A. Fuel Loading Error (Mislocated or Misoriented Fuel Bundle Event)

A.1 Summary of Fuel Loading Error

GNF proposes a change in the way the analysis of the fuel loading error (FLE) is performed from that of an “incident of moderate frequency” (AOO) to that of an “infrequent incident.” This would result in the fuel loading error event being evaluated at 10% of 10CFR100 limits or 10% of 10CFR50.67 limits for Alternate Source Term (AST) plants. The analysis of the FLE as an infrequent incident is in conformance with Standard Review Plan 15.4.7 (Reference A.1). The AST doses were based on the methodology of Regulatory Guide 1.183 (Reference A.2).

Since 1978, the FLE has been analyzed as an AOO and, as such, the change in CPR for the event has been factored into the determination of the MCPR operating limit for each cycle. Section 6.3 of the GESTAR Rev 0 SER May 12, 1978 (Appendix C, Pg. US.C-4) describes the basis for this treatment of the FLE, which includes fuel-loading experience in that time period. In 1981, utilities began improving the procedures used for core verification following refueling. The fuel loading error rate for the recent 25-year period and the trend for the most recent 10 years of refueling outages support the classification of the FLE event as an “Infrequent Incident.”

The adverse consequences from an incident of a fuel loading error (either a mislocated fuel bundle or a misoriented fuel bundle) would be the failure of one or more fuel rods in a single fuel bundle that is operating in a higher–than–normal power range. The results of such an incident would be similar to a fuel bundle operating with one or more leaking fuel rods, “leakers.” However, the radiological consequences, even though minor, would be difficult to assess for each fuel bundle in the core for each operating cycle. Therefore, to provide a clearly bounding analysis for this event, it is assumed that all of the fuel rods in five fuel bundles experience instantaneous failure during normal operation.

The radiological consequences of failing all of the fuel rods in five fuel bundles has been analyzed for two different scenarios to provide results for different plant configurations: (1) those plants having a main steam line high radiation isolation trip, and (2) those plants without this trip where the release is treated by an augmented offgas system. Section A.5 summarizes the results for both scenarios, as well as the control room habitability dose consequences. Both scenarios as well as the control room study depend on the meterological dispersion coefficient (Chi/Q). The bounding analysis is applicable for any plant that has a Chi/Q less than the limiting value. For the second scenario, the radiological consequences also depend upon the plants’ offgas system capability and hold-up time for krypton and xenon.

No other adverse consequences will result from a fuel loading error as shown in Section A.5.

Therefore, the FLE event can be analyzed as an infrequent incident in accordance with SRP 15.4.7. Plants applying the infrequent incident analysis basis must confirm that the plant specific parameters are within the limits of the generic analysis. The requirement to apply the infrequent incident basis, i.e., the core verification characteristics, will be confirmed during the reload design process. This will be documented in the supplemental reload licensing report.

GESTAR II Amendment 28 provides page changes to GESTAR II and its U. S. Supplement (Reference A.3) to reflect this classification of the fuel loading error event.

A.2 Fuel Loading Error Event Description

The event discussed in this report is the improper loading of a fuel bundle and subsequent operation of the core. Two types of fuel loading errors are possible, the mislocation of a fuel assembly and the misorientation of a fuel assembly. Three errors must occur for the mislocation event to take place. First, a bundle must be misloaded into a wrong position in the core. Second, the bundle that was supposed to be loaded where the mislocation occurred would have to be overlooked and also be placed in an incorrect location. Third, both misplaced bundles would have to be overlooked during the core verification performed following core loading. For the misorientation event, two errors must take place. First, the assembly must be rotated while being lowered into position. Second, the misoriented bundle would have to be overlooked during the core verification performed following core loading.

Both the mislocated and the misoriented fuel bundle events are referred to as the fuel loading error event here for the purposes of discussion. For a fuel loading error event, it is assumed that the improper loading of a fuel assembly is not discovered and corrected through the core verification program, and the plant is operated throughout the operating cycle assuming that the design core configuration has been correctly implemented.

There is a possibility that the core monitoring system will recognize the FLE, thereby allowing the reactor operators to mitigate the consequences. However, it is assumed that the FLE is not detected and that fuel rods operate above the thermal and mechanical limits. The potential exists that one or more fuel rods will experience cladding failure. If this were to occur, the adverse consequences are detectable and can be suppressed during operation similar to leaking fuel rods resulting from other failure mechanisms. For the FLE, the initial adverse consequences would consist of perforation of a small number of fuel rods in the assembly. Any perforations in the fuel cladding that may occur would be localized and not propagate to other assemblies. A control rod inserted in the vicinity of the leaking fuel rod(s) would suppress the power in the leaking fuel rod(s) and reduce the fission product release and the offgas activity.

A.3 Event Classification and Rational for the Fuel Loading Error Event

A.3.1 Regulatory Guidance

The fuel loading error event is that incident listed in Table 15–1 of Regulatory Guide 1.70, *Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants*. It comes under the general heading of Section 4 – "Reactivity and Power Distribution Anomalies" and the specific heading of Section 4.7 – "Inadvertent loading and operation of a fuel assembly in an improper position." General Design Criterion 10 requires that "...systems shall be designed with appropriate margin to assure that specified acceptable fuel design limits are not exceeded during normal operation, including the effects of Anticipated Operational Occurrences (AOOs)." NUREG–0800, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants* describes the basis and acceptance criteria by which the USNRC evaluates events such as the fuel loading error event. NUREG–0800 is general and applies to all light water reactor designs. The NUREG–0800 Standard Review Plan for Section 15.4.7, "Inadvertent Loading and Operation of a Fuel Assembly in an Improper Position," lists two acceptance criteria:

1. To meet the requirements of GDC 13, plant operating procedures should include a provision requiring that reactor instrumentation be used to search for potential fuel loading errors after fueling operations.
2. In the event the error is not detectable by the instrumentation system and fuel rod failure limits could be exceeded during normal operation, the offsite consequences should be a small fraction of the 10 CFR Part 100 guidelines.

The requirements as applied by GNF have been specified in GESTAR II. GESTAR II describes the methodology and acceptance criteria to show that the outcome of events shown in Regulatory Guide 1.70 is acceptable as applied to BWRs. The unacceptable safety results for infrequent incidents (unexpected operational occurrences) listed in GESTAR (referred to herein as criteria) are as follows:

1. Release of radioactivity which results in dose consequences that exceed a small fraction (10%) of 10CFR100 or 10% of 10CFR50.67 for AST plants;
2. Failure of fuel cladding which could cause changes in core geometry such that core cooling would be inhibited;
3. Generation of a condition that results in consequential loss of function of the reactor coolant system;
4. Generation of a condition that results in a consequential loss of function of a necessary containment barrier; and
5. Nuclear system stresses in excess of those allowed for the accident classification by applicable industry codes.

A.3.2 Fuel Loading Error Event Acceptance Criteria

For plants applying the "Infrequent Incident" basis for the fuel loading error event, avoidance of unacceptable results criteria 1 and 2 is ensured primarily by showing that failing all of the rods in a five-bundle array does not exceed 10% of 10CFR100 (or 10% of 10CFR50.67) offsite dose requirements.

The fuel loading error may cause the operating mechanical LHGR limit to be exceeded, because it may have worse peaking than the normally–loaded bundle. If the fuel loading error operates above the operating mechanical LHGR limit, one or more rods may approach the design limit and experience cladding failure. If this were to occur, the adverse consequences would be the perforation of a small number of fuel rods in the misplaced bundle. The subsequent release of fission products to the reactor coolant would be detected by the offgas system.

For plants meeting the offgas system design and atmospheric dispersion coefficient basis, the dose for failure of all rods in a five–bundle cell (the number or array of the fuel rods does not matter) does not exceed 10% of 10CFR100 (or 10% of 10CFR50.67) offsite dose requirements.

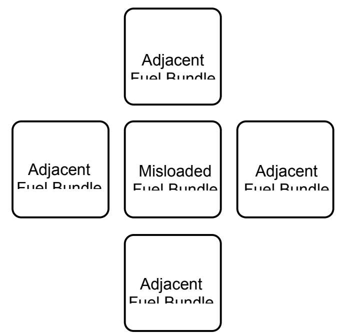
Therefore, avoidance of unacceptable results related to infrequent incidents acceptance criteria 1 and 2 listed in Section A.3.1 are achieved.

The fuel loading error event is not a limiting event for infrequent incidents acceptance criteria 3, 4 or 5, because the reactor remains at normal operating pressure throughout the event, there is no challenge to the RPV and primary systems, such as process barrier stress limitations, ensuring compliance with criteria 3 and 5. Since SRVs do not open in this event, the containment also remains at normal operating pressure and temperature, ensuring compliance with criterion 4.

A.4 Fuel Loading Error Event Bounding Radiological Analysis

Analytical methods used to demonstrate that fuel loading error event meets the acceptance criteria requirements discussed in Section A.3.2 are summarized in Attachment B.

For a very conservative approach for the reactor core, a fuel loading error residing in a cell can be considered. Instead of one or two rods failing, for dose evaluation, it was assumed that all the fuel rods in a mislocated fuel assembly or a misoriented fuel assembly and all the rods in the four adjacent fuel assemblies experience instantaneous failure during normal operation. (See the included figure)



To further assure that the fuel bundles containing the maximum fission products for release are included, all five bundles (array independent) are multiplied by:

1. A factor of 1.4 to account for variations in fission product inventory over the operational cycle; and
2. A second factor of 2.5 to account for variations in cycle–dependent bundle power as a ratio to the end of cycle average bundle power.

This results in a total factor of $1.4 \times 2.5 = 3.5$ to bound the bundle end of cycle inventory.

A.5 Fuel Loading Error Event Results and Conclusion

This section presents the scenarios that were evaluated, the results of the fuel loading error event analysis, and how the acceptance criteria discussed in Section A.3.2 are met. The radiological consequences of failing all of the fuel rods in five fuel bundles has been analyzed for two scenarios to provide results for different plant configurations: (1) those plants having a main steam line high radiation isolation trip, and (2) those plants without this isolation trip where the release is treated by an augmented offgas system.

The radiological consequences of failing all of the fuel rods in five fuel bundles for the first scenario, plants having a main steam line high radiation isolation trip, show the results to be:

10CFR100			10CFR50.67		
Scenario 1	**Analysis Results**	**Limit (10% of 10CFR100)**		**Analysis Results**	**Limit (10% of 10CFR50.67)**
Chi/Q = 1.67×10^{-3} s/m^3			Chi/Q = 5.04×10^{-3} s/m^3		
Whole body	0.6 Rem	2.5 Rem	TEDE	2.5	2.5
Thyroid	30 Rem	30.0 Rem			

For each radiological basis, the limiting 2-hour Chi/Q value at the exclusion area boundary (EAB) is shown in the table. Any dispersion coefficient less than this value will result in a smaller dose.

For the second scenario, for plants not having a main steam line high radiation trip, the radiological consequences are dependent upon the plants' offgas system capability, hold-up time for krypton and xenon, and meterological dispersion coefficient (Chi/Q). As a specific example, low temperature offgas systems supplied by GE provide minimum decay times of 46 hours for krypton and 42 days for xenon, with the relatively high design basis air inleakage rate of 30 cubic feet per minute. For these decay times, the doses corresponding to 100% release from Figures B-2 and B-3 for the limiting 2-hour Chi/Q value at the EAB of 3×10^{-4} are approximately 1.6×10^{-3} and 7.9×10^{-3} for krypton and xenon, respectively. Summing these doses results in an approximate total of 9.5×10^{-3} Rem, which is much less than the 2.5 Rem whole body dose limit based on 10% of 10CFR100. In a similar fashion, Figures B-5 and B-6 are used to determine the TEDE dose for the 10CFR50.67 AST based plants.

For control room habitability on a Non-AST basis, the thyroid dose was found to be the limiting dose for a control room operator from the assumed failure of the fuel rods in five fuel bundles. The 30 Rem thyroid regulatory accident dose limit is reached with an atmospheric dispersion factor of 1.81×10^{-3} s/m^3 (See Figure B-7). Chi/Q dispersion values less than 1.81×10^{-3} s/m^3 will result in a thyroid dose below the 30 Rem limit. For control room habitability on an AST basis, the 5.0 Rem TEDE regulatory accident dose limit is reached with an atmospheric dispersion factor of 1.25×10^{-2} s/m^3 (See Figure B-8).

Therefore, the fuel loading error event can be analyzed as an infrequent incident in accordance with SRP 15.4.7. The plant will provide specific parameters during the reload design process to be used to examine the applicability of the analysis and confirm that the plant specific results are within the limits.

For both plant configurations, the five criteria for infrequent incidents listed in Section A.3.1 are met for the fuel loading error event. The fuel loading error event was evaluated to meet the radioactive release limitations, as required. Compliance with criteria 1 and 2 is ensured primarily by showing that the dose from the failed rods is less than 10% of 10CFR100 (or 10% of 10CFR50.67). Because the reactor remains at normal operating pressure throughout the event, there is no challenge to the RPV and primary systems, such as process barrier stress limitations, ensuring compliance with criteria 3 and 5. Since no SRVs open, the containment also remains at normal operating pressure and temperature ensuring compliance with criterion 4.

A.6 References:

A.1. NUREG–0800, *Standard Review Plan*, Section 15.4.7, "Inadvertent Loading and Operation of a Fuel Assembly in an Improper Position," Draft Revision 2, April 1996.

A.2 Regulatory Guide 1.183, "Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Plants," July 2000.

A.3. *General Electric Standard Application for Reactor Fuel (GESTAR II)*, NEDE–24011–P–A–15, September 2005, and *General Electric Standard Application for Reactor Fuel (GESTAR II Supplement for United States)*, NEDE–24011–P–A–15–US, September 2005.