Current Status of Reactivity-Initiated Accident Criteria in the United States

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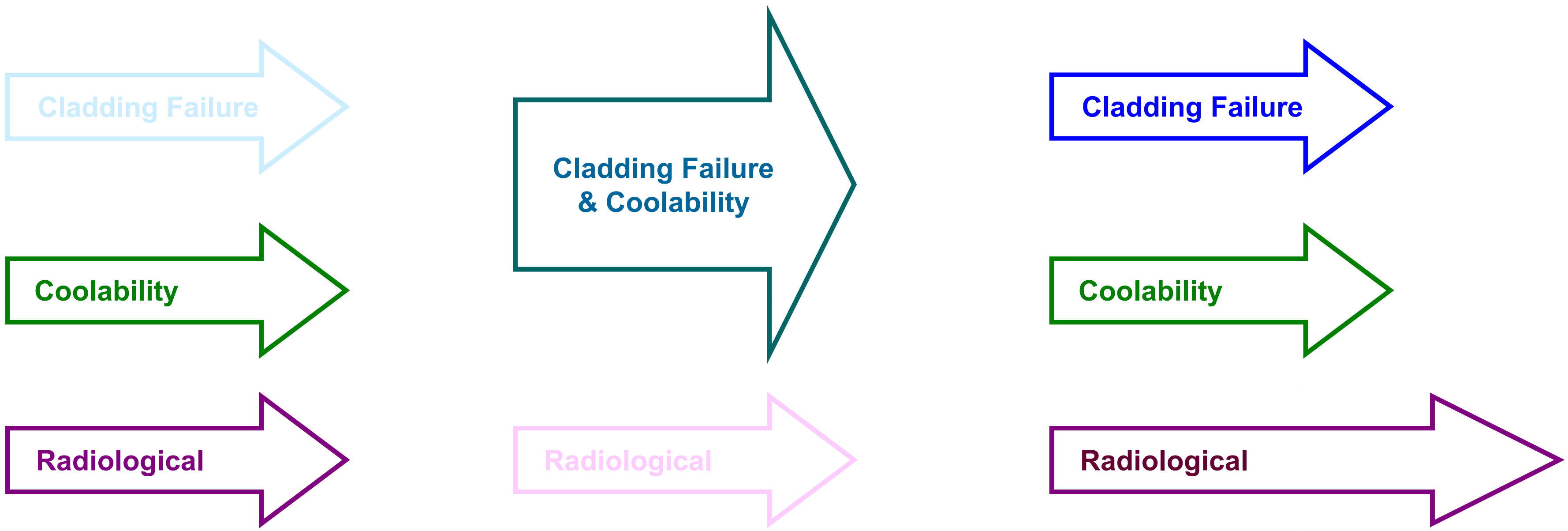
History



Regulatory Guide 1.77

Research Information Letter 0401

Interim Acceptance Criteria

RIA CRITERIA

Current criteria for the reactivity-initiated accident are incorporated into Appendix B of U.S. Nuclear Regulatory Commission's Standard Review Plan (NUREG-0800), Section 4.2, "Fuel System Design," Revision 3, March 2007.

Revised RIA Criteria

- Revised the high temperature cladding failure threshold
- Introduced a new cladding failure threshold related to pellet-cladding mechanical interaction
- Introduced a new fission gas release source term based on grain boundary separation
- Revised the upper limit on fuel enthalpy to preserve coolable geometry
- Introduced a new criterion to preclude molten fuel-to-coolant interaction
- Introduced new criteria related to ensuring a coolable geometry (e.g., mechanical interaction between non-molten fuel particles in coolant)

Openess in the Development of RIA Criteria

Nuclear regulation is the public's business, and it must be transacted publicly and candidly.

The public must be informed about and have the opportunity to participate in the regulatory processes as required by law.

NRC Principles of Good Regulation

Public Meetings on RIA

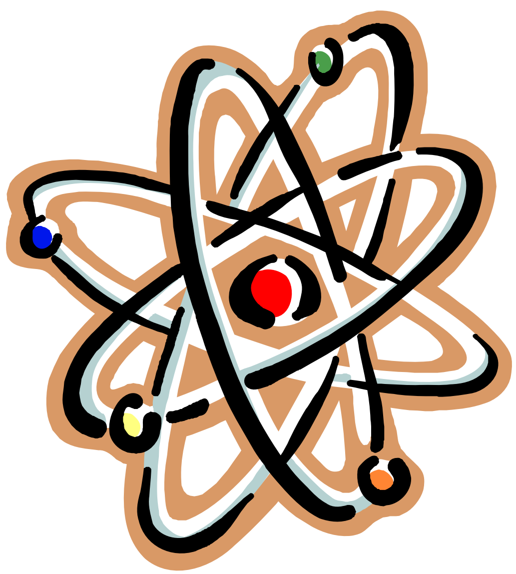
09 November 2006

19 December 2006

16 October 2007

25 September 2008

CLADDING FAILURE



Previous Cladding Failure Criteria

NRC Standard Review Plan, Section 4.2, previously defined Reactivity-Initiated Accident (RIA) fuel cladding failure criteria:

- Radial average fuel enthalpy greater than 170 cal/g for Boiling Water Reactors (BWRs) at zero or low power.
- Local heat flux exceeding fuel thermal design limits, e.g. Departure from Nucleate Boiling (DNB) for all Pressurized Water Reactor (PWR) events and Critical Heat Flux (CHF) for at-power events in BWRs.

Issues with Previous Cladding Failure Criteria

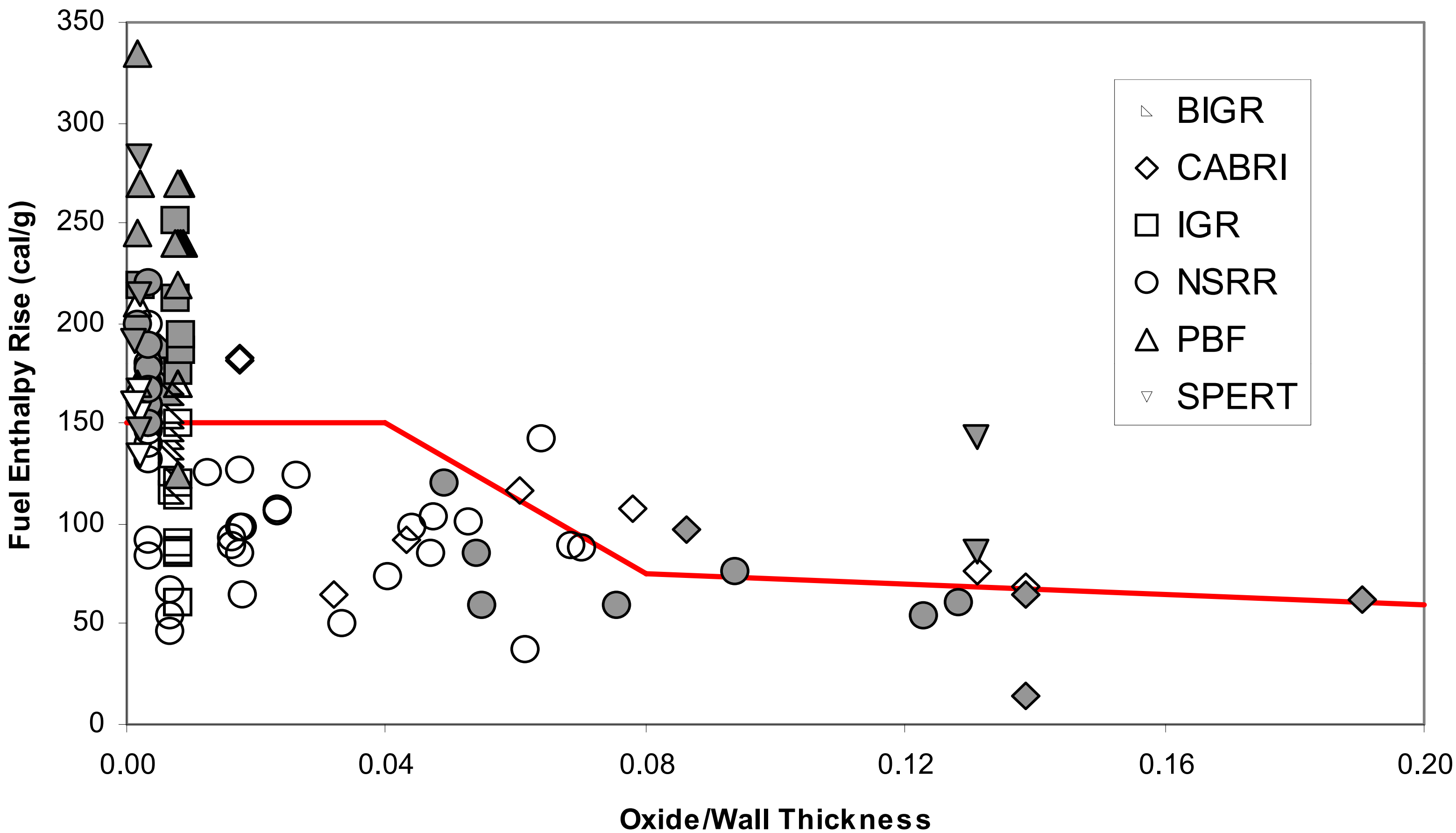
- ✓ Criteria based on low burnup fuel tests.
- ✓ The 170 cal/g criterion is not always adequate to protect fuel rod integrity.
- ✓ Presumption of fuel failure based on a steady-state DNB or CHF correlation may not be appropriate for fast transients.

Revised Cladding Failure Criteria

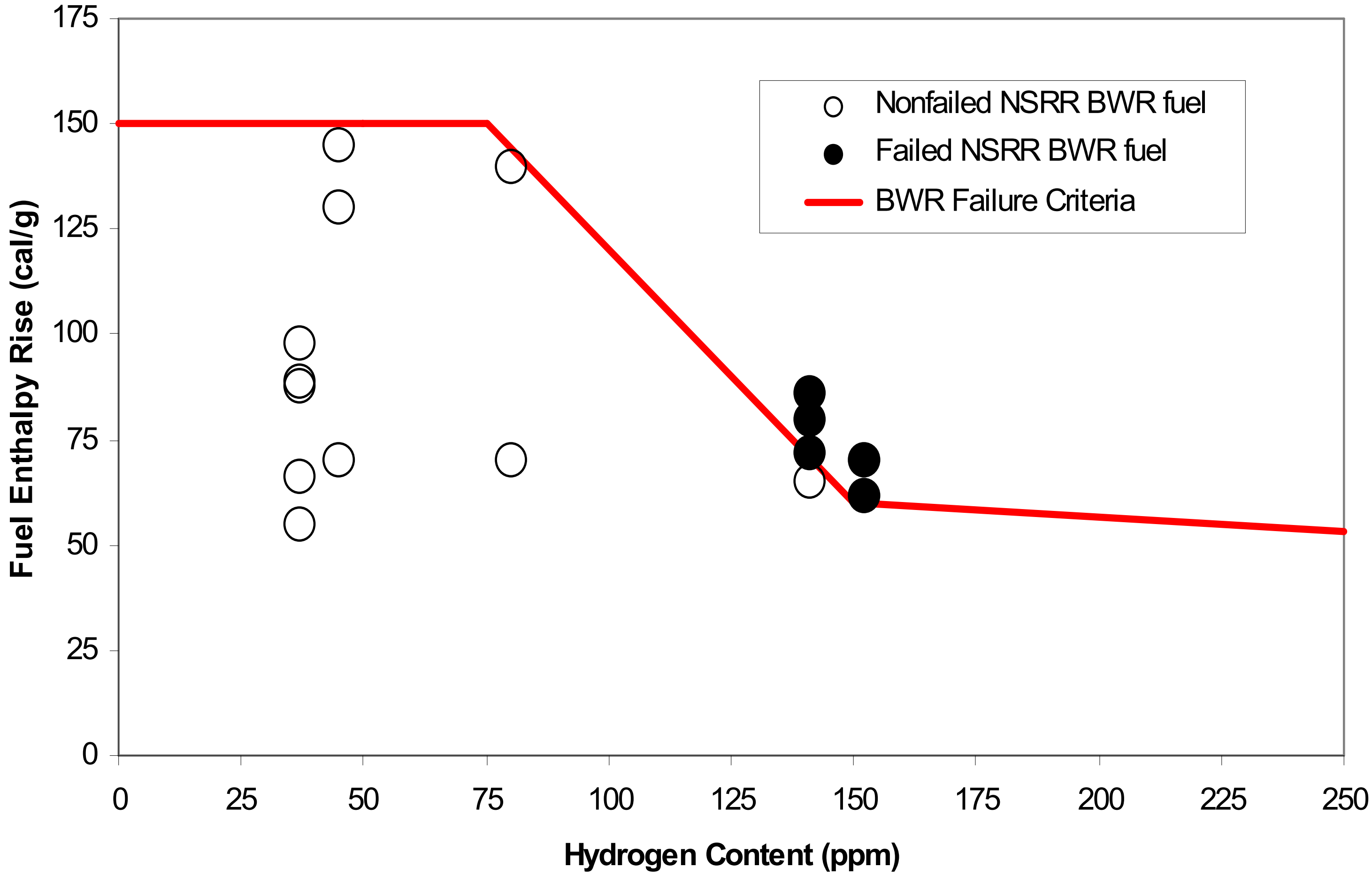
- ✓ The high cladding temperature failure criteria for zero power conditions is a peak radial average fuel enthalpy greater than 170 cal/g for fuel rods with an internal rod pressure at or below system pressure and 150 cal/g for fuel rods with an internal rod pressure exceeding system pressure. For intermediate and full power conditions, fuel cladding failure is presumed if local heat flux exceeds thermal design limits (e.g. DNB and CHF).

- ✓ The PCMI failure criteria is a change in radial average fuel enthalpy greater than the corrosion-dependent limits.

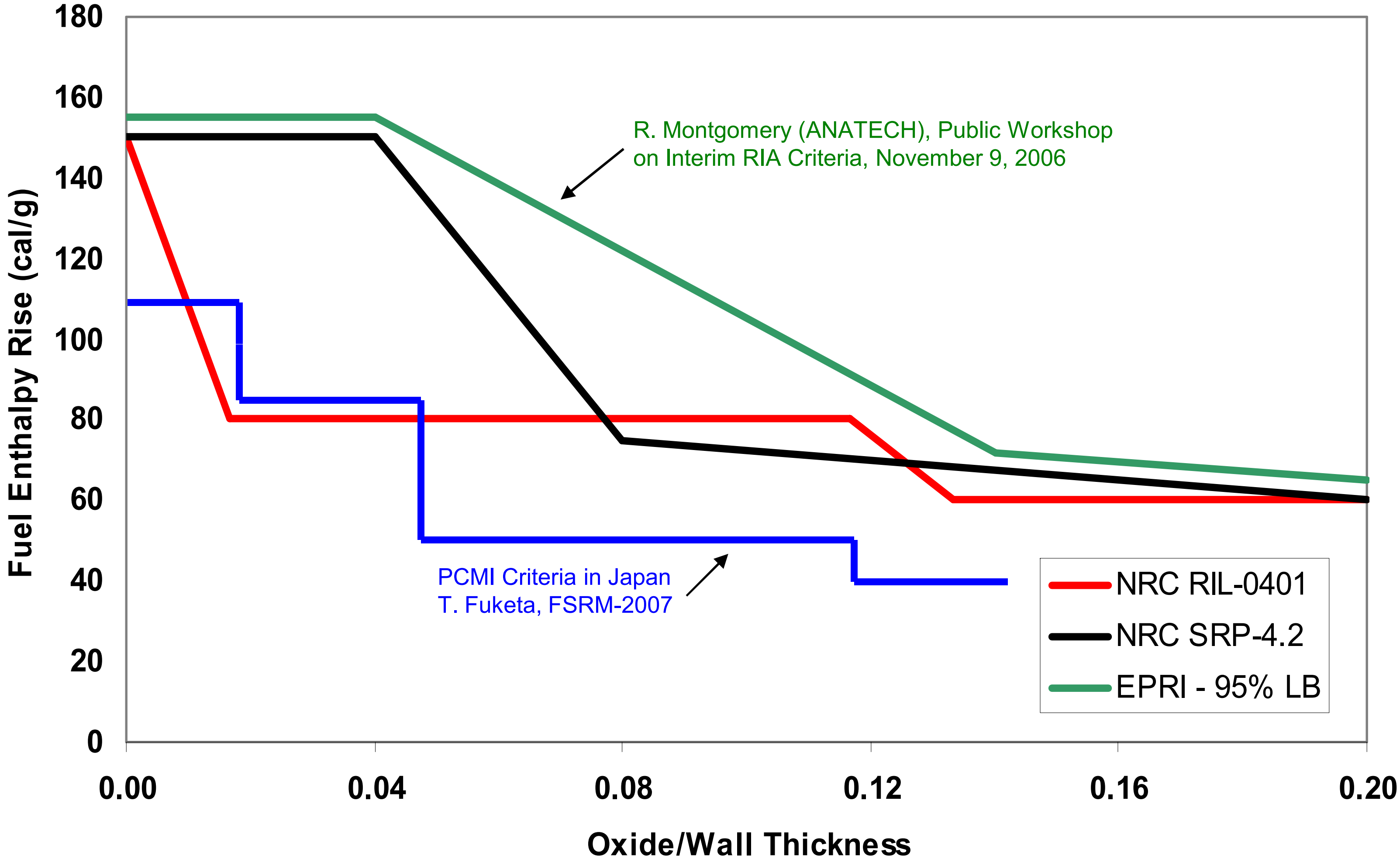
PWR Failure Criteria



BWR Failure Criteria



Comparing PWR Criteria



Benchmark Meetings

12 August 2008

(PNNL)

24-25 March 2009

(ANATECH)

Benchmark Cases

- HBO-1
- HBO-5

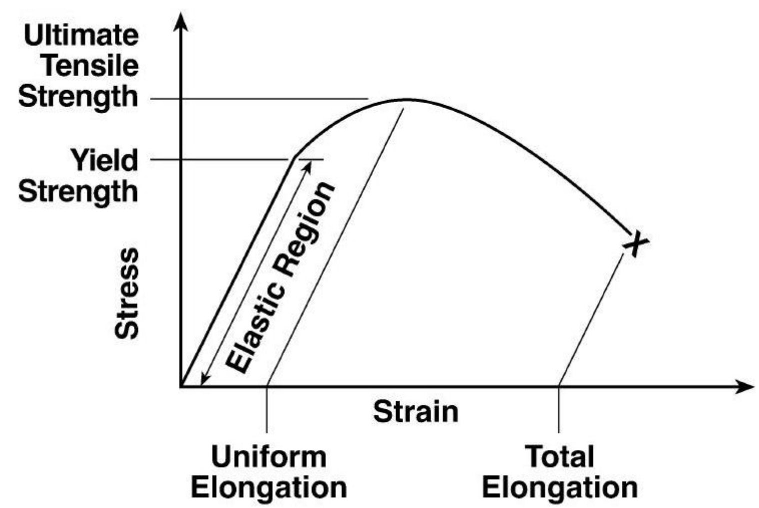
  (actual and hypothetical “hot capsule” conditions)
- HBO-6
- REPNa-3
- Westinghouse 17x17

  (hypothetical RIA event)

Benchmark Issues

- Cladding Temperature
  (transient cladding-to-coolant heat transfer)

- UE versus TE
  (effect of material properties)

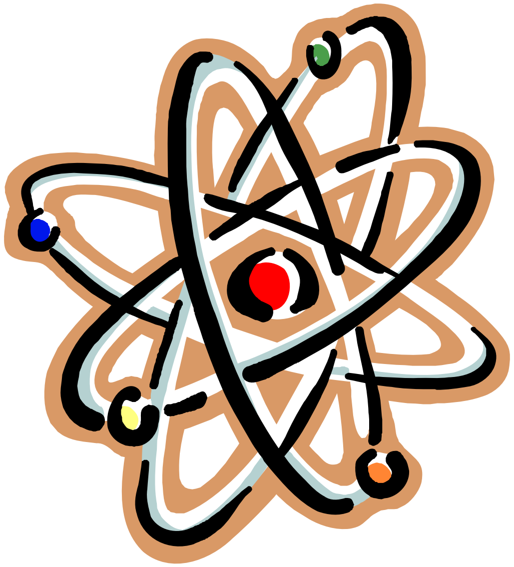


- Temperature Effects
  (“cold” versus “hot” test conditions)

Implementation

- Interim criteria and guidance included in revised Standard Review Plan (NUREG-0800).
- For new reactors, encourage licensees and vendors to develop and submit new 3D core neutronic methods and strategy to handle long-term coolability concerns.
- Complete further evaluation and adjust, if necessary, criteria and guidance by December 2009.
- Finalize criteria and revise Standard Review Plan and Regulatory Guides.
- Backfit determination per 10 CFR 50.109.

COOLABILITY



Previous Coolability Criteria

RG 1.77 identifies acceptable PWR analytical methods and assumptions as well as the following acceptance criteria:

- Fuel radial average energy density limited to 280 cal/g at any axial node.
- Maximum reactor pressure limited to the value that will cause stresses to exceed Service Level C as defined in the ASME Boiler and Pressure Vessel code.

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Issues with Previous Criteria

- ✓ In 1980, MacDonald et al. reviewed test data from SPERT, TREAT, and PBF and concluded:
  - SPERT and TREAT results were misinterpreted. A more appropriate coolability criterion would be 230 cal/g.
  - LWR fuel rods subjected to the regulatory limit, radial average fuel enthalpy of 280 cal/g, will be severely damaged and post-accident cooling may be impaired.
- ✓ Fuel fragmentation and dispersal not addressed.
- ✓ Fuel rod ballooning not addressed.

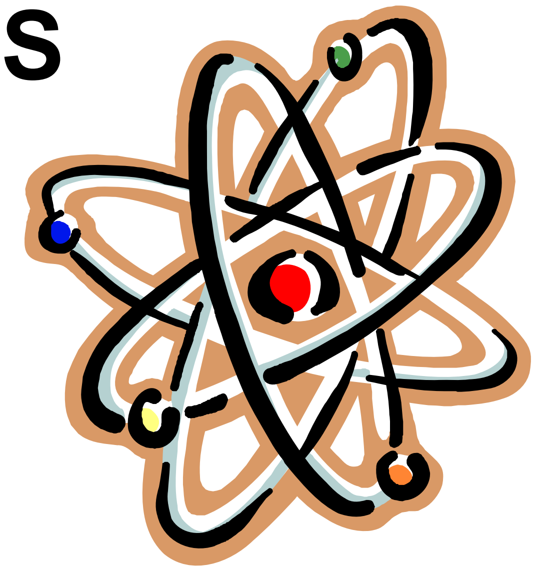
One Approach

One approach is to combine cladding failure and coolability limits. For example:

"[E]nergetic ejection of fuel into the coolant is prevented by preserving the cladding integrity during high energy deposition pulses by staying below the cladding and fuel cal/g limits and below the fuel melt temperature."

U.S. EPR Rod Ejection Accident Methodology Topical Report, AREVA ANP-10286 (Non-Proprietary, November 2007)

RADIOLOGICAL CONSEQUENCES



Revised Assumptions for Gap Inventory

For the reactivity-initiated accident

- Appendix B of NRC Standard Review Plan 4.2 uses steady-state and a transient fission gas release terms.
  - Transient release based on fuel enthalpy rise.

- In February 2009, both calculations were revised.

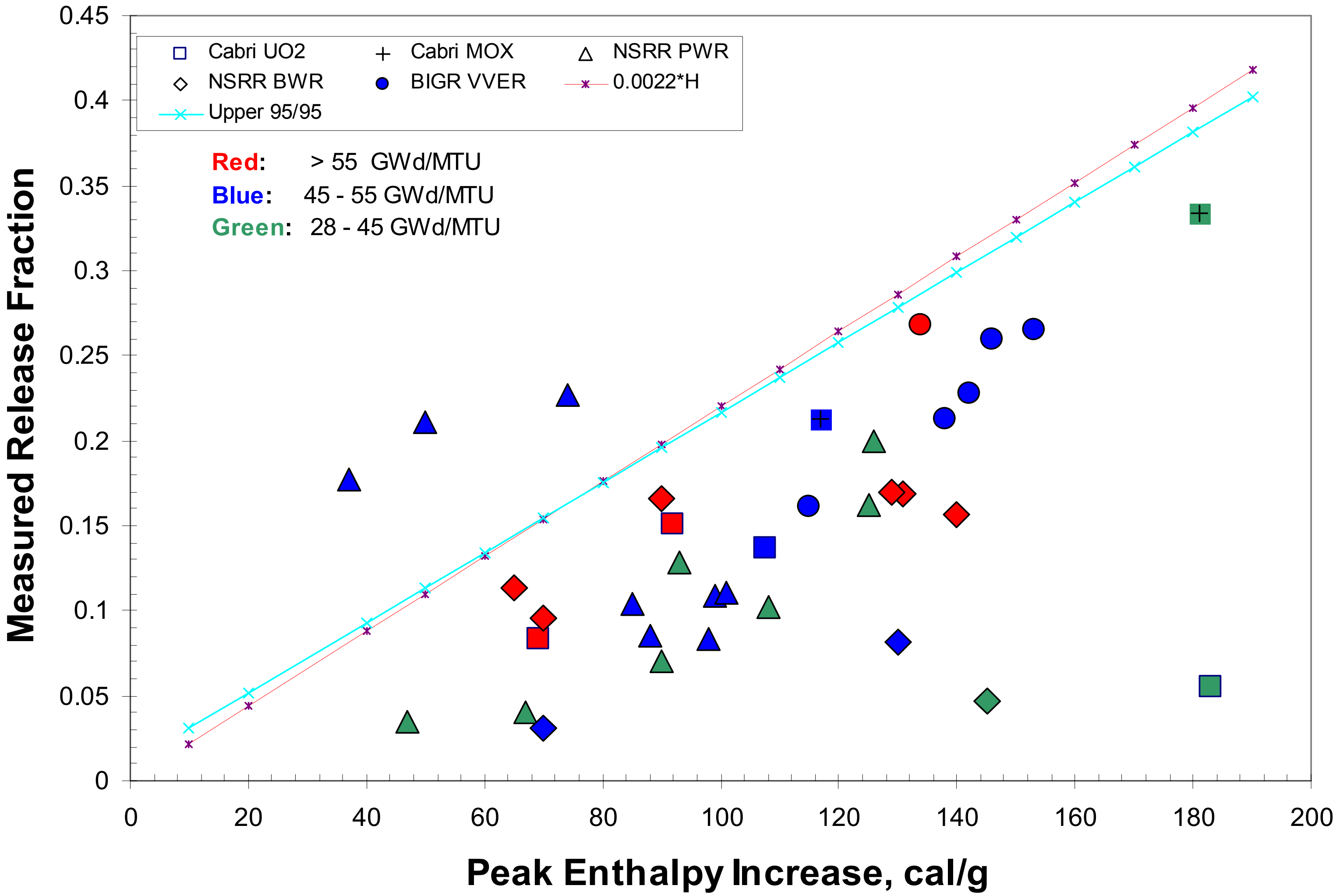
NRC memorandum on *Technical Basis for Revised Regulatory Guide 1.183 Fission Product Fuel-to-Cladding Gap Inventory*, February 10, 2009 [ADAMS Public Accession Number ML090360256]

Fission Product Fractions

Steady-State Assumptions for RIA and Other Events not for LOCA – not for MOX

Group	Fraction
I-131	0.08
I-132	0.23
Kr-85	0.35
Other Noble Gases	0.04
Other Halogens	0.05
Alkali Metals	0.46

Transient Releases



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Conclusion

No safety concerns due to conservative methods

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