



**U.S.NRC**

UNITED STATES NUCLEAR REGULATORY COMMISSION

*Protecting People and the Environment*

# **10 CFR 50.46c ECCS Rulemaking**

## **Public Meeting**

### **October 22, 2015**



# Agenda

- |                    |   |
|--------------------|---|
| <b>1:00-1:10pm</b> | Purpose and Ground Rules (NRC)                              |
| <b>1:10-1:30pm</b> | High-Level Draft Preliminary Changes to 10 CFR 50.46c (NRC) |
| <b>1:30-2:30pm</b> | Industry Discussion (Industry)                              |
| <b>2:30-3:00pm</b> | Public Discussion (Public)                                  |
| <b>3:00-3:50pm</b> | Open Discussion (All)                                       |
| <b>3:50-4:00pm</b> | Closing Remarks   |
| <b>4:00pm</b>      | Adjourn   |



# Meeting Purpose

- Inform stakeholders of the draft preliminary changes to the 10 CFR 50.46c rule since it was published for comment
  - Comment period ended on August 21, 2014
- Discussion is intended to help the NRC and stakeholders prepare for an Advisory Committee on Reactor Safeguards (ACRS) subcommittee meeting on November 3, 2015
- Discuss implementation as described in the draft final rule, fulfilling the Cumulative Effects of Regulation guidelines



## Meeting Purpose (cont'd)

- Staff will consider oral comments made in developing the final rule and guidance
  - NRC will not be providing, in the final rulemaking, written comment responses to any oral comments made at this meeting
- The NRC is not taking written public comments at this meeting



# Preliminary Draft Package

- The NRC provided a draft preliminary version of the 10 CFR 50.46c rule package on regulations.gov, Docket ID NRC-2008-0332.
- These draft documents have not received NRC management review and approval and thus pre-decisional and subject to change.
- Draft preliminary 50.46c documents are also found in ADAMS at the following accession numbers:
  - SECY-XX-XXXX- Final Draft Rulemaking: ML15281A203
  - *Federal Register* Notice of Final Rulemaking: ML15281A196
  - NRC Staff Responses to Public Comments on Proposed Rule: ML15281A199
  - RG 1.222 (DG-1261)– Measuring Breakaway Oxidation Behavior: ML15281A170
  - RG 1.223 (DG-1262)– Determining Post Quench Ductility: ML15281A188
  - RG 1.224 (DG-1263)– Establishing Analytical Limits for Zirconium-Alloy Cladding Material: ML15281A192
  - RG 1.229 (DG-1322)– Risk-Informed Approach for Addressing the Effects of Debris: ML15292A012
    - Appendix C: ML15292A010
  - NRC Staff Responses to Public Comments on DG-1322: ML15292A009
  - Backfit and Issue Finality Discussion: ML15294A471
  - Regulatory Analysis: ML15294A467



# U.S. NRC

UNITED STATES NUCLEAR REGULATORY COMMISSION

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## 50.46c Rulemaking Summary of Changes

Public Workshop  
October 2015

Paul M. Clifford  
Division of Safety Systems  
Nuclear Reactor Regulation



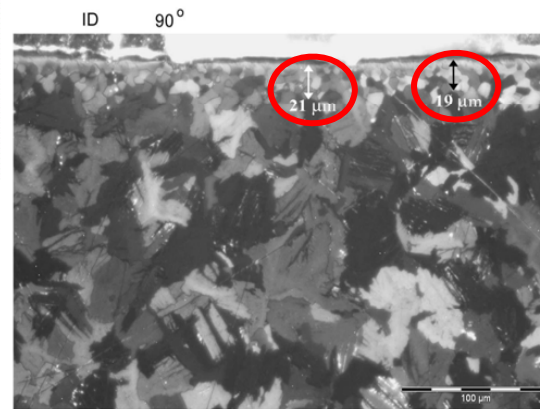
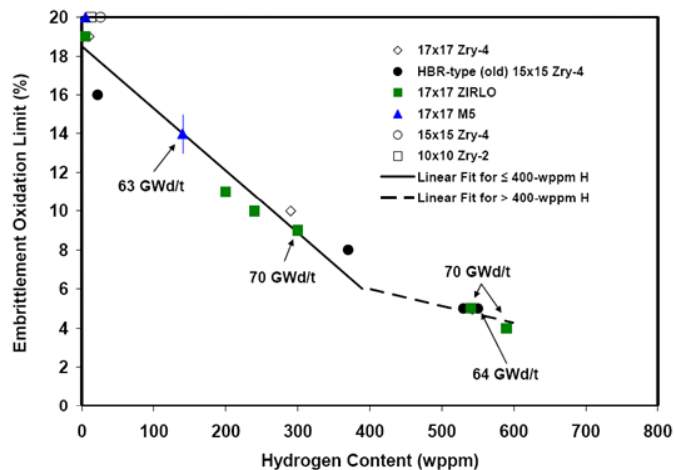
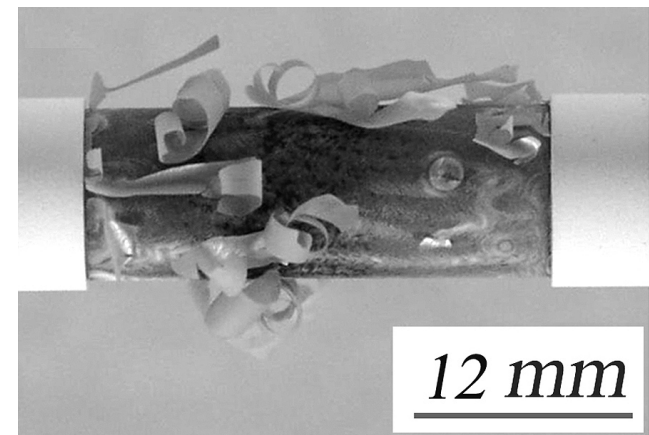
## 50.46c Rulemaking Goals

- Revise emergency core cooling system (ECCS) acceptance criteria to reflect recent research findings
- Expand applicability to all fuel designs and cladding materials
- Replace prescriptive analytical requirements with performance-based requirements
- Address concerns raised in two petitions for rulemaking (PRMs): PRM-50-71 and PRM-50-84
- Allow an alternative risk-informed approach to evaluate the effects of debris on long-term cooling

# Research Findings

## New Embrittlement Mechanisms:

1. Hydrogen-enhanced beta layer embrittlement.
2. Cladding ID oxygen diffusion
3. Breakaway oxidation







## **U.S.NRC 50.46c Requirements - Unchanged**

- Peak cladding temperature criterion, 2200 °F
- Core wide oxidation criterion, 1.0%
- Requirement to address debris effects

The logo for the U.S. Nuclear Regulatory Commission (NRC) features a stylized atom with a blue nucleus and three orange and blue elliptical orbits.

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## **50.46c Requirements - New**

- Hydrogen-dependent cladding embrittlement criteria, integral time-at-temperature and peak cladding temperature
- Breakaway oxidation test and analytical requirement
- Cladding ID oxygen ingress analytical requirement
- Crud thermal conductivity analytical requirement
- LTC fuel performance requirement
- Alternative risk-informed approach for treatment of debris



## Major Revisions from the Proposed Rule to Draft Final Rule

- Breakaway oxidation testing and reporting
  - Deleted annual reporting requirement
  - Revised confirmatory periodic testing, no specified frequency
- Long-term cooling fuel performance requirement
  - Deleted PCT analytical limit and ductility performance metric
  - If debris prompts a post-quench reheat transient, then research must be conducted to demonstrate no further cladding failure
- Implementation plan
  - Deleted Table 1 plant assignments
  - Adopted NEI proposal. Within 6 months each licensee must submit an implementation plan and schedule
    - LAR must be submitted within 60 months of final rule.
    - Compliance must be achieved within 84 months of final rule.
- Significant changes to DG-1261, DG1262, and DG-1263



## Breakaway Oxidation

(iii) Breakaway oxidation. An analytical time limit that has been shown to preclude breakaway oxidation using an NRC-approved experimental technique must be determined and specified for each zirconium-alloy cladding material. The analytical limits must be approved by the NRC. The total time that the cladding is predicted to remain above the temperature that the zirconium-alloy has been shown to be susceptible to breakaway oxidation must be less than the analytical limit. **The breakaway oxidation behavior must be periodically confirmed** using an NRC-approved experimental technique capable of determining the effect of composition changes or manufacturing changes on the breakaway oxidation behavior. The frequency of confirmatory testing must provide reasonable assurance that fuel is being manufactured consistent with the specified analytical limit.



## LTC Performance

(v) Long-term cooling. After any calculated successful initial operation of the ECCS, the calculated core temperature must be maintained to **prevent further cladding failure**, and the ECCS shall provide sufficient coolant to remove decay heat, for the extended period of time required by the long-lived radioactivity remaining in the core.

SOC:

In the absence of a debris-induced, post-quench reheat transient, the staff has determined that: 1) currently approved analytical models and methods continue to be acceptable and 2) no further fuel testing and analysis is required to satisfy the more explicit performance requirement discussed below.



## Implementation

(2)(i) Each holder of an operating license issued under this part as of [INSERT DATE THAT IS 30 DAYS AFTER THE DATE OF PUBLICATION IN THE FEDERAL REGISTER], and each holder of an operating license issued under this part which is based upon a construction permit in effect as of [INSERT DATE THAT IS 30 DAYS AFTER THE DATE OF PUBLICATION IN THE FEDERAL REGISTER] (including deferred and reinstated construction permits), **must submit an implementation plan and schedule for achieving compliance with the provisions of this regulation with the exception of the consideration of debris effects under paragraph (d)(2)(iii) of this section. The implementation plan must identify the evaluation model(s), fuel design(s) and cladding alloy(s), and analytical limits to be used in the ECCS performance demonstration, along with the relative level of effort needed to complete the performance demonstration. The schedule must identify, for each element of the ECCS performance demonstration required to be submitted to the NRC for review (e.g., evaluation model, hydrogen uptake model, cladding alloy), the earliest possible date for submission and the expected date of submission. The implementation plan and schedule must be submitted within 6 months of [INSERT DATE THAT IS 30 DAYS AFTER THE DATE OF PUBLICATION IN THE FEDERAL REGISTER], and updated by the licensee every 12 months until the license amendment request has been submitted and docketed by the NRC for review.**



## Implementation

(ii) The licensee's request for NRC approval under paragraph (d)(2) of this section must be in the form of license amendment application under § 50.90. The application must be submitted by no later than **60 months** after [INSERT DATE THAT IS 30 DAYS AFTER THE DATE OF PUBLICATION IN THE FEDERAL REGISTER].

(iii) Licensees must be in compliance with the requirements of this section no later than **84 months** after [INSERT DATE THAT IS 30 DAYS AFTER THE DATE OF PUBLICATION IN THE FEDERAL REGISTER]. Until such compliance is achieved, the requirements of § 50.46 continue to apply for purposes of ECCS design and fuel design.

(8) Combined licenses under part 52 of this chapter issued before [INSERT DATE THAT IS 30 DAYS AFTER THE DATE OF PUBLICATION IN THE FEDERAL REGISTER], and combined licenses issued after [INSERT DATE THAT IS 30 DAYS AFTER THE DATE OF PUBLICATION IN THE FEDERAL REGISTER], whose applications were docketed before [INSERT DATE THAT IS 30 DAYS AFTER THE DATE OF PUBLICATION IN THE FEDERAL REGISTER], must comply with the requirements of this section by **initial fuel loading or 84 months** from [INSERT DATE THAT IS 30 DAYS AFTER THE DATE OF PUBLICATION IN THE FEDERAL REGISTER], whichever is later.



# 50.46c Analytical Limits Regulatory Guides

October 22, 2015

Michelle Flanagan Bales  
Division of Systems Analysis  
Nuclear Regulatory Research





# Regulatory Guides

- RG 1.222, *Measuring Breakaway Oxidation Behavior*: Test procedure for measuring breakaway oxidation behavior and periodically confirming consistent behavior
- RG 1.223, *Determining Post Quench Ductility*: Test procedure for measuring post quench ductility using ring compression tests
- RG 1.224, *Establishing Analytical Limits for Zirconium-Alloy Cladding Material*: Guidance to develop analytical limits from measured data and approach to demonstrate compliance.

# Context

## *Relationship to rule language*

**RG 1.224**

50.46c(g)(1)(iii) *Breakaway oxidation*. **An analytical time limit that has been shown to preclude breakaway oxidation using an NRC-approved experimental technique** must be determined and specified for each zirconium-alloy cladding material. The analytical limit must be approved by the NRC. The total time that the cladding is predicted to remain above the temperature that the zirconium-alloy has been shown to be susceptible to breakaway oxidation must be less than the analytical limit. The breakaway oxidation behavior must be periodically confirmed using **an NRC-approved experimental technique** capable of determining the effect of composition changes or manufacturing changes on the breakaway oxidation behavior. The frequency of confirmatory testing must provide reasonable assurance that fuel is being manufactured consistent with the specified analytical limit.

**RG 1.222**



# Context

## *Relationship to rule language*

**RG 1.224**

50.46c(g)(1)(ii) *Post-quench ductility*. **Analytical limits on peak cladding temperature and integral time at temperature shall be established** that correspond to the measured ductile-to-brittle transition for the zirconium-alloy cladding material based on **an NRC-approved experimental technique**. The calculated maximum fuel element temperature and time at elevated temperature shall not exceed the established analytical limits. The analytical limits must be approved by the NRC. If the peak cladding temperature, in conjunction with the integral time at temperature analytical limit, established to preserve cladding ductility is lower than the 2200 °F limit specified in paragraph (g)(1)(i) of this section, then the lower temperature shall be the applicable analytical limit on peak cladding temperature.

**RG 1.223**



# Response to Public Comments

## ***RG 1.222***

- Industry commenters expressed that
  - Requiring licensees to report breakaway oxidation results was unnecessary and suggested that the fuel cladding vendors could address the concerns regarding breakaway oxidation with their quality assurance programs.
  - Periodic testing sample frequency should be reduced and be more flexible
  - Testing protocol, such as temperature calibration and sample preparation, should be more flexible
- A member of the public comments that the test protocol were not similar enough to the expected conditions in a LOCA
- The NRC agreed that the periodic confirmation objective of the rule could be achieved through vendor testing programs that are reviewed and approved by the NRC and without reporting of periodic breakaway oxidation results. However, results will be subject to NRC audit.
- The NRC agreed that testing protocol and periodic testing frequency could be more flexible (default frequency is offered as one test per ingot).
- The rule language and regulatory guide were revised accordingly.



# Response to Public Comments

## ***RG 1.223***

- Industry commenters expressed that
  - Testing protocol, such as temperature calibration and sample preparation, should be more flexible.
  - There should be more flexibility to define an acceptable sample set to evaluate the ductile-to-brittle transition for a given hydrogen content – to have flexibility to “bin” samples with hydrogen contents within a narrow range of the target.
  - The acceptable methods to evaluate data scatter and determine the ductile-to-brittle transition should be made more clear.
  - The function and content of RG 1.223 and RG 1.224 should be better differentiated.
  
- The NRC agreed with all comments
  - Guidance was added outline conditions where data in a narrow range of hydrogen content could be “binned” in order to evaluate the ductile-to-brittle transition.
  - Guidance was added to deal with data scatter more clearly.
  - Testing protocol was made more flexible.
  - Content was moved between RG 1.223 and RG 1.224 to better separate the function of each guide.



# Response to Public Comments

## ***RG 1.224***

- Industry commenters expressed that
  - Treatment of legacy fuel to show compliance with 50.46c should be expressly defined.
  - The function and content of RG 1.223 and RG 1.224 should be better differentiated.
  - Evaluation of breakaway oxidation should consider time above 800C rather than 650C.
  - The guidance should include a set of conditions that could eliminate the need for testing of irradiated material testing.
  - The lack of approved hydrogen pick-up models presents a challenge to implementation.



# Response to Public Comments

## ***RG 1.224***

- The NRC agreed with all comments, several changes were made to address comments.
  - Guidance was added address (g)(1)(ii) and (g)(1)(iii) analytical limits for legacy fuel.
  - Content was moved between RG 1.223 and RG 1.224 to better separate the function of each guide.
  - Threshold for evaluation of breakaway oxidation changed to 800C.
  - Guidance added to establish conditions to eliminate the need for testing of irradiated material testing.
  - Default hydrogen pick-up models developed and documented in an Appendix.



# 50.46c Risk-Informed Alternative for Long-Term Core Cooling

Public Workshop  
October 22, 2015

Steve Laur  
Division of Risk Assessment  
Nuclear Reactor Regulation





## 50.46c(e)

- Risk-informed approach is a new alternative for evaluating the effect of debris on long term cooling
  - Must assess risk of debris, and demonstrate adequate defense in depth and safety margins
  - Requires NRC review and approval via a license amendment request
  - RG 1.229 will provide guidance on using this method (relies heavily on RG 1.174 and RG 1.200)
- Summary of changes from draft rule
  - Clarified the relationship to 50.46c(d)(2)
  - Reorganized (e)(1) for clarity
  - Added requirement that the systematic risk assessment be performed under a suitable QA program
  - Added requirement for a performance monitoring program
  - NRC staff is considering limiting use of the risk-informed approach to emergent issues; i.e., it would not usually be approved for new designs or modifications to existing designs (still under internal deliberation)



## 50.46c(m)

- Reporting, corrective action, and periodic update:
  - If an entity discovers that risk exceeds the acceptance criteria or that defense in depth or safety margins are not maintained, it must
    - (m)(6) – make a report
    - (m)(7) – take corrective action
      - Before being licensed: request an amendment
      - Licensees: take timely action to meet the acceptance criteria
  - (m)(8) requires updating of the risk-informed approach
    - New reactors no later than initial fuel load
    - All licensees using the alternative approach – at least every 4 years
- Summary of changes from draft rule
  - Rearranged 50.46c(m) to allow parallel construction between the deterministic and risk-informed requirements



## Other Comment

- The public commented that other regulations may require exemptions to implement the risk-informed approach, specifically GDC-19 and 10 CFR 50.67
- This is currently under consideration by the NRC staff



## Reg. Guide 1.229

- Over 200 public comments on DG-1322
- Changes in RG 1.229
  - Created two appendices for clarity
    - Detailed approach in Appendix A
    - Simplified approach in Appendix B
  - Consolidated uncertainty discussion
  - Added guidance for some rule aspects
    - Monitoring program
    - QA for the systematic risk assessment
    - Periodic update
    - Submittal content
- Still working on a technical basis for LOCA initiating event frequencies



## Conclusions

- Many changes were made to proposed rule to clarify the requirements to implement a risk-informed approach to address the effects of debris on long-term cooling
- NRC intends to limit the use of risk-informed evaluations to the effects of debris on LTC
- NRC intends to allow the use of the risk-informed alternative only for emergent conditions, not to allow problematic material to be designed into a plant (under consideration at present)
- NRC is currently finalizing the guidance that will assist in implementing the risk-informed alternative (RG 1.229)