Elements of Prospective Information Request: Potential Embrittlement of Fuel Rods During Postulated Loss-of-Coolant Accidents

NOTE: The following is presented for informational purposes only and is intended to facilitate discussion at a public workshop scheduled for April 28-29, 2010. No information is being requested by this document, and no responses are necessary. The NRC is not soliciting formal public comments and is under no obligation to respond to any comments submitted at this time. Public comments may be provided if the NRC decides to publish this information in the *Federal Register*.

REASON FOR INFORMATION REQUEST

The U.S. Nuclear Regulatory Commission's (NRC) loss-of-coolant accident (LOCA) research program identified new cladding embrittlement mechanisms which demonstrated that, under certain circumstances, the current emergency core cooling system (ECCS) performance requirements specified in Title 10 of the *Code of Federal Regulations* (10 CFR) 50.46(b) may not always be sufficient to ensure an acceptable level of fuel rod cladding post-quench ductility (PQD). Adequate PQD is necessary to assure that fuel and clad damage does not interfere with continued effective core cooling following a LOCA as required by 10 CFR Part 50, Appendix A, General Design Criterion (GDC) 35 (or equivalent plant-specific design criterion).

Licensees may be asked to confirm that these circumstances do not exist at their facilities. The circumstances, as discussed above, include fuel management schemes with fuel rods operating at high power levels with significant amounts of absorbed hydrogen in their cladding, or fuel rods with a cladding alloy or surface finish susceptible to early breakaway oxidation.

As indicated in a recent Advance Notice of Proposed Rulemaking (ANPR), dated August 13, 2009 (74 FR 40765), the NRC is considering revising the current 10 CFR 50.46(b) ECCS acceptance criteria to capture the research findings. This rulemaking campaign is likely to take several years to finalize and implement across the fleet. In the interim, the NRC is pursuing an information request which would provide detailed plant-specific information (relative to the research data) necessary to confirm safe operation or inform further action.

ADDRESSEES

All holders of an operating license or construction permit for a nuclear power reactor, except those who have ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

PURPOSE

The purpose of this correspondence would be to:

(1) Request that addressees evaluate their facilities in light of the research data and, if appropriate, take additional actions.

(2) Request that addressees review current fuel management schemes and ECCS performance and inform the Commission whether or not any fuel rods are susceptible to embrittlement following a LOCA when evaluated against the research data.

(3) Require that addressees submit a written response to the NRC in accordance with NRC regulations in 10 CFR Section 50.54(f).

REQUESTED INFORMATION

In accordance with 10 CFR 50.54(f), all addressees would be requested to provide the results of an assessment of their current fuel management schemes and ECCS performance and inform the Commission whether or not any fuel rods are susceptible to embrittlement following a LOCA when evaluated against the research data and information provided below. Addressees should consider the following items when performing the assessment.

<u>Post Quench Ductility</u>:

(1) The PQD results shown in Figure 1 (plotted as allowable CP-ECR [Cathcart-Pawel equivalent cladding reacted] and PCT [peak cladding temperature] as a function of hydrogen content in cladding metal) serve as an acceptable evaluation standard for the purposes of conducting the assessment. Examination of this figure reveals that calculated PCT is limited to 2050 °F above 400 wppm hydrogen.

(2) For accurate comparison to the research data, local oxidation calculations must be performed using the CP correlation (unless otherwise justified). Exothermic reaction rates for heat balance should be performed using current correlations (e.g., BJ [Baker-Just] or CP).

(3) It is unnecessary to subtract pre-existing corrosion thickness, as documented in Information Notice 98-29.

(4) An alloy-specific cladding hydrogen uptake model will be required to utilize the hydrogen dependent PQD embrittlement threshold shown in Figure 1. For the application of Figure 1 to an individual fuel rod (or fuel rod grouping), the allowable CP-ECR should be based on predicted peak circumferential average hydrogen content for the individual rod (or fuel rod grouping).

   a. Hydrogen measurements may be used to distinguish hydrogen present in the base metal from hydrogen present in the oxide layer and adjust uptake models. In the absence of such data, all of the hydrogen should be assumed to reside in the metal.

b. A plot of predicted versus measured cladding hydrogen content should be included in the response.

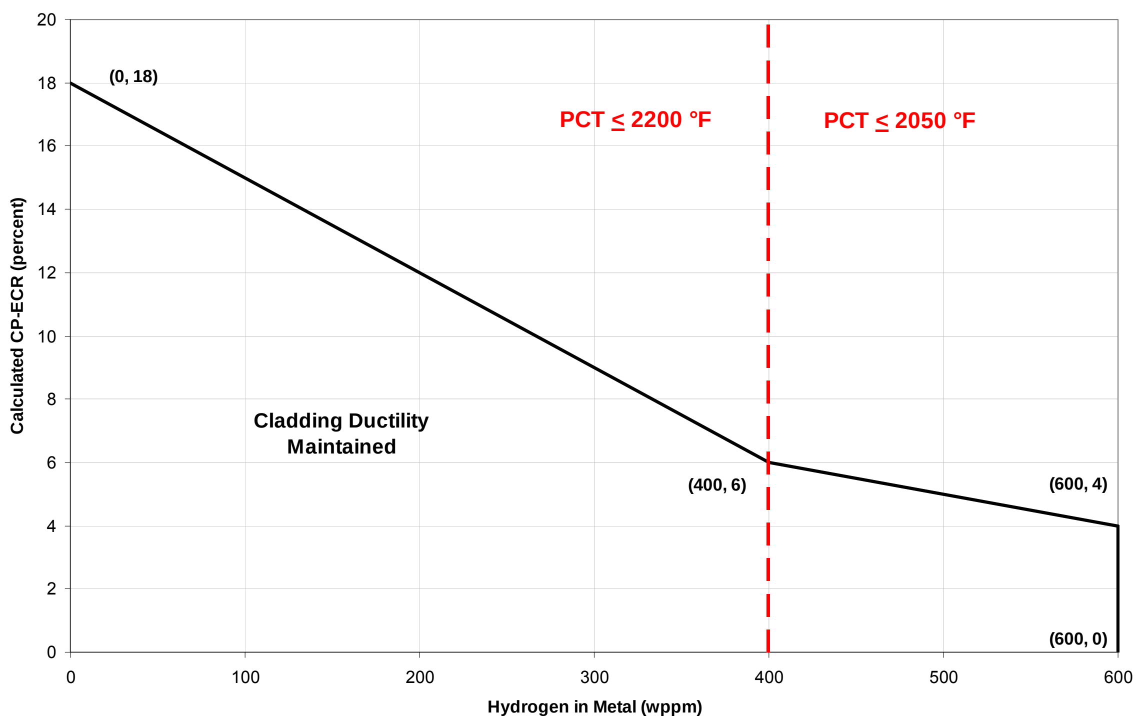
(5) For fuel rods with a local (nodal) exposure beyond 45 GWd/MTU, the inside surfaces of the cladding should be included in the oxidation calculation (i.e., double-sided CP-ECR). No heat addition from the exothermic metal-water reaction on the inside surfaces of the cladding needs to be considered away from the burst node.

(6) Credit may be taken for rod power histories based on core reload depletions or established thermal-mechanical rod power operating limits.

(7) If applicable, provide an estimate of the number of fuel rods which are predicted to exceed the empirical ductile-to-brittle transition depicted in Figure 1. Include a description of the operating conditions under which these rods exceed the transition (e.g., linear heat generation rate, rod burnup, cladding corrosion).

(8) Any departure from currently approved LOCA models and methods (excluding the considerations described above) should be justified.

FIGURE 1: Ductile-to-Brittle Transition Oxidation Level



Breakaway Oxidation:

(1) For the purposes of conducting the assessment, provide evidence that no LOCA scenario results in calculated cladding temperature above the cladding alloy's as-fabricated $\alpha \rightarrow \alpha + \beta$ transition temperature for longer than the measured breakaway time listed in Table 1. For cladding alloys not listed in Table 1, use a breakaway time of 3,000 seconds.

(2) Reasonable operator actions may be credited in this assessment to limit duration at elevated temperatures. Any operator actions must be in accordance with existing emergency operating procedures.

(3) Any departure from currently approved LOCA models and methods (excluding the considerations described above) should be justified.

(4) Table 1 provides measured breakaway times on specific lots of domestic cladding alloys. Discuss any steps taken in fuel quality control, receipt, or inspection programs to ensure that future batches behave in a similar manner. Specifically, discuss any procedures adopted to evaluate changes (either planned or unintentional) in cladding composition or fabrication which could affect breakaway susceptibility.

TABLE 1: ANL Breakaway Test Results

Alloy	Measured Breakaway Time
Zircaloy-2	> 5000 seconds
Zircaloy-4	3800 seconds
ZIRLO™	3000 seconds
M5	> 4100 seconds