Edwin I. Hatch Nuclear Plant
Proposed Exemption to 10 CFR 50.46 and
10 CFR 50 Appendix K to Allow GNF-Ziron Fuel Cladding

Enclosure 3

GNF-0000-0079-7396NP, "Technical Basis Supporting GNF-Ziron Lead Test Assembly Introduction into the Hatch Nuclear Plant," March 2008
(Nonproprietary)

Global Nuclear Fuel

A Joint Venture of GE, Toshiba, & Hitachi

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Technical Basis Supporting GNF-Ziron Lead Test Assembly Introduction into the Hatch Nuclear Plant

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Technical Basis Supporting GNF-Ziron Lead Test Assembly Introduction into the Hatch Nuclear Plant

I. Purpose:

Southern Nuclear – Southern Company (SNC) and Global Nuclear Fuel (GNF) intend to establish an option for use of GNF-Ziron fuel cladding in the Edwin I. Hatch Nuclear Plant (Units 1 and 2). This document describes the licensing basis for using GNF-Ziron in Plant Hatch to obtain operating experience with GNF-Ziron cladding material. It is proposed that this operating experience be obtained through irradiation of two GE14 Lead Test Assemblies (LTAs) with selected rods (29 rods in each assembly) clad with GNF-Ziron up to the GE14 licensed [[ ]] The NRC has previously approved (ML082950149) exemption to cladding-specific requirements of 10 CFR 50.46, and 10 CFR 50 Appendix K requirements for operation of the LTAs in Plant Hatch Unit 2 during Cycles 21, 22, and 23. The LTAs will have completed operation in Plant Hatch Unit 2 during Cycles 21 and 22 by February 2013, but these LTAs are not planned to be in operation during Cycle 23. Instead, SNC intends to continue irradiating these LTAs for one or more additional cycles in Unit 1 or Unit 2 of the Edwin I. Hatch Nuclear Plant. The purpose of this document is to provide the technical bases to support SNC's request for exemption to cladding-specific requirements of 10 CFR 50.46, and 10 CFR 50 Appendix K for operation of the LTAs up to the peak pellet exposure limit. In addition, this document also discusses the licensing approach to meeting the requirement in Reference 1 that lead test assemblies be analyzed with approved methods.

II. GNF-Ziron Characteristics and Properties

GNF-Ziron is a zirconium-based alloy that is a slight modification to Zircaloy-2, which is widely used in the BWR industry as the material for fuel rod cladding and other fuel assembly components. The primary compositional difference is in the iron content of GNF-Ziron, which is selected to be above the range for Zircaloy-2 as specified in the ASTM B350 (UNS R60802) industry standard. GNF-Ziron has an [[ ]] compared with a 0.20 wt% upper limit for Zircaloy-2. For Zircaloy-2, the ASTM standard B350 describes the compositional requirements on Sn, Fe, Cr, and Ni as the major alloying elements, but the oxygen content is not defined. Since the late 1980s, GNF has employed a tighter set of specifications for Zircaloy-2, termed controlled-chemistry (CC) Zircaloy-2. A comparison of the minimum and maximum compositions for ASTM and GNF's CC Zircaloy-2, and GNF-Ziron is given in Table 1.

Table 1
Comparison of the Minimum, Maximum and Typical Compositions for ASTM Zircaloy-2, GNF's CC Zircaloy-2, and GNF-Ziron

wt%	Zircaloy-2					GNF-Ziron		
	ASTM		Controlled Chemistry					
	Min	Max	Min	Max	Typical	Min	Max	Typical
Sn	1.20	1.70	[[			[[		
Fe	0.07	0.20						
Cr	0.05	0.15						
Ni	0.03	0.08						
O	per PO							
FeCrNi	0.18	0.38						
Zr	97.9	98.6			]]			]]

As Table 1 shows, GNF-Ziron is similar to both ASTM and CC Zircaloy-2, in that all three types of alloy are based on ~98 wt% of zirconium with alloying additions consisting of Sn, Fe, Cr, and Ni. GNF-Ziron differs from ASTM and CC Zircaloy-2 primarily in that the iron content is increased. It should be noted that the indicated composition range for GNF-Ziron is [[

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Table 1 also shows the typical or expected target compositions for GNF's CC Zircaloy-2 and GNF-Ziron. It is noted that the difference in the target/typical [[
]] This small compositional difference is due to the increased iron content at the expense of the base zirconium, while the ranges of the other alloying additions are intended to be unchanged. As a comparison, this compositional difference is small compared to the changes associated with recent introduction of other new cladding materials in the PWR sector to replace Zircaloy-4, a zirconium based alloy similar to Zircaloy-2 but without nickel and with 0.18 – 0.24 wt% iron and 0.07 – 0.13 wt% chromium.

The material properties that are inputs to approved methods for evaluating the performance of fuel rods during various operating conditions (e.g., normal operation, LOCA) were evaluated and were documented in a Licensing Topical Report (LTR) submitted to the NRC (Reference 2). The contents of the LTR are discussed further in the next section. A number of properties or characteristics for GNF-Ziron were obtained through testing; these are listed in Table 2. A number of other properties are governed by the major alloy element zirconium and are therefore not sensitive to small changes in the alloy composition; these properties are provided in Table 3.

Based on the evaluation of properties in Tables 2 and 3, GNF concludes that the properties of GNF-Ziron are [[ ]] One notable feature of GNF-Ziron is a lower propensity to absorb corrosion-released hydrogen, despite a similar corrosion performance compared with Zircaloy-2. This reduced tendency to absorb hydrogen is the primary reason to consider GNF-Ziron as a fuel rod cladding material.

Table 2
Material Characteristics and Properties Assessed Based on Test Data

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Table 3
Material Properties Expected to be Nearly Identical to Zircaloy-2 Based on Similarity in Composition

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III. Reload Licensing Strategy

A. Current GNF-Ziron Status in the GE14 Licensing Basis

GE14 fuel is licensed according to criteria and requirements specified in GESTAR II (General Electric Standard Application For Reactor Fuel, NEDE-24011-P-A), as reported in the GE14 compliance report (GE14 Compliance With Amendment 22 of NEDE-24011-P-A, NEDC-32868P, Revision 2). The GE14 compliance report states that the GE14 fuel cladding and water rods are made of Zircaloy-2. Because the composition of GNF-Ziron deviates slightly from the ASTM-specification ranges for Zircaloy-2 (ASTM Standard B350 for UNS60802), as described in the previous section (see also Table 1), the application of the GE14 licensing basis to GE14 fuel with GNF-Ziron material must be addressed.

B. Two-Phase Approach

GNF proposes to approach the licensing basis for introduction of GNF-Ziron fuel cladding in two phases, which were discussed in a LTR pre-submittal meeting with the NRC during July, 2007 (FLN-2007-026, Subject: Ziron and Additive Fuel Pre-Submittal Meeting, Final Presentations July 24, 2007). Phase 1 consists of GNF preparing and submitting a LTR to the NRC in December 2010 (Reference 2). The submitted LTR addresses the application of GNF-Ziron to GNF Fuel Designs for reload applications. This submittal is necessary because GNF-Ziron is not addressed in the GE14 compliance report, which stated Zircaloy-2 as the cladding material, and because GNF-Ziron cannot be considered as Zircaloy-2, as discussed above. This LTR compares the properties of GNF-Ziron with those of Zircaloy-2 [[ ]] The LTR includes evaluations of potential differences in compliance with design limits when GNF-Ziron properties are used as inputs to approved methods. Once approved by the NRC, this LTR together with the GE14 compliance report will permit the application of GNF-Ziron on a reload basis for the GE14 fuel design, and accordingly, the GE14 compliance report will be revised to include the use of GNF-Ziron. Phase 1 does not invoke advantages of GNF-Ziron, i.e., reduced hydrogen absorption, and will retain [[ ]] currently applied to GE14. Phase 2, the schedule for which remains to be determined, will require the submittal to the NRC of a separate LTR on GNF-Ziron that will address [[ ]] In addition, Phase 2 [[ ]] Application of the second GNF-Ziron LTR and [[ ]]

IV. Lead Test Assemblies (LTA) Program at Plant Hatch

A LTA irradiation program is currently in progress at Plant Hatch to provide in-reactor experience with the GNF-Ziron cladding in GE14 fuel. (The LTAs also includes GNF-Ziron [[ ]] however, they are not discussed further in this report since they are not specifically addressed in 10 CFR 50.) This operating experience, along with the revised GE14 compliance report to be issued following the approval of the GNF-Ziron LTR, will form the basis for future reload applications of GE14 fuel clad with GNF-Ziron at Plant Hatch.

The program consists of two GE14 LTAs with selected rods (29 rods in each assembly) clad with GNF-Ziron. The LTAs started irradiation in Plant Hatch Unit 2 in 2009, and by February 2013 will have completed operation in Cycles 21 and 22, but these LTAs are not planned to be in operation during Cycle 23. Instead, SNC intends to continue irradiating these LTAs for one or more additional cycles up to the peak pellet exposure limit in one of the units at Edwin I. Hatch Nuclear Plant. SNC has informed GNF that use of GNF-Ziron cladding is not prevented by the Plant Hatch Technical Specifications; therefore, subsequent to NRC-approval of this submittal, loading the LTAs into one of the units at Edwin I. Hatch Nuclear Plant for one or more additional cycles of operation up to the peak pellet exposure limit will be evaluated as a change to the Plant as required by 10 CFR 50.59. GNF will provide SNC with technical information to support this evaluation. As demonstrated in the GNF-Ziron LTR (Reference 2), GNF's approved methods remain applicable to, and unaffected by, incorporation of GNF-Ziron.

V. Review of Methods

As described in Reference 1 "As long as the analysis of the LTAs using approved methods meets the approved criteria, it would be concluded that no unreviewed safety question exists." GEH/GNF currently performs fuel rod thermal-mechanical design and licensing analyses with the PRIME03 (Reference 3) code and its associated application methodology.

Fuel rods are designed such that, if they are operated within their specific thermal-mechanical operating limits of power versus exposure (LHGR limits), all licensing and design criteria are explicitly satisfied. The LHGR limits are specified to ensure compliance with the primary fuel rod thermal-mechanical licensing and design constraints.

The primary thermal-mechanical licensing parameters that may be impacted by the introduction of a new cladding material such as GNF-Ziron are:

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An assessment of the impact of the Ziron cladding for each of these parameters has been performed (Reference 2). The conclusion from the assessment was that, [[

]] implementation of GNF-Ziron will have no detrimental impact on thermal-mechanical licensing limits or margins.

In addition to the thermal-mechanical design limits associated with PRIME03, GNF uses a number of other NRC approved methods to demonstrate compliance with other design limits. GNF has evaluated the potential impact of incorporating GNF-Ziron properties into these methods (nuclear, thermal hydraulic, safety limit MCPR, transient analyses, stability, ATWS, rod drop accident, channel bow, and LOCA) and concluded there is no significant impact on the use of these methods as a result of this change. This conclusion is consistent with [[

]] (Reference 2).

VI. Technical Basis for Exemptions to 10 CFR 50.46 and Part 50 Appendix K

Title 10 of the Code of Federal Regulations (10 CFR) 50.46, "Acceptance criteria for emergency core cooling systems for light-water nuclear power reactors," requires that the calculated emergency core cooling system (ECCS) performance for reactors with Zircaloy or ZIRLO fuel cladding meet certain criteria. 10 CFR 50 Appendix K, "ECCS Evaluation Models," further requires that the Baker-Just equation be used in the ECCS evaluation model to determine the rate of energy release, cladding oxidation, and hydrogen generation after a postulated loss-of-coolant accident (LOCA). The Baker-Just equation presumes the use of Zircaloy or ZIRLO fuel cladding. There is no provision for cladding material other than Zircaloy or ZIRLO in 10 CFR 50.46 and 10 CFR 50 Appendix K. Exemptions to 10 CFR 50.46 and 10 CFR 50 Appendix K are therefore required for the use of GNF-Ziron as the cladding material.

In 10 CFR 50.46 and within the Baker-Just equation, no differentiation is made between types of Zircaloy, specifically between the commercially available Zircaloy-2 and Zircaloy-4. The underlying reason is that differences in composition between the two types of Zircaloy are not sufficient to result in significant differences in the high temperature oxidation characteristics. As noted in Section II, the composition of GNF-Ziron deviates only slightly from that of Zircaloy-2. The behavior and properties of GNF-Ziron during and after a postulated LOCA [[ ]]

10 CFR 50.46 has requirements related to the maximum cladding oxidation, peak cladding temperature, maximum hydrogen generation, coolable geometry and long-term cooling. High temperature oxidation tests have been conducted [[ ]] to demonstrate the applicability of the Baker-Just equation to GNF-Ziron and the results are shown in Figure 1. Figure 1 shows that the use of the Baker-Just equation remains conservative in the postulated LOCA circumstances relative to the measured GNF-Ziron data. The maximum cladding oxidation and peak cladding temperature limits are collectively known as the embrittlement criteria. In order to address the potential embrittlement due to absorbed hydrogen associated with a postulated LOCA, [[ ]] The predicted ECR values were calculated using the Baker-Just equation. The test results showed that [[ ]] The test results thus indicate margin to embrittlement relative to the 17% ECR clad oxidation limit stated in 10 CFR 50.46.

As noted in Section II, the Fe content of GNF-Ziron deviates only slightly from that of Zircaloy-2, while the alloy compositions are otherwise the same. Consequently, a significant change in the hydrogen generated from cladding-water reaction is not expected. Moreover, in the context of the proposed irradiation of LTAs at either one of the units at Edwin I. Hatch Nuclear Plant, any core-wide change in hydrogen generation due to a change from Zircaloy-2 to GNF-Ziron would be further diminished by the fact that only two assembles will be involved and that each assembly will contain a fraction of GNF-Ziron rods. Additionally, the composition change is only in increased Fe content relative to Zircaloy-2, the change in essence replaces some zirconium atoms with iron atoms. The potential effect on hydrogen generation due to replacing one Zr atom with a Fe atom can be estimated as follows. Each Zr atom will react with two H_2O molecules to form stoichiometric ZrO_2, thereby releasing 4 hydrogen atoms. Since Fe has a lower valence than Zr, each Fe atom can result in the release of 2, 3, or 2.67 atoms of hydrogen depending on whether stoichiometric Fe0, Fe_2O_3 or Fe_30_4, respectively, is formed from the reaction with water. The expected result of replacing one Zr atom with one Fe atom is therefore a reduction in the number of released hydrogen atoms. Thus, because of the similarity in composition between Zircaloy-2 and GNF-Ziron, evaluation of hydrogen release based on GNF-Ziron cladding is conservatively bounded by the calculation based on Zircaloy-2 cladding. Furthermore, any difference in calculated hydrogen generation would be slightly less for the GNF-Ziron case.

The coolable geometry criterion is generally addressed through high temperature perforation tests. A comparison of test data obtained from GNF-Ziron with available data for Zircaloy-2 is shown in Figure 2, which shows that the high temperature perforation characteristics, and hence coolable geometry evaluation, for GNF-Ziron [[ ]] because of the similar composition.

The similarity in composition with Zircaloy-2 and the high temperature test results described above thus demonstrate with a high degree of confidence that the underlying requirements of 10 CFR 50.46 and 10 CFR 50 Appendix K are met when GNF-Ziron is used as the cladding material. Therefore, there is no anticipated decrease in coolability or increase in dose consequences as a result of a postulated LOCA for GNF-Ziron relative to evaluations performed assuming Zircaloy cladding.

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Figure 1

Weight Gain Data for GNF-Ziron [[ ]] Compared with Baker-Just

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Figure 2
Perforation Hoop Stress of GNF-Ziron Cladding Compared with Zircaloy-2 Data

VII. Summary

10 CFR 50.46 and Part 50 Appendix K explicitly state or implicitly assume the cladding material to be zircaloy or Zirlo. In order to allow the development and in-reactor testing of a fuel cladding material which is neither zircaloy nor Zirlo, it is necessary to request the NRC grant exemptions to 10 CFR 50.46 and Part 50 Appendix K for the Plant Hatch LTAs containing GNF-Ziron cladding. Based on the similarity in composition with Zircaloy-2 and the high temperature test results, the underlying requirements of 10 CFR 50.46 and Part 50 Appendix K are shown to be met with a high degree of confidence when GNF-Ziron is used as the cladding material.

[[ ]] GNF has concluded that evaluations based on the currently approved methods for fuel rod performance during various operating conditions, including accidents, are fully applicable to GE14 fuel bundles with GNF-Ziron fuel rod cladding. The GE14 LTAs with selected rods clad with GNF-Ziron to be inserted into one of the units at Edwin I. Hatch Nuclear Plant for one or more additional cycles of operation up to the peak pellet exposure limit will be evaluated using existing approved methods utilizing the equivalency in properties.

VIII. References

1. NRC Letter, "Lead Test Assembly Licensing," T. A. Ippolito (NRC) to R. E. Engel, September 23, 1981.
2. Licensing Topical Report, Application of GNF-Ziron to GNF Fuel Designs, NEDC-33353P and NEDO-33353, December 22, 2010.
3. GNF Licensing Topical Report, The PRIME Model for Analysis of Fuel Rod Thermal – Mechanical Performance, Technical Bases - NEDC-33256P-A, Revision 1, Qualification - NEDC-33257P-A, Revision 1, and Application Methodology - NEDC-33258P-A, Revision 1, September 2010.

Edwin I. Hatch Nuclear Plant
Proposed Exemption to 10 CFR 50.46 and
10 CFR 50 Appendix K to Allow GNF-Ziron Fuel Cladding

Enclosure 4

Exemption Request Background and Supporting Information

Background

The Southern Nuclear Operating Company, Inc. (SNC) is the holder of the Renewed Facility Operating License Nos. DPR-57 and NPF-5, which authorizes operation of the Edwin I. Hatch Nuclear Plant (HNP), Unit Nos. 1 and 2, respectively. The license provides, among other things, that the facility is subject to all rules, regulations, and orders of the U.S. Nuclear Regulatory Commission (NRC or the Commission) now or hereafter in effect.

The facility consists of a boiling-water reactor located in Appling County in Georgia.

Request / Action

Pursuant to Title 10 of the Code of Federal Regulations (10 CFR), Section 50.12, "Specific Exemptions", SNC requests an exemption from the fuel cladding material requirements in 10 CFR 50.46, "Acceptance Criteria for Emergency Core Cooling Systems for Light-Water Nuclear Power Reactors," and Appendix K to 10 CFR part 50, "ECCS Evaluation Models," (Appendix K). The regulation in 10 CFR 50.46 contains acceptance criteria for emergency core cooling system (ECCS) for reactors fueled with Zircaloy or ZIRLO™ cladding. In addition, Appendix K requires that the Baker-Just equation be used to predict the rates of energy release, hydrogen concentration, and cladding oxidation from the metal-water reaction. The exemption request relates solely to the specific types of cladding material specified in these regulations. As written, the regulations presume the use of Zircaloy or ZIRLO™ fuel rod cladding. Thus, an exemption from the requirements of 10 CFR 50.46, and Appendix K is needed to continue to irradiate a lead test assembly (LTA) comprised of different cladding alloys at HNP.

The NRC has previously approved (ML082950149) exemption to cladding-specific requirements of 10 CFR 50.46, and 10 CFR 50 Appendix K requirements for operation of the LTAs in HNP Unit 2 during Cycles 21, 22, and 23. The LTAs have completed operation in HNP Unit 2 during Cycles 21 and 22 by February 2013, but these LTAs are not planned to be in operation during Cycle 23. Instead, SNC intends to continue irradiating these LTAs for one or more additional cycles in either Unit 1 or Unit 2 of the HNP.

Exemption Request

Pursuant to 10 CFR 50.12, the Commission may, upon application by any interested person or upon its own initiative, grant exemptions from the requirements of 10 CFR Part 50, when (1) the exemptions are authorized by law, will not present an undue risk to public health or safety, and are consistent with the common defense and security; and (2) when special circumstances are present. Under Section 50.12(a)(2) of 10 CFR, special circumstances include, among other things, when application of the specific regulation in the particular circumstance would not serve, or is not necessary to achieve, the underlying purpose of the rule.

<u>Authorized by Law</u>

This exemption would allow the SNC to insert two lead test fuel assemblies with fuel rod cladding that does not meet the definition of Zircaloy or ZIRLO™ as specified by 10 CFR 50.46, and Appendix K, into the core of HNP. As stated above, 10 CFR 50.12 allows the NRC to grant exemptions from the requirements of 10 CFR Part 50. Granting of SNC's proposed exemption will not result in a violation of the Atomic Energy Act of 1954, as amended, or the Commission's regulations. Therefore, the exemption is authorized by law.

No Undue Risk to Public Health and Safety

In regard to the fuel mechanical design, the exemption request relates solely to the specific types of cladding material specified in the regulations. The underlying purpose of 10 CFR 50.46 is to establish acceptance criteria for ECCS performance. In Section VI of Enclosures 2 (proprietary) and 3 (non-proprietary), SNC provides a technical basis supporting the continued applicability of the 50.46 Paragraph (b) fuel criteria to GNF-Ziron. Quench tests under a restrained load have been conducted on GNF-Ziron samples oxidized to various levels at elevated loss-of-coolant accident (LOCA) temperatures. While these tests differ from the post-steam oxidized ring-compression testing (which forms the basis of the 50.46 post-quench ductility criteria), these results provide reasonable assurance that the 17 percent oxidation and 2200 degree Farenheit criteria are valid for GNF-Ziron and meet the underlying purpose of the rule, which is to maintain a degree of post-quench ductility in the fuel cladding material.

Based on an ongoing LOCA research program at Argonne National Laboratory, as discussed in NRC Research Information Letter 0801, "Technical Basis for Revision of Embrittlement Criteria in 10 CFR 50.46," ADAMS Accession No. ML081350225, cladding corrosion (and associated hydrogen pickup) has a significant impact on post-quench ductility. Post-irradiation examinations demonstrate the favorable hydrogen pickup characteristics of GNF-Ziron as compared with standard Zircaloy. Hence, the GNF-Ziron fuel rods would be less susceptible to the detrimental effects of hydrogen uptake during normal operation and their impact on post-quench ductility.

Paragraph I.A.5 of Appendix K to 10 CFR Part 50 states that the rates of energy, hydrogen concentration, and cladding oxidation from the metal-water reaction shall be calculated using the Baker-Just equation. Since the Baker-Just equation presumes the use of Zircaloy clad fuel, strict application of the rule would not permit use of the equation for the LTA cladding for determining acceptable fuel performance. Metal-water reaction tests performed by GNF on GNF-Ziron demonstrate conservative reaction rates relative to the Baker-Just equation. Thus, application of Appendix K, Paragraph I.A.5 is not necessary for SNC to achieve its underlying purpose in these circumstances.

High temperature perforation test results are provided in Enclosures 2 and 3. These test results illustrate similar burst characteristics of GNF-Ziron as compared with standard Zircaloy. In addition, SNC provides further comparisons of material properties between GNF-Ziron and Zircaloy. Based upon this comparison of material properties, GNF and SNC believe that currently approved methods and models are directly applicable to GNF-Ziron.

Through mechanical testing and a comparison of material properties, SNC has provided reasonable assurance that anticipated in-reactor performance will be acceptable. Further, SNC has demonstrated that the use of current methods and models are reasonable for evaluating the cladding's performance in response to anticipated operational occurrences and accidents.

Consistent With Common Defense and Security

The proposed exemption would allow SNC to continue irradiating two LTAs with fuel rod cladding that does not meet the definition of Zircaloy or ZIRLO™ as specified by 10 CFR 50.46, and Appendix K, for one or more additional cycles in either Unit 1 or Unit 2 of the HNP. This change has no relation to security issues. Therefore, the common defense and security is not impacted by this exemption.

Special Circumstances

Special circumstances, in accordance with 10 CFR 50.12, are present whenever application of the regulation in the particular circumstances is not necessary to achieve the underlying purpose of the rule. The underlying purpose of 10 CFR 50.46 and Appendix K to 10 CFR part 50 is to establish acceptance criteria for emergency core cooling system performance. The wording of the regulations in 10 CFR 50.46 and Appendix K is not directly applicable to these advanced cladding alloys, even though the evaluations discussed above show that the intent of the regulations is met. Therefore, since the underlying purpose of 10 CFR 50.46 and Appendix K is achieved with the use of these advanced cladding alloys, the special circumstances required by 10 CFR 50.12 for the granting of an exemption from 10 CFR 50.46 and Appendix K exist.

Conclusion

As demonstrated above, SNC believes this exemption request is in accordance with the criteria of 10 CFR 50.12. Specifically, the requested exemption is authorized by law, will not present an undue risk to public health or safety, and is consistent with the common defense and security. Additionally, special circumstances are present as previously described.