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M5 Topical Report Revision

- June 6, 2018

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Agenda

- Jerry Holm
- Licensing Engineer

Agenda

- Objectives
- Background
- Topical Report Contents
- Next Steps

Objectives

- Inform NRC of:
  - Motivation for topical report revision
  - Content of topical report
- NRC feedback

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Background

- Jacqueline Stevens
- Materials Engineering

BAW-10227-PA Revision 1 Background

- BAW-10227 Revision 0 approved in 2000
  - Introduced M5 as a cladding and structural material (guide tubes, grids)
  - RAIs resulted in revisions to basic models – documented in approved appendices
  - Full report included revisions to other topical reports in Appendices
  - Incorporated M5 characteristics and models into B&W methods
- BAW-10227 Revision 1 approved in 2003 – extended burnup to 62 GWd/mtU
- Approved topical report allows for limited update of M5 models
- BAW-10240PA addressed the M5 application in Siemens methods for W/CE plants, referencing BAW-10227

BAW-10227-PA
Current Content

BAW-10227-PA Revision 1 Supplement 1 Background

- **Accepted for review in 2017**
- **Addresses increase of iron maximum limit to [ ] ppm**
  - **Demonstrated that adjustment of the maximum iron limit had a negligible impact on properties and performance**
- **Approval desired [ ] (before submittal of rev 2)**

Section in BAW-10227PA-01 Supplement 1

1.0 Introduction

2.0 Summary

3.0 Material Definition

4.0 Material Properties

5.0 Irradiation Experience

6.0 References

Purpose of Revision 2 to BAW-10227PA

- Update material properties and performance models
  - Based on expanded test database
  - LOCA Swelling & Rupture Model – expanded EDGAR database
  - Align with values used in modern analyses and fuel rod performance codes
- Update databases for support of extended material limits
- M5 material is not changing
- Not mandatory for current plants licensed under Revision 1 to switch to Revision 2
- Provide a base for a supplement on chromium coated cladding

Obtain NRC Concurrence for updated M5 models and extended material limits

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Topical Report Content

- Jacqueline Stevens
- Lisa Gerken

Structure of BAW-10227P Revision 2

- **Similar to BAW-10334PA 'Q12 Topical Report'**
  - **Follows criteria of Standard Review Plan**
  - **Content adjusted to address requirements associated with cladding material**

1.0 Abstract
2.0 Introduction
3.0 Summary
4.0 Applicable Regulatory Guidance
5.0 Material Definition
6.0 Irradiation Experience
7.0 Physical Properties
8.0 Mechanical Behavior
9.0 Oxidation and Hydrogen Pick up During Normal Operation
10.0 Growth
11.0 LOCA-specific Material Performance
12.0 Surveillance
13.0 Update Process
14.0 References

Material Definition

- M5 is a Zr1Nb alloy
- Fully recrystallized
- [

  ]
- Performance compared to Zr-4
  - Very low corrosion & hydrogen pickup
  - Improved creep and growth

Irradiation Experience (Dec 2016)
Cladding

Irradiation Experience (Dec 2016)
Structural Material

Physical Properties

- No changes to most physical properties used in current codes and methods
  - Thermal properties, density, elastic modulus, …
- Clarification of applicability ranges (temperatures, material forms)
- Update to thermal expansion model
  - BAW-10227PA provided figures, no models
  - BAW-10240PA provided models

Mechanical Properties

- Updates to [ ] mechanical models will be provided
  - Based on expanded database
  - Includes YS, UTS, Elongation
  - Biaxial and Uniaxial conditions
- Alignment of models with those used in advanced fuel rod codes
- Update definitions of stress intensity limits
  - Align with methodologies licensed separately & ASME BPVC
  - [ ]

Corrosion / Hydrogen Pickup Philosophy

- **Why do we evaluate corrosion?**
  - Reduction in load-carrying cross-section due to oxide layer growth
  - Avoid significant oxide spallation
  - Oxide thickness is easy to measure
  - Mechanism driving hydrogen pickup into material
  - Oxide thickness limit is enforced as a way to control hydrogen
- **Why does hydrogen in material matter?**
  - Reduces material ductility / leads to embrittlement
  - The effects are practically realized in Transient Cladding Strain, LOCA, and RIA events
- [

  ]

Corrosion

- **Update Models (cladding)**
  - Based on expanded database
  - Model form remains same
  - Alignment of model constants with those used in COPERNIC and GALILEO fuel rod codes
- **Provide Models (structural components)**
  - Same model form as cladding, different model constants
  - Developed similarly as for Q12 structural components
    - [

      ]
- **Maintain current cladding oxide limit of [ ] microns as protective against detrimental spallation**

Hydrogen Pickup

- **Provide model for calculating hydrogen content**
  - **BAW-10227PA Revision 0 only provided value for hydrogen pickup fraction**
  - **Full model based on expanded database**
  - **Alignment of model constants with those used in GALILEO fuel rod code**

Free Growth

- Revision 1 did not address
- Revision 2 will provide free growth models for cladding

Creep

- Revision 1 recommended creep models adjusted from Zr-4 models
- Revision 2 will provide updated creep models for M5 cladding
  - Developed from M5 database
  - Consistent with models in advanced fuel rod code

Fuel Rod Growth

- Expanded database will be graphically shown
- Current models will be provided
  - Shoulder gap methodology approved in Rev 01 no longer used

Fuel Assembly Growth

- Current database of FA growth will be shown against upper and lower bounding models
- Will focus on current fuel assembly design types

LOCA-specific Material Performance

- 10 CFR 50.46 is not explicitly applicable to M5
  - BAW-10227PA Revision 1 Appendix G supports the applicability of the 50.46 criteria
  - BAW-10227PA Revision 1 Appendix D provides the results of the high temperature oxidation tests performed on M5 to support the use of the NRC-acceptable metal water reaction rate correlations
- No change to conclusions
- [

]

LOCA-specific Material Performance

M5 Swelling and Rupture Model (SRM)

- Similar to Zr-4 SRM, but modified for M5 performance
  - BAW-10227PA Revision 1 Appendix C, I, and K
  - Based on EDGAR facility ramp tests available at the time
  - Based on LOCA performance range at the time
- Since the time of approval, there have been changes in methods and plant operation and additional EDGAR tests performed
- Framatome identified a necessary update to the SRM in 2017
  - 50.46 ΔPCTs for existing AORs, method deviations for new AORs
- BAW-10227P Revision 2 will incorporate the updated M5 SRM

Extended Limits

[ ]

Expanded Limits

[ ]

Update Process

- **Maintain current update process as defined and approved in BAW-10227PA Revision 1**

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Next Steps

- Jerry Holm
- Licensing Engineer

Next Steps

- Topical report submittal [ ]
- Audit for understanding
- RAIs
- RAI response
- Final SE [ ]

Acronyms

AOR	Analysis of Record
ASME	American Society of Mechanical Engineers
BPVC	Boiler Pressure Vessel Code
B&W	Babcock and Wilcox
CE	Combustion Engineering
LOCA	Loss of Coolant Accident
NRC	Nuclear Regulatory Commission
RAI	Request for Additional Information
RIA	Reactivity Insertion Accident
SE	Safety Evaluation
SRM	Swelling and Rupture Model
W	Westinghouse
UTS	Ultimate Tensile Strength
YS	Yield Strength
Zr1NB	Zircaloy 1 % Niobium
Zr-4	Zircaloy 4

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