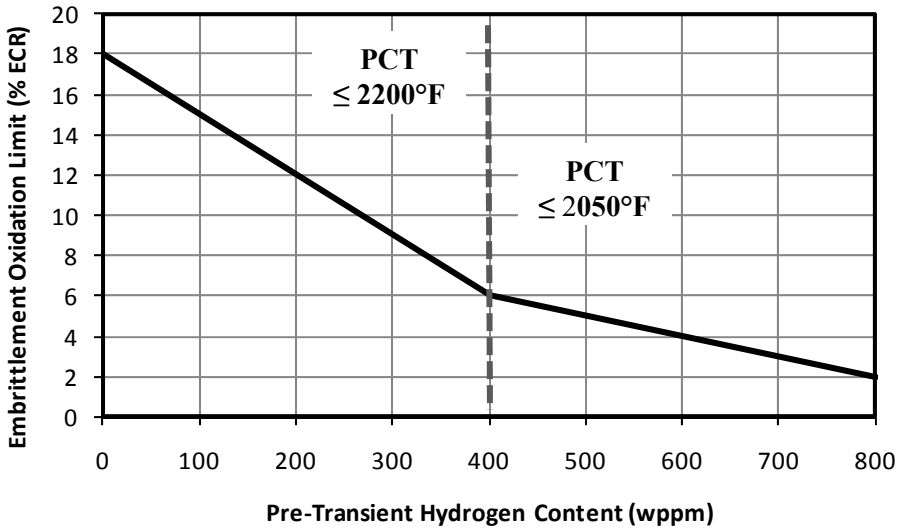
Future Direction and Recap

Figure 2



NRC is considering:

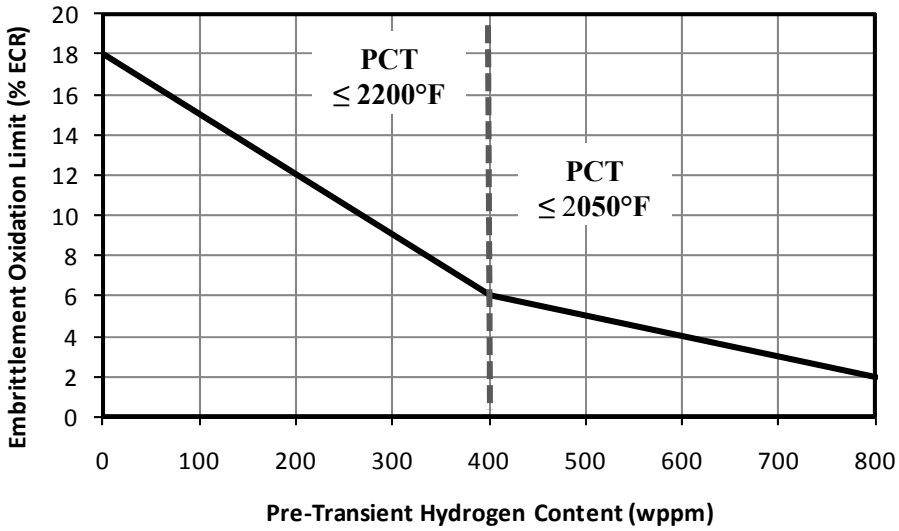
New alloy's that (1) use the same reduction method, (2) operate less than or equal to the maximum fluence, (3) include only the alloying elements present in the materials tested and (4) have similar alloying content of each element to the materials tested, then a reduced level of testing could be considered to adopt figure 2.

- As-received (AR) material
- Reduce pre-hydrided testing to only 2 [H] levels
- Eliminate testing of irradiated material

Default definition of "similar" as 10% deviation from alloying limits defined for tested alloy

Alternative definitions of "similar" can be proposed and reviewed

Figure 2



Alternatives proposed in comments and during discussion:

- Alloys that fall in the above range can use Figure 2 without testing
- Total alloying content <2.2% can use Figure 2 without testing
- Testing of an alloy used to develop Figure 2 in combination of a new alloy, showing similar behavior to the tested alloy, should be acceptable to adopt Figure 2.

Breakaway Oxidation

- The objective of periodic testing would be to confirm that the breakaway oxidation results provided when a cladding alloy is first reviewed and approved remain valid over the production life-cycle of that alloy.
- Vendors would submit breakaway oxidation test programs to the NRC for review and approval. These proposals can include a frequency and sampling population that deviates from the default included in the guidance.
- A default value would be provided, possibly mirroring an ASTM spec
- The key subject for review and approval of a vendor test program would be the demonstration that the frequency of confirmatory testing is sufficient "*to ensure that there is reasonable assurance that fuel is being manufactured consistent with the specified analytical limit*."
- Additions to DG-1263 would provide guidance to address vendor test programs and provide an approach to determine an appropriate test frequency for breakaway oxidation periodic testing.
- A "learning feature" can be built into the testing program

Breakaway Oxidation

Discussion of default frequency and sampling population:

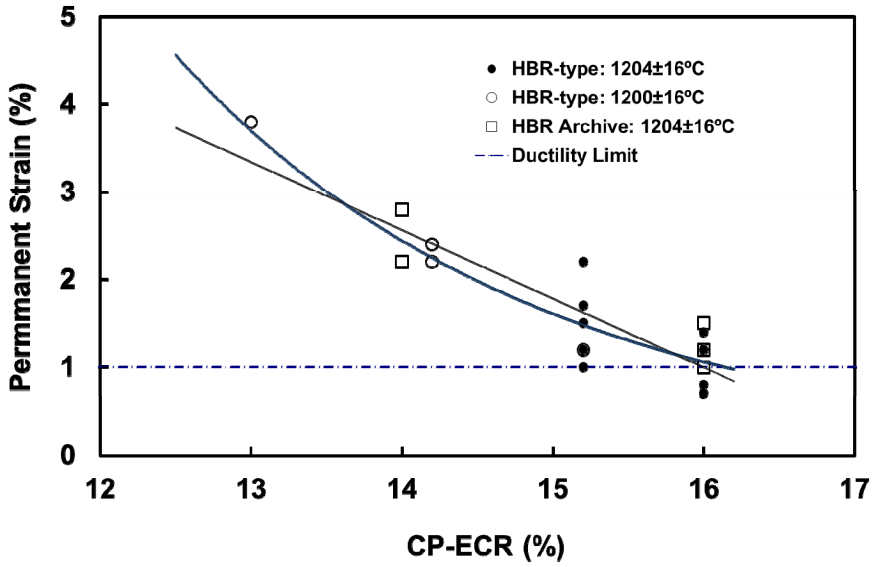
- Regulatory Guidance: Testing once per ingot (three repeat tests at the conditions defined by analytical limit), testing final cladding at the end of cladding manufacturing, accounting for factors that may influence behavior between manufacturing and loading in the reactor (for example, surface effects)

- Vendor activities: Testing of ingots for chemical effects, justification of change control processes to address implications of manufacturing processes on breakaway oxidation behavior.

- Alternative proposals:
  - Single pass/fail test, no repeat testing for periodic testing
  - Minimal requirement to qualify a process, require confirmation when process changes.
    - Challenge: how to define a “process”
  - Use value higher than 650C in the application of the breakaway oxidation analytical limit

DBT from RCT

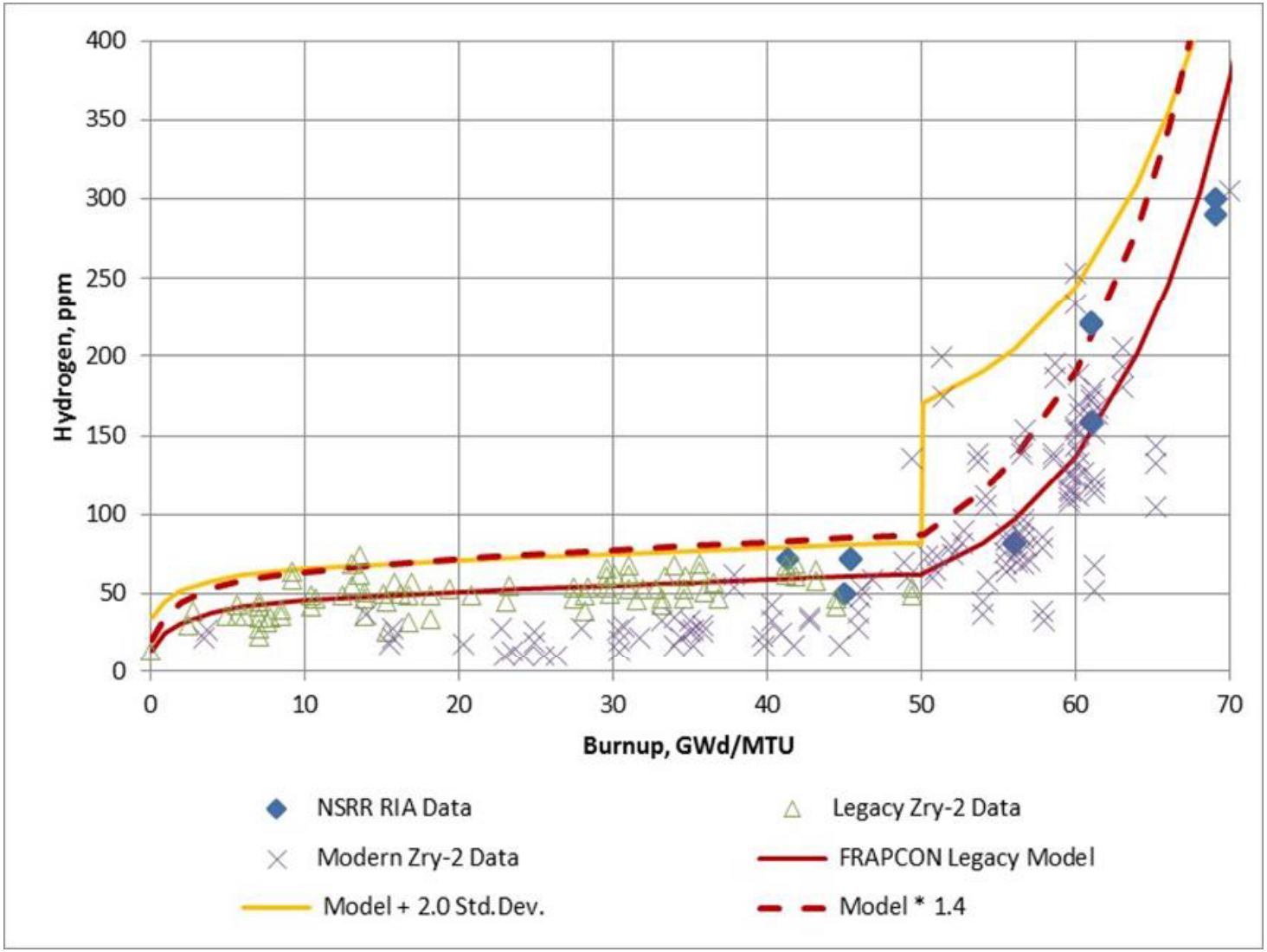
- A line can be drawn through RCT data to interpolate the DBT provided:
  - RCT data is measured above AND below the appropriate ductility criteria
  - RCT data below and above the ductility criteria resulted from tests no more than 1.0% ECR apart
  - The line is drawn through only RCT data with less than 7% offset or 5% permanent strain
  - Intersection ECR should be rounded to the nearest 0.1% ECR
  - Both linear and exponential fits could be used in this range to determine the intersection of the data trend with the ductility criterion
  - The number of repeat tests needed would be correlated with observed data scatter.



DBT from RCT

- If all RCT results from a single oxidation sample are ductile, declare that oxidation level ductile
- If all RCT results from a single oxidation sample are brittle, declare that oxidation level brittle
- If the RCT results from a single oxidation sample include both ductile and brittle results declare that oxidation level transitional
- Alternatively, a proposal for conditions where “brittle” results can be averaged with ductile RCT results from a single oxidation and quench sample. Offset strain values greater than or equal to 2% can be averaged with other ductile results. Permanent strain values greater than or equal to 0.8% can be averaged with other ductile results.
- Values of [H] for each ring should be measured following RCT and noted in the table
- The DBT could be determined as the CP-ECR, rounded to the nearest 0.1%, from interpolation between an oxidation level for which the RCT results were ductile and an oxidation level for which the RCT results were brittle and the CP-ECR values differ by no more that 2.0%.
- Alternatively, the DBT could be determined as the CP-ECR, rounded to the nearest 0.1%, from interpolation between an oxidation level for which the RCT results were ductile and an oxidation level for which the RCT results were transitional and the CP-ECR values differ by no more that 1.0%.
- The number of repeat tests needed would be correlated with observed data scatter.

Hydrogen Pickup models



Hydrogen Pickup models

- Based on the above discussion, the staff finds the following bounding hydrogen pickup fractions acceptable.

Zircaloy-4	= 20% hydrogen absorption
ZIRLO™	= 25% hydrogen absorption
Optimized ZIRLO™	= 25% hydrogen absorption
M5™	= 15% hydrogen absorption

- These hydrogen pickup fractions should be used, along with a best-estimate prediction of the peak oxide thickness using an approved fuel rod thermal-mechanical model, to estimate the cladding hydrogen content.

Hydrogen Pickup models

- Need to define details of "best-estimate prediction of **peak** oxide thickness" - Capture the concept that axial dependent oxide models would be acceptable

- Very recent data indicates potential non-conservatism in proposed Zr-2 model for high HPU data. Default models should account for this recent data.

General Themes / additional points

Ensure requirements and level of effort is commensurate with the impact on public health and safety

Ensure requirements consider the manufacturing process and practices;

Default values are strict, even though it's possible for vendors to support alternatives, how straightforward and transparent will these alternatives be to get approved?

Concern regarding the number of locations where conservatisms are incorporated into models, criterion, approaches, test conditions and techniques. Are these conservatisms compounded to create a highly conservative LOCA criteria.

Ensure that expectations are communicated clearly, have multiple readers confirm consistent interpretation.

Be careful with using terms interchangeably (particularly, oxidation, ECR, CP-ECR, "time at temperature"), need to be clear about use of B-J in Appendix K