Exelon Generation Company, LLC

Notification of Planned ATF LTA Use at Clinton Unit 1

ATTACHMENT 3

NON-PROPRIETARY REPORT

NEDC-33903, Revision 0,
"GNF IronClad ATF Lead Test Assembly for Clinton Unit 1,"
dated November 2018

Global Nuclear Fuel

Global Nuclear Fuel

NEDO-33903
Revision 0
November 2018

Non-Proprietary Information

GNF IRONCLAD ATF LEAD TEST ASSEMBLY

FOR

CLINTON UNIT 1

INFORMATION NOTICE

This is a non-proprietary version of the document NEDC-33903P Revision 0, which has the proprietary information removed. Portions of the document that have been removed are indicated by an open and closed bracket as shown here [[ ]].

IMPORTANT NOTICE REGARDING

CONTENTS OF THIS REPORT

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REVISION HISTORY

Revision	Date	Description of Change
0	11/2018	Initial Release

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ACRONYMS

Term	Definition
ATF	Accident Tolerant Fuel
CFR	Code of Federal Regulations
COLR	Core Operating Limits Report
CPR	Critical Power Ratio
DOE	Department of Energy
FeCrAl	Iron Chrome Aluminum Ferritic Steel
GE	General Electric
GNF	Global Nuclear Fuel – Americas, LLC
LH1	Clinton Unit 1
LOCA	Loss-of-Coolant Accident
LTA	Lead Test Assembly
LTR	Lead Test Rod
MCPR	Minimum Critical Power Ratio
NRC	Nuclear Regulatory Commission
OLMCPR	Operating Limit MCPR
SAFDL	Specified Acceptable Fuel Design Limit
SRLR	Supplemental Reload Licensing Report
TMOL	Thermal Mechanical Operating Limit

ABSTRACT

Exelon Generation Company, LLC (Exelon) plans to load approximately [[ ]] Lead Test Assemblies (LTAs) as part of the Clinton Unit 1 (LH1) Reload 19 Cycle 20 during the 2019 refueling outage. These bundles, also referred to as IronClad LTAs or ATF LTAs or IronClad ATF LTAs, are conventional GNF2 assemblies in which a [[

]]. These LTAs are planned to be in operation as part of a joint program with Global Nuclear Fuel – Americas, LLC (GNF) on behalf of the United States Department of Energy's (DOE) Accident Tolerant Fuel Program.

This report contains information that is to be provided to the United States Nuclear Regulatory Commission (NRC). Included in this report are a description of GNF FeCrAl and the IronClad LTAs, a discussion of the licensing analyses, a description of the LTA program objectives, and measurements planned for the assemblies.

1.0 Introduction

Exelon Generation Company, LLC plans to load approximately [[ ]] Lead Test Assemblies (LTAs) as part of the Clinton Unit 1 (LH1) Reload 19 Cycle 20 during the 2019 refueling outage. These bundles, also referred to as IronClad ATF LTAs, are planned to be in operation as part of a joint program with Global Nuclear Fuel – Americas, LLC (GNF) on behalf of the DOE.

This report contains information that is to be provided to the NRC to comply with Reference 1 that provides guidelines to be followed to license LTAs. Included in this report are a description of the IronClad ATF LTAs, a discussion of the licensing analyses, a description of the LTA program objectives, and any applicable measurements planned for the LTAs.

The LTA design is described in Section 2 along with GNF FeCrAl cladding material that is the aspect to be tested. The subject LTAs are GNF2 bundles with [[ ]]. The subject LTRs are [[ ]]. A subset of rods [[ ]]. No other aspects of the bundle are modified. The fuel material is conventional UO_2. The IronClad naming convention encompasses all of the varieties of FeCrAL material described herein.

Section 3 describes the licensing analyses that will be performed. Section 4 states the objectives of the LTA program and describes the measurements planned.

2.0 GNF FeCrAl & IronClad ATF LTA Description

As part of the DOE's Accident Tolerant Fuel program, GNF and collaborating partners are developing a ferrous metallic FeCrAl alloy with a ferritic structure as an alternative fuel rod cladding material to contemporary zirconium based alloys. Model alloys with substantially improved resistance to the metal-water reaction under accident conditions have been under investigation since the Great Earthquake of Eastern Japan that occurred on March 11, 2011.

2.1 GNF FeCrAl

GNF FeCrAl encompasses a broad range of alloying elements, the principals being iron, chrome, and aluminum as described in Table 2-1. GNF FeCrAl is a ferrous metal alloy with a body-centered-cubic ferritic structure and has demonstrable resistance to corrosion at normal reactor operating conditions (i.e., 300 °C water) as well as off-normal conditions including accident conditions (i.e., very high temperature steam approaching the material melting temperature).

In addition to its oxidation resistance, GNF FeCrAl exhibits good thermal and mechanical properties that are important for fuel rod function and is suitable for conventional manufacturing processes.

2.2 Lead Test Assembly Description

The LTA is essentially a standard production GNF2 fuel assembly as described in Reference 2 in which several normal full-length fuel rods are replaced with full length [[
]] clad with GNF FeCrAl as depicted in Figures 2-1 and 2-2, or [[ ]]. The fuel pellet material in fueled segments is conventional UO_2. The outside diameter is the same as a normal GNF2 fuel rod. As such, the thermal hydraulic characteristics in the active region of the assembly can be treated as normal fuel. As illustrated in Figure 2-3, the LTRs (noted in green) are restricted to interior positions in the bundle that operate at lower power than peripheral locations. For fueled segments, this provides inherent margin relative to the limiting rods within the bundle to accommodate uncertainties in irradiated material properties.

Table 2-1 Nominal GNF FeCrAl Alloy Composition, w/o

Alloy	Fe	Cr	Al
GNF FeCrAl	Balance	10 - 22	4 - 6

[[

]]

Figure 2-1 Rod Segment Schematic

[[

]]

Figure 2-2 Segmented Rod Axial Arrangement

[[

]]

Figure 2-3 Allowable Lead Test Rod Locations

3.0 Licensing Analyses

For specified engineering evaluations (e.g., fuel rod thermal mechanical), the IronClad ATF LTAs have been, or will be, analyzed using the NRC approved methods described in Reference 3. These methods [[ ]]; however, irradiated material properties data is incomplete which is the motivation for installing the LTAs. As such, these methods cannot be considered qualified, or approved for this application. To adequately conform to standard Specified Acceptable Fuel Design Limits (SAFDLs), the following conservatisms are introduced:

- Fuel rod engineering evaluations to establish the LTR thermal mechanical operating limits (TMOL) for fueled rods will apply [[ ]] in irradiated material properties.
- The LTRs shall be limited in number [[ ]].
- The LTAs shall be installed into core locations that are not limiting with respect to thermal limits.

The LTRs have the same fuel rod outside diameter as a normal fuel rod in the active region of the assembly, and the effect of the mechanical interfaces between segments has been evaluated as not significantly affecting the liquid film. GEXL17 shall be applied to the analysis and monitoring of the LTAs. While the axial heat flux distribution is not continuous due to the presence of non-fueled portions of fueled segments, this results in a reduction in film evaporation and increased margin to boiling transition for the LTRs. The applicability of GEXL17 to the LTAs that contain entirely unfueled LTRs shall be affirmed. The Operating Limit Minimum Critical Power Ratio (OLMCPR) established for the reload fuel will be confirmed to be applicable to the LTAs as GEXL17 is applied to the prediction of boiling transition (i.e., critical power). Additionally, as stated above, the LTAs shall be installed into non-limiting core locations resulting in increased margin. Normal reload licensing analyses will be performed for the LTAs for each cycle of their operation.

Plant dependent, cycle independent evaluations (e.g., control rod drop accident, fuel handling accident, LOCA, fuel storage, etc.) shall be performed to assure conformance to established regulatory requirements. It is recognized that the aforementioned regulatory requirements are, to some extent, specific to zircaloy cladding; however, they are considered adequate and appropriate for this purpose.

Exelon Generation Company, LLC intends to insert the subject LTAs into Clinton Unit 1 and to operate Cycle 20 under the provisions of Technical Specification 4.2.1 and in concert with 10 CFR 50.59 where applicable and in conjunction with the LTA requirements stipulated in Reference 3

(GESTAR II); however, cycle-specific analyses to establish fuel operating limits are not yet complete. When cycle-specific analyses are complete, GNF and Exelon will document the results in each respective Supplemental Reload Licensing Report (SRLR). Exelon Generation Company, LLC will update the Clinton Unit 1 Core Operating Limits Report (COLR) accordingly.

4.0 LTA Program Objectives And Planned Inspections

The purpose of this LTA program is to [[

]] and fuel rod design for potential reload application.

Poolside surveillance is planned throughout the irradiation period and [[

]] is expected. The frequency and extent of these surveillances and rod removal evolutions will necessarily depend upon the operational constraints at the station as determined by Exelon and the evolving goals of the DOE's ATF program.

5.0 References

1. Letter, T. A. Ippolito (NRC) to R. E. Engel (GE), "Lead Test Assembly Licensing," MFN-182-81, September 23, 1981.

2. Global Nuclear Fuel, "GNF2 Advantage Generic Compliance with NEDE-24011-P-A (GESTAR II)," NEDC-33270P, Revision 9, December 2017.

3. Global Nuclear Fuel, "General Electric Standard Application for Reactor Fuel (GESTAR II)," NEDE-24011-P-A-27, August 2018.

Exelon Generation Company, LLC

Notification of Planned ATF LTA Use at Clinton Unit 1

ATTACHMENT 4

NON-PROPRIETARY REPORT

NEDC-33904, Revision 0,
"GNF ARMOR ATF Lead Test Assembly for Clinton Unit 1,"
dated November 2018

Global Nuclear Fuel

NEDO-33904
Revision 0
November 2018

Non-Proprietary Information

GNF ARMOR ATF LEAD TEST ASSEMBLY FOR CLINTON UNIT 1

INFORMATION NOTICE

This is a non-proprietary version of the document NEDC-33904P Revision 0, which has the proprietary information removed. Portions of the document that have been removed are indicated by an open and closed bracket as shown here [[ ]].

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REVISION HISTORY

Revision	Date	Description of Change
0	11/2018	Initial Release

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ACRONYMS

Term	Definition
ARMOR	Abrasion Resistant, More Oxidation Resistant
ATF	Accident Tolerant Fuel
CFR	Code of Federal Regulations
COLR	Core Operating Limits Report
CRDA	Control Rod Drop Accident
DOE	Department of Energy
GNF	Global Nuclear Fuel – Americas, LLC
LOCA	Loss-of-Coolant Accident
LTA	Lead Test Assembly
LTR	Lead Test Rod
NRC	Nuclear Regulatory Commission
OLMCPR	Operating Limit Minimum Critical Power Ratio
[[ ]]	[[ ]]
SAFDL	Specified Acceptable Fuel Design Limit
SRLR	Supplemental Reload Licensing Report
TMOL	Thermal Mechanical Operating Limit
US	United States

ABSTRACT

Exelon Generation Company, LLC (Exelon) plans to load approximately [[ ]] Lead Test Assemblies (LTAs) as part of the Clinton Unit 1 Reload 19 Cycle 20 during the 2019 refueling outage. These bundles, also referred to as Abrasion Resistant, More Oxidation Resistant (ARMOR) LTAs or ARMOR Accident Tolerant Fuel (ATF) LTAs, are standard GNF2 assemblies in which a [[

]]. These LTAs are planned to be in operation as part of a joint program with Global Nuclear Fuel – Americas, LLC (GNF) on behalf of the United States (US) Department of Energy's (DOE) ATF program.

This report contains information that is to be provided to the Nuclear Regulatory Commission (NRC). Included in this report are a description of the ARMOR coating and the ARMOR LTAs, a discussion of the licensing analyses, a description of the ARMOR LTA program objectives, and measurements planned for the ARMOR LTAs.

1.0 Introduction

Exelon plans to load approximately [[ ]] LTAs as part of the Clinton Unit 1 Reload 19 Cycle 20 during the 2019 refueling outage. These bundles, also referred to as ARMOR ATF LTAs, are planned to be in operation as part of a joint program with GNF on behalf of the US DOE.

This report contains information that is to be provided to the NRC to comply with Reference 1. Reference 1 provides guidelines to be followed to install and operate LTAs. Included in this report are a description of the ARMOR ATF LTAs, a discussion of the licensing analyses, a description of the LTA program objectives, and any applicable measurements planned for the LTAs.

The LTA design is described in Section 2.0 along with the ARMOR coating that is the feature to be tested. The subject LTAs are GNF2 bundles [[

]] No other aspects of the bundle are modified. The fuel material in fueled segments is standard UO_2 or additive UO_2.

Section 3.0 describes the licensing analyses that will be performed. Section 4.0 states the objectives of the ARMOR LTA program and describes the measurements planned.

2.0 GNF ARMOR Coating and ARMOR ATF LTA Description

As part of GNF's effort to improve fuel performance against debris fretting, GNF has developed a fuel cladding coating that provides greater resistance to cladding failure due to debris wear. The coating has been named ARMOR, based on its abrasion resistant and more oxidation resistant characteristics. Owing to its improved oxidation resistance in high temperature steam, the ARMOR coating is also GNF's coated-zircaloy technology within the US DOE's ATF program.

2.1 ARMOR Coating

ARMOR is a [[ ]] coating that is applied by [[ ]] as an add-on process following production of fuel cladding using standard manufacturing processes. The coating is [[ ]] with a nominal chemical composition as indicated in Table 2-1. [[

]]
when compared with Zircaloy-2 cladding without the ARMOR coating. The ARMOR coating has demonstrated [[ ]]

As the ARMOR coating is [[

]] by that of the base Zircaloy-2 cladding.

2.2 Lead Test Assembly Description

The LTA is essentially a standard production GNF2 fuel assembly as described in Reference 2 [[

]] as depicted in Figures 2-1 and 2-2. The ends of the fuel rod [[ ]] processes and qualification. The fuel pellet material in fueled segments is standard UO_2 or additive UO_2. As the ARMOR coating is [[ ]] GNF2 fuel rod. As such, the thermal hydraulic characteristics in the active region of the assembly can be treated as normal fuel. As illustrated in Figure 2-3, the LTRs are located in [[ ]] positions in the bundle that operate at [[ ]]. This provides inherent margin relative to the limiting rods within the bundle to accommodate [[ ]]

Table 2-1 Nominal ARMOR Coating Composition

Coating	[[	
ARMOR		]]

[[

]]

Figure 2-1 Rod Segment Schematic

[[

]]

Figure 2-2 Segmented Rod Axial Arrangement

[[

]]

Figure 2-3 Allowable Lead Test Rod Locations

3.0 Licensing Analyses

For specified engineering evaluations (e.g., fuel rod thermal-mechanical), the ARMOR ATF LTAs have been, or will be, analyzed using the NRC-approved methods described in Reference 3. These methods [[
]]; however, irradiated material property data of the [[
]] for installing the LTAs. To adequately conform to standard Specified Acceptable Fuel Design Limits (SAFDLs), the following conservatisms are introduced:

- Fuel rod engineering evaluations to establish the LTR Thermal Mechanical Operating Limits (TMOLs) will apply [[
]] in material properties.
- The LTRs shall be limited in number to [[
]]
- The LTAs shall be installed into core locations that are not limiting with respect to thermal limits.

Because the ARMOR coating is [[
]] and the effect of the mechanical interfaces between segments has been evaluated as not significantly affecting the liquid film. Therefore, GEXL17 is applicable to the analysis and monitoring of the LTAs. While the axial heat flux distribution is not continuous due to the presence of non-fueled portions of the segments, this results in a reduction in film evaporation and increased margin to boiling transition for the LTRs. The Operating Limit Minimum Critical Power Ratio (OLMCPR) established for the reload fuel will be confirmed to be applicable to the LTAs as GEXL17 is applied to the prediction of boiling transition (i.e., critical power). Additionally, the LTAs shall be installed into non-limiting core locations resulting in increased margin. Standard reload licensing analyses will be performed for the LTAs for each cycle of operation.

Plant dependent, cycle independent events (e.g., Control Rod Drop Accident (CRDA), fuel handling accident, Loss-of-Coolant Accident (LOCA), and fuel storage) are considered to ensure conformance to established regulatory requirements. Because the ARMOR coating is thin, the zircaloy characteristics dominate, and the existing evaluations are adequate to support the safe installation and operation of the LTAs.

Exelon intends to insert the LTAs into Clinton Unit 1 starting in Cycle 20 and to operate Cycle 20 under the provisions of Technical Specification 4.2.1 and in concert with 10 Code of Federal Regulations (CFR) 50.59 where applicable and in conjunction with the LTA requirements stipulated in Reference 3 (GESTAR II); however, cycle-specific analyses to establish fuel operating limits are not yet complete. When cycle-specific analyses are complete, GNF and Exelon will document the results in each respective Supplemental Reload Licensing Report (SRLR). Exelon will update the Clinton Unit 1 Core Operating Limits Report (COLR) accordingly.

4.0 LTA Program Objectives and Planned Inspections

The purpose of the ARMOR ATF LTA program is to demonstrate coating integrity throughout the expected operational life of the LTRs. The program also offers the opportunity to [[

]], thereby supporting fuel rod design for reload application.

Poolside surveillance is planned throughout the irradiation period and [[

]] may be performed. The frequency and extent of these surveillances and examinations will be jointly developed by Exelon and GNF consistent with the operational constraints at the station as determined by Exelon and the evolving goals of the US DOE's ATF program.

5.0 References

1. Letter, T. A. Ippolito (NRC) to R. E. Engel (GE), "Lead Test Assembly Licensing," MFN-182-81, September 23, 1981.
2. Global Nuclear Fuel, "GNF2 Advantage Generic Compliance with NEDE-24011-P-A (GESTAR II)," NEDC-33270P, Revision 9, December 2017.
3. Global Nuclear Fuel, "General Electric Standard Application for Reactor Fuel (GESTAR II)," NEDE-24011-P-A-27, August 2018.