ENCLOSURE 2

FLN-2007-026

Ziron and Additive Fuel, Final Presentations

Non-Proprietary Information

IMPORTANT NOTICE

This is a non-proprietary version of Enclosure 1 to FLN-2007-026, which has the proprietary information removed. Portions of the document that have been removed are indicated by white space with an open and closed bracket as shown here [[ ]].

Pre-Submittal Meeting
GNF-Ziron

July 25, 2007

GNF
Global Nuclear Fuel

Agenda

- Scope
- Background on GNF-Ziron
- In-reactor Experience and Testing Data
- Licensing Plan

Scope

SER approval for:

GNF-Ziron as material for fuel rod and assembly components.

- Fuel Rods, Water Rods, End Plugs, Spacers, Channel
- Applied within the framework of GESTAR.

Two-step approach to licensing

[[

]]

Why GNF-Ziron?

Issue:

- Hydrogen absorption at high exposures.

Solution:

- This alloy has lower end of life [H].

Change:

- Fe level for tubing material from

[[[[

]]

]]

Composition Comparison (wt%)

	Zircaloy-2	GNF-Ziron
Zirconium	> 97	[[ ]]
Tin	1.20 – 1.70	[[ ]]
Iron	0.07 – 0.20 [[ ]]	[[ ]]
Chromium	0.05 – 0.15	[[ ]]
Nickel	0.03 – 0.08	[[ ]]

[[

]]

GNF Global Nuclear Fuel

GNF-Ziron Background

- 20+ years of development supported by in-reactor testing at [[

]]

GNF Global Nuclear Fuel

GNF-Ziron Experience

Irradiation	Purpose	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06
[[																					]]

GNF Global Nuclear Fuel

GNF-Ziron – Lead Use Applications

- Lead Use Assemblies at [[

GNF Global Nuclear Fuel

]]

GNF-Ziron Properties Assessment

Physical properties not significantly affected[[
]]

Main properties (corrosion and mechanical) similar or better than Zircaloy-2.

[[ ]]

- Hydrogen uptake
- Mechanical properties
- Creep
- Cladding corrosion
- Water Rod Growth
- Simulated LOCA tests (weight gain and perforation stress)

Hydrogen Uptake

[[

]]

Room Temp. Tensile Properties

[[

]]

Tensile Strength

[[

]]

Creep Behavior

[[

]]

Corrosion

[[

]]

Irradiation Growth Rates

[[

]]

Simulated LOCA Oxidation Results

[[

]]

Simulated LOCA Test Results

[[

]]

Simulated LOCA Test – additional tests

[[

]]

GNF-Ziron Licensing Plan

- Phase 1

  [[ ]]

  [[ ]]

- Phase 2

  [[ ]]

  [[ ]]

- Will require exemption regarding "*zircaloy or ZIRLO cladding*" in 10CFR50.46

GNF-Ziron Licensing Topical Report

TABLE OF CONTENTS

Executive Summary

1.0 Introduction

2.0 Material Properties Assessment

3.0 Methods & Licensing Assessment

4.0 Summary

5.0 References

GNF-Ziron Licensing Topical Report

TABLE OF CONTENTS (cont-1)

Executive Summary

1.0 Introduction

- 1.1 Material Bases for GNF Fuel Design
- 1.2 GNF-Ziron Composition
- 1.3 Experience & Testing

2.0 Material Properties Assessment

3.0 Methods & Licensing Assessment

4.0 Summary

GNF-Ziron Licensing Topical Report

TABLE OF CONTENTS (cont-2)

2.0 Material Properties Assessment

- 2.1 Physical Properties
- 2.2 Thermal Properties
- 2.3 Mechanical Properties
  - Yield and Ultimate Stress, Strain, Perforation Stress, Hardness, Fatigue, Creep, Irradiation Growth
- 2.4 Oxidation / Corrosion
  - Normal Operation, High Temp Oxidation Kinetics
- 2.5 Hydrogen Absorption / Hydriding

3.0 Methods & Licensing Assessment

GNF-Ziron Licensing Topical Report

TABLE OF CONTENTS (cont-3)

2.0 Material Properties Assessment

3.0 Methods & Licensing Assessment

- 3.1 Methods
- 3.2 Regulatory Requirements

  Fuel Melting, Fuel Rod Internal Pressure, Cladding Plastic Strain, Cladding Stress/Strain, Cladding Fatigue, Cladding Creep Collapse, Metal Thinning, LOCA, RIA, Dry Storage, etc.

4.0 Summary

5.0 References

Summary

[[

]]

- GNF would like to deploy GNF-Ziron as licensed fuel assembly material.

[[ ]]

Discussion:
- Is a LTR necessary?
- Review timeframe & resource considerations

Pre-Submittal Meeting
Additive UO_2 and $(U,Gd)O_2$ Fuel

25 July 2007

GNF
Global Nuclear Fuel
A Joint Venture of GE, Toshiba, & Hitachi

Agenda

- Present bases for applying an additive in BWR fuel
- Propose an approach for licensing additive UO_2 and $(U,Gd)O_2$ fuel
- Obtain comments from NRC regarding additional data needs and licensing approach

Overview

- The [[ ]] (additive) is an effective remedy for PCI
- Additive fuel is well characterized and has recently completed operation to bundle average exposures of [[ ]]
- Additive fuel has been used in commercial BWR fuel in Japan since 1999

Overview – Cont.

- Additive fuel properties are included in the computer models of GNF
  - GSTRM: Approved in 1987
  - PRIME03: Models included in LTR
- GNF wants to introduce additive fuel to gain additional margin to duty-related failure processes
- Need to review such an introduction with the NRC to
  - Identify areas of concern not already addressed by prior development work
  - Identify best process for submittal and review; e.g., administrative amendment to GESTAR supported by additive LTR or ?

Additive Experience

[[

]]

GNF Global Nuclear Fuel

5/

Additive Objectives

- Reasons for using additive
  - Defense in depth against duty-related cladding failures
    - [[
    -]]
  - [[

    ]]
  - Support industry initiative for zero leakers by 2010
- General approach
  - [[

  -

    ]]

GNF Global Nuclear Fuel

6/

Additive Description

- Composition
  - Preferred: [[ ]]
  - Experience range:
    - o [[
    - o]]
- Concentration
  - Preferred: [[ ]]
  - Experience range: [[ ]]

Visual Appearance of Additive Fuel

Additive fuel looks just like non-additive UO_2 or $(U,Gd)O_2$ on a macroscopic scale

As-Sintered Pellet Structure

[[

]]

GNF Global Nuclear Fuel

9/

Additive Structure

[[

]]

GNF Global Nuclear Fuel

10/

Additive Structure – Cont.

[[

]]

GNF Global Nuclear Fuel

11 /

Post-Irradiation Pellet Structure *LUA*

[[

]]

GNF Global Nuclear Fuel

12 /

Post-Irradiation Pellet Structure *Ramp Test*

[[

]]

GNF Global Nuclear Fuel

13 /

Post-Irradiation Structure *Ramp Test – Cont.*

[[

]]

GNF Global Nuclear Fuel

14 /

Ternary Liquidus Phase Diagrams

[[

]]

GNF Global Nuclear Fuel

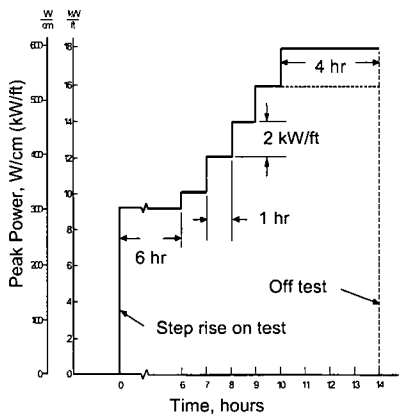
UO_2-Additive Phase Diagrams

[[

]]

GNF Global Nuclear Fuel

PCI Ramp Test Description



- Base irradiation in power reactor
- Transfer to test reactor
- Pre-conditioning at 9 kW/ft
- Power increased in steps, with a hold time of 1 hr at each stage, 4 hrs at peak target power
- Peak target power requested: 18 kW/ft
  Peak attained in test: 16 kW/ft
- Test terminated if rod fails or survives
  peak power for 4 hours

GNF Global Nuclear Fuel

PCI Resistance

[[

]]

GNF Global Nuclear Fuel

Radial Temperature Distribution

[[

]]

GNF Global Nuclear Fuel

Melting Temperature

[[

]]

GNF Global Nuclear Fuel

Pellet Stability

[[

]]

GNF Global Nuclear Fuel

Thermal Limit

[[

]]

GNF Global Nuclear Fuel

Thermal Diffusivity

[[

]]

GNF Global Nuclear Fuel

Thermal Conductivity

[[

]]

GNF Global Nuclear Fuel

Pellet Centerline Temperature

[[

]]

GNF Global Nuclear Fuel

25 /

Fission Gas Release

[[

]]

GNF Global Nuclear Fuel

26 /

Pellet Density

[[

]]

GNF Global Nuclear Fuel

27 /

Densification and Swelling

[[

]]

GNF Global Nuclear Fuel

28 /

Stress-Strain Behavior

[[

]]

GNF Global Nuclear Fuel

Microstructure after Yielding

[[

]]

GNF Global Nuclear Fuel

Yield Stress

[[

]]

GNF Global Nuclear Fuel

Creep Rate

[[

]]

GNF Global Nuclear Fuel

RIA Behavior

[[

]]

GNF Global Nuclear Fuel

Properties Summary

- Small differences between additive fuel and standard UO_2
- [[

  ]]
- Properties implemented in GSTRM and PRIME03 computer models
- Additive fuel is consistent with existing design methodology

GNF Global Nuclear Fuel

Licensing Approach (Proposed)

- Additive LTR addressing
  - Properties
  - Behavior
  - Methods
  - Effects on licensing criteria
- Administrative amendment of GESTAR

LTR Topics (Proposed)

- GSTRM/PRIME03
  - Physical properties
  - Thermal properties
  - Mechanical properties
  - Irradiation behavior
- Application methodology (GESTAR): Regulatory requirements
  - Fuel melting
  - Gap conductance
  - Stored energy
  - Fuel rod internal pressure
  - Cladding strain
  - AOO
  - Core stability
  - LOCA
  - RIA

Feedback Needed from NRC

- Areas of specific concern
  - Properties
  - Models, methods
- Licensing approach