Risk-Informed Revision of ECCS Evaluation Model Requirements (Appendix K)

Public Meeting with Stakeholders

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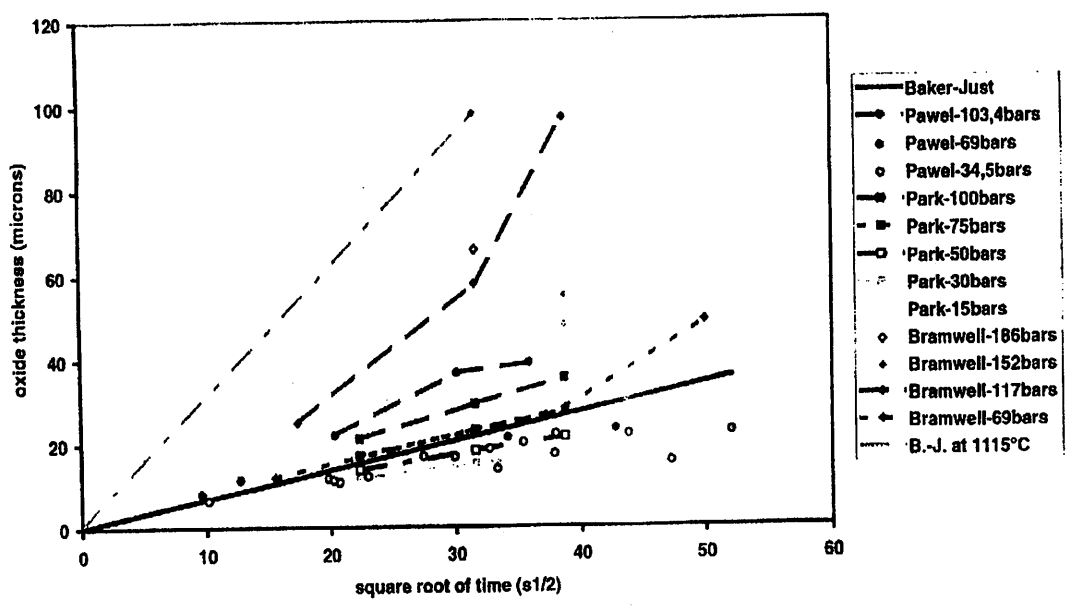
Appendix K Modeling Requirements
Metal-Reaction Heat Release

- Original rulemaking assumed Baker-Just was conservative at 2000 ^{0}F, but was approximately correct at 2200 ^{0}F.
- Baker-Just equation based on pure Zr data - not alloys. Review of more recent data covering several different Zr based alloys shows low experimental data scatter and good agreement with Cathcart-Pawel.
- All Zr-based alloys exhibit about the same oxidation kinetics. Reason: Dominant rate-controlling step at high temperatures is diffusion of oxygen through ZrO_2 surface layer.

Recommendation:

The Baker-Just correlation for exothermic heat release can be replaced with the Cathcart-Pawel correlation or suitable realistic correlation shown applicable to a specific alloy. An adjustment to Cathcart-Pawel or other correlation is necessary if used at high pressure.



- **Experimental data however, exhibits enhanced oxidation rates at high pressure. Cathcart-Pawel correlation is non-conservative for heat release at high pressure.**

Appendix K Modeling Requirements
Steam Cooling Below 1 inch/sec

- **Paragraph I.D.5.b. of Appendix K states that:**

"During refill and during reflood when reflood rates are less than one inch per second, heat transfer calculations shall be based on the assumption that cooling is only by steam, ...

- **Experimental data from FLECHT series of tests demonstrated high rates of entrainment & carryover, even for VIN < 1 ips.**

Recommendation:

Delete the requirement for steam cooling only at reflood rates below 1 inch/sec.

Appendix K Modeling Requirements
Return to Nucleate Boiling During Blowdown

- Paragraph I.C.4.e. in Appendix K prohibits the return to nucleate boiling heat transfer even if the fluid and surface conditions apparently justify the return.

- Rewet during blowdown supported by LOFT experiments. However, overall database demonstrating blowdown rewet is sparse for Zr cladding and Tmin can be predicted only with very high uncertainty.

Recommendation:

Retain the prohibition on assuming a return to nucleate boiling during blowdown.

Appendix K "Non-Conservatisms"

Sources of potential non-conservatism:

1. **Thermal-hydraulic processes and fuel behavior that have been observed in experimental programs since 1973, but are not specifically addressed by Appendix K.**

2. **Large calculational uncertainties that are on the order of the overall conservatism of the EM. This was a main concern of SECY-86-318, ("Revision of the ECCS Rule Contained in Appendix K and Section 50.46 of 10 CFR Part 50) which recommended that the Appendix K decay heat guidelines <u>not</u> be revised unless model uncertainties were accounted for.**

Non-Conservative Processes Identified:

- **Downcomer Boiling**
- **Reflood ECC (Downcomer) Bypass**
- **Fuel Relocation**

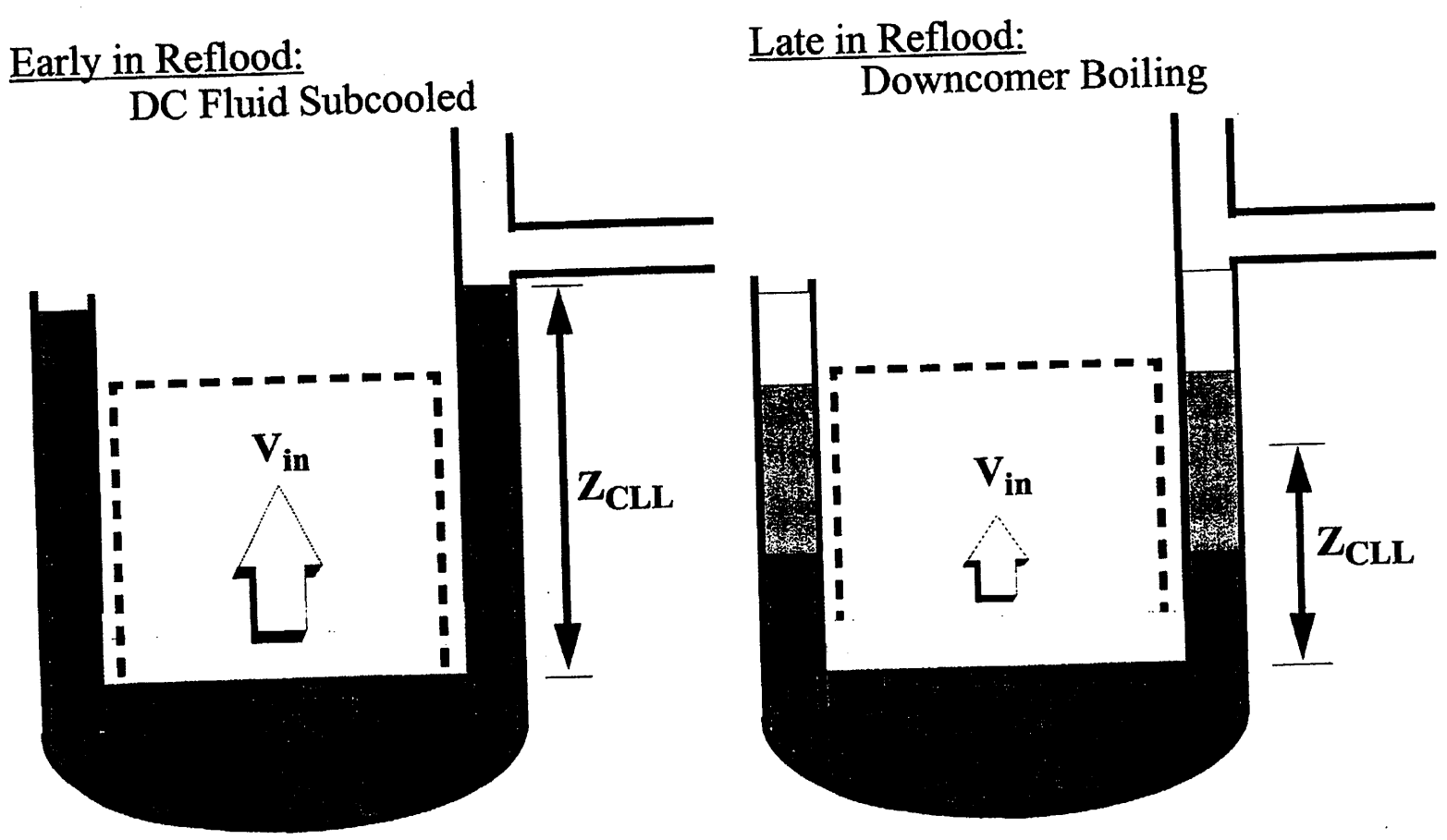
◆ Downcomer Boiling

- Experimental data from several facilities, and simulations using "Best Estimate" thermal-hydraulic codes show that stored heat in vessel walls, core barrel and lower plenum structures can cause coolant in the downcomer to boil during reflood.

- Voiding in the downcomer can result in a significant reduction in downcomer head. This reduces the flooding rate and increases the PCT.

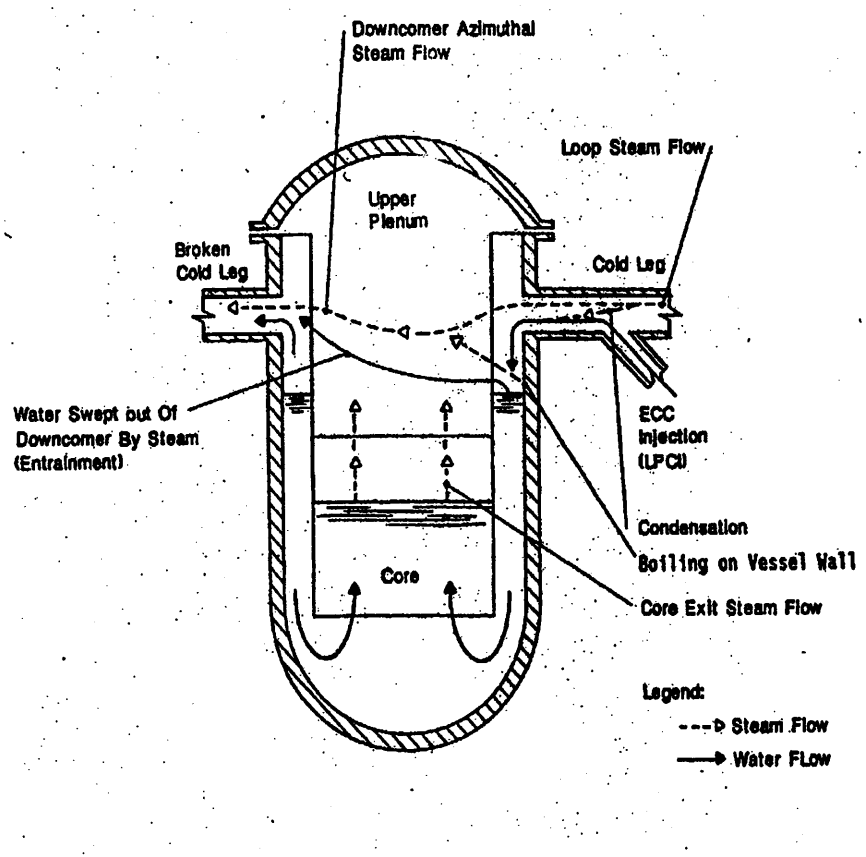
- PWR Appendix K reflood models <u>do not</u> model downcomer boiling. Yet, for at least some plants in all three PWR vendor designs, the existence of downcomer boiling has at least been acknowledged.

DOWNCOMER BOILING



Downcomer Boiling: Causes Net Loss of Driving Head & Reduces Reflood Rate

◆ Reflood ECC (Downcomer) Bypass



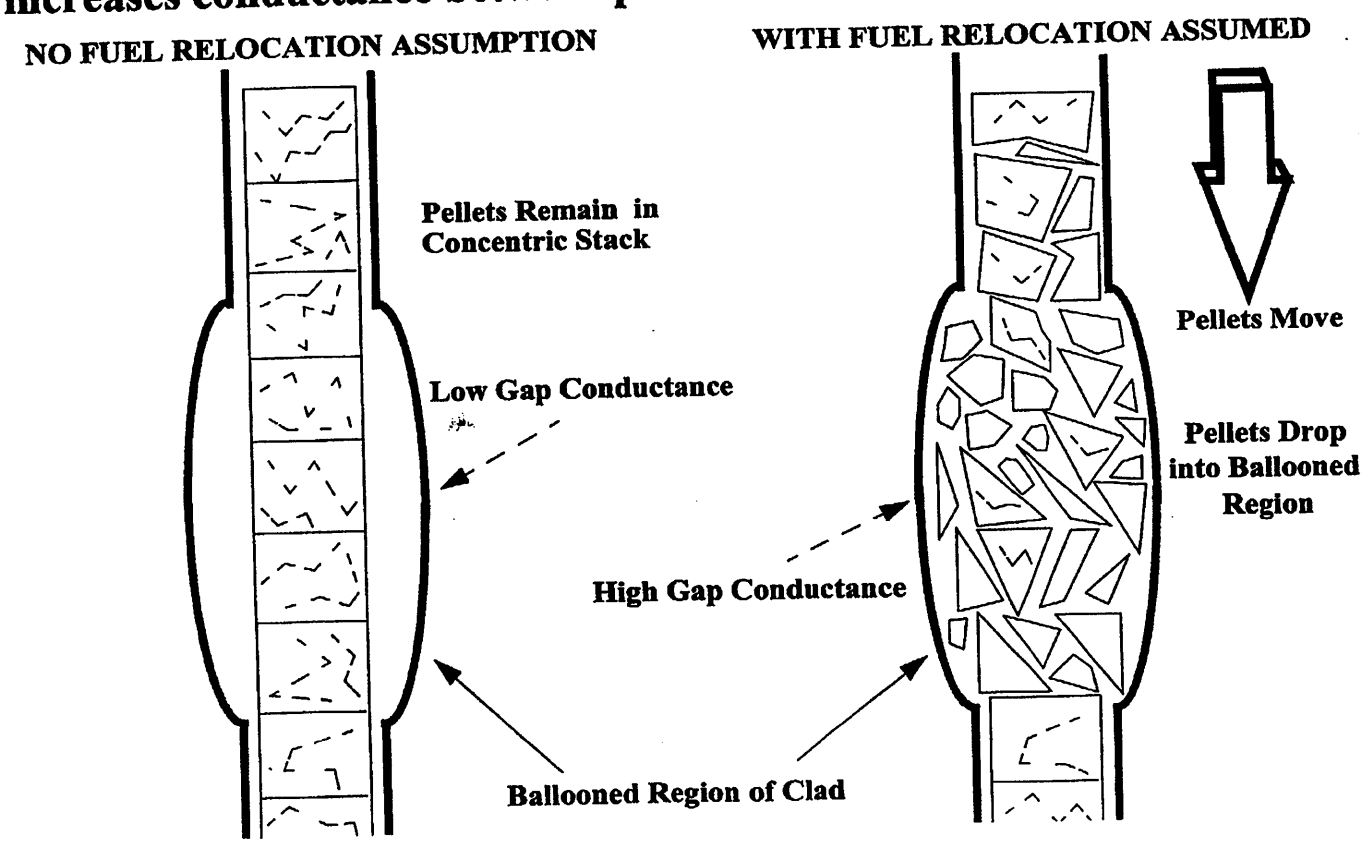
- Experimental tests in the full scale UPTF facility showed that steam from intact loops could entrain significant amounts of water from the downcomer during reflood.

- High entrainment and carryover to the break reduced the downcomer water level and can result in a reduction in downcomer head. This reduces the flooding rate and increases the PCT.

- Process is a strong function of the downcomer water level and oscillations.

◆ Fuel Relocation

- Experiments in PBF-LOC, FR2 (Germany) and FLASH5 (France) showed significant fuel movement in regions where clad has ballooned.
- Relocation of additional fuel into ballooned region increases local power and increases conductance between pellets and clad.



Appendix K "Non-Conservatisms"

Recommendations:

A. Evaluation Models making use of a new, optional Appendix K should account for the non-conservatisms of downcomer boiling, downcomer ECC bypass, and fuel relocation.

B. These new Evaluation Models must demonstrate sufficient overall conservatism in their results.

Conclusions & Recommendations

1. Revise the 10 CFR 50.46 acceptance criteria for PCT and ECR to be "performance-based".
2. Replace 1971 ANS Decay Heat Standard with 1993 Standard
3. Replace the Baker-Just correlation with Cathcart-Pawel for metal-water reaction heat release.
4. Delete the requirement for steam cooling only at reflood rates below 1 inch/sec.
5. Retain the prohibition on assuming a return to nucleate boiling during blowdown.
6. Require that the new Evaluation Models to demonstrate sufficient overall conservatism and that they account for several identified non-conservatisms.