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An Integrated Approach to Closing the Technical Data Gap for High Burnup Spent Fuel Performance during Normal Conditions of Transport (NCI)

IAEA International Conference on Management of Spent Fuel From Nuclear Power Reactors

Ken Sorenson: Sandia National Laboratories
Brady Hanson: Pacific Northwest National Laboratories
Sylvia Saltzstein: Sandia National Laboratories

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Objectives of the US DOE Used Fuel Disposition (UFD) Storage and Transportation R&D Program:

Contribute to:

1. *the technical bases to demonstrate used fuel integrity for extended storage periods*
2. *the technical bases for fuel retrievability and transportation after long term storage*
3. *the technical basis for transportation of high burnup fuel*

Focus of this presentation:

Progress and status on the ability for high burnup spent fuel to maintain its integrity during Normal Conditions of Transport.

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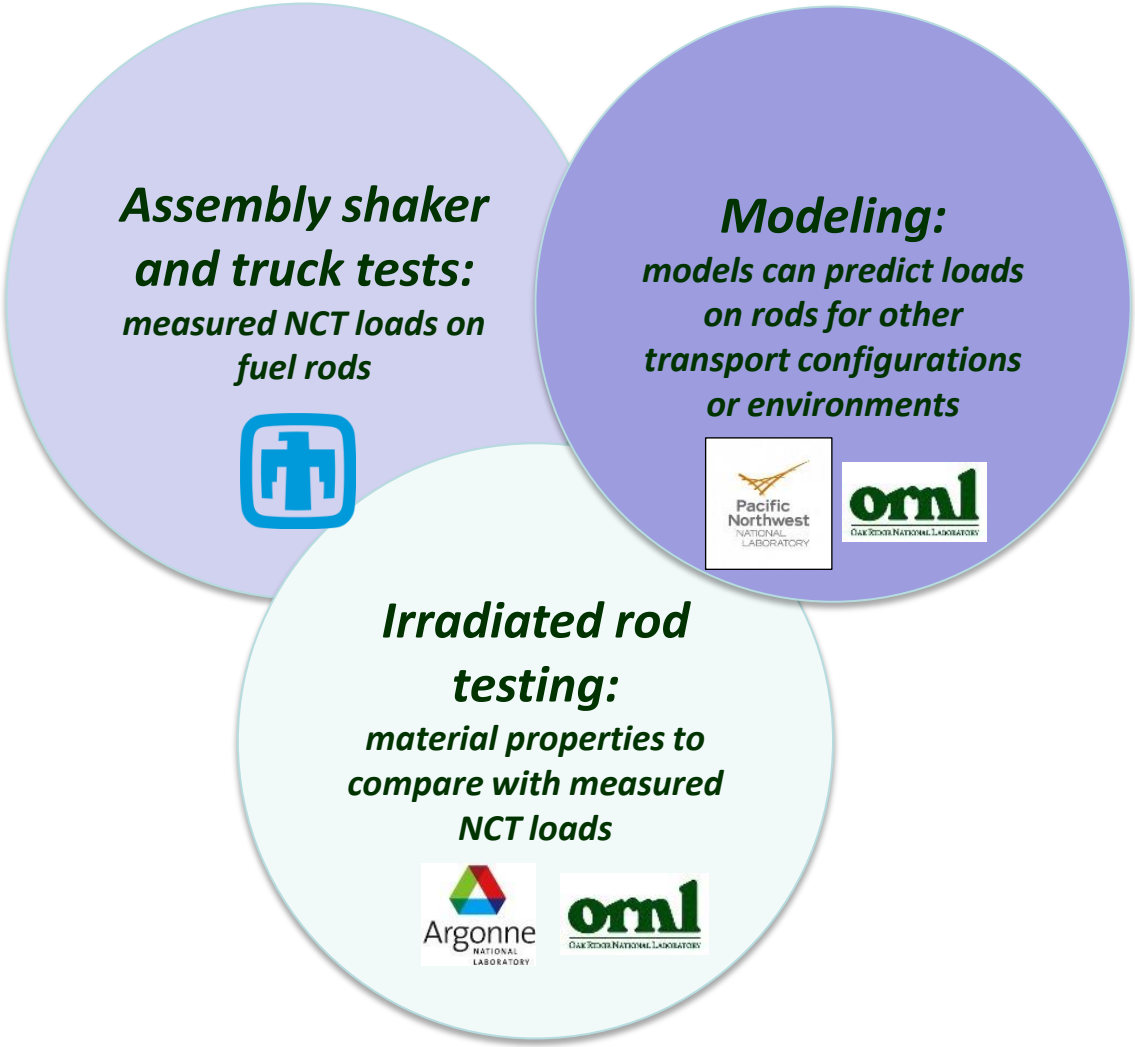
Can high burnup irradiated rods withstand Normal Conditions of Transport (NCT)?



Can high burnup irradiated rods withstand NCT?

Cladding and fuel behavior of high burnup used fuel under NCT loading

Fundamentally: ***applied stress/strain < material strength***

Requires determination of:
- ***Applied loads on the fuel***
- ***Measured strains***
- ***Calculated stresses***

Requires determination of:
- ***Material properties***
  - ***Yield/ultimate strength***
  - ***Ductility***
  - ***Fracture toughness***
- ***Constitutive relationships***
- ***Pellet-clad interaction***

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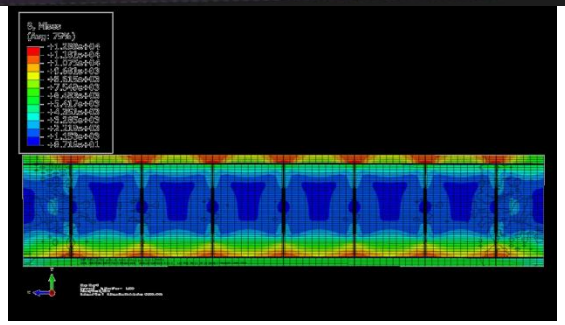
Material properties:

- Cladding and fuel response to cyclic loadings
- Pellet/clad interaction (PCI)

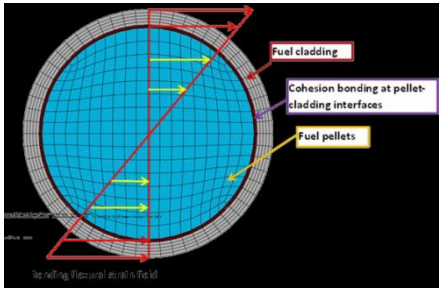
Note: NRC initiated and funded development of test apparatus, procedures and data collecting. Funding for FY14 efforts was shared by NRC and DOE.

Pellet-Clad & Pellet-Pellet Bonding

CIRFT test apparatus developed at ORNL
CIRFT: Cyclic Integrated Reversible-bending Fatigue Tester



In-cell measured displacements and applied moment provides necessary data for strain/stress calculations



Due to PCI, fuel provides structural support to applied load

Jy-An Wang; Oak Ridge National Laboratory, 2014 ASTM C26 Committee Meeting, June 2014

Jy-An Wang; Oak Ridge National Laboratory, WM2014 Conference, March 2014

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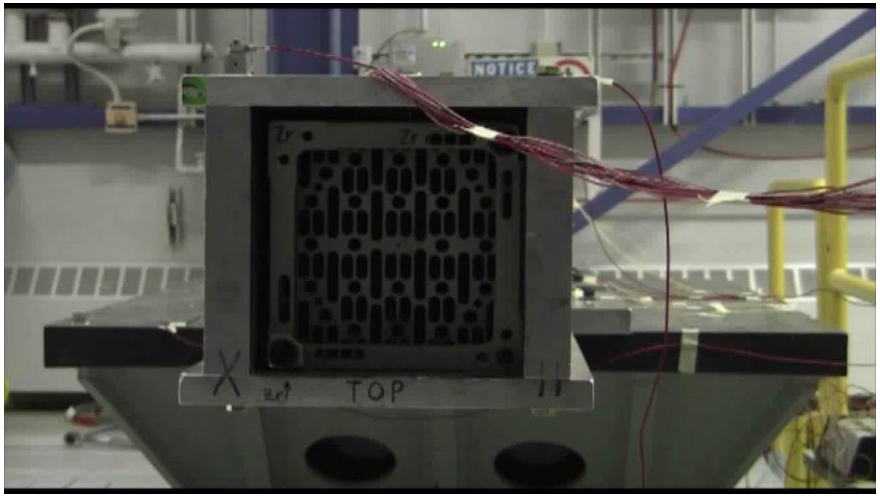
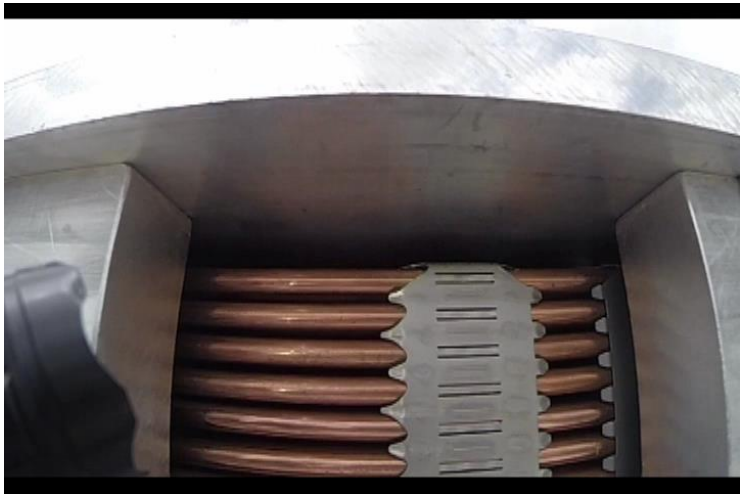
Normal Conditions of Transport: Fuel Assembly Loadings





2013 Shaker Table Test

2014 Over-the-road Test

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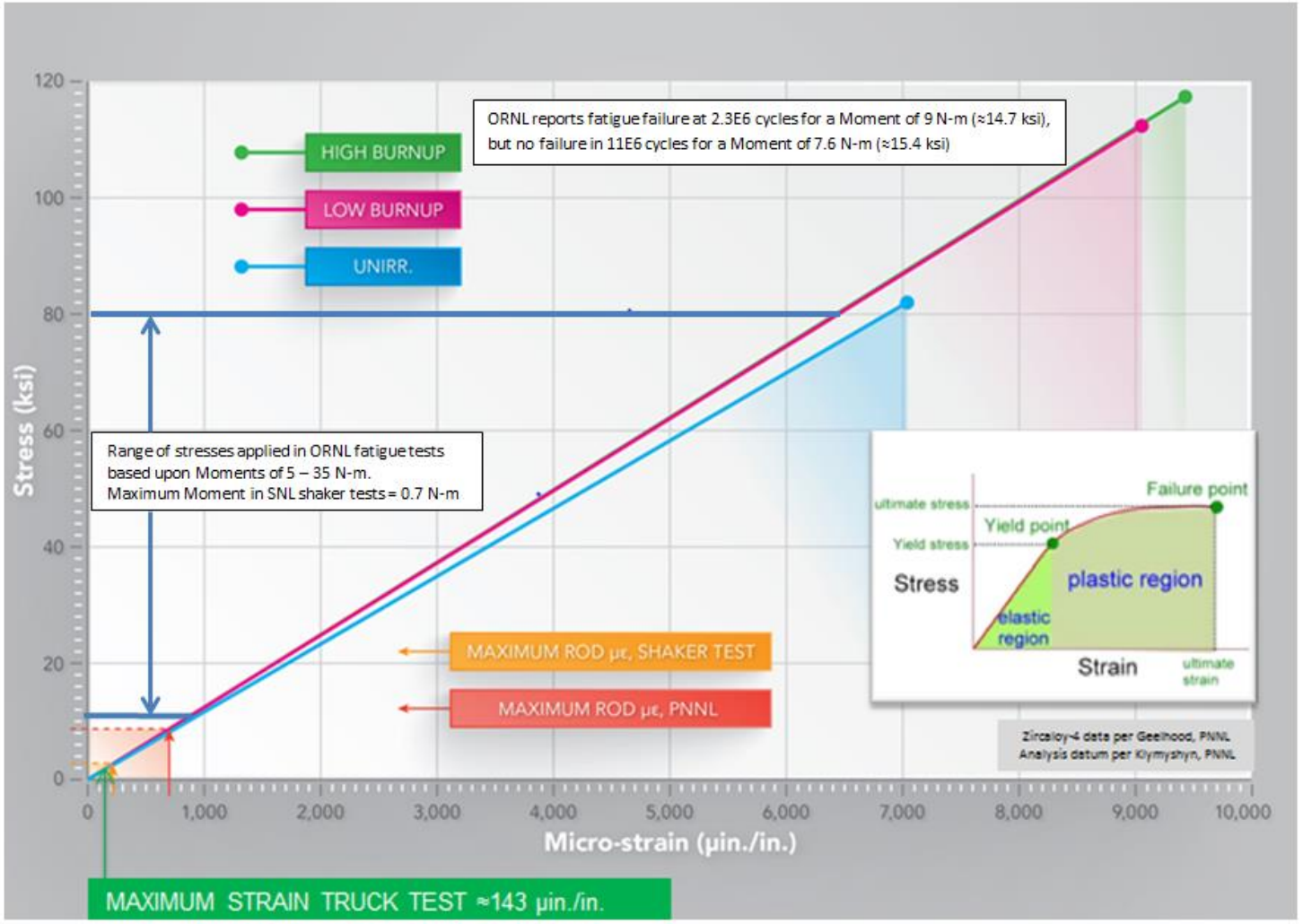
Measured strains very low relative to elastic limit of Zircaloy



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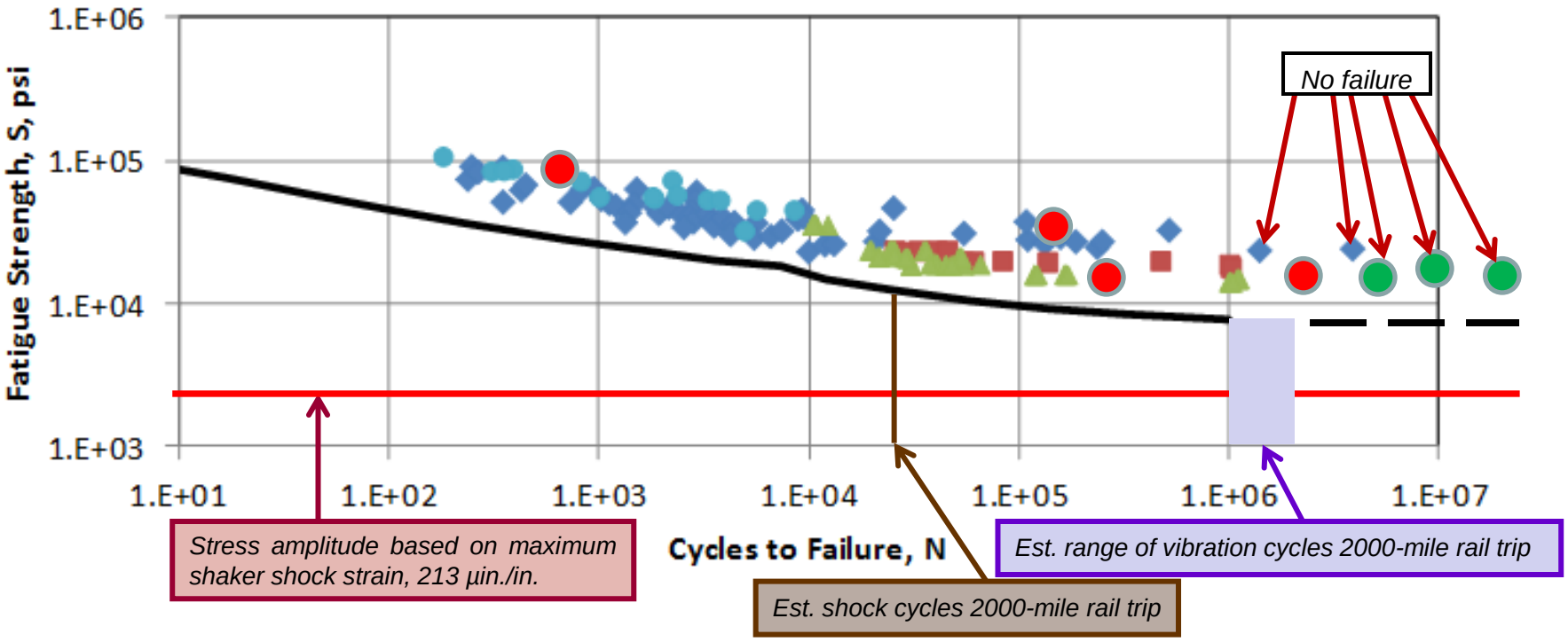
NCT vibrations unlikely to result in fatigue failure



Fatigue design curve (▬): O'Donnel and Langer, "Fatigue Design Basis for Zircaloy Components," Nucl. Sci. Eng. 20, 1, 1964. (cited in NUREG-0800, Chapter 4)

Data plot courtesy of, PNNL
The large circles are courtesy of ORNL

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NCT Conclusions

- **The strains measured on the rods in the surrogate PWR assembly NCT test program were in the micro-strain levels**
- **Strains on irradiated fuel rods during NCT may be less than strains measured on the unirradiated Zircaloy-4**
- **Preliminary investigations suggest that HBU spent fuel will maintain its integrity when subjected to NCT loading conditions**

Anecdotal evidence from transport experience in France:

- More than 75,000 LWR used fuel assemblies transported
  (from France, Japan, Germany, Belgium, Switzerland, the Netherlands, Italy)
- About 7,500 loaded casks with LWR assemblies
- La Hague reprocessing plant has received 15,156 assemblies … with burn-up greater than 45GWd/tU (from EDF).
  [Fuel shipped with relatively short cooling times]
- No assemblies have ever been damaged during transport
- ***Experience and gap analysis on used fuel and dry cask components behaviour in transport and storage***

Herve ISSARD, TN International - ESCP International subcommittee meeting, Tokyo 2014

AREVA TN information EDF website: http://www.edf.com/fichiers/fckeditor/Commun/En_Direct_Centrales/Nucleaire/General/Notes_Info/Note_info_transport_comb._dechets_nucl_082010.pdf

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Conclusions

- Real progress is being made on understanding the response of high burnup spent fuel to Normal Conditions of Transport.

- Given observed loading data, mechanical property data, and rod stiffness response characteristics, there are positive indications that high burnup spent fuel will maintain its integrity during NCT.

- Work is on-going to further address technical issues:
  - The 30-cm drop will be assessed analytically to estimate spent fuel response to this specific condition
  - Consistency and continuity of PCI along the length of the spent fuel rod
  - Assessment of PCI for low burnup fuel