Enclosure 4

Westinghouse Closed Session Slide Package for the ACRS Full Committee Meeting on WCAP-18446-P/NP

(Non-Proprietary)

April 2024

Westinghouse Electric Company
1000 Westinghouse Drive
Cranberry Township, PA 16066

Meeting of the Advisory Committee on Reactor Safeguards (ACRS)

Incremental Extension of Burnup Limit for Westinghouse and Combustion Engineering Fuel Designs, Westinghouse Topical Report WCAP-18446

Closed Session

Jeffrey Kobelak
Jim Laird
Westinghouse Electric Company
May 2024

Westinghouse

Overview and Purpose of Meeting

- WCAP-18446-P/NP, "Incremental Extension of Burnup Limit for Westinghouse and Combustion Engineering Fuel Designs" was submitted for NRC review by letter dated December 14, 2020
- A draft Safety Evaluation Report (SER) on the topical report has been made available to Westinghouse and the ACRS
- This meeting will provide an overview of the incremental burnup extension to the ACRS

Presentation Overview

- Introduction
- Key Findings from NRC Review
- Discussion of Specific Functional Areas
  - Nuclear Design
  - Fuel Rod Design
  - Mechanical Design
  - Thermal-Hydraulic Design, Non-LOCA and Containment Analysis
  - LOCA Analysis
- Plant-Specific Implementation

Westinghouse

Introduction

Key Findings from NRC Review

Discussion of Specific Functional Areas

Plant-Specific Implementation

Incremental Burnup Rationale and Benefits

- Utility Benefits
  - Improved fuel utilization
  - Improved backend cost
- Regulatory Benefits: Requires that various legacy issues are addressed and that utilities adopt latest regulatory guidance to implement
  - [
  -]a,c
  - Incorporate PAD5 (explicitly accounts for thermal conductivity degradation (TCD)) into licensing basis
- Westinghouse Benefits
  - Provides a means to gather more high burnup data from rods in non-limiting locations

Constraints of Incremental Burnup Extension

- Limit on maximum rod average burnup of [ ]a,c
- Limited to rods in core peripheral assemblies
- Limited to rods which do not burst during a LOCA
- Limited to rods which [ ]a,c
- Expected limits on assembly and rod power vs burnup for incremental burnup rods and associated assemblies
  - Exact limits will be based on plant-specific implementation
    - Expect maximum rod relative power approximately [ ]a,c
    - Expect maximum assembly relative power approximately [ ]a,c

Constraints address fuel fragmentation, relocation, and dispersal (FFRD) for the fuel rods in the incremental burnup regime

Introduction

Key Findings from NRC Review

Discussion of Specific Functional Areas

Plant-Specific Implementation

Key Findings from NRC Review

- Nuclear Design
  - Technical Specification Limit on Hot Channel Enthalpy Rise (FdH) at High Burnup
- Fuel Rod Design
  - Applicability of PAD5 to Higher Burnup Fuel Rods
- Loss-of-Coolant Accident Analysis
  - Addressing Potential for Fuel Dispersal
  - Criterion for Cladding Rupture
  - Research Findings Underpinning Draft 10 CFR 50.46c Rulemaking
  - Transient Fission Gas Release

Introduction

Key Findings from NRC Review

Discussion of Specific Functional Areas

Plant-Specific Implementation

Incremental Burnup Application Impact for Fuel Management

- Allows for fuel only in peripheral locations to exceed the current 62 GWD/MTU pin burnup limit
  - [ ]a,c
  - Allows higher burned assemblies following two cycles of operation interior to the core to be used on the periphery
- Allows for a [ ]a,c feed assembly reduction per cycle when compared to an optimized design at current burnup limits
  - Higher enrichment of remaining feed assemblies offset reduced number of feeds
  - [
-]a,c

Application and Fuel Cost Benefit 3-Loop Core

a,c

Application and Fuel Cost Benefit 4-Loop Core

a,c

Impact of Incremental Burnup On Safety

- +/-8 Assemblies is within the current cycle-to-cycle variation
- Safety limit confirmation for each core reload to confirm assembly power assumed in LOCA analysis
- Peaking factors are slightly higher with lower number feeds but still retain acceptable margin to the TS limits

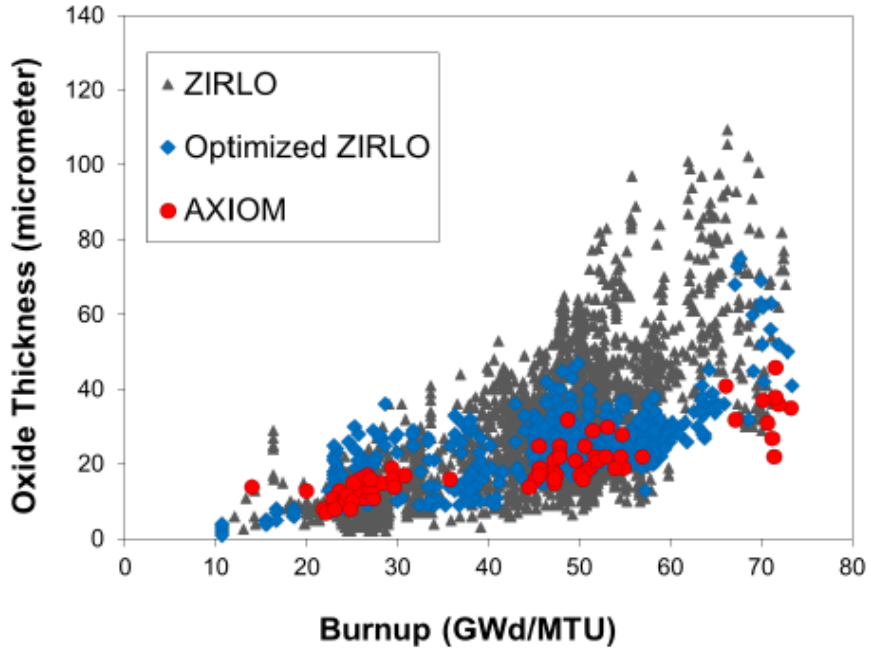
a,c

ND Codes and Methods for Incremental Burnup Extension

- Nuclear Design principal codes and methods are based on NRC approved ALPHA-(PHOENIX/PARAGON)-ANC or APA codes
- Rod burnup extension up to [ ]^{a,c} does not require modification or updating of any previously NRC-approved topical reports assessing neutronics and nuclear design
- Methods implemented in the neutronic codes for fuel depletion remains unchanged and already contains the depletion capability to very high burnup for pellets exceeding 62 GWd/MTU in rods with an average burnup of 62 GWd/MTU

Fuel Rod Design - Introduction

- Westinghouse fuel performance code PAD5 licensed for rod average burnup of 62 GWd/MTU, but was intended for high burnup application [ ]a,c
- Fuel performance models, database, and application methodology for design criteria were reassessed relative to extending the application to rod average burnup of [ ]a,c from 62 GWd/MTU
  - No changes are needed
    - Halden Project experiments provide measured fuel temperatures to [ ]a,c
    - Commercial irradiation programs provide measured fission gas release and rod growth data up to [ ]a,c
    - Joint International test programs provide data on fuel power ramp behavior to [ ]a,c



Westinghouse

Fuel Rod Design – PAD5 High Burnup Models

a,c

Technical bases for rod average burnup up to [ ]^{a,c} are provided in PAD5 topical

Fuel Assembly Mechanical Design

- No change in current methods for evaluating Fuel Assembly (FA) performance under a given loading pattern for incremental burnup increase to a maximum of [ ]^{a,c} rod average
- Methods are benchmarked to FA data with rods > [ ]^{a,c}
- Codes providing inputs to FA analysis such as temperatures and fast neutron fluence are valid to > [ ]^{a,c} rod average burnup
- [

]^{a,c}

T/H Design, Non-LOCA and Containment Analysis

a,c

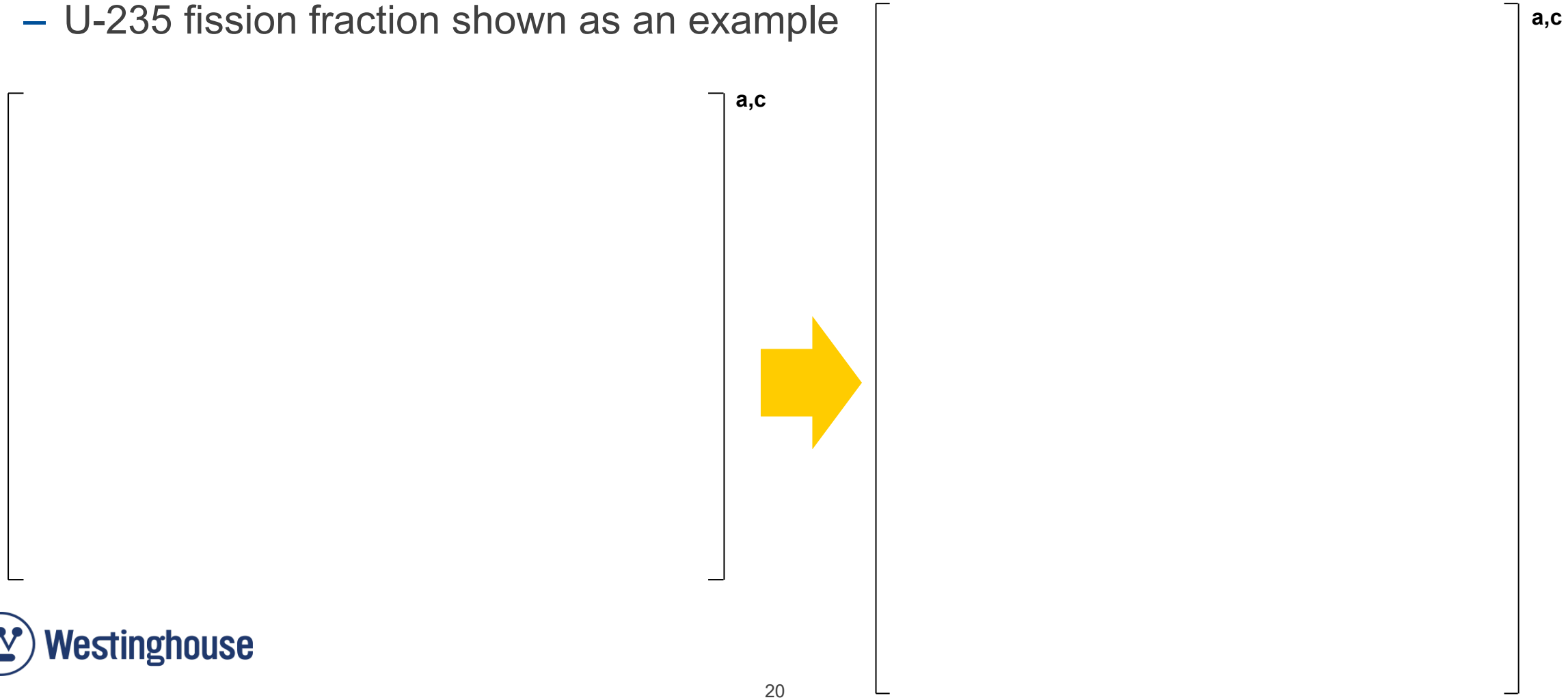
LOCA Analysis: Overview

- Primary LOCA-related concern with incremental burnup is FFRD
- Introduction of incremental burnup extension [
-
-
  ]a,c
  - New and updated models implemented into the associated thermal-hydraulic system code (WCOBRA/TRAC-TF2) to analyze higher burnup fuel rods

Westinghouse

Nuclear Physics Data

- Updated nuclear physics data to higher burnup
  - U-235 fission fraction shown as an example



Cladding Rupture Criterion

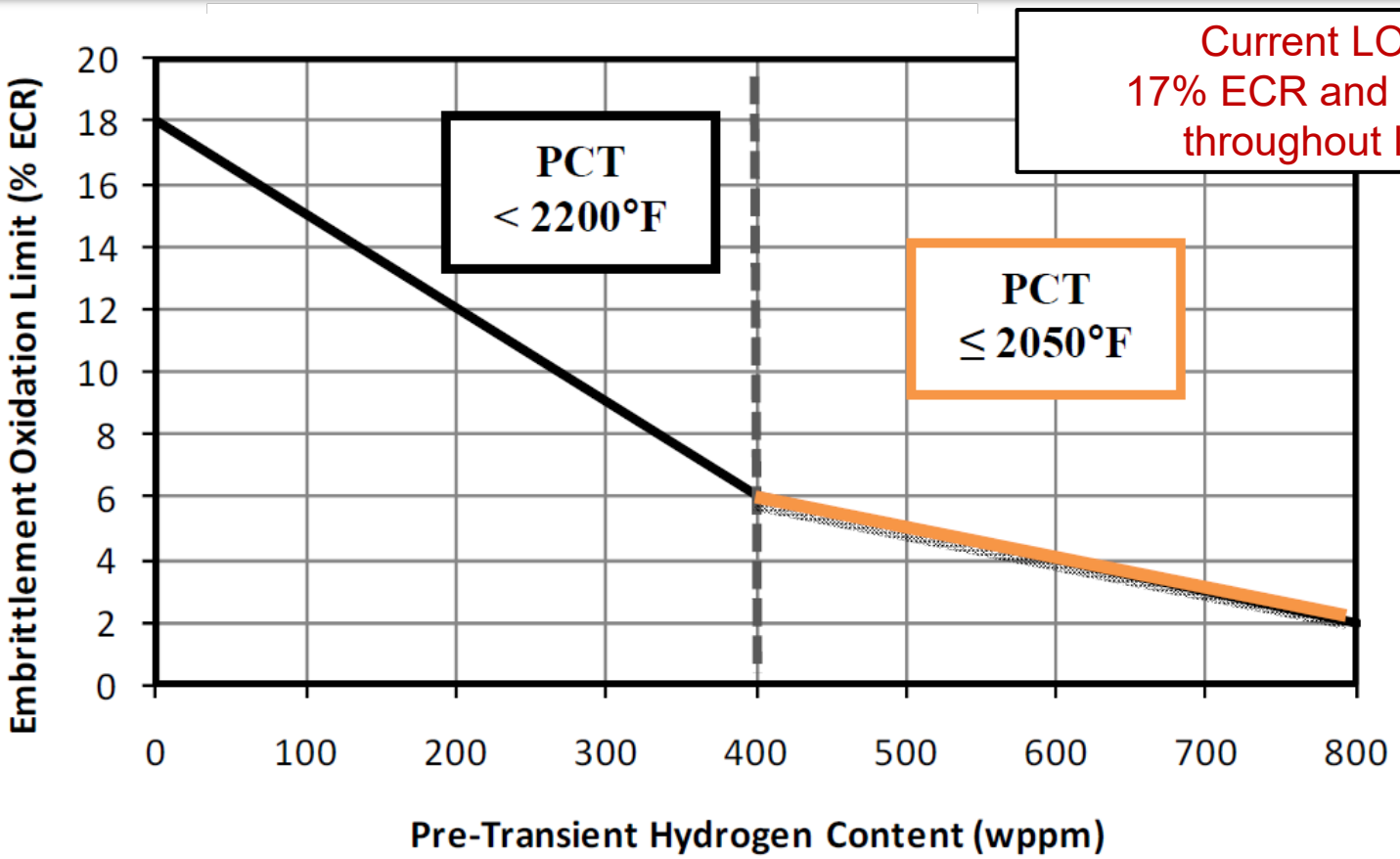
a,c

- Cladding rupture model based on NUREG-0630 framework
- Robust database
  - [
  -

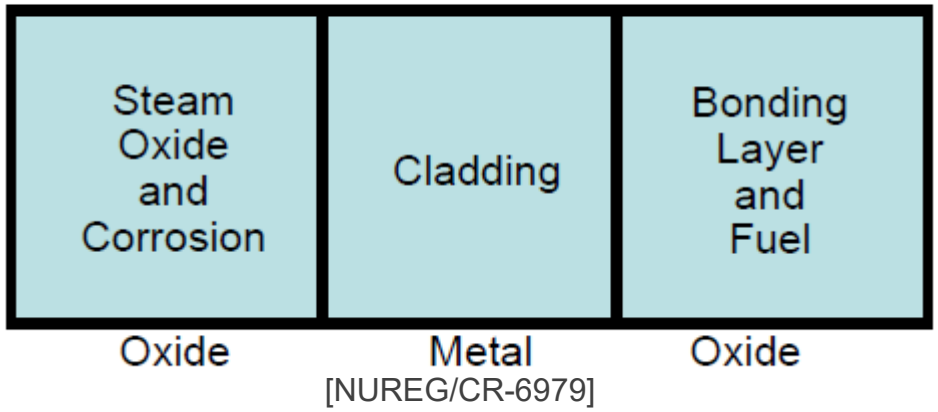
]a,c

[ ]a,c

Research Underpinning Draft 10 CFR 50.46c Rulemaking



Oxygen enters cladding from oxide-bond-fuel layer



[NUREG/CR-6979]

[ ]a,c

Conclusions Regarding Transient Fission Gas Release

a,c

Introduction

Key Findings from NRC Review

Discussion of Specific Functional Areas

Plant-Specific Implementation

Implementation

- Two parts to implementation

- 1: Generic topical report (today's topic)
  - Address burnup-related limitations and conditions on existing topical reports
  - Describe any required method updates or demonstrate that no updates are required for the various functional areas
  - Justify applicability of existing designs and methods for high burnup

- 2: Site-specific effort
  - Execute analyses, evaluations, and requirements of generic topical report
  - Plant-specific LAR submittal

Site-Specific Implementation: Most Significant Impacts

- [
  -]a,c
  - LOCA: Demonstrate no rupture in high burnup rods
- **FSLOCA** EM implementation (if not already completed)
  - Addresses TCD using fully NRC-approved methods
- “Not LOCA” PAD5 implementation (if not already completed)
  - Transient Analysis (Includes mechanistic DNB propagation evaluation method)
  - Fuel Rod Design

Culminates with LAR Submittal to the NRC for Review

Questions

Acronyms / Codes / Labels

Acronym	Definition
3D	3-Dimensional
ACRS	Advisory Committee on Reactor Safeguards
ADOPT	Advanced Doped Fuel
BOC	Beginning of Cycle
Bu	Burnup
CFR	Code of Federal Regulations
DNB	Departure from Nucleate Boiling
DNBR	Departure from Nucleate Boiling Ratio
ECCS	Emergency Core Cooling System
EM	Evaluation Model

Acronyms / Codes / Labels

Acronym	Definition
EOC	End of Cycle
FA	Fuel Assembly
FGR	Fission Gas Release
FRD	Fuel Rod Design
FSLOCA	FULL SPECTRUM LOCA
IBLOCA	Intermediate Break LOCA
ID	Inner Diameter
LAR	License Amendment Request
LBLOCA	Large Break LOCA
LOCA	Loss-of-Coolant Accident

Acronyms / Codes / Labels

Acronym	Definition
NRC	Nuclear Regulatory Commission
OD	Outer Diameter
OFA	Optimized Fuel Assembly
PAD	Performance Analysis and Design
PCT	Peak Cladding Temperature
RG	Regulatory Guide
SBLOCA	Small Break LOCA
SER	Safety Evaluation Report
T/H	Thermal-Hydraulic
TCD	Thermal Conductivity Degradation

Acronyms / Codes / Labels

Acronym	Definition
TS	Technical Specification
tFGR	transient Fission Gas Release
WCAP	Westinghouse Commercial Atomic Power