5.0 NUCLEAR CRITICALITY SAFETY

The American Centrifuge Plant (ACP) possesses large quantities of uranium hexafluoride (UF_6) at enrichments of up to 10 weight (wt.) percent uranium-235 (^{235}U). The specific authorized uses for each class of U. S. Nuclear Regulatory Commission (NRC)-regulated material are shown in Table 1.2-2 of this license application. USEC Inc. is required to comply with the performance requirements of 10 *Code of Federal Regulations* (CFR) 70.61. 10 CFR 70.61(d) requires that the risk of nuclear criticality accidents be limited by assuring that under normal and credible abnormal conditions, nuclear processes are subcritical, including use of an approved margin of subcriticality for safety. It also requires that preventive controls and measures must be the primary means of protection against nuclear criticality accidents. Accordingly, this chapter summarizes the ACP Nuclear Criticality Safety (NCS) Program.

In accordance with the requirements contained in 10 CFR 70.62, the likelihood and risks of an inadvertent nuclear criticality were evaluated in the Integrated Safety Analysis (ISA). The evaluation considered moderation events, maintenance evolutions, machine upset conditions, and cylinder operations. The ISA concluded that credible nuclear criticality accident scenarios that could be identified for the ACP were controlled through a combination of administrative and engineered controls in compliance with the performance requirements of 10 CFR 70.61(d). The plant has established a threshold of 1 wt. percent or higher enriched ^{235}U and 100 grams (g) or more of ^{235}U for determining when an evaluation for NCS considerations of planned operations must be performed. This 100 g ^{235}U mass is a minimum of a factor of 10 below the minimum critical mass at 10 percent ^{235}U enrichment, regardless of whether the material is non-oily, oily, or heterogeneous for a fully reflected system. Based on this, the value is sufficiently low to use as a threshold limit. In view of this threshold, many of the ACP NCS Program features described in this chapter may not be required to be implemented for operations below the threshold. In this regard, the NCS Program provides the framework for a defense-in-depth philosophy to help ensure the risk of inadvertent criticality is maintained acceptably low. The NCS Program also provides the framework and resources for evaluating plant performance in establishing NCS analyses and controls for the design and operation of a uranium enrichment plant.

5.1 Management of the Nuclear Criticality Safety Program

5.1.1 Program Elements

The NCS Program described in this chapter is implemented by plant procedures. The NCS procedures address plant personnel NCS responsibilities, adherence to Nuclear Criticality Safety Evaluation (NCSE) requirements, review and approval of fissile material operations, posting and labeling requirements, response to NCSE violations, and NCS training requirements. Controls and/or barriers that are relied on to prevent inadvertent criticalities are designated as items relied on for safety (IROFS) in the ISA. The NCS Program meets the Baseline Design Criteria (BDC) requirements in 10 CFR 70.64(a) concerning application of the double contingency principle in determining NCS controls and IROFS in the design of new facilities.

5.1.2 Program Objectives

The NCS Program meets the requirements of 10 CFR Part 70. The objectives of the program include:

- Preventing an inadvertent nuclear criticality;
- Protecting against the occurrence of an identified accident sequence in the ISA Summary that could lead to an inadvertent nuclear criticality;
- Complying with the NCS performance requirements of 10 CFR 70.61;
- Establishing and maintaining NCS safety parameters and procedures;
- Establishing and maintaining NCS safety limits and NCS operating limits for IROFS;
- Conducting NCS evaluations to assure that under normal and credible abnormal conditions nuclear processes remain subcritical, and maintain an approved margin of subcriticality for safety;
- Establishing and maintaining NCS IROFS, based on current NCS evaluations;
- Providing training in emergency procedures in response to an inadvertent nuclear criticality;
- Complying with NCS BDC requirements in 10 CFR 70.64(a);
- Complying with the NCS ISA Summary requirements in 10 CFR 70.65(b); and
- Complying with the NCS ISA Summary change process requirements in 10 CFR 70.72.

5.2 Organization and Administration

5.2.1 Nuclear Criticality Safety Responsibilities

The Director, American Centrifuge Plant assigns responsibilities and delegates commensurate authority to ACP managers/supervisors for the implementation and oversight of the NCS requirements. The managers/supervisors ensure that sufficient resources are available for implementation of NCS requirements. The Engineering Manager is responsible for implementing the ACP NCS Program. The Nuclear Safety Manager reports to the Engineering Manager and is also responsible for the management of NCS functions, including administering the NCS Program. The NCS Manager reports to the Nuclear Safety Manager and is responsible for the direct management of the NCS functions and administration of the NCS Program on a day-to-day basis.

The ACP organization managers are responsible for ensuring that operations involving uranium enriched to 1 wt. percent or higher ^{235}U and 100 g or more of ^{235}U (hereafter referred to as

fissile material operations) are identified and evaluated for NCS considerations prior to initiation of the operation. The organization managers or their designees are also responsible for ensuring NCS evaluations are requested, and for ensuring implementation of the requirements contained in the evaluations for these same operations. For those fissile material operations performed by personnel from multiple organizations, the Director, American Centrifuge Plant assigns responsibility for that operation to a single organization manager or designee.

Management is responsible, in their respective operations, for ensuring that personnel are made aware of the requirements and limitations established by approved NCSEs either through pre-job briefings, required reading, training, and/or procedures (based on the complexity of the change). These managers/supervisors are responsible for ensuring fissile material operations that do not have approved NCSEs will not be performed until the necessary approvals have been obtained. Management is responsible for ensuring that only personnel who have received and passed NCS training as specified in ACP NCS procedures will handle fissile material.

Managers/supervisors who are responsible for one or more fissile material operations are trained in NCS and ensure appropriate personnel receive NCS training as specified in ACP NCS procedures. This training provides personnel with the knowledge necessary to fulfill their NCS responsibilities. Section 11.3.1.4 of this license application discusses the NCS training program.

The fissile material operators are responsible for conducting operations in a safe manner in compliance with procedures or work instructions and are required to stop operations if unsafe conditions exist.

The NCS Manager has, as a minimum, a bachelor's degree in engineering, mathematics or related science or equivalent technical experience, and four years nuclear experience, including six months at a uranium processing facility where nuclear criticality safety was practiced. The NCS Manager is responsible for the administration of the NCS Program. This includes reviewing the overall effectiveness of the NCS Program, ensuring that NCS staff members are placed, trained, and qualified in accordance with written procedures, and that NCSEs are prepared and technically reviewed by qualified NCS engineers. NCS is independent of organizations that require NCSEs.

Qualified NCS Engineers and Senior NCS Engineers are responsible for performing the following functions:

- Providing NCSEs for fissile material operations;
- Performing walk-throughs of facilities which handle fissile material and advising appropriate management of any NCS concerns;
- Participating in investigation of incidents involving NCS and in the determination of recommendations for eliminating such incidents;
- Assisting in emergency preparedness planning;
- Providing support to the Plant Safety Review Committee (PSRC);

- Participating in the review of procedures that involve fissile material operations to ensure NCSE commitments have been effectively incorporated into operating procedures; and

- Participating in the review of work packages that involve fissile material operations to ensure NCSE commitments have been effectively incorporated into work package instructions. For work packages that are used repeatedly for the same kind of job, the review is only necessary once. For work packages that have the NCSE commitments incorporated into an approved procedure, additional NCS review is not necessary.

NCS group personnel have the authority to halt any unsafe activity.

The responsibilities of Senior NCS Engineers performing technical reviews of NCSEs are specified in the NCS evaluation and approval procedure. These responsibilities include:

- Verifying that sufficient information is documented to allow independent analysis by a reviewer with knowledge of the process and the NCS Program;

- Verifying that credible process upsets related to criticality safety are properly identified and evaluated;

- Verifying compliance with the double contingency principle;

- Checking for accuracy; and

- Verifying applicability of the calculational methods.

5.2.2 Nuclear Criticality Safety Staff Qualifications

The minimum requirements for a qualified NCS Engineer are:

- Bachelor's degree in engineering, mathematics, or related science;

- Familiarization with NCS by having a minimum of one year experience at an enriched uranium processing facility;

- Completion of NCS-related training course and KENO V.a training course or equivalent;

- Performance of at least four evaluations under the direction of a Senior NCS Engineer; and

- Performance of walk-through inspections under the guidance of a qualified NCS Engineer.

The NCS Manager can modify the minimum qualified NCS Engineer qualification requirements for personnel who have worked for a minimum of three years at other facilities as an NCS Engineer.

The minimum requirements for a qualified Senior NCS Engineer are:

- Completion of the minimum requirements for a qualified NCS Engineer;
- Performance of the functions of a qualified NCS Engineer;
- Completion of one year as a qualified NCS Engineer; and
- Approval by the NCS Manager (or equivalent).

The NCS Manager (or equivalent) may modify the minimum Senior NCS Engineer qualification requirements for personnel who have worked for a minimum of five years at other facilities as a nuclear criticality safety engineer.

5.3 Management Measures

5.3.1 Procedure Requirements

Operations to which NCS pertains are governed by written procedures or work packages. These procedures or work packages contain the appropriate NCS controls for processing, storing, and handling fissile material. The NCSE requirements that specify employee actions are incorporated into procedures or work packages as work instructions and are identified. Identifying these requirements ensures changes to these requirements are not made without review and approval by NCS. The NCSE requirements are incorporated into the appropriate procedures or work packages as required by the NCS Program procedure.

New and modified procedures or work packages are reviewed by the appropriate safety organizations, including NCS, as specified in the procedure for procedure control and/or work control process. NCS reviews the procedures and/or work instructions to verify that the appropriate NCSE requirements have been incorporated and to verify that the proposed operation complies with NCS Program requirements. Section 11.4 of this license application provides more details related to the procedure development and change process.

5.3.2 Posting and Labeling Requirements

Administrative NCS limits and controls for areas, equipment, and containers are presented through the use of postings and labels as specified in approved NCSEs and procedures. Postings and labels are proposed, reviewed, and approved during the NCSE review and approval process. Postings and/or labels are not required for engineered controls and may not be required for administrative controls when those limits and controls are included in "in-hand" operating procedures. These limits and controls are posted on the NCS requirements signs as required by the plant NCS procedures. Approved NCSEs specify the wording for the postings. Labels are prepared in accordance with the plant NCS procedures and used as required by NCSEs. Limits and controls are printed or written in an appropriate size, and the postings and labels are placed in conspicuous locations determined by the supervision responsible for the material.

5.3.3 Change Control

A configuration management (CM) program ensures that any change from an approved baseline configuration is managed so as to preclude inadvertent degradation of safety or safeguards. The CM Program, described in Section 11.1 of this license application, includes organization and administrative processes to ensure accurate, current design documentation that matches the plant's physical configuration. The CM program applies to NCS and a change control process is utilized that helps ensure that the requirements of 10 CFR 70.72 are met, including the ISA Summary update requirements contained in 10 CFR 70.72(d)(3).

Functional and physical characteristics of operations controlled for NCS are described in NCSEs. Components and features that are identified in the NCSEs are analyzed to determine the "boundary" of the system, encompassing those interconnecting and/or supporting items that are essential to ensure availability and reliability. The boundaries are identified on system drawings, and the configuration is verified to be as-built. These components and features are maintained in a design control document for the building or process. Each time a change is planned, the document is reviewed by the individual (e.g., design authority, systems engineer, operations manager, maintenance, etc.) planning the change to determine if the change affects an IROFS. The NCS Program establishes and maintains NCS safety limits and NCS operating limits for IROFS in nuclear processes and maintains adequate management measures to ensure the availability and reliability of the IROFS.

The change control process specifies the organizations required to perform reviews of changes. If an item is relied on for the criticality safety of an operation, it will be identified and NCS reviews the NCSE for the specific operation and determines if the change affects the analysis performed and the conclusions made in the NCSE. The change request will be approved by NCS only if the change does not adversely impact NCS, or once a revised NCSE has determined that the change is acceptable and meets NCS Program requirements. If a change affects the ISA Summary, it is updated appropriately. In this way, modifications to controlled operations are evaluated and approved prior to implementation and placing the affected structures, systems, or components in service.

Records management and document control (RMDC) is another element of CM and is described in Section 11.7 of this license application. Procedures, documents, and records control programs provide for centralized control and issuance of documents essential to the maintenance of the design history, and a repository for records to verify this maintenance. NCSEs are specifically included in the index of documents that are required to be controlled.

5.3.4 Operation Surveillance and Assessment

To ensure that the NCS Program is properly established and implemented, walk-throughs, assessments, and audits are utilized.

Operating SNM process areas are reviewed on a regular basis through a combination of walk-throughs and reviews by work crew supervision. NCS walk-throughs of facilities that may contain fissile material operations are performed by NCS personnel to determine the adequacy of implementation of NCS requirements and to verify that conditions have not been altered to adversely affect NCS. These walk-throughs are performed as specified by the NCS procedure on walk-throughs. For example, a walk-through inspection can be performed in response to trend data, at the request of the operations personnel, or due to concerns raised by employees or NCS personnel. As a minimum, these walk-throughs are completed for applicable areas annually and may be performed in conjunction with the assessments discussed below.

Work crew supervision provides real-time assessments of fissile material operations within their operating area to ensure NCS requirements are being adequately implemented and operating conditions have not been altered to adversely affect NCS.

Internal audits of the NCS Program are conducted or coordinated by the Quality Assurance Manager as described in Section 11.5 of this license application. The purpose of these audits is to determine the adequacy of the overall NCS Program. This includes the adequacy of the NCSEs, internal assessment programs, and implementation of the NCS requirements.

The results of these walk-throughs, assessments, and audits are documented and reported to appropriate management.

If a condition is identified that is non-compliant with NCS program requirements, field personnel are to report the condition as directed by plant procedures. If the condition is not covered by an existing procedure, consultation with a qualified NCS engineer is required before taking any corrective action. Immediate corrective actions may be provided by the responding NCS engineer verbally or in writing. NCS emergency response is discussed in Section 5.4.2 below.

Managers in charge of fissile material operations are provided additional training on NCS and response to NCS deficiencies. NCS deficiencies are reported in accordance with the requirements contained in 10 CFR Part 70, Appendix A or other appropriate reporting requirements. Incident reporting and investigation is described in Section 11.6 of this license application. The deficiency data is trended to monitor and prevent future violations. Corrective actions are taken for adverse trends in accordance with the Quality Assurance Program Description for the American Centrifuge Plant and the Corrective Action Program as described in Section 11.6.7 of this license application, and records of actions taken are retained in accordance with RMDC requirements described in Section 11.7 of this license application.

5.4 Methodologies and Technical Practices

5.4.1 Adherence to American National Standards Institute/American Nuclear Society Standards

The NCS Program has been developed to comply with the American National Standards Institute (ANSI)/American Nuclear Society (ANS) ANSI/ANS-8.1-1998, ANSI/ANS-8.19-1996, and ANSI/ANS-8.21-1995 standards as discussed in this section.

5.4.2 Process Evaluation and Approval

Each operation involving uranium enriched to 1 wt. percent or higher ^{235}U and 100 g or more of ^{235}U is evaluated for NCS prior to initiation. The evaluation describes the scope of the operation, evaluates credible criticality accident contingencies, and establishes NCS requirements to maintain the operation subcritical. The evaluation process is governed by written procedures.

When an NCSE (or a change to an existing NCSE) is needed for a particular fissile material operation, a request is submitted to the NCS group to evaluate the proposed operation. Other methods for initiating an NCS change include, but are not limited to: 1) the engineering change process, and 2) the corrective actions process, self-assessments, and external audits and inspections.

In response to the request, an NCS evaluation may be performed or the request may be returned due to inadequate detail, the change is bounded by a current analysis, or the operation does not involve uranium enriched to 1 wt. percent or higher ^{235}U and with mass of 100 g or more ^{235}U (see Section 5.4.2.1). If necessary, a NCSE is prepared (or an existing NCSE is revised) to document the analyses performed as specified in the NCS evaluation procedure. A hazard identification process (e.g., a "What-If" analysis) is used to identify and document potential upset conditions, or contingencies, presenting NCS concerns. Engineering judgment of the qualified NCS engineer may indicate the need for a more detailed study. For example, a hazards and operability study may be used if the operation is complex and involves multiple interacting systems that require substantial input from operations, maintenance, and other subject matter experts to identify the possible upset conditions. A contingency analysis is performed in which the subcriticality of a process, given the occurrence of the contingency, is assessed. This analysis demonstrates the double contingency principle for the proposed operation.

The double contingency principle as stated in ANSI/ANS-8.1-1998, Section 4.2.2, is: "Process designs should incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible." The ACP NCS Program meets the double contingency principle by implementing at least one control on each of two different parameters or implementing at least two controls on one parameter. Controls include passive engineered barriers (e.g., structures, vessels, piping, etc.); active engineered features (e.g., valves, thermocouples, flow meters, etc.); reliance on the natural or credible course of events (e.g., relying on the nature of a process to keep the density of uranyl fluoride less than a specified fraction of theoretical); and administrative controls that require performance of human actions in accordance with approved procedures or work instructions, or by other means that limit parameters within

specified values. If two controls are implemented for one parameter, the violations or failure scenarios addressed by the controls will be independent. Application of this principle ensures that no single credible event can result in an accidental criticality or that the occurrence of events necessary to result in a criticality is not credible.

The NCSE will document the basis for the conclusion that a change in a process or parameter is “unlikely”. The basis may be an engineered feature, administrative control, the natural or credible course of events, or any combination of these or other means necessary to ensure the change is unlikely to occur. The parameters or conditions relied on and the limits must be specified in the NCSE and controlled.

Where the natural or credible course of events is relied upon in whole or in part to prevent a process condition change, the factors that influence the process are described in sufficient detail in the NCSE as items related to NCS and programmatically controlled. For items that are established, maintained, and implemented by non-NCS programs, credit for availability and reliability is established as described in Section 11.1 of this license application without the need for additional NCS controls. For situations where the NCS-credited controls do not provide adequate assurance of availability or reliability (i.e., situations where non-NCS programmatic and physical plant changes could adversely affect the intended criticality safety function of the items relied upon for criticality safety), specific NCS controls are established, maintained, and implemented to ensure criticality safety.

The NCS evaluation process involves a review of the proposed operation and procedures or work instructions, discussions with the subject matter experts to determine the credible process upsets which need to be considered, development of the controls necessary to meet the double contingency principle, and identification of the assumptions and equipment (i.e., physical controls) needed to ensure criticality safety.

Engineering judgment of both the analyst and the technical reviewer is used to ascertain independence of events and their likelihood or credibility. The basis for this judgment is documented in the NCSEs. Depending on the complexity of the operation, analytical methods such as Fault Tree and Event Tree Analyses may be used in the evaluation process to examine potential accident scenarios. When needed to support the analytical method, qualitative or quantitative estimates of event frequency are developed to support the determination of the likelihood of an event.

Once the NCSE is completed, a technical review of the evaluation is performed and documented. The technical review of an NCS evaluation is performed by a Senior NCS Engineer or is a NCS Engineer completing the technical review under the guidance of a Senior NCS Engineer.

The NCSE documents the NCS requirements for the operation. The NCS requirements include the process conditions that must be maintained to meet the double contingency principle or preserve the documented basis for criticality safety and restrict the modes of operation to those that have been analyzed in the NCSE. The requirements to be included in operating procedures and/or work instructions, and postings are identified.

The NCSE approval process first involves the acceptance of the NCSE by the technical reviewer. A review is then performed by the NCS Manager to ensure consistency with other NCSEs and other potentially conflicting requirements or regulations. After approval by the NCS Manager, a review is performed in accordance with 10 CFR 70.72 as described in Section 11.1.4 of this license application to determine whether prior NRC approval of the NCSE is required. If NRC approval is not required, the NCSE is reviewed by the responsible organization manager. Editorial changes require only the approval of the NCS Manager. Editorial changes are defined as changes that do not change the technical basis of the NCSE. Once approved, the NCS controls, limits, evaluation assumptions, and safety items are verified to be fully implemented in the field. The operations organization and NCS personnel perform this verification process. The documentation of this verification process is maintained as a quality record along with the NCSE.

Management of the operating organization is responsible for implementing, through training and procedures or work instructions, the conditions delineated in the NCSE. Operational aids such as postings, labels, boundaries for fissile material operations, and fissile material movement guidelines are provided as specified in the NCSE. The manager/supervisor ensures postings and labels are prepared and verify that they are properly installed as required by the NCSE. The procedures and/or work instructions are prepared or modified to incorporate the NCSE requirements. Managers/supervisors are responsible for ensuring the employees understand the procedures and/or work instructions and understand the NCS requirements before the work begins.

Each completed NCSE is issued as a controlled document. Completed NCSEs are archived and retrievable as permanent quality records in accordance with the RMDC requirements described in Section 11.7 of this license application. The NCSE process provides assurance that operations will remain subcritical under both normal and credible abnormal conditions.

Emergencies arising from unforeseen circumstances can present the need for immediate action. If NCS expertise or guidance is needed immediately to avert the potential for a criticality accident, direction will be provided orally or in writing. Such direction can include a stop work order or other appropriate instructions. Documentation will be prepared within 48 hours after the emergency condition has been stabilized.

New operations must comply with the double contingency principle.

5.4.2.1 Non-Fissile Material Operations

Some operations involve situations in which the uranium has an enrichment of less than 1 wt. percent ^{235}U or an inventory of less than 100 g ^{235}U. These operations are termed "non-fissile material operations" and are performed without the need for NCS double contingency controls. The determination of which operations are fissile versus which operations are non-fissile may be contained within a NCSE or as a separate document. When the determination is outside a NCSE, the determination need not be performed by a qualified NCS Engineer. Controls are sometimes applied to a non-fissile material operation to ensure it does not inadvertently involve fissile material. These controls can be either engineered or administrative and may be incorporated into applicable operating procedures or work instructions at the discretion of the responsible line manager.

5.4.3 Design Philosophy and Review

Through the CM Program, designs of new fissile material equipment and processes must be approved by NCS before implementation. Where practical, the use of engineered controls on mass, geometry, moderation, volume, concentration, interaction, or neutron absorption will be used as the preferred approach over the use of administrative controls. Advantage will be taken of the nuclear and physical characteristics of process equipment and materials, provided control is exercised to maintain them if they may credibly degrade such that control of the parameter is jeopardized.

The preferred design approach includes two goals. The first is to design equipment such that NCS is independent of the amount of internal moderation or fissile concentrations, the degree of interspersed moderation between units, or the thickness of reflectors. The second is to minimize the possibility of accumulating fissile material in inaccessible locations and, where practical, to use favorable geometry for those inaccessible locations. The adherence to this approach is determined during the preparation and technical review of the NCSE performed to support the equipment design. This preferred design approach is implemented as described in NCS procedures.

Fissile material equipment designs and modifications are reviewed to ensure that engineered controls are used for NCS to the extent practical. Administrative limits and controls will be implemented to satisfy the double contingency principle for those cases where the preferred design approach is not practical.

5.4.4 Criticality Accident Alarm System Coverage

A criticality accident alarm system (CAAS) that complies with 10 CFR 70.24 and ANS/ANSI-8.3 is provided to alert personnel if a criticality accident occurs. The system utilizes an audible and/or visual signal to alert personnel in the area to evacuate to reduce radiation exposure resulting from the incident.

The need for CAAS coverage is considered during the development process for NCS evaluations. In general, coverage is provided for fissile material operations, except the UF_6 cylinder storage yards as specified in Section 1.2.5 of this license application. Other exceptions to CAAS coverage are documented in NCS evaluations and are based on a conclusion in the NCSE that a criticality accident is non-credible in the area where the fissile material operation is ongoing. Conclusions of non-credibility require at a minimum that the inventory of ^{235}U in the area is less than 700 g, less than 50 g per square meter, or less than 5 g in any 10 liter volume. In addition, CAAS is not required for areas having material that is either packaged or stored in accordance with 10 CFR Part 71 or specifically exempt according to 10 CFR 71.53. Areas that do not contain fissile material operations do not require a NCSE and do not require CAAS coverage.

The CAAS is designed to detect neutron radiation levels that would result from the minimum criticality accident of concern as defined by ANSI/ANS 8.3-1997 and to provide an audible evacuation alarm. A secondary function is to activate the building radiation warning lights and alarms at the X-3012 Process Support Building Area Control Room (ACR) and the X-1020 Emergency Operations Center.

For each area requiring CAAS coverage, a monitoring system is installed that provides coverage of the area by at least two independent detection units, each with the ability to actuate the alarm. This arrangement allows for one detection unit to be temporarily out of service with fissile operations continuing under the coverage of the other detection unit. A detection unit is a set of at least three neutron sensitive radiation detectors that may be co-located or may be distributed over the area. The detection logic of the system requires that two of the three neutron detectors must be activated to initiate the building evacuation alarm system. Each detector may be logically part of more than one detection unit.

The building evacuation alarm system includes interior evacuation horns and exterior radiation warning lights to deter personnel from re-entering the building after an evacuation. In addition, facilities within 200 feet of a building/facility requiring CAAS coverage have radiation evacuation horns installed inside and radiation warning lights installed on the exterior. Personnel who have routine access to these facilities have been trained to recognize and respond to these indications as described in Section 11.3.1.1.2 of this license application.

To protect against the loss of coverage, the CAAS includes redundant decision logic, a backup power supply, detector status information and system self-diagnostic information are provided to the X-3012 building ACR and X-1020 building. The CAAS has been designed to survive and/or withstand credible abnormal events as described in the accident analysis for a sufficient time to warn personnel to evacuate. In the event CAAS coverage is lost for an operation, plant procedures provide for compensatory actions, which may include shutdown of equipment, limiting access, halting movement of uranium-bearing material, or other actions.

Additional information provided by the CAAS includes a historical log of events and the capability to monitor and record the criticality accident for managing the post-accident situation and any remedial action. Nuclear accident planning and response is discussed in Section 2.2.4 of the Emergency Plan for the American Centrifuge Plant.

5.4.4.1 Portable CAAS

In the event a fissile material operation requiring CAAS coverage is performed beyond the detection range of established CAAS instrumentation, a portable unit may be used. The portable unit has the same detection capabilities as the permanently installed units, although those capabilities may be based on gamma radiation. Alarm annunciation, however, is usually limited to the immediate area within the audible range of the unit's alarm with an additional telemetric link to the X-3012 ACR and X-1020. This link will transmit the location of the unit, if mobile, and allow the use of the plant PA system to warn personnel within 200 feet of the area of the portable unit to evacuate. A portable unit may only be used on a temporary basis and it may be located indoors, outdoors, or on a vehicle.

5.4.5 Technical Practices

5.4.5.1 Application of Parameters

Moderation

Water is considered to be the most efficient moderator commonly found in the ACP. When moderation is not controlled either optimum moderation or worst credible moderation is assumed as the normal case when performing analyses. When moderation is controlled, credible abnormal process upset conditions determine the worst-case moderated conditions. Generally, moderation control is not maintained by measurement; however, when used, dual independent sampling methods are implemented.

Moderation control is applied to plant equipment containing UF_6. In areas where greater than the safe mass of uranium (as defined below) is handled, processed, or stored and moderation controls are applied, restrictions are placed on firefighting procedures to limit the use of moderator material. However, even in these areas, the application of the double contingency principle ensures the worst credible loss of moderation control cannot result in a critical configuration without an additional independent and concurrent upset event.

The centrifuge process equipment is comprised of a variety of closed systems designed to process gaseous UF_6. This closed system prevents the introduction of moderation due to wet air in-leakage. Also, because UF_6 reacts chemically with moisture (a moderator) to produce solid uranium-bearing compounds that impedes the proper operation of the process equipment, the UF_6 bearing systems are designed to minimize introduction of moisture.

Volume

Volume limits are used as specified in NCSEs. The bases for volume limits are provided in each NCSE prepared for those operations requiring containers. Specific details of these bases can be obtained by referring to the applicable NCSE. When volume control is used, the size of the containers is ensured through the CM Program and/or by procedurally requiring the use of certain containers for fissile material operations.

Interaction

Interaction is controlled by spacing items bearing fissile material when those items could result in a criticality accident if not properly spaced. The spacing necessary to maintain a safe array of fissile material units is determined in the NCSE performed for the array. The amount of spacing needed between items is determined based on analysis of the normal and credible abnormal process upset conditions for the particular operation. The basis for the spacing is documented in NCSEs. In accordance with the preferred design approach, described in Section 5.4.3 of this chapter, passive engineered controls are used to the extent possible to ensure spacing requirements are maintained. When used, the structural integrity of the spacers or racks is sufficient to maintain spacing for normal

and credible abnormal upset conditions.

Geometry

Geometry control is applied by limiting equipment dimensions for those systems that depend on the geometry for criticality safety. The geometry is determined in the NCSE that is performed for each system and depends on the normal and credible abnormal process upsets conditions related to the specific system. Geometry controls are specified in the NCSEs, are maintained by the CM Program, and are verified prior to authorizing initial operation. Safe geometry dimensions may be obtained from established standards or operation specific reactivity calculations.

Mass

Mass controls are applied on a case-by-case basis depending on the fissile material operation involved. The acceptable mass is determined based on the specific NCSE performed for the operation. The safe mass value depends on many factors including the geometry, the ^{235}U enrichment, composition, etc. Safe mass values may be obtained from established standards or operation specific reactivity calculations. Experimental data is not used as the sole source for safe mass values. Safe mass values are chosen to ensure no single credible upset can result in a critical configuration. The safe mass values are communicated to the operating personnel via the operating procedures and/or work packages.

Unless specifically controlled, an item containing enriched uranium is assumed to contain the most ^{235}U credible based on the available volume. When mass is determined through measurement, instrumentation is used.

Enrichment

Uranium-containing material in the ACP with ^{235}U enrichment less than 1 wt. percent is considered incapable of supporting a nuclear chain reaction, but interaction of such materials with materials of higher enrichment is taken into consideration in the specific NCSE for those operations which involve material enriched to greater than 1 wt. percent.

The maximum ^{235}U enrichment of UF_6 in the ACP is 10 wt. percent. Small quantities of greater than 10 wt. percent ^{235}U may be present outside of plant equipment in the form of laboratory samples or standards. Some buildings on the reservation may be used to process and/or store fissile material from both the ACP and Portsmouth Gaseous Diffusion Plant (GDP). Although the GDP has historically processed material at greater than 10 wt. percent ^{235}U, this material is no longer readily available to interact with ACP operations. However, for conservatism, some operations in these common buildings may be analyzed at greater than 10 wt. percent ^{235}U enrichment.

The maximum ^{235}U enrichment for each operation is established by the specific NCSE. The NCSE specifies the maximum acceptable enrichment for each operation. Credible process upset conditions that could alter the ^{235}U enrichment are also considered in the NCSEs. Due to the difficulty in obtaining reliable, real-time enrichment measurements that are both accurate and precise

enough to use as a NCS control, enrichment is assumed to be the maximum credible for each operation. When the enrichment of uranium needs to be measured for a NCS control, the measurement is obtained using either installed equipment or based on samples analyzed in a laboratory.

Density

The density of materials used in a given operation is justified in the NCSE for the operation being considered. If the density must be controlled to maintain compliance with the double contingency principle, it will be documented in the specific NCSE for the operation and it will be measured using instrumentation.

UF_6 in the gaseous phase, at any credible pressures and temperatures existing in the plant equipment, is incapable of supporting a nuclear chain reaction even when intermixed with hydrogenous material (e.g., hydrogen fluoride [HF]). UF_6 in the gaseous phase in plant equipment has low material density.

Heterogeneity

Heterogeneous configurations are considered for those operations that involve small fissile material and moderator regions. Heterogeneous groupings may occur for the handling of small sample containers; however, 10 wt. percent ^{235}U is assumed for samples handled on a safe mass basis. Using the homogeneous safe mass of 10 wt. percent ^{235}U is also safe for heterogeneous 10 wt. percent ^{235}U because, at this enrichment, the homogeneous and heterogeneous minimum critical masses are close in value.

Concentration

Concentration controls are used on a case-by-case basis. When the criticality safety of an operation depends on the concentration of fissile material, the medium is sampled twice, the samples are verified to be properly taken by a second individual, and the two samples are independently analyzed as required by the specific NCSE for the operation involved. The specific controls and details are documented in the NCSE for each operation that relies on concentration controls. No operations exist at the plant where concentration control is applied to an operation involving more than a safe mass of uranium. A container with concentration controlled solution is kept normally closed. Precipitating agents, including freezing, are controlled as necessary to ensure they do not inadvertently increase the concentration.

A typical operating limit is 5 g ^{235}U per liter, regardless of enrichment. A concentration of 11.6 g ^{235}U per liter is considered subcritical at any enrichment, as recognized by ANSI/ANS-8.1. If, under all postulated conditions, the concentration is always less than 11.6 g ^{235}U per liter, the operation is considered subcritical.

Reflection

Normal and credible abnormal reflection is considered when performing NCS evaluations. The possibility of full water reflection is considered when performing analyses. It is recognized that concrete can be a more efficient reflector than water, and its potential presence is considered. Reflection controls are used to limit the potential reactivity of a fissile material operation.

Neutron Absorption

When neutron absorbers are used as NCS controls, the intended distributions and concentrations under both normal and credible abnormal conditions are maintained in accordance with the requirements of the applicable NCSE and ANSI/ANS-8.21-1995. These requirements are: representative sampling of the neutron absorber, sampling at a frequency based on the environment to which the neutron absorber is exposed, analyzing of samples for all material attributes for which credit is taken in the NCSE, and periodic inspections of fixed neutron absorbers to ensure adequate distribution as specified in the NCSE.

A NCS evaluation can take credit for the neutron absorption properties of the materials (1) added specifically for the purpose of absorbing neutrons, and (2) of construction, provided an allowance has been made for manufacturing and dimensional tolerances, corrosion, chemical reactions, neutron spectra, and uncertainties in the neutron cross-sections.

5.4.5.2 Methods of Calculation

Experimental Data

Experimental data are not specific enough to allow evaluation of operations performed in the ACP. The generic nature of the experimental data does not address the variables present in the different operations. However, experimental data are used for validation of the computer code (e.g., KENO V.a) used to perform the calculations needed to support the development of NCSEs. The experimental data used are discussed in the code validation report (Reference 11).

Handbooks

Handbooks are also used in some cases when simple systems are being evaluated. Most of the operations performed in the ACP are too complicated to be adequately addressed by data in a handbook. When isolated operations are performed with small amounts of fissile material, referencing handbooks is useful to support conclusions in the NCSE. Examples of the handbooks used include, but are not limited to, ARH-600, *Criticality Handbook* and LA-10860-MS, *Critical Dimensions of Systems Containing* ^{235}U, ^{239}Pu, *and* ^{233}U.

Hand Calculations

Applicable methods for evaluating single units include Modified Two Group Diffusion Equation (i.e., Critical Equation), Buckling Conversion, and Comparative Analysis.

- **Modified Two Group Diffusion Equation** – This method is applicable to, and most widely used for, solution systems.

- **Buckling Conversion –** The method of buckling conversion or shape conversion is applicable to all materials.

- **Comparative Analysis –** This method involves direct comparison of the system configurations to subcritical data from NCS handbooks.

Applicable methods for evaluating arrays include the Solid Angle Method and the Surface Density Method using unit shape factor.

- **Solid Angle Method –** This method is applicable to solution systems. It is not useful if reflection is more effective than a thick water reflector located at the array boundary. The conditions that must be satisfied in order to successfully apply the solid angle method are (1) $k_{effective}$ (k_{eff}) of any unreflected unit does not exceed 0.80; (2) each unit is subcritical when completely reflected by water; (3) the minimum surface-to-surface separation between units is 0.3 meters; and (4) the allowed solid angle does not exceed 6 steradians.

- **Surface Density Method** using unit shape factor – This method can be used as an approximation for large arrays of identical units containing solutions and metals. This method determines the spacing and mass of units independent of the number of units. An important feature of the Surface Density Method is that it is equally applicable to more irregular geometries.

Computer Calculations

For those cases where adequate references are not available, NCS computational analyses are performed, which involve the calculation of k_{eff} to determine whether the system will be subcritical under both normal and credible abnormal process conditions. Computer codes that simulate the behavior of neutrons in a process system or that solve the Boltzmann transport equation are used.

Computer calculations of k_{eff} provide a method to relate analytical models of specific system configurations to experimental data derived from critical experiments. A critical experiment is defined as a system that is intentionally constructed to achieve a self-sustaining neutron chain reaction or criticality. Critical experiments that have specific, well-defined parametric values and are adequately documented are termed benchmark experiments. Computer codes are validated using experimental data from benchmark experiments that, ideally, have geometries and material compositions similar to the systems being modeled.

Validation of the computer code determines its calculational bias or uncertainty as well as the

effective margin of subcriticality. The validation involves the modeling of benchmark critical experiments over a range of applicability. Because the k_{eff} value of a critical experiment is essentially 1, the bias of the code is taken to be the deviation of the calculated values of k_{eff} from unity. Statistical analysis is employed to estimate the calculational bias, which includes the uncertainty in the bias and uncertainties due to extensions of the area of applicability, as well as the effective margin of subcriticality. Uncertainty in the bias is a measure of both the precision of the calculations and the accuracy of the experimental data. The validation of the computer code specifically defines the maximum acceptable k_{eff} used to determine subcriticality.

The margin of subcriticality used for the plant results in a k_{eff} upper safety limit that ensures that there is a 95 percent confidence that 99.9 percent of future k_{eff} values less than this limit will be subcritical. The minimum margin of subcriticality of 0.02 in k_{eff} is used to establish the acceptance criteria (i.e., upper safety limit) for criticality calculations. The upper safety limit varies with the computer system, codes, cross sections, and materials used in the validation.

The calculation of k_{eff} is accomplished by the use of computer codes that utilize Monte Carlo techniques to determine k_{eff} of a system. Computer models representing the geometrical configuration and material compositions of the system are developed for use within the code. The development of appropriate models must account for or conservatively bound both normal and credible abnormal process conditions.

When NCS is based on computer code calculations of k_{eff}, controls and limits are established to ensure that the maximum k_{eff} complies with the applicable code validation for the type of system being evaluated. For example, NCS related IROFS developed during initial license application were developed using reactivity calculations performed on personal computers running the Microsoft Windows XP operating system and validated as described in Reference 11 with an upper safety limit of 0.955. Reactivity calculations, performed after initial license application, comply with the code validation for the specific system used to perform the calculation.

Scoping and analysis calculations may be performed utilizing various unvalidated computer codes; however, computer calculations of k_{eff} used as the basis for NCS evaluations are confirmed by, or performed using, configuration-controlled codes and cross-section libraries for which documented validations are performed with at least the same degree of conservatism as that presented in the validation report WSMS-CRT-03-0093, Revision 0, November 2003, and are in accordance with ANSI/ANS-8.1-1998.

The computer codes and cross sections used in performing k_{eff} calculations are maintained in accordance with a configuration control plan. Changes to the hardware or software are evaluated in accordance with 10 CFR 70.72 change requirements. The System Administrator, a NCS engineer, is responsible for controlling access to the software.

5.5 References

1. ANSI/ANS-8.1-1998, *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors*

2. ANSI/ANS-8.3-1997, *Criticality Accident Alarm System*

3. ANSI/ANS-8.19-1996, *Administrative Practices for Nuclear Criticality Safety*

4. ANSI/ANS-8.21-1995, *Use of Fixed Neutron Absorbers in Nuclear Facilities Outside Reactors*

5. ARH-600, *Criticality Handbook*, Volumes I, II, and III, Atlantic Richfield Hanford Co. report (1968)

6. LA-3605-0003, Integrated Safety Analysis Summary for the American Centrifuge Plant

7. LA-10860-MS, *Criticality Dimensions of Systems Containing* ^{235}U, ^{239}Pu, *and* ^{233}U, 1986 Revision

8. NRC Regulatory Guide 3.71, Revision 0, *Nuclear Criticality Safety Standards for Fuels and Material Facilities*

9. NUREG-1513, *Integrated Safety Analysis Guidance Document*

10. NUREG-1520, *Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility*

11. WSMS-CRT-03-0093, United States Enrichment Corporation (USEC) PC-SCALE 4.4a Validation (U), Revision 0, November 2003

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