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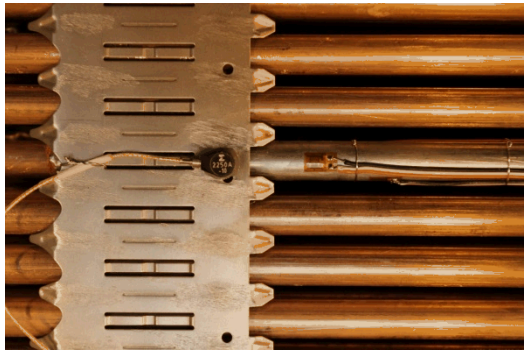


PWR Assembly Tests Simulating Normal Conditions of Transport

BAM/Sandia National Labs Collaboration Meeting

29-30 October 2015

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U.S. DEPARTMENT OF ENERGY | Nuclear Energy

NNSA National Nuclear Security Administration

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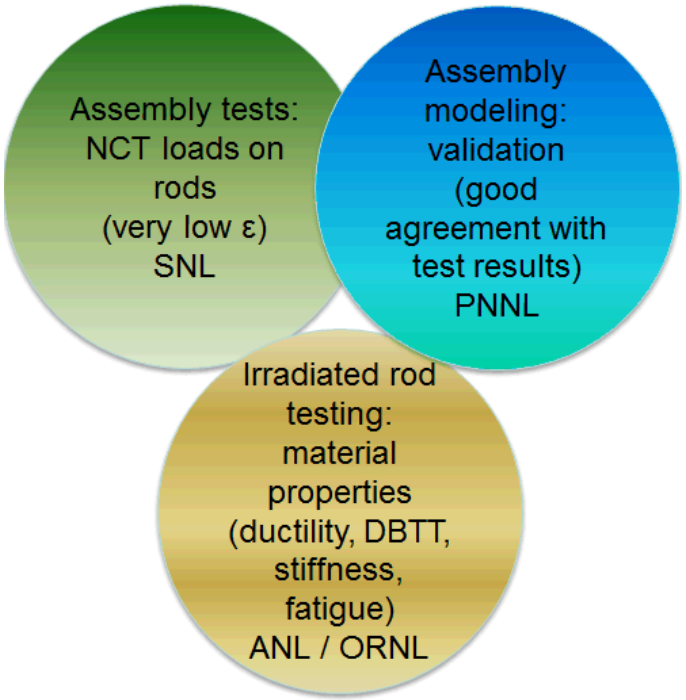
Rationale for Fuel Assembly Testing

- NRC, DOE, and industry concerns regarding transportation of high burnup UNF: Possible failure of rods during Normal Transport
- Until now, there was no data on the strains imposed on UNF ***rods*** during Normal Conditions of Transport
- The assembly tests compliment UFD-funded material property tests of high burnup Zircaloy at ANL and ORNL



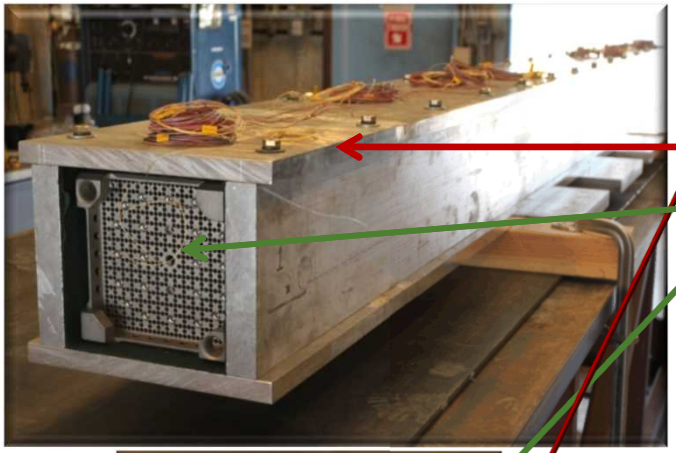
Three Series of Tests were Conducted Using a PWR Assembly

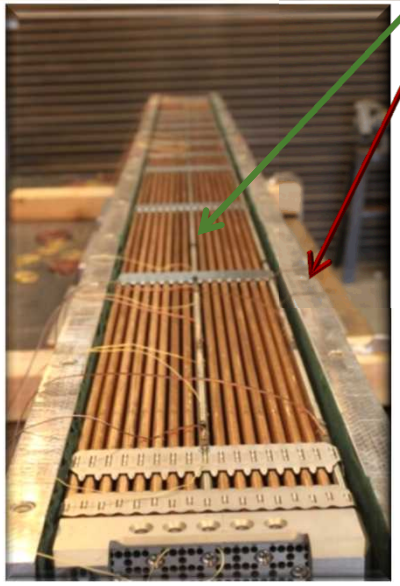
1. Tests on a SNL shaker
   - Vertical accelerations only
   - Truck NCT simulations
2. Over-the-road truck test
3. Test on commercial seismic shaker
   - 6-degrees of motion
   - Rail and truck NCT simulations

Inputs to the shakers simulated Normal Conditions of Truck and Rail Transport (vibrations and shocks).

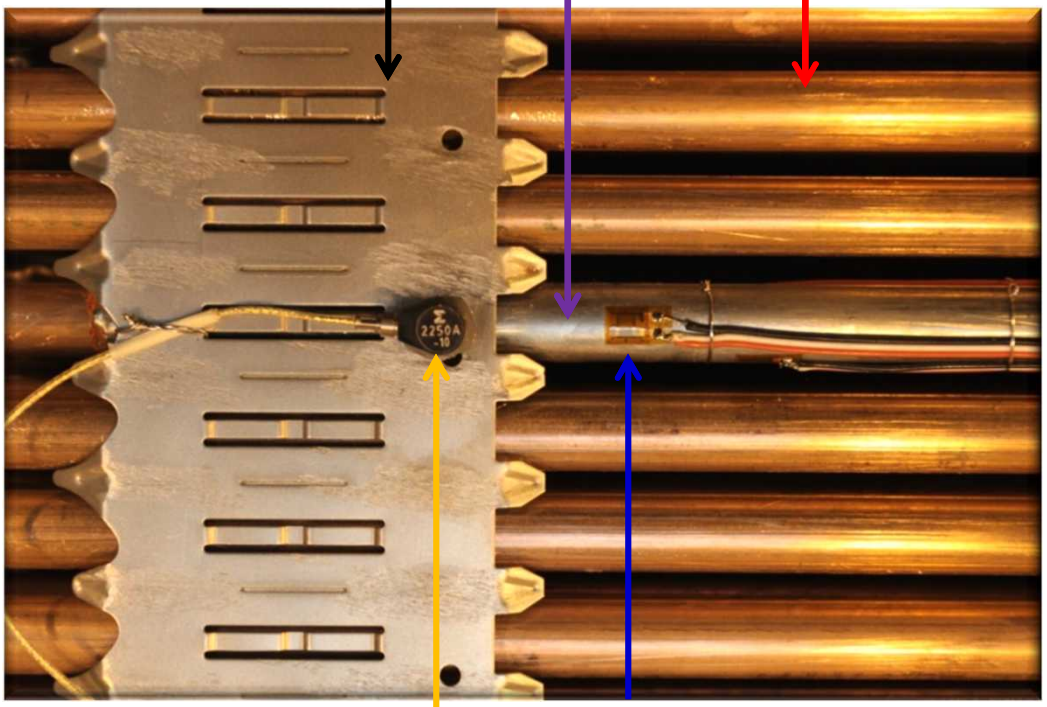
- Zircaloy-4 rods on the PWR assembly were instrumented with strain gauges and accelerometers.

PWR Assembly/Basket Test Unit





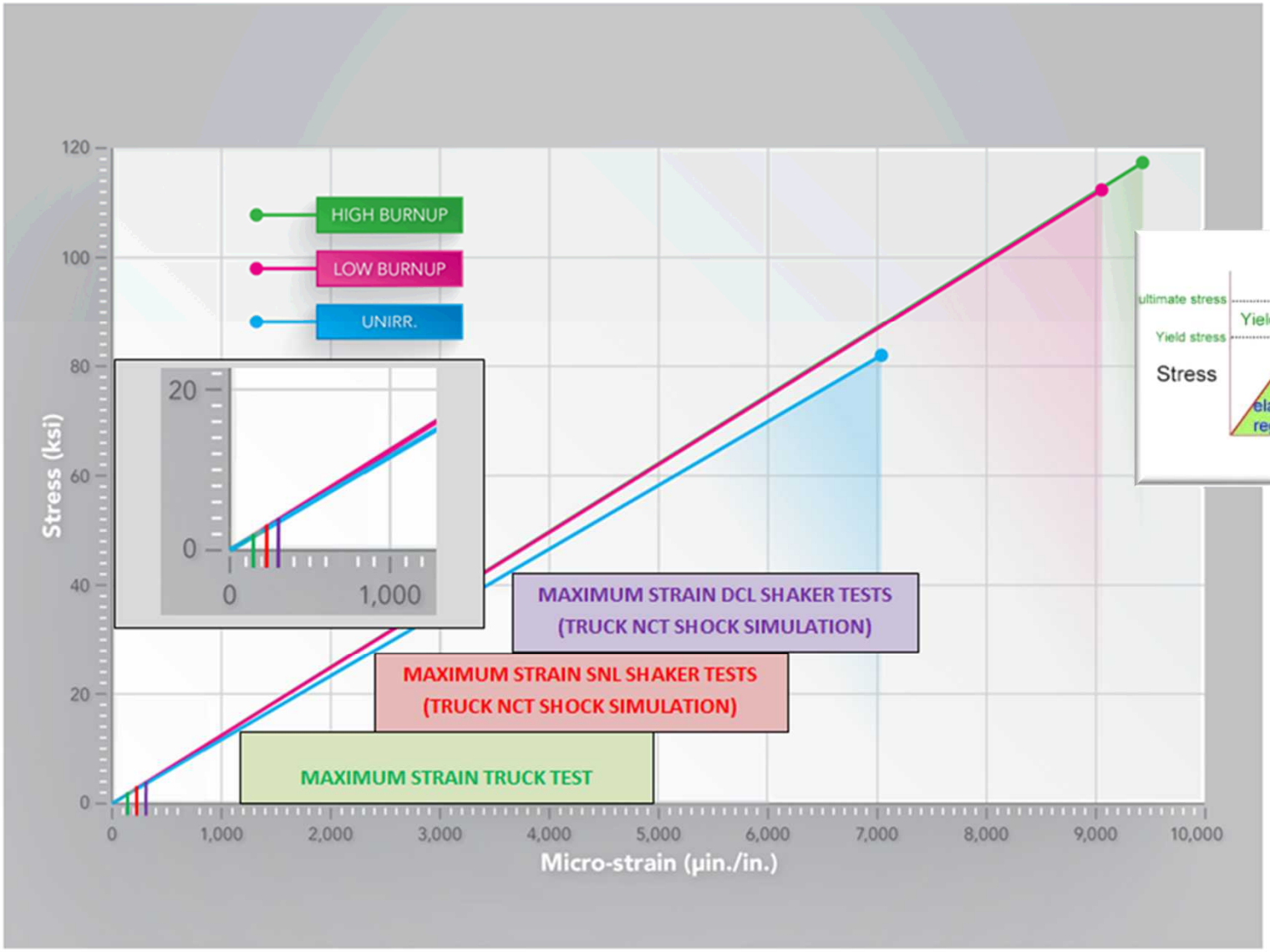
Basket Assembly

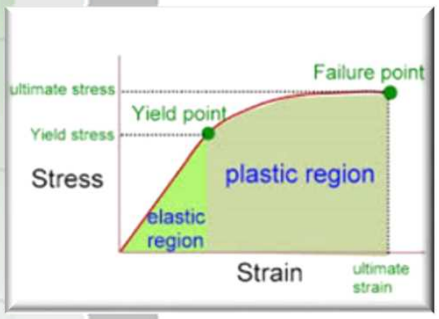


Maximum strains measured in all three test series were extremely low

Strain Gauge / Surrogate UO_2 Material within Zircaloy-4 Tube	Rod Location within Assembly (Axial Location on Assembly: Adjacent to First Spacer Grid, Middle Span) Same Axial Location for all Strain Gauges	Sandia Shaker Truck Shock Test Maximum Micro-Strain (µin./in.)	Truck Test Maximum Micro-Strain (µin./in.)	DCL Shaker Truck Shock Test Maximum Micro-Strain (µin./in.)
S3 - 0° Pb "rope"	Middle Rod		143	
TMR-G-S5-0° Pb "rope"	Middle Rod	119		
S3- 0° Pb pellets	Right-edge Rod			160
S7 - 0° Mo pellets	Middle Rod			214
S8 - 0° Pb "rope"	Left-edge Rod			301

How low were the strains?





We have also looked at brittle fracture and fatigue and found similar large margins of safety.

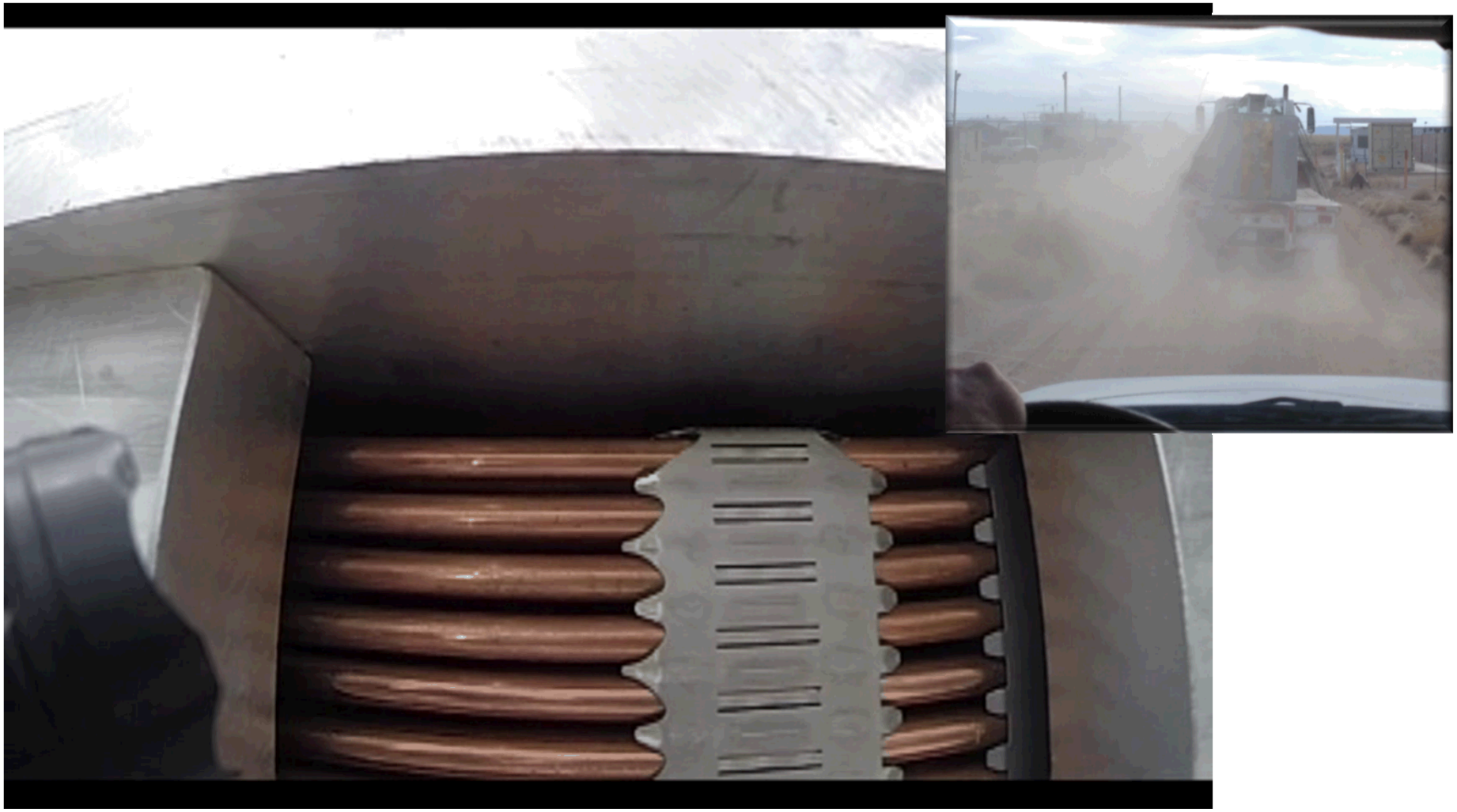
Shaker Test Video Simulating NCT Rail Shock

Shaker Test Video Simulating Rail Coupling Shock **not** a Normal Condition of Transport Simulation

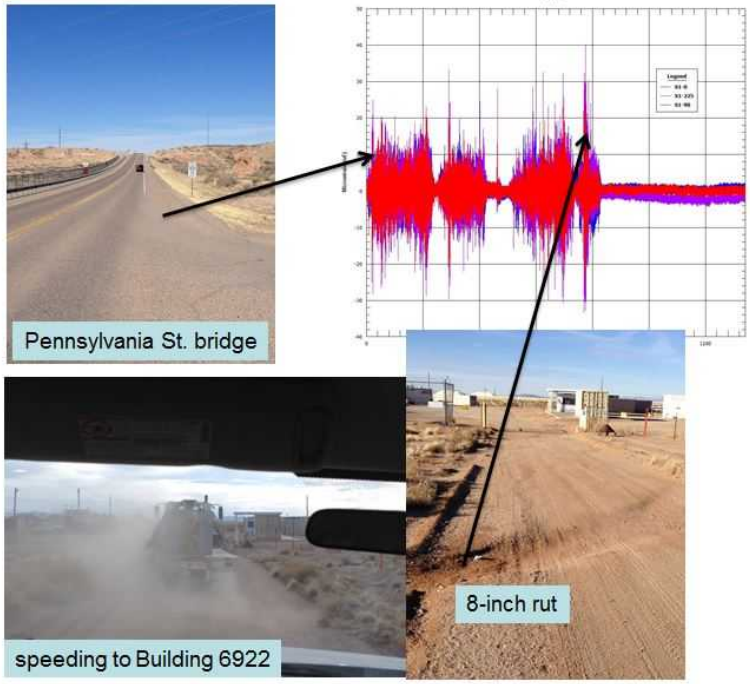
Rail Coupling Shock Shaker Test, GoPro® Side View of Rods (NOT NCT)

Test Unit on Trailer for Over-the-Road Test

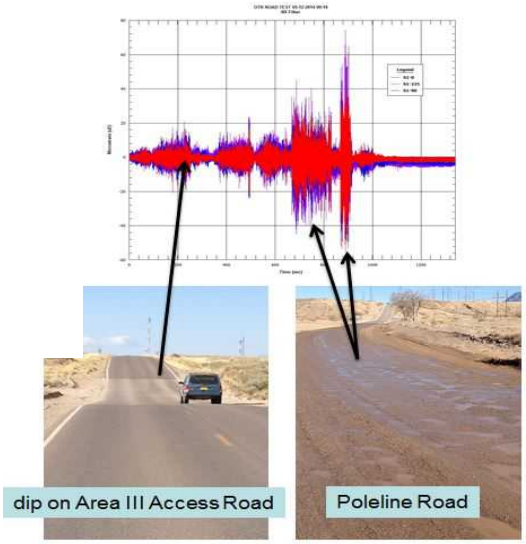
Video of Assembly during the Truck Test Rough Asphalt and Dirt Road

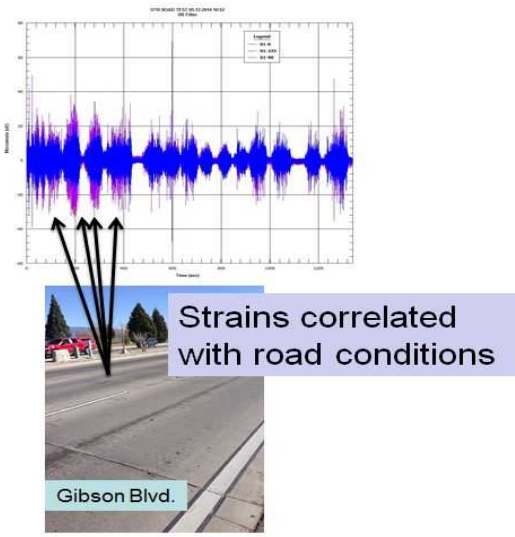


Strain data from over-the-road Truck Test

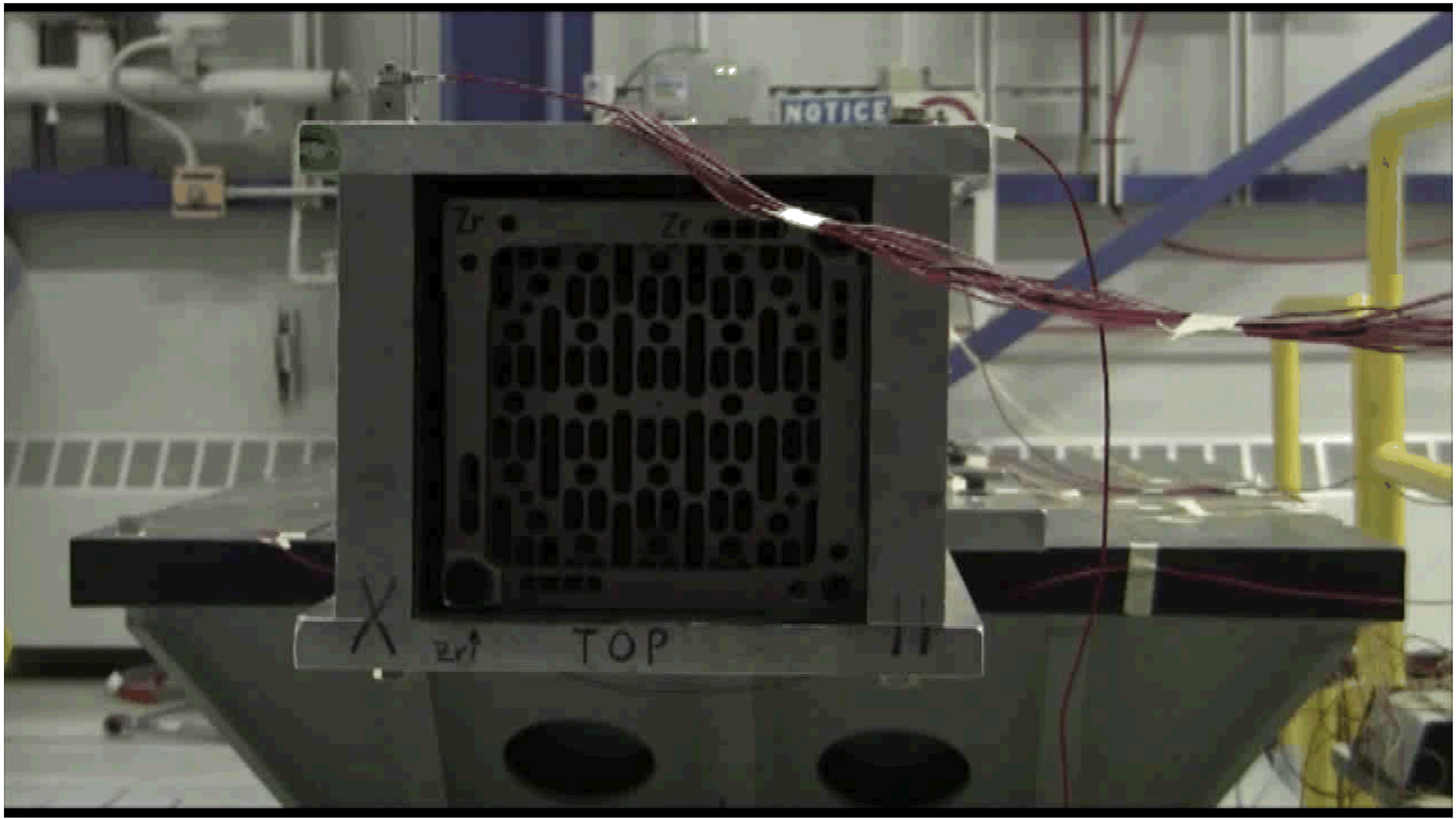


- Very low strains
- Strains correlated with road features





SNL Shaker Shock Test Video



Comparison of Strains from all Three Test Series at Same Location on Assembly

Strain Gauge ID	Location on Assembly: Adjacent to first spacer grid, Span 5	Sandia Shaker Truck Shock Test Maximum Strain Absolute Value (µin/in)	Truck Test Maximum Strain Absolute Value (µin/in)	DCL Shaker Truck Shock Test Maximum Strain Absolute Value (µin/in)
S3 - 0° Pb "rope"	Middle rod		143	
TMR-G-S5-2 (0°) Pb "rope"	Middle rod	119		
S3 - 0° Pb pellets	Right-edge rod			160
S7 - 0° Mo pellets	Middle rod			214
S8 - 0° Pb "rope"	Left-edge rod			301

What these Tests Tell Us

- The strains measured on the rods during the NCT test simulations were in the micro-strain levels – well below the elastic limit for either unirradiated or irradiated Zircaloy-4
- Based upon the test results, which simulated normal vibration and shock conditions of truck and rail transport, failure of fuel rods during normal transport seems unlikely
- Fatigue during transport does not appear to be an issue
- These results have received positive feedback from NRC, and NWTRB staff, and the technical community
- These results correlate with the used nuclear fuel transportation experience of Areva in France, i.e.: no rod failures during NCT

Plans for Completing this Work

- Prepare detailed Test Plan (FY16) for tests of PWR assemblies configured:
  - Within a rail-cask basket which is…
  - within an actual rail cask which is…
  - on a rail car which will be…
  - transported.

- Performance of rail cask tests of the assembly (FY17) using a gratis cask from ENSA (not pictured)
  - Over commercial rail lines, and
  - at the Association of American Railroads Transportation Technology Center, Inc.

These rail tests will:
- **Confirm the loadings measured during the shaker table tests,**
- **support future licensing and transport of UNF,**
- **support public acceptance of rail transport.**