STAFF EVALUATION OF GLOBAL NUCLEAR FUEL-AMERICAS, LLC
WILMINGTON, NORTH CAROLINA
FACILITY RESPONSE TO GENERIC LETTER 2015-01
"TREATMENT OF NATURAL PHENOMENA HAZARDS IN FUEL CYCLE FACILITIES"

I. Background

On June 22, 2015, the U.S. Nuclear Regulatory Commission (NRC) issued Generic Letter (GL) 2015-01, "Treatment of Natural Phenomena Hazards (NPH) in Fuel Cycle Facilities" (Agencywide Documents Access and Management System [ADAMS] Accession Number ML14328A029). The GL 2015-01 was issued for two purposes: (1) to request that addressees submit information to demonstrate compliance with regulatory requirements and applicable license conditions regarding the treatment of natural phenomena events in the facilities' integrated safety analysis; and (2) to determine if additional NRC regulatory action is necessary to ensure that licensees comply with their licensing basis and existing NRC regulations.

On July 22, 2015, Global Nuclear Fuels – Americas (GNF-A or Licensee) sent ACH-15-001 (ADAMS ML15203A018) requesting an extension to respond to the GL until January 29, 2016. This resulted in issuing Amendment 10 to SNM-1097 on October 23, 2015 (ADAMS ML15268A348) to address the commitment to submit the response by the specified date. The NRC staff completed its evaluation of the Global Nuclear Fuel-Americas, LLC response to GL 2015-01 dated January 29, 2016 (ADAMS ML16029A144) including the responses to requests for supplemental information dated August 12, 2016 (ADAMS ML16218A258) and February 16, 2017 (ADAMS ML17044A036).

The purpose of this evaluation report is to document the staff's review of GNF-A response to GL 2015-01, including its responses to requests for supplemental information and staff review of calculations, to determine if GNF-A adequately addressed the potential effects of Natural Phenomena Hazards (NPH) events in the integrated safety analysis (ISA). The staff selected a subset of NPH events using a risk-informed approach to verify that GNF-A used appropriate methods to evaluate the impacts of NPH in conducting the facility's ISA. The staff did not perform a complete assessment of the ISA for all NPH events nor did it conduct a design certification review for NPH. This method is consistent with NRC guidance in Chapter 3 of NUREG-1520, "Standard Review Plan for the Review of a License Application for a Fuel Cycle Facility." The staff also used Interim Staff Guidance (ISG) Number FCSE-ISG-15, "Natural Phenomena Hazards in Fuel Cycle Facilities" (ADAMS ML15121A044) for its review. The staff will perform an inspection using Temporary Instruction (TI) 2600/016, "Inspection Activities Associated with GL 2015-01" (ADAMS ML15317A506) to independently verify that GNF-A is in compliance with the regulatory requirements and applicable license conditions regarding the treatment of NPH in its ISA. The inspection results from this TI will also be used to follow-up with previously identified Unresolved Items regarding the treatment of NPH and to inform the closure process of NRC GL 2015-01. The results of these regulatory activities will allow the staff to verify that GNF-A demonstrates compliance with regulatory requirements and applicable license conditions regarding the treatment of NPH at the facility.

GNF-A is located in Wilmington, North Carolina. GNF-A manufactures nuclear fuel for boiling water reactors. Existing processes at GNF-A are not required to meet the requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) Paragraph 70.64(a), "Baseline design criteria," which applies to new facilities or new processes at existing facilities.

II. GL 2015-01 Requested Actions

In the GL, the staff requested that all addressees provide information to verify the assumptions in their facilities' ISAs regarding how each facility provides adequate protection against the occurrence of natural phenomena events. Specifically, the staff asked that addressees take the following actions:

a) Submit definitions of “unlikely,” “highly unlikely,” and “credible” in evaluating natural phenomena events in the ISA such as earthquakes, tornadoes, tornado missile impacts, floods, hurricanes, and other wind storms. (See Section III.1.0 on page 2).

b) Submit a description of the safety assessment for the licensing and design basis natural phenomena events, including the following information: (See Section III.2.0 on page 3).

   i. likelihood and severity of the natural phenomena events, such as earthquakes, tornadoes, floods, hurricanes, and other wind storms;

   ii. accident sequences as a result of natural phenomena event impacts to facility structures and internal components;

   iii. assessment of the consequences for the accident sequences from item ii that result in intermediate and/or high consequence events; and

   iv. items relied on for safety (IROFS) to prevent or mitigate the consequences of the events from items ii and iii.

c) For facilities subject to 10 CFR Part 70, Subpart H requirements, submit a description of the results of the ISA review used to comply with 10 CFR 70.62(c), identifying the characteristics of the licensing and design basis natural phenomena events applicable to the site, that evaluates possible changes in the methodology, likelihood, and severity of natural phenomena events with those used in the original design/evaluation of the facility.

d) Submit for staff review a summary of the results of any facility assessments or walkdowns, if performed, to identify and address degraded nonconforming, or unanalyzed conditions that can affect the performance of the facility under natural phenomena and have available for NRC inspection the documentation of the qualifications of the team.

III. GNF-A Response to GL 2015-01 and Staff Evaluation

1.0 <u>NRC GL 2015-01, Requested Action (1)a</u>: Submit the definitions of “unlikely,” “highly unlikely,” and “credible” in evaluating natural phenomena events in the ISA such as earthquakes, tornadoes, tornado missile impacts, floods, hurricanes, and other wind storms.

GNF-A submitted definitions, which are consistent with SNM-1097, for “unlikely,” “highly unlikely,” “credible”, and “not credible”. More specifically, in Table 3.3 of SNM-1097, the definition for *unlikely* is a frequency of event occurrence of between $1x10^{-3}$/year and $1x10^{-4}$/year and *highly unlikely* is a frequency of event occurrence of less than or equal to $1x10^{-4}$/year.

An accident sequence initiated by an evaluation basis NPH event is considered *not credible* if any of the following criteria from Section 3.3.3 of SNM-1097 are met:

(1) An external event for which the frequency of occurrence can conservatively be estimated as less than once in a million years.

(2) A process deviation that consists of a sequence of many unlikely events or errors for which there is no reason or motive. In determining that there is no reason for such errors, a wide range

of possible motives, short of intent to cause harm, must be considered. Necessarily, no such sequence of events can ever have actually happened in any fuel cycle facility.

(3) Process deviations for which there is a convincing argument, based on physical laws, that they are not possible, sound engineering or technical data that the deviations are not possible, or are unquestionably extremely unlikely. The validity of the argument must not depend on any feature of the design or materials controlled by the facility's system of IROFS or management measures.

Staff Evaluation:

The definitions that GNF-A provided are appropriate and consistent with existing guidance. The staff finds that GNF-A has adequately responded to GL 2015-01 Requested Action (1)a.

2.0 NRC GL 2015-01 Requested Action (1)b: Submit a description of the safety assessment for the licensing and design basis natural phenomena events, including the following information (See Section III.2.1, III.2.2 and III.2.3):

i. likelihood and severity of the natural phenomena events, such as earthquakes, tornadoes, floods, hurricanes, and other wind storms;

ii. accident sequences as a result of natural phenomena event impacts to facility structures and internal components;

iii. assessment of the consequences for the accident sequences from item ii that result in intermediate and/or high consequence events; and

iv. IROFS to prevent or mitigate the consequences of the events from items ii and iii.

GNF-A submitted a methodology that uses a successive screening process to determine which NPH events are not credible and those that are credible. GNF-A used a qualitative determination, based on environmental reports and publically available geological and climatic data, to identify the natural phenomena events that are not credible. If the unmitigated consequence initiated by a particular NPH is not credible, then it was screened out from further consideration. The following NPH events were screened out using the qualitative process: 1) dam/levee/dike failures; 2) flash flooding; 3) tsunami; 4) seiche; 5) erosion; 6) subsidence; 7) volcanoes; 8) avalanche/rockslide/landslide; and 9) meteorite impact.

The NPH events that did not screen out using initial screening process, went through an additional screening to determine whether the NPH can adversely affect compliance with performance requirements. An interdisciplinary team of experts was formed to specifically consider effects of applicable NPH events that could result in high or intermediate consequence accident sequences. The review team screened the structures, systems, and components (SSCs) from further evaluation if high and intermediate consequence accident sequences would not occur or are highly unlikely even assuming the worst, most damaging effects. The NPH events were also screened out if all associated accident sequences were bounded by the existing process hazard analysis (PHA). If the initiating event can be considered subsumed by the existing PHA initiating event frequency, and the consequences are not more severe, and the controls for the PHA accident sequence are unaffected by the initiating event, then the PHA sequence is considered bounding. The following NPH events were screened out using the second screening process: 1) windborne missiles, 2) high and low temperatures, 3) fog, 4) lightening, 5) wildfires.

The NPH events that did not screen out in the first and second screening processes were retained for further evaluation. These NPH events include: 1) seismic hazards (earthquake), 2) flooding hazards (river flooding, excessive rain, hurricane storm surge), 3) Wind and tornado loading (hurricane winds, tornados, extreme straight winds), and 4) extreme weather conditions (snow, ice).

After performing an evaluation basis event determination for the NPH events listed above, GNF-A further refined the list by bounding some of the events. For example, the tornado and extreme straight winds were bounded by the hurricane NPH event. As such, the final list of NPH events that GNF-A provided evaluation results for were: 1) earthquake, 2) hurricane, and 3) roof loads from precipitation.

Staff Evaluation:

The staff found the screening methodology that GNF-A provided was reasonable. GNF-A initially included many NPH events and then screened out those that are not credible based on the facility location (e.g., volcano, tsunami.) Furthermore, GNF-A screened out additional events using an interdisciplinary team of experts and a qualitative process, bounding some NPH events, and developed an appropriate list of NPH events for detailed evaluation.

2.1 Earthquakes

2.1.1 ISA for Seismic Hazards

GNF-A provided information regarding implementation of its ISA methodology to determine whether additional IROFS are needed as a result of seismic induced accident sequences. Using the 2008 version of United States Geological Survey (USGS) seismic hazard maps, GNF-A selected an evaluation earthquake with ground motions associated with a 10 percent probability of exceedance in 50 years, i.e. a return period of 475 years. GNF-A performed a structural engineering evaluation of the main building structures: Fuel Manufacturing Operations (FMO), FMO Expansion (FMOX), Dry Conversion Process (DCP), and 421 Warehouse. GNF-A also performed a seismic evaluation of the building internal SSCs. The evaluations of the main buildings and their internal SSCs conclude that the FMO/FMOX, DCP, 421 Warehouse, and the evaluated internal components will survive the evaluated earthquake with a 475 year return period. In addition, GNF-A evaluated the DCP building using the 2014 version of USGS seismic hazard maps with a 2 percent probability of exceedance in 50 years, i.e. a return period of 2475 years, and concluded that it has sufficient capacity to withstand the loads. Therefore, GNF-A applied the associated frequency of 2.1 E-3 earthquake per year as the initiating event frequency for all seismic induced accident sequences. GNF-A also considered conditional failure probabilities of 0.048 or less for the evaluated SSCs. Based on the conditional probabilities and the initiating event frequency, GNF-A concluded that seismic induced accident sequences with intermediate or high consequences are highly unlikely and consequently, there are no new IROFS to consider within the ISA.

Staff Evaluation:

The staff reviewed GNF-A's responses, engineering evaluations, and the updated 2016 ISA Summary (ADAMS ML16029A085). Specifically, the staff evaluated GNF-A's approach for considering seismic events within its ISA and the methodologies applied to determine likelihoods, consequences, and IROFS.

As previously stated, for the seismic analysis of the facility, GNF-A based its evaluation on loads associated with earthquakes with return periods of 475 and 2475 years. For the purposes of the ISA, GNF-A assessed the initiating event frequency of this earthquake as 2.1E-3 per year. GNF-A arrived at this estimation using a standard equation that calculates annual frequency based on the probability of exceedance for the 475 year return period. According to GNF-A's likelihood definitions, GNF-A designated the likelihood of this event as "unlikely." Therefore, the staff agrees that GNF-A's approach to classify the likelihood of seismic induced events based on the definitions established within its ISA methodology is adequate.

The staff reviewed GNF-A's approach to determining the consequences of criticality and non-criticality accident sequences. GNF-A, as part of its seismic evaluation, stated that it reanalyzed all nodes previously identified in its ISA with accident sequences that could result in intermediate or high consequences. GNF-A defines a node as a well-defined section such that the process inputs and outputs and their interactions with other sections can be analyzed. GNF-A grouped the nodes by consequence such that all nodes with criticality were designated as high consequence to workers, the public, and the environment; Hydrogen Fluoride (HF) and Uranium Hexafluoride (UF_6) releases as high chemical consequence to workers and the public; UF_6 releases as high radiological consequence to workers and the public and intermediate consequence to the environment, and fires and explosions as the consequence from the resulting release, e.g. criticality, HF, or UF_6. Based on the results of the node categorization, the staff agrees that GNF-A's approach to determining the consequences of seismic induced accident sequences is conservative and adequate. The staff would expect GNF-A to apply this categorization to any newly discovered seismic induced accident sequences within existing nodes or nodes from new processes or structures. The staff further notes that the number of nodes GNF-A reanalyzed is approximately half of the total nodes cited in the ISA Summary. The staff will confirm GNF-A's application of its consequence determination methodology during the temporary inspection.

The staff reviewed GNF-A's approach to identify IROFS required to prevent or mitigate seismic induced accident sequences. GNF-A did not identify new accident sequences and, therefore, no new IROFS. However, according to the seismic evaluation process, had GNF-A identified components that did not withstand the seismic loads, as evaluated, GNF-A would have analyzed it further with the goal of satisfying the 10 CFR 70.61 performance criteria. The staff reviewed "Natural Phenomena Hazard Screening, Definition, and Evaluation," CALC 900-007 dated January 28, 2016 (ADAMS ML16288A778); which describes the evaluation process and the results. CALC-900-007 discusses the evaluation criteria for determining further analysis which includes a screening methodology. The screening methodology categorizes each node into component groups then qualitatively evaluates the component's vulnerability to a specific set of seismically induced conditions such as falling block walls and falling overhead equipment. The staff agrees that a structured screening process that qualitatively evaluates the vulnerability of internal components and equipment is an adequate approach to identifying the need for further detailed evaluation.

However, the staff notes that the evaluation process as described in the updated 2016 ISA Summary states that GNF-A would demonstrate compliance with 10 CFR 70.61 by showing that accident sequences involving NPH are highly unlikely. The staff acknowledges that one method of demonstrating compliance with 10 CFR 70.61 is to show that an unmitigated high consequence accident sequence is highly unlikely. In the context of NPH, however, relying on the likelihood of the NPH alone could result in an incomplete analysis of NPH on the facility. The staff recognizes that NPH, such as earthquakes, are rare events with initiating event frequencies that could equate to likelihoods of highly unlikely. In other words, a licensee would consider the performance requirements met through the likelihood of the natural phenomena without the support of a structural analysis, the application of a structural code such as IBC 2012, or the implementation of any IROFS. Under those circumstances, according to GNF-A's approach as described in the ISA and CALC-900-007, IROFS for high consequence sequences would not be necessary. Similarly, according to GNF-A's approach, IROFS for intermediate consequence sequences would not be necessary for natural phenomena with initiating event frequencies equivalent to 1E-3 or less. This approach does not take into account the significant uncertainties associated with calculating an initiating event frequency for NPH. Given GNF-A's as-described approach to identifying IROFS, during the temporary inspection, the staff will further evaluate GNF-A's conclusion that there are no new accident sequences or IROFS to consider.

Although the staff does not agree with GNF-A's described approach for identifying IROFS for seismic induced accident sequences, the staff does agree that, based on a seismic evaluation of the structures and internal components, as described in Sections 2.1.2; the chemical safety evaluation in Section 2.1.3; the criticality evaluation in Section 2.1.4; and the fire protection evaluation in Section 2.1.5, GNF-A has demonstrated defense-in-depth in establishing IROFS. Specifically, NUREG-1520, Revision 2, defines defense-in-depth as "the degree to which multiple IROFS or systems of IROFS must fail before the undesired consequences (e.g., criticality, chemical release) can result." The updated 2016 ISA Summary enumerates the IROFS whereby, only through the failure of multiple IROFS could intermediate or high consequences occur as defined in the performance requirements of 10 CFR 70.61. These IROFS include diverse active engineered controls, diverse passive engineered controls, inspected passive safety devices with diverse active engineered or administrative backups, and diverse administrative controls. Furthermore, GNF-A does not cite any sole IROFS in its ISA Summary. Given these factors, a seismic induced accident sequence could occur only if the unlikely seismic induced degradation or failure of the structure is combined with multiple seismic induced IROFS failures. Therefore, the staff agrees that GNF-A has implemented a defense-in-depth approach to establishing IROFS. While noting the potential inherent deficiencies above, the staff agrees that GNF-A's general methodology to classify the likelihood of seismic induced events; determine the consequences of criticality and non-criticality accident sequences, and identify appropriate IROFS is adequate.

2.1.2 Seismic Evaluation of Building Structures Systems and Components

<u>Building Structures</u>

GNF-A stated in Section 3.0 of the 2016 ISA Summary and Section 2.0 of the report titled "Natural Phenomena Hazard Screening, Definition, and Evaluation," CALC 900-007 dated January 28, 2016 (ADAMS ML16288A778); that the FMO, FMOX, DCP, and 421 Warehouse buildings at its Wilmington site were designed and constructed to comply with the North Carolina State Building Code (NCSBC) criteria for the year of construction. The primary building structures of interest due to processing of regulated material at the Wilmington site fuel fabrication facility are mostly composed of steel frame with metal siding, reinforced concrete frame, concrete masonry unit (CMU) walls, and Building 421 being a pre-engineered metal building.

The FMO and FMOX buildings are steel frame structures composed of columns, roof trusses, and braced frames with metal siding for exterior walls. These buildings are generally one story with a limited number of interior mezzanines. The manufacturing floor is a concrete floor slab on grade and is independent of the building superstructure. The flat roofs of the FMO and FMOX buildings are supported by trusses with a 65-foot column spacing in north to south direction and a 35-foot column spacing in the east to west direction. In the north to south direction, the buildings are mostly composed of frames between roof trusses and columns; and in the east to west direction composed of a braced frame with diagonal braces along the exterior walls. The DCP building is a reinforced concrete frame structure with a roof designed using a multilayered reinforced concrete slab system. Building 421 is a pre-engineered metal building.

In Section 2.0 of CALC 900-007, the GNF-A stated that the building codes in effect when GNF-A site structures were constructed have been updated to include seismic or other NPH requirements. GNF-A also stated that design information on many structures were incomplete or not readily available. Additionally, the original design documentation that is available does not reflect modifications that have been made to the structures over several decades of operations. Therefore, GNF-A evaluated the performance of important systems structures or components for applicable NPH using criteria from the American Society of Civil Engineers (ASCE) 7-05 or ASCE 7-10; IBC-15; and the NCSBC-12.

Dry Conversion Process Building and Building 421 Warehouse

GNF-A conducted a seismic analysis of the DCP building using NCSBC-12 and ASCE 7-05 as documented in report titled "Global Nuclear Fuel DCP and FMO Building Evaluation Basis Analysis," dated January 22, 2016. GNF-A used the equivalent static force method for the structural analysis using an importance factor of 1.5 and a site soil class D. GNF-A conducted a structural analysis based on a 10 percent exceedance in 50 years seismic loads and then checked for the resistance capacity for a 2 percent exceedance in 50 years seismic loads. The licensee stated that a combination of the original construction documents and information obtained during walk-downs of the building were utilized to build a three dimensional structural model of the building using the computer codes RISA Floor, RISA-3D, and RISA Foundation. Based on the structural analysis results for the 10 percent exceedance probability in 50 years seismic loads, GNF-A stated that the building lateral force systems have substantial capacity to resist these loads. GNF-A also analyzed the DCP framing response to the 2 percent exceedance probability in 50 years seismic loads and concluded that the building is stable under these seismic loads and is not near a collapse state.

GNF-A analyzed the pre-engineered metal building, Building 421 Warehouse using the finite element structural analysis code SAP2000. Computer model geometry is based on the original drawings of the building and information obtained during the building walk-downs. Building 421 was analyzed using ASCE 7-10 and IBC-15 seismic parameters for a 2 percent exceedance probability in 50 years, an importance factor 1.5 and site soil class D. Based on the analysis results, GNF-A concluded that Building 421 is stable and is not near a collapse state.

Staff Evaluation of the DCP Building and Building 421 Warehouse

The staff reviewed a sample of the structural analysis reports of the DCP and 421 Warehouse buildings to determine if the methodology was adequately implemented. The staff also reviewed the seismic hazards curves and seismic input parameters to verify that GNF-A selected the appropriate ground motion parameters for the seismic evaluation. Therefore, the staff makes the following conclusions.

- The staff concludes that GNF-A has adequately modeled, analyzed, and identified the failure modes of the structures of the DCP and 421 Warehouse.
- The staff agrees with the use of the seismic criteria from the NCSBC-12 and ASCE 7-05 and IBC-15 with ASCE 7-10, respectively, as an acceptable methodology for the evaluation of earthquake hazards at the facility for the main buildings of the GNF-A Wilmington site.
- The staff agrees that the use of the ground motions referenced by the ASCE 7-05 and 7-10 with a 2 percent probability of exceedance in 50 years are adequate and consistent with NRC FCSE-ISG-15 "Natural Phenomena Hazards in Fuel Cycle Facilities" and industry practices.
- The staff further agrees with the categorization of the DCP and 421 Warehouse as an "Essential Facility" and the use of an importance of 1.5.
- The staff agrees, based on the information provided by GNF-A, that the DCP and the 421 Warehouse building structures are stable under the above mentioned seismic loads and not near a collapse state.

FMO Building and FMOX Building

GNF-A performed a seismic analysis of the FMO and FMOX buildings that was documented in report “Global Nuclear Fuel DCP and FMO Building Evaluation Basis Analysis,” dated January 22, 2016. On August 12, 2016, the NRC staff issued a letter to GNF-A (ADAMS ML16218A258) which included several RSI. In the RSI the staff included questions on the methodology used for the structural evaluation of the FMO and FMOX and the assumptions made in the ISA Summary for the assessment of the likelihood of a seismic event. By letter dated September 14, 2016 (ADAMS ML16258A260), GNF-A indicated to the NRC staff that a new seismic evaluation was being performed on the FMO and FMOX building. On October 14, 2016, GNF-A submitted a new seismic analysis of the FMO and FMOX building titled “Seismic, Wind, Rain, and Snow Evaluation of the Global Nuclear Fuels – America FMO and FMOX Buildings” dated September 2016 (ADAMS ML16288A778) hereinafter referred to as the report.

As stated in the report, GNF-A performed the structural evaluation using the following references: 1.) ASCE 7, “Minimum Design Loads for Buildings and Other Structures”; 2.) American Institute of Steel Construction (AISC) 341, “Seismic Provisions for Structural Steel Buildings”; 3.) AISC 360, “Specification for Structural Steel Buildings” and 4.) U.S. Department of Energy DOE-STD-1021, “Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components.”

The methodology GNF-A used for the structural analysis was based on the equivalent lateral force procedure and seismic load combinations from ASCE 7 to determine seismic loading. GNF-A classified the structures as essential facilities corresponding to a Performance Category 2 (PC-2) facility according to DOE-STD-1021 and Risk Category IV according to ASCE 7. The analysis used 2008 USGS seismic hazard data to obtain seismic spectral response accelerations with a 2 percent probability of exceedance in 50 years with site class D correction factors based on soil reports. Using this information, GNF-A has evaluated structures to the seismic design category D. The finite element code “SAP2000” was used to perform the three-dimensional structural analysis of the buildings.

GNF-A stated that for the seismic load cases, the designation of the lateral force resisting system (LFRS) was taken as a “steel intermediate moment frame” with a response modification factor “R” of 4.5 for calculation of the seismic base shear. The determination to consider the structural system as an intermediate moment frame (IMF) was made by GNF-A in its analysis after identifying in the results of the first model that most of the diagonal bracing members along the building exterior were overloaded (i.e., tensile demands exceeded the tensile capacity of the braces). Due to the initial results, GNF-A removed the diagonal bracing members from the model and re-analyzed the FMO and FMOX building. In this re-analysis, GNF-A assumed that the building was an IMF as defined in ASCE 7 and AISC 341, “Seismic Provisions for Structural Steel Buildings.” Based on the structural re-analysis results, GNF-A concluded that both FMO and FMOX buildings are stable and not near a collapse state under the applied seismic load.

On February 16, 2017, the NRC staff issued a RSI (ADAMS ML17044A038) requesting information to address technical questions concerning the justification for the assumption of the IMF classification, meeting the requirements of ASCE 7 and ACSE 341 for IMFs, consideration of large lateral displacements and story drift angles in the structural stability analysis, and related technical issues. By letter dated April 24, 2017 GNF-A responded to the RSI (ADAMS ML17115A098).

By letter dated June 6, 2017, the NRC staff provided the results of its evaluation of the GNF-A responses to the staff RSI dated April 24, 2017. In the enclosure to the letter, the staff indicated to GNF-A that its response transmitted on April 24, 2017, does not adequately address the technical concerns identified in the staff's RSI dated February 16, 2017. The reasoning for this determination and a summary of the NRC staff's outstanding issues were included in the staff June 6, 2017 letter. In the letter the NRC staff indicated that there were two outstanding concerns: 1) the methodology and assumptions made in GNF-A's structural analysis (e.g., the classification of the FMO/FMOX structure as an IMF and the evaluation of drift and stability requirements) and 2) an analysis of the connections that considers all potential failure modes was not provided.

By telephone conference on July 6 2017, (ADAMS ML17208A096) GNF-A stated that it would submit an addendum to its September 2016 structural report with additional seismic structural evaluations of the FMO and FMOX buildings to address the NRC staff's above mentioned concerns. By letter dated July 28, 2017, GNF-A submitted "Seismic, Wind, Rain, and Snow Evaluation of the Global Nuclear Fuels – America FMO and FMOX Buildings Addendum," Rev. 0 dated July 2017 (ADAMS ML17212B117).

The July 2017 report evaluated the FMO and FMOX seismic structural capacity using the same methodology, finite element model and referenced codes described in the September 2016 report. The equivalent lateral force procedure and seismic load combinations from IBC 2015 and ASCE 7-10 were used. The following exceptions and changes were implemented by GNF-A.

- Design spectral accelerations: 3 different parameters were used as listed in the table below.

Code of Reference	IBC 2015/ASCE 7-10	ASCE 41-13	IBC 2018/ASCE 7-16*
Probability of excedance	2 percent in 50 years	10 percent in 50 years	2 percent in 50 years
$\mathbf{S_{DS}}$	0.235	0.115	0.163
$\mathbf{S_{D1}}$	0.144	0.075	0.108
*Values obtained from the 2015 NEHRP Provisions for future incorporation into ASCE 7			

- Response modification factor (R): the north-south direction of the building was assumed to be an Ordinary Moment Frame with R value of 3.5 and the east-west direction of the building was assumed to be an Ordinary Braced Frame with R value of 3.25.
- Reduced Roof Load: original evaluation used a 20 pounds per square foot (psf) for the FMO and FMOX per the original design documents. GNF-A stated that the roof was replaced with a lighter material, therefore the roof dead load was lowered to 10 psf.
- Reduced piping allowance load: initial evaluation used 15 psf for items supported by the roof trusses. Original design documentation specified a 15 psf and 5 psf allowance for piping for the FMO and FMOX, respectively. In the new model the allowance was lowered to 5 psf since GNF-A states that few items are supported from the trusses.

GNF-A stated that it performed the re-evaluation of the building focusing on LFRS, which in this case are the diagonal braces. GNF-A indicated they performed a linear and a non-linear structural analysis. For the linear analysis, GNF-A concluded that the roof displacements were small, that several diagonal braces experienced high stress levels, and that the FMO West has the controlling case with higher loads. Using a non-linear "yielding" analysis, GNF-A then concluded:

- 4 diagonal braces yield with the IBC 2015 (2 percent in 50 year) seismic parameters, 2 diagonal braces yield with the 2015 NEHRP (2 percent in 50 years) seismic parameters and no bracing yielded with the ASCE 41-13 (10 percent in 50 years) seismic parameters;
- Diagonal brace connections have adequate capacity and limiting state is failure of the bracing;
- Column interaction values using equations H1-1a and H1-1b from AISC 14th Edition are

low with a maximum of 0.299;
- Colum connections have adequate capacity; and
- Column to roof truss connections have adequate capacity.

Therefore, based on the above GNF-A concluded the FMOX and FMOX structures are stable under the above mentioned seismic loads and not near a collapse state.

Staff Evaluation of the FMO and FMOX Building Structures

The staff performed detailed reviews of the structural analysis reports for the FMO and FMOX buildings to determine if the methodology as provided in the GNF-A structural reports dated September 2016 and July 2017 were adequately implemented. As previously stated, the staff, by letter dated June 6, 2017 (ADAMS ML17146A569), determined that GNF-A's response to the staff RSI associated to the September 2016 structural report, does not adequately address the technical concerns identified. Based on the information provided by GNF-A in its July 2017 report the staff makes the following conclusions and notes.

- The staff agrees with the use of the seismic criteria from the IBC-2015 and ASCE 7-10 as an acceptable methodology for the evaluation of earthquake hazards for the FMO and FMOX buildings. The staff further notes that the use of the equivalent lateral force procedure is an acceptable method for the evaluation of the FMO and FMOX.
- The staff verified the seismic hazards curves and seismic input parameters and concludes that GNF-A selected the appropriate ground motion parameters for the seismic evaluation.
- The staff agrees that the a design spectral acceleration corresponding to a probability of exceedance of 10 percent in 50 years as a design basis ground motion from the ASCE 41-13 is adequate and consistent with NRC FCSE-ISG-15 "Natural Phenomena Hazards in Fuel Cycle Facilities" and industry practices. The staff further notes that the use of this probability of exceedance is acceptable considering that the FMO and FMOX is an existing facility that was built to codes with no or limited seismic design criteria. The staff also notes that the use of this probability of exceedance is acceptable taking into consideration that GNF-A has demonstrated defense-in-depth in establishing IROFS as documented in Sections 2.1.1 and 2.1.4. Since the process at the FMO and FMOX buildings are mostly dry powder, the risk is lower when compared to other areas of the facility like the DCP. However, criticality, chemical, and fire accident sequences can still exceed the performance requirements. The results of the staff evaluation of these accident sequences can be found in Sections 2.1.3, 2.1.4 and 2.1.5.
- The staff agrees with the use of the response modification factor of 3.5 in the north-south direction of the building and 3.25 in the east-west direction.
- The staff agrees with the categorization of the FMO and FMOX as an "Essential Facility" and the use of an importance factor of 1.5.
- The staff agrees with the approach of reducing the roof and piping dead loads given the existing conditions of the structure. Lowering the associated dead loads ultimately results in a better estimation of the capacity of the structure. The staff will validate this assumption during the inspection.
- The staff cannot conclude, based on the information provided by GNF-A in its July 2017 report, that no braces are overloaded or "yielding" using seismic loads from ASCE 41-13 with a 10 percent probability of exceedance in 50 years. The staff also cannot conclude, based on the information provided by GNF-A, that a limited number of braces are overstressed or yielded using ground motions from the IBC 2015 (2 percent in 50 year) and the 2015 NEHRP (2 percent in 50 years) seismic parameters.

  The staff notes that the non-linear yielding analysis performed by GNF-A relied on the application of amplification factors to increase the yield stress of the braces beyond the minimum yield stress of steel that is required by the codes GNF-A used as the basis of their analysis. The increase in yield stress is typically prescribed by the AISC 341 code as factors multiplied to Fy and Fu in what is termed capacity design. The increase in strength or stress in the capacity design approach is typically implemented as a measure to ensure yielding of specific elements of the LFRS by ensuring the adjoining member or connections can withstand the expected demands that the element can develop.

- The NRC staff can conclude that the FMO/FMOX building is stable and not near a collapse state at a seismic hazard with a 10 percent probability of exceedance in 50 years. The staff is reaching this conclusion based on the following factors:
  - The staff compared the demand over capacity (D/C) ratios using the load and resistance factor design (LRFD) methodology and specified factors for Fy and Fu. Using this information, the staff notes that only a handful of braces are overstressed.
  - Considering the results of GNF-A's analysis and that the displacements at the roof level are small; the truss-to-column connections and column-to-foundation connections were found acceptable; the staff agrees that the structure can be considered stable, not near collapse, and with additional margin to withstand loads above the 10 percent in 50 year seismic hazard. Since the capacity of the columns was compared to loads reactions specified in the building drawings, the staff will validate this assumption during the inspection.

GNF-A relies on adequate structural performance during a seismic event to prevent the collapse of the main structures housing the processing of NRC regulated materials. This structural performance is relied on in the ISA to demonstrate compliance with the regulatory requirements of 10 CFR 70.62. The staff concludes, based on the information provided by GNF-A, that the FMO and FMOX structures are stable and not near a collapse state under loads associated to seismic hazards with a probability of exceedance of 10 percent in 50 years and that the initiating event frequency for seismic induced accident sequences credited in GNF-A's ISA is acceptable.

<u>Equipment and CMU Walls</u>

GNF-A presented, in its report "Seismic Evaluation of Equipment for Global Nuclear Fuels – America," Revision 1 dated February 2016 (here after called seismic equipment evaluation report), a seismic evaluation of selected equipment at the GNF-A facility. The equipment that was evaluated is located primarily in the FMO, FMOX, and DPC buildings with only a limited number located in the Building 421. The equipment and their locations are provided in Section 2.3 and Figure A-8 of the seismic equipment evaluation report. The design basis earthquake (2 percent exceedance probability in 50 years) parameters for each building were determined applying IBC-15 and ASCE 7-10 procedure and the response spectrum associated with these parameters was provided in Section 3.2 of the seismic equipment evaluation report.

The IBC-15 provisions for equipment resting on the buildings are contained in 13.3.1 of ASCE 7-10. The mechanical and electrical equipment contained in Table 13.6-1 of ASCE 7-10 were considered, and bounding values were determined for the mechanical and electrical components and distributed systems. This procedure determined the seismic applied force in each equipment calculated as a percentage of its weight and are provided in Section 3.3 of seismic equipment evaluation report. The equipment evaluation is primarily concerned with equipment overturning stability, sliding stability, structural strength, and seismic induced displacements at piping attachment locations.

Based on the results of seismic equipment analysis, GNF-A concluded the following: (i) several CMU walls will fail under at the 2 percent probability of exceedance in 50 years earthquakes but under 10 percent probability of exceedance in 50 years earthquakes will be marginal but will remain stable and are not near a collapse state, (ii) piping support system in the UO_2 furnace room be modified to meet current piping code support requirements, and (iii) the anchoring system of the sheet metal cover over pellet boat storage rack be reworked.

Regarding the first recommendation, GNF-A conducted a subsequent seismic evaluation of the CMU walls in the FMO, FMOX and DCP buildings that has been documented in its report “CMU Wall Evaluation of the FMO, FMOX, and DCP buildings” Revision 0 dated October 2016. The CMU walls are located throughout the FMO, FMOX, and DCP buildings. These walls are typically composed of 8-inch CMU that have been divided by GNF-A into three major categories: (i) ground floor walls that extend from ground floor to the mezzanine level, (ii) mezzanine level walls that extend from the mezzanine to the roof, and (iii) full height walls that extend from the ground floor to the roof. GNF-A stated that most ground floor, mezzanine level, and full height CMU walls are non-load-bearing walls. GNF-A also stated that only a very limited number of ground floor walls that form small enclosed area with overhead roof supported by steel beams, which bear upon the CMU walls are load-bearing walls. GNF-A states that typically CMU walls are attached to adjacent columns, when present, thereby providing lateral support along the wall vertical edges.

In its report GNF-A stated that all the CMU walls analyzed can survive an earthquake with a return period of approximately 2475 years (i.e., 2 percent exceedance probability in 50 years) except one FMO mezzanine to roof CMU wall that can survive an earthquake with a return period of approximately 1,000 years. GNF-A considered this wall to be acceptable for the evaluation conducted herein.

With respect to the second recommendation, in its evaluation report “Natural Phenomena Hazard Screening, Definition, and Evaluation,” GNF-A stated that based on the inadequacies identified with the piping supports, damage resulting in a gas leak could potentially occur as a result of a seismic event. Given the evaluation basis initiating seismic event size and frequency, the likelihood of forming a significant leak is low (e.g., on the order of $1.0x10^{-3}$ per year or less). If a leak occurred, the maximum potential release rate into the room would be limited by flow restrictions IROFS, operator actions, and emergency response actions. GNF-A stated that the likelihood of an explosion event initiated by earthquake is considered by existing accident sequence evaluations for flammable gas leaks. Therefore, GNF-A stated that an explosion/criticality accident sequence initiated by a seismic event is highly unlikely based on the low likelihood of the evaluation basis event, credit for the existing IROFS, and conditional probabilities of explosion/criticality. The staff will validate this assumptions during the TI inspection.

Regarding the third recommendation, the evaluation of the storage area roofs by GNF-A identified deficiencies associated with the anchoring of its supports. GNF-A stated that if these supports were to fail the roof could fall onto the conveyors below. Based on the construction/weight of the roofing and the robustness of the storage conveyors this is not expected to cause a consequence of concern. The seismic performance of the storage conveyors themselves was determined to be acceptable. Accident sequences resulting from boat storage conveyor collapses as a result of the seismic evaluation basis event are therefore considered highly unlikely. The staff will validate this assumptions during the TI inspection.

<u>Staff Evaluation of Equipment and CMU Walls</u>

The staff reviewed the evaluation of the equipment and CMU walls in the FMO, FMOX, and DCP buildings. The staff agrees that the types and locations of CMU walls evaluated represent the bounding cases of the CMU walls in these buildings. The staff agrees with the use of the seismic criteria from the IBC-2015 and ASCE 7-10 as an acceptable methodology for the seismic evaluation of selected equipment at the GNF-A facility. The staff further notes that the use of the equivalent lateral force procedure is an acceptable method to obtain seismic load as a percentage of weight for the equipment. Based on these reviews, the staff concludes that

GNF-A has adequately modeled and analyzed the equipment and CMU walls under design basis seismic motion.

2.1.3 Seismically Induced Chemical Consequences

GNF-A evaluated the potential for acute chemical exposure impacts due to NPH at the GNF site. The evaluation focused on chemical hazards under NRC regulatory jurisdiction. Section 2.2.3.2 of the 2016 ISA Summary summarized information from the report titled "Natural Phenomena Hazard Screening, Definition, and Evaluation," CALC 900-007 dated January 28, 2016 (ADAMS Accession No.: ML16288A778). GNF-A examined the potential for UF_6/HF releases from DCP (nodes 201/202) for the evaluation basis seismic event with a frequency of 2.1E-3 events/yr. GNFA report CALC 900-007 (Section 7.1.2) summarized the detailed analysis in several reports and concluded that UF_6 equipment and piping within DCP would not be damaged (i.e., no UF_6 release) for the evaluation basis seismic event. The evaluation included consideration of masonry walls within the DCP. GNF-A discussion in ISA Section 2.2.3.2 concluded that seismic initiated UF_6 releases that would result in intermediate or high consequences were highly unlikely.

GNF examined to potential for high winds (hurricanes/tornados) to produce high consequence from the release of hazardous materials in the buildings. GNF noted the historical hurricanes that have occurred in the Wilmington area, the slow-developing nature of such events which allows for protective measures (e.g., shut down processes) as well as the ability of the buildings to withstand 200 year wind gusts. GNF-A also examined the likelihood of tornado wind gusts in the Wilmington area and the ability of the building to withstand such gusts. GNF concluded in Section 2.2.3.1 of the ISA Summary that no intermediate or high consequence events would be initiated by structural failure of site buildings due to evaluation basis wind events. This includes chemical exposure events.

Based on the staff's evaluation of both the likelihood and consequences for both seismically-initiated chemical releases, the staff concludes that the risk of acute chemical exposure from natural phenomena events is adequately mitigated. The staff will inspect samples of chemical accident sequences during the implementation of TI inspection to validate that the assumptions used for seismic initiating events.

2.1.4 Seismically Induced Criticality Consequences

As stated in CALC-900-007, earthquakes at GNF-A are not a major concern because this is an area of "relatively low seismic activity." Most building structures are expected to survive at the 2 percent in 50 year level, corresponding to a failure rate of ~4E-4/yr, though some internal block walls will only survive at 10 percent in 50 years, or 2E-3/yr. Criticality is considered a high-consequence event and therefore required to be prevented to "highly unlikely" in accordance with 10 CFR 70.61(b), which the licensee defines as 1E-4/yr. Unlike other hazards, the occurrence of an accidental criticality is required to be prevented regardless of whether radiation doses to an individual may be incurred (under 10 CFR 70.61[d]). Such doses cannot be ruled out in the event of a seismic-induced earthquake, because earthquakes occur without warning, and the onset of criticality can be essentially instantaneous. Mitigation for such events is therefore not practical.

Therefore, meeting the performance requirements of 10 CFR 70.61 for criticality requires that the conditional probability of criticality in the event of an earthquake must be less than 0.25 for structures performing at the 4E-4/yr likelihood (i.e., surviving a 2475-year earthquake), and less than 0.05 for structures performing at the 2E-3/yr likelihood (surviving a 475-year earthquake). The form and nature of the licensed material, and nature of licensed activities, ensures that even in the event of an earthquake, accidental criticality is unlikely. GNF-A processes low-enriched uranium (LEU) up to 5wt percent ^{235}U. This material must be assembled together into a compact configuration and sufficiently moderated and/or reflected. Earthquakes and other natural phenomena tend to disperse rather than collect material together, rendering a compact arrangement at least unlikely. Moreover, LEU enriched to 5wt percent ^{235}U cannot sustain criticality without the addition of significant moderator. Most of the processing of Special Nuclear Material at GNF-A is dry, such as in the dry conversion process and fuel fabrication processes. While sources of moderator exist, sufficient moderator is not intimately mixed with the uranium under normal conditions, and an earthquake does not generally introduce large quantities of moderator into the process. The possibility that an earthquake could result in a concurrent loss of piping or tank containment must be considered, but ruptures, leaks, and spills of liquid-bearing equipment are considered routinely in criticality evaluations. Only in moderation-restricted areas are these such events of concern; in those areas, engineered and administrative measures (e.g., double roof, restriction on water piping) are in place to limits available quantities of moderators. Based on the foregoing considerations, the conditional probability of achieving a sufficient combination of geometry, moderation, and reflection to attain criticality is qualitatively judged to be very low.

CALC-900-007 contains a list of process nodes evaluated for the risk of criticality in Table 5.1-1. Table A-1 in Appendix A contains more detailed results of the seismic screening, and identified several nodes in which seismic-induced criticality could not be ruled out. Criticality hazards resulted from falling block walls, falling overhead equipment, equipment instability, and/or breach of containment. Specific components identified as being of concern were identified in Section 7.1.2. They consisted of flammable gas lines, block walls, and the UO_2 boat storage cover, which were identified in Table 7.1-1 by process node along with technical references supporting their evaluation. The staff's review of these areas is discussed below.

Nodes 401 & 503, "UO_2 Press" and "Gad Press"

Hazards discussed in Table A-1 of CALC-900-007 consist of dropping of pellet boats and a spill from the press feed tubes along with concurrent loss of moderator. Spilling a few pellet boats is not a concern, because pellets will tend to roll and scatter rather than collect together, leading to a less reactive configuration than in the boats. In addition, there must be a concurrent loss of moderator, which would have to be mixed with the pellets. Due to their physical characteristics, any liquid that would pool around the spilled pellets would tend to drain away.

Scenarios involving spills from the press feed tubes were previously considered in the follow-up to Event Notification EN 48076. During follow-up to this event, the licensee identified a previously unanalyzed scenario in which a lube oil fire could both melt the Tygon gad press feed tube and cause concurrent sprinkler activation, resulting in a common-mode failure of geometry and moderation control. While the scenario identified was induced by a fire, an earthquake could cause a similar failure of both geometry and moderator control.

The licensee's seismic evaluation of the UO_2 and gad powder presses is contained in Atkins-TR-GNF-2015-01, "Seismic Evaluation of Equipment for Global Nuclear Fuels-America." The evaluation uses pseudo-static earthquake analysis methods, in which equipment is treated as a rigid body for the purpose of evaluating its stability against overturning and sliding. To evaluate overturning, the press is fixed at one end and the moments acting on the body during a seismic event are calculated. To evaluate sliding, the press is assumed not to be anchored down and a conservative coefficient of friction is used. This shows that the presses are stable against both overturning and sliding, with margin. Staff notes the evaluation conservatively assumes that the presses are rigid bodies and neglects their anchorage. In addition, the evaluation determined the maximum horizontal displacement for the feed tube, using the peak spectral acceleration at a frequency appropriate to a damped oscillator representing the press. This simple model led to a maximum displacement of 0.09 inches. The Tygon tubing is flexible, and this displacement is determined not to unduly stress the tubing connections so as to lead to a loss of containment. The staff also notes that, as in the fire scenario discussed above, the amount of uranium in the feed tube is limited by a rotary valve interlocked to a level sensor to less than 36 kg of UO_2. In response to the event, the mass controls on the process were enhanced. Although this slightly exceeds a minimum critical mass of UO_2, it is sufficiently small that nearly optimal conditions (e.g., nearly spherical geometry, nearly optimal moderation, nearly full reflection) would still be needed to attain criticality. The likelihood of achieving these conditions by chance in a seismic event is very low. While the likelihood has not been quantified, the conditional likelihood of this is judged to be sufficiently low to ensure that such a scenario is at least "highly unlikely."

Node 405, "UO_2 Sinter"

Hazards of concern in the UO_2 sintering area include both an explosion resulting from a break in flammable gas lines (natural gas and/or hydrogen) and falling of overhead equipment onto pellet boat storage containers. With regard to flammable gas lines, an explosion is a highly energetic event that tends to disperse, rather than collect, licensed material. A fire could induce sprinkler activation, but the pellets would tend to scatter and would not hold up liquid water. Staff also notes that the licensee's ISA evaluates natural gas and hydrogen explosions not resulting from an earthquake. Scenario 5.11.5.12, involving a natural gas explosion in the Fuel Manufacturing Operation, assumes an initiating event of 3.3E-2/yr, which exceeds that of either the 500- or 2500-year earthquake by more than an order of magnitude. The conditional probability of an explosion in the event of a leak—or exceeding the lower flammability limit—is taken as 0.01. The IROFS consist of a restriction on the natural gas flow rate (IROFS 405-18), natural gas line inspections and surveys (IROFS 405-19 and 405-20), and natural gas leak detection and response (IROFS 900-18). Staff only considers the flow rate restriction to be reliable in the event of a seismic-induced leak. The inspections and surveys are management measures to detect chronic leaks, not the acute leak caused by seismic stresses on gas piping, and leak detection and response is an administrative control that cannot be relied on in an earthquake due to the likely confusion and evacuation of the facility. However, the staff determined that the combination of the earthquake initiating event frequency, the likelihood of a resulting explosion, the presence of the flow restriction, and the conditional probability needed to achieve a critical geometry with sufficient moderation and/or reflection, provides reasonable assurance that a seismic-induced criticality is "highly unlikely." Similar considerations would apply for a seismic-induced hydrogen leak.

The licensee's seismic evaluation indicates that the roof over the UO_2 pellet boats could fail, resulting in a loss of geometry control over the pellet boat conveyors. Upon further evaluation, the licensee determined this to not be of concern due to the roof weight and robustness of the pellet boat covers. The staff considers that even if several boats were overturned, the pellets would tend to roll and scatter, rather than collect together, reducing reactivity. Moreover, the presence of substantial moderator would be needed before criticality is possible. This scenario is therefore not of concern.

Nodes 801 & 802, "Auxiliary Operations"

Hazards of concern include the impact of falling block walls onto the dry storage conveyors, wet storage conveyors, and scrap pack floor storage. These areas consist of sealed containers in a single layer on either conveyors or on the floor, with spacing between containers controlled to ensure subcriticality. Similar considerations apply as for the pellet boat conveyors in Node 405, except that the containers are sealed and would not necessarily spill their contents if impacted by the falling masonry walls. Individual containers are designed so that no single spacing upset can lead to criticality. Moreover, because of the relative ease with which administrative spacing upsets can occur, storage arrays are generally designed with substantial safety margin so that a large number of containers would have to be stacked together before criticality is possible. Thus in general, criticality would require either the stacking together large numbers of containers or the breach of multiple containers and collection of their contents into a pile. If they contained dry material, subsequent moderation and/or reflection would also be needed. The stacking of multiple containers is very unlikely because of their normal storage configuration (i.e., a single layer, conservatively determined spacing between containers), and the tendency of individual containers to roll and scatter rather than collect together. The breach of a few containers has not been ruled out, but several containers would have to release their contents, which would then have to collect together. The impact from falling debris would have to be severe enough to breach multiple containers, but not sufficient to disperse the material significantly. While the likelihood of such a rearrangement of material and, for dry containers, subsequent moderation, has not been quantified, the staff's judgment is that it would be much less than the conditional probability of 0.05 needed to demonstrate that criticality is highly unlikely.

Spacing and moderation upsets for storage arrays are considered in the licensee's ISA. The staff reviewed several scenarios in Section 5.22 of the ISA Summary to determine if the above events were bounded by the licensee's analysis for non-seismically induced such scenarios. Scenario 5.22.2.3 involved the spill of substantial moderator onto dry storage conveyors. For conveyors with the most reactive geometry, double conveyors, criticality requires at least three overweight containers in close proximity. The initiating event is a significant overhead leak of water, which is conservatively assigned a frequency of 0.5/yr. The two IROFS on this sequence are IROFS 900-01, mass control on an individual container, assigned a probability of failure of 0.1, and IROFS 900-007, equipment barrier (container integrity credited for moderation), with a failure probability of 5E-5. This latter number is very low, but is arrived at by assuming 1E-3 for the first container, 0.1 for the second, and 0.5 for the third, since at least three containers are needed for criticality. While some of the conditional probabilities would not necessarily apply, this scenario has some applicability to both seismic and high wind (with roof damage) induced scenarios. For seismic, it must be recalled that the earthquake initiator was given an assigned frequency of 2E-3/yr (for the 475-year earthquake, which is needed for failure of the block wall). The block wall is assumed to fail for such an earthquake, even though the seismic evaluation indicates the performance of some block walls is "marginal" at that level. The block wall must fail and impact the storage containers, and concurrently cause a major pipe break. More than three containers (since at least three are needed if they are overfilled) must be pushed together and impacted sufficiently by falling debris that they allow this moderator to leak in. Even if very high probabilities are assigned to all these conditional events (i.e., block wall failure, pipe break, pushing more than 3 containers together, breaching each container, etc.), the combination of events is such that criticality would be highly unlikely.

The staff also considered Scenario 5.22.2.6, involving spill of moderator onto a wet conveyor. This is similar to the dry conveyor scenario discussed above. Less excess moderator is needed than in the dry case, but the container and storage array geometry (ensured by passive design of the conveyors) is more conservative. Scenario 5.22.2.5 involves several cans falling off the wet conveyor. This assigns a frequency of 1E-3/yr to the conveyor collapse, and credits mass control and container integrity in showing that criticality is highly unlikely. The initiating event frequency is a factor of 2 lower than the seismic frequency of 2E-3/yr, but there are uncredited factors of safety, including that the cans must be pushed or piled together once they fall off the conveyor.

These scenarios illustrate several facts about seismic-induced criticality generally. First, the licensee's processes, and particularly storage arrays, are designed with substantial margins of safety, and it is very unlikely that a much more reactive rearrangement of geometry would come about accidentally from the chaotic and randomizing nature of an earthquake. Earthquakes and other violent phenomena, tend to disperse rather than gather material, which generally results in a less reactive configuration. Second, accident scenarios resulting in similar conditions to those that could (but are unlikely to) result from an earthquake have generally been considered in the ISA and shown to be highly unlikely. Third, while not all the controls on such sequences may be applicable to the seismically induced event, the corresponding seismic sequence starts from an initiating event that is already very unlikely. The existing non-seismically induced sequences may not bound the seismic sequence, but may be similar enough that some combination of the credited controls and other conditional events is sufficient to demonstrate that criticality is highly unlikely.

Additional Criticality Scenarios

Besides those discussed above, Table A-1 of CALC-900-007 contains several nodes for which the seismic screening indicated that further evaluation was needed. Similar considerations to those discussed above generally apply. In all cases, seismically induced criticality requires the material gathered together in a compact geometry, with sufficient moderation and/or reflection. Because most of GNF-A's processes are dry, concerns about spills of solutions into unfavorable geometry do not arise, and introduction of moderator is an additional conditional event that must occur. Therefore, based on the licensee's seismic evaluation, and analysis of similar scenarios in the ISA, the staff has reasonable assurance that seismically induced criticality at GNF-A is highly unlikely.

2.1.5 Seismic Induced Fire Consequences

In its response to NRC GL 2015-01, GNF-A analyzed the fire consequences from a natural phenomenon event. The staff reviewed the licensee's submittal and ISA summary and concludes that the accident sequences analyzed in the ISA and the resulting consequences bound a natural phenomenon event that may occur at the facility.

The staff reviewed the licensee's ISA summary to see if any accident scenarios could be pushed outside the bounds of the performance requirements in 10 CFR 70.61. The licensee analyzed the building structure and internal components and the facility is expected to withstand the seismic loading of a natural phenomenon event. Therefore, the performance requirements are not expected to be exceeded during a seismic event. The one exception is the piping within the UO_2 furnace room. The piping supports in the UO_2 furnace room are not expected to survive the potential seismic loading in the event of an earthquake. A natural gas leak in the furnace room is an accident scenario considered in the ISA. Even if the piping support does fail during a seismic event, the performance requirements are not expected to be exceeded due to other IROFS in place, such as gas flow restrictions and detectors. The staff will validate this assumptions during the TI inspection.

After reviewing the licensee submittal and ISA summary, the staff finds that the evaluation of seismic induced fire consequences is adequate.

2.2 <u>High Winds</u>

In its 2016 ISA Site Summary, GNF-A discusses the initiating event frequency of high wind NPH such as tornadoes, hurricanes, and tropical storms. Specifically, the 2016 ISA Site Summary discusses historical wind speeds, hurricane, and tornado activity in Wilmington, NC. CALC-900-007 contained an evaluation of hurricane statistics. The licensee determined that since 1851 there were nine major hurricanes within 100 nautical miles of Wilmington. A major hurricane was determined to be a Category 3 or higher on the Saffir-Simpson scale, which was qualitatively judged to have the potential to cause structural damage to facility buildings. This produces a return period of 17 years for a major hurricane. The FMO/FMOX roof was recently refurbished to Factory Mutual requirements. There is also a secondary roof for moderation control. The licensee assumed a 200-year return period for a hurricane severe enough to cause significant roof damage.

GNF-A evaluated the buildings using the ASCE 7-05 and ASCE 7-10 wind requirements. Due to the design of the building and its capability to withstand the wind loads without damage, GNF-A concluded that it is highly unlikely that high winds from hurricanes or tropical storms would result in failures of the building structure, causing a release of hazardous material. Furthermore, GNF-A states that with advanced warning of a hurricane or tropical storm, operations will be shut down and other protective measures will be implemented. Based on these factors, GNF-A further concluded that there are no additional accident sequences from hurricanes or tropical storms to consider and, therefore, there are no additional IROFS to apply.

For tornadoes, GNF-A estimated the wind speed of a highly unlikely (1E-4 event/year) tornado strike at the site using NUREG/CR-4461. The resulting wind speed was 93 mph. Given that this wind speed is significantly lower than that of the design evaluation, GNF-A concluded that tornado induced accident sequences are highly unlikely, and therefore, there are no additional IROFS to apply.

The staff evaluated GNF-A's approach for considering high wind and tornado induced events within its ISA and the methodologies applied to determine likelihoods, consequences, and IROFS. With respect to determining likelihood, the staff reviewed GNF-A's likelihood estimation of a tornado strike and the wind speed data from other high wind events. As previously mentioned, according to GNF-A's likelihood definitions, GNF-A designated the likelihood of a tornado strike at GNF-A as "highly unlikely." Based on the tornado strike probabilities in Appendices A, B, and C of NUREG-CR/4461, Revision 2, the staff agrees that a tornado strike at GNF-A is highly unlikely and, therefore, agrees that GNF-A's approach to classify the likelihood of tornado events based on the definitions established within its ISA methodology is adequate.

In reference to hurricanes and tropical storms, the updated 2016 ISA Summary states that the evaluation wind speed has an estimated return period of 200 years or frequency of 5E-3 event/year. According to GNF-A's definition of likelihood, this event would be considered unlikely. Because GNF-A did not identify any new accident sequences or IROFS, the staff could not evaluate methodologies used to determine consequences or IROFS for accident sequences from high wind events. However, the staff reviewed the design basis for wind speeds in the associated building codes and agrees that, assuming the protective measures (e.g. shut down operations) GNF-A implements are adequate, damage as a result of high winds from hurricanes, tropical storms or tornadoes is highly unlikely. During the temporary inspection, the staff will further evaluate the protective measures and GNF-A's conclusion that there are no new accident sequences or IROFS to consider.

Wind-Induced Criticality Consequences

High wind, primarily from a hurricane, is one of the dominant NPH for criticality at GNF-A. This is due to the site's proximity to the southern Atlantic coast of the United States and the low seismic risk. The main concern is the possibility of siding and roof damage along with a substantial rainfall impacting bulk quantities of UO_2 powder in MRAs. The storm surge from a hurricane is discussed in Section 2.4 below. The licensee analyzed the potential for a wind-induced criticality in CALC-900-007.

Roof leaks are considered in the ISA. For example, Scenario 5.16.3.6 considers an initiating event frequency for a primary roof leak of 1E-1/yr, which is reasonable given small leaks that occur routinely. The MRA requirements are credited with a probability of failure of 1E-2. These consist of both passive and administrative requirements, but only the secondary roof is applicable to the hurricane-induced scenario. Passive equipment barriers are credited with for an additional 1E-2. This bounds the hurricane-induced scenario, which has a lower initiating event frequency (5E-3/yr), and also can take credit for the secondary roof and passive barriers.

Therefore, the staff has reasonable assurance that the scenario in which a hurricane causes roof damage that can lead to moderating licensed material in an MRA is highly unlikely.

Additional material at risk exists in storage locations in the 421 Warehouse and near the outside walls of the FMO/FMOX building. GNF-A stated that outside storage of licensed material is no longer used. GNF-A assumed a return period of 20 years (initiating event frequency of 2E-2/yr) for a hurricane capable of stripping siding off buildings. Each individual storage container is of safe volume, so the likelihood of breaching and moderating two or more containers was taken as 1E-2, with an additional 1E-1 likelihood for pushing the containers together into an unsafe configuration. Based on the initiating event frequency, container integrity, and storage array spacing controls, the staff has reasonable assurance that criticality in storage containers that are moderated following loss of siding is highly unlikely.

The other wind hazard to be considered is a tornado. GNF-A used the guidance in DOE-STD-1020-2002, “Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities,” in evaluating the impact of windborne missiles. The criterion for windborne missiles for Performance Category PC-3 is a 15-lb 2x4 lofted to 30 feet. Staff considered that a PC-3 seismic event has a 2000-year return period; assuming a comparable likelihood to other natural phenomena results in a frequency for the occurrence of such a windborne missile of about 5E-4/yr. The missile is then postulated to impact storage containers situated 20 feet inside the building. Taking the cross-sectional area of a 55-gallon drum (nominally 22.5” in diameter and 33.5” in height) divided by the area of a sphere of 20 feet radius produces a conditional probability of impact of ~1E-3. Even if the initiating event frequency is somewhat higher than for other (seismic) hazards, the likelihood of a tornado missile impacting a storage container inside the building is highly unlikely. Similar considerations to those for a hurricane also apply (e.g., likelihood of breaching the container, getting rainwater inside it, and pushing multiple containers together), further reducing the likelihood below what has been credited. Therefore, based on the low initiating event frequency, building structure and other passive barriers, container integrity, and conditional probabilities for rearranging and moderating the material, the staff has reasonable assurance that criticality from high winds and rain will be highly unlikely.

2.4 Flooding, Rain Snow and Ice

Similar to its approach for considering seismic activity and high winds in its ISA, GNF-A analyzed the potential hazards from floods, rain, snow, and ice.

For floods, GNF-A states in its updated 2016 ISA Summary that the ground floors of the main buildings are situated at least 20 feet above the 500-year floodplain. The updated 2016 ISA Summary further states that the slow-developing nature of a flooding event would allow for the implementation of protective measures. Therefore, GNF-A determined that no further evaluation was needed to conclude that flood induced accident sequences are highly unlikely. With respect to ice, the updated 2016 ISA Summary states that although ice may cause the loss of power, no accident sequences with intermediate or high consequence can be initiated from a loss of power.

GNF-A considered loads from rain, snow and ice that could potentially compromise the integrity of storage area building roofs and result in a criticality accident sequence initiated by uncontrolled moderator bypassing a failed roof structure. GNF-A reviewed historical rainfall data for the Wilmington area and noted that the four of the highest rainfall events occurred while GNF-A was in operation. The roofs are sloped appropriately to ensure that rainwater runs off and does not accumulate and create a load. GNF-A noted that some roofs do have some internal drains that can overflow, directing excess rainwater over the roof edges. As such, some minimal ponding can occur around the internal drains and other depressions in the roof surface. GNF-A determined that 11 snow fall events of greater than 6” have occurred in the Wilmington, NC area since 1870. Using ASCE 7-05, GNF-A estimated that the 50-year ground snow or ice load event is approximately 7 pounds per square foot (psf). Furthermore, GNF-A noted per ASCE 7-05 that the storage area roofs can withstand a 20 psf snow or ice load. Similar to the hurricane assessment, GNF-A would shut down processes in anticipation of a severe snow or ice storm. Given the expected snow or ice load of 7 psf and the ability of the storage area roofs to withstand an expected 20 psf, GNF-A determined that high consequence events initiated by a rain, snow, or ice load are *highly unlikely*.

The staff reviewed the floodplain data to confirm the potential flood levels. The staff noted that GNF-A reviewed the appropriate historical data to support estimating potential roof loads from rain, snow, or ice. Although Wilmington, NC does experience heavy rain fall events, the storage area roofs are designed such that they do not accumulate water to develop a significant load. In addition, the expected snow and ice loads over a 50-year recurrence period are about 7 psf and the roofs are capable of withstanding 20 psf, which is sufficient margin. The staff agreed with GNF-A's approach in shutting down facility processes in anticipation for a severe snow or ice storm since transportation to and from the site would be challenging and the facility would be in a safe condition operationally. Based on the storage area roofs to withstand expected rain, snow, or ice loads, the staff concluded that any high consequence event involving a criticality accident sequence initiated by a roof collapse from a rain, snow, or ice load is *highly unlikely*.

Based on the evaluation of buildings and assuming the IROFS and protective measures GNF-A implements are adequate, the staff agrees that GNF-A considered other NPH in its ISA. During the temporary inspection, the staff will further evaluate the protective measures and GNF-A's conclusion that there are no new accident sequences or IROFS to consider.

Flooding-Induced Criticality Consequences

The presence of large quantities of dry uncontained SNM (e.g., UO_2 powder) at GNF-A, which rely primarily on moderator control, necessitates that flooding be considered as a hazard with the potential to lead to criticality. Large portions of the process buildings are designated as MRAs, with passive and administrative barriers to prevent the intrusion of internal and external moderation—from sources such as pipe breaks and roof leaks—from coming into contact with licensed materials. These barriers (particular those that are administrative) may not be effective in the event of a massive external flood. For example, a prohibition on liquid-bearing containers is not applicable to the flood scenario, and a roof leak will not prevent flood levels from rising on the floor. Features such as sloped floors, dikes, and drains, may assist in a small flood, but could be overwhelmed by a massive deluge. Flooding has the potential to moderate bulk powders if allowed to intimately mix, to provide interstitial moderation in arrays and reflection to individual containers and equipment, and to rearrange material into a more reactive configuration. Most licensed material is stored well above the floor level, though there is some floor storage, and thus would need a flood significantly above grade before it could mix with licensed material. Interstitial moderation and full reflection would only be a concern in MRAs, as it would have to be considered as part of normal conditions in other areas. Moreover, where bulk quantities of uncontained material are present, passive barriers (e.g., equipment and container integrity) are part of the control scheme to protect the material from moderator intrusion. If floodwaters were to leak into unfavorable geometry equipment with more than a critical mass, criticality could result. If they were to wash the material out, it would tend to disperse rather than collect it together, though some risk of criticality in the transient and intermediate state would remain. The main focus therefore is in evaluating whether floodwaters can rise to a level that could bring it into contact with licensed material.

As stated in CALC-900-007, the main sources of flooding that are postulated are river floods, excessive rainwater, and hurricane storm surge (other effects of hurricanes being discussed in the following section). The site topography is such that GNF-A sits on high ground relative to its surroundings, which provide for natural drainage. The nearest river is the NE Cape Fear River, which sits about a mile to the southwest, which flows into the Cape Fear River and ultimately the Atlantic Ocean. There are no nearby dams whose failures could lead to significant flooding. CALC-900-007 indicates the 500-year flood is at 14 feet above mean sea level (AMSL), while most of the site ranges from 34 to 43 feet AMSL. The all-time record, which included both rain and storm surge, occurred after Hurricane Floyd in September 1999, and was 22.48 feet AMSL. Although the frequency of a 500-year flood is not sufficient to demonstrate that flooding the site would be "highly unlikely," the site sits substantially above the 500-year flood level (at least 20 additional feet). Due to the FMO/FMOX and DCP level on the site, and the fact that most of the licensed material is stored and processed at least several feet off the floor, a flood even higher than that needed to initiate site flooding would be needed to constitute a criticality concern. The licensee did not evaluate the likelihood of exceeding the 500-year flood by such a margin, but qualitatively judged it low enough to render flood-induced criticality highly unlikely.

The staff reviewed the topographical maps provided in Appendix B and independently verified the site elevation data (using USGS data and Google Earth). The available topographical information shows that the FMO/FMOX and DCP buildings site on high ground relative to the remainder of the site, which sits on high ground relative to its immediate surroundings, which provides for natural drainage. Moreover, the topography is such that it slopes steeply in places around the banks of the NE Cape Fear River, and slopes more gradually at higher elevation as the GNF-A site is approached. This means that with decreasing slope, every additional foot of flooding will require a correspondingly larger total volume of water. Thus, based on the nearly topography, a flood that reaches 28 feet AMSL, for example, requires more than twice as much water as was needed to reach 14 feet AMSL (the 500-year flood). Reaching the floor of the FMO/FMOX and DCP buildings requires a flood level at least three times higher than the 500-year flood, which would require substantially more than three times as much volume of water, due to topography and more drainage. The flood hazard curve has not been quantitatively determined for greater than the 500-year flood, but given that many times this volume of water would be needed to put the facility at risk of criticality, the staff has reasonable assurance that a flood-induced criticality is at least highly unlikely.

An additional consideration is that, although 10 CFR 70.61(d) requires criticality to be prevented regardless of the potential for dose, a flood is a slowly-developing condition and there would be substantial time to secure licensed material and evacuate the facility, further reducing the risk to workers and the public.

3.0 <u>NRC GL 2015-01 Requested Action (1)c</u>: For facilities subject to 10 CFR Part 70, Subpart H requirements, submit a description of the results of the ISA review used to comply with 10 CFR 70.62(c), identifying the characteristics of the licensing and design basis natural phenomena events applicable to the site, that evaluates possible changes in the methodology, likelihood, and severity of natural phenomena events with those used in the original design/evaluation of the facility.

GNF-A provided in its response to GL 2015-01 the seismic, wind, rain, and snow reassessment of the primary building structures. The facility was evaluated to determine which parts met the requirements of the applicable building code and NPH parameter, and for the parts of the facility that did not meet the current requirements, to identify their stress state and assess whether these members can still perform their original intended function. The analysis included an assessment of internal components.

The staff reviewed the seismic, high winds, and flooding analysis and the staff evaluation is included in Section III above. Based on the staff evaluation the staff finds that GNF-A has adequately responded to NRC GL 2015-01 Requested Action (1)c.

4.0 <u>NRC GL 2015-01 Requested Action (1)d</u>: Submit for staff review a summary of the results of any facility assessments or walkdowns, if performed, to identify and address degraded, nonconforming, or unanalyzed conditions that can affect the performance of the facility under natural phenomena and have available for NRC inspection the documentation of the qualifications of the team.

GNF-A stated in its response to GL 2015-01 that walkdowns were performed to verify the configuration of the structure as part of developing the analytic model used to assess seismic and wind loads on the facility. The results of the walkdowns were incorporated in the model to assess the performance of the primary building structures. Pictures showing typical details of the connections of the columns to truss, column to foundation slab, among others were included in the technical report.

The staff will inspect the bases, execution, and results of the above mentioned walkdowns during the implementation of TI 2600/016, "Inspection Activities Associated with NRC GL 2015-01," (ADAMS ML16293A899). Therefore, the staff finds that GNF-A has adequately responded to NRC GL 2015-01 Requested Action (1)d.

IV. Conclusion

On the basis of this evaluation, the staff finds that GNF-A adequately responded to Requested Actions (1)a through (1)d of GL 2015-01. The staff will perform an inspection using TI 2600/016 to independently verify that GNF-A is in compliance with the regulatory requirements and applicable license conditions regarding the treatment of NPH in its ISA. The results of these regulatory activities will allow the staff to verify GNF-A demonstrates compliance with regulatory requirements and applicable license conditions regarding the treatment of NPH's at the facility.