GLOBAL
Laser Enrichment

Julie Olivier
GLE Licensing Manager
P. O. Box 780 – M/C H-10
Wilmington, NC 28402 USA
T 910-819-4799
M 910-547-1659
Julie.Olivier@ge.com

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Attn: Document Control Desk
Brian Smith, Chief
Uranium Enrichment Branch
Fuel Facility Licensing Directorate
Division of Fuel Cycle Safety & Safeguards
Office of Nuclear Materials Safety & Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555-0001

Subject: **REVISION 6 TO GLOBAL LASER ENRICHMENT LICENSE APPLICATION – PUBLIC VERSION**

Dear Mr. Smith:

GE-Hitachi Global Laser Enrichment LLC (GLE) hereby submits revision 6 of the GLE License Application, Chapter 5 (Enclosure 1). A non-public version of the revised License Application has been prepared and will be submitted under separate enclosure.

If there are any questions regarding this letter and its contents, please do not hesitate to contact me at 910-819-4799 or at Julie.Olivier@ge.com.

Sincerely,

Julie A. Olivier

Julie Olivier
GLE Licensing Manager

NMSS01

Enclosures:

1. Revision 6 of the GLE License Application

Cc (without enclosures):

Tim Johnson (NRC)
Chris Monetta (GLE)
Jerry Head (GEH)
Ken Givens (GLE)
Lon Paulson (GEH)

CHAPTER 5
REVISION LOG

Rev.	Effective Date	Affected Pages	Revision Description
0	04/30/2009	ALL	Initial Application Submittal.
1	03/31/2010	7, 11-14, 18-20, 24, 27, 28, 31	Incorporate RAI responses submitted to the NRC via MFN-09-577 dated 09/04/2009 and MFN-09-801 dated 12/28/2009.
2	06/25/2010	19, 25, 26	Section 5.4.1.3.2 revised to include nonparametric method for determination of bias uncertainty, Section 5.4.4.5 revised to remove reference to MRA
3	12/17/2010	25	Section 5.4.4.5 revised to clarify terminology
4	03/10/2011	5, 12, 17, 20, 23, 24	Added applicable revision number to ANS 8.1 reference. Section 5.3.5 revised to clarify how the CAAS is maintained and to provide more detail with regard to the scope and timing of compensatory measures upon loss of CAAS coverage. Replaced "MMS" with MoS".
5	08/01/2011	12, 13, 17, 24, 27, 31	Added detail regarding likelihood of cylinder damage due to forklift breach followed by rain accumulation. Changed "activities with the potential to result in inadvertent nuclear criticality" to "fissile materials operations". Replaced minimum margin of subcriticality (MMS) with margin of subcriticality (MoS) throughout chapter to align with supporting validation report terminology and ANSI/ANS-8.24 (2007) national consensus standard guidance. Revised Section 5.4.4.2 to add clarity about crediting neutron absorbers. Revised Section 5.4.4.8 to add clarity about crediting neutron absorbers. Updated revision of reference 5-12.
6	11/11/11	13, 21, 25	Revised Section 5.3.5 to clarify the criteria used to determine if greater than 4 hours of loss of CAAS coverage is necessary. Revised Section 5.4.1.3.4 to clarify the minimum MoS that will be used.

Rev.	Effective Date	Affected Pages	Revision Description
			Revised Section 5.4.4.2 to add clarifying descriptor.

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FIGURES

NONE

5. NUCLEAR CRITICALITY SAFETY

5.1 MANAGEMENT OF THE NUCLEAR CRITICALITY SAFETY PROGRAM

5.1.1 Nuclear Criticality Safety Design Philosophy

In accordance with baseline design criterion (9) contained in 10 CFR 70.64(a), *Requirements for New Facilities or New Processes at Existing Facilities (Ref. 5-1)*, the design of fissile material processes must "provide for criticality control including adherence to the double contingency principle." The double contingency principle, as identified in American National Standard Institute (ANSI)/American Nuclear Society (ANS) 8.1-1998 (R2007), *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors (Ref. 5-2)*, is the fundamental technical basis for design and operation of fissile material processes within the GE-Hitachi Global Laser Enrichment LLC (GLE) Commercial Facility. As such, process designs shall incorporate sufficient margins of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible. As used in the double contingency principle, the term "concurrent" means: if the effect of the first process change persists until a second change occurs, an inadvertent nuclear criticality could result. It does not mean the two initiating events must occur simultaneously. The possibility of an inadvertent nuclear criticality can be markedly reduced if failures of nuclear criticality safety (NCS) controls are rapidly detected and processes rendered safe.

The established NCS design criteria and NCS reviews are applicable to: (1) new and existing processes, facilities, or equipment which process, store, transfer, or otherwise handle fissile materials; and (2) any change in existing processes, facilities, or equipment which may have an impact on the established basis for NCS. For fissile material operations, double contingency protection may be provided by either control of at least two independent parameters, or control of a single parameter using a system of multiple independent controls. The defense of one or more system parameters provided by at least two independent controls is documented in the GLE Criticality Safety Analyses (CSAs).

In accordance with the requirements contained in 10 CFR 70.61(d), *Performance Requirements (Ref. 5-3)*, "the risk of nuclear criticality accidents must be limited by assuring that under normal and credible abnormal conditions all nuclear processes are subcritical." The NCS Program evaluates each fissile material process to identify the normal and credible abnormal conditions, and establish the controls required to meet the double contingency design criteria. Use of the double contingency design criteria assures that all nuclear processes remain subcritical under credible conditions. As required in 10 CFR 70.62, *Safety Program and Integrated Safety Analysis (Ref. 5-4)*, the Integrated Safety Analysis (ISA) documents the credible accident sequences that could lead to an inadvertent nuclear criticality, and identifies the likelihood of occurrence for each potential accident sequence. For these credible accident sequences, the engineered and administrative NCS controls required to prevent an inadvertent nuclear criticality and meet the overall likelihood requirements specified in GLE LA Chapter 3, *Integrated Safety Analysis,* are designated as Items Relied on for Safety (IROFS). For each IROFS identified, appropriate management measures are applied to assure the control is available and reliable to perform its function when needed. The ISA methodology is described in GLE LA Chapter 3, and the ISA Summary.

5.1.2 Nuclear Criticality Safety Program Objectives

The NCS Program establishes and maintains NCS safety limits and operating limits for controlled parameters in nuclear processes. Qualified NCS personnel evaluate operations involving fissile material to determine the basis for safety of operation based on the assessment of both normal and credible abnormal conditions. Functional requirements for criticality safety controls are specified commensurate with the NCS design criteria, and management measures are applied to ensure the availability and reliability of the controls. The GLE NCS Program management commits to the following objectives:

- Develop, implement, and maintain an NCS Program that meets the regulatory requirements of 10 CFR 70, *Domestic Licensing of Special Nuclear Material (Ref. 5-5)*;
- Provide sufficient IROFS and defense-in-depth, and demonstrate an adequate margin of safety to prevent an inadvertent nuclear criticality in operations in which fissile material is present;
- Protect against the occurrence of accident sequences identified in the ISA Summary, which could result in an inadvertent nuclear criticality;
- Comply with NCS performance requirements in 10 CFR 70.61;
- Establish and maintain NCS controlled parameters and procedures;
- Establish and maintain NCS subcritical limits and operating limits for identified IROFS;
- Conduct NCS evaluations, herein referred to as CSAs, to assure under normal and credible abnormal conditions, fissile material processes remain subcritical and maintain an adequate margin of safety;
- Establish and maintain NCS postings, training, and emergency procedure training;
- Establish and maintain NCS IROFS, based on current NCS determinations;
- Adhere to NCS baseline design criteria requirements in 10 CFR 70.64(a), for new facilities and new processes at existing facilities requiring a license amendment under 10 CFR 70.72, *Facility Changes and Change Process (Ref. 5-6)*;
- Comply with NCS ISA Summary requirements in 10 CFR 70.65(b), *Additional Content of Applications (Ref. 5-7)*;
- Comply with NCS ISA Summary configuration management (CM) requirements in 10 CFR 70.72.

5.1.3 Evaluation of Nuclear Criticality Safety

As part of the design of new facilities, or significant additions or changes in existing facilities, the proposed design is reviewed and approved by the NCS function. Prior to operation of a new or modified facility/process, an evaluation is performed to demonstrate that the entire process will remain subcritical under both normal and credible abnormal conditions. When NCS considerations are impacted by a change, the NCS function recommends changes to the process parameter necessary to maintain safe operation of the facility, and specifies appropriate controls and management measures required for safety. The approval by the NCS function is required prior to operation of a new or modified facility/process. This NCS approval is documented in accordance with established practices and conforms to the CM Program described in GLE LA Section 11.1, *Configuration Management*.

GLE personnel initiate proposed changes to the facility (such as, design changes, changes to processes, operating and maintenance procedures, IROFS, and management measures) through use of a change request. Change requests are processed in accordance with approved written procedures. Change requests, which establish or involve a change in existing criticality safety parameters, require a Senior NCS Engineer to disposition the proposed change with respect to impacts to the safety basis and the need for a CSA. If a new analysis or a revision to an existing analysis is required, the change is not placed into operation until the CSA is complete and preoperational requirements specified by the NCS function are fulfilled. This assures that the documented safety basis is applicable to the current configuration of the facility.

The purpose of the CSA is to demonstrate compliance with 10 CFR 70.64(a)(9), the double contingency principle, through control of one or more parameters important to criticality safety. The parameters to be controlled and the controls on specified parameters are determined and evaluated in the CSA. The controls specified in the CSA may be passive engineered, active engineered, or administrative. Additional requirements for management measures such as postings, periodic inspections, and maintenance requirements are also specified in the CSA to assure the NCS controls are available and reliable. Application of the double contingency principle assures that the process will remain subcritical under normal and credible abnormal conditions.

5.2 ORGANIZATION AND ADMINISTRATION

5.2.1 General Organization and Administrative Methods

The GLE organizational structure and administrative practices have been established consistent with the guidance in ANSI/ANS 8.1-1998 and ANSI/ANS 8.19-2005, *Administrative Practice for Nuclear Criticality Safety (Ref. 5-8)*. Organizational positions, experience, and qualification requirements of personnel and functional responsibilities are described in GLE LA Chapter 2, *Organization and Administration*, which includes an outline of the organizational relationships. The GLE Operations Organization shall be provided adequate resources to ensure an effective NCS Program is implemented.

5.2.2 Nuclear Criticality Safety Organization

The NCS function is administratively independent of the Operations Organization and has the authority to shutdown potentially unsafe operations. The NCS function consists of an NCS Manager responsible for implementation of the NCS Program, and at least one Senior NCS Engineer to allow independent reviews of NCS evaluations. Specific details of the responsibilities and qualification requirements for the NCS Manager, Senior NCS Engineer, and NCS Engineer are described in GLE LA Chapter 2.

NCS personnel are trained in the interpretation of data pertinent to NCS and are familiar with the operation of the GLE Commercial Facility prior to being qualified as a member of the NCS function. Training and qualification of NCS personnel is described in Section 5.3.1, *Training and Qualification of the Nuclear Criticality Staff*.

5.2.3 Operating Procedures

Fissile material operations are performed in accordance with approved written operating procedures. If personnel encounter a condition not covered by the operating procedure, the individual is required to safely stop the operation and report the defective condition to the NCS function, either directly or through Operations management. The operation may not be restarted until the NCS function has evaluated the situation and the necessary procedure instructions are provided. Operations personnel are trained in this procedural compliance policy.

Procedures that govern the handling of enriched uranium are reviewed and approved by the NCS function. The Operations Organization is responsible for developing and maintaining operating procedures that incorporate limits and controls established by the NCS function. GLE management assures operators and other affected personnel review and understand these procedures through postings, training programs, and/or other written, electronic, or verbal notifications.

Documentation associated with the review and approval of operating procedures, and operator training or orientation is maintained within the CM Program and further described in GLE LA Chapter 11, *Management Measures*.

5.2.4 Postings and Labeling

NCS requirements defined by the NCS function are made available at workstations in the form of approved written or electronic operating procedures, and/or clear visible postings. Postings may include the placement of signs and/or marking on walls, floors, or process equipment to summarize key NCS requirements and limits, to designate approved work and storage areas, or to provide instructions or specific precautions to personnel. Information that may be displayed on postings include: limits on material types and forms, allowable quantities by weight or number, required spacing between units, critical control steps in the operation, and control limits (when applicable) on quantities such as moderation, density, or enrichment. Storage postings are located in conspicuous places and include, as appropriate: material type, container identification, number of items allowed, and mass, volume, moderation, and/or spacing limits. In addition, when administrative controls or specific actions/decisions by operators are involved, postings include pertinent requirements identified within the CSA.

Where practical, fissile material containers are labeled such that the material type, ^{235}U enrichment, and gross and/or net weight can be clearly identified or determined. Exceptions to this labeling process include the following:

- Large process vessels in which the content is continuously changing;
- Shipping containers which are labeled as required for shipment;
- Uranium hexafluoride (UF_6) cylinders containing heels in which the net weight is known but the exact fissile content is not quantified;
- Containers of one liter volume or less, or where labeling is not practical;
- In limited circumstances, where the exact enrichment of the material contained is not known (for example, equipment cleanout material or sludge removed from sumps); and
- Waste boxes/drums and contaminated items in which the exact fissile content is very small and not quantified.

Where labeling does not indicate the exact material type, enrichment, and gross and/or net weight, other methods are used to identify the presence of fissile material such as postings, procedures, and training.

5.3 NUCLEAR CRITICALITY SAFETY MANAGEMENT MEASURES

5.3.1 Training and Qualifications of the Nuclear Criticality Safety Staff

Training and qualification of NCS staff is conducted consistent with the guidance in ANSI/ANS 8.26-2007, *Criticality Safety Engineer Training and Qualification Program (Ref. 5-9)*. As such, GLE has established a formalized NCS Engineer Training and Qualification Program that is periodically reviewed and maintained by the qualified NCS engineers. This program includes on-the-job training (OJT), demonstration of proficiency, periodic required technical classes or seminars, and participation in offsite professional development activities.

The NCS Engineer Training and Qualification Program content emphasizes on-the-job experience to fully understand the processes, procedures, and personnel required to assure that NCS controls on identified NCS parameters are properly implemented and maintained.

5.3.2 Auditing, Assessing, and Upgrading the Nuclear Criticality Safety Program

NCS audits and assessments are performed consistent with the guidance in ANSI/ANS 8.19-2005. Details of the GLE NCS Audit and Assessment Program are described in GLE LA Section 11.5, *Audits and Assessments*.

NCS audits are conducted by approved NCS personnel and documented in accordance with approved written procedures. Findings, recommendations, and observations are reviewed with the GLE Environmental, Health, and Safety (EHS) Manager to determine if other safety impacts exist. NCS audit findings are transmitted to applicable line managers and area managers for appropriate action and are tracked to completion.

NCS professionals, independent of GLE NCS personnel, conduct periodic NCS Program reviews. The program review provides a means to independently assess the effectiveness of GLE NCS Program components. The audit team is composed of individuals recommended by the NCS Manager, and the team's audit qualifications are approved by the GLE Facility Manager or GLE EHS Manager. Audit results are reported in writing to the NCS Manager, who disseminates the report to line management. Results in the form of corrective action requests are tracked to completion.

5.3.3 Integrated Safety Analysis Summary Revisions and the Nuclear Criticality Safety Program

In accordance with ANSI/ANS 8.19-2005, the CSA is a collection of information that "provides sufficient detail, clarity, and lack of ambiguity to allow independent judgment of the results." The CSA documents the safety basis for the defined fissile process, establishes the subcritical limits on associated controlled parameters, and establishes controls on said parameters to satisfy the double contingency principle.

Documented CSAs are controlled elements of the ISA methodology described in GLE LA Chapter 3 and the ISA Summary. The CSA establishes the NCS bases for a particular system under normal and credible abnormal conditions. CSAs are prepared or updated for new or significantly modified fissile units, processes, or facilities within the GLE Commercial Facility in accordance with the established CM Program described in GLE LA Chapter 11. When a facility change requires a CSA to be re-evaluated or modified, the modifications are carefully evaluated for effects on the ISA Process Hazards Analysis (PHA) and ISA Summary. Likewise, when changes are made to the PHA or ISA Summary, the changes are evaluated for effects on the documented CSAs. Documentation of the ISA Team review and approval of changes made to the PHA or ISA Summary is maintained in accordance with the CM Program.

5.3.4 Modifications to Operating and Maintenance Procedures

Operating and maintenance procedures are maintained consistent with the guidance in ANSI/ANS 8.19-2005. The Operations Organization is responsible for developing and maintaining operating procedures that incorporate limits and controls established by the NCS function. GLE management assures that appropriate GLE personnel and contractors review and understand these procedures through processes such as postings, training programs, and/or other written, electronic, or verbal notifications.

Procedures that govern the operation and maintenance of equipment involved in fissile material processes are reviewed and approved by the NCS function. Based on the review, the NCS function verifies that the required limits and controls have been incorporated into the procedure. In addition, the NCS function assures no single, inadvertent departure from a procedure could cause an inadvertent nuclear criticality and recommends modifications to the procedures to reduce the likelihood of occurrence of an inadvertent nuclear criticality. Documentation of the procedure review and approval process is maintained as described in GLE LA Sections 11.1 and 11.4.

5.3.5 Nuclear Criticality Accident Alarm System

The Criticality Accident Alarm System (CAAS) is designed and maintained to ensure compliance with requirements in 10 CFR 70.24, *Criticality Accident Requirements (Ref. 5-10)*, and ANSI/ANS 8.3-1997, *Criticality Accident Alarm System (Ref. 5-11)* as modified by Regulatory Guide 3.71, *Nuclear Criticality Safety Standards for Fuels and Material Facilities (Ref. 5-12)*. An evaluation that demonstrates compliance with the CAAS requirements of 10 CFR 70.24 is documented and maintained under CM. The location and spacing of the detectors are selected taking into account shielding by massive equipment or materials. Spacing between detectors is reduced where high-density building materials such as brick, concrete, or grout-filled cinder block shield a potential accident area from the detector. Low-density materials of construction, such as wooden stud construction walls, plaster, or metal corrugated panels, doors, non-load walls, and steel office partitions, are accounted for with conservative modeling approximations in determining detector placement.

The CAAS initiates immediate evacuation of the facility to ensure radiation exposure to workers is minimized. Employees are trained to recognize the evacuation signal and to evacuate promptly to a designated safe location. This system and proper response protocol is described in the GLE Radiological Contingency and Emergency Plan (RC&EP). Emergency response planning, procedures, and training to address an inadvertent criticality are consistent with the guidance in ANSI/ANS 8.23-1997, *Nuclear Criticality Accident Emergency Planning and Response (Ref. 5-13)*.

GLE commits to having a CAAS that:

- Has components that are located or protected to minimize damage in case of fire, explosion, corrosive atmosphere, or other credible extreme conditions;
- Is designed to minimize the potential failure, including false alarms, due to human error and has major system components labeled;
- Is designed to remain operational in the event of seismic shock equivalent to the requirements of the International Building Code;
- Is uniform throughout the facility for the type of radiation detected, mode of detection, alarm signal, and system dependability;
- Provides coverage in each area that needs CAAS coverage by a minimum of two detectors; and
- Is clearly audible in areas that must be evacuated, or provides alternate visual notification methods documented to be effective in notifying personnel of a necessary evacuation.

The CAAS is maintained through routine response checks, scheduled functional tests, and periodic instrument calibrations conducted in accordance with approved written procedures. In the event of loss of normal power, emergency power is automatically supplied to the CAAS. In the event that CAAS coverage is lost and not restored to an area, affected operations are promptly rendered safe. In this context, promptly means that the actions are initiated within one hour and completed consistent with the evaluations associated with the activity and completion times. The situation is initially rendered safe by shifting modes to the Standby Mode in the affected area or by suspension of fissile material operations within four hours, unless longer time periods have been determined and justified in advance. The criteria for determining whether greater than four hours is necessary is physical inability to perform a safe, controlled shutdown in 4 hours; or shutting down affected processes sooner would incur safety risks. Continuing protection for the duration of the CAAS coverage loss is accomplished by implementing compensatory measures (e.g., self-alarming dosimetry, personnel access restriction to affected area, etc.) or by restoring equivalent coverage with a portable CAAS unit(s) for continued operation in any mode. Selection of compensatory measures is to be consistent with the extent and cause of the outage. In the Standby Mode, fissile material process systems are idled (no significant movement or enrichment of process gas) and manual movement, handling, or processing of fissile materials outside of process systems is secured.

5.3.5.1 CAAS Exemption Basis

10 CFR 70.24 requires that licensees authorized to possess SNM in a quantity exceeding 700 g of contained ^{235}U shall maintain, in each area in which such licensed SNM is handled, used, or stored, a monitoring system capable of detecting a criticality that produces an absorbed dose in soft tissue of 20 rads of combined neutron and gamma radiation at an unshielded distance of two meters from the reacting material within one minute.

10 CFR 70.17, *Specific Exemptions (Ref. 5-14),* allows the U.S. Nuclear Regulatory Commission (NRC), upon application of any interested person or upon its own initiative, to grant such exemptions from the requirements of the regulations in this part as it determines are authorized by law and will not endanger life or property or the common defense and security and are otherwise in the public interest. The requested exemption is authorized by law because there is no statutory provision prohibiting the grant of the exemption. The requested exemption will not endanger life or property or the common defense and security and is otherwise in the public interest for the reasons discussed below. Exemption from CAAS coverage is requested for each of the following locations based on the discussion presented.

5.3.5.1.1 UF_6 Cylinder Storage Pads

The Tails and In-Process Pads are used for storage of source material only (not SNM) and therefore would not require CAAS coverage according to the regulations. Although a potential exists for storing UF_6 cylinders containing SNM on these pads (a wrong cylinder event), the 30B and 48GLE model cylinders are sufficiently different due to size, in the case of the 30B, and in color, in the case of the 48GLE, that such upsets will be immediately identifiable and correctable. Controls exist prior to material being stored on the cylinder pads to prevent such a mishap. 30B model cylinders are stored on the product pad and contain 5 wt% ^{235}U, or less, enriched material. 48GLE model cylinders are stored under CAAS coverage in the Cylinder Shipping and Receiving Area. Transport, handling, and storage of the 30B model cylinder, only involves solid UF_6 and is doubly contingent based on the robust nature of the container, routine certification of the cylinders, and on post-handling inspections that verify the integrity of the cylinder.

- UF_6 cylinder vessel is engineered to be "leak-tight" containers that prevent moderating materials from entering the cylinder. The packaging shall consist of bare metal cylinders (no protective overpacks required), which are designed, fabricated, inspected and marked in accordance with ANSI N14.1, *Nuclear Materials – Uranium Hexafluoride – Packaging for Transport (Ref. 5-15),* standard in effect at the time of manufacture.
- Cylinder integrity is verified through routine operational and periodic inspections and testing pursuant to ANSI N14.1 standard in effect at the time of action.
- To prevent cylinder breach (loss of cylinder integrity), only approved overhead crane rigging, forklift, or transport carrier is used for handling UF_6 cylinders in accordance with approved procedures and authorized trained personnel. The overall likelihood of damage to a cylinder on the pad due to a forklift impact with subsequent rain accumulation to the point which a criticality occurs has been determined to be highly unlikely (e.g., $\leq 10^{-5}$ per year).

- The robust design of the 30B model cylinders are established as defense-in-depth criticality safety controls to ensure the health and safety of the public and workers and are maintained by the GLE Quality Program to applicable ANSI standards.

Evaluation of historical data associated with 30B model cylinder handling also concludes that the cylinders have not been damaged as frequently as 48-inch cylinders of any make (due in part because fewer 30B model cylinders are handled, 30B model cylinders are stacked only one-high, 30B model cylinders have a shorter storage period, and 30B model cylinders are smaller and lighter than 48-inch cylinders). Further, most 48-inch cylinder failures have been small and healed with uranium tetrafluoride (UF_4), hydrated uranyl fluoride (UO_2F_2- x H_2O), and corrosion product "patches" that significantly slowed further intrusion from water (liquid or vapor) *(Ref. 5-16)*.

Due to the high turn-around rate of 30B model cylinders in use, failure to identify corrosion type cylinder wall failures is judged highly unlikely. Evaluation of puncture events to these cylinders have concluded that under maximum rainfall rates for the region, the time to accumulate enough water in a 30B model cylinder to support criticality ranges from 2 to 8 days for very conservatively postulated 12- to 6-inch diameter holes that are difficult to miss during post-handling inspections. Further, these evaluations were conservatively based on an enrichment of 8 wt% ^{235}U and not the approved 5 wt% ^{235}U, or less, approved for 30B model cylinders stored on the Product Pad.

Administrative controls require damage to be remediated within eight hours of identification of the post-handling inspection. Lastly, the Product Pad is not a continuously occupied area. Personnel enter the area only to move 30B cylinders to and from the pad and to inspect cylinders and the cylinder yards to satisfy the requirements for various programs (Material Control and Accounting [MC&A], Quality Assurance [QA], and Fire Protection [FP]).

5.3.5.1.2 Trailer Storage Area

UF_6 cylinders temporarily stored in this area are packaged according to U.S. Department of Transportation (DOT) requirements in over-packs (for SNM containing 30B cylinders) and, as such, have undergone substantial evaluation to evaluate the accidental criticality hazard and assure that the packaging system provides conservative protection against accidental criticality to preclude the need for CAAS in transit.

5.3.5.1.3 UF_6 Cylinder Staging Area

UF_6 cylinders handled in this area are in the process of being packaged in an over-pack (for SNM containing 30B cylinders). The cylinders are either in the DOT packaged state or continuously monitored until the packaging is complete or the cylinder is removed to the Cylinder Shipping and Receiving Area (a CAAS covered area). Any mishaps that occur are immediately identified by the DOT packaging inspection process and corrective actions taken to remediate any hazard identified. Packaging activities are not performed in this area during rain (this requirement is driven by the need to perform radiological surveys on "dry" surfaces of the cylinders, shipping packages, and truck) where moderation control failure can occur during a cylinder mishap. Once packaged according to DOT requirements in an approved over-pack, the staging area is a location for temporary storage until the trailer is moved to Over Road Truck Trailer Storage Area for shipment.

In addition to the above features for safe storage of the cylinders to preclude accidental criticality, the increased vehicular and pedestrian traffic in support of CAAS maintenance and calibration requirements in these areas would cause a subsequent increased likelihood for impact events involving cylinders. CAAS detection clusters are required to be mounted high over the storage areas and the calibration and maintenance activity causes additional vehicular traffic in the area and introduces new drop hazards (bucket truck or man-lift collapse) that do not otherwise exist. This equipment and traffic increases the likelihood for fire and impact events on the UF6 Cylinder Pads and this places workers at a higher risk for injury and exposure relative to the mitigative value provided by the activation of the CAAS.

5.3.6 Corrective Action Program

A regulatory compliance tracking system is used to track planned corrective or preventive actions in regard to procedural, operational, regulatory, or safety-related deficiencies. NCS Program management assures that unacceptable performance deficiencies, which could result in an inadvertent nuclear criticality, are addressed using the Corrective Action Program. The Corrective Action Program is described in GLE LA Section 11.6, *Incident Investigations*.

5.3.7 Nuclear Criticality Safety Records Retention

Records of CSAs are maintained in sufficient detail and form to permit independent review and audit of the calculation method and results. Such records are retained during the conduct of activities and in accordance with approved written procedures following cessation of such activities. Records of employee nuclear safety training and NCS related documents under configuration control are maintained as described in GLE LA Section 11.7, *Records Management*.

5.4 NUCLEAR CRITICALITY SAFETY METHODOLOGIES AND TECHNICAL PRACTICES

5.4.1 Nuclear Criticality Safety Analysis Methods

5.4.1.1 K_{eff} Limits

Validated analytical methods may be used to evaluate individual process operations or potential system interaction. When analytical methods are used, the effective neutron multiplication factor (k_{eff}) of the system, plus three times the standard deviation of the analytical method, must be less than or equal to the established upper subcritical limit (USL) for both normal and credible process upset (accident) conditions; that is:

$$k_{eff} + 3\sigma \leq USL$$

Normal operating conditions assume the optimum credible conditions (that is, most reactive) expected to be encountered when the criticality control systems function properly. Credible process upsets assume optimum credible conditions anticipated for each off-normal or credible accident condition, and must be demonstrated critically safe in accordance with Section 5.1.1, *Nuclear Criticality Safety Design Philosophy*. The NCS function derives safety limits and operating limits by using these criteria to ensure processes remain subcritical under both normal and credible abnormal conditions. Safety and operating limits are established with sufficient margin of safety taking into consideration variability and uncertainty in process parameters under control to protect against a limit being accidentally exceeded. The sensitivity of key controlled parameters are evaluated with respect to the effect on k_{eff} for each system to assure adequate criticality safety controls are defined for the analyzed system. These studies are performed to correlate the change in k_{eff} that occurs as a result of a change to a controlled parameter.

5.4.1.2 Analytical Methods

Methodologies currently employed by the NCS function include hand calculations utilizing published experimental data (such as, ARH-600, Criticality Handbook [*Ref. 5-17]*), and Monte Carlo codes (specifically, Geometry Enhanced Merit [GEMER]) that utilize stochastic methods to approximate a solution to the three-dimensional neutron transport equation. Additional Monte Carlo code packages (such as, SCALE, MCNP) or S_n Discrete Ordinates codes (such as, ANISN, DORT, TORT, or the DANTSYS code package) may be used after validation has been performed as described in Section 5.4.1.3, *Validation Techniques*, and Section 5.4.1.4, *Validation Reports*.

The primary analytical method used for GLE criticality calculations is the GEMER Monte Carlo Program. GEMER is a multi-group Monte Carlo Program that approximates a solution to the neutron transport equation in three-dimensional space. The GEMER Criticality Program is based on 190-energy group structure to represent the neutron energy spectrum. In addition, GEMER treats resolved resonances explicitly by tracking the neutron energy and solving the single-level Breit-Wigner Equation at each collision in the resolved resonance range in regions containing materials whose resolved resonances are explicitly represented. The cross-section treatment in GEMER is especially important for heterogeneous systems since the multi-group treatment does not accurately account for resonance self-shielding.

5.4.1.3 *Validation Techniques*

The validity of the calculational method (computer code and nuclear cross-section data) used for the evaluation of NCS must be demonstrated and documented in validation reports according to approved written procedures. The validation of the computer code must determine its calculational bias, bias uncertainty, and the margin of subcriticality (MoS) using well-characterized and adequately documented critical experiments. The following definitions apply to the documented validation report(s):

<u>Bias</u> – The systematic difference between calculated results and experimentally measured values of k_{eff} for a fissile system.

<u>Bias Uncertainty</u> – The integrated uncertainty in experimental data, calculational methods, and models estimated by a valid statistical analysis of calculated k_{eff} values for critical experiments.

<u>Margin of Subcriticality (MoS)</u> – An allowance for any unknown (or difficult to identify or quantify) errors or uncertainties in the method of calculating k_{eff}, that may exist beyond those which have been accounted for explicitly in calculating bias and bias uncertainty.

GLE validation methodologies are consistent with the guidance in ANSI/ANS 8.1-1998 and ANSI/ANS 8.24-2007, *Validation of Neutron Transport Methods for Nuclear Criticality Safety Calculations (Ref. 5-18)*. In accordance with the requirements of these national consensus standards, the GLE criteria to establish subcriticality requires the calculated k_{eff} to be less than or equal to an established USL, as presented in the validation report, for a system or process to be considered subcritical. The validation of the calculational method and cross-sections considers a diverse set of parameters that include, but are not limited to:

- Fuel enrichment, composition, and form of associated uranium materials,
- Homogeneity or heterogeneity of the system,
- Presence of neutron absorbing materials,
- Characterization of the neutron energy spectra,
- Types of neutron moderating materials,
- Types of neutron reflecting materials,
- Degree of neutron moderation in the system (such as, H/fissile atom ratio), and
- Geometry configuration of the system (such as, shape, size, spacing, reflector).

Within the validation, various areas of applicability are established based on parameters having a significant effect on the calculation of k_{eff}, bias, and bias uncertainty. The areas of applicability are established by grouping experiments with common parameters of importance to determine bias and bias uncertainty. Parameters with a significant effect on the calculation include: (1) neutron energy spectrum; (2) neutron absorbing materials; and (3) heterogeneity (for low-enriched uranium [LEU] systems). Based on these known parameters of importance, a typical grouping of areas of applicability for a validation may be as follows:

- Homogeneous LEU systems (thermal spectrum),
- Heterogeneous LEU systems (thermal spectrum),
- Common absorber systems (such as, boron, cadmium, gadolinium).

In performing CSA, the appropriate area of applicability shall be applied based on a comparison of parameters being evaluated to parameters covered by the area of applicability. For GLE Commercial Facility Operations, the most common area of applicability is homogeneous LEU systems based on the fact that materials evaluated are typically: (1) homogeneous (uranium hexafluoride and uranyl fluoride); (2) low-enriched ($\leq$ 10 wt% ^{235}U); and (3) slightly to optimally moderated (thermal spectrum). When applying the validation outside an area of applicability, justification must be provided in the CSA. The selection of critical experiments, for each identified area of applicability of the NCS computer code validation, incorporates the following considerations:

- Experimental data for validation is assessed for completeness, accuracy, and applicability to operations prior to selection and use as a critical benchmark.
- Selection of experiments must encompass appropriate parameters spanning the range of normal and credible abnormal conditions that are anticipated to be evaluated using the calculational method.
- To minimize systematic error, benchmark data selected for validation are drawn from multiple, independent series, and sources of critical experiments. The range of parameters characterized by selected critical experiments is used to define the area of applicability for the code.
- The calculational method used to analyze the set of critical benchmarks incorporates the same analytic techniques used to analyze systems or processes to which the validation is applied.
- Data outliers in results obtained for the critical experiments selected for the validation may only be rejected based upon inconsistency of the data with known physical behavior.

The calculational bias, bias uncertainty, and USL over each defined area of applicability are determined by statistical methods as described in the following sections.

5.4.1.3.1 Calculational Bias

The bias is determined either as a constant, if no trends exist, or as a smooth and well-behaved function of a selected characteristic parameter (for example, hydrogen-to-fissile ratio) by regression analysis. Regression analysis may be used when trends exist with parameters statistically significant over the area of applicability.

Bias is determined from the calculated benchmark k_{eff} data, which are weighted using the overall uncertainty of each calculated data point. The overall uncertainty accounts for calculation uncertainty and benchmark uncertainty. Bias is applied over its negative range and assigned a value of zero over its positive range.

5.4.1.3.2 Bias Uncertainty

The bias uncertainty may be estimated using one of the following statistical methods. The details of each statistical method are documented in the validation report.

Single-Sided Lower Confidence Band (SSLCB): Estimates bias uncertainty to ensure, at a 95% level of confidence, a future calculation of k_{eff} for a critical system or process is actually above the lower confidence limit. The SSLCB may be used when there is a clear trend in the calculated critical benchmark results.

Single-Sided Lower Tolerance Band (SSLTB): Estimates the bias uncertainty to ensure, at a 95% level of confidence, at least 95% of future calculations of k_{eff} for critical systems or processes are actually above the lower tolerance limit. The SSLTB may be used when there is a clear trend in the calculated critical benchmark results.

Single-Sided Lower Tolerance Limit (SSLTL): Estimates the bias uncertainty to ensure, at a 95% level of confidence, at least 95% of future calculations of k_{eff} for critical systems or processes are actually above the lower tolerance limit. The SSLTL is used when there are no trends apparent in the calculated critical benchmark results.

Non-Parametric Method: Estimates the bias uncertainty to ensure, at a 95% level of confidence, that future calculations of k_{eff} for critical systems or processes are actually above the lower tolerance limit. This statistical technique is based on a rank order analysis of the data. When the sample size is insufficient to obtain a 95% confidence level using the statistical method, additional non-parametric margin is applied to assure the desired degree of confidence is achieved. The non-parametric technique is applied in cases where the calculated critical benchmark results (non-trending data) or the residuals of bias regression (trending data) fail the normality test.

5.4.1.3.3 Data Normality

Where no trends to a characteristic parameter exist (SSLTL), the normality of calculated k_{eff} values for the set of critical experiments must be verified prior to estimation of bias and bias uncertainty. Where trends to a characteristic parameter do exist (SSLCB and SSLTB), normality of the regression analysis residuals must be verified prior to estimation of the bias and bias uncertainty.

5.4.1.3.4 *Upper Subcritical Limit (USL)*

The USL is established based on calculated bias, bias uncertainty, and MoS for the area of applicability as follows:

$$USL = 1 + bias - bias\ uncertainty - MoS$$

At GLE, a minimum *MoS* = 0.03 is used to establish acceptance criteria for criticality calculations, which compared to the uncertainty in calculated k_{eff} values, is large. A larger MoS shall be used in cases where the bias and associated bias uncertainty exceeds 0.03.

The following acceptance criteria, considering worst-case credible accident conditions, must be satisfied, when using k_{eff} calculations by Monte Carlo methods, to establish subcritical limits for the GLE Commercial Facility:

$$k_{eff} + 3\sigma \leq USL$$

where σ is the standard deviation of the k_{eff} value obtained from the calculational method.

5.4.1.4 *Validation Reports*

Validation reports are documented, reviewed, and approved for each analytical method used to derive NCS limits. Validation reports are created, revised, reviewed, and approved by the NCS function and are controlled under the CM Program. The following requirements apply to Validation reports documented by the NCS function:

- Describe the NCS analytical method to which the validation applies.
- Clearly describe the theory of the validation methodology in sufficient detail to allow understanding of the methodology and independent duplication of results.
- Describe the mathematical and statistical operations used in the validation methodology to determine bias and bias uncertainty, including statistical testing performed to verify the acceptability of results.
- Provide a description or summary of the benchmark experiments or critical experiments selected for the validation, which indicate experiment characteristics important to the area of applicability and a reference to reliable experimental data.
- Identify the bias, uncertainty in the bias, uncertainty in calculated data, uncertainty in the benchmark experiments, and margin of subcriticality. If the derived bias is positive, it must be assigned a value of zero.
- Summarize the range in (or values of) NCS parameters describing the area of applicability. The area of applicability should be consistent with the values of parameters used in selected benchmark experiments. Any extrapolation beyond the area of applicability should be supported by an established mathematical methodology or sound engineering judgment. The mathematical method used to determine the acceptable extrapolation limit for a regression model is the leverage statistic. The leverage statistic

is a measure of the distance between the extrapolation point for a predication and the mean of trending parameter values in the critical benchmark data set. For a predication by extrapolation to be considered reliable with the predefined confidence level, its leverage value should not exceed the largest leverage value in the benchmark data set.

- Provide a description of the analytical method verification process and assurance that only verified software and hardware are used in the validation process.

5.4.1.5 Computer Software and Hardware Configuration Control

The software and hardware used within the criticality safety calculational system is configured and controlled in accordance with CM approved written procedures. Software changes are conducted in accordance with CM Program described in GLE LA Section 11.1.

Software, designated for use in NCS, are compiled into working code versions with executable files traceable by length, time, date, and version. Working code versions of compiled software are validated against critical experiments using an established methodology with differences in experiment and analytical methods being used to calculate bias and uncertainty values to be applied to the calculational results.

Each individual workstation is verified to produce results equivalent to the development workstation prior to use of the software for criticality safety calculation demonstrations on the production workstation. The verification results are documented for each individual workstation. Modifications to software and nuclear data affecting the calculational logic require re-validation of the software. Modifications to hardware or software that do not affect calculational logic are followed by code operability verification; in which case, selected calculations are performed to verify equivalent results from previous verifications. Deviations noted in code verification that may alter the bias or uncertainty requires re-qualification of the code prior to release for production use.

5.4.2 Control Practices

CSAs identify specific independent controls necessary to provide safe double contingent protection of a process. As discussed in Section 5.1.1, controls identified in the CSA are selected to assure no single credible event or failure can result in a criticality accident. As such, it is demonstrated that the process will remain subcritical under both normal and credible abnormal conditions. Prior to use in any enriched uranium process, NCS controls are verified against CSA criteria. The ISA methodology described in GLE LA Chapter 3 implements performance based management of process requirements and specifications important to NCS.

5.4.2.1 Verification and Maintenance of Controls

Reliable methods and instruments are used when NCS parameters are controlled by measurement. To assure continued reliability, required periodic verification and maintenance of controls are performed as described in GLE LA Section 11.2, *Maintenance*. The purpose of the verification program is to ensure the controls selected and installed fulfill the requirements identified in the CSA.

Processes are examined in the "as-built" condition to validate safety design and to verify the installation conforms to control specifications identified in the CSA. NCS personnel observe or monitor the performance of initial functional tests, and conduct preoperational audits to verify the controls function as intended, and the installed configuration agrees with the control specifications identified in the CSA. Operations personnel are responsible for subsequent verification of controls through the use of periodic functional testing or verification. When necessary, control calibration and routine maintenance are normally provided by the Instrument and Calibration and/or Maintenance functions. The purpose of the Maintenance Program is to ensure that the effectiveness of NCS controls designated for a specific process are maintained at the original level of intent and functionality. This requires a combination of routine maintenance, functional testing, and verification of design specifications on a periodic basis.

Verification and maintenance activities are performed per established practices documented through the use of forms and/or computer tracking systems. NCS personnel randomly review control verifications and maintenance activities to assure controls remain effective. Details of the Maintenance Program are described in GLE LA Section 11.2.

5.4.2.2 Consideration of Material Composition (Heterogeneity)

The CSA for each process determines the effects of material composition (for example, type, chemical form, physical form) within the process being analyzed, and identifies the basis for selection of compositions used in subsequent system modeling activities. In considering material composition, it is especially important to distinguish between homogeneous and heterogeneous system conditions. Heterogeneous effects are particularly relevant for LEU processes where all other parameters being equal; heterogeneous systems are typically more reactive than homogeneous systems. Systems involving uranium hexafluoride and uranyl fluoride are typically homogeneous; however, solid forms of uranium oxides may be heterogeneous. Evaluation of systems where the particle size varies must take into consideration effects of heterogeneity, as appropriate, for the process being analyzed.

5.4.3 Means of Control

The relative effectiveness and reliability of controls are considered during the CSA process. Passive engineered controls are preferred over other system controls and are utilized when practical and appropriate. Active engineered controls are the next preferred method of control. Administrative controls are the least preferred; however, augmented administrative controls are preferred over simple administrative controls. A criticality safety control must be capable of preventing a criticality accident independent of operation or failure of any other criticality control for a given credible initiating event.

5.4.3.1 Passive Engineered Controls

A device using only fixed physical design features to maintain safe process conditions without any required human action. Assurance is maintained through specific periodic inspections or verification measurement(s), as appropriate.

5.4.3.2 Active Engineered Controls

A physical device using active instrumentation, electrical components, or moving parts to maintain safe process conditions without any required human action. Assurance is maintained through specific periodic functional testing, as appropriate. Active engineered controls are designed to be fail-safe (that is, failure of the control results in a safe condition).

5.4.3.3 Administrative Controls

Either an augmented administrative control or a simple administrative control as defined herein:

Augmented Administrative Control – A procedurally required or prevented human action, combined with a physical device, which alerts an operator when action is needed to maintain safe process conditions or otherwise adds substantial assurance of the required human performance.

Simple Administrative Control – A procedural human action prohibited or required to maintain safe process conditions.

Use of administrative controls is limited to situations where passive and active engineered controls are not practical. Administrative controls may be proactive (requiring action prior to proceeding) or reactive (proceeding unless action occurs). Proactive administrative controls are preferred. Assurance is maintained through periodic verification, audit, and training.

5.4.4 Control of Parameters

NCS is achieved by controlling one or more parameter(s) of a system within established subcritical limits. The CM Program may require NCS staff review of proposed new or modified processes, equipment, or facilities to ascertain impact on controlled parameters associated with the particular system. Assumptions relating to processes, equipment, or facility operations, including material composition, function, operation, and credible upset conditions, are justified and documented in the CSA and independently reviewed.

Identified below are specific controlled parameters, which include mass, geometry, enrichment, reflection, moderation, concentration, interaction, neutron absorption, and process characteristics that may be considered during the NCS review process.

5.4.4.1 Mass

Mass control may be used for NCS control alone or in combination with other control methods. Mass control may be utilized to limit the quantity of uranium within specific process operations or vessels and within storage, transportation, or disposal containers. Mass may be controlled by direct measurement (for example, use of certified scales) through the use of fixed geometric dimensions and the assumption of a conservative fissile material density, or by using analytical or non-destructive methods.

Establishment of mass limits involves consideration of enrichment, potential moderation, reflection, geometry, spacing, and material composition. The CSA considers normal operations and credible process upsets in determining actual mass limits for the system and for defining additional controls. When only administrative controls are used for mass-controlled systems, double batching is considered to ensure adequate safety margin.

Where mass is the only parameter being controlled, and double batching is considered credible, the mass of any single accumulation shall not exceed either: (1) a safe batch, which is defined to be 45 percent of the minimum critical mass; or (2) 50 percent of the safe mass limit derived using validated analytical methods and an approved MoS.

Where mass is one of two parameters being controlled, or where engineered controls prevent over batching, the mass of any single accumulations shall not exceed either: (1) 75 percent of the minimum critical mass; or (2) the safe mass limit derived using validated analytical methods and an approved MoS.

When experimental data from published handbooks are used for mass limits, the following assumptions are applicable to the minimum critical mass: (1) spherical geometry; (2) full water reflection; (3) optimal moderation content; and (4) maximum credible enrichment. In addition, the chemical and physical form specified in the handbook must be at consistent with, or more restrictive than, that which may be present in the actual system to which the limit will be applied.

5.4.4.2 Geometry

Geometry may be used for NCS control alone or in combination with other control methods. Favorable geometry is based on limiting dimensions of defined geometrical shapes to established subcritical limits. Full advantage may be taken of any nuclear characteristics of the process materials and equipment, consistent with ANSI/ANS 8.1 (Ref. 5-2) and other applicable license commitments. At the GLE Commercial Facility, favorable geometry is developed conservatively assuming full water or concrete equivalent reflection, optimal hydrogenous moderation, worst credible heterogeneity, and maximum credible enrichment. Examples of parameters used for engineered geometry controls include cylinder diameters, annulus inner and outer radii, slab thickness, and/or fixed volumes.

Subcritical limits for geometry controls may be derived using either validated analytical methods and an approved MoS or experimental data. Where experimental data are used, the margins of safety are 90 percent of the minimum critical cylinder diameter, 85 percent of the minimum critical slab thickness, and 75 percent of the minimum critical sphere volume.

Geometry control systems are analyzed and evaluated allowing for fabrication tolerances and dimensional changes that may likely occur through corrosion, wear, or mechanical distortion. Before beginning operations, dimensions and nuclear properties applicable to the geometry control are verified using appropriate instrumentation. The CM Program is used to maintain these applicable dimensions and/or nuclear properties within acceptable limits. Provisions are also made for periodic inspection, if credible conditions exist in which changes in the dimensions or nuclear properties of the equipment could occur, resulting in the inability to meet established NCS limits.

5.4.4.3 Enrichment

Enrichment control may be utilized to limit the weight percent ^{235}U within a process, vessel, or container, thus providing a method for NCS control. Enrichment controls may be used to segregate materials of different enrichment or to prevent material from being enriched above an NCS limit. Where enrichment is controlled, active engineered or administrative controls are required to measure or verify the enrichment, or to prevent the introduction of uranium at unacceptable enrichment levels within a defined subsystem. In cases where enrichment control is not utilized, the maximum credible enrichment for the particular process or subsystem is utilized in the CSA.

5.4.4.4 Reflection

Most systems are designed and operated with the assumption of 12-inch water or optimum reflection surrounding the system. In such cases, controls limiting reflection are not required since optimum reflection has been demonstrated safe. However, subject to approved controls limiting reflection, certain system designs may be analyzed, approved, and operated in situations where the analyzed reflection is less than optimum. In the CSA, the neutron reflection properties of the credible process environment are also considered. For example, reflectors more effective than water (such as, concrete) and adjacent structural materials are considered when appropriate.

5.4.4.5 Moderation

Moderation control may be used for NCS control alone or in combination with other control methods. Moderation controls are used to limit the amount of moderation present within fissile material. Where moderation is used as an NCS controlled parameter, moderation controls are implemented consistent with the guidance in ANSI/ANS 8.22-1997, *Nuclear Criticality Safety Based on Limiting and Controlling Moderators (Ref. 5-19)*. When moderation control is used, the area is posted as a Moderation Controlled Area (MCA) and specific moderation controls are delineated. Operations in MCAs must be demonstrated safe under normal and abnormal conditions such that the double contingency principle is satisfied.

In evaluating systems where a controlled parameter is moderation, the following requirements apply:

- Identify credible sources of moderation intrusion and control the ingress of moderation in accordance with the double contingency principle;
- Design physical structures, barriers, and/or equipment involved in the system to limit or control the ingress of moderation;
- Use qualified instrumentation where moderation control requires the moderation content or other system parameters to be measured or monitored;
- Use redundant independent sampling methods where moderation control is the only controlled parameter; and

- Control combustible materials, document fire-fighting methods in approved written procedures, and provide for approved sprinkler systems, manual means, or non-hydrogenous chemicals for fire-fighting as specified by the process analysis.

Where moderation control is the only controlled parameter, the minimum protection is never less than two independent controls on moderation for each credible accident sequence, which must fail before a criticality accident is possible. Additional defense in depth protection may also be specified in process evaluations. The basis for selection of moderation controls shall be documented in CSAs and evaluated in accordance with the ISA Process described in GLE LA Chapter 3. The introduction and use of moderating materials (such as, cleaning agents, oils, or lubricants) within designated MCAs are subject to controls/limits that are approved by the NCS function.

5.4.4.6 Concentration (or Density)

Concentration control may be used for NCS control alone or in combination with other control methods. Concentration controls are established to ensure the concentration level is maintained within defined limits for the system. Each process relying on concentration control has engineered controls in place to detect and/or mitigate the effects of high concentration within the system; otherwise, the most reactive credible concentration (density) is assumed.

Concentration control is typically used in processes containing solution with low uranium concentrations such as a liquid effluent system. In evaluating systems containing concentration-controlled solution, the following requirements apply:

- Preclude a high concentration of uranium in a process unless the process is demonstrated safe at any credible concentration (for example, a favorable geometry tank);

- Equip the tank/vessel with backflow prevention controls (for example, air break, siphon breaks, overflow lines) where appropriate and inspect periodically for buildup; and

- Take precautions where precipitating agents are added to ensure agents are not inadvertently introduced.

When concentration is the only parameter controlled to prevent criticality, concentration may be controlled by two independent combinations of measurement and physical control, with each physical control capable of preventing the concentration limit from being exceeded in an unsafe location. The preferred method of attaining independence is to ensure that at least one of the two combinations is an active engineered control.

5.4.4.7 Interaction (or Unit Spacing)

Interaction/spacing control may be used for NCS control alone or in combination with other control methods. Interaction controls are based on either neutronic isolation or spacing of interacting units to control neutron leakage. Physical separation between process operations, vessels, or containers may be provided by either engineered or augmented administrative controls depending on the application. Where engineered spacing controls are required the structural integrity of the engineered feature must be sufficient for normal and credible abnormal conditions.

Units may be considered effectively non-interacting (isolated) if they are: (1) separated by 12-inches of full density water equivalent; (2) separated by the larger of 12-foot air distance or the greatest distance across an orthographic projection of the largest fissile accumulation on a plane perpendicular to the line joining their centers; or (3) shown to be non-interacting based on comparison of the calculated effective multiplication factor for the unit and that of the entire system.

5.4.4.8 Neutron Absorbers

Neutron absorbing materials may be utilized to provide a method for NCS control for a process, vessel, or container. Stable compounds such as boron carbide fixed in a matrix (such as, aluminum or polyester resin, elemental cadmium clad in appropriate material, elemental boron alloyed stainless steel, or other solid neutron absorbing materials) with an established dimensional relationship to the fissionable material are recommended. The use of neutron absorbers in this manner is defined as part of a passive engineered control. When evaluating the absorber effectiveness for an application, the neutron spectrum is considered in the CSA.

Where neutron absorbers are credited as an NCS controlled parameter (whether as engineered additives or as credited materials of construction), fixed neutron absorbers controls are implemented consistent with the guidance in ANSI/ANS 8.21-1995, *Use of Fixed Neutron Absorbers in Nuclear Facilities Outside Reactors (Ref. 5-20).*

Only fixed absorbers may be used as NCS controls on neutron absorption. Soluble neutron absorbers (for example, boric acid) and removable neutron absorbers (for example, Raschig Rings) are not used as NCS controls.

5.4.4.9 Process Characteristics

Within certain fissile material operations, credit may be taken for physical, chemical, and nuclear properties of the process and/or materials as NCS controls. Use of process characteristics is based upon the following requirements:

- Identify the bounding conditions and operational limits in the CSA and communicate, through training and procedures, to appropriate Operations personnel.
- Base bounding conditions for such process and/or material characteristics on established physical, chemical, or nuclear reactions, known scientific principles, and/or facility-specific experimental data supported by operational history.

- The devices and/or procedures, which maintain the limiting conditions, must have the reliability, independence, and other characteristics required of a criticality safety control.

5.4.5 Criticality Safety Analyses

The scope and content of any particular CSA reflects the needs and characteristics of the system being analyzed and typically includes the applicable information requirements listed below.

Scope – Defines the stated purpose of the analysis.

General Discussion – Presents an overview of the process affected by the proposed change. This section includes, as appropriate: process description, flow diagrams, normal operating conditions, system interfaces, and other important to design considerations.

Criticality Safety Controls/Bounding Assumptions – Defines the controlled parameter(s) and summarizes the criticality safety controls on each identified parameter that are imposed as a result of the evaluation. This section also clearly presents a summary of the bounding assumptions used in the analysis. Bounding assumptions include: worst credible contents (for example, material composition, density, enrichment, and moderation), boundary conditions, inter-unit water, and a statement on assumed structure. In addition, this section may include a statement summarizing interface considerations with other units, subareas, and/or areas.

Model Description – Presents a narrative description of the actual model used in the analysis. An identification of both normal and credible upset (accident) conditions and model file naming convention is provided. Key input listings and corresponding geometry plot(s) for both normal and credible upset cases are also provided.

Calculational Results – Identifies how the calculations were performed, what tools or reference documents were used, and when appropriate, presents a tabular listing of the calculational result and associated uncertainty (for example, $K_{eff} + 3\sigma$) results as a function of the key parameter(s) (for example, wt. fraction H_2O). When applicable, the assigned bias of the calculation is also clearly stated and incorporated into both normal and/or accident limit comparisons.

Safety During Upset Conditions – Presents a concise summary of the upset conditions considered credible for the defined unit or process system. This section includes a discussion as to how established NCS limits and controls address each credible process upset (accident) condition to maintain subcriticality.

Specifications and Requirements for Safety – When applicable, presents both design specifications and criticality safety requirements for correct implementation of established controls. These requirements are incorporated into operating procedures, training, maintenance, and QA as appropriate to implement the specifications and requirements.

Compliance – Concludes the analysis with pertinent summary statements and includes a statement regarding license compliance.

Verification – A qualified Senior NCS Engineer, who was not involved in the analysis, verifies each CSA in accordance with GLE LA Section 5.4.5.1, *Technical Reviews*.

Appendices – Where necessary, include a summary of information ancillary to calculations such as parametric sensitivity studies, references, key inputs, model geometry plots, equipment sketches, useful data, etc., for each defined system.

5.4.5.1 Technical Reviews

Independent technical reviews of proposed criticality safety control limits specified in the CSA are performed. A Senior NCS Engineer is required to perform the independent technical review. The independent technical review consists of a verification that the neutronics geometry model and configuration used adequately represent the system being analyzed. In addition, the reviewer verifies that the proposed material characterizations such as density, concentration, etc., adequately represent the system. The reviewer also verifies that the proposed criticality safety controls are adequate. The independent technical review of the specific calculations and computer models is performed using one of the following methods:

- Verify the calculations with an alternate computational method;
- Verify methods with an independent analytic approach based on fundamental laws of nuclear physics;
- Verify the calculations by performing a comparison to results from a similar design or to similar previously performed calculations; or
- Verify the calculations by performing specific checks of the computer codes used, and by performing evaluations of code input and output.

Based on one of these prescribed methods, the independent technical review provides a reasonable measure of assurance that the chosen analysis methodology and results are correct.

5.5 REPORTING REQUIREMENTS

A program for evaluating the criticality significance of NCS events is established for making the required notification to the NRC Operations Center. Qualified individuals make the determination of the significance of NCS events. The determination of loss or degradation of double contingency protection is made against the documented CSA, the License, and 10 CFR 70, Appendix A. GLE commits to the following NCS reporting requirements:

- The reporting criteria of 10 CFR 70, Appendix A and the report content requirements of 10 CFR 70.50, *Reporting Requirements (Ref. 5-21)*, are incorporated into approved written procedures.

- If it cannot be ascertained within one hour of the discovery of an event, whether the criteria of 10 CFR 70, Appendix A, Paragraph (a) applies, the event should be treated as a one-hour reportable event.

- If it cannot be ascertained within 24 hours of discovery of an event, whether the criteria of 10 CFR 70, Appendix A, Paragraph (b) applies, the event should be treated as a 24-hour reportable event.

- The required report is issued when the IROFS credited is lost, irrespective of whether the safety limits of the associated parameters are actually exceeded.

5.6 REFERENCES

5-1. 10 CFR 70.64, *Requirements for New Facilities or New Processes at Existing Facilities*, U.S. Nuclear Regulatory Commission, 2008.

5-2. ANSI/ANS 8.1-1998, *Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors*, American Nuclear Society, January 1998.

5-3. 10 CFR 70.61, *Performance Requirements,* U.S. Nuclear Regulatory Commission, 2008.

5-4. 10 CFR 70.62, *Safety Program and Integrated Safety Analysis,* U.S. Nuclear Regulatory Commission, 2008.

5-5. 10 CFR 70, *Domestic Licensing of Special Nuclear Material*, U.S. Nuclear Regulatory Commission, 2008.

5-6. 10 CFR 70.72, *Facility Changes and Change Process*, U.S. Nuclear Regulatory Commission, 2008.

5-7. 10 CFR 70.65, *Additional Content of Applications,* U.S. Nuclear Regulatory Commission, 2008.

5-8. ANSI/ANS 8.19-2005, *Administrative Practice for Nuclear Criticality Safety*, American Nuclear Society, January 2005.

5-9. ANSI/ANS 8.26-2007, *Criticality Safety Engineer Training and Qualification Program*, American Nuclear Society, June 2007.

5-10. 10 CFR 70.24, *Criticality Accident Requirements*, U.S. Nuclear Regulatory Commission, 2008.

5-11. ANSI/ANS 8.3-1997 (R2003), *Criticality Accident Alarm System*, American Nuclear Society, January 1997.

5-12. Regulatory Guide 3.71, *Nuclear Criticality Safety Standards for Fuels and Material Facilities*, U.S. Nuclear Regulatory Commission, Revision 2, December 2010.

5-13. ANSI/ANS 8.23-1997, *Nuclear Criticality Accident Emergency Planning and Response*, American Nuclear Society, January 1997.

5-14. 10 CFR 70.17, *Specific Exemptions*, U.S. Nuclear Regulatory Commission, 2008.

5-15. ANSI N14.1-2001, *Nuclear Materials – Uranium Hexafluoride – Packaging for Transport,* American National Standards Institute, January 2001.

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5-18. ANSI/ANS 8.24-2007, *Validation of Neutron Transport Methods for Nuclear Criticality Safety Calculations*, American Nuclear Society, 2007.

5-19. ANSI/ANS 8.22-1997 (R2006), *Nuclear Criticality Safety Based on Limiting and Controlling Moderators*, American Nuclear Society, January 1997.

5-20. ANSI/ANS 8.21-1995 (R2001), *Use of Fixed Neutron Absorbers in Nuclear Facilities Outside Reactors*, American Nuclear Society, January 1995.

5-21. 10 CFR 70.50, *Reporting Requirements*, U.S. Nuclear Regulatory Commission, 2008.