Westinghouse/EPRI/NRC
Workshop on Reactivity Initiated Accident

EPRI & NRC Offices
September 22 & 25, 2008

Westinghouse Electric Company LLC
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Monroeville, PA 15146-2886

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Agenda

- New Standard Review Plan Requirements (i.e., Rev 3)
- Technical Aspects
- Implementation of New Criterion Limits
- Health and Safety of the Public

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New Standard Review Plan Requirements (i.e., Rev 3)

Failure Criteria:

- *Zero power conditions: 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 greater than 5% rated thermal power and full power conditions, fuel cladding failure is presumed if local heat flux exceeds thermal design limits (e.g. DNBR and CPR)*

- *PCMI failure criteria is a change in radial average fuel enthalpy greater than the corrosion-dependent limit depicted in Figure B-1 (PWR) and Figure B-2 (BWR)*

New Standard Review Plan Requirements (i.e., Rev 3)

Coolability Criteria:

- *Peak radial average fuel enthalpy must remain below 230 cal/g.*
- *Peak fuel temperature must remain below incipient fuel melting conditions.*
- *Mechanical energy generated as a result of (1) non-molten fuel-to-coolant interaction and (2) fuel rod burst must be addressed with respect to reactor pressure boundary, reactor internals, and fuel assembly structural integrity.*
- *No loss of coolable geometry due to (1) fuel pellet and cladding fragmentation and dispersal and (2) fuel rod ballooning.*

Technical Aspects

Coolability Criteria:

- As indicated in the Technical & Regulatory Basis (Reference 1) for the Interim Criteria, the new coolability criteria are intended to address the prompt critical power excursions (HZP case, where the concern with fuel melt is related to the pellet rim material)

- Application of the "no fuel melt" criterion to the HFP case would be in conflict with the failure criteria, which allows limited fuel melt

- Application of the "no fuel melt" criteria to the HFP case would incorrectly shift the focus from the HZP case to the HFP case

Technical Aspects

Coolability Criteria:

- The basis of limited centerline melt for the HFP case is based on work documented in References 2 & 3 where it was shown that significant fuel centerline melting (i.e., up to 80%) would not be expected to result in fuel failure
- As documented in Reference 2, fuel melting involving up to 80% of the inner fuel pellet radius has been observed in the power-coolant mismatch (PCM) experiments in Idaho without cladding failure (Reference 3)
- The molten fuel remained at the center of the fuel pellet with no significant adverse effects on the fuel rod behavior

Technical Aspects

Coolability Criteria:

- Thus, the second criterion under the Coolability Criteria should be modified to acknowledge the acceptability of limited centerline melting, but no rim melting
- The mechanical energy generation is primarily due to the fact that this is a heat-up event
- Non-molten fuel to coolant interactions or releases of rod internal pressures do not result in any significant system wide pressure transients (i.e., NUREG/CR-0269 and all the new test conducted in CABRI, NSRR, BIGR, show no significant pressure transients until 300 cal/gm energy deposition levels are reached), small localized pressure effects are bounded by seismic/LOCA grid crush requirements

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Technical Aspects

Coolability Criteria:

- Based on the previous facts, the third and fourth criterion under the coolability criteria do not seem relevant or correct
- Final criteria should include results from testing performed at representative operating conditions
- Additional near-term testing results are anticipated

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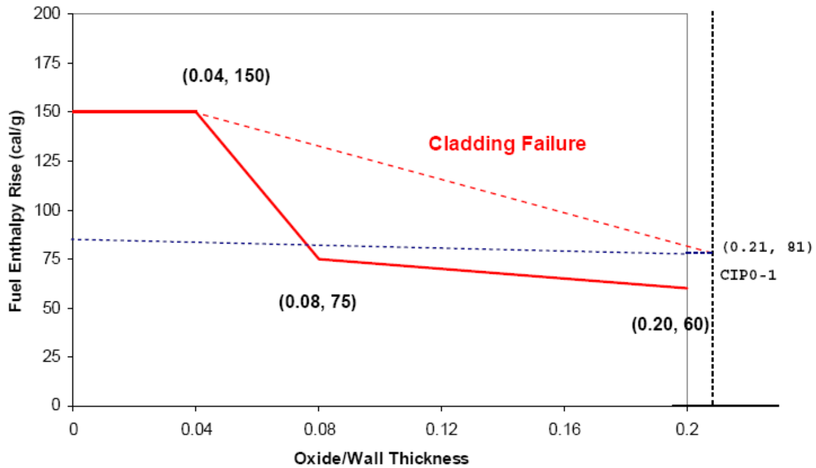
Technical Aspects

Failure Criteria:

- The step change basis in the existing Figure B-1 is based on NSRR cold capsule test that are non-representative of PCMI, at temperature cladding will maintain sufficient ductility as demonstrated by the CIP0-1 CABRI test

- Thus the proposed failure limit in SRP 4.2, Rev 3, Appendix B, Figure B-1 is excessively conservative



CIP0-1:
~ 110 μ corrosion
98 cal/gm deposited or 81 cal/gm enthalpy rise
An oxide/wall ratio of 0.21
No failure!

Implementation of New Criterion Limits

Costs: Monetary and time

- If the “no fuel melting” criterion is applied to the HFP case, each licensee will be paying fairly large $ for 3-D Rod Ejection analyses which would take approximately 6 months to complete depending on workloads

- Based on the new analysis, each licensee would then need to make a submittal to the NRC, which would take a minimum of one year to review by the NRC and again would cost the licensee upwards of $100 K

Regulatory Burden

- Additional Licensing Amendment Request (LAR) competing with COL applications for resources

- Additional cost for each LAR submittal

Health and Safety of the Public

Benefits to the health and safety of the public:

- None. As documented in Reference 1, the NRC "concludes that no real safety concern exists"

Cost to the Public

- Large monetary costs due to unnecessary regulatory reviews

References

1. NRC Memorandum from Ralph Landry to Thomas Martin, “Technical and Regulatory Basis for the Reactivity-Initiated Accident Interim Acceptance Criteria and Guidance,” January 19, 2007.

2. MacDonald, P. E. et al., “Response of Unirradiated and Irradiated PWR Fuel Rods Tested Under Power-Cooling-Mismatch Conditions,” Nuclear Safety, Vol. 19, No. 4, July-August 1978.

3. El-Genk, W. S., “An Assessment of Fuel Melting, Radial Extrusion and Cladding Thermal Failure During a Power-Cooling Mismatch Event in Light Water Reactors,” NUREG/CR-0500, EG&G Idaho Inc, May 1979.

4. Fujishiro, T., Johnson, R., MacDonald, P., McCardell, R., “Light Water Reactor Fuel Response During Reactivity Initiated Accident Experiments,” NUREG/CR-0269, TREE-1237, August 1978.

Backup

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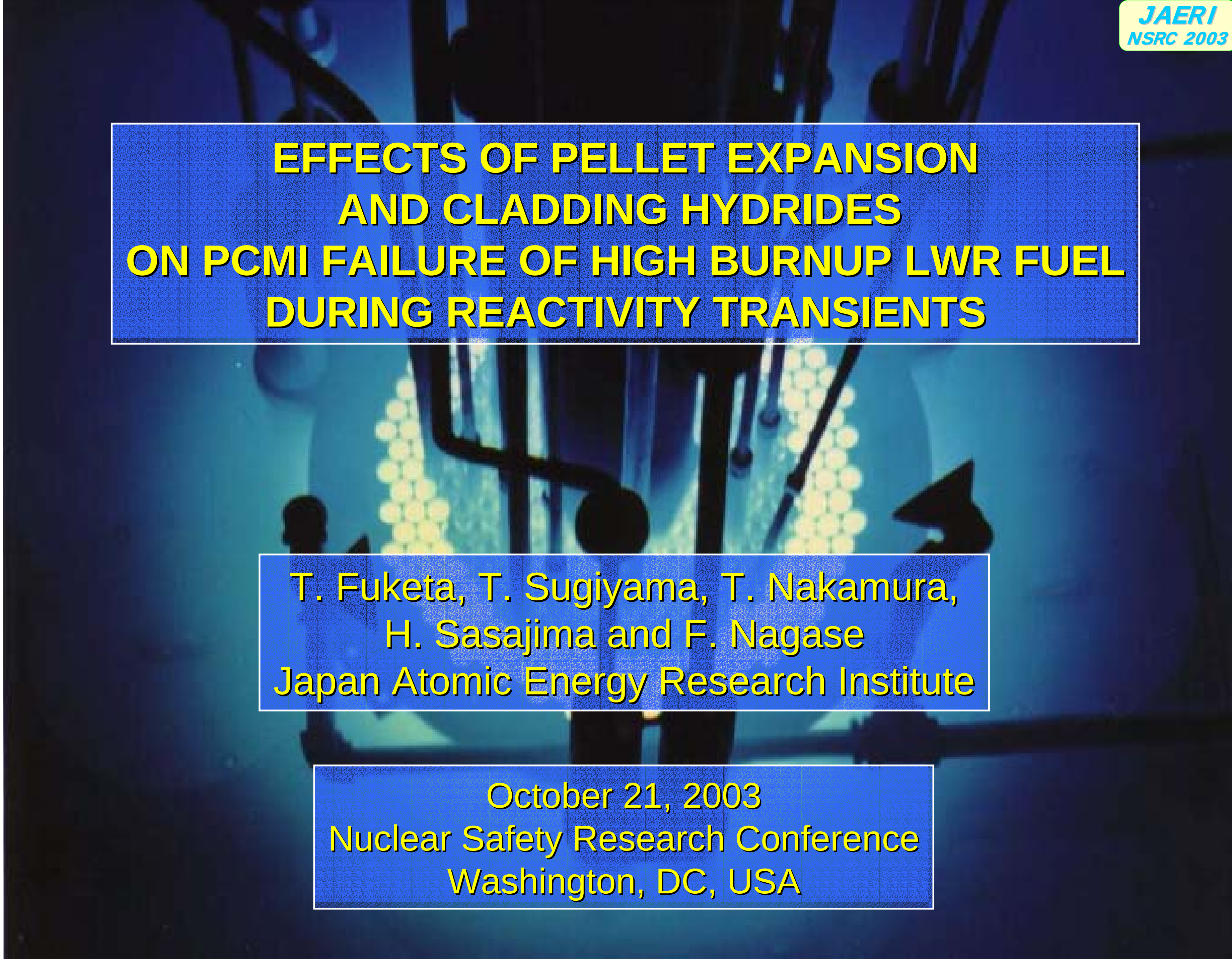
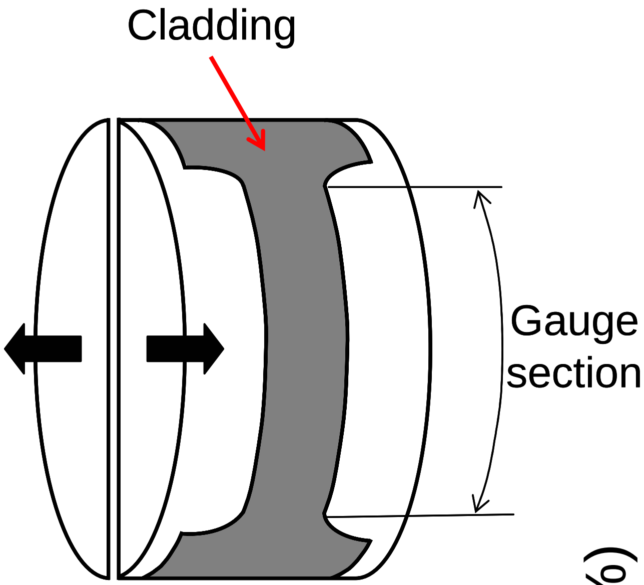


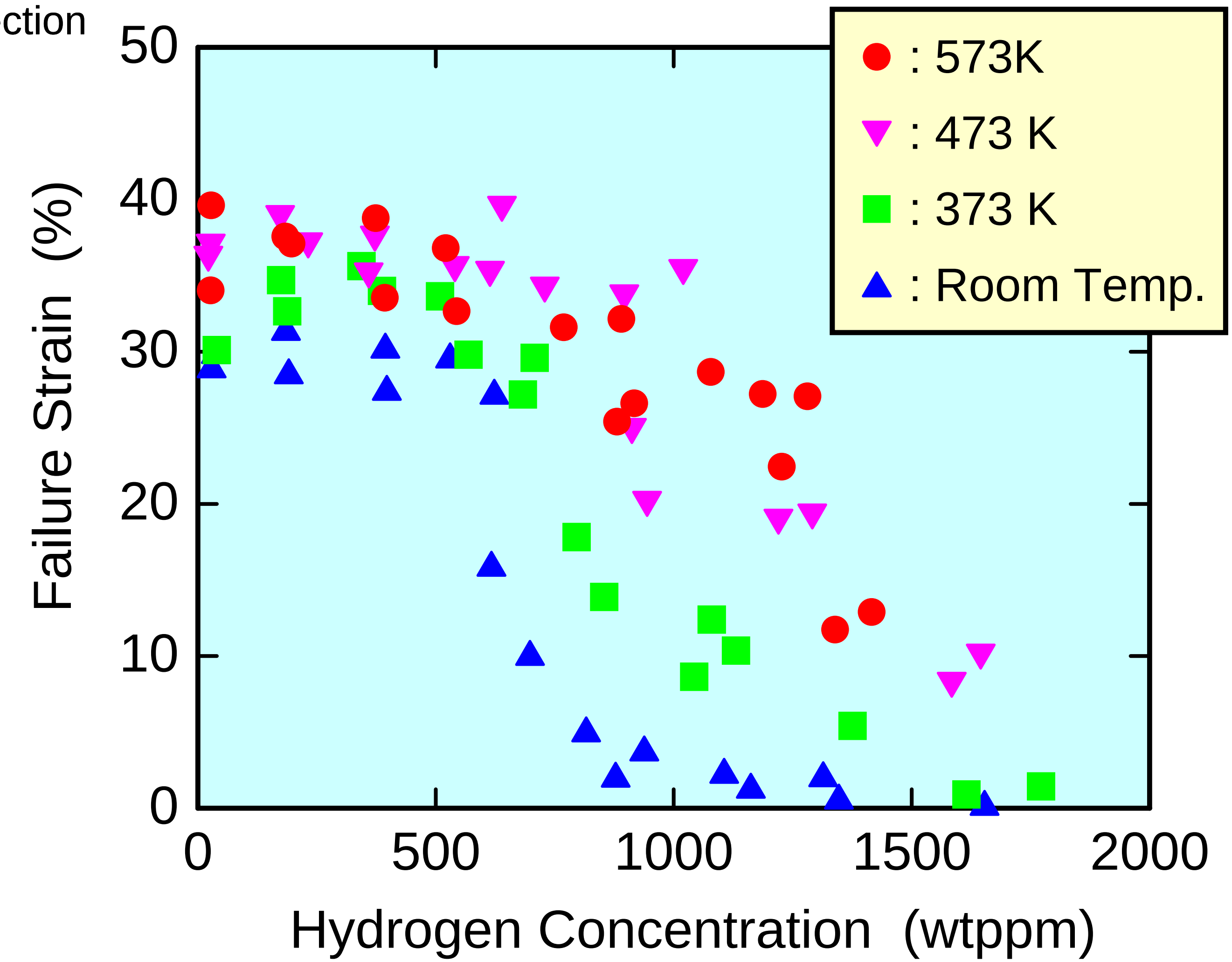
EFFECTS OF PELLET EXPANSION AND CLADDING HYDRIDES ON PCMI FAILURE OF HIGH BURNUP LWR FUEL DURING REACTIVITY TRANSIENTS

T. Fuketa, T. Sugiyama, T. Nakamura,
H. Sasajima and F. Nagase
Japan Atomic Energy Research Institute

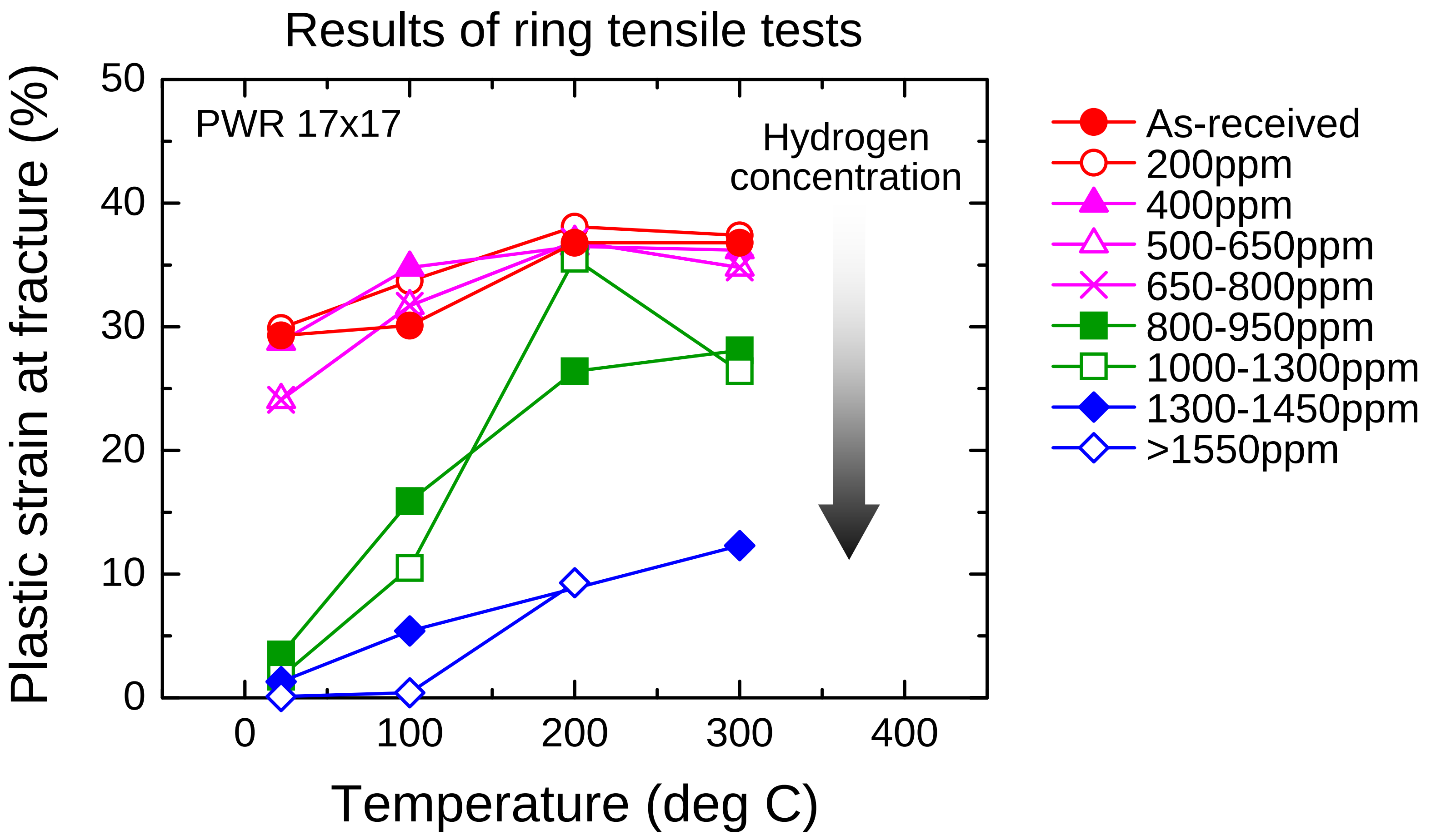
October 21, 2003
Nuclear Safety Research Conference
Washington, DC, USA

Ring Tensile Test





Temperature effect on cladding ductility



- Influence of hydrogen concentration and temperature on the cladding ductility

➢ High-temperature capsule in NSRR experiments