ENCLOSURE 2

M180003

CRDA Methodology Pre-Submittal Presentation

Non-Proprietary Information - Class I (Public)

IMPORTANT NOTICE

This is a non-proprietary version of Enclosure 1, from which the proprietary information has been removed. Portions of the enclosure that have been removed are indicated by an open and closed bracket as shown here [[ ]].

Global Nuclear Fuel

CRDA Methodology LTR
NEDE-33885P Rev. 0

Pre-Submittal Meeting
Date: December 7, 2017

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Motivation and Basis

Purpose of Meeting

- The purpose of this meeting is to introduce and describe the key elements of the new Control Rod Drop Accident (CRDA) Licensing Topical report (LTR) that GNF is planning to submit to the US NRC for approval.
- The intent of this meeting is to familiarize the reviewers and prompt any key feedback to be addressed prior to the LTR submittal.

Current CRDA Compliance Elements

- Absolute allowed pellet enthalpy is 280 cal/g which when adjusted to preclude melting for fuel rods with gadolinium or fuel rods at higher exposure reduces to 230 cal/g
- Presumed cladding failure limit is 170 cal/g
  - Current licensing basis conservatively supports that control blades worth less than 1.0% Δk will result in less than 170 cal/g during a CRDA
- Banked Position Withdrawal Sequence (BPWS) used as means to limit static blade worths to 1.0% Δk
- BPWS has requirements for banking and provisions for inoperable blades

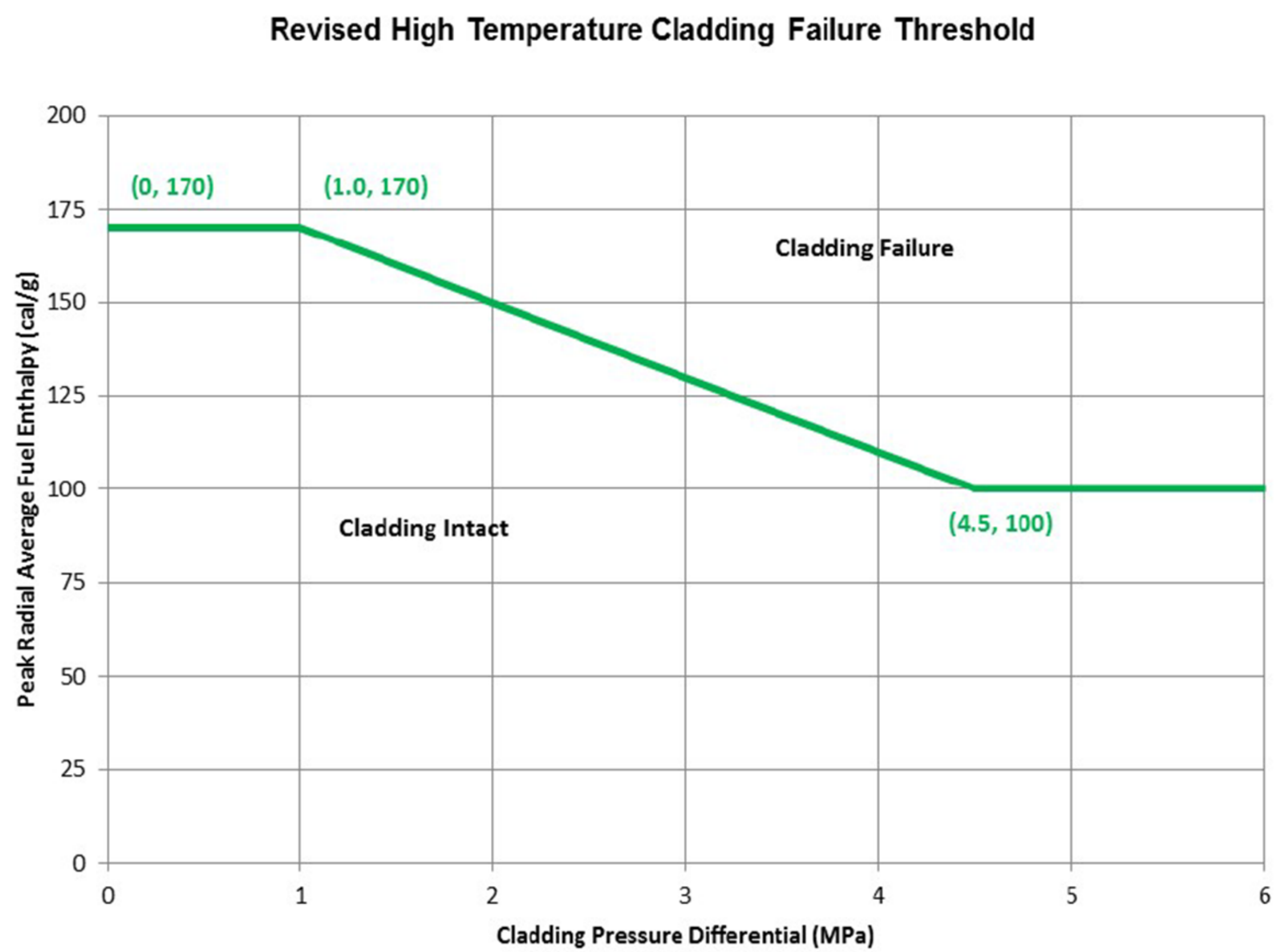
BPWS (as currently applied)

- Purpose
  Limit control blade worth such that in the event of a CRDA, the enthalpy limit will not be exceeded. Current BPWS blade worth limit is 1.0% Δk.
- Certain groups bank at 00-04-08-12-48
  - Restrictive banking slows blade withdrawals and increases startup times
  - Potentially small incremental worths while banking can result in reduction in flux counts as moderator continues to heat up (subcriticality event)
- Inoperable blades
  - Must be separated by 2 cells and no more than 3 blades per BPWS group
  - Can restrict blade movement and delay startup if the inoperable blades are present during a mid-cycle outage or scram event
  - Specific time-critical analyses are performed to address limitations
  - Often occurs during leaker suppression

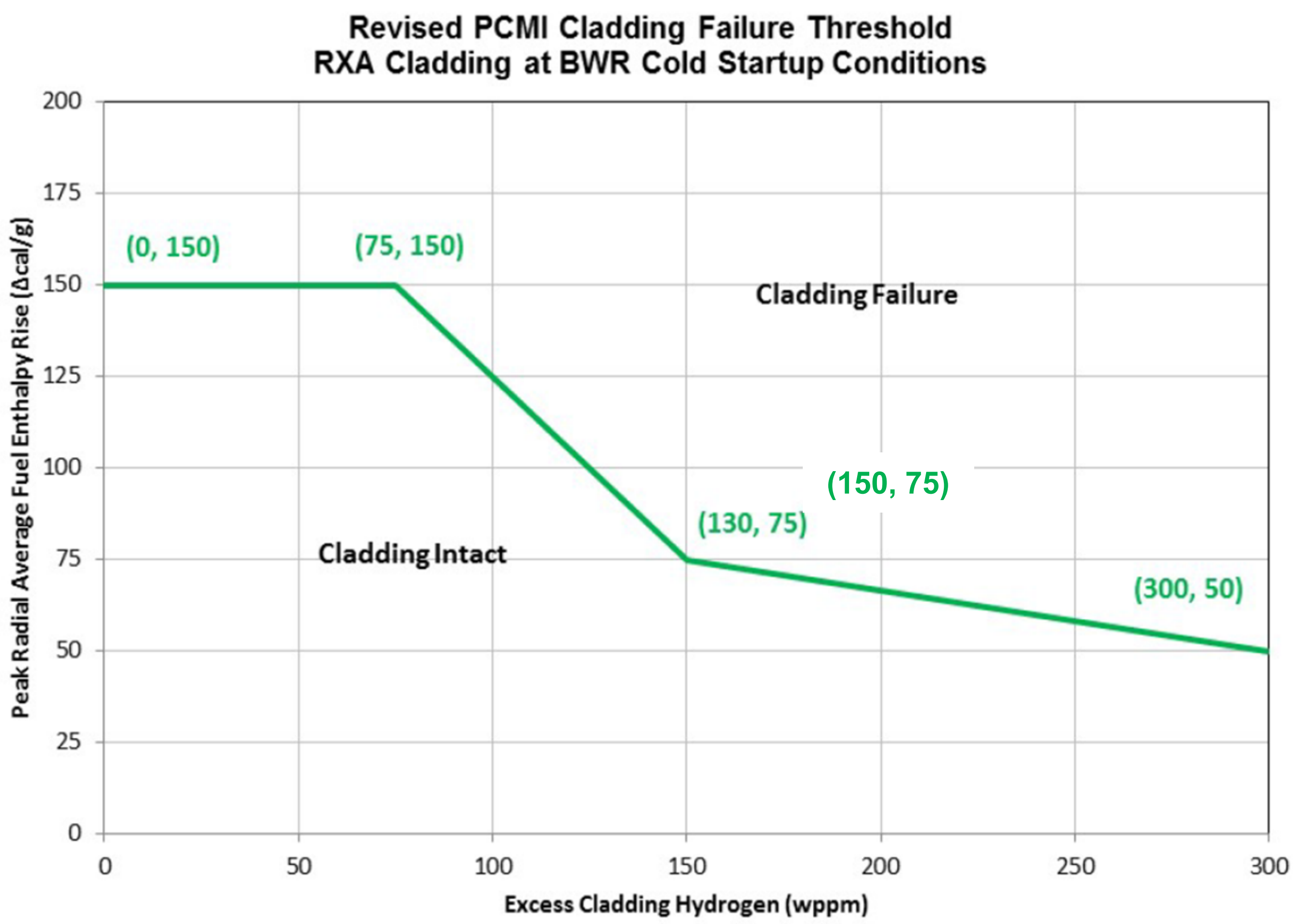
Updated CRDA Requirements

- NUREG-0800 (SRP) Section 4.2 Appendix B, Rev. 3 (March 2007)
  - Pellet Cladding Mechanical Interaction (PCMI) limit of 150 cal/g for prompt enthalpy rise decreases as hydrogen content increases with increasing exposure
- Technical and Regulatory Basis memos ML14188C423 & ML15133A306 (March 2015)
  - High Temperature Cladding Failure (HTCF) limit of 170 cal/g decreases with internal fuel rod pressure and requires consideration of transient Fission Gas Release (FGR)
  - Updated PCMI limits
  - Revised fuel rod cladding hydrogen uptake models for zirconium alloys
- DG-1327 (November 2016)
  - Aggregated most recent technical basis for CRDA including PCMI and HTCF limits
- Compliance demonstration requires NRC approved methodology
  - GEH CRDA methodology approved in Switzerland
  - Overall approach accepted in US for ESBWR
  - Similar approach being applied for UK-ABWR

HTCF Enthalpy Criterion



PCMI Enthalpy Criterion



Scenario Description

- Startup conditions in a BWR
- Control blade becomes decoupled from its drive mechanism
- At a subsequent time, drive is withdrawn, but blade sticks at a location above the drive
- Then, at a later point in the sequence the blade un-sticks, and drops to the drive position, resulting in a positive reactivity insertion
- Resulting power pulse causes and increase in enthalpy/temperature, which has the potential to cause fuel failure
- [[ ]]

Example Reload Application

Example Reload Application – Process Flow Chart (Reload)

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Example Reload Application – Application Example Inputs

- Group Definitions – A1, B1, etc.
  - Determines which blades are withdrawn during startup or inserted during rated power operations
- Group Order(s) – 1,2,4,3, etc.
  - Blades are associated into groups which are then pulled in given order(s)
- Exposures – [[

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Example Reload Application - [[ ]]

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Example Reload Application – Application Example

Example blade grouping provided below as used to defined blade sequence.

	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	
1					6	3	5	4	5	3	6					59
3				5	1	+	2	+	2	+	1	5				55
5			6	3	8	4	7	3	7	4	8	3	6			51
7		5	1	+	2	+	1	+	1	+	2	+	1	5		47
9	6	3	8	4	7	3	8	4	8	3	7	4	8	3	6	43
11	1	+	2	+	1	+	2	+	2	+	1	+	2	+	1	39
13	5	4	7	3	8	4	7	3	7	4	8	3	7	4	5	35
15	2	+	1	+	2	+	1	+	1	+	2	+	1	+	2	31
17	5	4	7	3	8	4	7	3	7	4	8	3	7	4	5	27
19	1	+	2	+	1	+	2	+	2	+	1	+	2	+	1	23
21	6	3	8	4	7	3	8	4	8	3	7	4	8	3	6	19
23		5	1	+	2	+	1	+	1	+	2	+	1	5		15
25			6	3	8	4	7	3	7	4	8	3	6			11
27				5	1	+	2	+	2	+	1	5				7
29					6	3	5	4	5	3	6					3
	2	6	10	14	18	22	26	30	34	38	42	46	50	54	58	

Example Reload Application – Application Example

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Example Reload Application – [[ ]]

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Example Reload Application – [[ ]]

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Methodology Description

Methodology Description - Overview

Licensing Basis:

CRDA calculation in TRACG to compare enthalpy response to NRC enthalpy acceptance criteria as defined in DG-1327

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Cycle-Specific Check:

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Methodology Description – [[ ]]

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Methodology Description – Model Descriptions

PANAC - Approved steady-state core simulator used in core design and monitoring and to provide initial conditions for plant licensing

TRACG – Approved thermal-hydraulic systems code used in many GEH licensing applications

PRIME – Approved thermal mechanical model

Examples include: Anticipated Operational Occurrence (AOO), Loss of Coolant Accident (LOCA), and Stability

Methodology Description – Model Descriptions - Continued

Modern Hydrogen Model (ML15133A306)

$C_H = 1.4 * \{22.8 + \exp[0.117 * (PPE - 20)]\}$

Where:

- C_H = Total hydrogen concentration (wppm)
- PPE = Peak Pellet Exposure (GWd/MTU)
- 1.4 = Uncertainty / Variation Multiplier

Transient Fission Gas Release Model (ML15133A306)

PPE < 50 GWd/MTU: Transient FGR (%) = $[(0.26 * \Delta H) - 13]$

PPE > 50 GWd/MTU: Transient FGR (%) = $[(0.26 * \Delta H) - 5]$

Where:

- FGR = Fission gas release, must be greater than or equal to zero (%)
- ΔH = Radial average fuel enthalpy increase throughout the event (Δcal/g)

Methodology Description – Post Failure Treatment

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Methodology Description – [[ ]]

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- Used to assess static control blade worth in a timely manner for a variety of startup scenarios
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Methodology Description – [[ ]]

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Methodology Description – TRACG Analysis [[

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- Ability to perform detailed enthalpy calculations
- Calculate the cladding differential pressure
- Calculates enthalpy for demonstrating compliance to the HTCF and PCMI criteria
- Calculates cladding temperature
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Methodology Description – TRACG Analysis – Key Assumptions

- Accident blade falls at maximum terminal velocity
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Methodology Description – TRACG Analysis – Initial Conditions

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Methodology Description – TRACG Analysis – Fission Gas

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Methodology Description – TRACG PCMI Enthalpy Results

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Methodology Description – TRACG HTCF Enthalpy Results

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Methodology Description – Bypassed Blades

- In-sequence blades may be bypassed for a variety of reasons, and could change the impact of a CRDA
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Methodology Description – Bypassed Blades

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Methodology Description – Application Range

The CRDA event for BWR's is applicable from cold zero power conditions, and extends up to a point at which the feedback mechanisms limit the control rod worth. [[

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Methodology Description – Conservatisms

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Methodology Description – [[ ]]

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Methodology Description – LTR Outline

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Methodology Description – LTR Outline

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Schedule

LTR Licensing Timeline

- LTR submittal for NRC Review [[ ]]
- Review Cycle:
  - Expected 2 year review cycle
  - Enables support of customers regarding DG-1327 during LARs.