U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

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SURROGATE ASSEMBLY 30 CM DROP TEST

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EPRI | ELECTRIC POWER RESEARCH INSTITUTE

EXTENDED STORAGE COLLABORATION PROGRAM

SAND2020-11351 C

November 12, 2020

30 cm Drop Test: Purpose, Incentive, Goals, and Implementation

Purpose:

Measure accelerations and strains on a surrogate 17x17 PWR fuel assembly

Incentive

- ❑ The 30 cm drop is one of the NRC normal conditions of transportation (NCT) regulatory requirements (10 CFR 71.71)
- ❑ There are no data on the actual surrogate fuel for the 30 cm drop.
- ❑ Obtaining these data is not a direct requirement, but it allows for:

Goals

- ➢ Completing the NCT mechanical testing environment
- ➢ Better understanding the potential implications of handling incidents
- ➢ Quantifying the risk of fuel breakage under the 30 cm drop conditions
- ➢ Defining transfer function from the cask to the fuel for more severe impacts

Implementation

- ❖ Ideally, the 30 cm drop test would be conducted with the full-scale cask containing full-scale surrogate assemblies.
- ❖ The cost of a full-scale cask and impact limiters make this test impractical.
- ❖ The accelerations and strains on a full-scale surrogate fuel assembly were obtained by implementing 3 consecutive steps.
- ❖ This presentation describes **Step 3.**

The photos and other materials in this presentation are in compliance with the NDA with Westinghouse per Ned Bahtishi e-mail from 09-23-20:

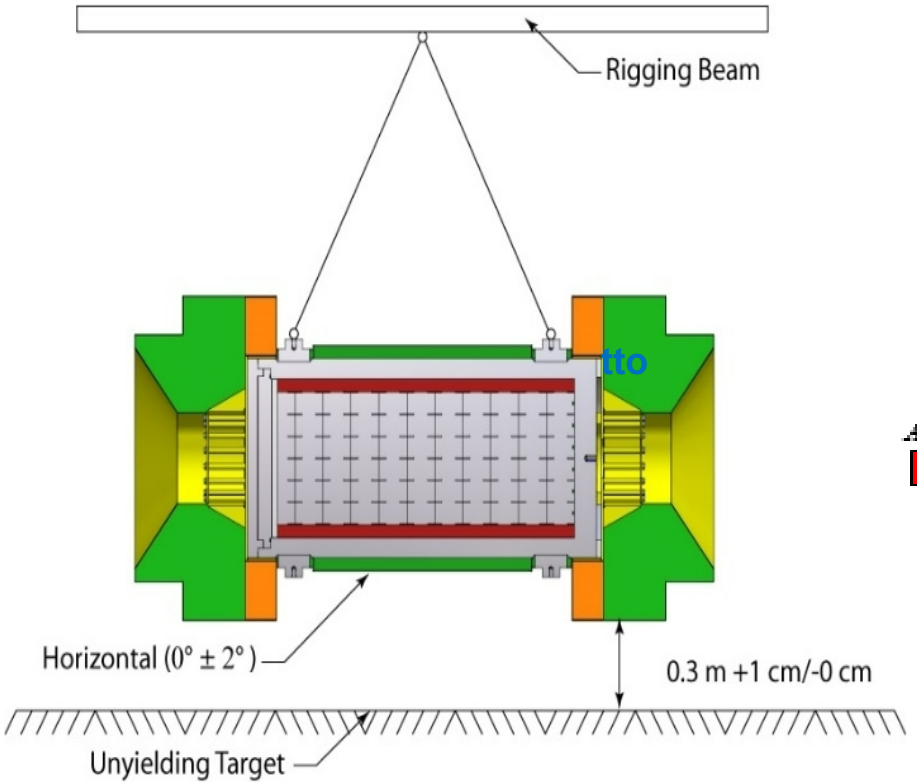
"We completed our review of the draft of the final report and did not find anything that discloses any Intellectual Property"

STEP 1 – 30 cm Drop of 1/3 Scale ENUN 32P Cask with Dummy Assemblies

BAM Facility in Berlin (Germany), December 2018

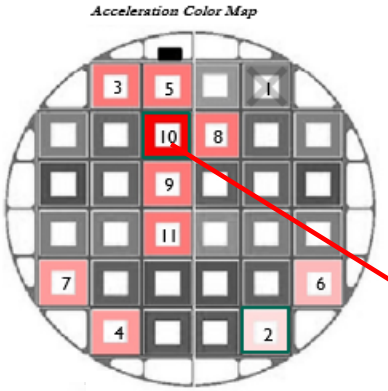
Details in PATRAM-2019 paper by Kalinina et al.

Drop Test Setup



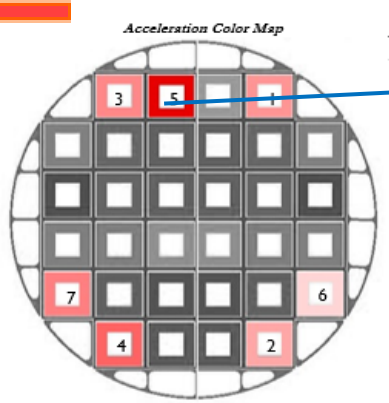
Maximum Accelerations on Dummy Assemblies

Top (Lid)

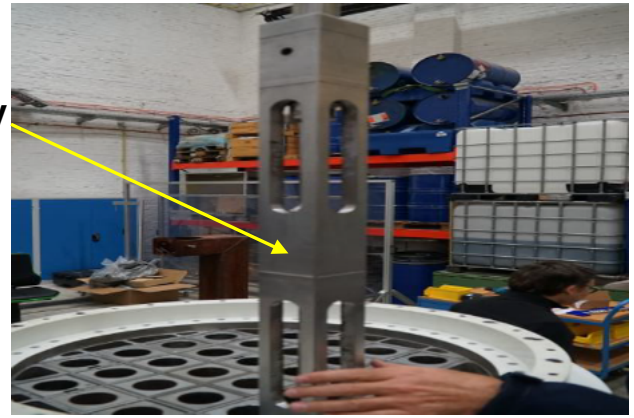


Acceleration

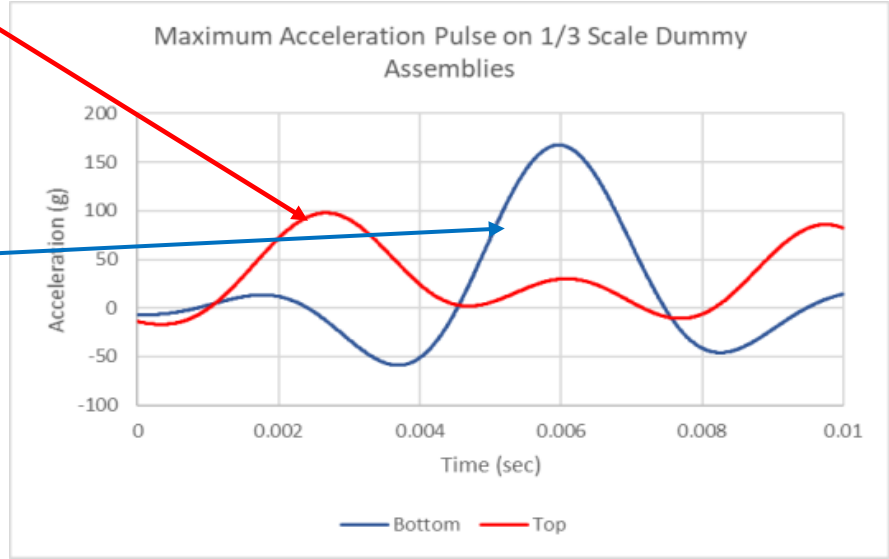
Bottom



Dummy Assembly



11 Instrumented 1/3 Scale Dummy Assemblies

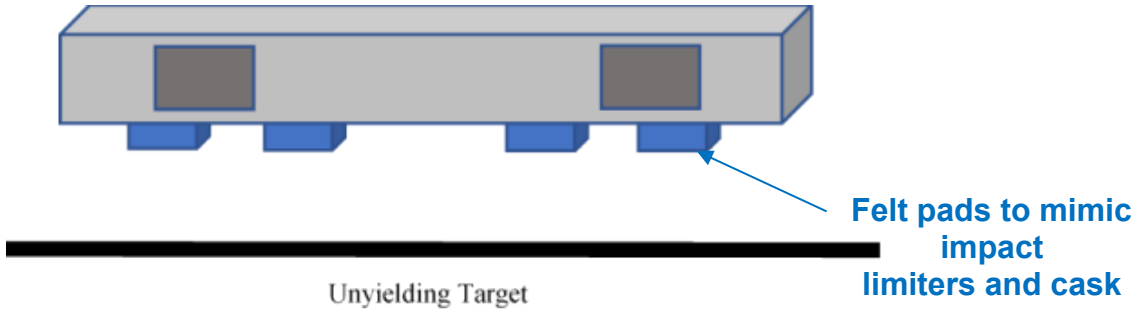


STEP 2 – 30 cm Drop of the Full-Scale Dummy Assembly

SNL drop tower in Albuquerque (NM), June 2019

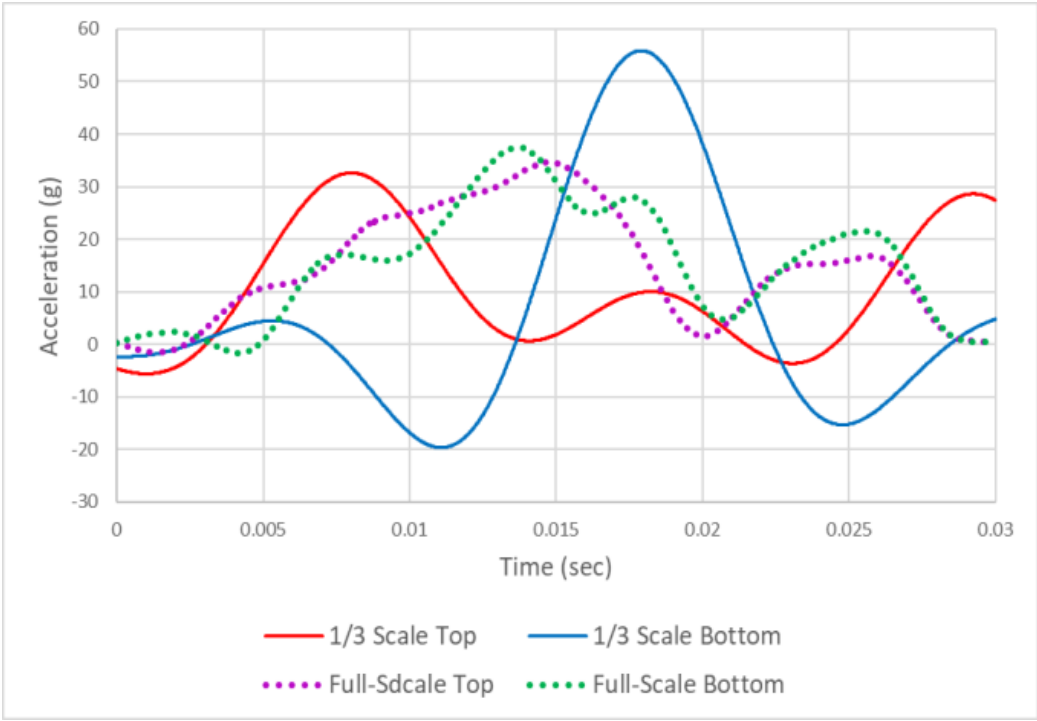
Details in MRS Advance paper by Kalinina et al. (2019)

Drop Test Setup

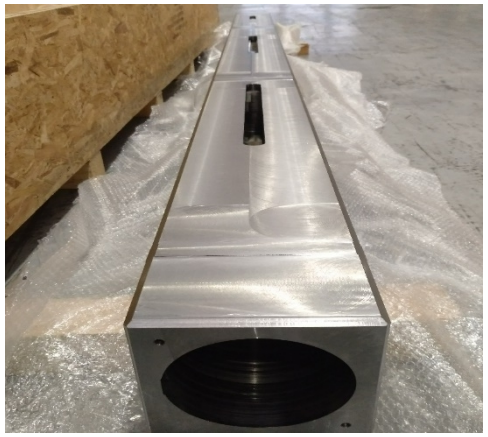


Goal: recreate a full-scale acceleration pulses on the dummy assembly that corresponds to the scaled measured pulses on the 1/3-scale dummies (from STEP 1).

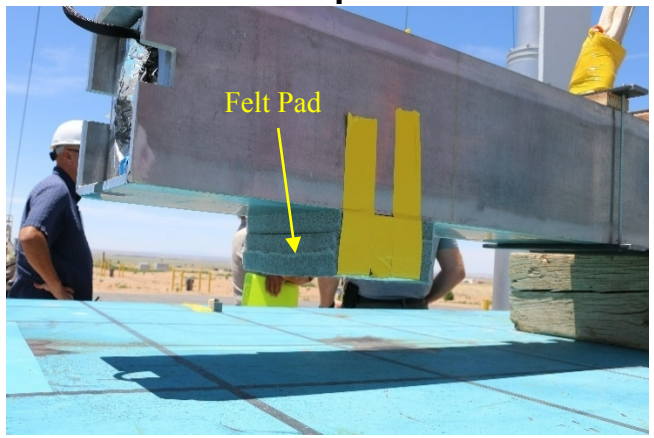
Acceleration Pulses in Test 4



Full-Scale Dummy Assembly

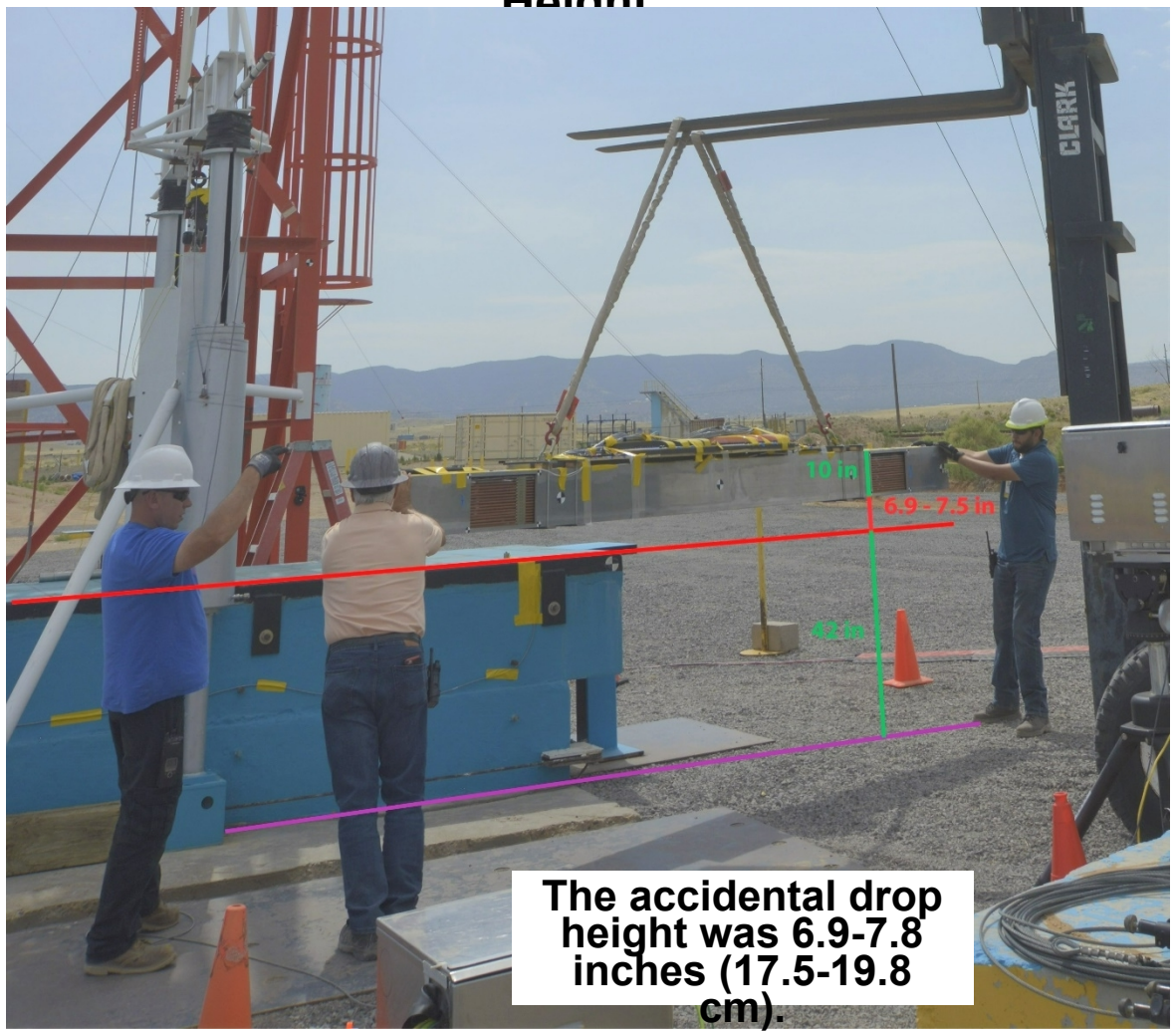


Felt pad configuration in Test 4



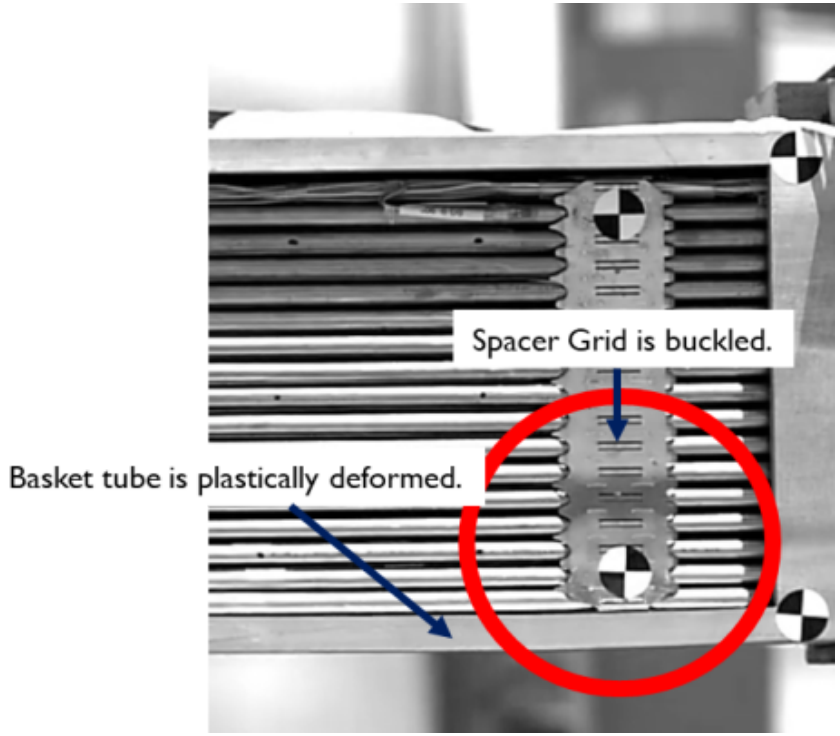
Handling Accident, June 2019

Pre-Accident Photo Used in Estimating Accidental Drop Height



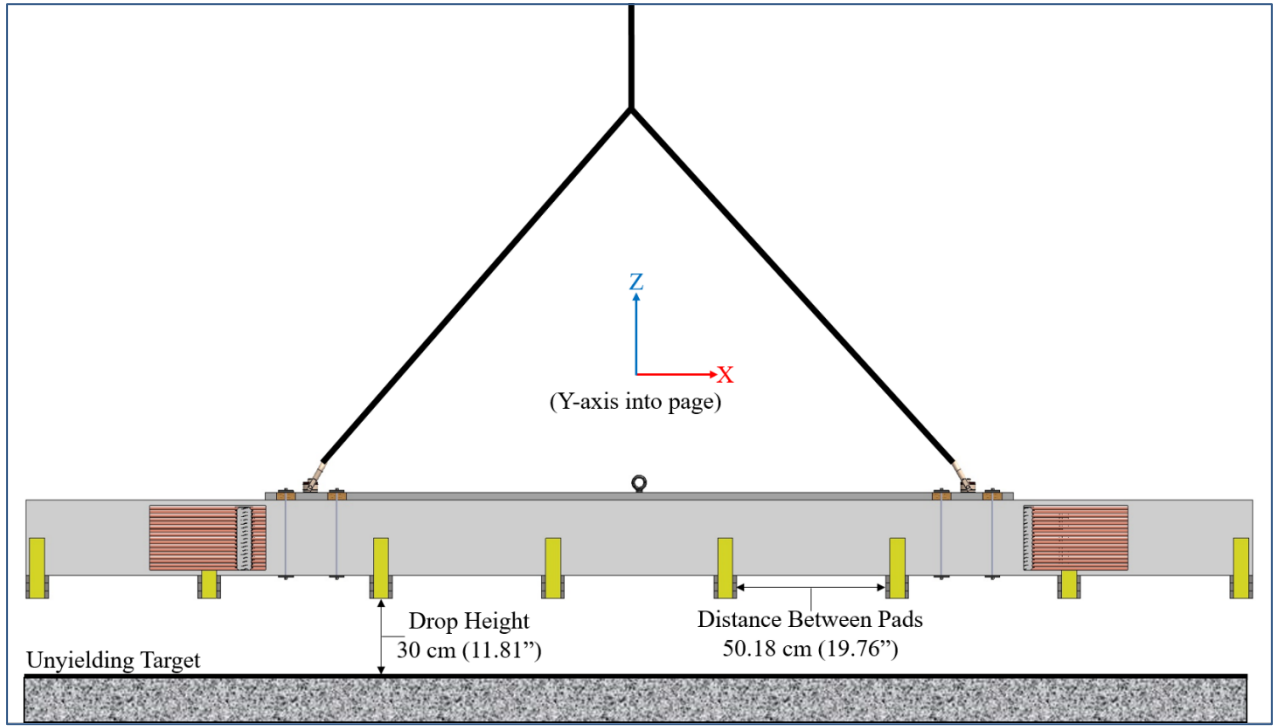
The accidental drop height was 6.9-7.8 inches (17.5-19.8 cm).

Damage Observed After the Accidental Drop



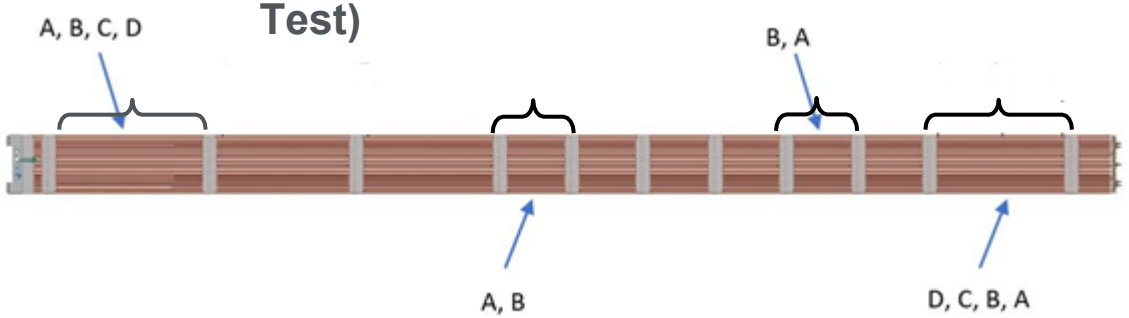
Test Setup and Pressure Paper Placement

Test Setup

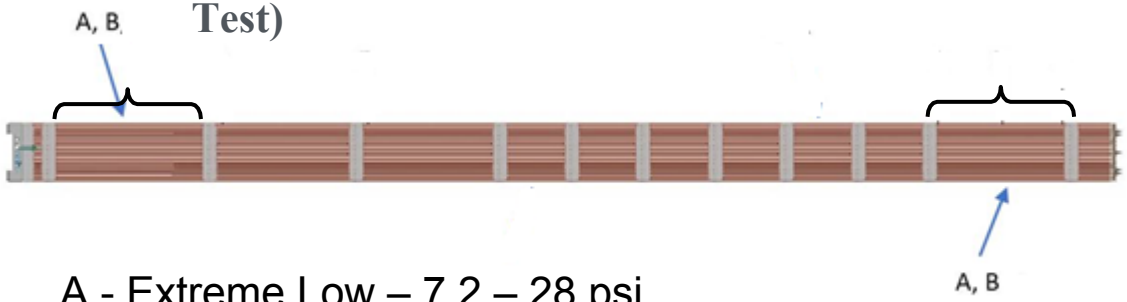


Pressure Paper Placement

New Surrogate Assembly (2020 Test)



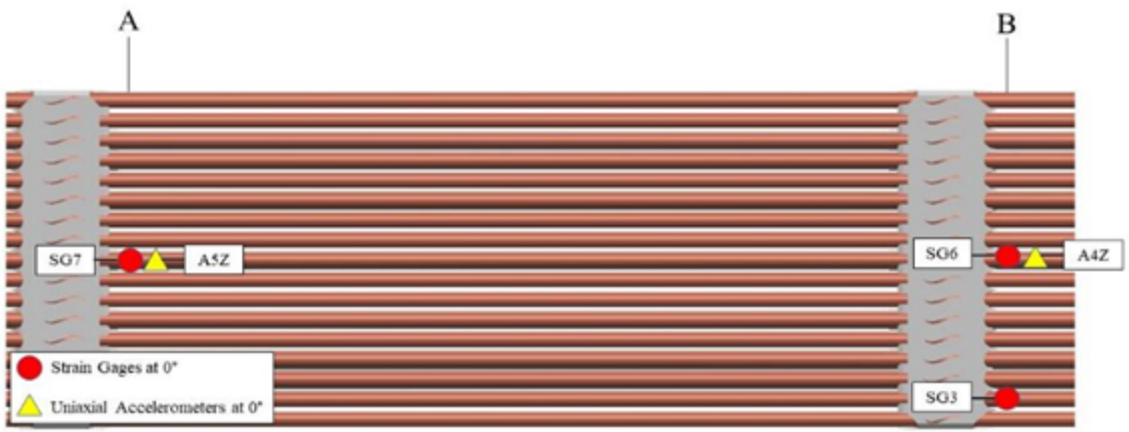
Old Damaged Surrogate Assembly (2019 Test)



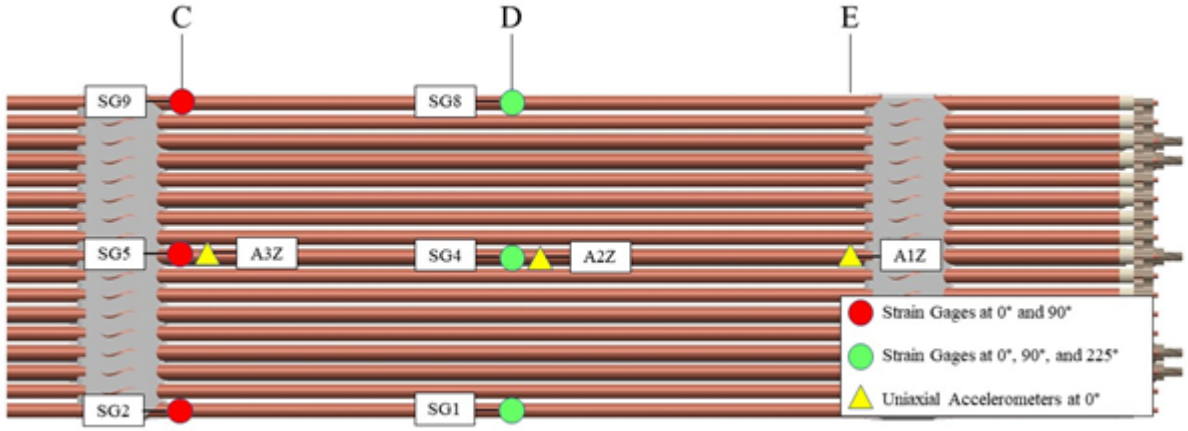
A - Extreme Low – 7.2 – 28 psi
B - Super Low – 70 – 350 psi
C – Low – 350 – 1,400 psi
D - Medium. – 1,400 – 7,100 psi

Instrumentation

Same Sensors as in MMTT

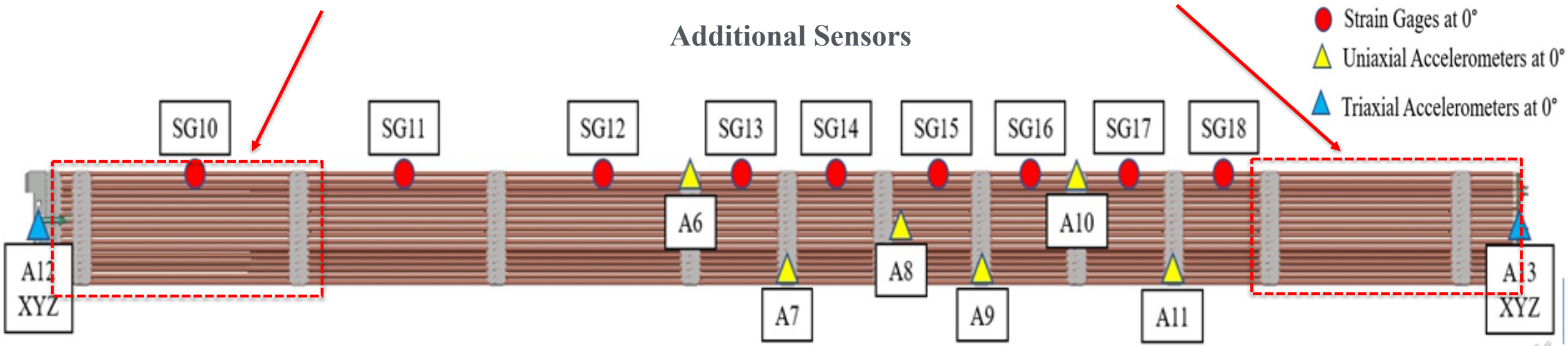


Bottom Nozzle End Instrumentation



Top Nozzle End Instrumentation

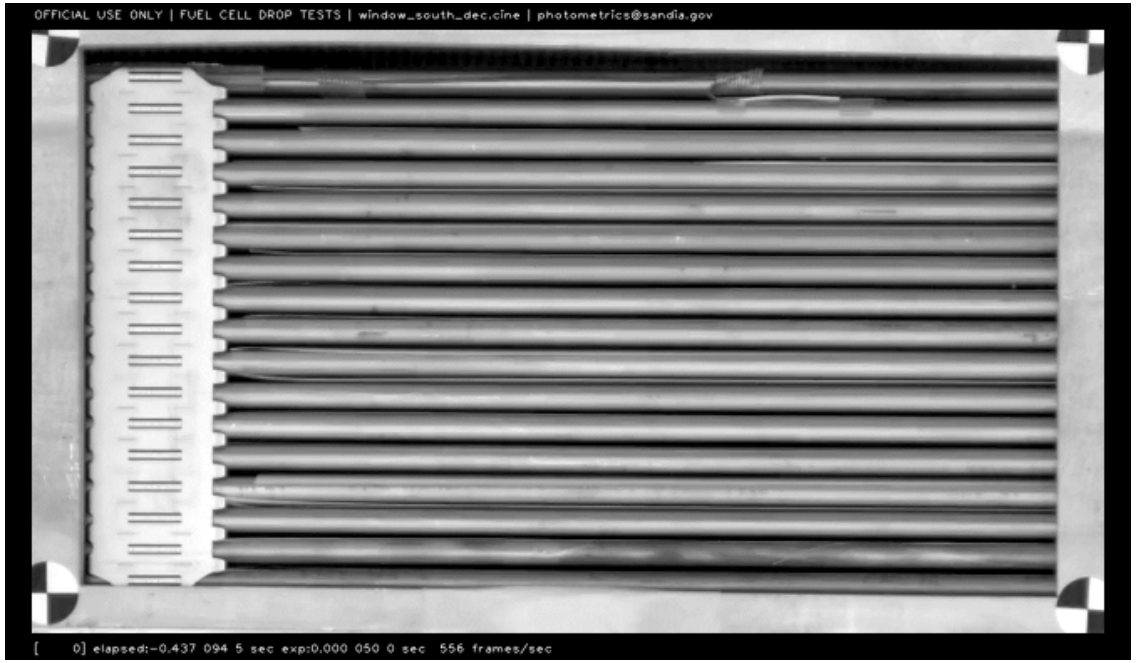
Additional Sensors



30 cm Drop Test with New Surrogate Assembly, May 7, 2020

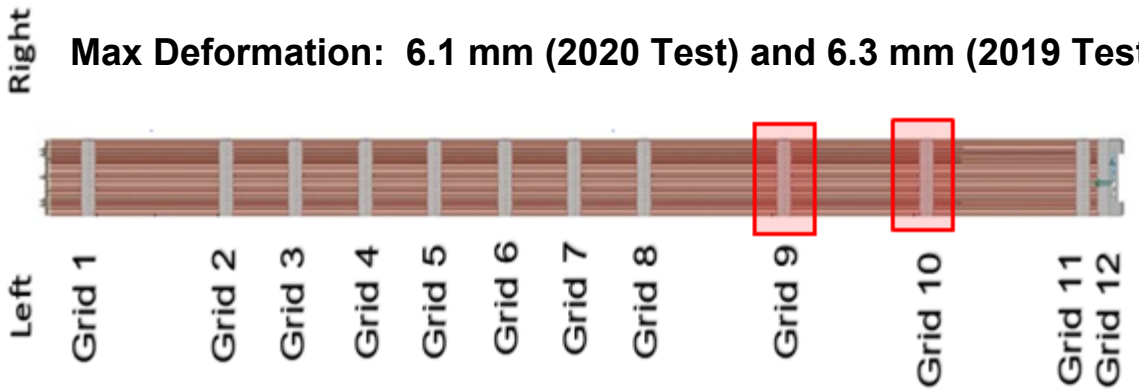
Test Video

High-Speed Video



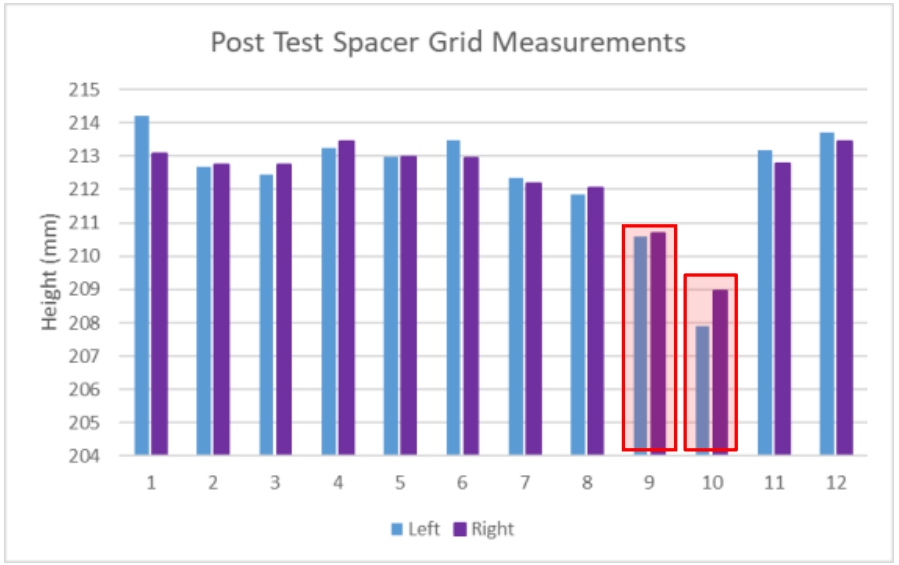
Post-Test Spacer Grid Conditions

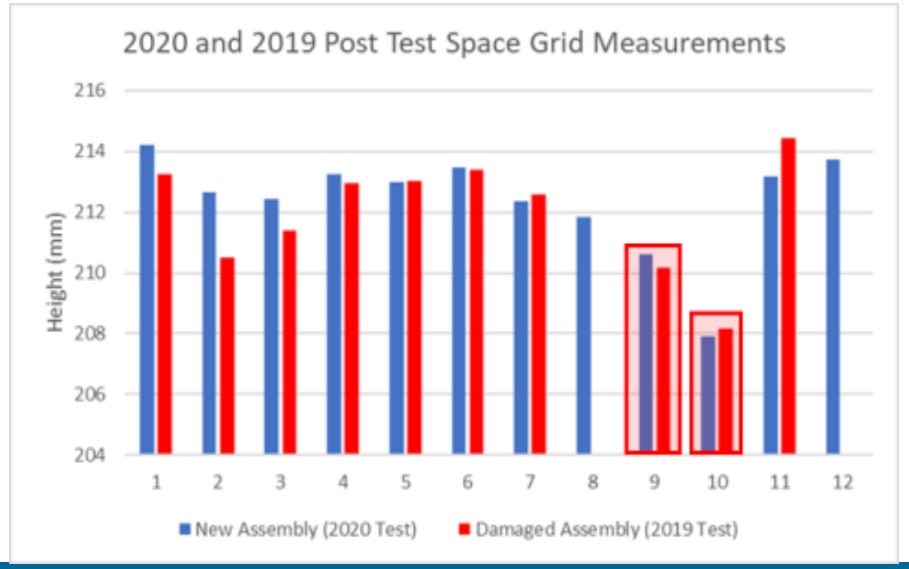
Max Deformation: 6.1 mm (2020 Test) and 6.3 mm (2019 Test)



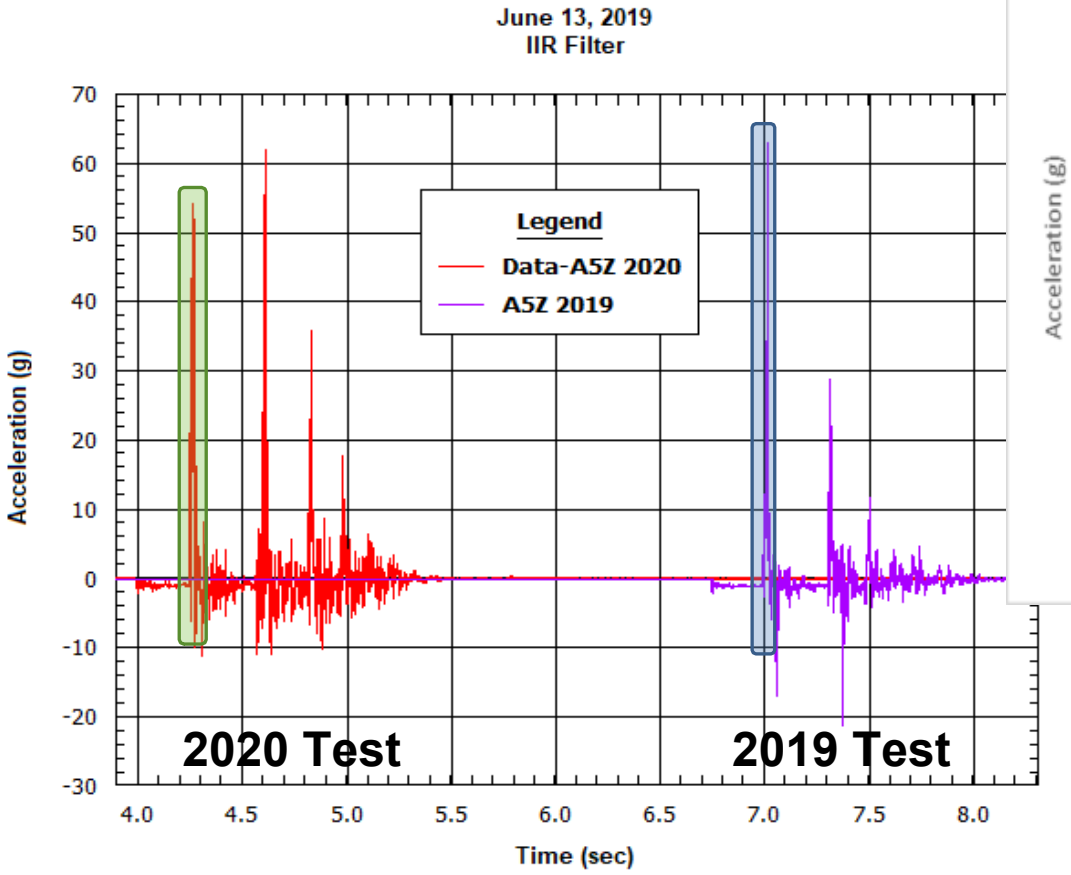
Grid 10 (right) , 2020 Test

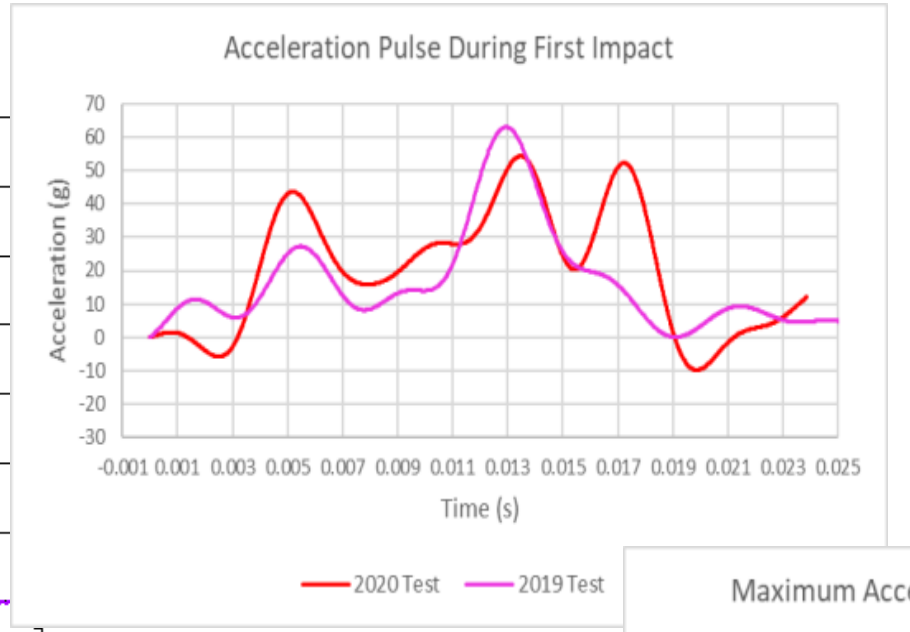
Grid 10 (right), 2019 Test



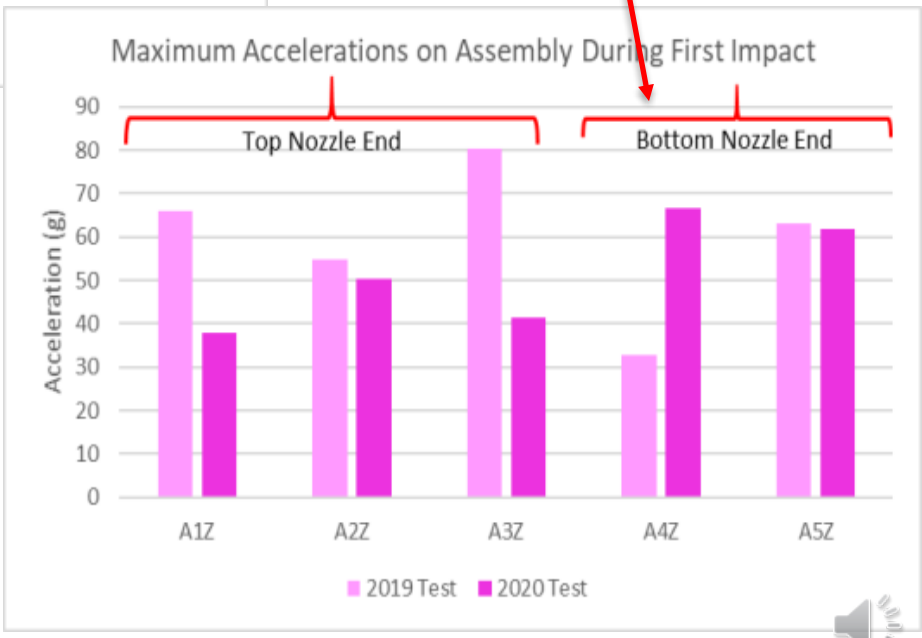


Accelerations in 2020 and 2019 Tests





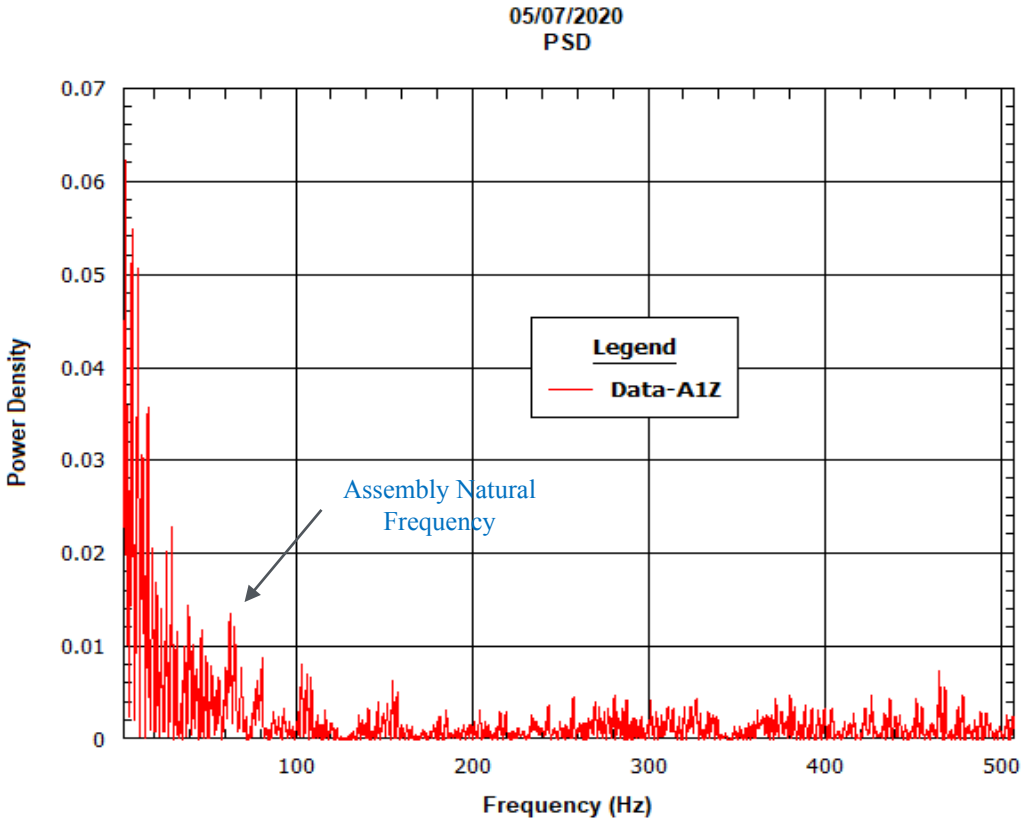
The assembly damage resulted in a smaller slap down effect in 2019 test



- ❑ The observed pulses on the surrogate assembly are in good agreement with the expected ones.
- ❑ The averaged observed pulse on the surrogate assembly is in good agreement with the observed pulse on the dummy assembly.

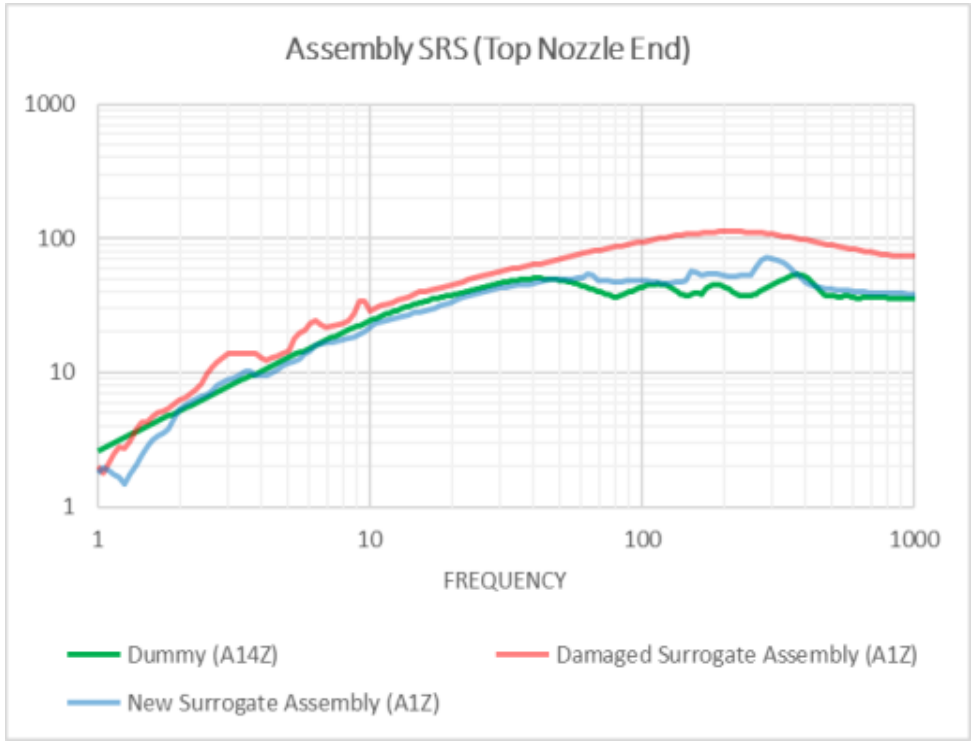
Acceleration Power Spectra Density (PSD) and Shock Response Spectra (SRS)

Acceleration PSD



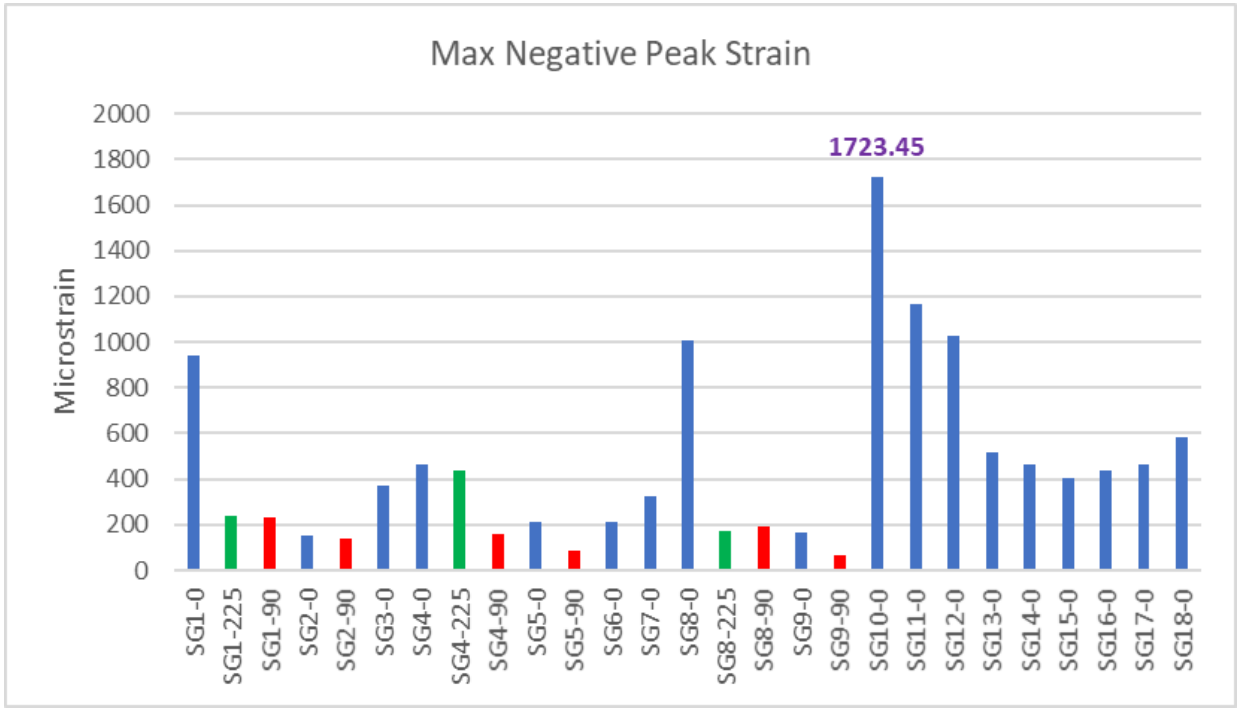
- The greatest acceleration PSD is within the frequency domain up to 150 Hz.

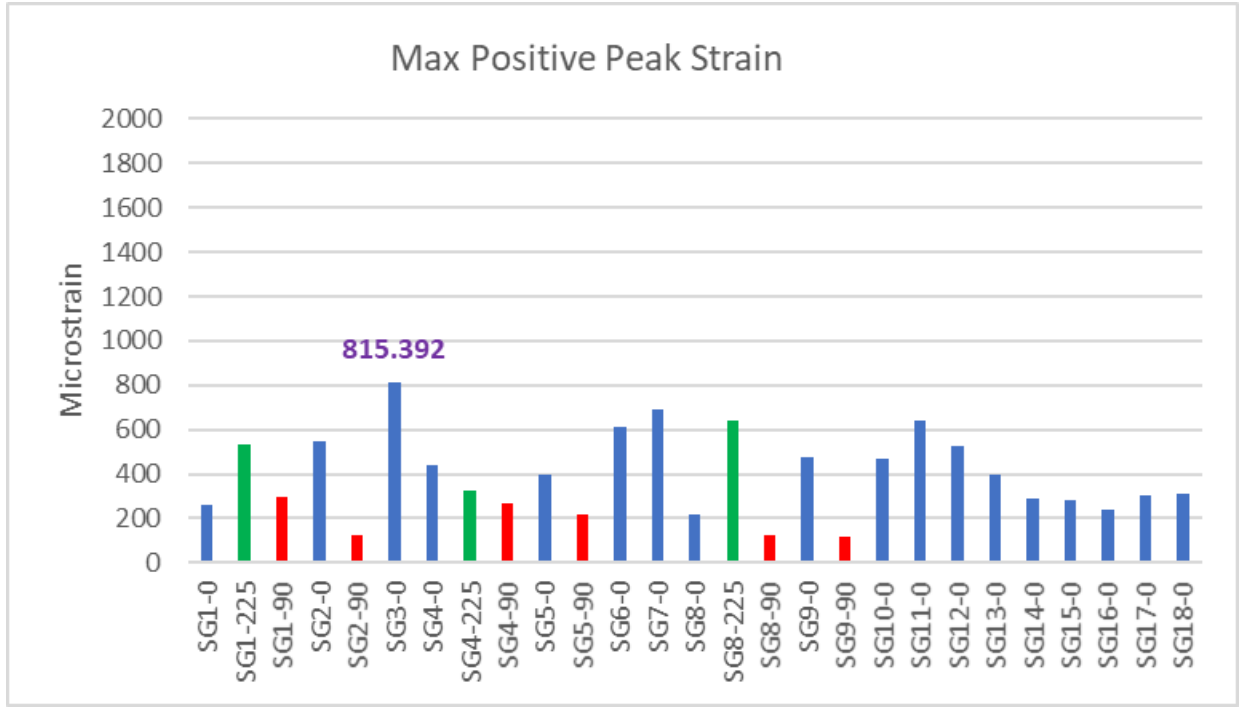
Acceleration SRS



- The damaged surrogate assembly acceleration SRS envelops the responses of the dummy and new surrogate assemblies.

Maximum Observed Strain on the Surrogate Assembly (2020 Test)

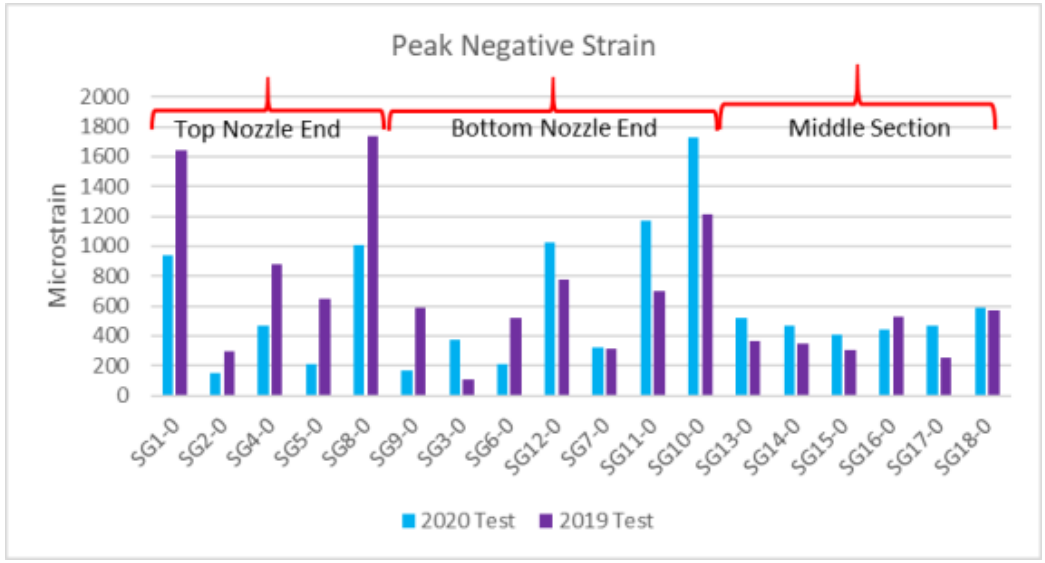


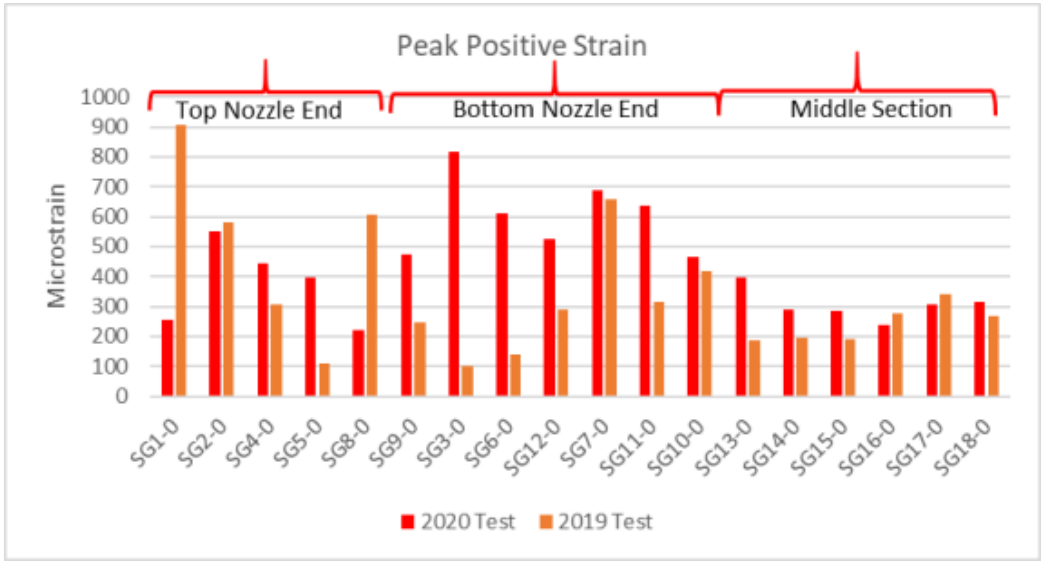


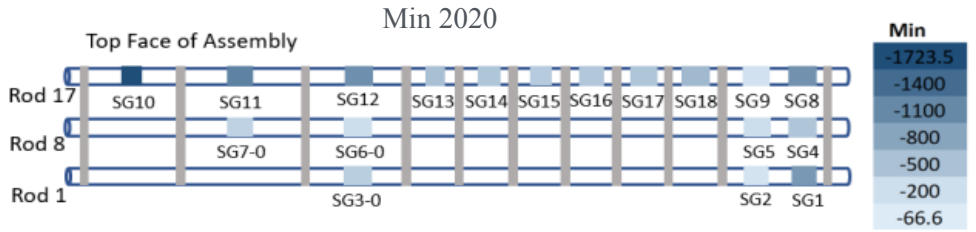
0^0 strain gauges
90^0 strain gauges
225^0 strain gauges

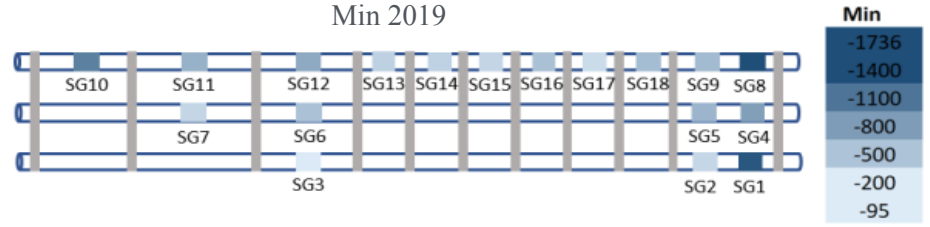
- Greatest negative strains were observed at the assembly bottom (slap down) end (SG10-0, SG11-0, and SG-12).
- Strains within the short spacer grid spans (SG13-0, SG14-0, SG15-0, SG16-0, SG17, and SG18-0) were noticeably lower as expected.
- The lateral (90^0) and combination (225^0) strain values were generally lower than the vertical ones.

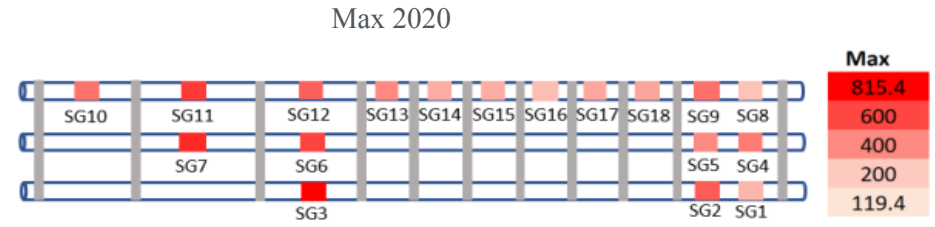
Strain in 2020 and 2019 Tests

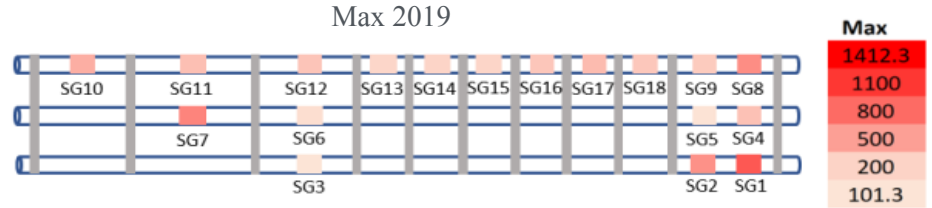








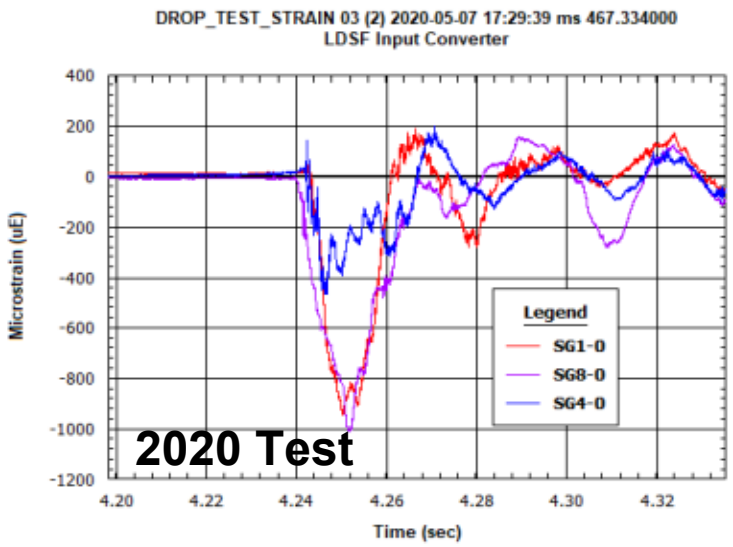


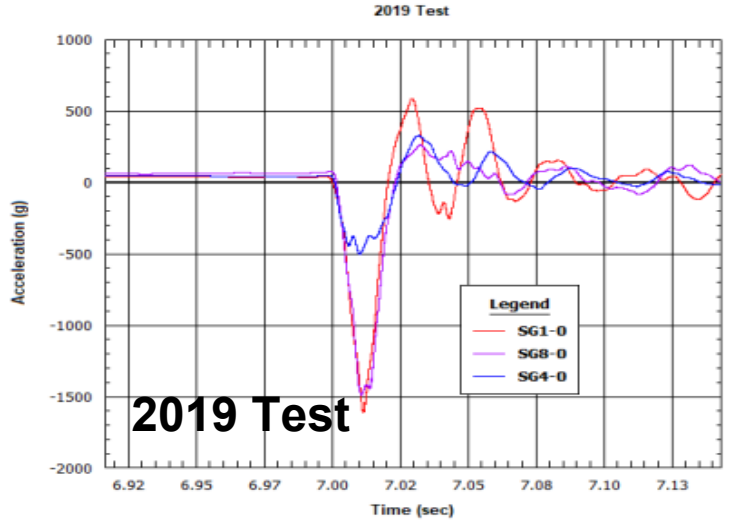


- In the 2019 test the spacer grid damage attenuated the slap down effect and reduced the ability of the rods to bend in vertical direction

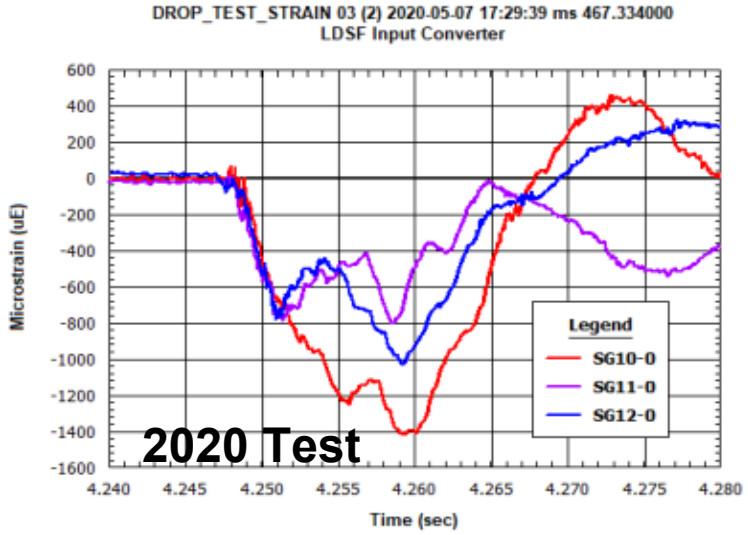
Strain Time Histories in 2020 and 2019 Tests

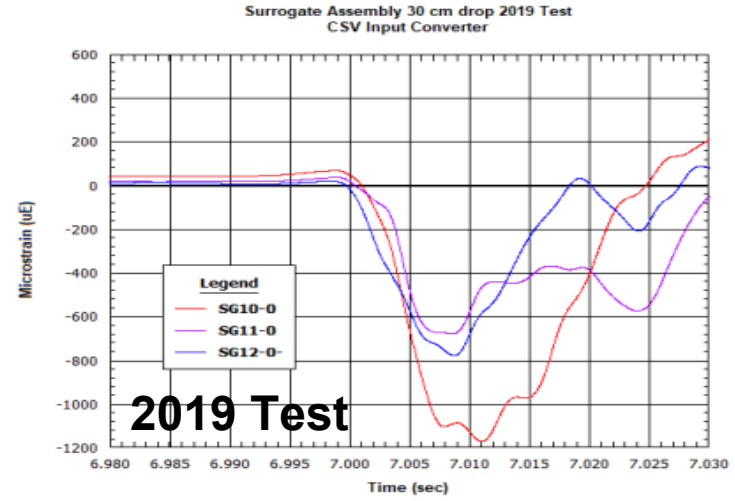
Assembly Top End



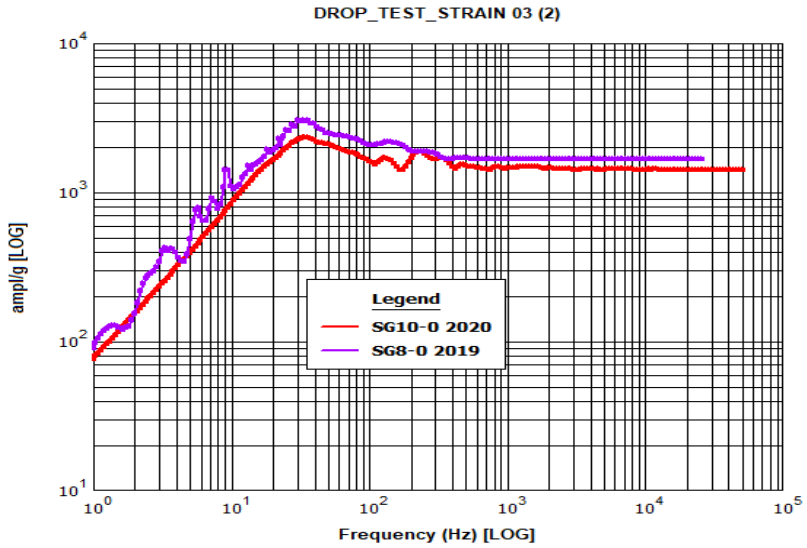


Assembly Bottom End





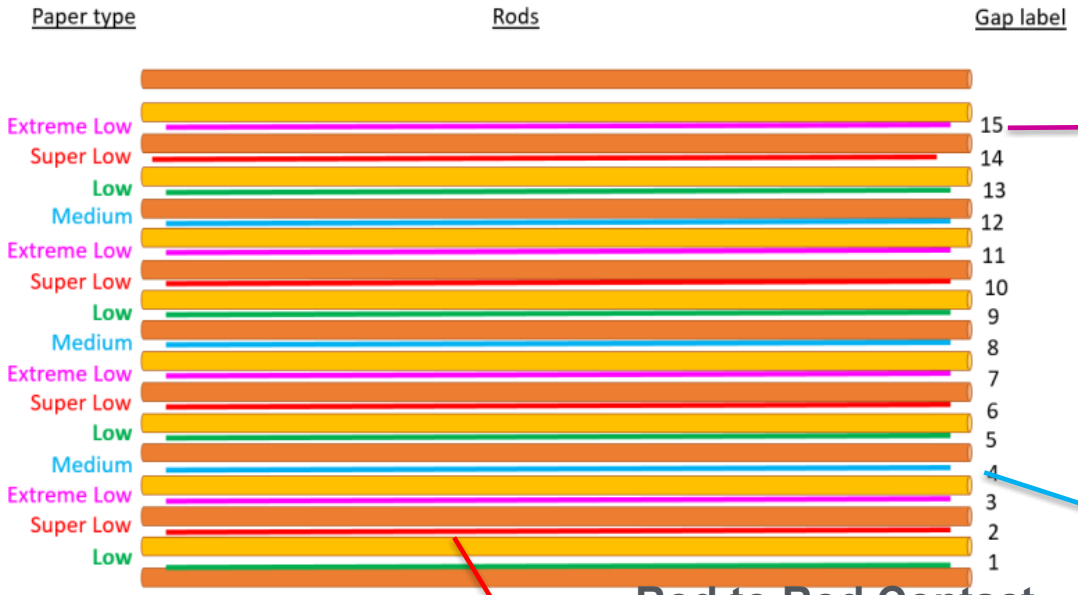
Max Peak Strain SRS in the 2020 and 2019 Tests.

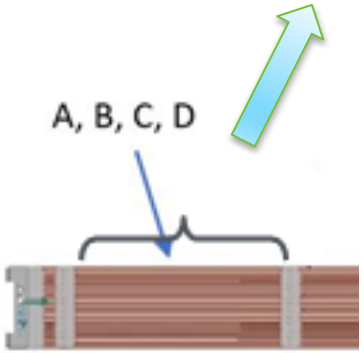


- The strain time histories in the 2020 and 2019 tests are very similar.
- The damaged surrogate assembly strain SRS (2019 test) envelops the responses of the new surrogate assembly (2020 test).

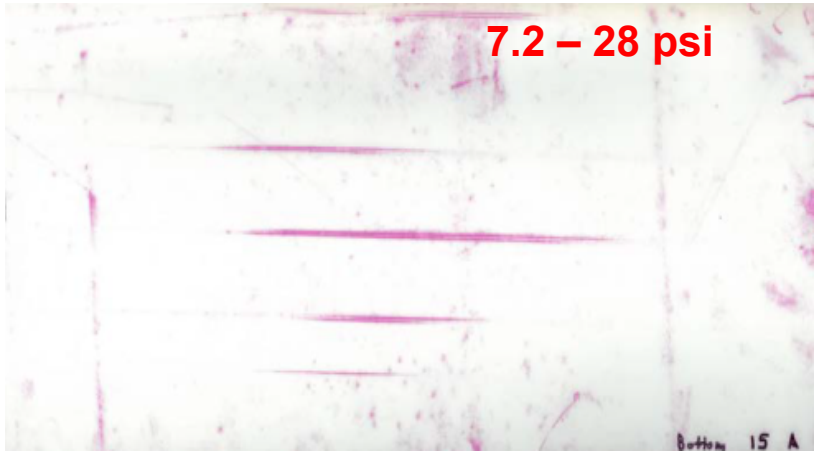
Pressure Paper Examples

Assembly Long Span, Bottom End

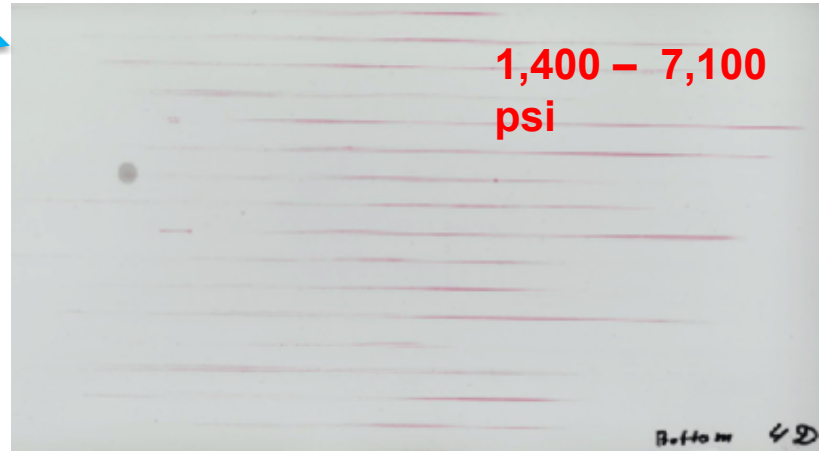




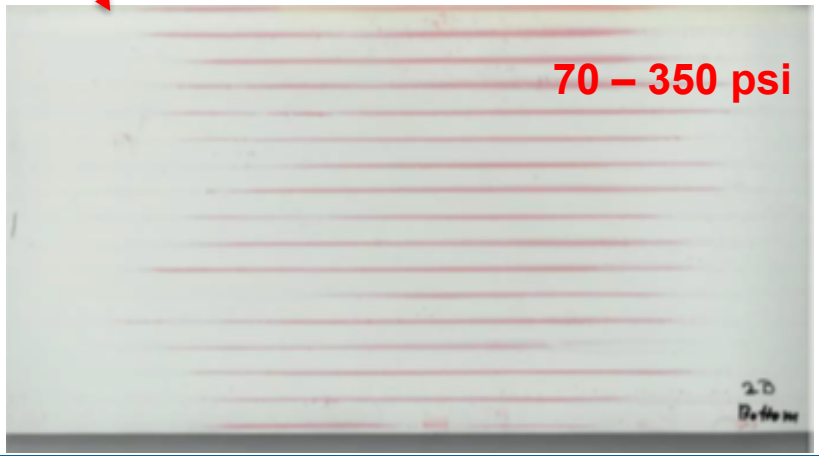
Rod to Guide Tube Contact



Rod to Rod Contact



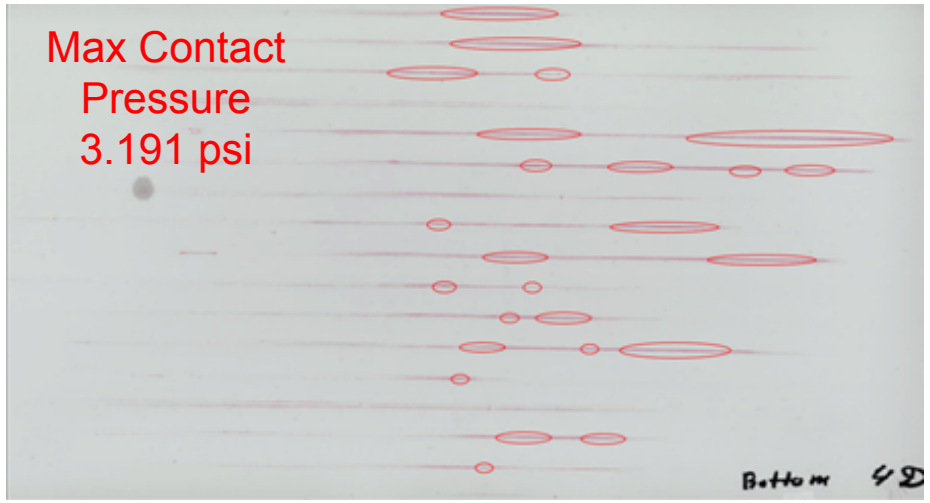
Rod to Rod Contact



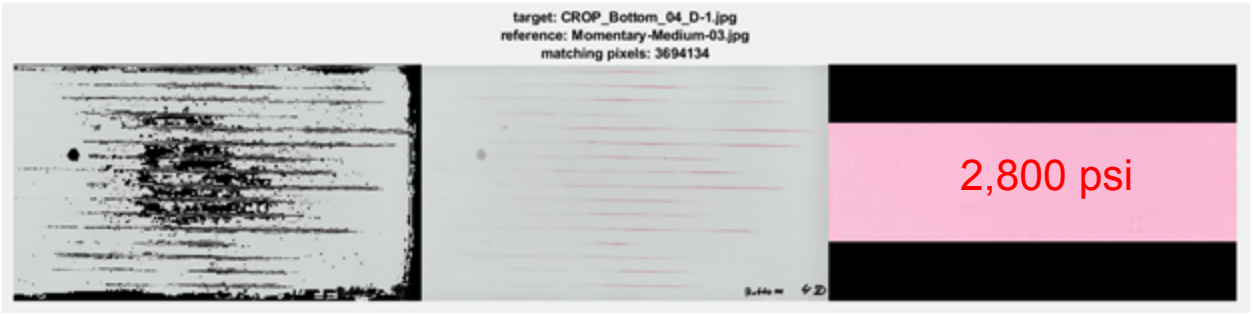
Pressure Paper Processing

- The pressure paper sheets from two short spacer grid spans were blank.
- A number of the pressure paper sheets from two long spans had the marks indicating rod-to-rod or rod to guide tube contact.
- The pressure paper scans were processed with Matlab to match the observed color to one of the color scale color and convert it to the corresponding contact pressure.

Maximum Contact Pressure Locations

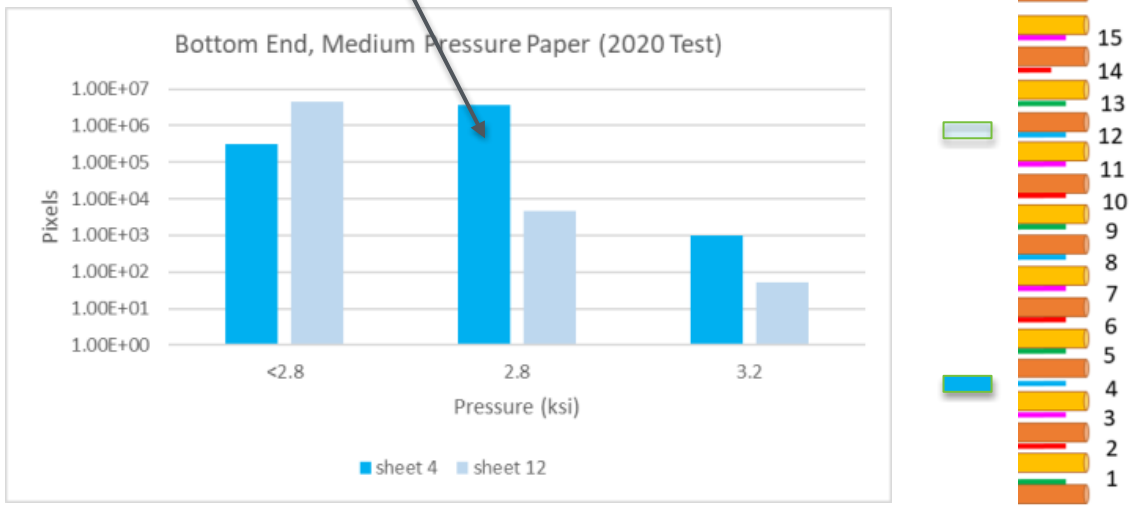


Example of the Pressure paper Processing



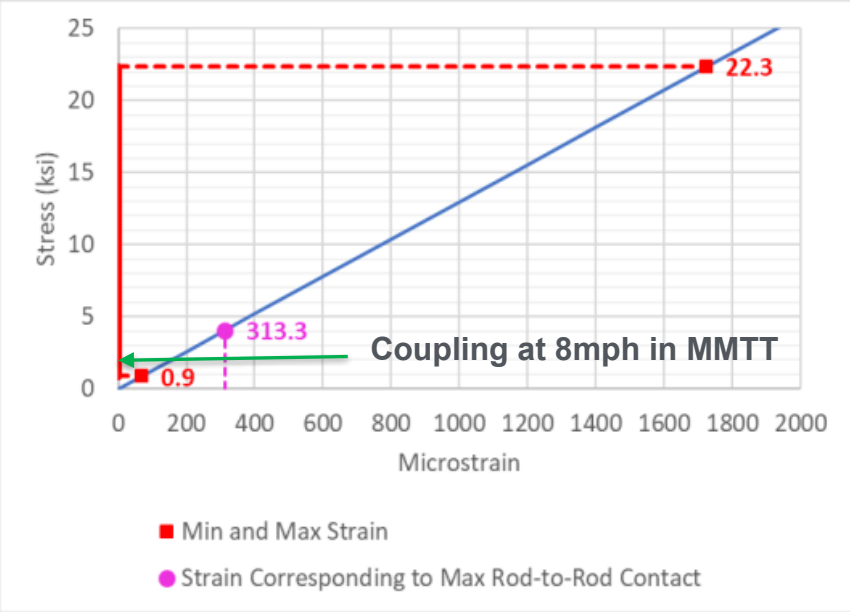
Processed Scan **Original Scan** **Color Scale Color**

- 3,694,134 pixels on the processed scan matched the selected color scale color

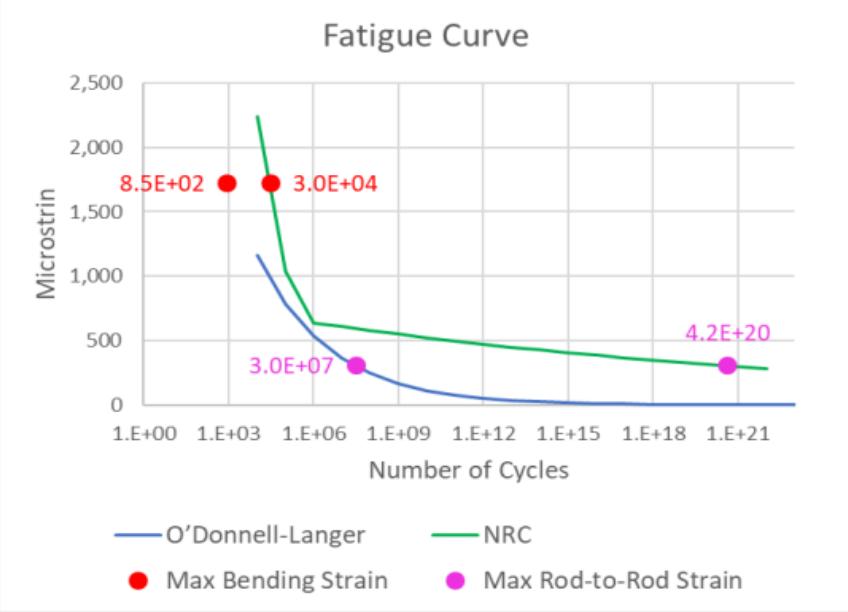


Conclusions

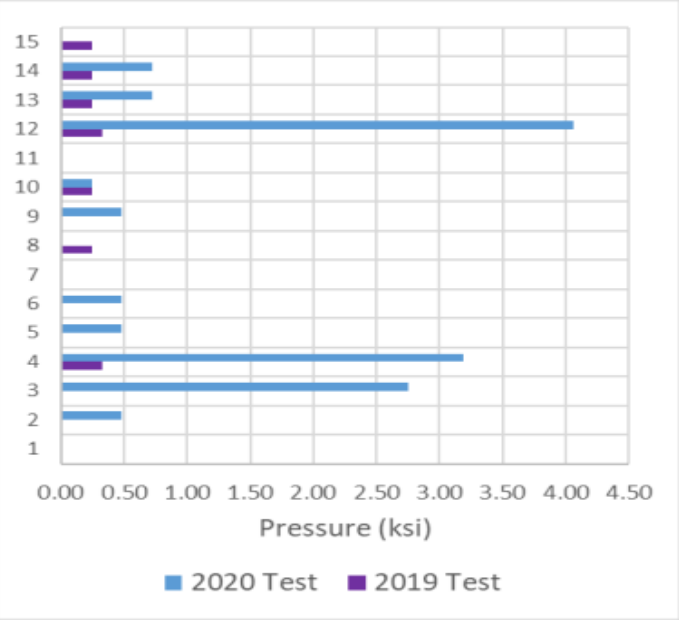
Closeup of the Stress-Strain



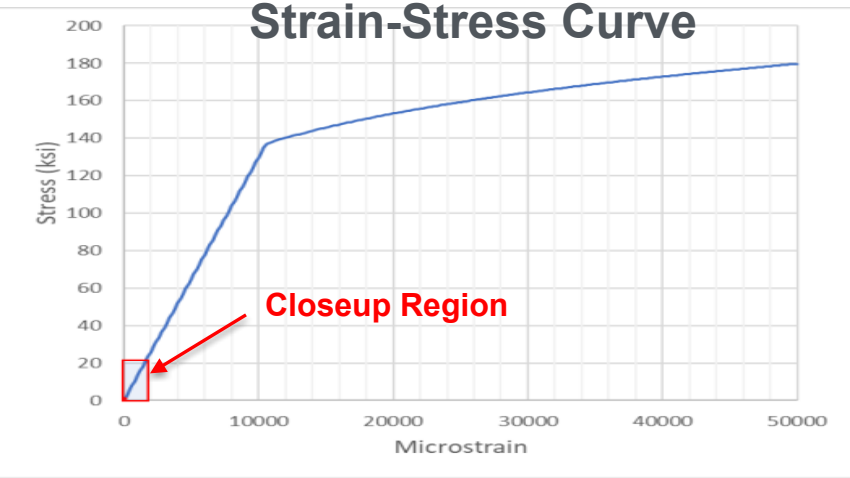
Fatigue Curve



Contact Pressure

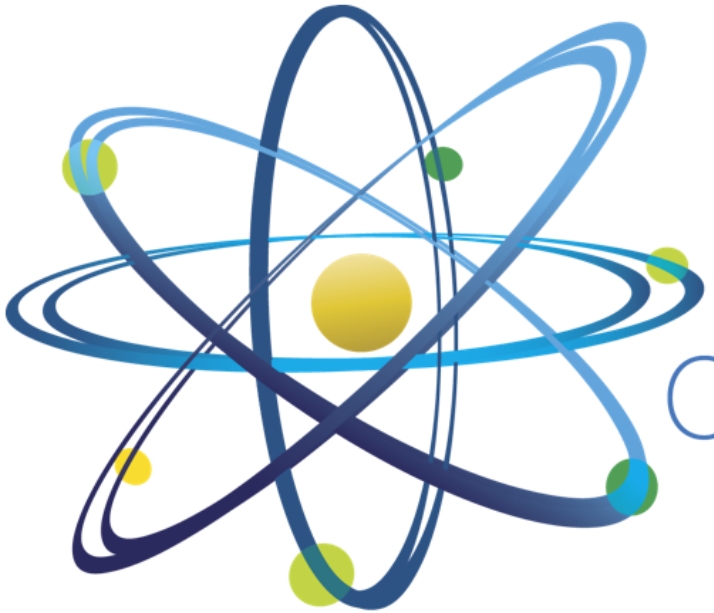


Strain-Stress Curve



- **The fuel rods will maintain their integrity after being dropped 30 cm or less more than once.**
  - The maximum rod-to-rod contact pressure was 4.1 ksi
  - The stress corresponding to the maximum strain value was 22.3 ksi (2020 Test) and 22.9 ksi (2019 Test).
  - The number of cycles to failure
    - Bending strain: ≥855
    - Rod-to-rod contact strain: ≥ 3.0E07

Questions?



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