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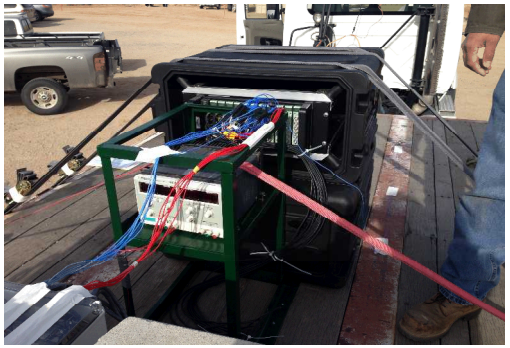

SNL Over-the-Road Truck Test

SNL/BAM MOU Technical Discussions Meeting

Doug Ammerman, Paul McConnell, Sylvia J. Saltzstein, Ken Sorenson

March 28, 2014

Berlin, Germany

BAM

U.S. DEPARTMENT OF ENERGY

NNSA

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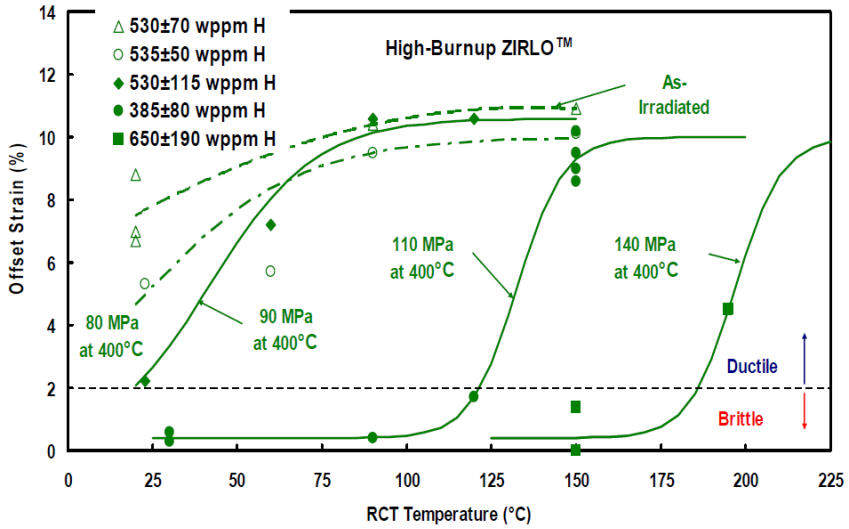
The February 25, 2014 Truck Test is all Realistic Conditions

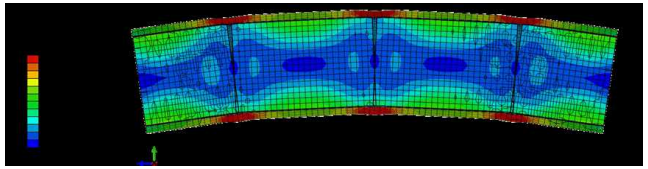
The Truck Test addresses three of the five Gaps seen in the shaker

- **Verify NRC NUREG/CR-0128 shock and vibrations loadings for NCT**
- **Test at lower frequencies: 0.1 Hz (shaker table test range 3 Hz to 1500 Hz)**
- **Test at all degrees of freedom**
- **Conduct test to simulate 30 cm drop?**
- **Conduct similar tests for rail conditions**
- **Integrate materials testing results into evaluations (e.g., DBTT, PCI)**



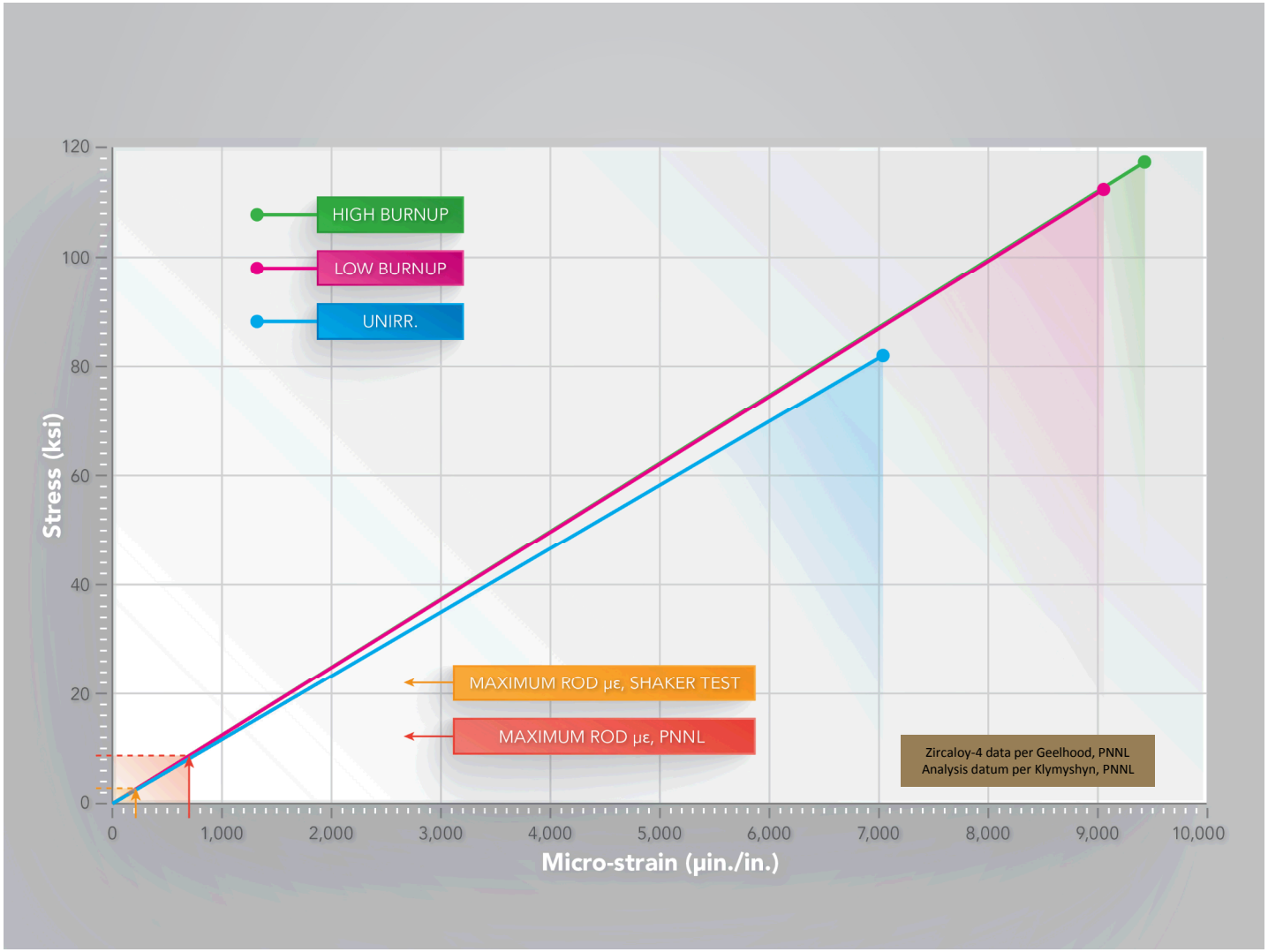
Billone, Argonne National Laboratory, EPRI ESCP Meeting, Dec. 2013

Relating curvature to flexural rigidity:
$EI = M/\kappa$



Jiang, Wang; Oak Ridge National Laboratory, WM2014 Conference, March 2014

Results of Shaker Test Measured Strains are Very Low Relative to the Elastic Limit of Zr-4



64 km Truck Route around Albuquerque to Experience Normal Conditions of Transport

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Over-the-Road Truck Test of 17x17 PWR Surrogate Assembly Inside an Aluminum Basket.

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The Basket was Bolted to Concrete Blocks

NAC-LWT weighs about 52000 lbs (23587 kg) including payload, lid, limiters, etc.; our payload was 46632 lbs (21152 kg) basket/assembly.

The Assembly had Blockers to Prevent Horizontal Sliding and Marks to Measure any Movement During Transport

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Blockers allowed 1.25 inch (3.175 cm) longitudinal motion towards the tractor. (No motion was detected post-test.)

The Basket was Firmly Tied to the Concrete Weights…

…and Bolted to the Concrete at ends and middle

Tri-Axial Accelerometers were Placed on the Trailer Bed

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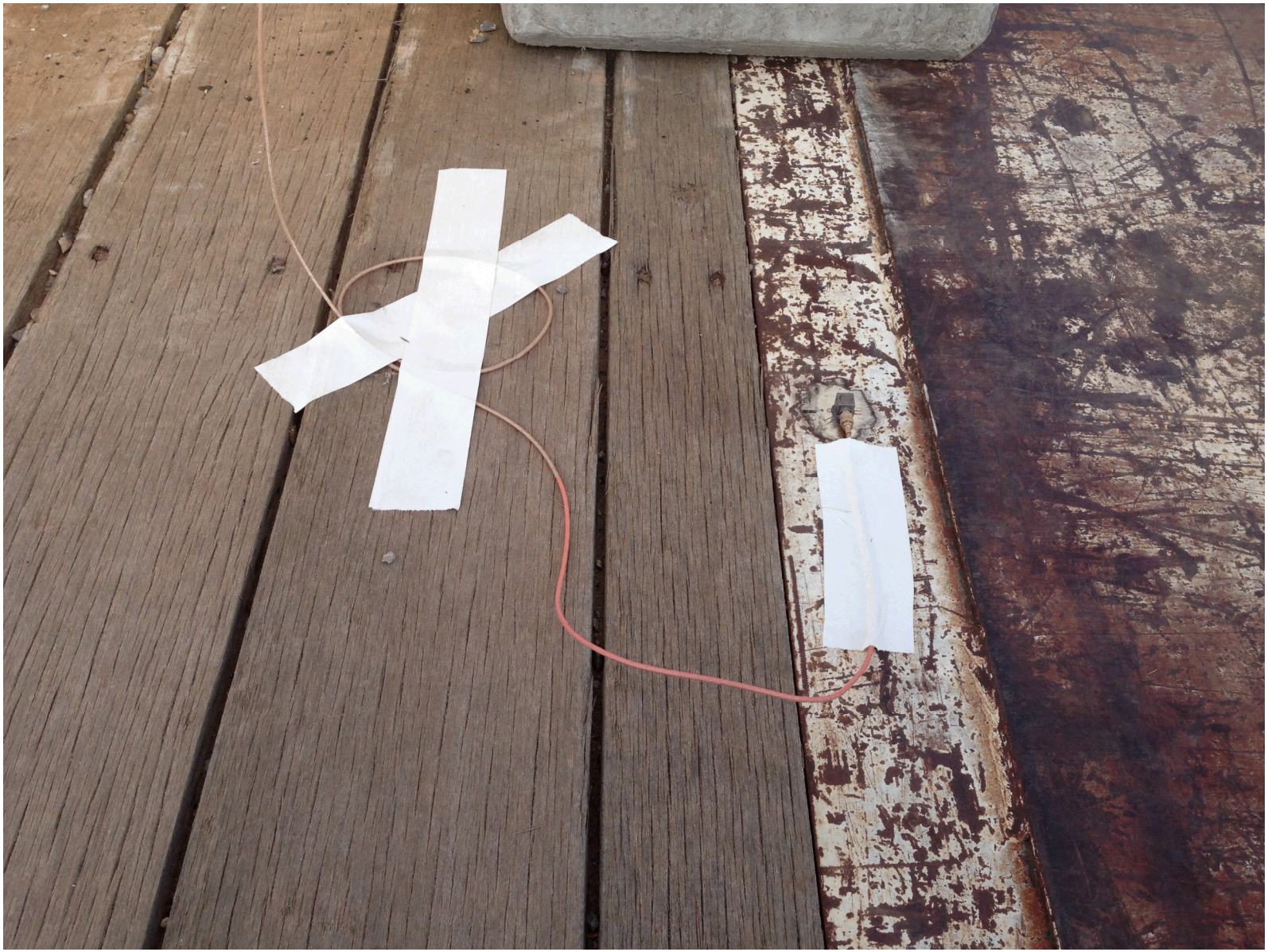

Tri-Axial Accelerometers were Placed on the Basket

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Assembly sits directly on basket. (no felt)

Accelerometer and Strain Gauge Leads

Data Collection Equipment on the Truck
Sample rate was 8192/second

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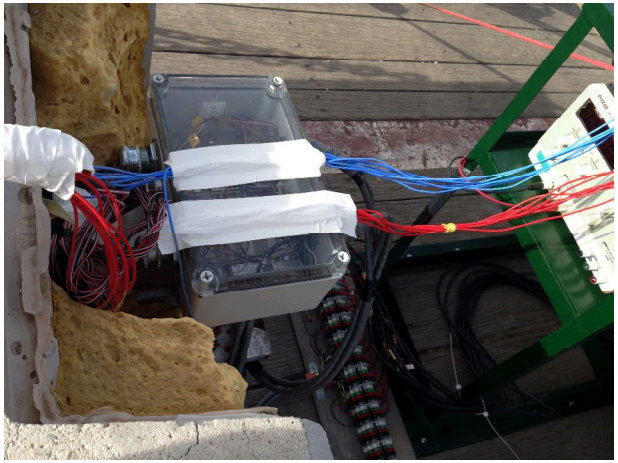


Initial Road Conditions (with 20 cm trough)

Now we are moving!

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Highway at 120 km/hr

Railroad Crossings

Some Representative Road Conditions

Stop Signs and 90° Turns

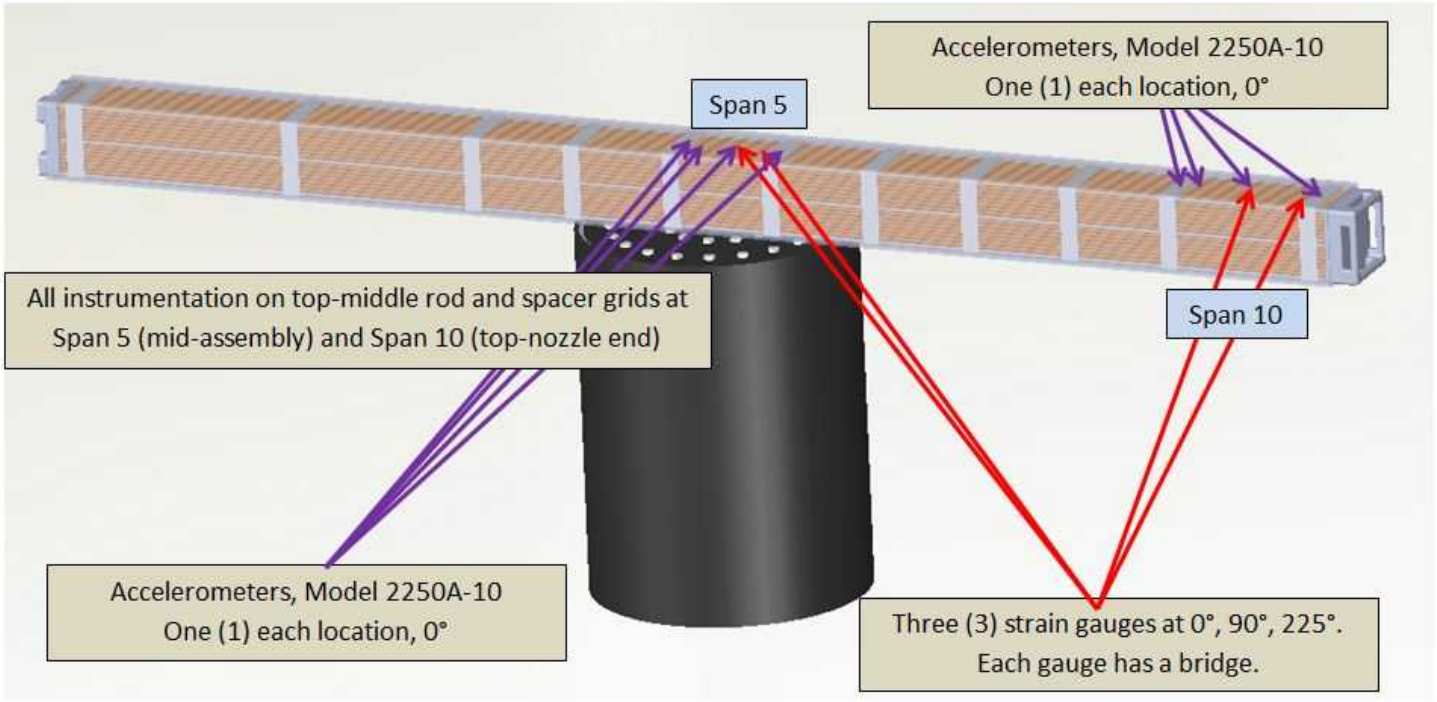
Secondary Road at 50mph (80 km/hr)

Secondary Roads

Very Washboard Section of Road

Very Hard, Bumpy Conditions

Instrumentation Positions



Strain gauges on top-middle Zircaloy-4 rod and accelerometers on top-middle Zircaloy-4 rod and Span 5 and Span 10 spacer grids for over-the-road truck test. Span 10 is the top nozzle end of the assembly. Triaxial accelerometers shall be placed on the basket at the mid-span and top-nozzle end and on the trailer at the kingpin, rear axle, and adjacent to the mid-span of the basket.

Preliminary Results

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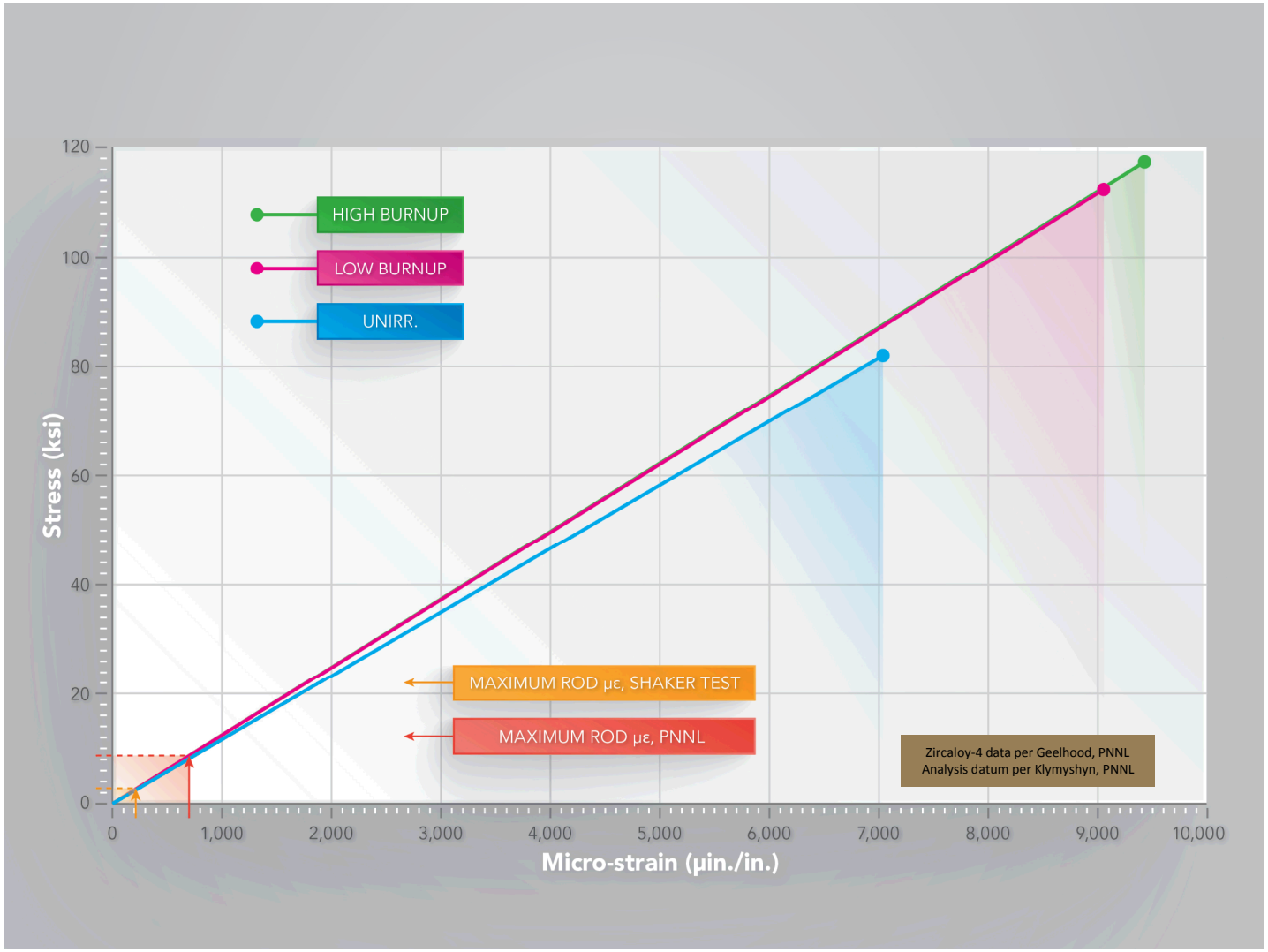
Axial Location of Strain Gauge along Fuel Assembly	Circumferential Position of Strain Gauge on Fuel Rod	Maximum Micro-Strain for Each Route Segment							
		Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Segment 6	Segment 7	Segment 8
Adjacent to First Spacer Grid, Span 10	S1 - 0°	393	369	362	377	374	373	375	379
	S1 -90°	152	125	118	120	112	110	114	112
	S1 - 225°	112	95	94	93	86	98	97	96
Mid-Span, Span 10	S2 - 0°	17	16	19	16	15	15	19	17
	S2 -90°	26	28	32	28	29	32	30	31
	S2 - 225°	28	27	27	27	29	31	31	32
Adjacent to First Spacer Grid, Span 5	S3 - 0°	30	26	29	24	25	26	24	24
	S3 -90°	137	144	138	145	144	145	138	143
	S3 - 225°	39	47	52	49	52	56	55	57
Mid-Span, Span 5	S4 - 0°	131	128	122	126	121	128	130	127
	S4 -90°	75	69	67	68	69	69	69	69
	S4 - 225°	264	266	260	267	259	273	274	277

Results
Measured Strains are Very Low Relative to the Elastic Limit of Zr-4



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Danke schön für Ihnen Aufmerksamkeit!

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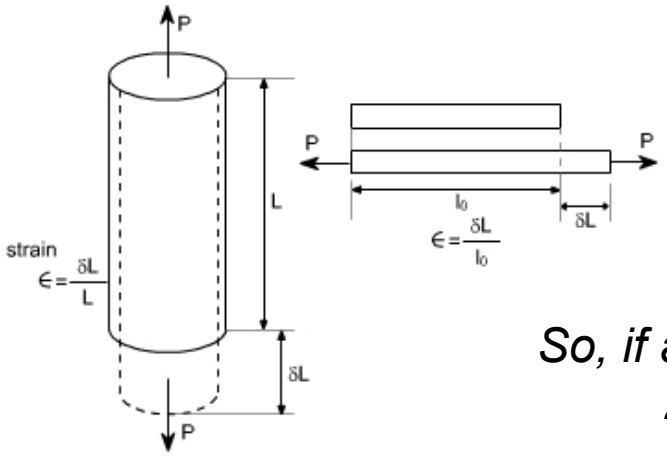
BACKUP SLIDES

All Results Were in Microstrains

A microstrain is the change in length ΔL per unit of the original length L *expressed in parts per million.*

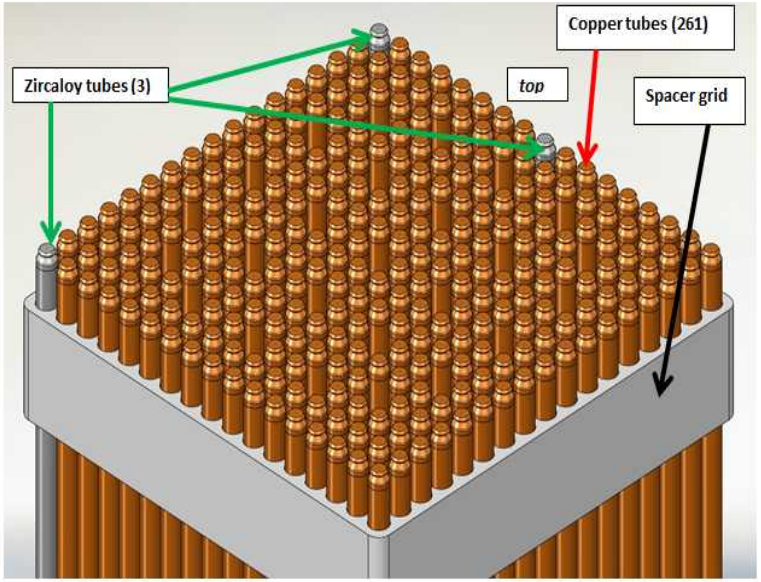


$$e = \frac{\Delta L}{L} = \frac{\ell - L}{L}$$

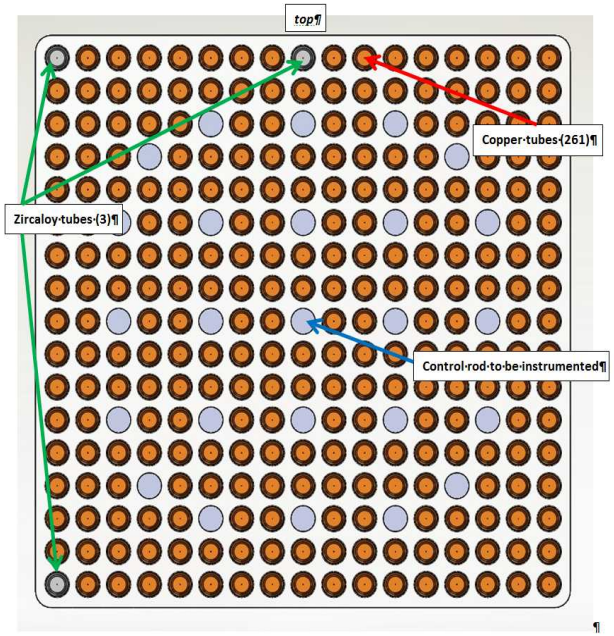
So, if a 4 meter rod is subjected to 200 microstrain:
200×10^{-6} x 4 m = 800 microns or 0.8mm

This means that a 4 meter rod subjected to 200 microstrain would experience a change of length of .79mm.
400 microstrain would move a 4 meter rod 1.6mm
700 microstrain would move a 4 meter rod 2.77 in.

Surrogate 17x17 PWR Experimental Assembly



Isometric View of Fuel Rods



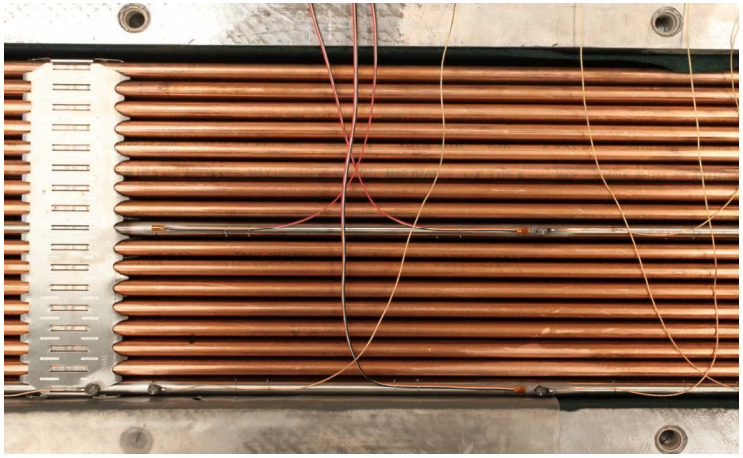
Top View of Assembly

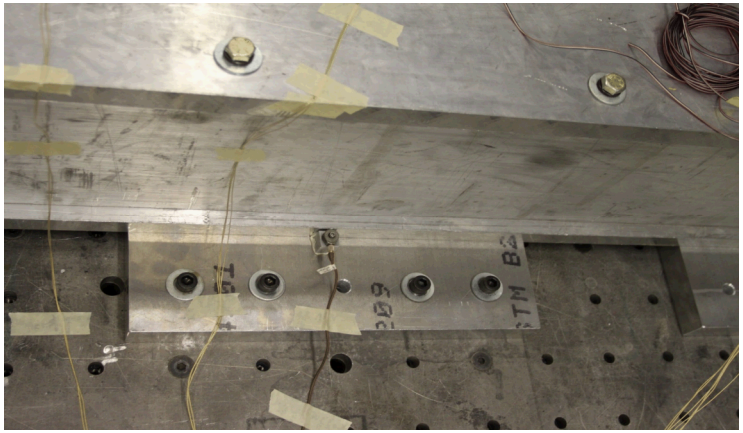
Surrogate rod:

- **Three Zr-4 rods**
- **Remainder: Copper**
- **All filled with lead rope**
- **Mass simulates fresh $U0_2$ fuel**

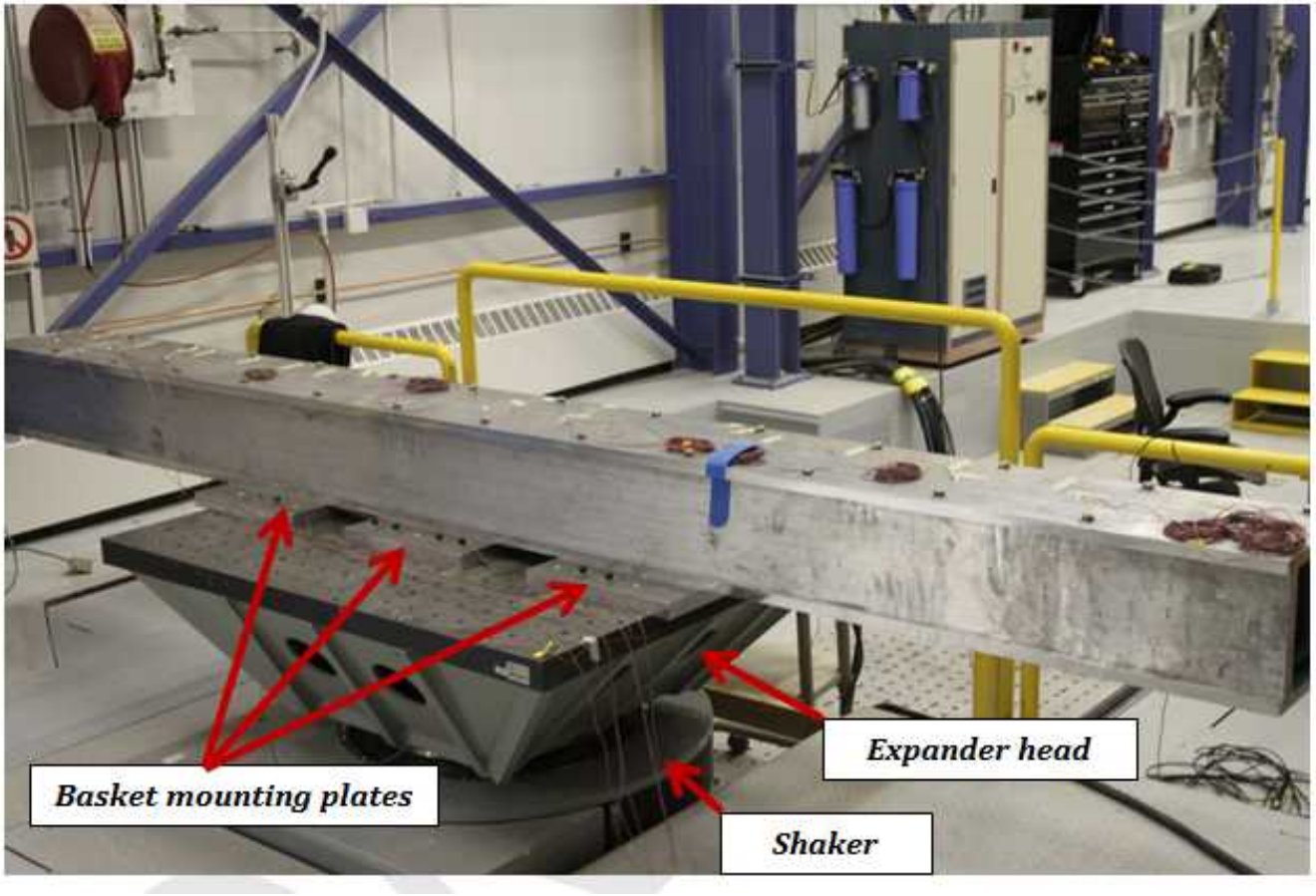
Instrumentation

- Instrumentation placement based on pre-test finite elements analyses
- Only the Zr-4 rods and spacer grids were instrumented
  - strain gages
  - tri-axial accelerometers on rods and grids





Shaker Table Test




WEBBING