ENCLOSURE 5

M190175

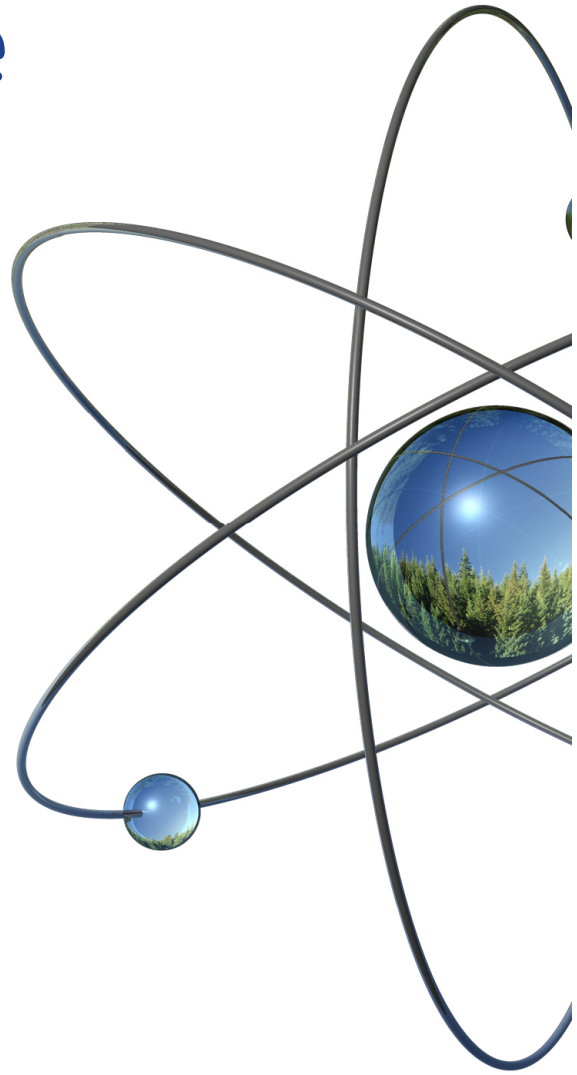
2019 Technology Update Presentation

Non-Proprietary Information

INFORMATION NOTICE

Enclosure 5 is a non-proprietary version of the 2019 Technology Update Presentations from Enclosure 4, which has the proprietary information removed. Portions that have been removed are indicated by open and closed double brackets as shown here [[ ]].

2019 Technology Update for the US NRC July 30



Brian R. Moore
General Manager
Core & Fuel Engineering

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

HITACHI

Thank You for Coming

- Safety Minute
- Introductions
- Housekeeping
  - The handouts
  - The facility
- Why we are here… sharing technical performance and direction.
- NRC Opening Statements

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July 30 - NRC Tech Update Agenda

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July 31 – Shop Tours

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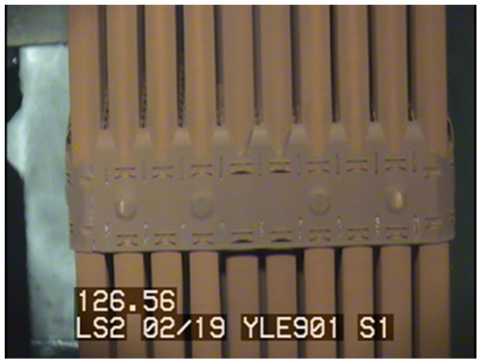
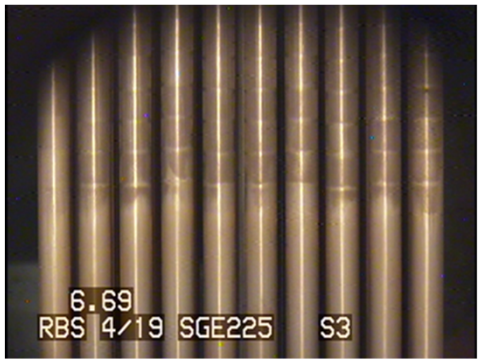
2019 Technology Update: US NRC





Fuel Experience Update

Rob Schneider, GNF Fuel Reliability

Global Nuclear Fuel

Agenda

- Fuel Experience Summary

  Total, current designs
- Reliability Trend

  historical, recent trends
- GNF2 experience details
- High Exposure Experience
- Details - recent fuel failures
- New Fuel Reload Surveillance Status
- LUA Surveillance Status & Objectives
  - Focus now on GNF3
- Rod Gap Observations
- Requested Topic – CRDM performance/crud

GNF Fuel Experience

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Largest BWR Fuel Experience Base in the World

NRC requested formats for reliability data

Fuel Performance formats

- Total Number of failed rods per year (not failed assemblies)

  provided in slide #9 and 10

- Failed rods per year broken down by failure mechanism

  provided in slide #11

- Failure Rate (failed rods per million manufactured) in US

  is provided in slide #5 by product line and #8 as function of time

Fuel Experience Update (through July 2019, 10x10 fuel)

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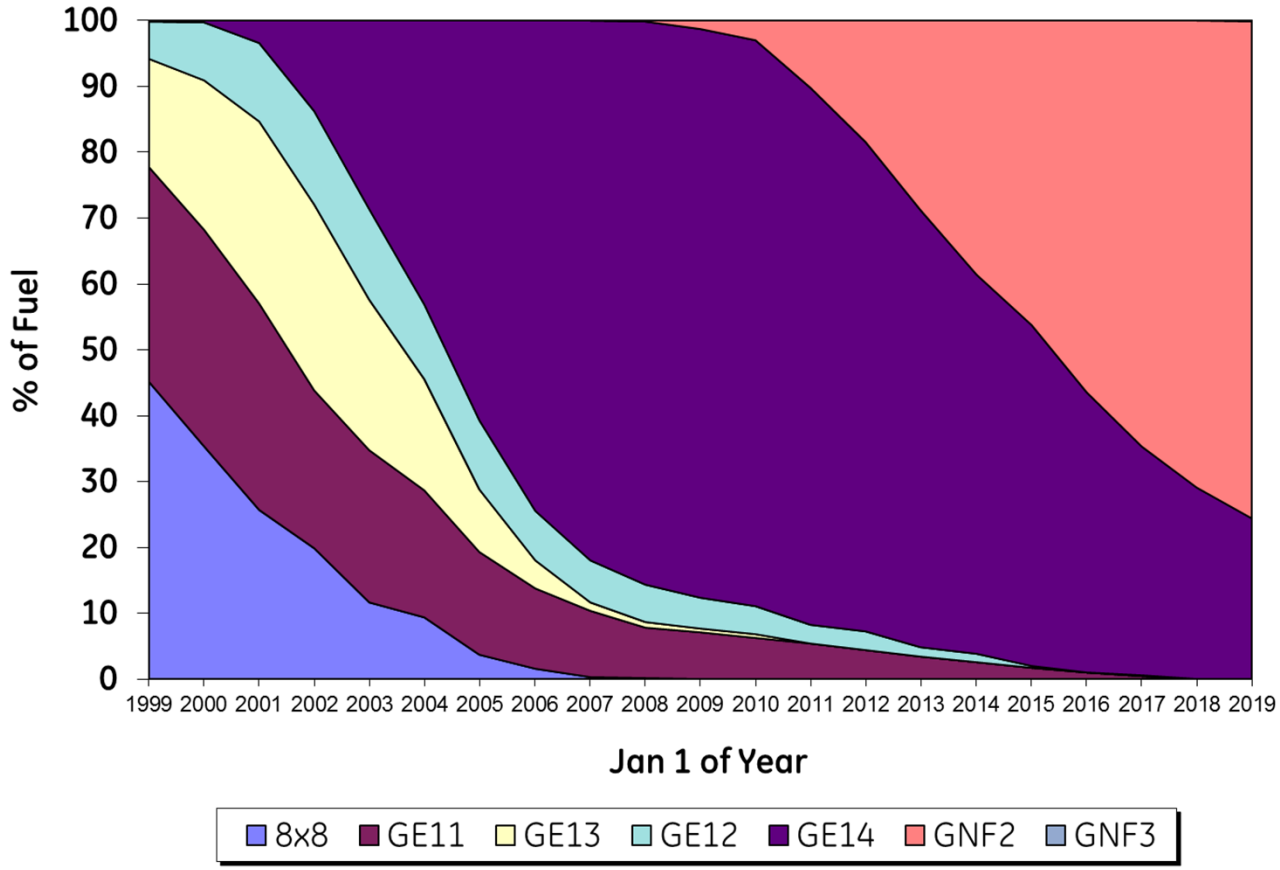
Fuel Experience Update

GNF-A, plus ENUSA/Europe, % of all bundles in-core/operating as of Jan 1 of calendar year

- # GNF2 >> # GE14 in operation
- Currently only LV-1,-2 receiving GE14
- ~88% of all GE14 is discharged, ~33% of GNF2



GNF2: Reloads & LUAs, Experience Summary

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Historical Reliability Trends

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GNF Fuel Failures per Year

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GNF Fuel Failures per Year – International

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Failed rods per year: by failure mechanism

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Rod Gap Surveillance

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Lead Use Assembly Surveillances

- GE14 LUA Irradiations & Inspections complete
- GNF2 LUAs Irradiations & Inspections complete
- GNF3 in progress

GNF3 Inspection Plans

Poolside inspections

- Visual exams & COINs (oxide, crud profilometry/diameter) periodically as outage schedules support
- Selected dimensional measurements at various exposures
- Some bundles not disassembled until end of life

GNF3 is a variant on GNF2

- Visual inspections at end of 1st & 2nd cycles completed ~Feb. ’17, ‘19
  - Confirmed mechanical integrity
  - Next inspections ~ Feb. ‘21
- Performance expectations:
  - Same spacer & fuel rod materials, uses GNF2 fuel rods
  - “Zero leakers” from mechanisms other than debris
  - Corrosion, shadow corrosion, growth, rod to rod spacing, etc. (no changes expected, none observed to date through ~40 GWd/MT)

BWR/6 Inspections – no "dryout" indications

- Inspections at Perry, RBS, Grand Gulf, and Cofrentes
  - Multiple at multiple cycles
- One, two, and three cycle GNF2 at a range of exposures and residence times inspected. From "limiting" and other cross beam core locations, with and without control, some specifically selected based on highest power or "Min CPR margin" during cycle
- No locally increased corrosion in areas "just upstream" of upper elevation spacers – nor anywhere on bundles
- No unusual crud deposition patterns in areas "just upstream" of upper elevation spacers – nor anywhere on bundles

High Exposure Experience & Limits

70 PPE:

US, Mexico, Spain

- Spain in process of “LUA” inspection program to extend >70 for Cofrentes
- 3 X 24 months cycles

80 PPE:

Switzerland (KKM)

- GNF2 LUAs to ~61.8 bundle average; ~79 PPE
- Will approach 80 PPE at end of current (final) cycle in some reload bundles

85 PPE:

Germany (RWE/Gundremmingen)

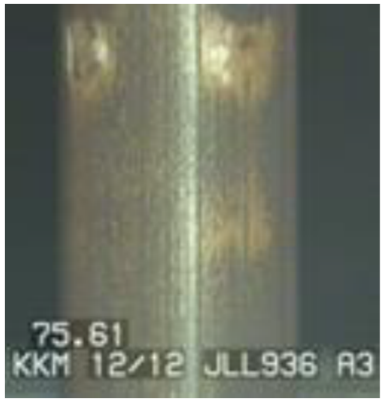
- Largest High Exposure experience base
- ~1,000 reload bundles have operated past 60 GWd/MT bundle average
- Equates to > ~72 PPE
- LUAs to higher – examples included

Nordic Countries:

Sweden 60 “peak bundle average,” ~73 PPE

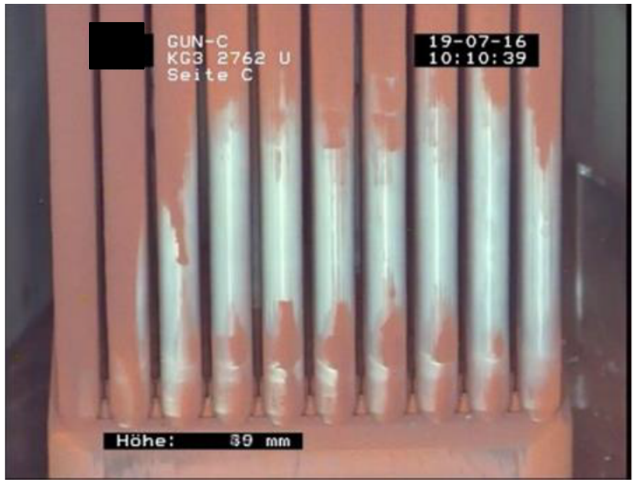
Finland 55 “peak bundle average”

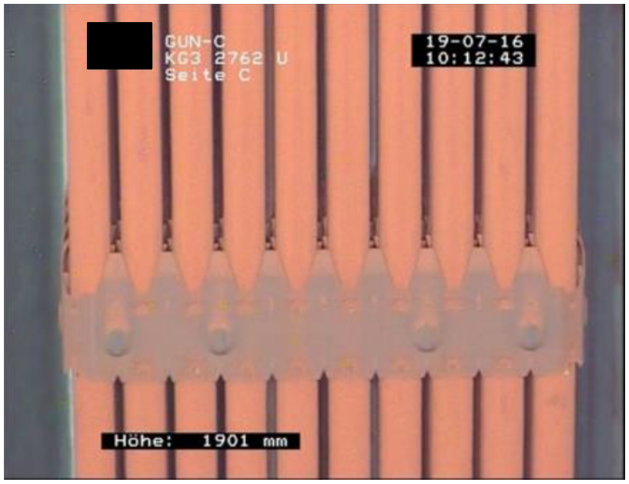
Inspection results

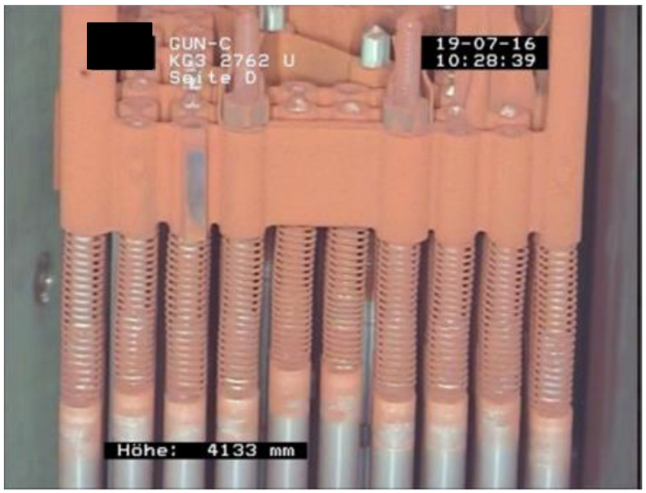


GNF2 LTA at ~61.8 MWd/kgU bundle average exposure

Inspection results







GNF2 LTA at 63.5 MWd/kgU bundle average exposure (~79.4 PPE)

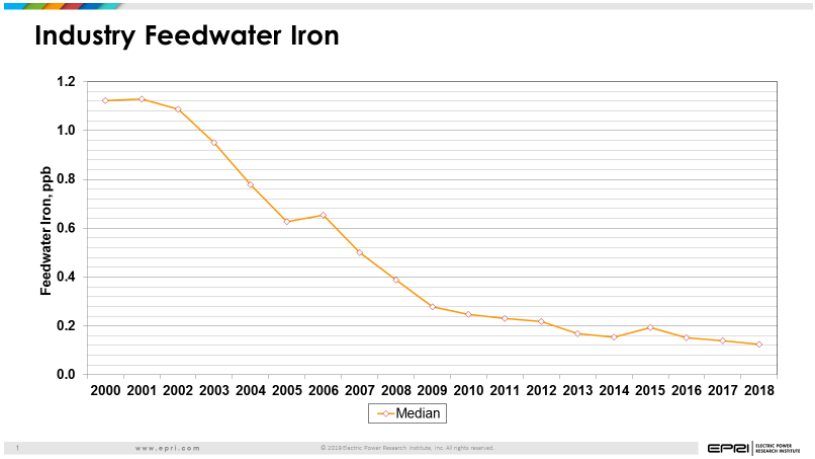
Inspection results

GE14 UHBU LTA at ~78 MWd/kgU bundle average exposure (~90 PPE)

CRDM Performance & Crud

- Excellent Reference – NUREG/CR 5699 (1992, ORNL for NRC)

- Symptoms of crud issues are usually seal damage
  - Generally different from cell friction
  - Increased seal leakage → sluggish performance, double-notching, settle at 00 after scrams but difficult to move from 00 after
  - Correlations – cycle water chemistry, outage crud transient events
  - Fleet-wide, FW Fe is down significantly vs. ~20 yrs ago.
  - Beneficial – Guide tube vacuuming, stroke blades in outages to reduce startup issues esp if crud transient in outage



Summary

- **Fuel Experience:**
  - 10x10 experience base now close to 6 million rods
- **Reliability Trends**
  - Mostly debris fretting failures - GNF supporting plants to continue operation
    - Operation with failed fuel / very low activity release routinely accomplished to ~18-20 months
- **GNF2 experience details**
  - Transition to GNF2 reloads ~complete. GNF3 started in '19
- **New Fuel Reload Surveillance Status**
  - Complete for legacy designs; extensive inspections.
- **LUA Surveillance Status & Objectives**
  - GNF3 Inspections began winter '17 after 1st 24-month cycle
  - Winter '19 after 2nd cycle
  - Next inspections February '21

ATF (ARMOR & IronClad) Programmatic Updates

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Other Projects Areas Within the ATF Program

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Non-Proprietary Information

2019 NRC/GNF Tech Update ARMOR Licensing

Tyler Schweitzer
Kent Halac
July 2019

ARMOR Licensing Topical Report (LTR) Objective and CTQs

Objective:

Obtain NRC approval for [[

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Critical To Quality:

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ARMOR Schedule

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ARMOR Licensing Strategy

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ARMOR LTR Overview

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GNF Expectations

- Material Licensing Plan…
  - Fundamental material acceptability (general compatibility, suitability for design, etc.)
  - Specific material performance criteria associated with operations and licensing
  - Licensing regulatory criteria (interpretation / modification)
  - Material plan to confirm performance and/or address gaps
  - Licensing strategy and timing

NRC Expectations

- Material Qualification Plan…
  - Current knowledge base/experience
  - Phenomena important to safety (new or different from standard Zr cladding)
  - Gaps in knowledge that need to be filled
  - Testing plans to address phenomena and gaps
  - Expected data to support TR submittal

Review Facilitation

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ARMOR Unirradiated Materials Testing Update

NRC Tech Update

July 30, 2019

ARMOR Unirradiated Materials Testing Update

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Post Quench Ductility Tests - at ORNL

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Burst tests - at ORNL

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Tensile tests

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Tensile tests - Fractography

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Interrupted Tensile Tests

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Global Nuclear Fuel

ID Expansion Test

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ARMOR-Zry2 Interface stability

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ARMOR-Zry2 Interface (1)

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ARMOR-Zry2 Interface (2)

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Additional Property Generation

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Additional Property Generation (2)

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Non-Proprietary Information

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ATF LTA Update

July 30, 2019

ATF Irradiation Programs In Process

Southern Nuclear

INL Idaho National Laboratory

Exelon.

ARMOR™

IronClad™

- Currently Installed ATF LTAs
  - Southern Nuclear - Hatch Unit 1, Cycle 29
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Non-Proprietary Information

Hatch Unit 1 Cycle 29 LTA Status

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Hatch LTA Poolside Inspections

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Post Irradiation Examination

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Acknowledgements

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Channel Performance Update

Dan Lutz
Paul Cantonwine

July 2019

Global Nuclear Fuel

Outline

- Channel Interference Trend
- Annual NSF Channel Performance Report (required by SER)

Channel Interference Trend

Channel Performance in GNF Core Designs

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Interference Problems in NSF Cells

Hope Creek Cycle 21 January 2018 sequence exchange

- 1X NSF/3X Zr-4 channel
- NSF exposure too low to cause the interference

Hope Creek Cycle 22 March 2019 MCO SCRAM

- 4 cells with insertion or settling problem, all contain some NSF
- Stalled drive cell contains 4 NSF channels
- B and Li release when CRD moved
- NSF exposure too low to cause the interference

Perry Cycle 17 shutdown

- 2 no-settle cells containing 2X Zr-4/2X NSF
- NSF exposure too low to cause the interference

Interference Problems Due to Causes Other than NSF

NSF Annual Performance Report

NSF SER Conditions and Limitations

- NRC approved NSF reload batches in 2015
- NRC set Conditions and Limitations for NSF reload licensing
  - EOL fast fluence < surrogate 70 GWD/MTU PPE
  - EOL ECBE < 55,000 inch-days
  - Continue application of SC11-05 until full NSF core in S-lattice plant does not have interference for 3 years
  - Complete NSF 8% mini batch LUC inspections
  - Annual experience report

NSF Lead-Use Channel Programs

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Pilgrim Mini-batch LUC Program

Pilgrim has permanently shutdown

- 1 cycle earlier than expected relative to LUC mini-batch program

Decided to terminate LUC inspections

- Low exposure not very helpful
- Consulted with NRC

Pilgrim is only D-lattice plant in program

- Will fill gap in other D-lattice plant(s) longer term

Recent NSF Channel Inspections

- LaSalle 2 (GNF3 LUA)
- Perry (LUC and mini-batch)
- Limerick 1&2 (LUC and mini-batch)
- River Bend (GNF3 LUA and mini-batch)

NSF LUC Mini-batch Inspection Scope

For cycles prior to discharge

- Visual 5% of batch size (3-4)
- Length 5% of batch size (3-4)

For cycles after discharge

- Visual 20% of batch size
- Length 20% of batch size
- Bow and bulge 50% of batch size
- Corrosion measurement of 20 channels

NSF Channel SIMCHAD/Length Measurement Database

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NSF Irradiation Growth Data

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New data shown by blue circles

NSF 120T Channel SIMCHAD Creep Bulge Database (no new data)

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NSF Measured Channel Bow (no new data)

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NSF Channel Shadow Bow (no new data)

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Future NSF Mini-batch Inspections for Discharge Exposures

Discharge inspections with bow and bulge scope will start with Fall 2019 outages

- Some inspections will be delayed/planned for off-outage

Clinton fall 2019

Grand Gulf Spring 2020

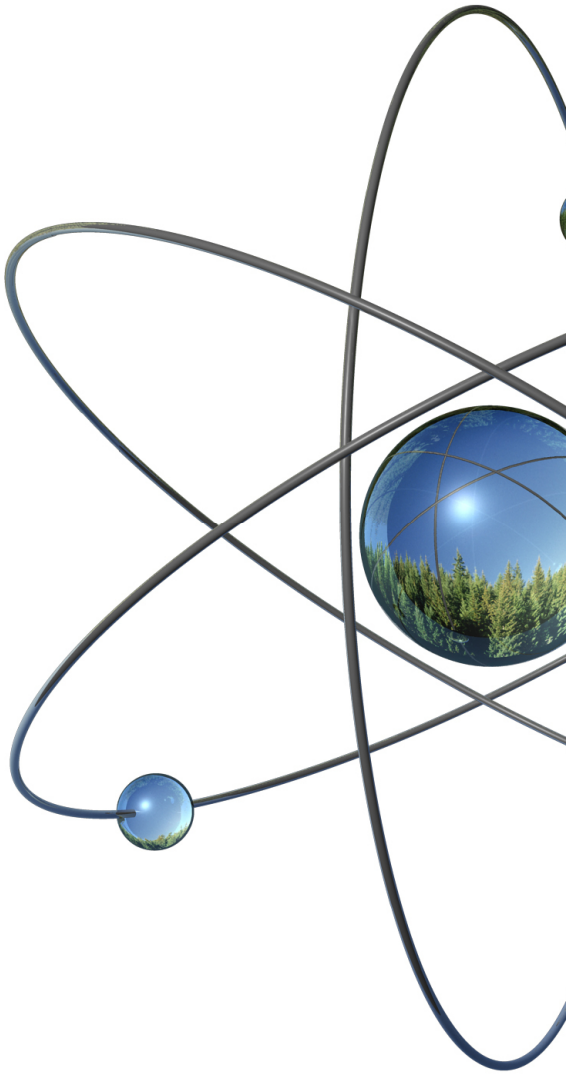
Perry, Limerick 2, River Bend 2021

Pilgrim D-lattice plant substitution 2022

Summary for 2019

- Interference still occurring at low rate with Zircaloy-2 and Zircaloy-4 channels
  - But is being well managed by plants following either SC08-05 (BWR/6) or SC11-05 (BWR/2-5)
  - Occasional interference in cells containing NSF is not caused by NSF
- Active NSF inspection program continues to demonstrate resistance to both fluence and shadow bow with acceptable corrosion
- GNF steadily expanding NSF volume with full NSF reloads

MELLLA+ L&C 23 Update



NRC Technology Update

July 2019

Global Nuclear Fuel

NEDC-33173P Limitation & Condition 23

Quote from Safety Evaluation:

"In the first plant-specific implementation of MELLLA+, the cycle-specific eigenvalue tracking data will be evaluated and submitted to the NRC to establish the performance of nuclear methods under the operation in the new operating domain. The following data will be analyzed:

- Hot critical eigenvalue
- Cold critical eigenvalue
- Nodal power distribution (TIP Nodal RMS)
- Bundle power distribution (TIP Radial RMS)
- Thermal margins (3DM vs. offline)
- Core flow and pressure drop uncertainties
- Minimum Critical Power Ratio Importance Parameter (MIP)"

Approved NRC Clarification Letter [Nov 20, 2015]

Changes to NEDC-33173P L&C 23:

	NEDC-33173P L&C 23	NRC Clarification Letter
Number of Plants	ONE (1) 1st plant-specific implementation	**FOUR (4)** Four plants to better represent fleet including higher power density
Parameters	• Hot critical eigenvalue • Cold critical eigenvalue • Nodal power distribution • Bundle power distribution • Thermal margins • Core flow and pressure drop uncertainties • MCPR Importance Parameter (MIP)	• Hot critical eigenvalue • Cold critical eigenvalue • Nodal power distribution • Bundle power distribution • Thermal margins • Core flow and pressure drop uncertainties • ~~**MCPR Importance Parameter (MIP)**~~
NRC Reporting	• Submit report following first cycle	• **Annual presentation at NRC Tech Update for 3-6 years** • Submit report following first full operating M+ cycle which contains substantial TIP data in M+ domain

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Plant-Specific MELLLA+ Implementation

- Monticello (2Q'14)
- Nine Mile Point Unit 2 (3Q'15)
- Peach Bottom Unit 2 (2Q'16)
- Peach Bottom Unit 3 (2Q'16)
- Grand Gulf (2Q'19)

Comparison Approach

- Non-TIP Data: Same approach as previous updates
  - Presentation of requested metrics based on operational data in the MELLLA+ domain has limited value without historical context
  - For each metric being compared, the following is provided to help establish methods performance on a comparative basis:
    - Fleet data from IMLTR or MELLLA+ submittals (if applicable)
    - Previous 3 cycles of information for each plant
    - Highlighted points where any cycle was operating in the MELLLA+ domain
      - Cold eigenvalues highlighted if any point in cycle MELLLA+
    - "Old MELLLA+" means shown in previous updates
    - "New MELLLA+" means new for this year's update
- TIP Data: Expanded comparisons and summary of IMLTR Supplement 6 efforts

Hot Critical Eigenvalue

Historical Basis – Source: IMLTR SE

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Monticello

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Peach Bottom Unit 2

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Peach Bottom Unit 3

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Nine Mile Point Unit 2

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Cold Critical Eigenvalue

Historical Basis – Source: IMLTR SE

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Cold Eigenvalue

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Thermal Margins:
Online Adapted (3DM) / Offline Non-Adapted (P11)

MFLPD Bias – Legacy (Pre-M+) Values

MFLPD = Maximum Fraction of Linear Power Density

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MFLPD Bias – Previously Provided Values

MFLPD = Maximum Fraction of Linear Power Density

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MFLPD Bias – 2019 Update Values

MFLPD = Maximum Fraction of Linear Power Density

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MAPRAT Bias – Legacy (Pre-M+) Values

MAPRAT = Maximum Average Planar Ratio

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MAPRAT Bias – Previously Provided Values

MAPRAT = Maximum Average Planar Ratio

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MAPRAT Bias - 2019 Update Values

MAPRAT = Maximum Average Planar Ratio

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MFLCPR Bias – Legacy (Pre-M+) Values

MFLCPR = Maximum Fraction of Limiting Critical Power Ratio

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MFLCPR Bias – Previously Provided Values

MFLCPR = Maximum Fraction of Limiting Critical Power Ratio

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MFLCPR Bias – 2019 Update Values

MFLCPR = Maximum Fraction of Limiting Critical Power Ratio

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Core Flow & Pressure Drop Uncertainties

Peach Bottom Unit 2

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Peach Bottom Unit 3

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Nine Mile Point Unit 2

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IMLTR Supplement 6 Experience and TIP Comparisons

IMLTR Supplement 6 Purpose and Timeline

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Nodal Power Distribution

Nodal TIP Comparisons

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Nodal TIP Comparisons

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Bundle Power Distribution

Radial TIP Comparisons

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Radial TIP Comparisons

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Closing Remarks

Closing Remarks

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ARMOR™ Manufacturing Upscaling

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ARMOR™ Manufacturing Capability

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ARMOR™ Machine Status

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ARMOR™ Manufacturing Timeline

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FCO Floor Map

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FCO Floor Map

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Global Nuclear Fuel

LWR HALEU lite & Higher Burnup with ARMOR - Pilot Program

Patty McCumbee
July 2019

Objectives for Pilot Plants

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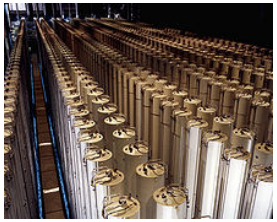
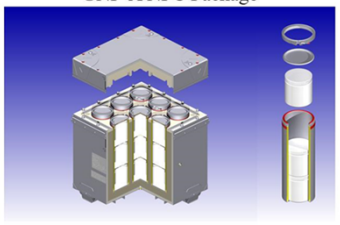
Focus Areas for HALEU lite & Higher Burnup

Enrichment Facilities



UF6 Transport

New Powder Container



Criticality Methods

Fabrication Facilities

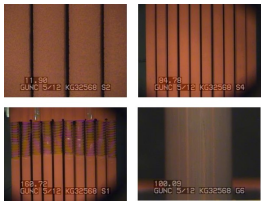
Front End

RAJ-II Fresh Fuel Transport

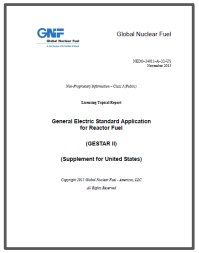
Fuel Storage

Engineering Methods

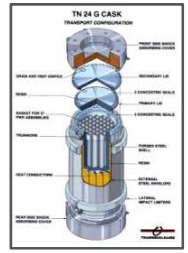
Fuel Performance



Licensing



Dry Cask Storage



In Service

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Front End

Transportation to the Factory

Feed Transport: UF6 Cylinder / UX-30

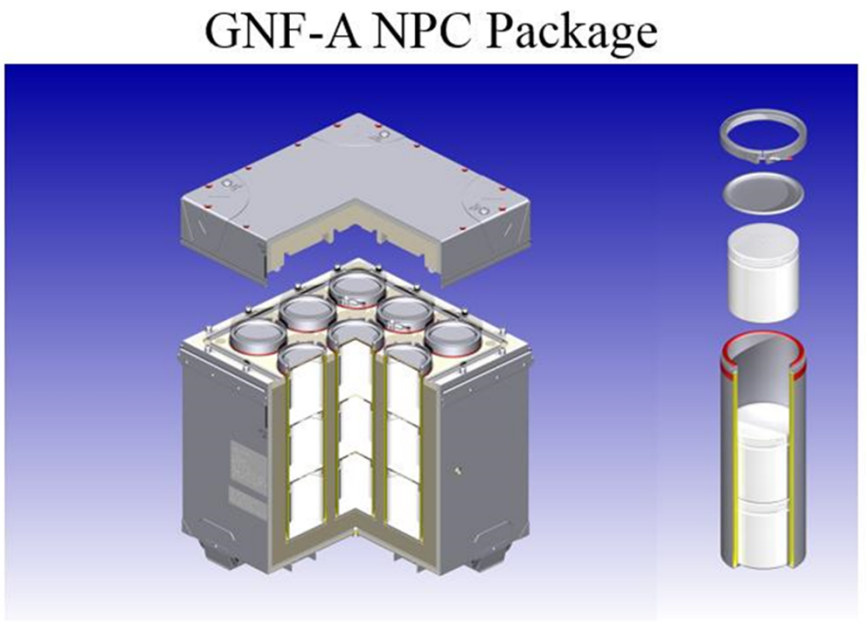
Model 30B UF6 Cylinder

Rule changes needed

Model UX-30 Overpacks on Flatrack

Global Nuclear Fuel

NPC Fissile Package Transport



Model NPC Type A Fissile Package [USA/9294/AF-96]

Uranic dry solid compounds, pellets, scrap U concentrates (both homogeneous and heterogenous material forms)

Material forms currently restricted to not more than 5.0 wt% U235

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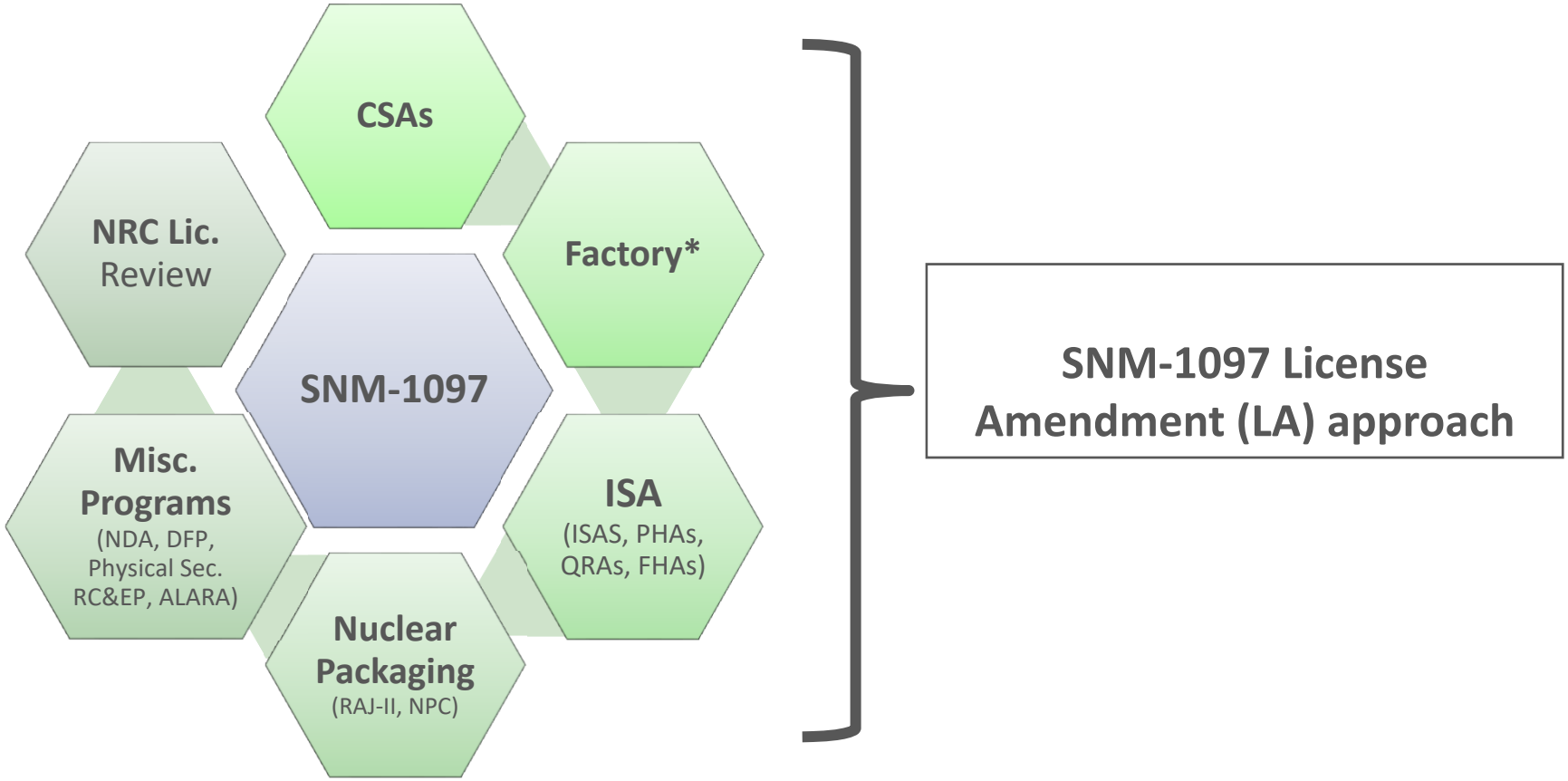
Front End

Factory Impact

GNF-A HALEU Elements of Change



* **Extent of factory changes depends on fuel form, enrichment limit**

Licensing & ISA

Commensurate with the SNM-1097 license [amendment] application, [[

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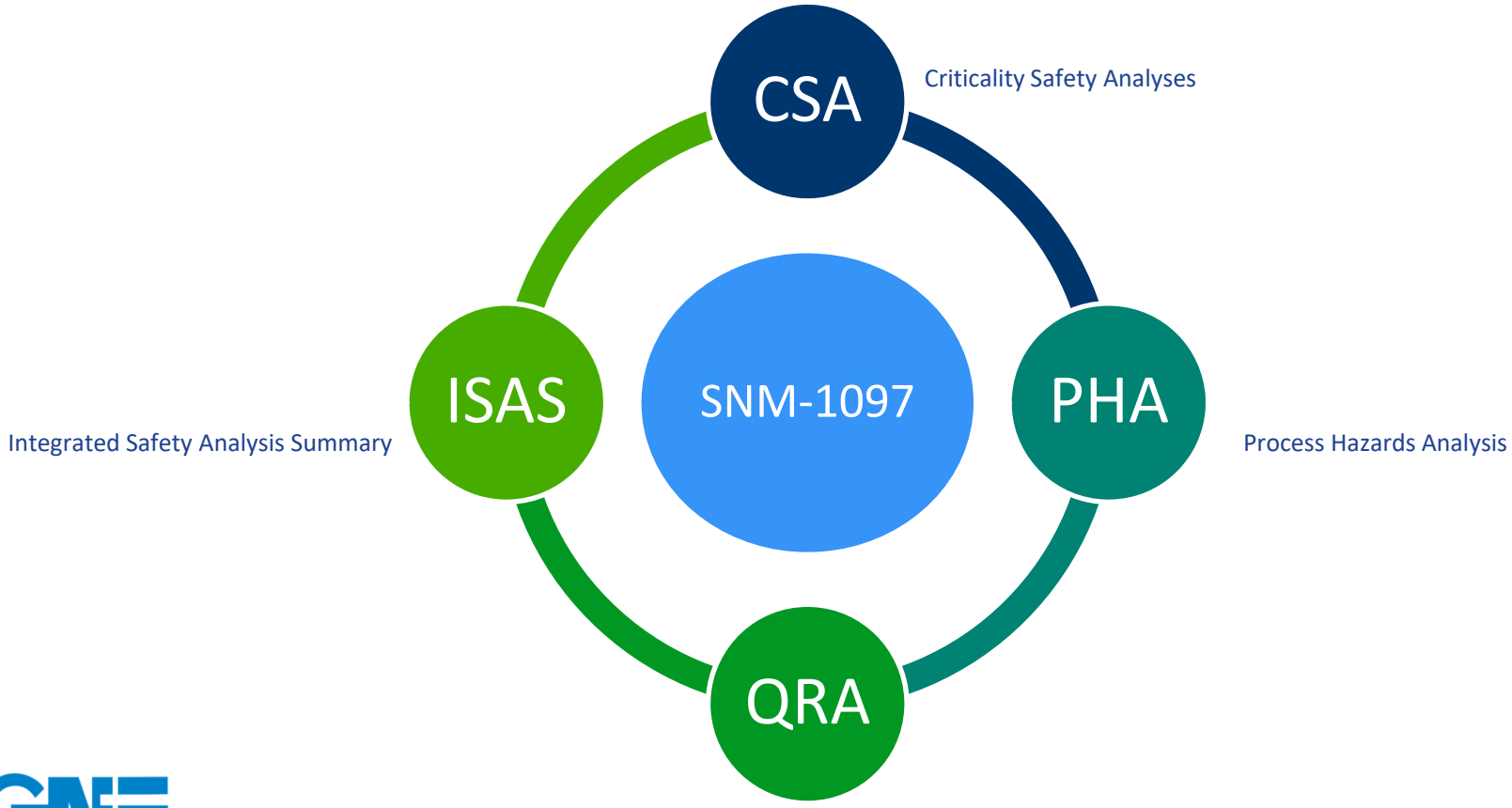

Criticality Safety Analyses (CSAs)

Technical analyses:

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Criticality Safety Analyses (CSAs)

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Summary for Manufacturing HALEU lite

HALEU lite fabrication pilot can capitalize on existing:

- Nuclear safety / ISA infrastructure
- Site security, safeguards, and MC&A programs
- Environmental permits and assessments
- Decommissioning Funding Plan (DFP)
- Established NRC/DOT nuclear packaging
- Recent GLE experience

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Front End

Transportation to the Plant Site

Fresh Fuel RAJ-II Container Transport

Model RAJ-II Type B Fissile Package [USA/9309/B(U)F-96]
BWR fuel assemblies, BWR/PWR fuel rods, UC rods

ECGU or RU per ASTM C996 material forms enriched to no more than 5.0 wt% U235

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Global Nuclear Fuel

Transportation

Currently restricted to not more than 5.0 wt% U235

RAJ-II Fresh Fuel (FF) Container

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New Powder Container (NPC) fresh fuel shipping

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GE Model 2000 irradiated fuel shipping cask

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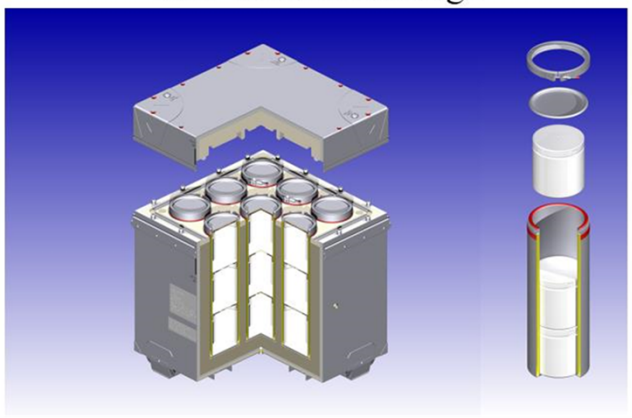
GNF-A NPC Package



Global Nuclear Fuel

In-Service

Fuel Performance Experience to High Exposure

Burnup Limits & In-Reactor Experience

Licensed to 70 GWd/MT PPE:

US, Mexico, Spain

- Spain in process of "LUA" inspection program to extend >70 GWd/MT for Cofrentes
- 3 X 24 months cycles

Licensed to 80 GWd/MT PPE:

Switzerland (KKM)

- GNF2 LUAs to ~61.8 GWd/MT bundle average; ~79 GWd/MT PPE
- Will approach 80 GWd/MT PPE at end of current (final) cycle in some reload bundles

Licensed to 85 GWd/MT PPE:

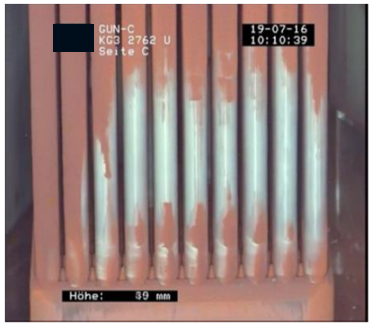
Germany (RWE/Gundremingen)

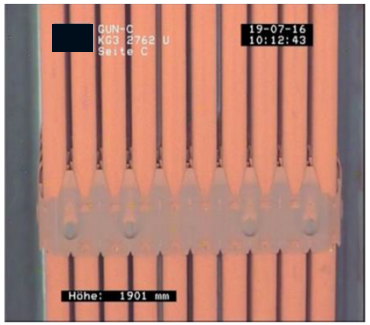
- GE14 & GNF2 LTAs to high exposure
- ~1,000 reload bundles have operated past 60 GWd/MT bundle average

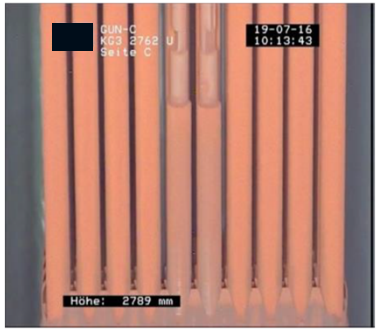
Significant high exposure fuel experience achieved

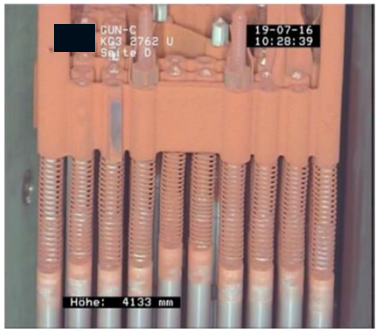
Global Nuclear Fuel

Inspection results – GUNC









GNF2 [63.5 GWd/MT bundle average exposure (~79.4 GWd/MT PPE)]

GE14 UHBU [~78 GWd/MT bundle average exposure (~90 GWd/MT PPE)]

Significant high exposure fuel experience achieved with no in-service performance, mechanical or corrosion issues

Global Nuclear Fuel

In-Service

Fuel Storage

Spent Fuel Pool and New Fuel Vault Criticality

SFP and NFV criticality licensing

Specific sites do not have a lot of margin in their SFP and NFV analyses of records (AORs)

This may require the site to create a dual zone SFP/NFV and/or make rack modifications to store higher enriched fuel bundles

Changes to SFP and NFV Technical Specifications for higher enrichments, higher in-core k-inf limits, or storage configurations (checker-board patterns/dual zone) would require a submittal to the NRC

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Global Nuclear Fuel

In-Service

Engineering Methods

Engineering Methods

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In-Service

Fuel & Reload Licensing

Fuel & Reload Licensing Approach

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Evaluate technical specifications

Assumes ARMOR LTR approved in appropriate timing

Global Nuclear Fuel

In-Service

Dry Cask Storage

Dry Storage Requirements

Dry storage of discharged fuel assemblies

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Some select product retrofits may evolve over time as burnup increases

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Global Nuclear Fuel

Looking Forward

Notional Timeline

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