ENCLOSURE 5 (CD-ROM #2)

MFN 12-015

2011 Technology Update Presentation

Non-Proprietary Information – Class I (Public)

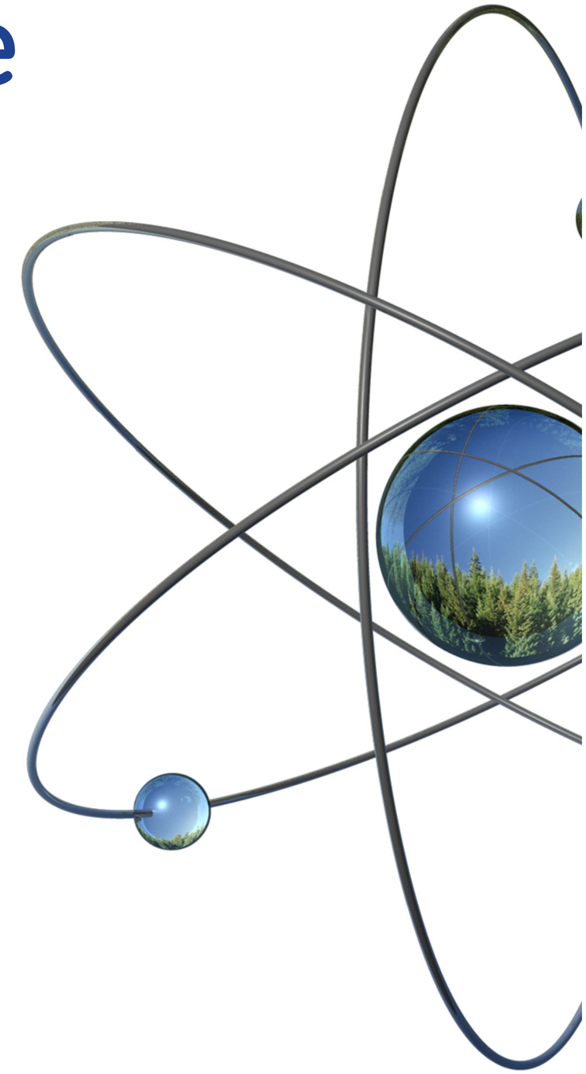
IMPORTANT NOTICE

Enclosure 5 is a non-proprietary version of the 2011 Technology Update Presentation 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 [[ ]].

Non-Proprietary Information – Class I (Public)

2011 Technology Update for the US NRC

June 2011



Andy Lingenfelter
Vice President,
Fuel Engineering

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

UNITED STATES NUCLEAR REGULATORY COMMISSION

HITACHI

Thank You for Coming

- Introductions
- Housekeeping
  - The handouts
  - The facility
  - Who is going on the tour?
- Why we are here.. sharing technical performance and direction.
- Tony

Non-Proprietary Information – Class I (Public)

June 20th

June 20, 2011				
	Time	Subject	Presenter	Delta
1	08:30	Welcome and Introductions	Andy Lingenfelter / Jerry Head	15 min
	08:45	NRC Comments	Tony Mendiola (NRC)	15 min
2	09:00	Materials Technology NSF Channel Additive Fuel Ziron Cladding	Paul Cantonwine Kevin Ledford	30 min
3	09:30	PRIME Implementation 5 Year Plan	Peter Diller Nayem Jahingir	45 min
	10:15	Break		15 min
4	10:30	Fuel Performance Update	Rob Schneider	45 min
5	11:15	Advanced Programs Co60 Bundles Moly99 Advanced Recycling PRISM Reactor	Brad Bloomquist John Berger Eric Loewen	60 min
	12:15	Lunch	All	60 min

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June 20th

6	13:15	Control Blades Annual Inspection Update Failure Analysis Lifetime Reduction New Blade Designs	Scott Nelson	45 min
7	14:00	50.46 Rulemaking Status	Paul Clifford (NRC)	30 min
8	14:30	GEH/GNF 50.46 Progress & Plans	Kurshad Muftuoglu Yang-Pi Lin	45 min
	15:15	Break		15 min
9	15:30	Fukushima Topics	Fran Bolger	45 min
10	16:15	Shutdown Margin Status	Gary Galloway	15 min
	16:30	General Discussion	All	30 min
	17:00	Adjourn	All	

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June 21th

June 21, 2011				
11	08:30	Comments and Morning Discussion	Andy Lingenfelter, et al	30 min
12	09:00	Recent 50.46 Notifications	Dave Knepper	30 min
13	09:30	ATWS Instability Analysis	Peter Yarsky (NRC)	15 min
14	9:45	ATWS Methods Status	Mike Cook	15 min
	10:00	Break	All	15 min
15	10:15	NRC Submittals Status & Predictions	Jim Harrison	30 min
16	10:45	Advanced Nuclear Methods LANCER Update Status of Current Methods	Walid Metwally Atul Karve	45 min
17	11:30	M+ Limitation 12.6	Atul Karve	30 min
18	12:00	General Discussion	All	30 min
	12:30	Closing Statements	Andy Lingenfelter Tony Mendiola (NRC)	15 min
	12:45	Adjourn		
	13:30	Factory Tour		

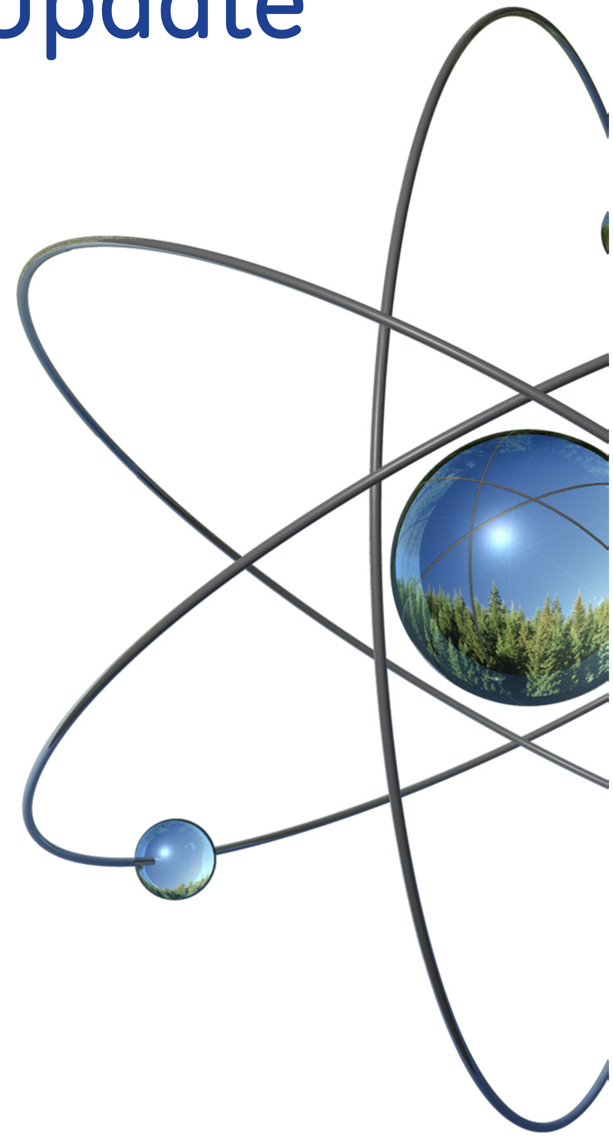
Non-Proprietary Information – Class I (Public)

GNF Channel Performance Update









Paul E. Cantonwine
Senior Engineer

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Summary: 2010 NRC Technology Update

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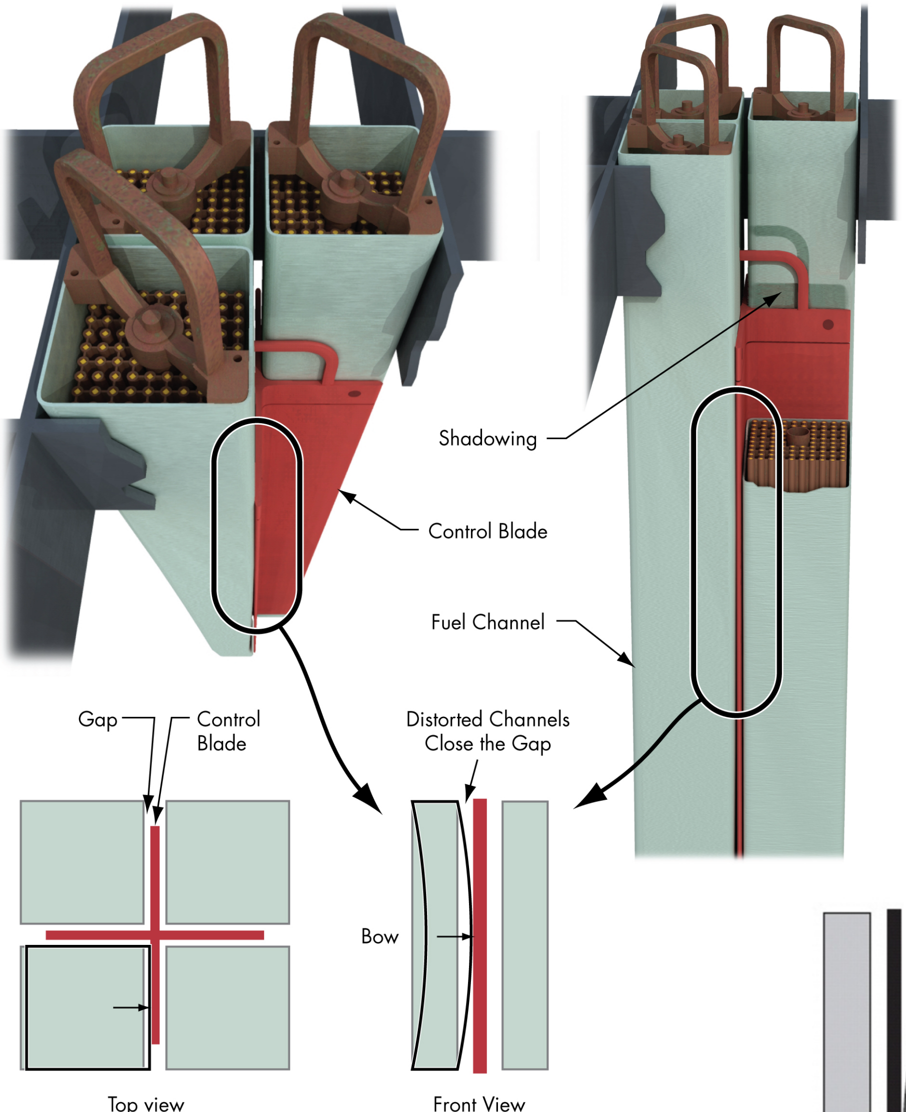
Outline

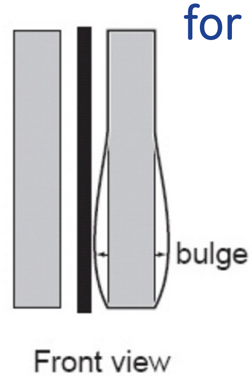
- Channel Distortion Background
- GNF Operational Experience
- Transition to NSF Channels

Channel Performance Consideration

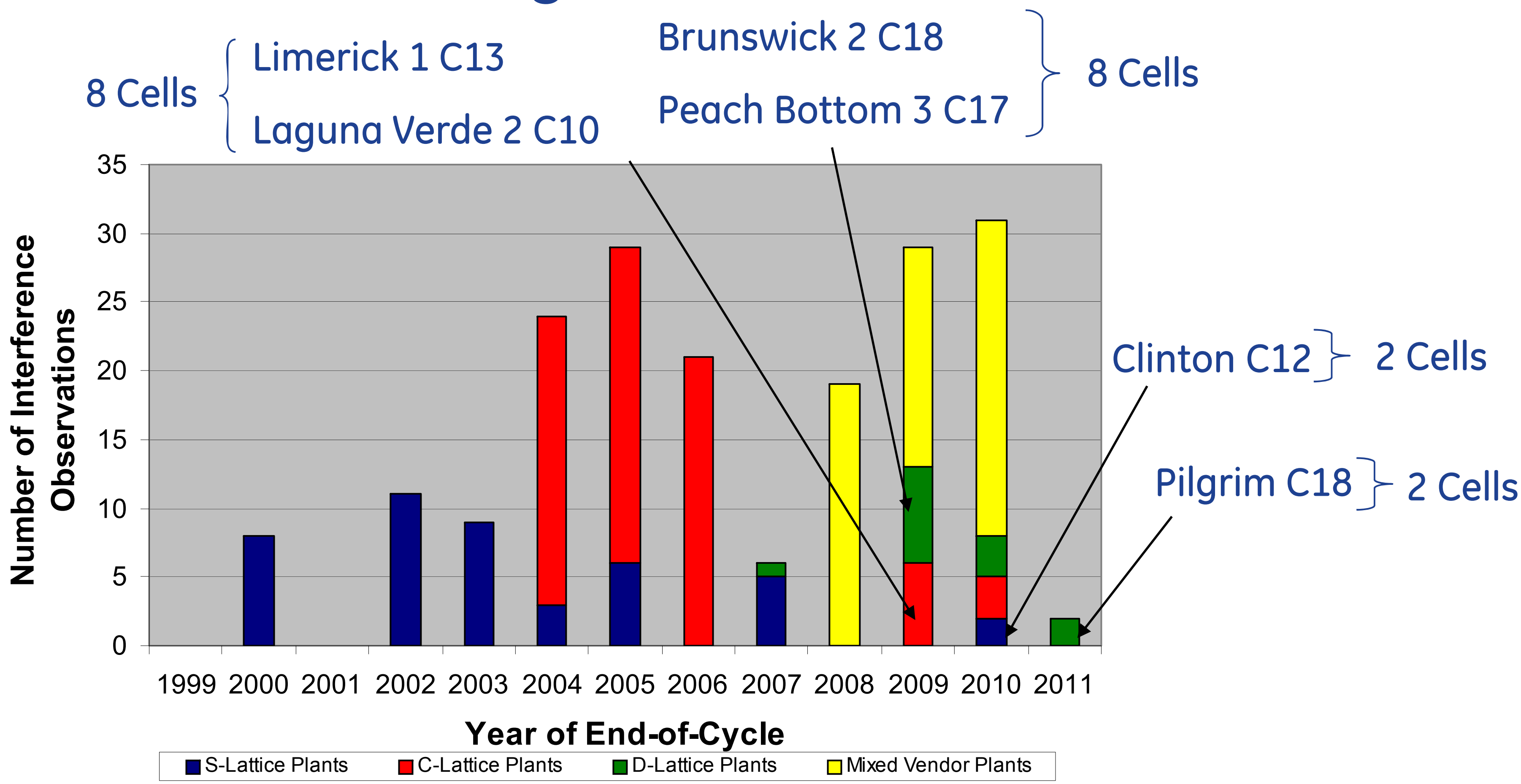


Channel Functions

- Guides control rods
- Directs reactor coolant flow
- Provides structural stiffness for fuel bundle
- Transmits seismic loads from assembly to top guide and fuel support piece (core plate)
- Provides a heat sink during LOCA
- Provides a stagnation envelope for incore fuel sipping



GNF Channel Performance: GNF Only and Mixed Vendor Core Designs



GNF is phasing out use of Zircaloy-2 in S- and C-Lattice Plants

2010: 50% Zircaloy-4, 50% Zircaloy-2

Two Recent Observations of Channel – Control Blade Interference

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GNF Planning Transition to NSF Channels

- NSF – 1% Nb, 1% Sn, 0.35% Fe

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NSF is in the same Zr – Nb,Sn,Fe Family as to E635 and ZIRLO

	NSF	E635	Zirlo
Sn	0.95	1.25	1.0
Nb	1.0	1.0	1.0
Fe	0.35	0.37	0.1
O	0.12	0.06	0.14

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Industry Experience

- Extensive experience with oxidized channels
  - Prior to ~1990 GE autoclaved all channels – oxidized in high temperature steam
  - No in-reactor corrosion issues associated with autoclaving

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Status of Lead-Use Channel Programs

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Summary

- Zircaloy-2 is still causing interference problems
- Expect observations to decrease with transition to Zircaloy-4
  - But Zircaloy-4 is still susceptible to interference in cells with high exposures and fluence gradients

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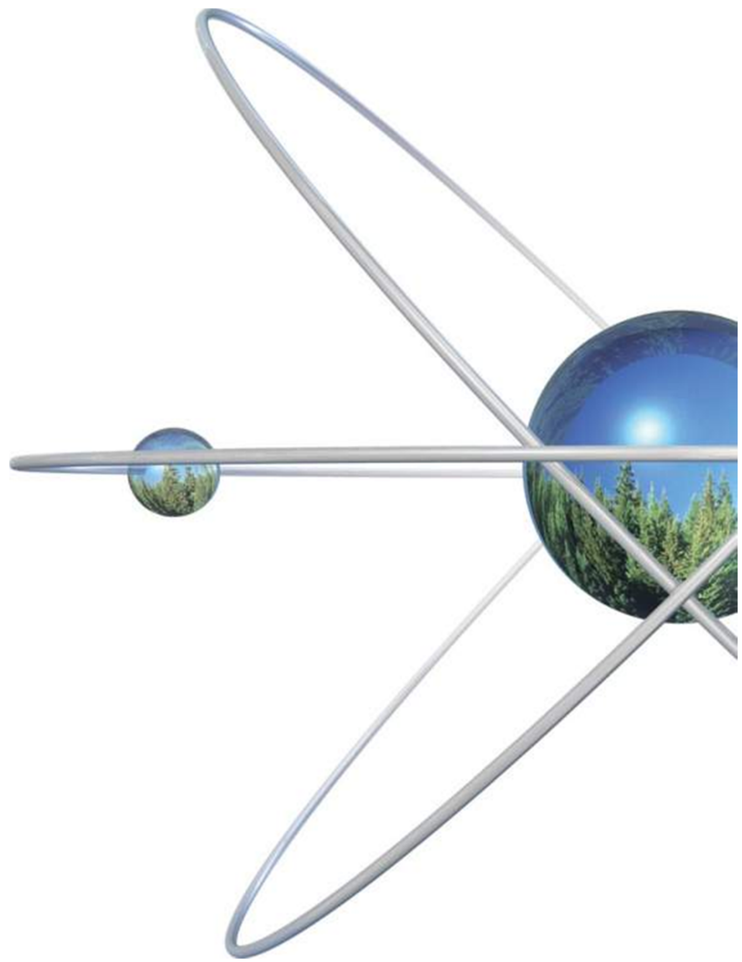
Technology Update for the US NRC
June 2011



GNF-Ziron
Additive Fuel

Kevin Ledford

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GNF-Ziron

- LTR Submitted (YE 2010)
  - Continue to evaluate GNF-Ziron performance in LTA/LUAs
- Active LTAs: [[
  - Forsmark (In 3rd Cycle) GNF2
  - VY (In 3rd Cycle) GNF2
  - Hatch 2 (In 1st Cycle) GNF2
  - Hatch 2 (In 2nd Cycle) GE14
  - Clinton 1 (In 3rd Cycle) (LUC) GE14
  - Perry (In 3rd Cycle) (LUC) GE14]]
- Recent LTA Completions:
  - Gun C GE14 (Completed 8th Cycle ~ 78 MWd/kgU)

  [[ ]]

Forsmark3 GNF2 LUA

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- Inserted 2008
- GNF –Ziron / Zr2 P8
- End of 2nd Cycle ~27 MWd/kgU
- No Significant Observed Differences
  - Crud Buildup
  - Rod growth
  - General Corrosion
  - Shadow Corrosion
  - Rod-to-Rod Spacing

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VY GNF2, 2nd Cycle, P8/GNF-Ziron (~26 GWd/MTU)

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- Continued observation of GNF-Ziron Performance
- Similar Performance - No Significant Observed Differences

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Alumino-Silicate Additive Fuel

- LTR Submitted (YE 2009) [[
  - RAIs provided by NRC Apr 2011.
- Recent LTA Completions:
  - Gun C (Completed 8th Cycle ~ 78 MWd/kgU)

  [[ ]]
- Process Deployment
  - Furnace Mod Complete (2010)
  - Process Qualification (In-process)

    - Same Process, Same Quality

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Technology Update for the US NRC June 2011






PRIME Status & Implementation

Nayem Jahingir & Peter Diller

GNF
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GNF New T-M Design Methodology

PRIME is the GNF's new Fuel Rod Thermal-Mechanical behavior simulation, design and licensing analysis methodology

- Developed based on the current approved GSTRM models
- Explicitly addresses high burnup fuel behaviors
  - Burnup dependency in the fuel pellet conductivity
  - High burnup structure formation & grain growth
  - Burnup dependency in the fission gas release, cladding creep & growth
- Includes an improved Gad pellet conductivity model
- Extensively qualified with high burnup fuel performance data

- **NRC SER Received on January 2010**

PRIME Activities Since NRC Approval

Since PRIME SER (Jan 2010)

- GESTAR II Rev 17 issued to include PRIME methodology **(Completed on March 10)**
- GNF2 T-M design & licensing with PRIME **(completed on March 10)**
- PRIME validation with the new fuel performance data to support the 5 yearly update **(on going)**
- PRIME properties & inputs implementation in the downstream safety analysis codes **(on going)**
- GE14 T-M design & licensing with PRIME **(on going)**

PRIME Validation with New Data

GNF collected new fuel performance data

- **Fission Gas Release** data collected from TVO OL1 reactor at Finland in '08 and '10
- **Fission Gas Release** data collected from GUN-C reactor at Germany in '09
- **Cladding irradiation growth** data collected from BOR-60 reactor at Russia

GNF is closely following **International Irradiation Programs** for new fuel performance data

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Fission Gas Release Measurements at TVO (gamma scanning)

2008 Measurements

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2010 Measurements

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TVO Fuel Rod Irradiation Histories

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Nodal LHGR:
Peak Median and Interquartile Range

Nodal Centerline Temperature:
Peak Median and Interquartile Range

2008 TVO Gamma Scanning Data

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Measured Fission Gas Release

[[ ]]

"Measured" Rod Internal Pressure

2008 TVO FGR Data Comparison with the GNF FGR Database

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Aluminosilicate Additive Fuel Fission Gas Release Measurements (rod puncture)

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GE14 Additive LUAs Irradiation Histories (measured rods)

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Nodal LHGR:
Peak Median and Interquartile Range

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Nodal Centerline Temperature:
Peak Median and Interquartile Range

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TVO & GUN-C Fission Gas Release Measurements

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PRIME Comparisons with the Measured FGR Data

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PRIME conservatively predicts the Measured FGR Data

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PRIME Comparisons with the “Measured” Rod Pressure Data

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PRIME conservatively predicts the “Measured” Rod Internal Pressure Data

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Cladding Irradiation Growth Measurments

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GNF irradiated different cladding alloys at BOR-60 Reactor in Russia (EPRI NFIR-V)

- Different alloy compositions and heat treatments were evaluated
- Fluence up to [[3.4 E22 n/cm^2 (E>1MeV) ~ 175 GWd/MTU]]
- Irradiation growths are measured

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Sample Canister

PRIME Comparison with the Measured Irradiation Growth Data

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PRIME predicts well even beyond the normal operating range

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Summary/Future Plans

PRIME adequately predicts the new data

- Conservatively predicts Fission Gas Release & Rod Internal Pressure
- Predicts the cladding irradiation growth data well beyond the normal operating range

GNF closely monitoring Halden, SCIP and NFIR irradiation programs and will use any data available for PRIME validation

GNF is planning to update the PRIME qualification report (NEDC-33257P) in **2015** with the available new data as per PRIME SER Limitation 4

PRIME Implementation

PRIME Implementation Overview

> Downstream implementation detailed in Supplement 4 to the Methods LTR (NEDO-33173)

> Methodologies will be updated to include PRIME conductivity and gap conductance models, or PRIME fuel temperature models

> PRIME to be implemented into all relevant downstream codes, i.e. those with a pellet thermal model

> GE14 thermal-mechanical curve to be re-analyzed with PRIME & Am. 22 report updated

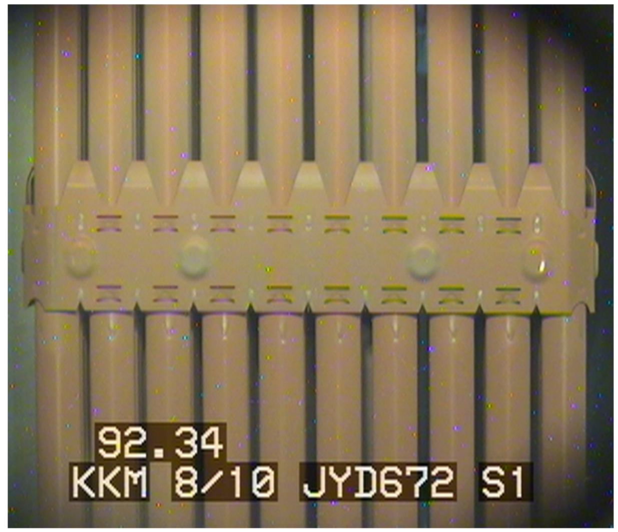
PRIME Implementation by Methodology

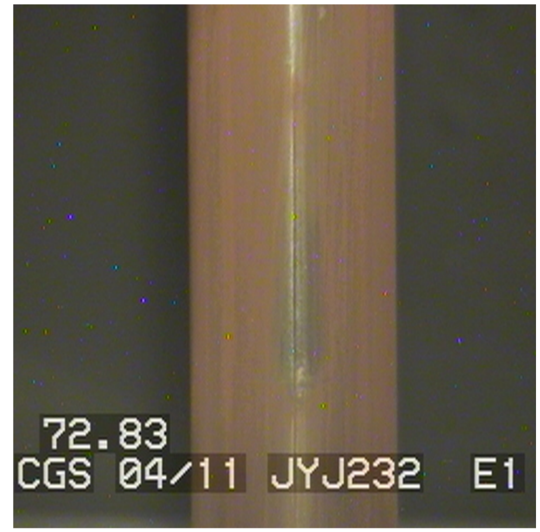
- All thermal models to be transitioned to PRIME
  - Thermal conductivity and gap conductance
    - ODYN, TASC, ODYSY, SAFER & CORCL
  - Heat flux table (fuel temp. v. thermal power & exposure)
    - PANAC, GESAM
- Code models implemented as switch with GSTRM still current default
- Sensitivity studies completed, impact small as expected

Supplement 4 Requirements

1. Testing of the PRIME models to ensure that the model, as coded, generates appropriate properties over the range of application
2. Process changes necessary to provide any additional inputs, such as providing PANAC11-generated nodal exposure information to downstream transient and accident codes
3. Comparison of the application process using PRIME relative to the previous method
4. Comparison of the code’s sensitivity to similar sensitivities predicted using TRACG
5. The significance of the changes considering the process for including uncertainties

Technology Update for the US NRC June 2011





Fuel Experience Update

Rob Schneider

GNF
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Agenda

Non-Proprietary Information – Class I (Public)

- **Fuel Experience Summary**
  - **Total, current designs**
- **Reliability Trend**
  - **historical, recent trends**
- **Details regarding recent fuel failures**
- **New Fuel Reload Surveillance Status**
- **LUA Surveillance Status & Objectives**
- **GNF2 experience details**
- **Rod Gap Observations**

GNF Fuel Experience

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Largest BWR Fuel Experience Base in the World

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NRC requested formats for reliability data

(1) Fuel Performance

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

  REPLY: this is provided in slide #8

- Failed rods per year broken down by failure mechanism

  REPLY: this is provided in slide #9

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

  REPLY: this is provided in slide #5

Fuel Experience Update (through May 2011, 10x10 fuel)

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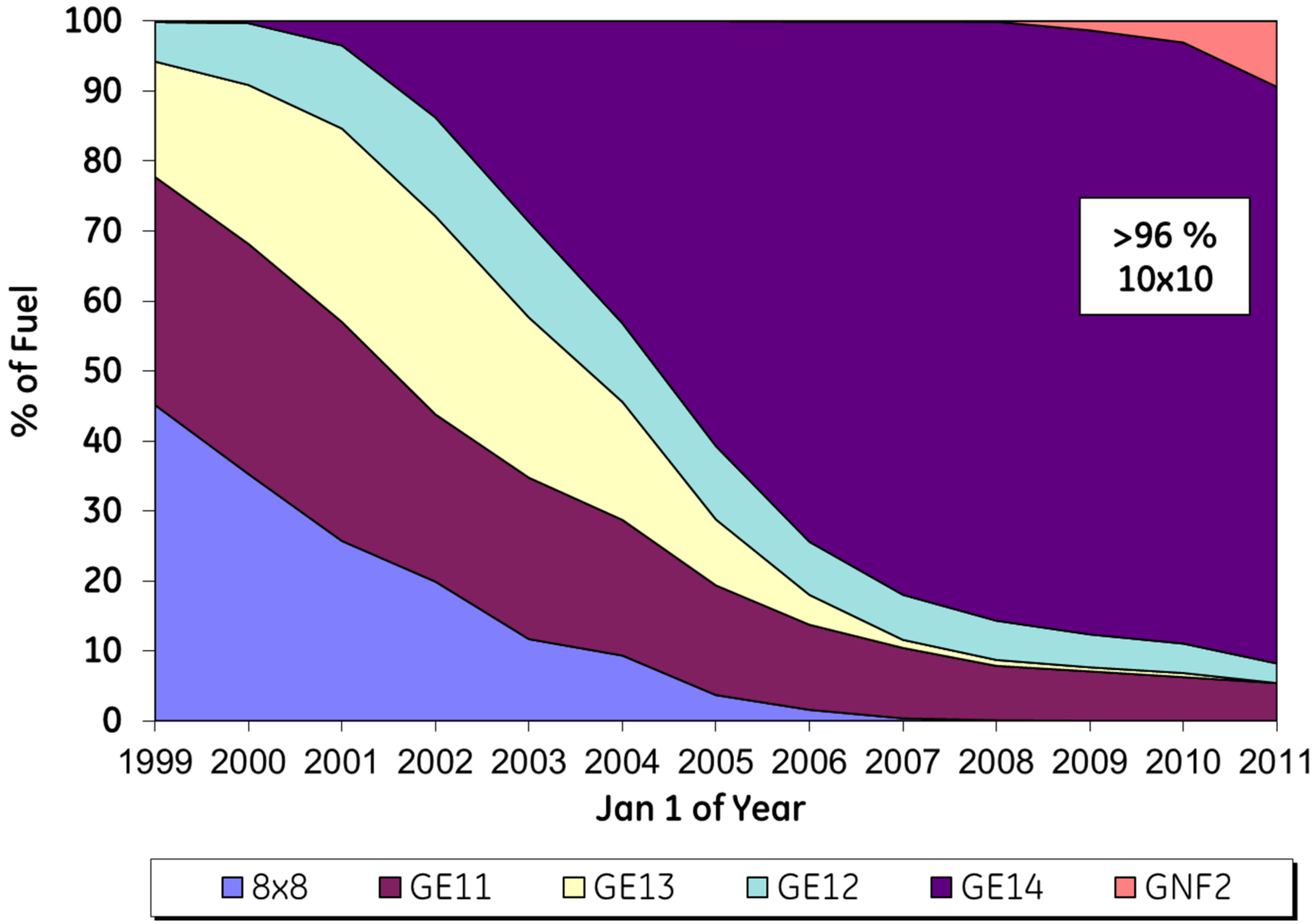
Fuel Experience Update

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



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Historical Reliability Trends

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GNF Fuel Failures per Year

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Failed rods per year broken down by failure mechanism

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Stop Debris Failures…..

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Debris Filter Technology for 10x10 Fuel

Debris Mitigation

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New Fuel Reload Surveillances

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Rod Gap Surveillance

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Lead Use Assembly Surveillances

- **GE14 LUA Irradiations & essentially all Inspections complete**
  - Some additional inspections planned at Gun-C UHBU LUAs, discharged fall 2010 at ~77.4 GWd/MTU bundle average
- **GNF2 LUAs began irradiation in 2005**

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  - **two new 4 bundle sets added in 2011, Hatch-2 and OL-1, utility demonstrations**

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GNF2 Inspection Plan

- Poolside inspections
  - Focus on new features
  - Visual exams & COINs (oxide, crud profilometry/diameter) every cycle (KKM LUAs, domestic PB3/VY LUAs to date)
  - Selected dimensional measurements at various exposures
  - Some bundles not to be disassembled until end of life inspection

GNF2: Reloads & LUAs, Experience Summary

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Latest GNF2 LUAs Inspection Results

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Latest GNF2 LUAs Inspection Results

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Recent & Upcoming Inspections

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Summary

- **Fuel Experience:**
  - **10x10 now >3.3 E6 rods**
- **Reliability Trend**
  - **Debris remains main challenge, but progress in many plants; a few outliers remain; GNF working with those plants; US plants doing well**
  - **All failure events are investigated**
- **New Fuel Reload Surveillance Status**
  - **Complete for GE14; extensive inspections**
- **LUA Surveillance Status & Objectives**
  - **Numerous inspections completed/planned**
- **GNF2 experience details**
  - **Transitioning to "mostly GNF2" reloads**

Non-Proprietary Information – Class I (Public)

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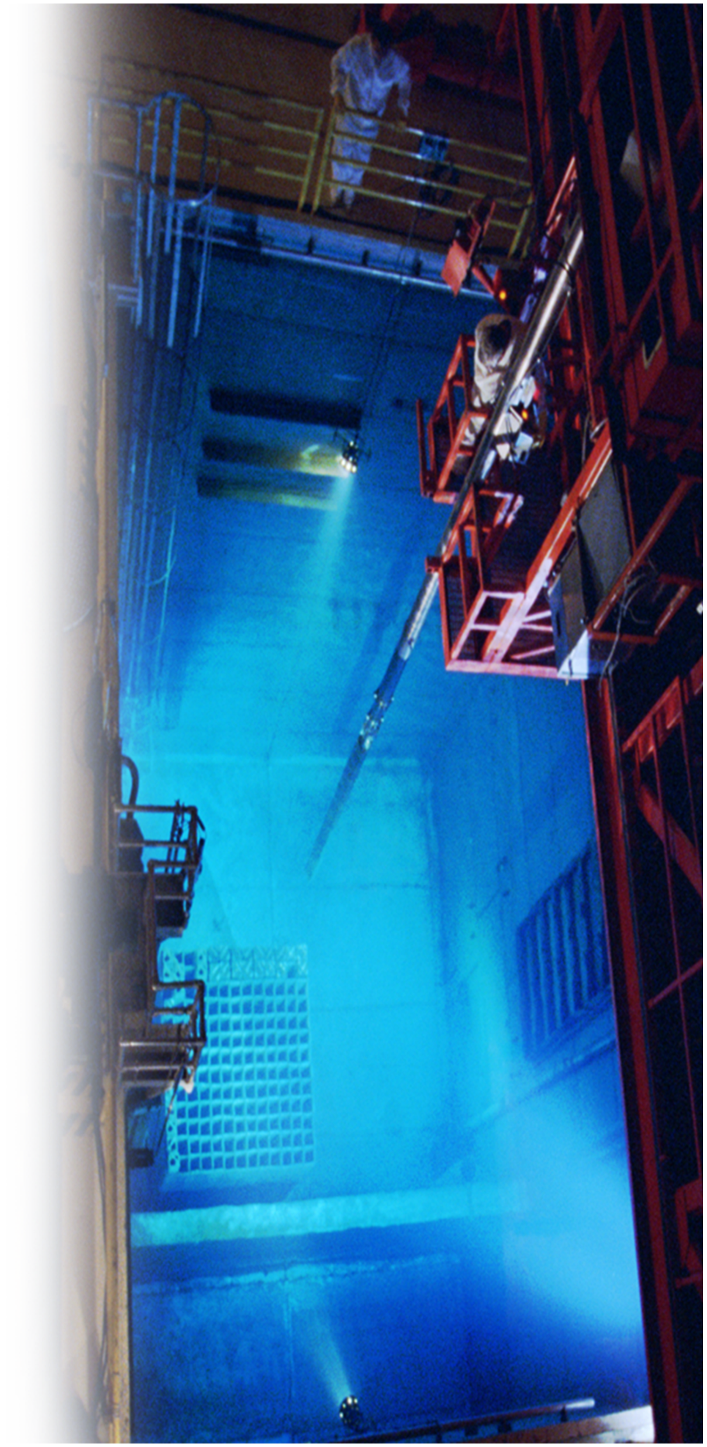
June 2011

High Temperature Oxidation Testing

Plans and Status



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Background

- High temperature oxidation is needed to address PQD, breakaway oxidation and establishing analytical limits
  - Draft language (ML110970044)
  - Draft Reg Guides (DG-1261, 1262 and 1263)
  - May 10th ACRS sub-committee meeting
- GNF engagement
  - QA approach to testing
  - PCT effect on PQD
  - Material effect on breakaway oxidation
  - Round Robin Testing
  - Text facility and compliance with Guides

Material processing and breakaway oxidation

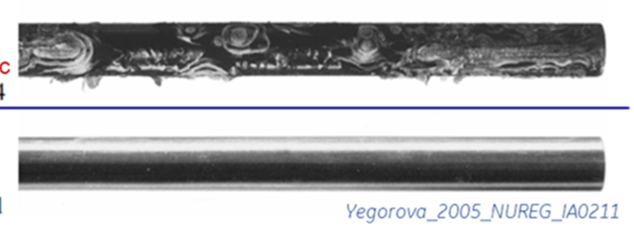
Kroll Process	Electrolytic Process
Zr(Hf)SiO_4	Zr(Hf)SiO_4
Carbo-chlorination $ZrSiO_4$ --> $ZrCl_4$	Zr/Hf separation
Zr/Hf separation	Convert to K_2ZrF_6
Zr Reduction by Liq. Mg $ZrCl_4$ --> Zr	**High Temperature, High Current Eletrolytic Cell, K_2ZrF_6+KCl as Electrolyte, Zr Formed at Cathode**
Distillation (Mg removal)	
Pure Zr (Sponge)	Pure Zr
Ingot (Pure Zr + Alloy Addition + Recycle)	Ingot (Pure Zr + Alloy Addition + Recycle)
Multiple melting	Multiple melting ?
Hot Forge	Hot Forge / Roll
Beta Quench	Beta Quench ?
Hot Extrusion	Hot Extrusion
Anneal	Anneal
Cold Pilger (Multiple)	Cold Pilger (Multiple)
Anneal	Anneal
Straighten	Straighten
Belt Polish (OD)	**Pickle (OD)**
Clean	Clean

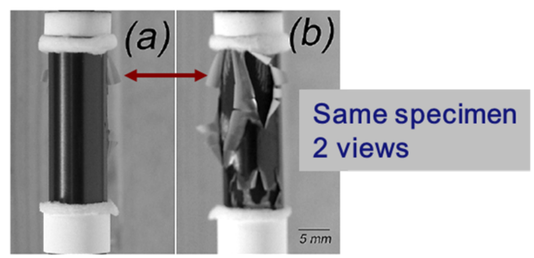
GNF

- Electrolytic Process and Pickle (and deep scratches) are known causes for early onset of breakaway oxidation
- Material chemistry and processing effects can be separated

E110 Electrolytic #44

E110 Kroll #91





Zry2 Kroll **Remelt**

Zry2 Electrolytic **Remelt**

Impurities effect (Kroll vs. electrolytic) established at ingot stage

Extremely low risk of early breakaway in Kroll material

Breakaway Oxidation Testing

Objective

- Confirm time to breakaway oxidation near 1000ºC (Zry2 > 5000 s @ 1000ºC with scratch, NUREG/CR-6967)
- Ensure cladding oxidation characteristics remain consistent

Approach under consideration

- Address key known effects: Impurities (Kroll vs. electrolytic), surface scratches (relatively minor), and surface finish (polish vs. pickle)
- **Material chemistry**
  - Ingot process (based on Kroll Zr) will not change.
  - Can test at any stage of processing (e.g. at ingot or billet stage)
  - Test annually per DG.
- **Processing**
  - Qualify key process step
    - Conduct breakaway oxidation testing to qualify **range** on surface scratches and conditions.
    - Test on final cladding during qualification and when process change.
  - Control surface contamination and surface scratches to within qualified range
    - Leverage other tests for surface condition and scratches
  - Re-qualify when significant change is made or new alloy

GNF Test Facility and status

- Being set up at Vallecitos
- 3 zone programmable 18" tube furnace
- Resistance-heating
- Rated for 1205°C
- Type S Thermocouple
- Initial trial testing underway
- Plan to be part of industry round robin
- Expect to be compliant with DGs (mostly)

Comments on DG-1261, 1262 and 1263

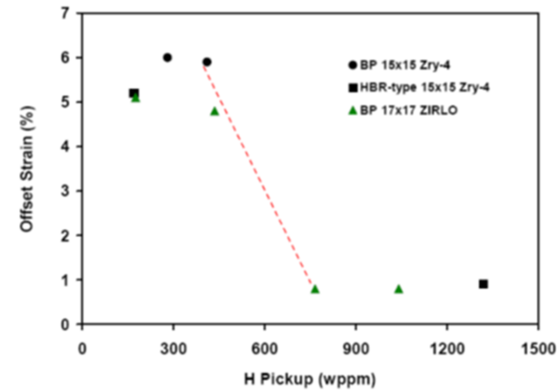
DG-1261 and 1262:

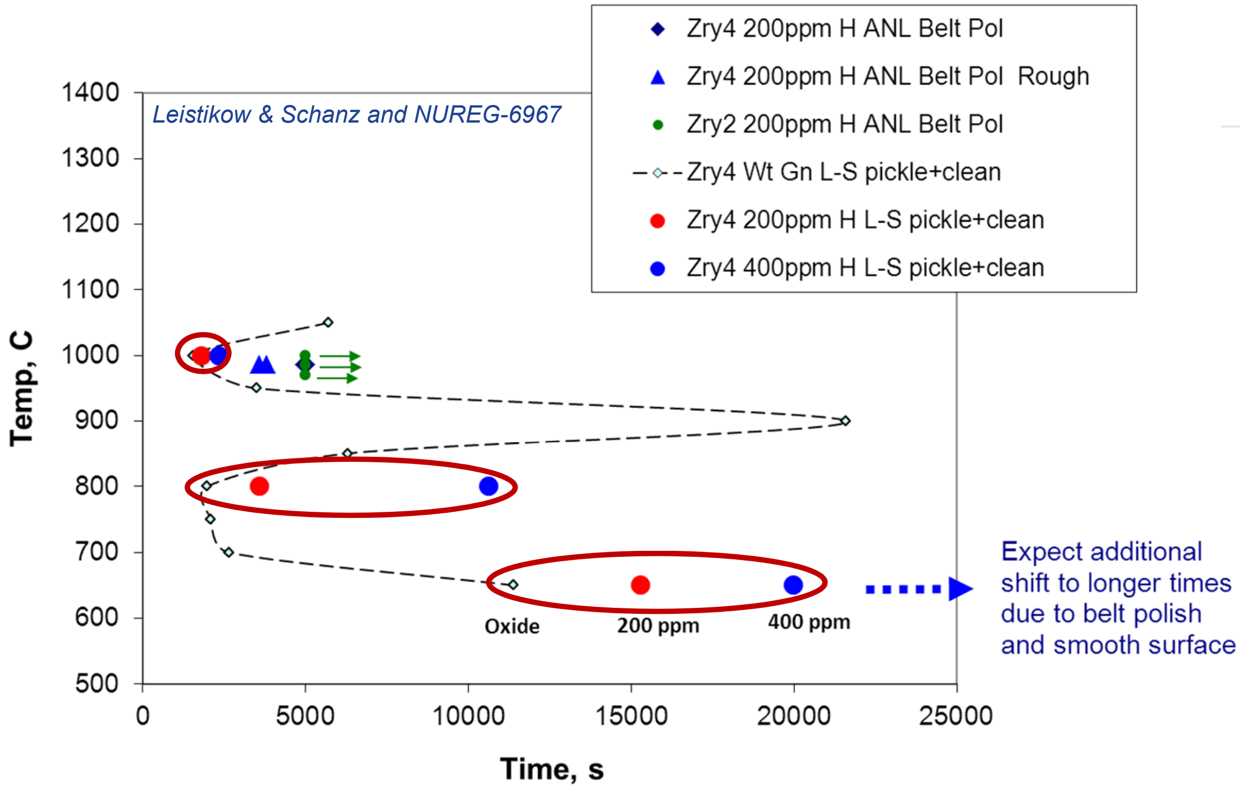
- Details could cause confusion with compliance with other requirements
  - DGs state that thermocouples and mechanical test equipments require certification/verification that meet ISO/ANSI/NCSL – could be interpreted as OK to perform tasks as <u>non-safety-related</u> per 10CFR Part 21.
  - Similar tasks at GNF are typically conducted on a commercial grade with dedication basis.

DG-1263: Analytical limit of 650°C

- DRL 50.46c (d)(1)(iii): the total accumulated time ….. above a <u>temperature</u> at which the zirconium alloy has been <u>shown to be susceptible</u> … shall not be greater than a specified and acceptable limit which corresponds to the <u>measured onset</u> of breakaway oxidation for the zirconium-alloy…..
- Difficult to understand basis for 650°C; appears to be based on concern on behavior of Russian Electrolytic alloys.
- Scoping run on Zry2 at 650°C indicates no breakaway after 18000 s
- Recommend flexibility

Breakaway Oxidation and Conservatism



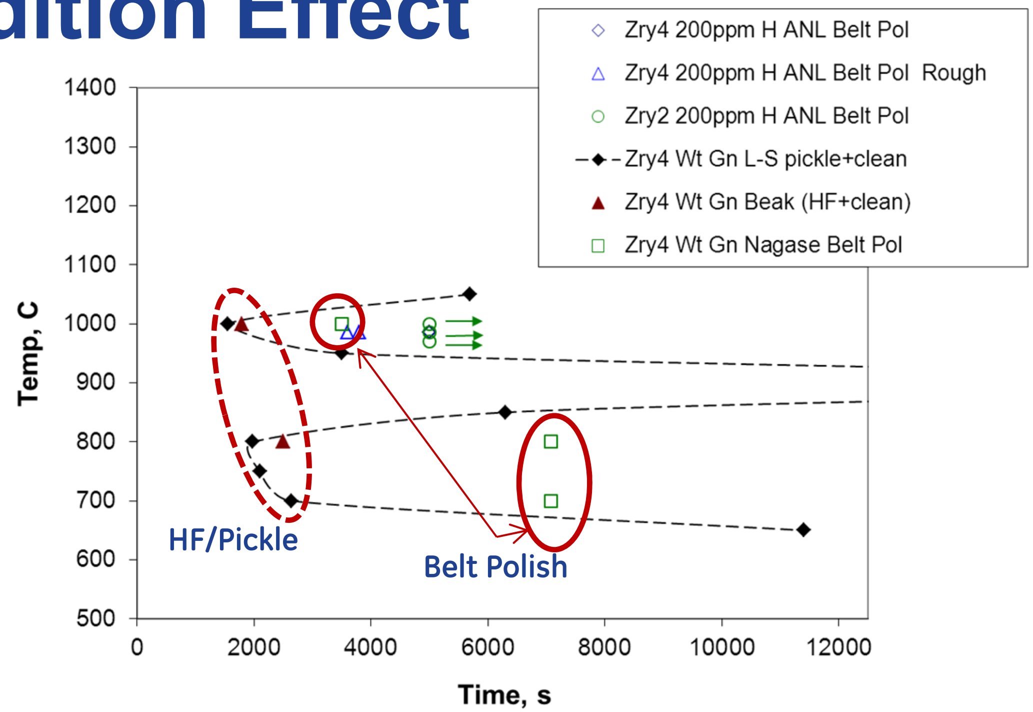


- Main concern is embrittlement due to hydrogen
- Time to breakaway similar for criterion based on oxidation or H pickup near 1000°C
- Time to breakaway NOT similar for criterion based on oxidation of H pickup below ~800°C

Applying breakaway time near 1000°C to 650°C for Kroll process appears to be excessively conservative

Non-Proprietary Information – Class I (Public)

Breakaway Oxidation – Surface Condition Effect



- Surface condition (pickle vs. polish) has large effect
- Even longer time to breakaway at 800°C and below using H based criterion
- Scoping run on belt-polished, Kroll Zry2 at 650°C shows no breakaway after >15000s

Breakaway oxidation not a concern within 5000s below 800°C for belt-polished, Kroll material

Summary

- GNF/GEH is getting ready to perform high temperature oxidation testing
- Would like to continue discussions on reg. guides to ensure NRC concerns are addressed

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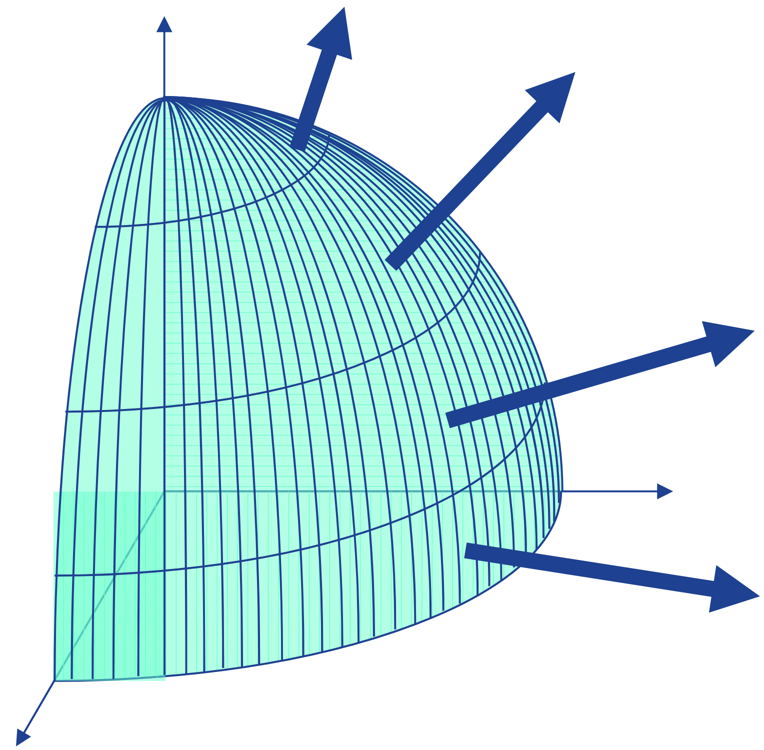

LANCR02P
Recent Developments

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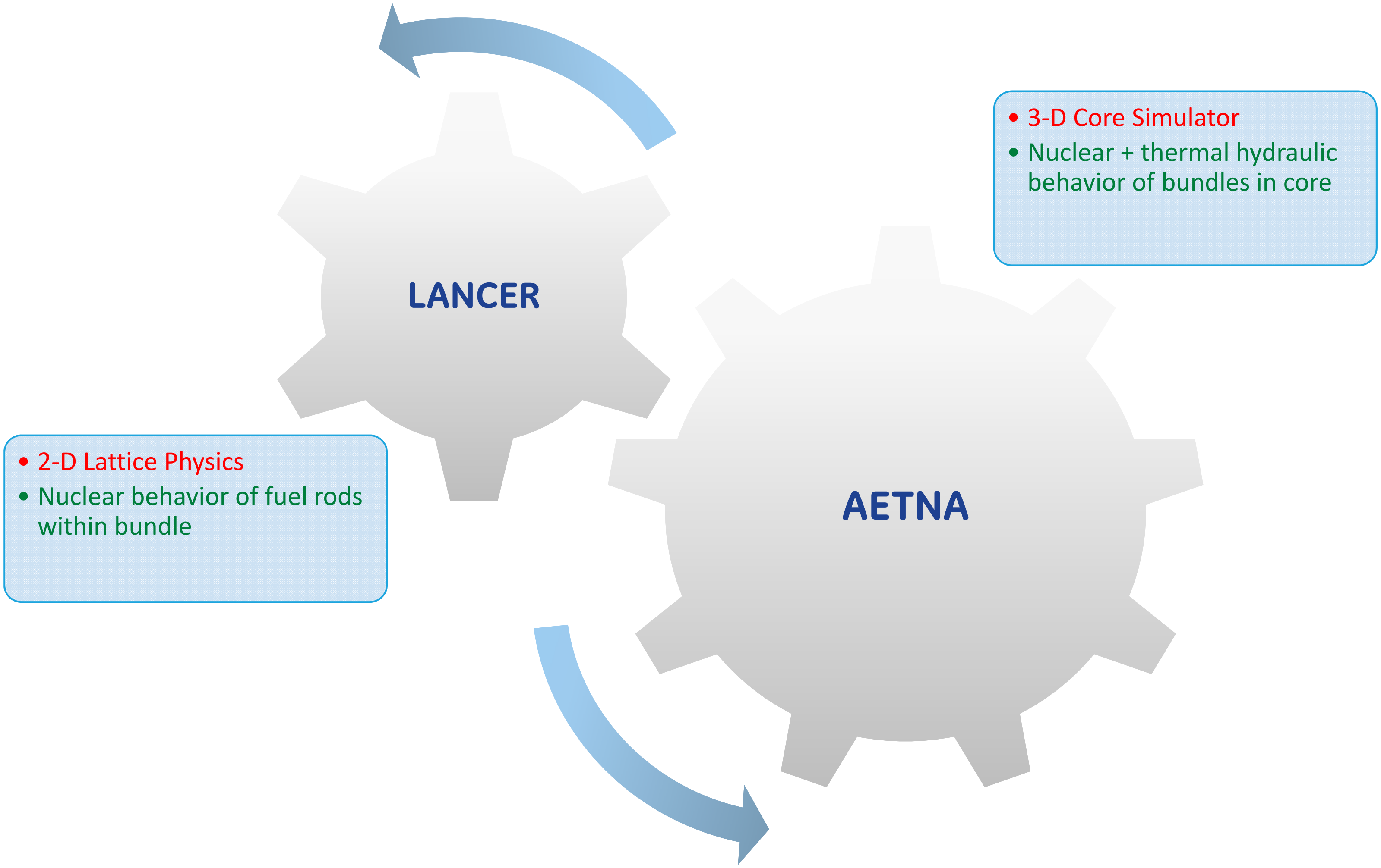
Agenda

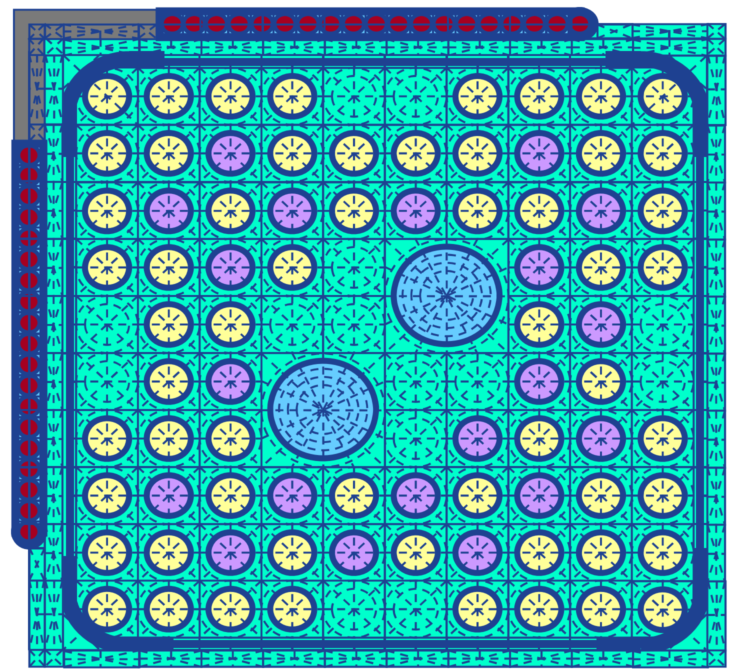
- LANCER & AETNA
- LANCER02 Highlights
- Recent Developments
- Status

LANCER & AETNA - How They Fit In



LANCER02 Highlights

- Model fuel rods (U+Gad) , water Rods, control blade within lattice
- Complex/exact geometry & material
- 2D fine-mesh spatial resolution (multiple angular + radial discretization)
- Method of Characteristics (MOC) transport solution – neutrons and gammas
- Detailed isotopic tracking
- Detailed neutron energy group structure
- Fine time-step temporal resolution (exposure dependence)
- Fundamental nuclear data from ENDF/B-VII Revision 0



LANCER02 Methodology

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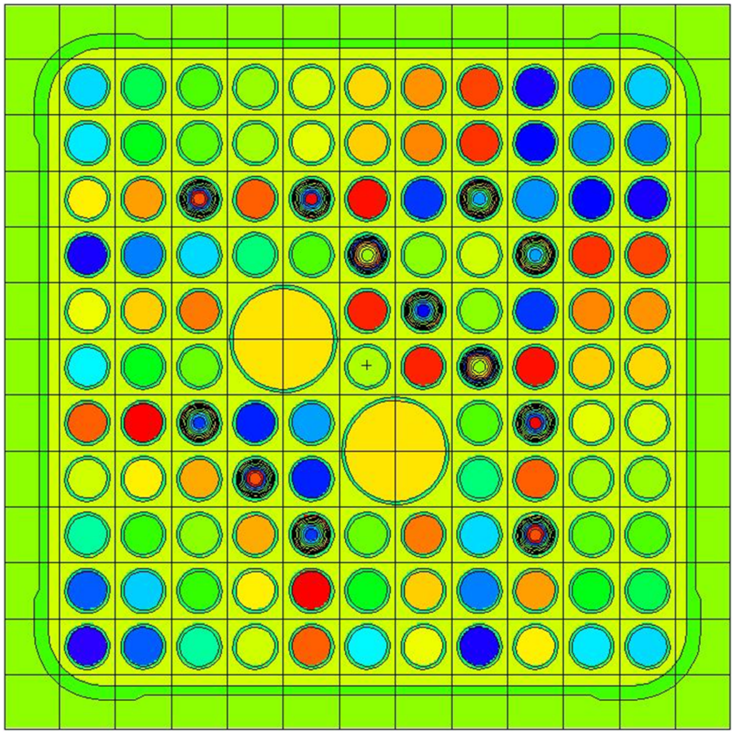
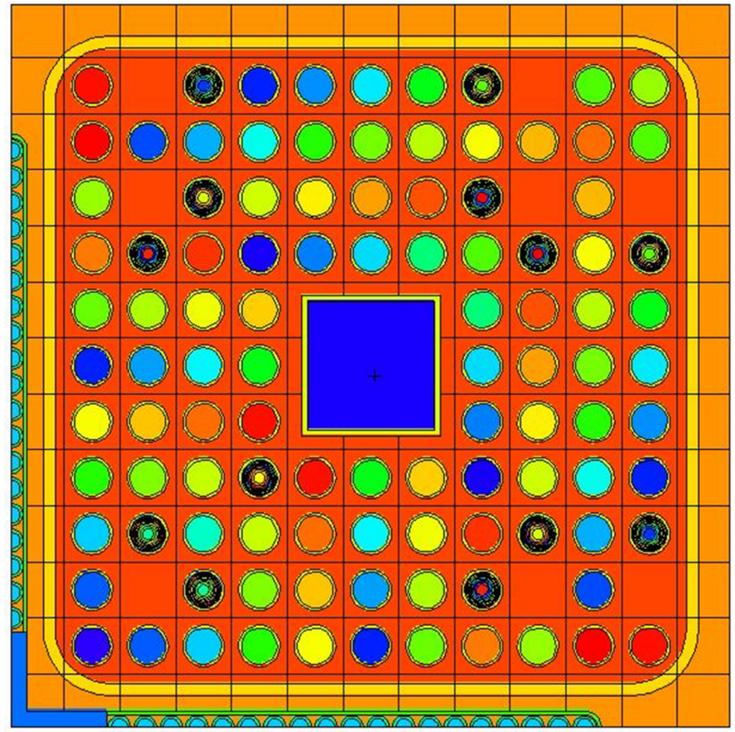
Recent Developments

- 11x11 fuel
- GNF3 fuel

11x11





Eigenvalue difference between LANCR and MCNP are consistent with those reported in the Qualification LTR.

Status

- RAIs
  - ✓ First batch submitted November 2010
  - ✓ Second batch submitted June 2011

- To be submitted in 2011
  - Final RAI responses
  - Revised Model Description LTR
  - Revised Qualification LTR

Questions

Non-Proprietary Information –
Class I (Public)

Technology Update for the US NRC June 2011

Methods Status Update

Atul Karve

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

Recent ECP Maintenance US NRC Approved Methodologies

- SAFER - PRIME downstream effects (Feb 2010)
- ODYSY - PRIME downstream effects, more fuel types (May 2010)
- TASC – PRIME downstream effects (Dec 2010)
- CORCL – bundle power grouping due to PLRs, PRIME (Feb 2011)
- ODYN – PRIME downstream effects (Apr 2011)

Recent ECP Maintenance
US NRC Approved Methodologies

- PANAC11 – fixes, PRIME downstream effects, CFM, GEXL module (Jul 2011)
- GESAM – PRIME downstream effects (Jun 2011)
- TRACG – automation, PRIME downstream effects (Sep 2011)
- ISCOR – convergence improvements (3Q 2011)

Non-Proprietary Information –
Class I (Public)

Technology Update for the US NRC June 2011

MELLLA+ Limitation 12.6

Atul Karve

GNF
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Safety Limit Minimum CPR

- MCPR value at which 99.9% of fuel rods are expected to avoid Boiling Transition
- Considers uncertainties determined from validation data
  - Plant uncertainties
  - Power distribution
  - GEXL critical power correlation

Safety Limit Minimum CPR LTRs

- “Methodology and Uncertainties for Safety Limit MCPR Evaluations,” NEDC-32601P-A, August 1999

- “Power Distribution Uncertainties for Safety Limit MCPR Evaluations,” NEDC-32694P-A, August 1999

MELLLA+ Limitation 12.6 – where is it?

- SE of NEDC-33006P-A Rev 3

- SLMCPR STATEPOINTS AND CF UNCERTAINTY (SECTION 2.2.1.1)

MELLLA+ Limitation 12.6 – what is it?

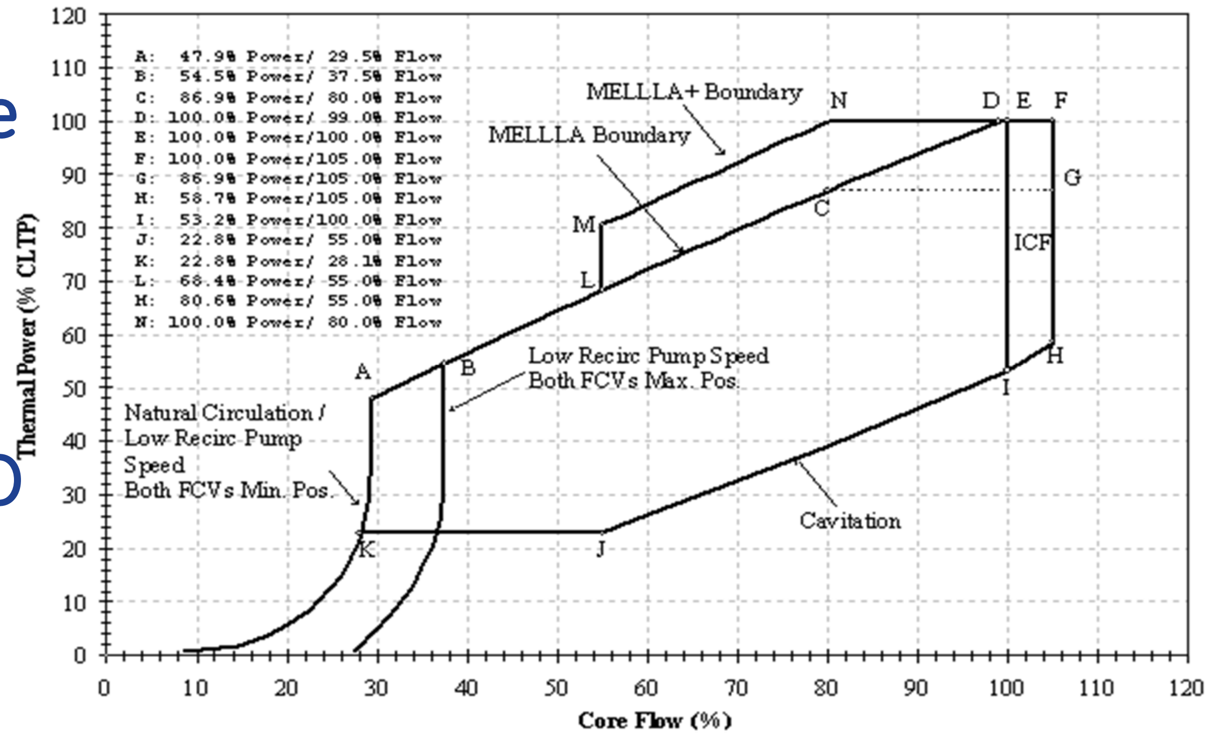
- Until such time when the SLMCPR methodology for off-rated SLMCPR calculation is approved by the staff for MELLLA+ operation, the SLMCPR will be calculated at:
  - the rated statepoint (120 percent P/100 percent CF)
  - the plant-specific minimum CF statepoint (e.g., 120 percent P/80 percent CF)
  - the 100 percent OLTP at 55 percent CF statepoint

MELLLA+ Limitation 12.6 – what is it?

- The currently approved off-rated CF uncertainty will be used for the minimum CF and 55 percent CF statepoints
- The uncertainty must be consistent with the CF uncertainty currently applied to the SLO operation or as NRC-approved for MELLLA+ operation
- The calculated values will be documented in the SRLR

Implementation of Limitation 12.6

- Document table in SRLR
- Use max to report TLO & SLO, SLO >= TLO
- IMLTR adders



Power (%CLTP)	Flow (%Rated)	Point	Uncertainties
100	100	E	TLO & SLO
100	80	N	SLO Only
80.6	55	M	SLO Only
100	105	F	TLO & SLO

- TLO: dual loop operation
- SLO: single loop operation

Plan to Address Limitation 12.6

- Flow related uncertainties are most relevant
- Assess these at low core flow and use them for SLMCPR calculations at off-rated conditions MELLLA+ statepoints
- Submit in 2Q2012 a supplement to address L&C 12.6