



Strategy for Revising Fuel Cladding Acceptance Criteria

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Current Regulation 50.46(b)

- (b)(1) *Peak cladding temperature.* The calculated maximum fuel element cladding temperature shall not exceed 2200° F.
- (2) *Maximum cladding oxidation.* The calculated total oxidation of the cladding shall nowhere exceed 0.17 times the total cladding thickness before oxidation.....
- (3) *Maximum hydrogen generation.* The calculated total amount of hydrogen generated from the chemical reaction of the cladding with water or steam shall not exceed 0.01 times the hypothetical amount that would be generated if all of the metal in the cladding cylinders surrounding the fuel, excluding the cladding surrounding the plenum volume, were to react.
- (4) *Coolable geometry.* Calculated changes in core geometry shall be such that the core remains amenable to cooling.
- (5) *Long-term cooling.* After any calculated successful initial operation of the ECCS, the calculated core temperature shall be maintained at an acceptably low value and decay heat shall be removed for the extended period of time required by the long-lived radioactivity remaining in the core.



LOCA Research Results

- ANL LOCA research program established to investigate burnup and alloying effects on post-quench ductility (PQD).
- Principal results of ANL LOCA research program
 - Cladding embrittlement mechanisms:
 - Prior β -layer embrittlement
 - Prior β -layer thinning
 - Hydrogen-enhanced Prior β -layer embrittlement
 - Degradation of protective oxide layer (hydrogen uptake)
 - Cladding ID oxygen diffusion
 - Hydrogen uptake in balloon/rupture region



LOCA Research Results (cont.)

- Principal results (cont.)
 - 2200 °F PCT regulatory limit remains adequate.
 - 17% ECR regulatory limit does not always ensure PQD.
 - New regulatory limit required for break-away oxide layer.
 - Experimental results sensitive to both fuel cladding fabrication, in-reactor service, and transient conditions:
 - Trace elements
 - Surface finish
 - Pre-LOCA hydrogen content (corrosion)
 - Burnup (ID oxide layer and fuel-cladding bond)
 - Cladding temperature history (cooling rate)

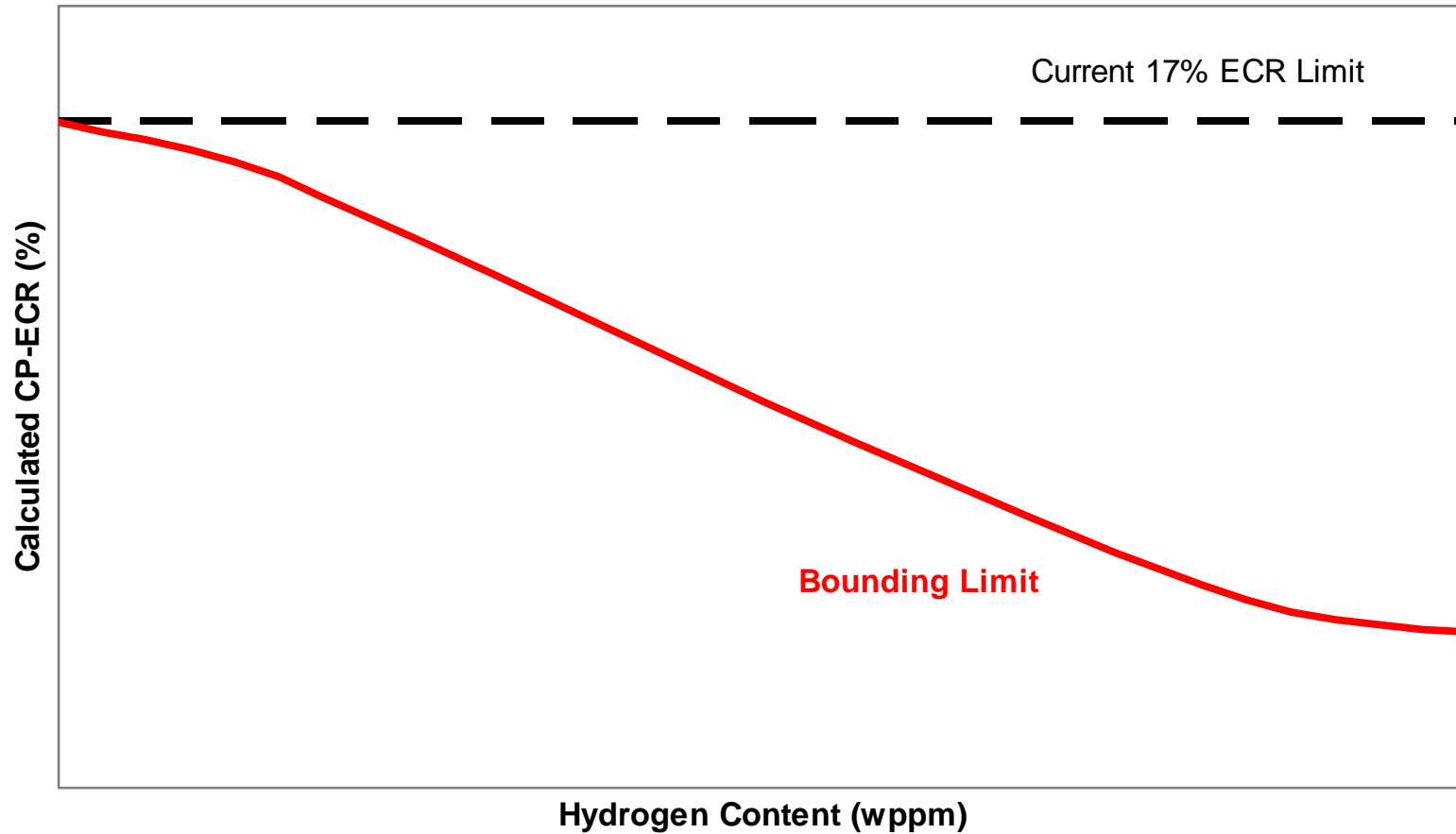


Ongoing LOCA Research

- Current research activities focused on supporting 50.46(b) rulemaking.
 - Empirically-based PQD regulatory limit (function of cladding hydrogen content) based on calculated CP-ECR.
 - Empirically-based breakaway oxidation limit based on calculated time above a specified cladding temperature.
 - Performance-based test program to validate future alloys.
- Future research activities required to address evaluation-model adequacy for fuel rod ballooning and fuel dispersal.

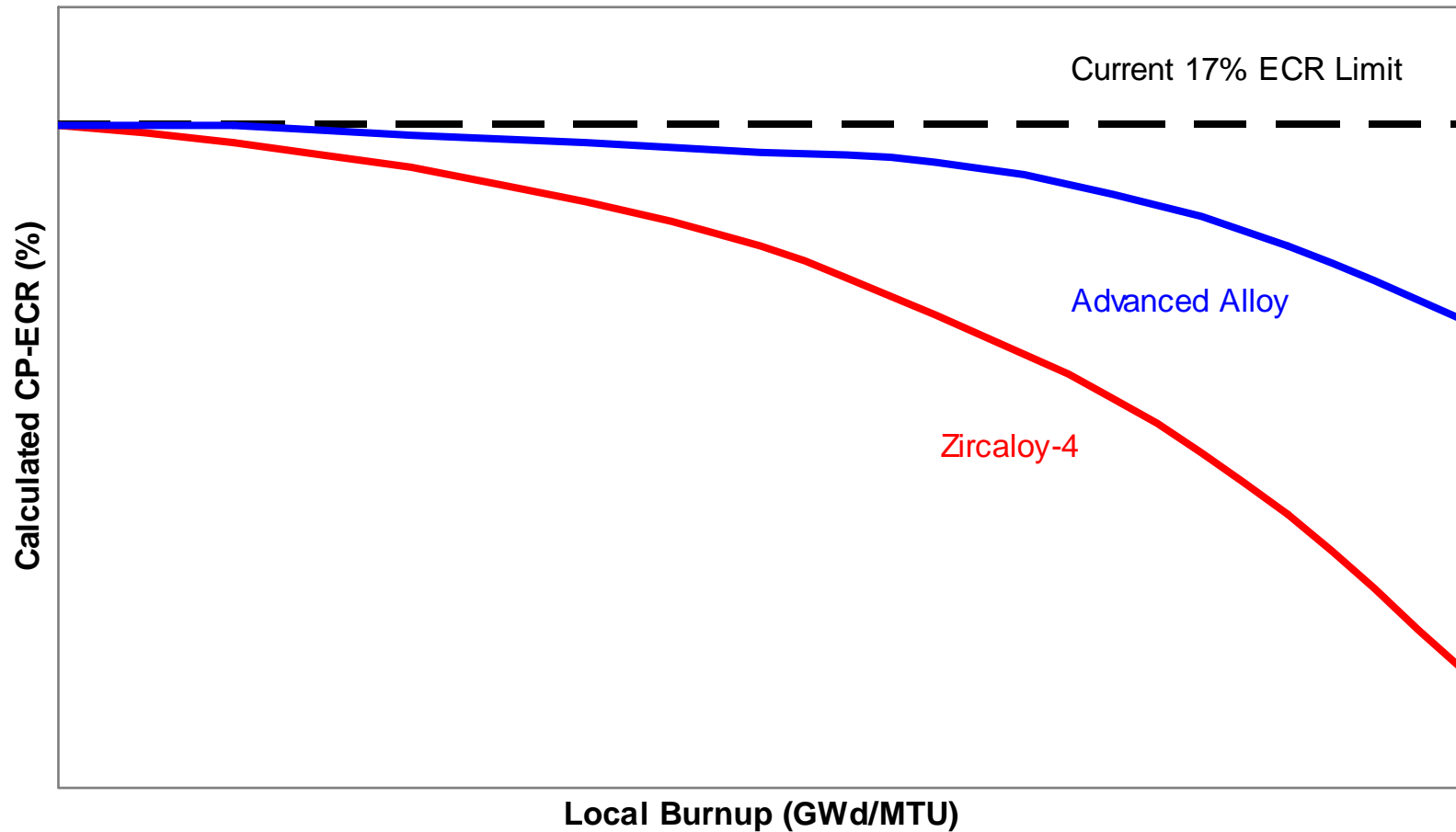
Post-Quench Ductility

Post-Quench Ductility Limit



Alloy Corrosion Properties

Post-Quench Ductility Limit



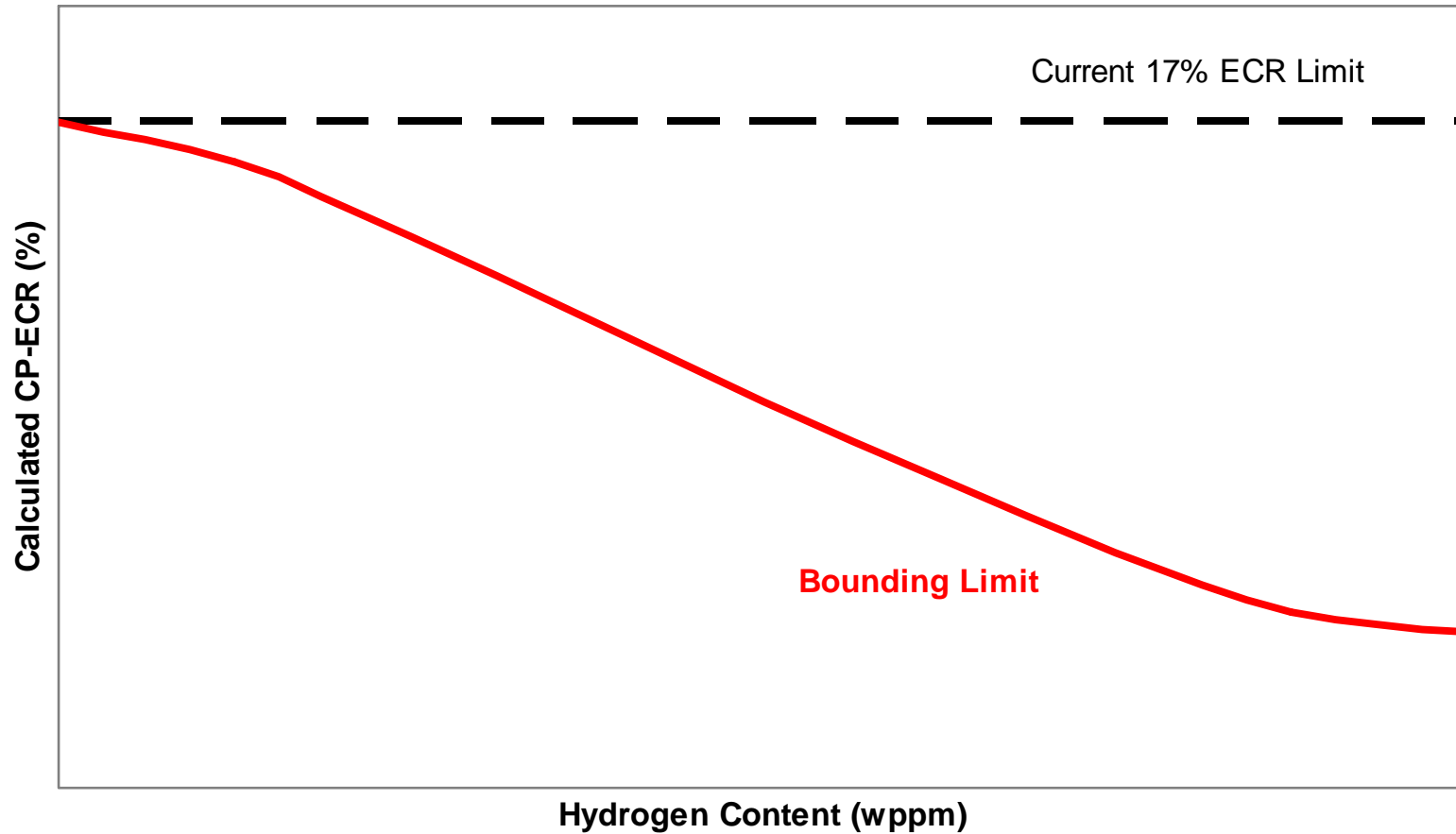


PQD Performance Testing

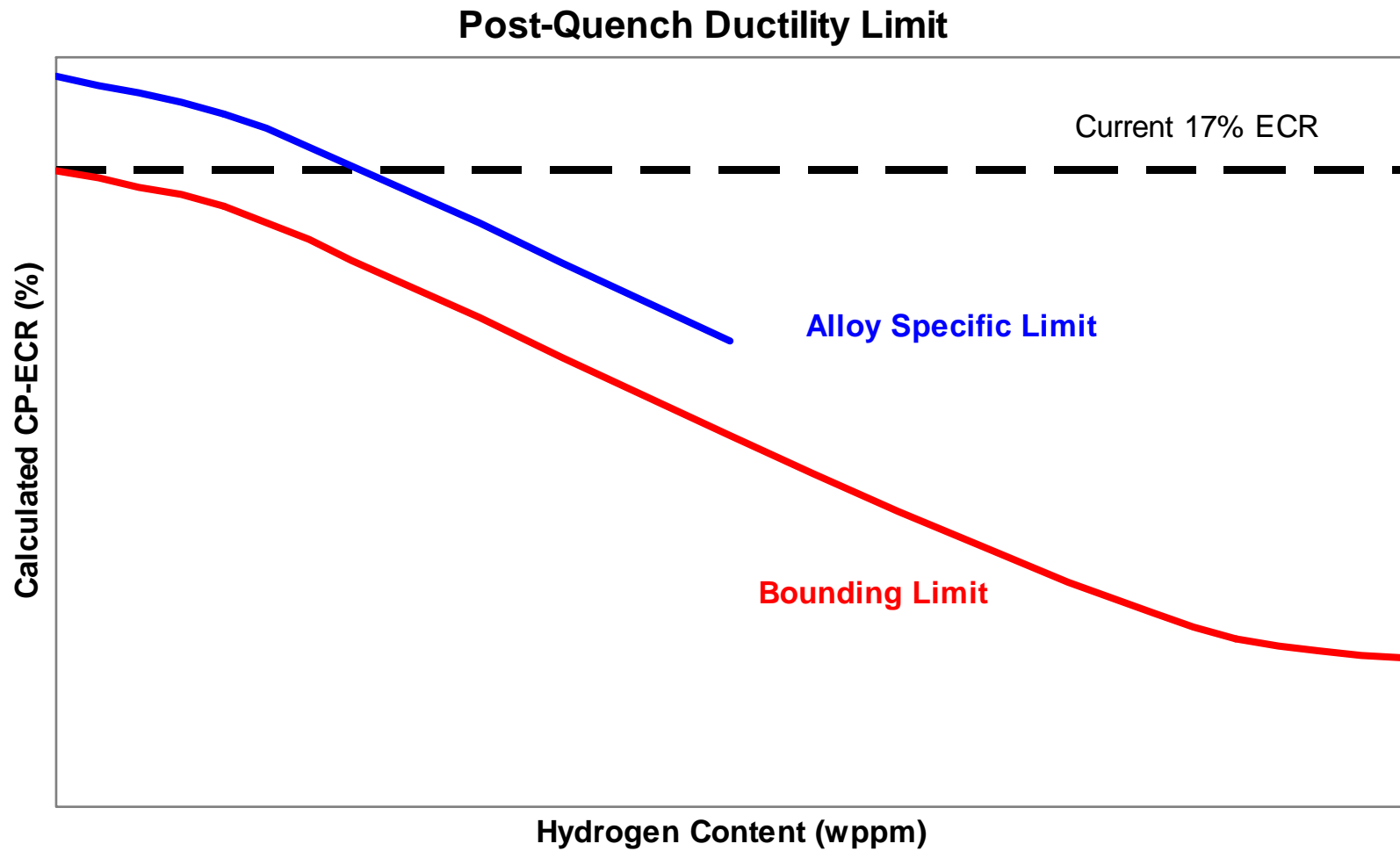
- Performance-based test program required for current cladding alloys.
 - Periodic testing captured within manufacturing QC procedures.
 - Test program captured within manufacturing change process.
- Performance-based test program required for future cladding alloys or alloy-specific limits.
- Testing for PQD and break-away.

Post-Quench Ductility

Post-Quench Ductility Limit

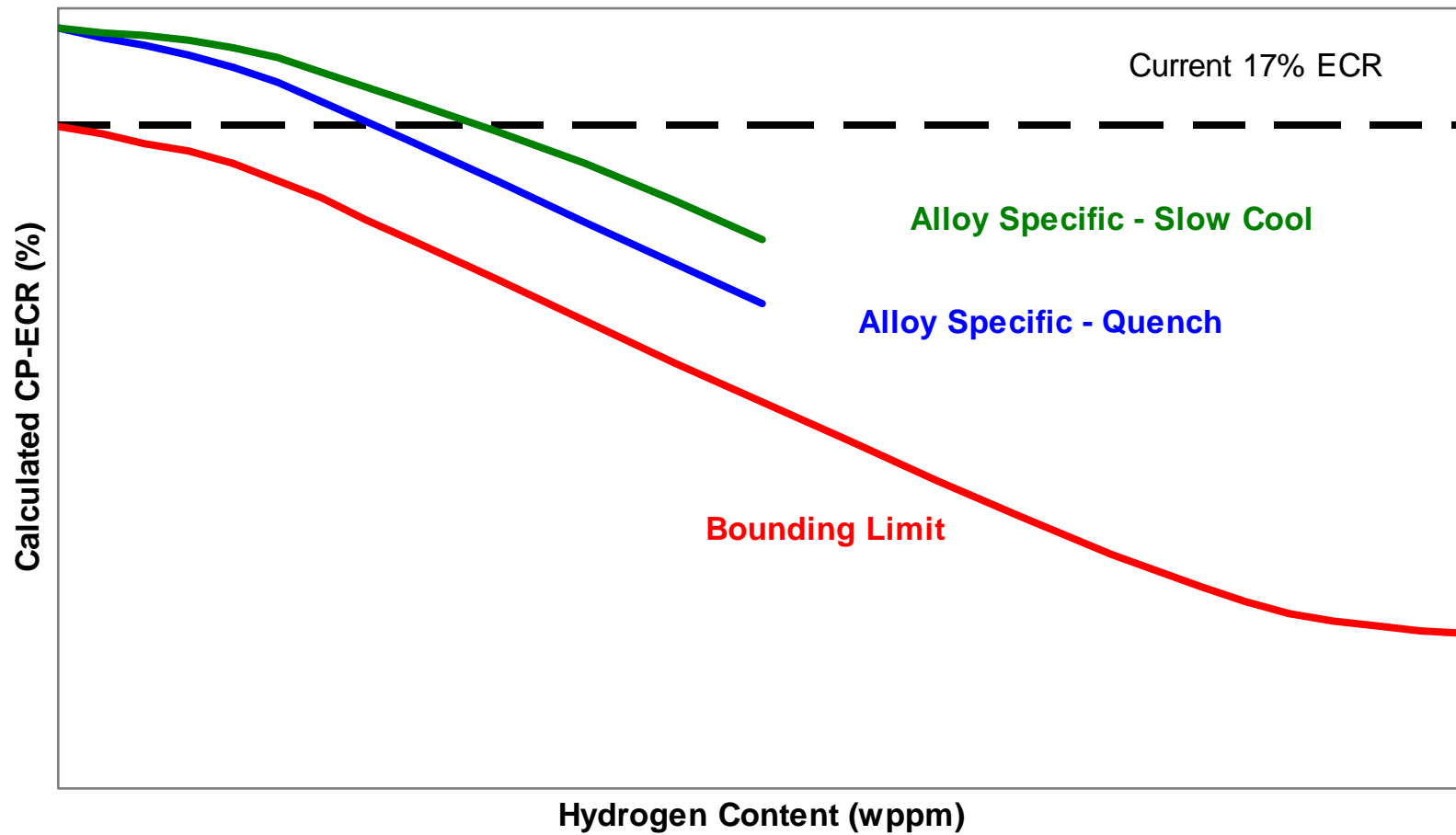


Alloy Specific PQD



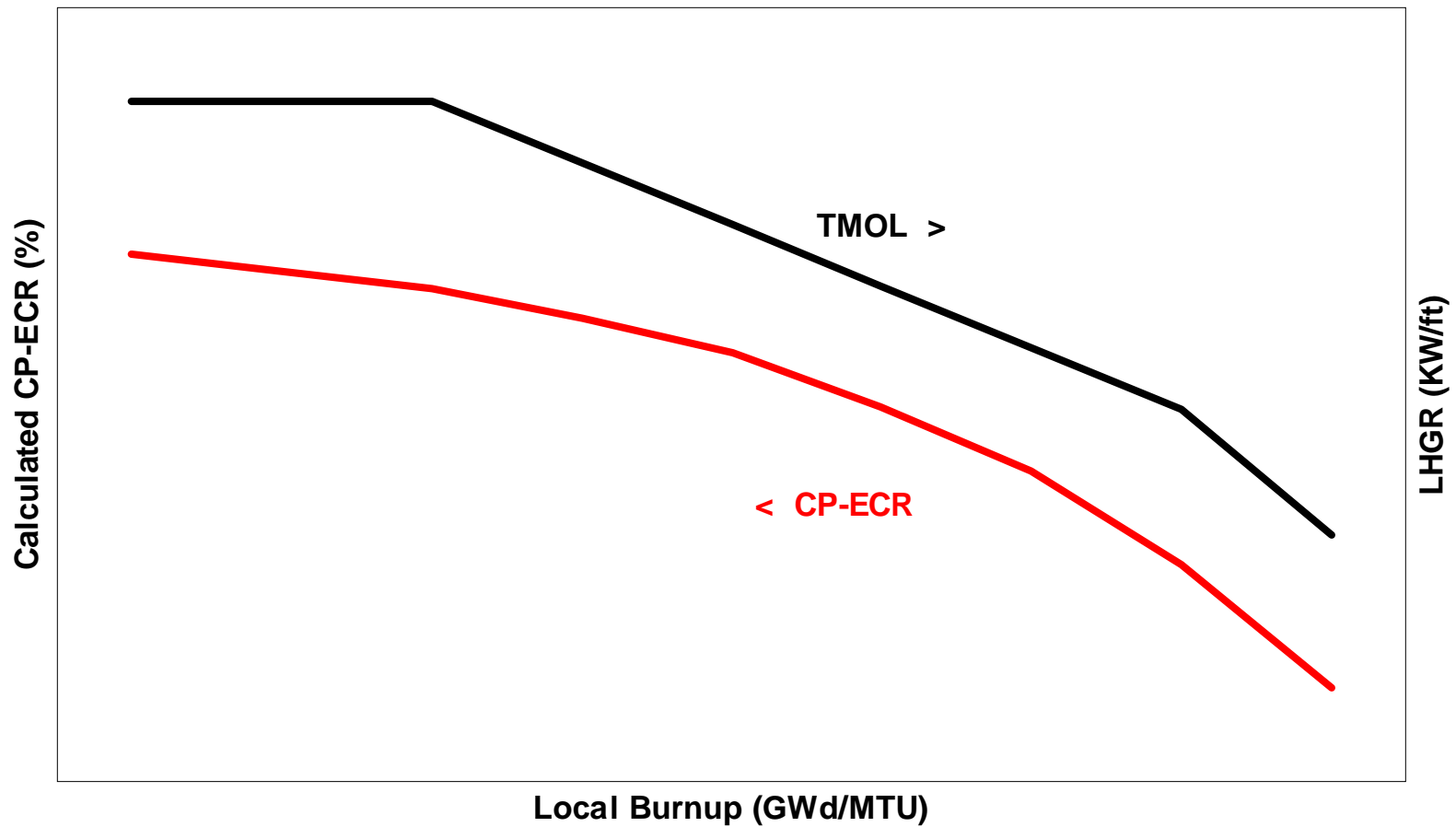
Cool-Down Dependent PQD

Post-Quench Ductility Limit



Implementation

ECR vs Rod Power





NRR Activities

- **50.46(b) Rulemaking Schedule***

2008:

- Technical basis for rule changes
- 1st public workshop
- Draft rule language

2009:

- NRC interoffice review
- 2nd public workshop
- ACRS review
- Proposed rule to Commission

2010:

- Proposed rule published in Federal Register
- Resolve public comments
- 3rd public workshop
- Complete final rule package
- ACRS review
- Final rule to Commission

* Calendar year, subject to change.