models, data, or assumptions are used for estimating source terms, such alternatives will be reviewed by the NRC staff to determine their acceptability.

Separate guidance provides direction on radiological effluent and environmental monitoring (Ref. 1), compliance with radiation protection standards (Ref. 2), and calculation of radiation doses from airborne materials (Ref. 3). Other related guides such as those for evaluating air pollution control devices and designing radon cover systems are being prepared.

Any information collection activities mentioned in this regulatory guide are contained as requirements in 10 CFR Part 40, which provides the regulatory basis for this guide. The information collection requirements in 10 CFR Part 40 have been approved under OMB Clearance No. 3150-0020.

B. DISCUSSION

The milling of uranium ores involves the handling of large quantities of ore containing as little as a few hundredths of a percent of U_3O_8. These ores, however, contain radionuclides in concentrations well above average background. Dusts and gas emissions result from ore handling, processing, and tailings (ore residues). Processing operations produce a uranium concentrate, "yellowcake," which when dried and packaged for shipment is a source term contributor. Residual wastes, including liquid and solid (tailings) wastes, are stored within manmade retaining structures where they are allowed to dry. Without proper planning and control, releases from each of these operations create the potential for doses to the public in excess of the applicable standards (e.g., 40 CFR Part 190), and compliance with the standards can be achieved only by strict emission controls at the mill (Ref. 4).

When environmental monitoring data are not yet available (as in the case of the licensing of new facilities or authorizing of significant modifications to existing ones), predictive models are used to evaluate the potential impacts of the prospective new operations (Ref. 2). Estimating radionuclide concentrations to which nearby individuals may be exposed involves making numerous assumptions. In some cases, simplifications are made about important but frequently uncertain factors such as mill releases and atmospheric transport. Nevertheless, potential problem areas can be identified, and this information can be used to establish or modify environmental monitoring programs and locations.

1. NEED FOR SOURCE TERMS

Estimates of the quantities of radionuclides and toxic substances released in the airborne effluents of a uranium mill are needed for use in the licensing decisions by the NRC staff to predict (1) radiation doses to the public, (2) the extent or degree of effluent control, (3) the environmental impact of milling operations, and (4) the degree to which mill operations meet the as low as is reasonably achievable (ALARA) concept. With these predictions, the NRC staff can judge whether the mill operation meets Federal, State, and local criteria for environmental release of these materials.

The source terms for a uranium mill vary over its lifetime. Predictions are made under varying operational conditions:

- Maximum throughput -- representing maximum releases from ore pads and mill operations.
- Year prior to tailings impoundment reclamation -- representing particulate and radon releases as the tailings dry out.
- Postreclamation of the tailings impoundment -- representing the long-term impacts.

The radionuclides in the uranium ore are generally assumed to be in secular equilibrium with uranium-238. Figure 1 depicts the decay scheme for uranium-238. After the uranium has been leached from the ore, long-lived daughter product isotopes are controlling factors in the tailings. Radon is considered separately since it emanates both from the ore and from the tailings and is therefore

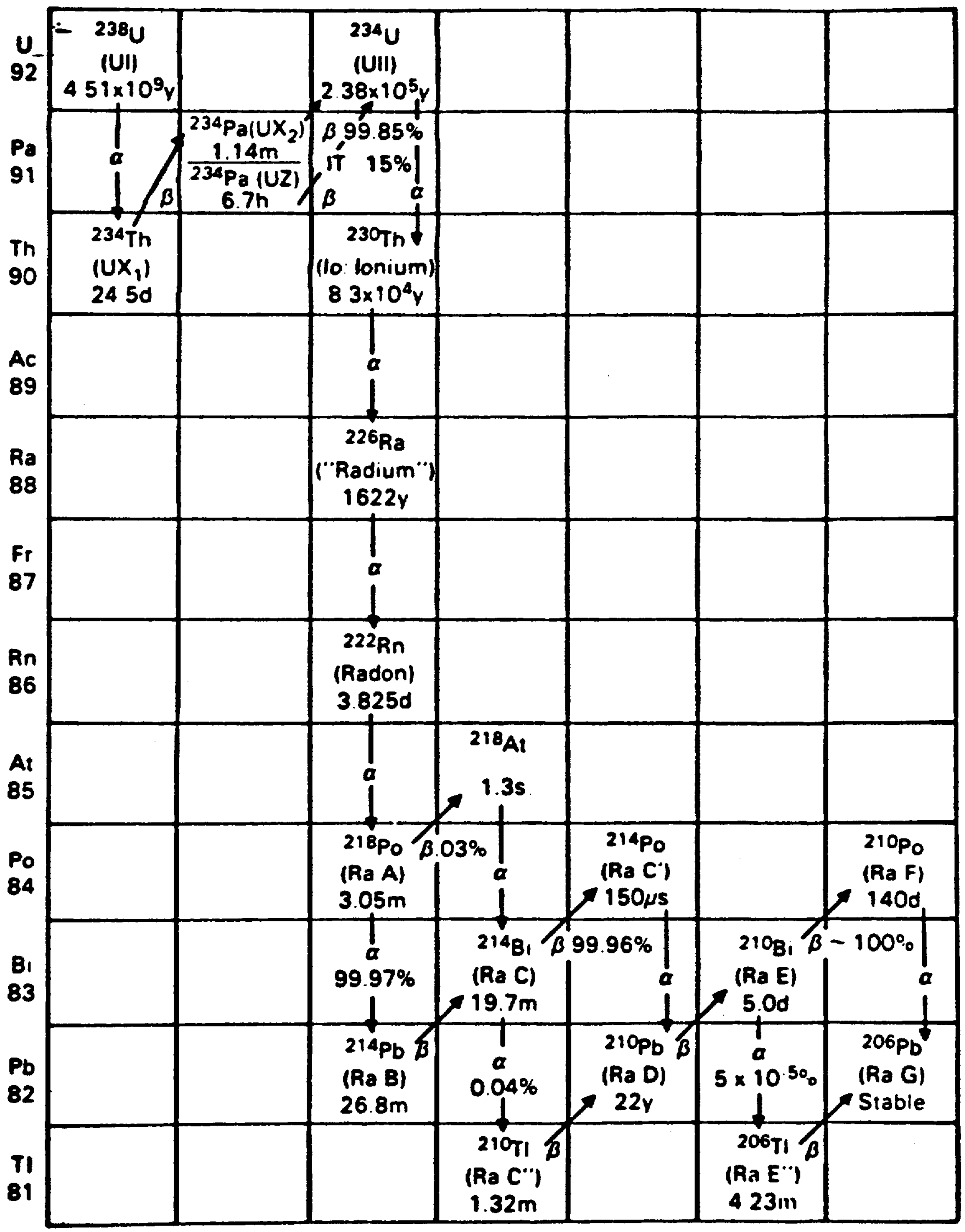

Figure 1. Decay Scheme for Uranium-238

released to the environment independently from other radioisotopes of the uranium decay chain. Thus, since models used in predicting radiological and environmental impact include the impacts of the short-lived decay products from longer-lived radionuclides, source term estimates for natural uranium, uranium-238, thorium-230, radium-226, lead-210, and radon-222 provide a sufficient base. Since the uranium-235 in natural uranium represents only about 0.7 percent of natural uranium, radionuclides from its decay chain contribute only a small fraction of the total radioactivity for natural uranium and thus are not included in the source term estimates.

Uranium ores usually contain small amounts of toxic elements such as arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. The release of these elements is also included in source term estimates.

2. IDENTIFICATION AND DESCRIPTION OF RELEASE POINTS

Radioactive and nonradioactive dusts and gases are released from several steps in uranium mill processes. Figure 2 shows the major processing steps and the airborne release sources for a typical uranium mill. These steps and sources are described in the following sections. Methods for estimating quantities released are discussed in the regulatory position of this guide.

2.1 Ore Storage

Information needed by the NRC staff to estimate source terms depends in part on operational procedures that determine the quantity of ores stored at the mill, climatic conditions, need for blending widely varying ore compositions, and general requirements for backlogging. In addition, moisture content, which is a function of mine source, age in storage, and climatic conditions, contributes to the degree to which ore dust is dispersed. The ore may dry out in the stockpile, making it more susceptible to dispersion. The quantity of dust that may be dispersed may be controlled by keeping the stockpile wet or spraying it with chemical suppressants as an interim measure. This will have little effect on radon release from the ore storage unless the ore is kept saturated and not allowed to dry out.

2.2 Ore Crushing and Grinding

Detailed information on the steps and controls used in ore crushing and grinding is needed by the NRC staff because ore dust containing radioactivity can be released to the environment during these operations. Ore received from the mine is blended and successively reduced in size by, for example, jaw crushers, cone crushers, and ball mills, to permit ready leaching of the uranium. Dust generated during these process steps is not generally confined within the equipment, although offgases from the smaller-sized reduction equipment are usually scrubbed. The ore is transferred between stations by belt conveyors, usually canopied, in enclosed structures where entrained particles are filtered out before the air is discharged from stacks. The last stages of grinding are usually done wet to eliminate the free flow of airborne particulates from the finely ground product.

Some of the radon from decay of radium-226 in the ore is released during the ore handling and crushing activities. The fraction of radon released varies, depending on the physical characteristics and chemical composition of the

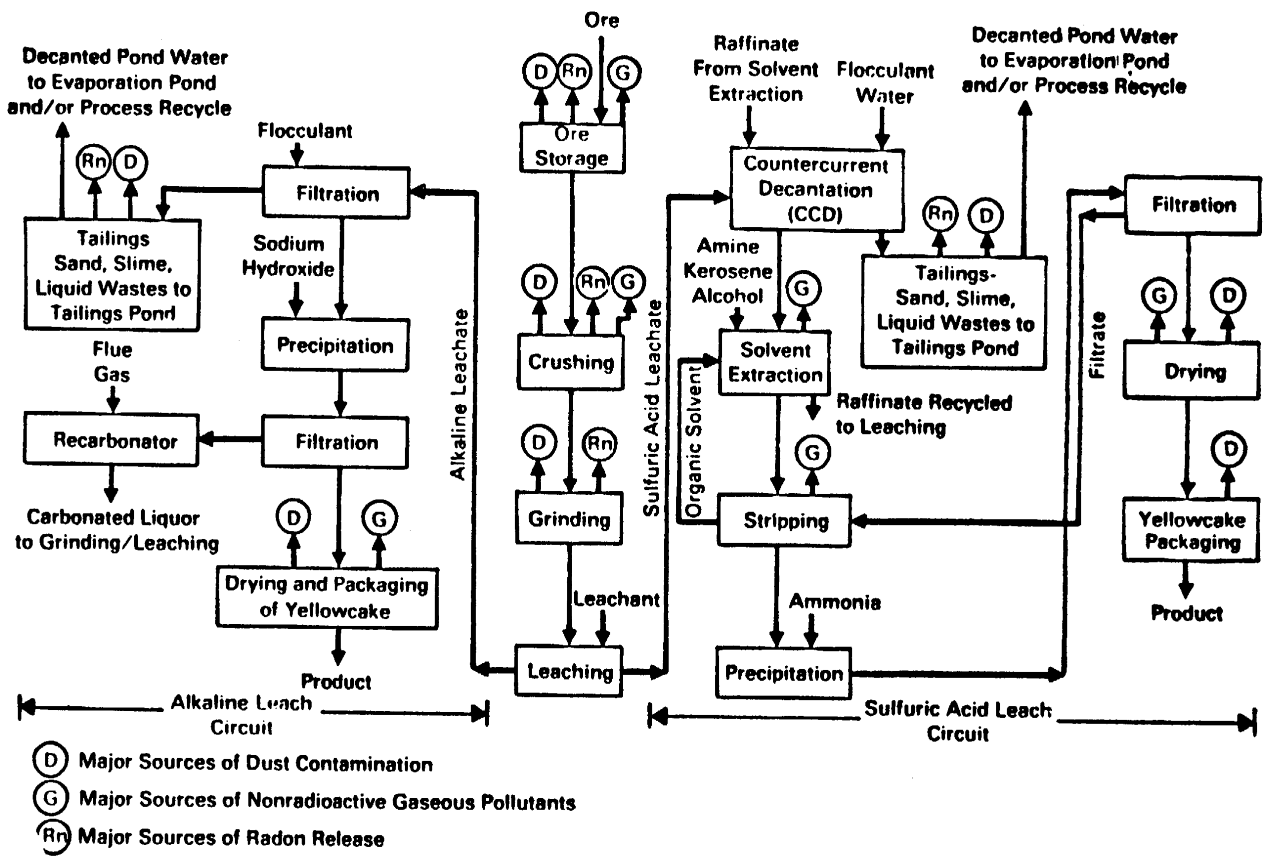

Figure 2. Block Flow Diagram for Uranium Milling Processes

ore. Although radon-222 (the primary radon isotope released from uranium ores) is chemically inert and has a short half-life (3.8 days), its decay products reach secular equilibrium quickly and are dispersed and are therefore subject to being breathed in by man and animals.

2.3 Ore Processing

For ore processing operations conducted in solutions or slurries, particulate emissions are negligible and therefore present little hazard. However, nonradioactive gaseous effluents consisting of carbon dioxide, sulfur dioxide, water vapor, and sulfuric acid mist from the leaching step, some of which are toxic, could be released. Organic chemical vapors consisting of kerosene with small amounts of amine and alcohol are released from the open solvent extraction settling chambers. Ion exchange processes are enclosed and chemical vapor releases are negligible.

2.4 Yellowcake Production, Drying, and Packaging

The potential for particulate releases during uranium concentrate (yellowcake) production depends on the degree to which the product is dried or calcined and on the effectiveness of offgas filtration. Particulate releases from the drying, calcination, and packaging steps are dependent on the control used to prevent release of excessive amounts of uranium in the offgases. Offgases are scrubbed or filtered prior to release via a stack.

Since the ore processing steps reject nearly all the radium to the tailings, very little radon is released during the production of yellowcake. However, yellowcake drying and packaging present a potential for particulate release and are therefore of concern in terms of this guide.

2.5 Tailings Impoundment

The processing of ore in uranium mills generates radioactive and nonradioactive waste generally referred to as tailings, which consist of the majority of the ore solids, process additives, and water. The industry uses different methods for storage of these tailings. The tailings together with the earthen dams or cells that contain these wastes are referred to as impoundments, and the impounded liquids are called tailings ponds. Depending on the procedure for disposing of the tailings in the impoundments, the significant airborne releases consist of the coarse sand solids, the finer slime solids, and the radon gas. Fugitive dust can be reduced by frequent wetting, application of chemical suppressants, or other physical strategies. Radon releases are more difficult to control because of the nature of radon gas. Interim reclamation, increased water cover, and below-grade design are some of the means by which radon release can be attenuated.

2.6 Heap Leaching

Heap leaching involves leaching low-grade ore ($<0.04\%$ U_3O_8) either by gravitational flow of the leachant through an open pile or by flooding a confined ore pile (Ref. 4). The leachate is treated on site by ion exchange or solvent extraction, and a crude yellowcake that may be shipped to a nearby mill for refinement is precipitated. When the ore dumps are reasonably near a mill, acid solutions from the mill may be used for the heap leaching and returned to the mill circuit for processing (Ref. 5).

Heap leaching has little impact on airborne environmental impacts. Radon-222 and its decay products are released and dispersed. The leached ore may be mixed with mill tailings. If the tailings are maintained as an isolated leached ore pile, control of fugitive dust is required.

2.7 Ore Leaching in Situ

Low-grade ores can be leached in situ by using a network of wells to inject a leach solution into the ore formation, mobilizing the uranium through formation of a soluble complex uranium salt, and removing the pregnant solution from the ore body through production wells. The uranium that has been made soluble is recovered by uranium mill processing operations producing yellowcake.

Radioactive airborne releases from in situ leaching are primarily limited to radon emanations from the solution resulting from the leaching of the ore. Some releases may occur from yellowcake dryers and packaging if such operations are present on site. Airborne releases from the chemical processing steps are comparable to those encountered during conventional mill operations.

Solid wastes that require controlled disposal are generated; however, the volume produced is much less than that created by conventional uranium mining and milling. Dried evaporative ponds can contain residual radionuclides and toxic minerals leached along with the uranium. If disposed to the tailings pond at a conventional mill, the waste solutions will be only a minor increment to the tailings impoundment system.

3. USE OF THIS GUIDE

Present NRC staff practice for estimating radioactive airborne release rates (source terms) from uranium milling facilities involves the characterization of such releases by radionuclide, particle size, and density (Ref. 4). These data, when combined with a meteorological dispersion model representing the annual average meteorological conditions of the mill site, provide a basis by which the NRC staff can estimate concentrations, which in turn are used to calculate radiation doses as described in Reference 3.

The primary calculational tool used by the NRC staff in evaluating the radiological impact of uranium milling operations is the MILDOS code (Ref. 6). As used by the NRC staff, the MILDOS code has only five primary radionuclides in the uranium-238 decay chain that are treated explicitly as source terms. These radionuclides are uranium-238, thorium-230, radium-226, lead-210, and radon-222. Release rates are required for these radionuclides for each potential release source. The code accounts for releases and ingrowth of other radionuclides, assuming secular equilibrium. For radon-222 decay products, which grow in during transport of radon-222 from the site, the code calculates the resulting ingrowth. These radon-222 daughters include polonium-218, lead-214, bismuth-214, lead-210, and polonium-210.

This guide provides technical guidance concerning methods, models, data, and assumptions acceptable to the NRC staff for estimating airborne emissions of radioactive and toxic materials from various steps in uranium milling. If alternative methods, models, data, or assumptions are used in estimating source terms, such alternatives will be reviewed by the NRC staff to determine their acceptability.

C. REGULATORY POSITION

Methods described below for estimating radioactive and nonradioactive source terms from uranium milling operations and tailings disposal reflect the approaches used by the NRC staff. Certain bases and assumptions used in making acceptable calculations are identified and explained. Nonradioactive particulate emission source terms may be estimated in the same way as radioactive particulate emissions, with an estimate of the toxic element composition of the ore (or tailings). Estimates of nonradioactive gas emissions from process operations are based on raw material and fuel uses. Principal parameters needed to estimate source terms are listed in Appendix A to this guide.

1. RADIOACTIVE PARTICLE EMISSION SOURCE TERMS

The major particle emission sources at a uranium mill include ore handling, ore storage, crushing and grinding, yellowcake production (especially drying and packaging), and tailings piles. Much of the data useful in calculating source terms is enumerated in Appendix A to Reference 3 and in Appendices A, B, and C to Regulatory Guide 3.8, "Preparation of Environmental Reports for Uranium Mills." Information from the applicant needed by the NRC staff to estimate source terms is listed in Appendix A to this guide. The general method for calculating source terms is to multiply together the normalized emission rate, contaminant content, emission control factor, and processing rate for each process being evaluated. The following discussion shows typical equations and example calculations used by the NRC staff for process and windblown emissions typical of uranium mills.

1.1 Process Emissions

Processes releasing particles include ore handling, grinding and crushing, conveying, and yellowcake drying and packaging.

The basic equation is:

$$S = MCEN(1 - R) \qquad (1)$$

where

S is the source term, quantity/time, e.g., kg ^{238}U/hr; Ci ^{238}U/yr;

M is the process rate, mass/time, e.g., metric ton ore/d;

C is the contaminate concentration, percent, pCi/g uranium, or ppm of toxic elements in ore;

E is the emission factor for process, dust released per metric ton of ore dumped to the grizzly;

N is the unitless activity enrichment ratio; and

R is the unitless emission control factor.

The unitless activity enrichment ratio, N, expresses the extent to which the contaminant concentration is higher in the suspended airborne particles that are larger than 20 μm in diameter than in the bulk material. The NRC staff uses

N = 2.5, conservatively based on measured values (Refs. 7 and 8) in which the content of uranium-238 and its progeny in fines* was found to be up to 2.5 times higher than the content in the bulk ore. The emission factor, E, is tabulated for various common operations in Appendix B to this guide. The unitless reduction factor, R, is tabulated in Appendix C for various control measures. Examples of calculating particle source terms follow.

1.1.1 Example Calculation: Crushing

The source terms for radionuclides in the chain for uranium-238 decay are the same as that for uranium-238 since they are in secular equilibrium. The following parameters are supplied by the applicant:

M = 145,000 MT processed/yr

C = 420 pCi ^{238}U/g bulk ore

N = 2.5 times greater ^{238}U content in dust than in bulk ore

The emission control device is a baghouse with an expected efficiency of about 80 percent for the dust produced by the operation. The applicant has determined that the moisture content of the stored ore at the time of crushing is 7 wt-%. Because tertiary crushing is not used, the estimated uncontrolled emission factor, E, from Appendix B is 0.16 lb/ton. The estimated uranium-238 source term, using Equation (1), is:

$$S = 145{,}000 \text{ MT/yr} \times 420 \text{ pCi/g} \times 0.16 \text{ lb/ton} \times 2.5 \times (1 - 0.80) \times 1.1025 \text{ ton/MT} \times 454 \text{ g/lb} \times 10^{-12} \text{ Ci/pCi} = 2.4 \times 10^{-3} \text{ Ci/yr}$$

1.1.2 Example Calculation: Truck Unloading to Ore Pad

The ore processing rate, M, is 193,000 MT/yr. The bulk ore content, C, of uranium-238 and progeny in secular equilibrium is 435 pCi/g. The ore is end-dumped from a truck. No control measures are used. Thus, the emission factor, E, is 0.04 lb/yd^3, based on Appendix B. The bulk density of the ore is 1.5 ton/yd^3. The dust/ore specific activity ratio, N, is 2.5, and the source term for uranium-238 and progeny, using Equation (1), is:

$$S = 193{,}000 \text{ MT/yr} \times 435 \text{ pCi/g} \times 0.04 \text{ lb/yd}^3 \times 1 \text{ yd}^3/1.5 \text{ ton} \times 1.1025 \text{ ton/MT} \times 454 \text{ g/lb} \times 2.5 \times 10^{-12} \text{ Ci/pCi} = 2.8 \times 10^{-3} \text{ Ci/yr}$$

1.1.3 Example Calculation: Fine Ore Storage

In this case, the fine ore is conveyed to and from the fine ore storage area for a total of four conveyor transfers. Ore is handled at a rate of 135,000 MT/yr, and the bulk uranium-238 and progeny content is 350 pCi/g. The 2.5 dust/ore activity ratio is applied. The operation occurs in an enclosed structure with a reduction factor of 75 percent based on engineering judgment (Appendix C). The emission factor for each transfer is 0.023 lb/ton (Appendix B). The combined emission factor for the fine ore storage conveying is:

*<100 μm in diameter.

$$E = 4 \text{ transfers} \times 0.023 \text{ lb/ton per transfer} = 0.092 \text{ lb/ton}$$

The uranium-238 and progeny source term is then:

$$S = 135{,}000 \text{ MT/yr} \times 350 \text{ pCi/g} \times 0.092 \text{ lb/ton} \times 1.1025 \text{ ton/MT} \times 454 \text{ g/lb} \times 10^{-12} \text{ Ci/pCi} \times (1 - 0.75) \times 1 = 5.4 \times 10^{-2} \text{ Ci/yr}$$

1.1.4 Example Calculation: Yellowcake Drying and Packaging

Releases from the stack for offgases from the yellowcake drying and packaging operations are quite variable (Ref. 9). Variability among mills and uniqueness of each mill are important factors. Also, changes in operating parameters can change emission rates over a period of time. Maintenance and repair work, malfunction of the exhaust air cleanup systems, and intermittent shutdown and startup are among other variables that can have an impact on the emissions from this operation. The NRC staff bases its estimates on measurements made at operating mills (Ref. 9) and the release assumed for the model mill in the GEIS on uranium milling (Ref. 4), which in turn were based on recommendations found in Reference 10. Accordingly, the staff estimates that 0.1 percent of yellowcake produced is released from the stack in the drying and packaging operations based on EPA-measured releases at six mills.

For a mill with a yellowcake production of 200 MT/yr, of which 90 percent is U_3O_8, the estimated release from the yellowcake stacks would therefore be:

$$S = 200 \text{ MT/yr} \times 0.90 \times 10^{6} \text{ g/MT} \times 3.33 \times 10^{-7} \text{ Ci/g } ^{238}\text{U} \times 0.85 \text{ g U/g } U_3O_8 \times 0.001 = 5.1 \times 10^{-2} \text{ Ci } ^{238}\text{U/yr}$$

In the absence of firm data, the NRC staff assumes that 0.5 percent thorium and 0.1 percent lead and radium are processed along with the yellowcake. Since the decay products of uranium in the ore are in secular equilibrium with the uranium, the radioactivity of thorium-230 released from the stack is estimated to be 0.005 of the radioactivity of the uranium released. Thus, the thorium release for the example mill is calculated to be:

$$S = 5 \times 10^{-2} \text{ Ci } ^{238}\text{U/yr} \times 0.005 = 2.5 \times 10^{-4} \text{ Ci } ^{230}\text{Th/yr}$$

The lead and radium release is:

$$S = 5 \times 10^{-2} \text{ Ci } ^{238}\text{U/yr} \times 0.001 = 5 \times 10^{-5} \text{ Ci/yr of either } ^{210}\text{Pb or } ^{226}\text{Ra}$$

The NRC staff prefers reliable monitoring data when available. Renewal of licenses or modification of licenses are examples of when such data may be submitted by the licensee.

It is noteworthy that particulate releases from the yellowcake production step occur almost entirely in drying and calcining operations. If the yellowcake product were to be packaged as a slurry or as a damp filter-cake product, particulate emissions from this operation would be negligible.

1.2 Windblown Emissions

Fugitive dust varies significantly from mill to mill. Meteorological conditions (wind, rainfall, temperatures), exposed surfaces, ore compositions and physical characteristics, particle size distributions, site characteristics, and operational procedures are among the factors that affect the degree to which dust is blown about.

1.2.1 Example Calculations: Tailings Pile

The NRC staff estimates windblown particle emissions using the method described in MILDOS (Appendix A to Ref. 6). In using this approach, the emission factor, E_w, is calculated as follows:

$$E_w = \frac{3.156 \times 10^7}{0.5} \times \sum_s R_s F_s \qquad (2)$$

where

E_w is the annual dust loss per unit area, $g/m^2 \cdot yr$;

F_s is the annual average frequency of occurrence of wind speed group s, dimensionless, obtained from joint relative frequency wind distribution for the site;

R_s is the resuspension rate for tailings sands at the average wind speed for wind speed group s, for particles ≦ 20 μm in diameter, $g/m^2 \cdot sec$;

3.156×10^7 is the number of seconds per year; and

0.5 is the fraction of the total dust loss constituted by particles ≦ 20 μm in diameter.

The MILDOS-calculated resuspension rates for tailings sands are tabulated in Table 1 for each wind speed group, s.

Table 1

Parameters for Calculating Annual Dusting Rate for Exposed Tailings Sands

Wind Speed Group, knots	Average Wind Speed, mph	Dusting Rate (R_s), $g/m^2 \cdot sec$
0-3	1.5	0
4-6	5.5	0
7-10	10.0	3.92×10^{-7}
11-16	15.5	9.68×10^{-6}
17-21	21.5	5.71×10^{-5}
21+	28.0	2.08×10^{-4}

The source term for each tailings beach area is then calculated as:

$$S = E_w ACfN(1 - R) \quad (3)$$

where

E_w is the emission factor in g/m²·yr, as calculated above;

A is the exposed surface area (of the beach at the tailings impoundment or of the ore pad, for example) in m²;

C is the contaminant concentration in percent, pCi/g of uranium, or ppm for toxic elements in the initial ore;

N is the unitless activity enrichment ratio of concentration in dust/bulk material;

R is a unitless control factor depending on the degree of control applied (see Appendix C); and

f is the fraction of a particular contaminant present.

The first example below estimates the radium-226 release from an abandoned tailings pile temporarily stabilized with a synthetic polymer coating sprayed onto the sand (R = 0.85, from Appendix C). The pile area, A, is 53 acres and contains 99.5 percent of the 300 pCi ^{226}Ra/g originally in the ore. The annual average frequency of occurrence of each wind speed group, resuspension factor, and their product are shown in Table 2.

Table 2

Parameters for Calculating Example Tailings Emission Factor

Wind Speed Group, knots	Resuspension Rate[a] R_s, g/m²·s	Frequency of Occurrence,[b] F_s	Product $R_s \times F_s$ g/m²·s
0-3	0	--	0
4-6	0	--	0
7-10	3.92×10^{-7}	0.4035	1.58×10^{-7}
11-16	9.68×10^{-6}	0.1942	1.88×10^{-6}
17-21	5.71×10^{-5}	0.0501	2.86×10^{-6}
21+	2.08×10^{-4}	0.0089	1.85×10^{-6}
			$\sum_s = 6.75 \times 10^{-6}$

[a]Dusting rate of a function of wind speed is computed by the MILDOS code (Ref. 6).

[b]Wind speed frequencies obtained from annual joint frequency data for the site.

The calculated emission factor (annual average dust loss rate) is:

$$E_w = 3.156 \times 10^7 \text{ s/yr} \times 6.75 \times 10^{-6} \text{ g/m}^2\cdot\text{s}/(0.5)$$
$$= 4.3 \times 10^2 \text{ g/m}^2\cdot\text{yr}$$

The radium-226 source term, using Equation (3), is therefore:

$$S = 4.3 \times 10^2 \text{ g/m}^2\cdot\text{yr} \times 53 \text{ acres} \times 4047 \text{ m}^2/\text{acre} \times 300 \text{ pCi } ^{226}\text{Ra/g} \times 10^{-12} \text{ Ci/pCi} \times 0.995 \times 2.5 \times (1 - 0.85)$$
$$= 1.0 \times 10^{-2} \text{ Ci } ^{226}\text{Ra/yr}$$

The second example considers an active tailings impoundment at the same site (same wind frequency occurrence, as above). Beaches are maintained wet, as needed (R = 25%, Appendix C), and are approximately 50 percent of the total impoundment area of 45 acres. Using Equation (3) and a specific activity concentration ratio of N = 2.5, the radium-226 source term is estimated to be:

$$S = 4.3 \times 10^2 \text{ g/m}^2\cdot\text{yr} \times 45 \text{ acres} \times 0.50 \times 4047 \text{ m}^2/\text{acre} \times 300 \text{ pCi } ^{226}\text{Ra/g} \times 10^{-12} \text{ Ci/pCi} \times 0.995 \times 2.5 \times (1 - 0.25)$$
$$= 2.2 \times 10^{-2} \text{ Ci } ^{226}\text{Ra/yr}$$

For an active below-grade impoundment system, the NRC staff usually estimates that particulate releases during operation are negligible since solid tailings material is covered by tailings solution. Therefore, few, if any, exposed solids are subject to wind erosion.

1.2.2 Example Calculations: Ore Pad

Particulates on the ore pad subject to wind erosion are less than those from tailings piles since the ore has not yet been ground. The NRC staff's approach is to base the fugitive dust release from the ore pad on an emission factor estimated to be 10 percent of that calculated for the tailings pile. Equation (2) for ore pads is thus modified to read:

$$E_w = 0.1 \times \frac{3.156 \times 10^7}{0.5} \times \sum_s R_s F_s \qquad (4)$$

Thus, for the site with the wind frequency occurrence described above, the annual average dust loss rate is estimated to be:

$$E_w = 0.1 \times 3.156 \times 10^7 \text{ s/yr} \times 6.75 \times 10^{-6} \text{ g/m}^2\cdot\text{s}/(0.5)$$
$$= 43 \text{ g/m}^2\cdot\text{yr}$$

The source term for an ore pad of 10 acres containing ore with 300 pCi ^{238}U/g, using Equation (3) and a specific activity concentration ratio of N = 2.5 and without any control (R = 0), is thus estimated to be:

$$S = 43 \text{ g/m}^2\cdot\text{yr} \times 10 \text{ acres} \times 4047 \text{ m}^2/\text{acre} \times 300 \text{ pCi/g} \times 10^{-12} \text{ Ci/pCi} \times 2.5$$
$$= 1.3 \times 10^{-3} \text{ Ci } ^{238}\text{U/yr}$$

Since the progeny from uranium-238 are in secular equilibrium in the ore, the source terms for uranium-234, thorium-230, radium-226, lead-210, and polonium-210 would also be 1.3×10^{-3} Ci/yr. Any control such as keeping the ore pile wet would reduce fugitive dust by the appropriate factor as shown in Appendix C.

1.3 Parameter Selection

Production rate, pile areas, description of operation, and contaminant specie contents are reasonably well-identified parameters used in particle source term measurements. Emission factors and emission control reduction factors are less certain parameters. The NRC staff realizes that many of these factors are difficult to measure, e.g., the tailings resuspension factor and the control factor for chemical dust suppressants. Factors measured by the applicant or by others in the regulatory and emission control fields may be used. Examples of such measured values include the efficiency of emission control devices installed in stacks and the historical emission measurements at an applicant's yellowcake dryer stack. The NRC staff prefers to use reliably measured values for these parameters. Design parameters are generally chosen only when other data are unavailable. An adjustment should be made for expected performance, and minimum performance should be noted. The following information sources are used in source term estimates:

1. Applicant's measurements,
2. Default values listed in this regulatory guide,
3. Other measurements or estimates shown by the applicant to be acceptable,
4. Manufacturers' specifications, and
5. Best engineering judgment.

Section 9 of the GEIS for uranium mills (Ref. 4) indicates that tailings surface control and an efficient yellowcake dust collection system are the major factors necessary to maintain acceptable airborne emissions.

Alternative methods for treating mill tailings in ways to reduce the potential of fugitive dust are discussed in Sections 8 and 9 of Reference 4. Various strategies can be used for controlling dust, including vegetative cover; gravel, crushed rock, or riprap cover; manmade covers and sealants; and combinations of the above. Some of these are also useful in reducing radon emissions, as discussed below. Progressive reclamation, i.e., the practice of drying up and covering tailings piles in sections as they are filled, is an effective method for reducing airborne particulates from the tailings and is used by several mills in the United States.

2. RADON EMISSION SOURCE TERM

Processing of uranium ore and subsequent tailings disposal presents pathways for release of radon to the environment. The major pathways for radon release occur from ore storage, ore crushing and grinding, and the mill tailings disposal site. The amount of radon released through each of the pathways depends on the ore type, ore storage procedures, crushing or grinding operations, and tailings disposal practices. The factors affecting radon common to all the source pathways are (1) radium content of ore, (2) emanating power (coefficient) of ore or tailings, (3) radon diffusion coefficient in ore stockpiled, ground ore, and tailings, and (4) physical characteristics, including configuration of ore storage and tailings pile. The following sections describe methods used to estimate the release of radon from ore storage, crushing and grinding, leaching and extraction, and the tailings impoundment. Example calculations illustrate the calculation procedures.

2.1 Run-of-Mine Ore Storage

Ore received at the mill is stockpiled on ore storage pads in sufficient quantity to provide for a continuous supply to the mill. Radon release from the ore storage area depends on (1) the characteristics of ore, (2) the area and thickness of the ore pads, and (3) the storage time. The quality of the ore received varies with respect to ore concentration, grade, and size. Selection of ores from the stockpile is generally made to allow for a reasonably consistent composition as feed to the mill chemical processes.

2.1.1 Estimation Using Flux Factor

In the majority of cases, the NRC staff estimates radon release by using a specific radon flux factor of 1 pCi $^{222}Rn/m^2 \cdot s$ per pCi/g of ^{226}Ra. Only the area of the ore stockpile and the average radium content need be known to make the calculation of yearly release. An example calculation for an ore pad covering 3 hectares (7.5 acres) and containing an average radium-226 concentration of 300 pCi/g is:

$$(1 \text{ pCi } ^{222}\text{Rn/m}^2 \cdot \text{s})/(\text{pCi/g } ^{226}\text{Ra}) \times 300 \text{ pCi } ^{226}\text{Ra/g} \times 3 \text{ ha} \times 10^4 \text{ m}^2/\text{ha} \times 3.156 \times 10^7 \text{ s/yr} \times 10^{-12} \text{ Ci/pCi}$$
$$= 285 \text{ Ci } ^{222}\text{Rn/yr}$$

2.2 Hopper, Feeder, Crushing, and Grinding

Blended run-of-mine ore from the storage pile is fed to the crushing and grinding circuits. Because of the short residence time in the crushing and grinding circuits, only a small amount of radon will be released. It is estimated that less than 10 percent of the radon in the ore will be released during crushing and grinding (Ref. 7). The radon released during the ore crushing and grinding is estimated as follows:

$$135{,}000 \text{ MT/yr} \times 350 \text{ pCi/g} \times 10^6 \text{ g/MT} \times 10^{-12} \text{ Ci/pCi} \times 10\% = 4.73 \text{ Ci/yr}$$

2.3 Leaching and Extraction

Leaching and extraction are wet processes and again require short residence times; therefore, radon-222 release is estimated not to be significant.

2.4 Yellowcake Drying and Packaging

No significant radon release occurs since only $\sim$0.1 percent of the original radium-226 in the ore is found in the yellowcake.

2.5 Tailings Disposal

The major waste discharged from a mill is the tailings slurry, which contains the barren ore plus process solutions. The tailings liquid contains residual acid or residual alkaline (depending on the leaching agent) and dissolved solids from the leaching steps. Some of the liquid (~1/3) may be returned to the mill for reuse. The tailings consist of sand, slimes, and a mixture of sand and slimes, which are the sources of radon. Estimates of radon release are based on about 99.9 percent of the radium-226 remaining with the tailings unless measurements that indicate lesser amounts of radium are available.

Radon will be released from the exposed tailings. During the active period of the tailings pile, the impoundment is assumed to have areas of saturated tailings (slimes) mostly covered with raffinate solution and areas of relatively dry tailings (beach sands). The factors affecting the release of radon from the tailings pile are basically the same as those for the ore storage pads, including (1) emanating power, (2) diffusion coefficient, (3) moisture, (4) density, and (5) tailings thickness. The basic difference, however, is that during the active life of the tailings pile there are two areas on the tailings piles: the drier beach area and the saturated slimes area, which is generally covered with the raffinate pond. The tailings in the beach areas generally contain less radium than the tailings in the slimes areas (Ref. 4). The relative amounts of slimes and sands or mixtures on the surface of a tailings pile depend not only on the quantity of sands and slimes but also on the procedure used to distribute the tailings on the pile. The beach areas have tailings with a higher radon diffusion coefficient resulting from the larger particle sizes and lower moisture contents. The slimes areas have tailings with finer particle sizes and higher moisture content, which reduce the radon coefficient.

2.5.1 Estimation Using Flux Factor

The condition (slimes/sands distribution, moisture content, fraction covered by solution raffinate, etc.) of the tailings impoundment is variable and complex and difficult to accurately predict. In general, the NRC staff uses the specific flux factor of 1 pCi $^{222}Rn/m^2 \cdot s$ per pCi $^{226}Ra/g$ to estimate the radon release from the tailings. Thus, for a hypothetical tailings pile containing an average of 300 pCi $^{226}Ra/g$ and covering 50 hectares (124 acres), the annual radon-222 release is:

$$(1 \text{ pCi } ^{222}\text{Rn/m}^2\cdot\text{s})/(\text{pCi } ^{226}\text{Ra/g}) \times 300 \text{ pCi } ^{226}\text{Ra/g} \times 50 \text{ ha} \times 10^4 \text{ m}^2/\text{ha} \times 3.165 \times 10^7 \text{ s/yr} \times 10^{-12} \text{ Ci/pCi} = 4750 \text{ Ci/yr}$$

2.6 Radon Release During in Situ Operations

The major source of radon release during in situ mining operations is the lixiviant which, when exposed to the atmosphere, will release radon. The release will occur when the lixiviant arrives at the process recovery surge tanks, ion exchange tanks, or columns or evaporation ponds.

Aquifer restoration, which includes ground-water sweeping and clean water circulation, is also a source of radon that must be considered.

The key parameters used to determine the average annual radon release are listed in Table 3.

Table 3

Parameters for Determining Radon Release from in Situ Mining

Ore grade, % U_3O_8
Concentration in ore
Mined area per year, m^2
Average lixiviant flow rate, L/min
Average restoration flow rate, L/min
Number of operating days
Formation thickness, m
Formation porosity
Rock density, g/cm^3
Residence time for lixiviant, d
Residence time for restoration solution, d
Emanating power of ore

In order to determine a reasonably conservative annual radon release, it is assumed that one mining unit will be mined, one unit soaked, and one unit restored during the year. The radon release from these operations is discussed in the following paragraphs.

2.6.1 Radon Release from Leaching

If the radium-226 content of the ore has not been measured, it is assumed that the uranium-238 is in equilibrium with all its daughters. The radium-226 and radon-222 concentration present in the ore would therefore be 2820 pCi/g per % U_3O_8. The radon emanating power is assumed to average 0.2 unless otherwise determined. The radon release at equilibrium, G, in 1 m^3 of rock may be calculated using Equation (4).

$$G = R\rho E(1 - p)/p \times 10^{-6} \qquad (4)$$

where

G is the radon release, Ci/m^3;

R is the radium content, pCi/g;

ρ is the rock density, g/cm^3;

E is the emanating power; and

p is the formation porosity.

The yearly radon release, Y (Ci/yr), may be calculated using Equation (5).

$$Y = GM\varepsilon D \times 1.44 \qquad (5)$$

where

G is the radon release at equilibrum, Ci/m^3 of rock;

M is the lixiviant production rate, L/min;

ε is the equilibrium factor for radon; and

D is the production days per year.

The equilibrium factor, ε, equals $1 - e^{-\lambda t}$ where λ is the radon decay constant and t is the residence time. This is a conservative estimate since it assumes that the radon immediately goes into the lixiviant solution.

2.6.2 Radon Release from Soaking

In addition to the release of radon from the lixiviant dissolution, it is estimated that one pore volume of nonproduction solution will be removed as each mining unit is put into service. The startup radon release, S, may be calculated using Equation (6).

$$S = GATp \tag{6}$$

where

G is the radon release at equilibrium, Ci/m^3 of rock;

A is the area of mining unit, m^2;

T is the thickness of ore, m; and

p is the formation porosity.

For a mining unit that will be soaked for 1 year, it is also assumed that one pore volume of mining solution will be removed when the lixiviant is added. Therefore, the release of radon would be the same as during the startup.

2.6.3 Radon Release During Restoration

The annual radon released during restoration, r (Ci/yr), is calculated using Equation (7).

$$r = GN\varepsilon D \times 1.44 \tag{7}$$

where

G is the radon release at equilibrium, Ci/m^3 of rock;

N is the restoration solution rate, L/min;

ε is the equilibrium factor; and

D is the restoration days per year.

In a similar manner to startup, it is assumed that one pore volume of solution will be removed before restoration begins.

2.6.4 Example Calculation: Radon Release from an in Situ Mine

The following is a sample calculation of the total release of radon from a hypothetical in situ uranium mining operation.

Assumptions:

Ore Grade	0.1% U_3O_8
Average area to be mined	10 acres
Average lixiviant flow	4000 L/min
Average restoration flow	400 L/min
Operating days per year	365
Formation thickness	3 m
Formation porosity	0.3
Rock density	1.8 g/cm^3
Residence time for lixiviant	5 days
Residence time for restoration solution	10 days
Emanating power	0.2

From mining and soaking, the radon release per cubic meter of the rock is estimated using Equation (4).

The radium content, R, is first calculated assuming secular equilibrium between the uranium-238 and radium-226.

$$R = 3.33 \times 10^5 \text{ pCi } U^{238}/\text{g U} \times 0.001 \text{ g } U_3O_8/\text{g ore} \times 0.85\text{g U/g } U_3O_8$$
$$= 28.3 \text{ pCi/g ore}$$

Next the radon release, G, is calculated.

$$G = R\rho E(1 - p)/p$$
$$= 28.3 \text{ pCi/g} \times 0.1\% \ U_3O_8 \times 1.8 \text{ g/cm}^3 \times 10^6 \text{ cm}^3/\text{m}^3 \times 0.2 \times (1 - 0.3)/0.3 \times 10^{-12} \text{ Ci/pCi}$$
$$= 2.4 \times 10^{-6} \text{ Ci/m}^3$$

Next the yearly release of radon is calculated using Equation (5).

$$Y = GM\varepsilon D \times 1.44$$
$$\varepsilon = 1 - e^{-(0.181/d)(5d)} = 0.6$$
$$Y = 2.4 \times 10^{-6} \text{ Ci/m}^3 \times 4000 \text{ L/min} \times 0.6 \times 365 \text{ d/yr} \times 1.44$$
$$= 3.0 \text{ Ci/yr}$$

The radon released from the startup solution and soaking is calculated using Equation (6).

$$S = GATp$$
$$= 2.4 \times 10^{-6} \text{ Ci/m}^3 \times 10 \text{ acres} \times 4074 \text{ m}^2/\text{acre} \times 3 \text{ m} \times 0.3$$
$$= 0.088 \text{ Ci/yr}$$

The total release of radon from the startup solution, production lixiviant, and soaking solution is:

Startup solution	0.09 Ci/yr
Production	3.0 Ci/yr
Soaking solution	0.09 Ci/yr
	3.18 Ci/yr

The radon release from the restoration operation is calculated using Equation (7).

$$r = GN\varepsilon D \times 1.44$$

$$\varepsilon = 1 - e^{-(0.181/d)(10d)} = 0.84$$

$$r = 2.4 \times 10^{-6} \text{ Ci/m}^3 \times 400 \text{ L/min} \times 0.84 \times 365 \text{ d/yr} \times 1.44$$
$$= 0.42 \text{ Ci/yr}$$

The total radon release from restoration includes a small increment of release similar to that from the startup solution. Therefore, the total release would be:

$$0.42 \text{ Ci/yr} + 0.09 \text{ Ci/yr} = 0.51 \text{ Ci/yr}$$

The total release from this 10-acre hypothetical in situ mining operation is then 3.18 + 0.51 = 3.69 Ci/yr.

3. NONRADIOACTIVE EMISSION SOURCE TERMS

During uranium milling, some nonradioactive contaminants and toxic elements are also released to the environment as shown in Table 4. In addition, combustion products are released from burning of fuel in the process and heating boilers.

Table 4

Nonradioactive Emissions Generated by Uranium Milling

Source	Emission
Ore storage and crushing/grinding	Ore dust
Leaching tanks vent	Sulfuric acid mist Sulfur dioxide
Solvent extraction vent	Organic solvent (kerosene)
Burning of fuel oil	SO_2, NO_2
Yellowcake precipitation	Ammonia
Yellowcake centrifuge or filter and calciner	Ammonia
Laboratory hood	Misc. vapors
Tailings pile	Tailings dust

3.1 Nonradioactive Particulate Emission Source Terms

The major sources of nonradioactive particulate emissions are the same as the sources for radioactive particulate emissions as previously described in Section C.1. The general method for calculating these source terms is the same as that for the radioactive source term discussed and illustrated in Sections C.1.1 and C.1.2. Example calculations of nonradioactive particulate source terms follow.

3.1.1 Example Calculation: Crushing

Source terms for toxic elements in the ore are estimated in a parallel manner to the radioactive particulate emissions. For example, if the applicant has indicated that the manganese content of the above ore is 500 ppm (500 g/MT), the annual release of manganese from ore crushing for a uniform concentration of manganese in the ore, N = 1 (assuming 80 percent reduction), is estimated using Equation (1) in Section C.1 to be:

$$\begin{aligned} S &= 145{,}000 \text{ MT/yr} \times 500 \text{ g Mn/MT} \times 0.16 \text{ lb/ton} \times 1 \text{ ton/2000 lb} \\ &\quad \times (1 - 0.80) \times 1 \\ &= 1.2 \times 10^3 \text{ g Mn/yr} \end{aligned}$$

3.1.2 Example Calculation: Truck Unloading to Ore Pad

In this example, the ore contains 250 ppm (250 g/MT) of lead; again assuming uniform concentration of lead in the ore, N = 1, the estimate of annual lead release would be:

$$\begin{aligned} S &= 193{,}000 \text{ MT/yr} \times 250 \text{ g/MT} \times 0.04 \text{ lb/yd}^3 \times 1 \text{ yd}^3/1.5 \text{ ton} \\ &\quad \times 1 \text{ ton/2000 lb} \times 1 \\ &= 640 \text{ g Pb/yr} \end{aligned}$$

3.1.3 Example Calculation: Fine Ore Storage

In this example, the fine ore is conveyed to and from the fine ore storage area for a total of four conveyor transfers. Ore is handled at a rate of 135,000 MT/yr. The operation occurs in an enclosed structure with a reduction factor of 75 percent based on engineering judgment (Appendix C). The emission factor for each transfer is 0.023 lb/ton (Appendix B). The combined emission factor for the fine ore storage conveying is:

$$E = 4 \text{ transfers} \times 0.023 \text{ lb/ton per transfer} = 0.092 \text{ lb/ton}$$

If, for example, the dust contained an arsenic content of 50 ppm (50 g/MT) and assuming N = 1, the estimate of annual arsenic release would be:

$$S = 135{,}000 \text{ MT/yr} \times 0.092 \text{ lb/ton} \times 1 \text{ ton/2000 lb} \times 50 \text{ g/MT} = 310 \text{ g As/yr}$$

3.2 Windblown Emissions

Fugitive dust varies significantly from mill to mill. Meteorological conditions (wind, rainfall, temperatures), exposed surfaces, ore compositions and physical and chemical characteristics, particle size distributions, site characteristics, and operational procedures are among the factors that affect the degree to which dust is dispersed into the atmosphere. The nonradioactive windblown particle emissions are estimated in a manner similar to that used for the radioactive particulate emissions described in Section C.1.2.

3.2.1 Example Calculations: Tailings Pile

Using the same assumptions presented in the example calculations in Section C.1.2.1 and Equations (2) and (3), the toxic element releases are estimated. For the ore with an initial lead concentration of 250 ppm (250 g/MT), with essentially all (99.9%) of the lead disposed to the tailings pile (assuming that the process conditions are identical to those in the crushing example, Section C.1.1.1), the source term for lead for the abandoned tailings pile example in Section C.1.2.1 is:

$$S = 4.3 \times 10^2 \text{ g/m}^2\cdot\text{yr} \times 53 \text{ acres} \times 4047 \text{ m}^2\text{/acre} \times 250 \text{ g Pb/MT} \times 1 \text{ MT/}10^6\text{g} \times (1 - 0.85) = 3.5 \times 10^4 \text{ g Pb/yr}$$

3.2.2 Example Calculations: Ore Pad

Particulates on the ore pad subject to wind erosion are less than those from tailings piles since the ore has not yet been ground. The NRC staff has estimated the fugitive dust release from the ore pad by assuming an emission factor of 10 percent of that calculated for the tailings pile. The modified equations for ore pads are discussed and presented in Section C.1.2.2. Thus, for the site with a wind frequency occurrence as described in Section C.1.2.2, the annual average dust loss rate is estimated to be:

$$E_W = 0.1 \times 3.156 \times 10^7 \text{ s/yr} \times 6.75 \times 10^{-6} \text{ g/m}^2\cdot\text{s/}(0.5) = 43 \text{ g/m}^2\cdot\text{yr}$$

The toxic source term for an ore pad of 10 acres containing ore with 200 ppm (200 g/MT) lead, no enrichment of lead in the fines,* $N = 1$, no emission control, $R = 0$, is estimated using Equation (3):

$$S = 43 \text{ g/m}^2\cdot\text{yr} \times 10 \text{ acres} \times 4047 \text{ m}^2\text{/acre} \times 200 \text{ g Pb/MT} \times 1 \text{ MT/}10^6 \text{ g} \times 1 = 348 \text{ g Pb/yr}$$

Any control such as keeping the ore pile wet would reduce fugitive dust by the appropriate factor as shown in Appendix C.

3.3 Nonradioactive Gas Emission Source Terms

Milling operations will result in the release of nonradioactive gases and vapors to the atmosphere (see Table 4). The main sources of these emissions are the leach circuit, the solvent extraction circuit, yellowcake precipitator and dryer, the analytical laboratory, and the mill power plant and heating systems. The annual average concentrations off site are expected to be below background and in general are too low to be measured (Ref. 4).

*<100 μm in diameter.

3.3.1 Leaching

Small amounts of sulfuric acid mist can escape from the vent system. Carbon dioxide can also be produced as a result of acid reaction with carbonate materials present in the ore. Trace quantities of sulfur dioxide and free chlorine may also be released. A demister can remove more than 99 percent of the acid mist. Release of hydrides such as arsine, stibine, and hydrogen sulfide during leaching are considered negligible (Ref. 11). Release factors that may be used to estimate releases from an acid circuit are shown in Table 5.

3.3.2 Solvent Extraction

Solvent extraction and stripping result in some evaporation loss of exposed organic solvents. Kerosene represents about 92 percent of the organic, with the remaining 8 percent an organic acid such as alkyl phosphoric acid. A wet scrubber can be used to reduce emissions by more than 99 percent. A source term may be calculated using data in Table 5 as follows:

Table 5

Chemical Airborne Release Factors for Acid Leach Mill

Material Released	Release Factor, kg/kg U
Sulfur oxides	2×10^{-4}
Nitrogen oxides	2×10^{-3}
Ammonia	2×10^{-3}
Kerosene	2×10^{-4}
Organic acids	5×10^{-3}
Aldehydes	8×10^{-4}
Hydrocarbons	3×10^{-3}

Source: Reference 12.

For a mill processing 145,000 MT/yr with an average U_3O_8 content of 0.1 percent and a wet scrubber with 99 percent efficiency (organic acid plus kerosene), the emission source term from solvent extraction is calculated as shown below.

$$\begin{aligned} S &= 145{,}000 \text{ MT ore/yr} \times 0.1 \text{ kg } U_3O_8\text{/MT ore} \\ &\quad \times 0.85 \text{ kg U/kg } U_3O_8 \times (5 \times 10^{-3} \text{ kg/kg U} + 0.2 \times 10^{-3} \text{ kg/kg U}) \\ &\quad \times (1 - 0.99) \\ &= 640 \text{ g organic acid plus kerosene/yr} \end{aligned}$$

3.3.3 Analytical Laboratory

Various process reagents and products will be analyzed. The fume hoods will collect air and a mixture of chemical fumes and mists. A wet scrubber could be used to reduce the emission by more than 99 percent.

3.3.4 Mill Power Plant and Building Heat Boiler

The source term for mill electrical power and process heat will depend on the systems and fuel used. For example, if a diesel-generator unit were used with number 2 diesel fuel (maximum 1% sulfur), several gaseous emissions would result: CO, hydrocarbons, NO_x, and SO_2. If an oil-fired boiler were used for process and building heat, similar emissions would occur. Emission factors for fuel combustion have been developed by EPA (Ref. 13). For convenience, the NRC staff has abstracted conservative values from the compilation and summarized them in Appendix D. Data from this appendix can be used to calculate appropriate combustion source terms.

To illustrate how the NRC staff would calculate the source term for a heat boiler, the following example is provided. Assume that the boiler will be used to supply supplementary heat during cold weather and that it will burn an average of 23 L/hr fuel oil distillate with a 0.1 percent sulfur content. The unit will operate for 120 days during the year. Based on the emission factors from fuel combustion presented in Appendix D, the following average estimated emissions would result:

	$kg/10^3$ L		L/hr		hr/d		d/yr		kg/yr
Sulfur dioxide	17 x 0.001*	x	23	x	24	x	120	=	1.1
Carbon monoxide	0.63	x	23	x	24	x	120	=	41.7
Hydrocarbons	0.12	x	23	x	24	x	120	=	7.9
Nitrogen oxides	2.8	x	23	x	24	x	120	=	185

*Sulfur content in fuel oil.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this regulatory guide.

The methods presented in this guide are acceptable to the NRC staff for complying with the Commission's regulations. Therefore, except in those cases in which the applicant or licensee proposes acceptable alternative methods for complying with the specified portions of the Commission's regulations, the methods described in the guide are being and will continue to be used in the evaluation of applications for or amendments to licenses for uranium milling operations to estimate radioactive and toxic airborne source terms for such operations.

APPENDIX A

Principal Primary Parameters Needed to Estimate Source Terms for Uranium Mill Operations[a]

Ore Quality

Concentration of U_3O_8 in ore (including ranges), % by weight

Processing rate, MT/d

Radionuclide content (^{238}U and daughter products), pCi/g

Concentration of nonradioactive toxic elements, g/MT (ppm)

Dust/ore activity ratio, 2.5[b]

Moisture content, % by weight

Bulk density, g/cm^3

Diffusion coefficient (D) for radon in ore piles (if available[c,d]), cm^2/s

Emanating power for radon (E) (if available[e])

Ore Unloading Storage Data[f]

Area of each pile or bin complex and total area, m^2

Average depth of pile, m

Average annual quantity of ore in storage, MT

Average porosity of the ore pile, %

Receipt (truck or rail unloading) rates, MT/d

Operational period, d/yr

Description of dusting control[g]

Quantity of each range of ore quality

Radon emission,[c] Ci/yr

Vehicle requirements

- type
- number
- capacity, MT or m^3/vehicle
- frequency of operation (deliveries/d, MT/delivery)

Crushing/Grinding

Description of ventilation air treatment, including

- design efficiency of scrubbers and filters
- expected efficiency of scrubbers and filters
- minimum efficiency of scrubbers and filters

Uncontrolled emission factors[h]

Description of emission controls

Leaching/Extraction

Ratio of leachant to ore, L/kg

Composition of leachant, M

Composition of solvent (if used)

Ion exchange medium (if used)

Residence time of ore in mill, d

Yellowcake Drying and Packaging

Yellowcake characteristics

- bulk density, g/cm^3
- purity, % U_3O_8

Production rates, MT/yr

- drying
- packaging

Processing times, hr/d and d/yr

Description of air ventilation controls

- design efficiencies
- expected efficiencies
- minimum efficiencies

Tailings Impoundment Systems

Tailings characteristics

- radionuclide content (^{238}U, ^{230}Th, ^{226}Ra, ^{210}Pb), pCi/g
- average radionuclides
- beach sands
- slimes
- dust/bulk solids activity ratio of tailings sands[b]

- bulk density, g/cm^3
- moisture content, % by weight
- diffusion coefficients for radon (if available[d]), cm^2/s
- emanating power for radon (E) (if available[e])
- radon emission,[c] Ci/yr

Impoundment Area,[i] m^2

Total

Beach sands

Under water

Exposed wet slimes

Dried slimes

Description of dust control

Estimated drying time required prior to initiation of reclamation procedures and basis

Estimated time required to stabilize and reclaim after drying and basis

Energy Requirements

Electricity, kWh/yr

Diesel oil and gasoline, L/yr

Fuel oil, gal/yr

Fuel gas, m^3/yr

Coal, tons/yr

Process Chemical Requirements

Sulfuric acid (including concentration), MT/yr

Sodium carbonate, MT/yr

Solvent (including composition), MT/yr

Oxidant, kg/yr

Ammonia, kg/yr

Others, annual use

Footnotes for Appendix A

a. Default values listed in these footnotes or in the text can be used unless measured values are provided.

b. The dust/ore activity ratio used by the NRC staff is 2.5 unless there is specific, convincing evidence that the enrichment factor should be another ratio, either lower or higher. The dust/bulk activity ratio used for tailings sands is also 2.5 (used for radioactivity releases only).

c. The NRC staff normally calculates the operation radon emission from ore stockpiles and tailings impoundments using the flux ratio:

$$(1.0\ \text{pCi/m}^2\cdot\text{s of }^{222}\text{Rn})/(\text{pCi/g of }^{226}\text{Ra})$$

d. If no data are available, the following diffusion coefficients, D, for radon may be considered:

- 2×10^{-2} cm^2/s for ores and beach sands (tailings)
- 5×10^{-3} cm^2/s for wet slimes (tailings)
- 1×10^{-2} cm^2/s for dry slimes (tailings)

As new data are obtained, these values will be changed as appropriate.

e. If specific data are not otherwise available, the NRC staff uses 0.2 as the emanating power of radon.

f. Information should be distinguished as to specific ore pad activity--front-end loaders, unloading, and storage.

g. Various emission reduction factors used by the NRC are listed in Appendix C.

h. If not available from onsite operations, uncontrolled emission factors used by the NRC staff are shown in Appendix B.

i. The indicated information is needed for varying operational periods, for example:

- last year of mill operations
- period just prior to pond drying up
- period just prior to reclamation
- period of maximum generation, if different from above

APPENDIX B

Emission Factors

Process	Uncontrolled Emission
1. Ore loadout to grizzly, or raw, or finished stockpile	0.002 lb/yd³ truck bottom dump[a] 0.04 lb/yd³ truck end dump[a] 0.023 lb/ton conveyor transfer point[a]
2. Transfer point such as conveyor loading	0.023 lb/ton[a]
3. Primary crushing, secondary crushing, and screening combined. The addition of tertiary crushing will double the chosen factor.	0.002 lb/ton (moisture ≥ 9%)[a] 0.04 lb/ton (moisture 8-9%)[a] 0.16 lb/ton (moisture < 8%)[a]
4. Yellowcake drying and packaging	0.1%[b]

[a]Reference 14.

[b]Based on EPA-measured releases at six mills, the NRC staff estimates controlled releases from yellowcake facilities at 0.1 percent.

APPENDIX C

Particulate Emission Reduction Factors[a]
for Ore Processing

Emission Control	% Reduction
Ore pads, heap leach piles, or tailings piles	
Chemical suppressant (synthetic polymer usually)	80
Mulch	85
Rapid revegetation	75
Wind breaks = mature forest	75
Wind breaks = height of pile	50
Wind breaks < height of pile	20
Frequent water (twice daily)	50
Water sprinkle as needed	50
Chemical and vegetation stabilization	93
Water cover	99
Soil cover	100
Rip rap + soil cover	100
Oiling	80
Complete enclosure (includes silos)	99
Partial enclosure	50
Canvas covers	80
Ore loadout to grizzly, or raw, or finished stockpile	
Negative pressure with fabric filter	85
Chemical suppressants	85
Enclosed structure	75
Telescopic chute	75
Stacker - water spray	75
Water spray	50
Wind guard	50
Stacker - height adjustable	25
Stone ladder	80
Ore crushing and grinding	
Bag filter	33
Semiautogenous grinding	100
Yellowcake drying and packaging	
Venture scrubber and demister	90
Slurry product	100

[a]Most from Reference 14; others based on staff's engineering judgment and Reference 4.

APPENDIX D

Emission Factors from Fuel Combustion Without Emission Control[a]

Sourse of Emissions	Particulates	Sulfur Oxides	Hydrocarbons	Carbon Monoxide	Nitrogen Oxides	Aldehydes
Coal, kg/MT						
Anthracite	8.5A[b]	c	Neg. (1.25)[d]	0.5 (45)[d]	9	
Bituminous	8.5A(10)[d]		0.5 (10)[d]	5 (45)[d]	28	0.0025
Fuel oil, kg/10^3 L						
Distillate oil	0.25	17S	0.12	0.63	2.8	
Natural gas, kg/10^6 m^3	240	9.6	128	320	3680	
Liquid petroleum gas (LPG), kg/10^3 L	0.23	0.09S	0.096	0.24	1.5	
Vehicles,[e] g/km						
Gasoline-powered						
Light-duty truck			2.1	26.6	3.3	
Heavy-duty truck			8.4	117	7.8	
Diesel-powered						
Heavy-duty truck	0.81	1.7	2.9	18	21	0.2
Off-highway, stationary sources						
Gas-fired, kg/10^6 m^3	220	83	670	1800	6600	
Oil-fired, kg/10^3 L	0.60	0.4	0.7	1.9	8.1	
Gasoline-powered, kg/10^3 L	0.78	0.64	16	470	12	0.52
Diesel-powered, kg/10^3 L	4.0	3.7	4.5	12	56	0.84

[a] Emission factors are abstracted on a conservative basis (higher values) from Reference 13.
[b] "A" represents the weight percentage of ash in the fuel.
[c] "S" represents the weight percentage of sulfur in the fuel.
[d] For hand-fired units.
[e] Data are for 1972 model year and for emissions at either high or low altitudes, depending on which value is higher. For earlier model years, consult Reference 13.

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VALUE/IMPACT STATEMENT

A draft value/impact statement was published with the draft version of this guide, task WM 407-4, when the draft guide was published for public comment in April 1986. No changes were necessary, so a separate value/impact statement for the final guide has not been prepared. A copy of the draft value/impact statement is available for inspection and copying for a fee at the Commission's Public Document Room at 1717 H Street NW., Washington, DC, under Task WM 407-4.

March 1988

U.S. NUCLEAR REGULATORY COMMISSION

REGULATORY GUIDE

OFFICE OF NUCLEAR REGULATORY RESEARCH

REGULATORY GUIDE 3.63
(Task ES 401-4)

ONSITE METEOROLOGICAL MEASUREMENT PROGRAM FOR URANIUM RECOVERY FACILITIES—DATA ACQUISITION AND REPORTING

A. INTRODUCTION

Section 40.31, "Applications for Specific Licenses," of 10 CFR Part 40, "Domestic Licensing of Source Material," requires that applicants for a license to receive, possess, or use source material in conjunction with uranium recovery facilities provide information needed to assist in demonstrating that operations can be conducted to meet the requirements set forth in 10 CFR Part 40. Section 40.65, "Effluent Monitoring Reporting Requirements," requires that licensees routinely report radionuclide releases to unrestricted areas in liquid and gaseous effluents. The Uranium Mill Tailings Radiation Control Act (UMTRCA) requires the NRC to conform to 40 CFR Part 192, which sets standards for the control of releases from tailings related to production operations. Meteorological data are also relevant to the preparation of environmental reports pursuant to 10 CFR Part 51, "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions" (see Regulatory Guides 3.8, "Preparation of Environmental Reports for Uranium Mills," and 3.46, "Standard Format and Content of License Applications, Including Environmental Reports, for In Situ Uranium Solution Mining").

Meteorological conditions in the vicinity of the facility need to be considered in the design and operation of tailings impoundments, the assessment of the potential impact of airborne effluent releases, and the monitoring of airborne effluents. This guide provides guidance acceptable to the NRC staff regarding the meteorological parameters that should be measured, the siting of meteorological instruments, system accuracies, instrument maintenance and servicing schedules, and the recovery, reduction, and compilation of data.

Any information collection activities mentioned in this regulatory guide are contained as requirements in 10 CFR Part 40, which provides the regulatory basis for this guide. The information collection requirements in 10 CFR Part 40 have been cleared under OMB Clearance No. 3150-0020.

B. DISCUSSION

An onsite meteorological measurement program employs instrument systems physically located on or near the site that are capable of measuring meteorological information representative of the site vicinity and that are operated under the authority of the applicant or licensee. The purpose of such a program at a uranium recovery facility is to provide the meteorological information needed to make assessments to assist in demonstrating that the facility design and the conduct of operations are such that releases of radioactive materials to unrestricted areas can be kept as low as is reasonably achievable. The information is used (1) for the design and operation of tailings impoundments and (2) for estimating the maximum potential annual radiation dose to the public and the environmental impact resulting from the routine release of radioactive materials in gaseous and particulate effluents.

Tailings impoundments need to be designed and operated so that they do not overfill or breach the impoundment restraints, either of which could result in offsite releases. The guidance in the regulatory position assumes that changes in the quantity of liquid in the impoundment are related only to facility operation and to the site precipitation and evaporation characteristics.

The maximum potential airborne annual radiation dose to the public and the environmental impact resulting from routine releases is dependent on the meteorological characteristics of the site. Wind direction, wind speed, and atmospheric stability near the site are factors that determine where the effluent will be transported and its concentration. The following guidance applies only to routine releases that occur within 30 meters (100 feet) of the ground.

C. REGULATORY POSITION

1. Meteorological Parameters

The meteorological parameters needed for the design and operation of tailings impoundments are precipitation and an indicator of evaporation. The parameters needed to estimate the atmospheric dispersion of radioactive materials are wind direction, wind speed, and an indication of atmospheric stability. For obtaining an indication of the atmospheric stability, a method such as one of the following (Refs. 1-4) may be used: insolation–cloud cover and wind speed (Pasquill-Gifford and similar methods), temperature lapse rate method, wind fluctuation method, split-sigma method, or Richardson Number.

Precipitation and evaporation data should be totaled daily and recorded as monthly and annual summaries.

The basic reduced wind direction, wind speed, and atmospheric stability data should be averaged over a period of 1 hour. At least 15 consecutive minutes of continuous data during each hour should be used to represent a 1-hour average. Wind direction data should be recorded as quarterly and annual wind rose summaries for the 16 compass directions. Quarterly and annual wind direction, wind speed, and atmospheric stability data should also be compiled in joint frequency and joint relative frequency (i.e., decimal frequency) form for heights representative of effluent releases. An example of a suitable format for data compilation and reporting purposes is shown in Table 1. Stability categories should be established to conform as closely as possible with those of Pasquill (Ref. 4).

The minimum amount of meteorological data needed for a siting evaluation is considered to be that amount of data gathered on a continuous basis for a consecutive 12-month period that is representative of long-term (e.g., 30 years) meteorological conditions in the site vicinity. To determine whether the period during which the onsite data was collected is representational, compare a concurrent period of meteorological data from a National Weather Service (NWS) station with the long-term meteorological data from that NWS station. The NWS station selected for this comparison should, if possible, be in a similar geographical and topographical location and be reasonably close (preferably within 50 miles (80 kilometers)) to the site. In some sections of the country, the spacing between NWS stations may necessitate the selection of an NWS station more than 50 miles away. The reduced data and supportive documentation should be retained and should be available for review for the period of facility operation.

2. Siting of Meteorological Instruments

The location of the meteorological instruments should represent as closely as possible the long-term meteorological characteristics of the area for which the measurements are being made. Whenever possible, the base of the instrument tower or mast should be sited at approximately the same elevation as the facility operation. Ideally, the instruments should be located in an area where localized singular natural or man-made obstructions (e.g., trees, buildings) will have little or no influence on meteorological measurements. Measurements of wind speed, wind direction, and sigma theta (if measured) should be made at least 10 obstruction heights away from the nearest obstruction (Ref. 5). To the extent practicable, these instruments should not be located in the prevailing downwind direction of an obstruction. At most facilities, the instruments could all be sited at one location. At some sites, instruments may need to be sited at more than one location if the meteorological conditions are not similar throughout the site vicinity. For example, a site could have a milling operation on a mesa where the wind blows predominantly from one direction and a tailings impoundment on the plain below in the lee of the mesa where the wind is most frequently from another direction at a lower speed and with an atmospheric stability regime different from that at the release point on the mesa.

Precipitation and evaporation are usually measured near ground level. If an evaporation pan is used to estimate evaporation, a fence or other barrier may be needed to minimize animal intrusion. Parameters such as air temperature, atmospheric moisture, and the pan water temperature should be monitored as appropriate for the type of evaporation model assessment being made.

For atmospheric dispersion assessments, wind speed and wind direction should be monitored at approximately 10 meters (33 feet) above ground level. For an open lattice tower, instruments should be located on booms oriented into the prevailing wind direction at a minimum distance of two tower widths from the tower to preclude substantial influence of the tower upon measurements (Ref. 5). Siting of the instruments used to estimate atmospheric stability is dependent on the methodology used. If instrumentation is used to measure incoming solar radiation, it should be located in an area as free as possible from terrestrial shadows. If the temperature difference with height method is used to estimate the atmospheric stability, the lower temperature-difference sensor should be located at 10 meters (33 feet) above the ground and the upper sensor should be positioned not less than 30 meters (100 feet) above the lower sensor. Aspirated temperature shields should either be pointed downward or laterally toward the north.

TABLE 1

PERIOD OF RECORD: PASQUILL STABILITY CATEGORY

Wind Direction	Wind Speed at 10-m Level 0.22-1.7 (0.5-3.9)	1.8-3.5 (4.0-7.9)	3.6-5.8 (8.0-12.9)	5.9-8.5 (13.0-18.9)	8.6-11.2 (19.0-24.9)	≥11.2 m/s ≥(25) (mph)	Total
N							
NNE							
NE							
ENE							
E							
ESE							
SE							
SSE							
S							
SSW							
SW							
WSW							
W							
WNW							
NW							
NNW							
Total							

Number of Calms*
Number of Invalid Hours
Number of Valid Hours

*A calm is any average wind speed below the starting threshold of the wind speed or direction sensor, whichever is greater. Calms should be included in the table above by assigning to each calm a wind speed that is equal to the starting threshold of the wind speed or direction sensor, whichever is greater. Wind direction during calm conditions should be assigned in proportion to the directional distribution of noncalm winds in the lowest noncalm wind speed category. The directional distribution of calms should then be included in the lowest noncalm wind speed category.

3. System Accuracy and Instrumentation Specifications

System accuracy refers to the composite accuracy reflecting the errors introduced by the entire system from the sensor to the data reduction process. This system normally consists of sensor, cable, signal conditioner, recorders, the humidity and temperature environment for signal conditioning and recording, and the data reduction process. The errors introduced by each of the separate components of the system should be determined by statistical methods (Ref. 6). The accuracies of all systems should be appropriate to the use to be made of the information over the range of environmental conditions expected to occur during the lifetime of facility operation and should be consistent with the current state of the art for the measurement.

The accuracies for time-averaged values of each parameter should be:

a. Precipitation: as measured by a recording rain gauge with a resolution of 0.25 mm (0.01 in.). The accuracy of the recorded value should be within 10 percent of the total accumulated catch for amounts in excess of 5 mm (0.2 in.).

b. Evaporation: consistent with the current state of the art. For information on installation and a description of measurement techniques using an evaporation pan, see Reference 7. An aspirated shielded device such as a lithium chloride or optical dewpoint hygrometer (Ref. 8) is suggested for measurement of humidity. Use of a hair hygrometer is not recommended. Temperature sensors should be consistent with the current state of the art for their use.

c. Wind direction: ±5° of azimuth with a starting threshold (the minimum wind speed above which the measuring instrument is performing within its minimum specification) of less than 0.5 m/s (1.0 mph).

d. Wind speed: ± 0.2 m/s (0.5 mph) for speeds less than 2 m/s (5 mph), 10% for speeds between 2 m/s (5 mph) and 22 m/s (50 mph), with a starting threshold of less than 0.5 m/s (1.0 mph).

Parameters not covered above but used to determine atmospheric stability should be measured with accuracies consistent with the current state of the art for measurement of these parameters (Refs. 1, 3).

The recording system for data acquisition may be either analog or digital. Analog recorders should be of the continuous strip chart recording type. Digital recorders should sample data at intervals no longer than 60 seconds for wind direction and speed measurements.

Accuracies for analog records of parameters that may vary rapidly with time (e.g., wind direction and wind speed) should not be more than 1.5 times those stated above. The system accuracies should include the reduction of data from the strip chart recorder to digital form.

4. System Maintenance, Servicing Schedules, and Data Recovery

The systems should be protected against severe environmental conditions such as blowing sand, lightning, and icing that may occur at the site. Meteorological systems should be inspected at least once every 15 days and serviced at a frequency that will minimize extended periods of outage and ensure an annual data recovery of at least 90% for each individual parameter measured (at least an annual 75% joint data recovery for wind speed, wind direction, and atmospheric stability). The use of redundant sensors and recorders may be an acceptable means of achieving this recovery goal. Systems should be calibrated at least semiannually to ensure that the system accuracies in this guide are met. In areas with high ambient aerosol or particulate loadings in the atmosphere (e.g., deserts), calibrations should be performed on a more frequent basis to maintain system accuracies.

Sufficient records should be retained and should be available for review for the period of uranium recovery facility operation to document any activities that may affect the quality of the meteorological data. The records should include operating logs and results of reviews, inspections, maintenance, calibrations, and audits; a description of the types of observations taken with the results and their acceptability; and actions taken in connection with any deficiencies noted.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this regulatory guide.

Except in those cases in which an applicant proposes an acceptable alternative method for complying with specified portions of the Commission's regulations, the methods described in this guide will be used by the NRC staff in evaluating pertinent portions of applications submitted to the NRC for new uranium recovery facility licenses and for amendments to existing licenses involving major modification of current facilities.

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VALUE/IMPACT STATEMENT

A draft value/impact statement was published with Task ES 401-4 when the draft guide was published for public comment in September 1985. No changes were necessary, so a separate value/impact statement for the final guide has not been prepared. A copy of the draft value/impact statement is available for inspection and copying for a fee at the Commission's Public Document Room at 1717 H Street NW., Washington, DC, under Task ES 401-4.

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April 25, 1980

Regulatory Guide 4.14
Revision 1

REGULATORY GUIDE DISTRIBUTION LIST (DIVISION 4)

SUBJECT: Regulatory Guide 4.14, Revision 1, "Radiological Effluent and Environmental Monitoring at Uranium Mills"

Regulatory Guide 4.14 was originally issued for public comment in 1977. That version has now been revised as appropriate in response to public comments. In addition, the scope of the guide has been expanded to include offsite environmental monitoring. The environmental monitoring programs described in this revision were previously included in NRC publication NUREG-0511, "Draft Generic Environmental Impact Statement on Uranium Milling," published for comment in April 1979.

The NRC staff developed the regulatory positions in this Revision 1 of Regulatory Guide 4.14 over a long period of time, taking into account public input as described above. The positions are already being used by the NRC staff in the licensing process. However, this revision represents the first opportunity for public review of the staff position as a consolidated document. For this reason, it is being provided to all addressees on the Division 4 distribution list. Comments on regulatory guides are encouraged at all times, and comments on this guide will be particularly helpful to the NRC staff in evaluating the need for another revision to this guide. Comments will be most useful if they are submitted within two months of the publication of the guide.

Robert B. Minogue

Robert B. Minogue, Director
Office of Standards Development

Revision 1 *
April 1980

U.S. NUCLEAR REGULATORY COMMISSION

REGULATORY GUIDE

OFFICE OF STANDARDS DEVELOPMENT

REGULATORY GUIDE 4.14

RADIOLOGICAL EFFLUENT AND ENVIRONMENTAL MONITORING AT URANIUM MILLS

A. INTRODUCTION

Uranium mill operators are required by Nuclear Regulatory Commission (NRC) regulations and license conditions to conduct radiological effluent and environmental monitoring programs. Regulations applicable to uranium milling are contained in 10 CFR Part 20, "Standards for Protection Against Radiation," and Part 40, "Domestic Licensing of Source Material." For example, § 40.65, "Effluent Monitoring Reporting Requirements," of 10 CFR Part 40 requires the submission to the Commission of semiannual reports containing information required to estimate doses to the public from effluent releases.

Information on radiation doses and the radionuclides in a mill's effluents and environment both prior to and during operations is needed by the NRC staff:

1. To estimate maximum potential annual radiation doses to the public resulting from effluent releases.

2. To ascertain whether the regulatory requirements of the NRC (including 10 CFR Part 20 dose limits, release limits, and the "as low as is reasonably achievable" requirement), mill license conditions, and the requirements of 40 CFR Part 190, "Environmental Radiation Protection Standards for Nuclear Power Operations," have been met.

3. To evaluate the performance of effluent controls, including stabilization of active and inactive tailings piles.

4. To evaluate the environmental impact of milling operations, both during operations and after decommissioning.

5. To establish baseline data to aid in evaluation of decommissioning operations or decontamination following any unusual releases such as a tailings dam failure.

This guide describes programs acceptable to the NRC staff for measuring and reporting releases of radioactive materials to the environment from typical uranium mills.

The programs described in this guide are not requirements. Licensing requirements are determined by the NRC staff on a case-by-case basis during individual licensing reviews. Individual applicants or licensees may propose alternatives for new or existing monitoring programs that need not necessarily be consistent with this guide. The justification for such alternatives will be reviewed by the NRC staff, and the acceptability of proposed alternatives will be determined on a case-by-case basis during individual licensing reviews. For example, it is anticipated that operational monitoring programs that do not include at least three continuous air samples at the site boundary will include more extensive stack sampling and more sampling locations than are described in this guide as well as meteorological data and additional environmental monitoring requirements.

B. DISCUSSION

The radiation dose an individual receives can be determined only if the radionuclides to which an individual is exposed are known. Therefore, monitoring programs should provide accurate information on the specific radionuclides in effluents from a mill, its ore piles, and its tailings retention system and in the surrounding environment.

Methods of sampling and analysis for the radionuclides associated with uranium milling are discussed in sources listed in the bibliography. The listing of these documents is not meant to be all inclusive, nor does it constitute an endorsement by the NRC staff of all of the methods in all of the listings. Rather, these listings are provided as sources of information to aid the licensee in developing a monitoring program.

The sampling program described below is divided into two parts: preoperational monitoring and operational

*The substantial number of changes in this revision has made it impractical to indicate the changes with lines in the margin.

monitoring. Preoperational data is submitted to the NRC as part of the application process. Operational data is reported as required by § 40.65 of 10 CFR Part 40 and specific license conditions and at times of license renewal.

C. REGULATORY POSITION

1. PREOPERATIONAL MONITORING

An acceptable preoperational monitoring program is described below and summarized in Table 1. At least twelve consecutive months of data, including complete soil sampling, direct radiation, and radon flux data, should be submitted to the NRC staff prior to any major site construction. A complete preoperational report with twelve consecutive months of data should be submitted prior to beginning milling operations. Prior to the start of local mining operations, if possible, monitoring data, including airborne radon measurements, should be submitted to the NRC staff.

Applicants may propose alternatives to this preoperational program. However, equivalent alternatives should be proposed for the operational program so that the programs remain compatible.

1.1 Preoperational Sampling Program

1.1.1 Air Samples

Air particulate samples should be collected continuously at a minimum of three locations at or near the site boundary. If there are residences or occupiable structures within 10 kilometers of the site, a continuous outdoor air sample should be collected at or near the structure with the highest predicted airborne radionuclide concentration due to milling operations and at or near at least one structure in any area where predicted doses exceed 5 percent of the standards in 40 CFR Part 190. A continuous air sample should also be collected at a remote location that represents background conditions at the mill site; in general, a suitable location would be in the least prevalent wind direction from the site and unaffected by mining or other milling operations.

Normally, filters for continuous ambient air samples are changed weekly or more often as required by dust loading.

The sampling locations should be determined according to the projected site and milling operation. Preoperational sampling locations should be the same as operational locations. The following factors should be considered in determining the sampling locations: (1) average meteorological conditions (windspeed, wind direction, atmospheric stability), (2) prevailing wind direction, (3) site boundaries nearest to mill, ore piles, and tailings piles, (4) direction of nearest occupiable structure (see footnotes of Tables 1 and 2), and (5) location of estimated maximum concentrations of radioactive materials.

Samples should be collected continuously, or for at least one week per month, for analysis of radon-222. The sampling locations should be the same as those for the continuous air particulate samples.

1.1.2 Water Samples

Samples of ground water should be collected quarterly from at least three sampling wells located hydrologically down gradient from the proposed tailings area, at least three locations near other sides of the tailings area, and one well located hydrologically up gradient from the tailings area (to serve as a background sample). The location of the ground-water sampling wells should be determined by hydrological analysis of the potential movement of seepage from the tailings area, and the basis for choosing these locations should be presented when data is reported. Wells drilled close to the tailings for the specific purpose of obtaining representative samples of ground water that may be affected by the mill tailings are preferable to existing wells.

Ground-water samples should also be collected quarterly from each well within two kilometers of the proposed tailings area that is or could be used for drinking water, watering of livestock, or crop irrigation.

Samples of surface water should be collected quarterly from each onsite water impoundment (such as a pond or lake) and any offsite water impoundment that may be subject to seepage from tailings, drainage from potentially contaminated areas, or drainage from a tailings impoundment failure.

Samples should be collected at least monthly from streams, rivers, any other surface waters or drainage systems crossing the site boundary, and any offsite surface waters that may be subject to drainage from potentially contaminated areas or from a tailings impoundment failure. Any stream beds that are dry part of the year should be sampled when water is flowing. Samples should be collected at the site boundary or at a location immediately downstream of the area of potential influence.

1.1.3 Vegetation, Food, and Fish Samples

Forage vegetation should be sampled at least three times during the grazing season in grazing areas in three different sectors having the highest predicted airborne radionuclide concentration due to milling operations.

At least three samples should be collected at time of harvest or slaughter or removal of animals from grazing for each type of crop (including vegetable gardens) or livestock raised within three kilometers of the mill site.

Fish (if any) samples should be collected semiannually from any bodies of water that may be subject to seepage or surface drainage from potentially contaminated areas or that could be affected by a tailings impoundment failure.

1.1.4 Soil and Sediment Samples

Prior to initiation of mill construction (and if possible prior to mining), one set of soil samples should be collected as follows:

a. Surface-soil samples (to a depth of five centimeters) should be collected using a consistent technique at 300-

meter intervals in each of the eight compass directions out to a distance of 1500 meters from the center of the milling area. The center is defined as the point midway between the proposed mill and the tailings area.

b. Surface-soil samples should also be collected at each of the locations chosen for air particulate samples.

c. Subsurface samples (to a depth of 1 meter) should be collected at the center of the milling area and at a distance of 750 meters in each of the four compass directions.

Soil sampling should be repeated for each location disturbed by site excavation, leveling, or contouring.

One set of sediment samples should be collected from the same surface-water locations as described in Section 1.1.2. For surface water passing through the site, sediment should be sampled upstream and downstream of the site. Samples should be collected following spring runoff and in late summer, preferably following an extended period of lowflow. In each location, several sediment samples should be collected in a traverse across the body of water and composited for analysis.

1.1.5 Direct Radiation

Prior to initiation of mill construction (and if possible prior to mining), gamma exposure rate measurements should be made at 150-meter intervals in each of the eight compass directions out to a distance of 1500 meters from the center of the milling area. Measurements should also be made at the sites chosen for air particulate samples.

Measurements should be repeated for each location disturbed by site excavation, leveling, or contouring.

Gamma exposure measurements should be made with passive integrating devices (such as thermoluminescent dosimeters), pressurized ionization chambers, or properly calibrated portable survey instruments.

Direct radiation measurements should be made in dry weather, not during periods following rainfall or when soil is abnormally wet.

1.1.6 Radon Flux Measurements

Radon-222 flux measurements should be made in three separate months during normal weather conditions in the spring through the fall when the ground is thawed. The measurements should be made at the center of the milling area and at locations 750 and 1500 meters from the center in each of the four compass directions. Measurements should not be taken when the ground is frozen or covered with ice or snow or following periods of rain.

1.2 Analysis of Preoperational Samples

Air particulate samples should be analyzed for natural uranium, thorium-230, radium-226, and lead-210.

Air samples collected for radon should be analyzed for radon-222.

The results of analyses of air samples should be used to determine the radionuclide concentrations for the sampling locations.

All ground-water samples collected near the tailings area should be analyzed for dissolved natural uranium, thorium-230, radium-226, polonium-210, and lead-210. Ground-water samples from sources that could be used as drinking water for humans or livestock or crop irrigation should also be analyzed for suspended natural uranium, thorium-230, radium-226, polonium-210, and lead-210.

Surface-water samples from water impoundments should be analyzed quarterly for natural uranium, thorium-230, and radium-226 and semiannually for lead-210 and polonium-210. The samples should be analyzed separately for dissolved and suspended radionuclides.

Surface-water samples from flowing surface water should be analyzed monthly for natural uranium, thorium-230 and radium-226 and semiannually for lead-210 and polonium-210. The samples should be analyzed separately for dissolved and suspended radionuclides.

The results of analyses of water samples should be used to determine the radionuclide concentrations for the sampling locations.

Vegetation, food, and fish (edible portion) samples should be analyzed for natural uranium, thorium-230, radium-226, lead-210, and polonium-210.

All soil samples should be analyzed for radium-226. Soil samples collected at air particulate sampling locations and ten percent of all other soil samples (including at least one subsurface set) should be analyzed for natural uranium, thorium-230, and lead-210. Analysis of extra soil samples may be necessary for repeat samples collected at locations disturbed by site excavation, leveling, or contouring.

Sediment samples should be analyzed for natural uranium, thorium-230, radium-226, and lead-210.

2. OPERATIONAL MONITORING

An acceptable monitoring program to be conducted during construction and after the beginning of milling operations is described below and summarized in Table 2. The results of this program should be summarized quarterly and submitted to NRC semiannually pursuant to § 40.65 of 10 CFR Part 40. An acceptable reporting format is shown in Table 3.

2.1 Operational Sampling Program

2.1.1 Stack Sampling

Effluents from the yellowcake dryer and packaging stack should be sampled at least quarterly during normal operations. The sampling should be isokinetic, representative, and adequate for determination of the release rates and concentrations of uranium. The sampling should also be adequate for the determination of release rates and concentrations of thorium-230, radium-226, and lead-210 if this data cannot be obtained from other sources.

Other stacks should be sampled at least semiannually. The samples should be representative (not necessarily isokinetic) and adequate for the determination of the release rates and concentrations of uranium, thorium-230, radium-226, and lead-210.

All stack flow rates should be measured at the time of sampling.

2.1.2 Air Samples

Air particulate samples should be collected continuously at (1) a minimum of three locations at or near the site boundary, (2) the residence or occupiable structure within 10 kilometers of the site with the highest predicted airborne radionuclide concentration, (3) at least one residence or occupiable structure where predicted doses exceed 5 percent of the standards in 40 CFR Part 190, and (4) a remote location representing background conditions. The sampling locations should be the same as those for the preoperational air samples (see Section 1.1.1). The sampling should be adequate for the determination of natural uranium, thorium-230, radium-226, and lead-210.

Normally, filters for continuous ambient air samples are changed weekly or more often as required by dust loading.

Samples should be collected continuously at the same locations, or for at least one week per month, for analysis of radon-222.

2.1.3 Water Samples

Samples of ground water should be collected from at least three sampling wells located hydrologically down gradient from the tailings area and from one background well located hydrologically up gradient. The samples should be collected monthly through the first year of operation and quarterly thereafter from the same downslope and background wells that were used for preoperational samples (see Section 1.1.2).

Samples should be collected at least quarterly from each well within two kilometers of the tailings area that is or could be used for drinking water, watering of livestock, or crop irrigation.

Samples should be collected at least quarterly from each onsite water impoundment (such as a pond or lake) and any offsite water impoundment that may be subject to seepage from tailings, drainage from potentially contaminated areas, or drainage from a tailings impoundment failure.

Samples should be collected at least monthly from any surface water crossing the site boundary and offsite streams or rivers that may be subject to drainage from potentially contaminated areas or from a tailings impoundment failure. Stream beds that are dry part of the year should be sampled when water is flowing. Operational samples should be collected upstream and downstream of the area of potential influence.

Any unusual releases (such as surface seepage) that are not part of normal operations should be sampled.

2.1.4 Vegetation, Food, and Fish Samples

Where a significant pathway to man is identified in individual licensing cases, vegetation, food, and fish samples should be collected as described below.

Forage vegetation should be sampled at least three times during the grazing season in grazing areas in three different sectors having the highest predicted airborne radionuclide concentration due to milling operations.

At least three samples should be collected at the time of harvest or slaughter or removal of animals from grazing for each type of crop (including vegetable gardens) or livestock raised within three kilometers of the mill site.

Fish (if any) samples should be collected semiannually from any bodies of water that may be subject to seepage or surface drainage from potentially contaminated areas or that could be affected by a tailings impoundment failure.

2.1.5 Soil and Sediment Samples

Surface-soil samples should be collected annually using a consistent technique at each of the locations chosen for air particulate samples as described in Section 2.1.2.

Sediment samples should be collected annually from the surface-water locations described in Section 2.1.3.

2.1.6 Direct Radiation

Gamma exposure rates should be measured quarterly at the sites chosen for air particulate samples as described in Section 2.1.2. Passive integrating devices (such as thermoluminescent dosimeters), pressurized ionization chambers, or properly calibrated portable survey instruments should be used (see Regulatory Guide 4.13).

2.2 Analysis of Operational Samples

Samples from the yellowcake dryer and packaging stack should be analyzed for natural uranium. Samples should also be analyzed for thorium-230, radium-226, and lead-210 if this data cannot be obtained from other sources such as isotopic analysis of yellowcake product. Samples from other stacks should be analyzed for natural uranium, thorium-230, radium-226, and lead-210.

Air particulate samples should be analyzed for natural uranium, thorium-230, radium-226, and lead-210.

Air samples collected for radon should be analyzed for radon-222.

The results of analyses of air samples should be used to determine the radionuclide release rates for the stacks and the radionuclide concentrations for the stacks and other sampling locations.

Water samples should be analyzed for natural uranium, thorium-230, radium-226, polonium-210, and lead-210.

Ground-water samples from sources not expected to be used as drinking water should be analyzed for dissolved radionuclides. Ground-water samples from sources that could be used as drinking water for humans or livestock and all surface-water samples should be analyzed separately for dissolved and suspended radionuclides. These results should be used to determine radionuclide concentrations for ground water and natural bodies of water.

All vegetation, food, and fish (edible portion) samples should be analyzed for radium-226 and lead-210.

All soil samples should be analyzed for natural uranium, radium-226, and lead-210.

All sediment samples should be analyzed for natural uranium, thorium-230, radium-226, and lead-210.

3. QUALITY OF SAMPLES

Provisions should be made to ensure that representative samples are obtained by use of proper sampling equipment, proper locations of sampling points, and proper sampling procedures (see bibliography).

Air samples may be composited for analysis if (1) they are collected at the same location and (2) they represent a sampling period of one calendar quarter or less. Air samples should not be composited if (1) they represent a sampling period of more than one calendar quarter, (2) they are from different sampling locations, or (3) the samples are to be analyzed for radon-222.

Samples collected for analysis of radon-222 should be analyzed quickly enough to minimize decay losses.

Samples other than air samples should not be composited.

4. SOLUBILITY OF AIRBORNE RADIOACTIVE MATERIAL

Table II of Appendix B, "Concentrations in Air and Water Above Natural Background," to 10 CFR Part 20 lists separate values for soluble and insoluble radioactive materials in effluents. In making comparisons between airborne effluent concentrations and the values given in Table II of Appendix B to 10 CFR Part 20, the maximum permissible concentrations for insoluble materials should be used.

5. LOWER LIMIT OF DETECTION

The lower limits of detection for stack effluent samples should be 10% of the appropriate concentration limits listed in Table II of Appendix B to 10 CFR Part 20.

The lower limits of detection for analysis of other samples should be as follows:

U-natural, Th-230, Ra-226 in air	- 1×10^{-16} μCi/ml
Pb-210 in air	- 2×10^{-15} μCi/ml
Rn-222	- 2×10^{-10} μCi/ml
U-natural, Th-230, Ra-226 in water	- 2×10^{-10} μCi/ml
Po-210 in water	- 1×10^{-9} μCi/ml
Pb-210 in water	- 1×10^{-9} μCi/ml
U-natural, Th-230, Ra-226, Pb-210 in soil and sediment (dry)	- 2×10^{-7} μCi/g
U-natural, Th-230 in vegetation, food, and fish (wet)	- 2×10^{-7} μCi/kg
Ra-226 in vegetation, food, and fish (wet)	- 5×10^{-8} μCi/kg
Po-210, Pb-210 in vegetation, food, and fish (wet)	- 1×10^{-6} μCi/kg

Obviously, if the actual concentrations of radionuclides being sampled are higher than the lower limits of detection indicated above, the sampling and analysis procedures need only be adequate to measure the actual concentrations. In such cases, the standard deviation estimated for random error of the analysis should be no greater than 10% of the measured value.

An acceptable method for calculating lower limits of detection is described in the appendix to this guide.

6. PRECISION AND ACCURACY OF RESULTS

6.1 Error Estimates

The random error associated with the analysis of samples should always be calculated. The calculation should take into account all significant random uncertainties, not merely counting error.

If the analyst estimates that systematic errors associated with the analysis are significant relative to the random error, the magnitude of the systematic error should be estimated.

6.2 Calibration

Individual written procedures should be prepared and used for specific methods of calibrating all sampling and measuring equipment, including ancillary equipment. The procedures should ensure that the equipment will operate with adequate accuracy and stability over the range of its intended use. Calibration procedures may be compilations of published standard practices, manufacturers' instructions that accompany purchased equipment, or procedures written in-house. Calibration procedures should identify the specific equipment or group of instruments to which the procedures apply.

To the extent possible, calibration of measuring equipment should be performed using radionuclide standards certified by the National Bureau of Standards or standards obtained from suppliers who participate in measurement assurance activities with the National Bureau of Standards (see Regulatory Guide 4.15).

Calibrations should be performed at regular intervals, at least semiannually, or at the manufacturer's suggested interval, whichever is more frequent. Frequency of calibration should be based on the stability of the system. If appropriate, equipment may be calibrated before and after use instead of at arbitrarily scheduled intervals. Equipment should be recalibrated or replaced after any repairs or whenever it is suspected of being out of adjustment, excessively worn, or otherwise damaged and not operating properly. Functional tests, i.e., routine checks performed to demonstrate that a given instrument is in working condition, may be performed using sources that are not certified by the National Bureau of Standards.

6.3 Quality of Results

A continuous program should be prepared and implemented for ensuring the quality of results and for keeping random and systematic uncertainties to a minimum. The procedures should ensure that samples and measurements are obtained in a uniform manner and that samples are not changed prior to analysis because of handling or because of their storage environment. Tests should be applied to analytical processes, including duplicate analysis of selected effluent samples and periodic cross-check analyses with independent laboratories (see Regulatory Guide 4.15).

7. RECORDING AND REPORTING RESULTS

This section provides guidelines for recording all results. Reports submitted to NRC should be prepared using these guidelines and the format shown in Table 3 of this guide.

7.1 Sampling and Analysis Results

7.1.1 Air and Stack Samples

For each air or stack sample, the following should be recorded:

1. Location of sample.

2. Dates during which sample was collected.

3. The concentrations of natural uranium, thorium-230, radium-226, lead-210, and radon-222 for all samples except stack samples.

4. The cconcentration of natural uranium, thorium-230, radium-226, and lead-210 for stack effluent samples.

5. The percentage of the appropriate concentration limit as shown in Table II of Appendix B to 10 CFR Part 20.

6. The estimated release rate of natural uranium, thorium-230, radium-226, and lead-210 for stack effluent samples.

7. The flow rate of each stack.

7.1.2 Liquid Samples

For each liquid sample, the following should be recorded:

1. Location of sample.

2. Type of sample (ground or surface water).

3. Date of sample collection.

4. The concentrations of natural uranium, thorium-230, radium-226, polonium-210, and lead-210. (If separate analyses were conducted for dissolved and suspended radionuclides, report each result separately.)

7.1.3 Other Samples

For other samples, the following should be recorded:

1. Location of sample.

2. Date of sample collection.

3. Type of sample (vegetation, soil, radon-222 flux, gamma exposure rate, etc.).

4. Analytical result (radionuclide concentration, gamma exposure rate, radon flux rate, etc.).

7.1.4 Error Estimates

Reported results should always include estimates of uncertainty. The magnitude of the random error of the analysis to the 95% uncertainty level should be reported for each result. If significant, an estimate of the magnitude of the systematic error should also be reported.

7.2 Supplemental Information

The following information should be included in each monitoring report submitted to NRC:

1. Name of facility, location, docket number, and license number.

2. Description of sampling equipment and discussion of how sampling locations were chosen.

3. Description of sampling procedures, including sampling times, rates, and volumes.

4. Description of analytical procedures.

5. Description of calculational methods.

6. Discussion of random and systematic error estimates, including methods of calculation and sources of systematic error.

7. The values of the lower limits of detection, along with a description of the calculation of the lower limit of detection.

8. The values of maximum permissible concentration from Table II of Appendix B to 10 CFR Part 20 used in any calculations.

9. Discussion of the program for ensuring the quality of results.

10. Description of calibration procedures.

11. Discussion of any unusual releases, including the circumstances of the release and any data available on the quantities of radionuclides released.

7.3 Units

Radionuclide quantities should be reported in curies. Radionuclide concentrations should be reported in microcuries per milliliter for air and water, microcuries per gram for soil and sediment, and microcuries per kilogram for vegetation, food, or fish. Direct radiation exposure rates should be reported in milliroentgens per calendar quarter. Radon flux rates should be reported in picocuries per square meter per second. Stack flow rates should be reported in cubic meters per second. (In the International System of Units, a curie equals 3.7×10^{10} becquerels, a microcurie equals 3.7×10^{4} becquerels, and a milliliter equals 10^{-6} cubic meters.)

Estimates of random error should be reported in the same units as the result itself. Estimates of systematic error should be reported as a percentage of the result.

Note: The Commission has discontinued the use in 10 CFR Part 20 of the special curie definitions for natural uranium and natural thorium (39 FR 23990, June 28, 1974). Reports to the Commission should use units consistent with this change.

7.4 Significant Figures

Results should not be reported with excessive significant figures, so that they appear more certain than they actually are. The reported estimate of error should contain no more than two significant figures. The reported result itself should have the same number of decimal places as the reported error.

7.5 Format

Reports should be submitted according to the format shown in Table 3.

The term "not detected," "less than the lower limit of detection (LLD)," or similar terms should never be used. Each reported result should be a value and its associated error estimate, including values less than the lower limit of detection or less than zero.

TABLE 1

PREOPERATIONAL RADIOLOGICAL MONITORING PROGRAM FOR URANIUM MILLS

Type of Sample	Sample Collection				Sample Analysis	
	Number	Location	Method	Frequency	Frequency	Type of Analysis
AIR						
Particulates	Three	At or near the site boundaries	Continuous[a]	Weekly filter change or more frequently as required by dust loading	Quarterly composites of weekly samples	Natural uranium, Ra-226, Th-230, and Pb-210
	One	At or close to the nearest[b] residence(s) or occupiable offsite structure(s) (if within 10 km of site)	Continuous	Weekly filter change or more frequently as required by dust loading	Quarterly composites of weekly samples	Natural uranium, Ra-226, Th-230, and Pb-210
	One	At a control or background location remote from site[c]	Continuous	Weekly filter change or more frequently as required by dust loading	Quarterly composites of weekly samples	Natural uranium, Ra-226, Th-230, and Pb-210
Radon Gas[d]	Five or more	Same locations as for air particulates	Continuous or at least one week per month representing about the same period each month	Continuous	Each sample or continuous	Rn-222
WATER						
Ground Water[e]	Six or more	Wells located around future tailings disposal area. At least three wells hydrologically down gradient from disposal area. At least three located on other sides of tailings disposal area.[f]	Grab	Quarterly	Quarterly	Dissolved natural uranium, Ra-226, Th-230, Pb-210, and Po-210
	One from each well	Wells within 2 km of tailings disposal area that are or could be used for potable water supplies, watering of livestock, or crop irrigation.	Grab	Quarterly	Quarterly	Dissolved and suspended natural uranium, Ra-226, Th-230, Pb-210, and Po-210
	One	Well located hydrologically up gradient from tailings disposal area to serve as control or background location.	Grab	Quarterly	Quarterly	Dissolved natural uranium, Ra-226, Th-230, Pb-210, and Po-210

TABLE 1 (Continued)

PREOPERATIONAL RADIOLOGICAL MONITORING PROGRAM FOR URANIUM MILLS

Type of Sample	Sample Collection				Sample Analysis	
	Number	Location	Method	Frequency	Frequency	Type of Analysis
Surface Water[(g)]	One from each body of water	Large permanent onsite water impoundments or offsite impoundments that may be subject to direct surface drainage from potentially contaminated areas or that could be affected by a tailings impoundment failure.	Grab	Quarterly	Quarterly	Suspended and dissolved natural uranium, Ra-226 and Th-230
					Semiannually	Suspended and dissolved Pb-210 and Po-210
Surface Water	One from each body of water	Surface waters passing through the site[(n)] or offsite surface waters that may be subject to drainage from potentially contaminated areas or that could be affected by a tailings impoundment failure.	Grab	Monthly	Monthly	Suspended and dissolved natural uranium, Ra-226, Th-230
					Semiannually	Suspended and dissolved Pb-210 and Po-210
VEGETATION, FOOD, AND FISH						
Vegetation	Three	Grazing areas near the site in different sectors that will have the highest predicted air particulate concentrations during milling operations.	Grab	Three times during grazing season	Three times	Natural uranium, Ra-226, Th-230, Pb-210, and Po-210
Food	Three of each type	Crops, livestock, etc. raised within 3 km of mill site	Grab	Time of harvest or slaughter	Once	Natural uranium, Ra-226, Th-230, Pb-210, and Po-210
Fish	Each body of water	Collection of fish (if any) from lakes, rivers, and streams in the site environs that may be subject to seepage or direct surface runoff from potentially contaminated areas or that could be affected by a tailings impoundment failure	Grab	Semiannually	Twice	Natural uranium, Ra-226, Th-230, Pb-210, and Po-210

TABLE 1 (Continued)

PREOPERATIONAL RADIOLOGICAL MONITORING PROGRAM FOR URANIUM MILLS

Type of Sample	Sample Collection				Sample Analysis	
	Number	Location	Method	Frequency	Frequency	Type of Analysis
SOIL AND SEDIMENT						
Surface Soil(k)	Up to forty	300-meter intervals to a distance of 1500 meters in each of 8 directions from center of milling area	Grab	Once prior to site construction. Repeat for location disturbed by excavation, leveling, or contouring	Once	All samples for Ra-226, 10% of samples natural uranium, Th-230, and Pb-210
Surface Soil	Five or more	At same locations used for collection of air particulate samples.	Grab	Once prior to site construction	Once	Natural uranium, Ra-226, Th-230, and Pb-210
Subsurface Soil Profile(l)	Five	At center reference location and at distances of 750 meters in each of 4 directions.	Grab	Once prior to site construction. Repeat for locations disturbed by construction.	Once	Ra-226 (all samples) Natural uranium, Th-230, and Pb-210 (one set of samples)
Sediment(m)	Two from each stream	Up and downstream of surface waters passing through site or from offsite surface waters that may be subject to direct runoff from potentially contaminated areas or that could be affected by a tailings impoundment failure	Grab	Once following spring runoff and late summer following period of extended low flow	Twice	Natural uranium, Ra-226, Th-230, and Pb-210
	One from each water impoundment	Onsite water impoundments (lakes, ponds, etc), or offsite impoundments that may be subject to direct surface runoff from potentially contaminated areas or that could be affected by tailings impoundment failure	Grab	Once prior to site construction	Once	Natural uranium, Ra-226, Th-230, and Pb-210
DIRECT RADIATION	Up to eighty	150-meter intervals to a distance of 1500 meters in each of 8 directions from center of milling area or at a point equidistant from milling area(i) and tailings disposal area.		Once prior to site construction. Repeat for areas disturbed by site preparation or construction.	Once	Gamma exposure rate, using passive integrating device such as TLD, pressurized ionization chamber, or properly calibrated portable survey instrument.

TABLE 1 (Continued)

PREOPERATIONAL RADIOLOGICAL MONITORING PROGRAM FOR URANIUM MILLS

Type of Sample	Sample Collection				Sample Analysis	
	Number	Location	Method	Frequency	Frequency	Type of Analysis
	Five or more	At same locations used for collection of particulate samples		Once prior to site construction	Once	Gamma exposure rate, using passive integrating device, pressurized ionization chamber, or properly calibrated portable survey instrument.
RADON FLUX[n]	Up to ten	At center reference location and at distances of 750 and 1500 meters in each of 4 directions.		One sample during each of three months.	Each sample	Radon-222 flux

TABLE 2

OPERATIONAL RADIOLOGICAL MONITORING PROGRAM FOR URANIUM MILLS

Type of Sample	Sample Collection				Sample Analysis	
	Number	Location	Method	Frequency	Frequency	Type of Analysis
STACKS						
Particulates	One for each stack	Yellowcake dryer and packaging stack(s)	Isokinetic	Quarterly	Each sample	Natural uranium, Th-230, Ra-226, and Pb-210 if not available from other sources. Measure stack flow rate semiannually.
Particulates	One for each stack	Other stacks	Representative grab	Semiannually	Each sample	Natural uranium Th-230, Ra-226, and Pb-210. Measure stack flow.
AIR						
Particulates	Three	Locations at or near the site boundaries and in different sectors that have the highest predicted concentrations of airborne particulates[b]	Continuous[a]	Weekly filter change, or more frequently as required by dust loading	Quarterly composite, by location, of weekly samples	Natural uranium, Ra-226, Th-230, and Pb-210
	One or more	At the nearest residence(s) or occupiable structure(s)	Continuous	Weekly filter change, or more frequently as required by dust loading	Quarterly composite, by location, of weekly samples	Natural uranium, Ra-226, Th-230, and Pb-210
	One	Control Location(s)[c]	Continuous	Weekly filter change, or more frequently as required by dust loading	Quarterly composite, by location, of weekly samples	Natural uranium, Ra-226, Th-230, and Pb-210
Radon Gas	Five or more	Same locations as for air particulates	Continuous or at least one week per month[d]	At least one week per calendar month representing approximately the same period each month	Monthly	Rn-222
WATER						
Ground Water	Three or more	Hydrologically down gradient and relatively close to the tailings impoundment[f]	Grab	Monthly (first year) Quarterly (after first year)	Monthly (first year) Quarterly (after first year)	Dissolved natural uranium, Ra-226, Th-230, Pb-210, and Po-210[e]
	At least one control sample	Hydrologically up gradient (i.e., not influenced by seepage from tailings)	Grab	Quarterly	Quarterly	Dissolved natural uranium, Ra-226, Th-230, Pb-210 and Po-210

TABLE 2 (Continued)

OPERATIONAL RADIOLOGICAL MONITORING PROGRAM FOR URANIUM MILLS

Type of Sample	Sample Collection				Sample Analysis	
	Number	Location	Method	Frequency	Frequency	Type of Analysis
	One from each well	Each well used for drinking water or watering of live-stock or crops within 2 km of the tailings impoundment	Grab	Quarterly	Quarterly	Dissolved and suspended natural uranium, Ra-226, Th-230, Pb-210, and Po-210
Surface Water	Two from each water body	Surface waters passing through the mill site or offsite surface waters that are suffi-ciently close to the site to be subject to surface drainage from potentially contami-nated areas or that could be influenced by seepage from the tail-ings disposal area.(h) One sample collected up-stream of mill site and one sample collected at the downstream site boundary or at a loca-tion immediately down-stream of location of potential influence	Grab	Quarterly	Quarterly	Dissolved and suspended natural uranium, Ra-226, Th-230, Pb-210, and Po-210(g)
	One from each water body	Large water impound-ments (i.e., lakes, reservoirs) near the mill site that are sufficiently close to the site to be sub-ject to drainage from potentially contaminated areas or that could be influenced by seepage from the tailings disposal area.	Grab	Quarterly	Quarterly	Dissolved and suspended natural uranium, Ra-226, Th-230, Pb-210, and Po-210
VEGETATION, FOOD, AND FISH						
Vegetation or Forage(o)	Three or more	From animal grazing areas near the mill site in the direction of the highest predicted airborne radionuclide concentrations	Grab	Three times during grazing season	Each sample	Ra-226 and Pb-210

TABLE 2 (Continued)

OPERATIONAL RADIOLOGICAL MONITORING PROGRAM FOR URANIUM MILLS

Type of Sample	Sample Collection				Sample Analysis	
	Number	Location	Method	Frequency	Frequency	Type of Analysis
Food	Three of each type	Crops, livestock, etc. raised within 3 km of mill site	Grab	Time of harvest or slaughter	Once	Ra-226 and Pb-210
Fish	Each body of water	Collection of fish (if any) from lakes, rivers, and streams in the site environs that may be subject to seepage or direct surface runoff from potentially contaminated areas or that could be affected by a tailings impoundment failure	Grab	Semiannually	Twice	Ra-226 and Pb-210
SOIL AND SEDIMENT						
Soil	Five or more	Same as for air particulate samples(k)	Grab	Annually	Annually	Natural uranium, Ra-226, and Pb-210
Sediment	One or two from each water body	Same as surface water samples(m)	Grab	Annually	Annually	Natural uranium, Th-230, Ra-226, and Pb-210
DIRECT RADIATION	Five or more	Same as for air particulate samples	Continuous passive integrating device	Quarterly change of passive dosimeters	Quarterly	Gamma exposure rate

Footnotes for Tables 1 and 2:

(a) Continuous collection means continuous sampler operation with filter change weekly or as required by dust loading, whichever is more frequent.

(b) The term "nearest" as used here means the location with the highest predicted airborne radionuclide concentrations during milling operations.

(c) Care should be taken in selection of the control sampling location so that it is representative of the site conditions. In general, a location in the least prevalent wind direction from the site should provide a suitable location for a control sampling site.

(d) Various methods are acceptable; for example: (1) Continuous collection of a gaseous air sample with samples being changed about every 48 hours for a 1-week period or (2) continuous sampling.

(e) If the sample contains appreciable suspended material, it should be filtered as soon as possible following collection through a membrane filter and the filtrate acidified to 1% hydrochloric acid.

(f) The location of the ground-water sampling wells should be determined by a hydrological analysis of the potential movement of seepage from the tailings disposal area. In general, the objective is to place monitor wells in all directions around the tailings area with the emphasis on the down gradient locations.

(g) Surface-water samples to be analyzed for dissolved and suspended fractions should be filtered as soon as possible following collection through a membrane filter and the filtrate acidified to 1% hydrochloric acid.

(h) Natural drainage systems (dry washes) that carry surface runoff from the site following a precipitation event should be sampled following the event but at a frequency not greater than monthly.

(i) The milling area refers to the area that includes ore storage pads, mill buildings, and other processing areas.

(j) Thermoluminescent dosimeters should contain two or more chips or otherwise provide for two readings per exposure period (see Regulatory Guide 4.13).

(k) Surface soil samples should be collected using a consistent technique to a depth of 5 cm.

(l) Subsurface soil profile samples should be collected to a depth of one meter. Samples should be divided into three equal sections for analysis.

(m) Several samples should be collected at each location and composited for a representative sample.

(n) Radon exhalation measurements should not be taken during periods when the ground is frozen or covered with ice or snow or following periods of rain. It is recommended that these measurements be taken in the spring through the fall during normal weather conditions.

(o) Vegetation or forage sampling need be carried out only if dose calculations indicate that the ingestion pathway from grazing animals is a potentially significant exposure pathway (an exposure pathway should be considered important if the predicted dose to an individual would exceed 5% of the applicable radiation protection standard).

TABLE 3[a]

SAMPLE FORMAT FOR REPORTING MONITORING DATA

1. STACK SAMPLES

For each sample analyzed, report the following information:

a. Date sample was collected
b. Location of sample collection
c. Stack flow rate (m^3/sec)

Radionuclide	Concentration (μCi/ml)	Error Estimate[b] (μCi/ml)	Release Rate (Ci/qr)	Error Estimate (Ci/qr)	LLD[c] (μCi/ml)	% MPC[c]
U-nat						
Th-230						
Ra-226						
Pb-210						

2. AIR SAMPLES

For each sample analyzed, report the following information:

a. Date sample was collected
b. Location of sample collection

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	LLD (μCi/ml)	% MPC
U-nat				
Th-230				
Ra-226				
Pb-210				
Rn-222				

[a] This table illustrates format only. It is not a complete list of data to be reported. (See text of guide and Tables 1 and 2.)

[b] Error estimate should be calculated at 95% uncertainty level, based on all sources of random error, not merely counting error. Significant systematic error should be reported separately. See Sections 6.1, 7.1.4, and 7.3.

[c] All calculations of lower limits of detection (LLD) and percentages of maximum permissible concentration (MPC) should be included as supplemental information.

TABLE 3 (Continued)

SAMPLE FORMAT FOR REPORTING MONITORING DATA

3. LIQUID SAMPLES

For each sample analyzed, report the following information:

a. Date sample was collected
b. Location of sample collection
c. Type of sample (for example: surface, ground, drinking, stock, or irrigation)

Radionuclide	Concentration (μCi/ml)	Error Estimate (μCi/ml)	LLD (μCi/ml)
U-nat (dissolved)			
U-nat (suspended)[d]			
Th-230 (dissolved)			
Th-230 (suspended)[d]			
Ra-226 (dissolved)			
Ra-226 (suspended)[d]			
Pb-210 (dissolved)			
Pb-210 (suspended)[d]			
Po-210 (dissolved)			
Po-210 (suspended)[d]			

4. VEGETATION, FOOD, AND FISH SAMPLES

For each sample analyzed, report the following information:

a. Date sample was collected
b. Location of sample collection
c. Type of sample and portion analyzed

Radionuclide	Concentration (μCi/kg wet)	Error Estimate (μCi/kg)	LLD (μCi/kg)
U-nat			
Th-230			
Ra-226			
Pb-210			
Po-210			

[d] Not all samples must be analyzed for suspended radionuclides. See Sections 1.2 and 2.2 of this guide.

TABLE 3 (Continued)

SAMPLE FORMAT FOR REPORTING MONITORING DATA

5. SOIL AND SEDIMENT SAMPLES

For each sample analyzed, report the following information:

a. Date sample was collected
b. Location of sample collection
c. Type of sample and portion analyzed

Radionuclide	Concentration (μCi/g)	Error Estimate (μCi/g)	LLD (μCi/g)
U-nat			
Th-230			
Ra-226			
Pb-210			
Po-210			

6. DIRECT RADIATION MEASUREMENTS

For each measurement, report the dates covered by the measurement and the following information:

Location	Exposure Rate (mR/qr)	Error Estimate (mR/qr)

7. RADON FLUX MEASUREMENTS

For each measurement, report the dates covered by the measurement and the following information:

Location	Flux (pCi/m^2-sec)	Error Estimate (pCi/m^2-sec)

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APPENDIX

LOWER LIMIT OF DETECTION

For the purposes of this guide, the Lower Limit of Detection (LLD) is defined as the smallest concentration of radioactive material sampled that has a 95% probability of being detected, with only a 5% probability that a blank sample will yield a response interpreted to mean that radioactive material is present. (Radioactive material is "detected" if it yields an instrument response that leads the analyst to conclude that activity above the system background is present.)

For a particular measurement system (which may include radiochemical separation):

$$LLD = \frac{4.66\ S_b}{3.7 \times 10^4\ EVY\ \exp(-\lambda \Delta t)}$$

where

LLD	is the lower limit of detection (microcuries per milliliter);
S_b	is the standard deviation of the instrument background counting rate (counts per second);
3.7×10^4	is the number of disintegrations per second per microcurie;
E	is the counting efficiency (counts per disintegration);
V	is the sample volume (milliliters);
Y	is the fractional radiochemical yield (when applicable);
λ	is the radioactive decay constant for the particular radionuclide; and
Δt	is the elapsed time between sample collection and counting.

The value of S_b used in the calculation of the LLD for a particular measurement system should be based on the actual observed variance of the instrument background counting rate rather than an unverified theoretically predicted variance.

Since the LLD is a function of sample volume, counting efficiency, radiochemical yield, etc., it may vary for different sampling and analysis procedures. Whenever there is a significant change in the parameters of the measurement system, the LLD should be recalculated.*

*For a more complete discussion of the LLD, see "HASL Procedures Manual," John H. Harley, editor, USERDA, HASL-300 (revised annually) and Currie, L.A., "Limits for Qualitative Detection and Quantitative Determination--Application to Radiochemistry," *Anal. Chem.* 40, 1968, pp. 586-93, and Donn, J. J. and R. L. Wolke, "The Statistical Interpretation of Counting Data from Measurements of Low-Level Radioactivity," *Health Physics*, Vol. 32, 1977, pp. 1-14.

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