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Design of a Resonant Plate Shock Fixture to Attenuate Excessive High-Frequency Energy Inputs

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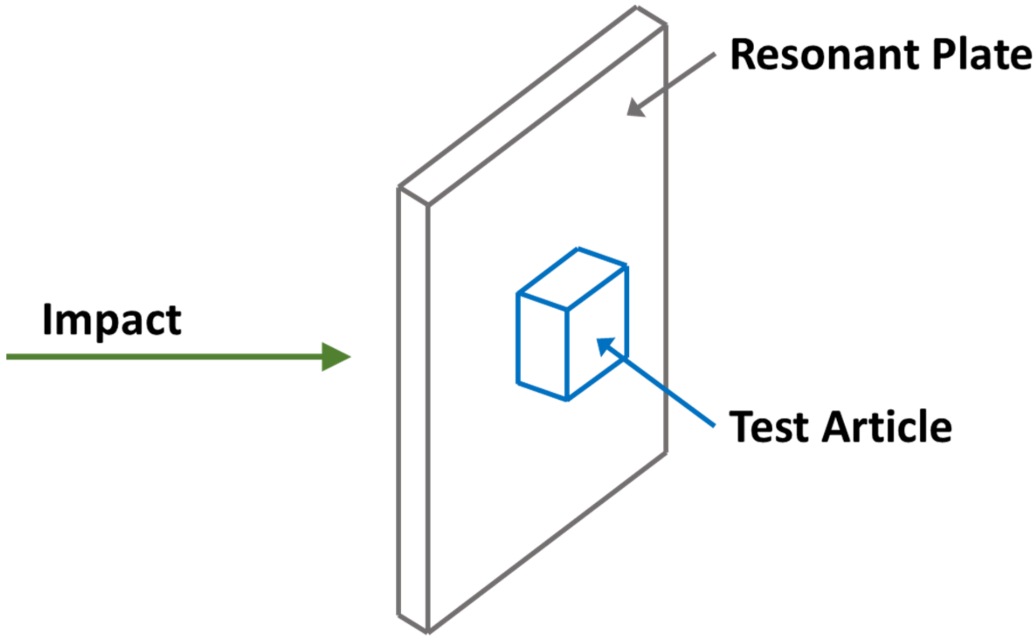
Outline

- Introduction and Overview of Resonant Plate Testing
- Discovery of the High-Frequency Excitation Problem
- Experimental Testing on Existing Plates
- New Resonant Plate Design
- Test Results from the New Plate
- Conclusions

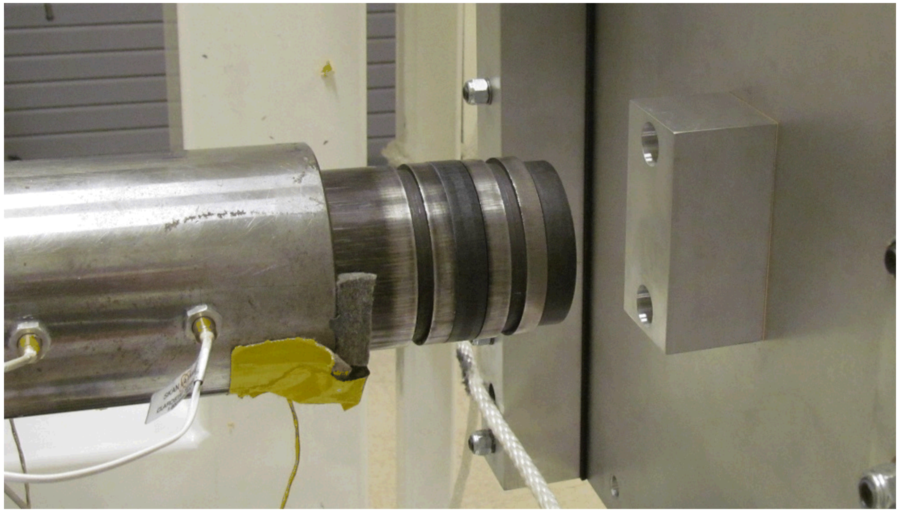
Introduction

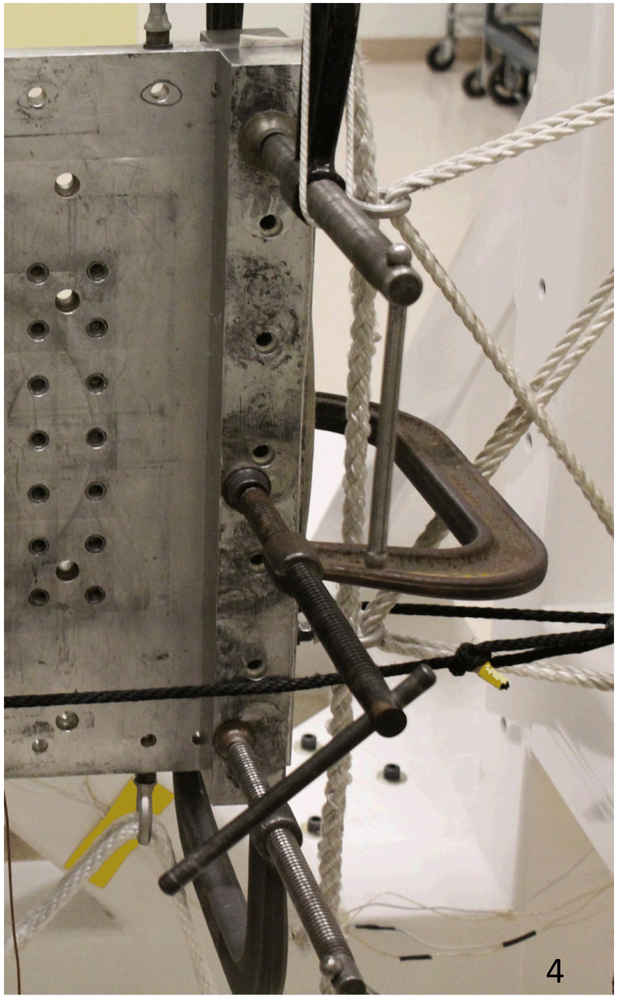
- Resonant plate testing is commonly used to simulate pyroshock events in the test lab
  - Safer and less expensive than actual pyroshock testing
- Testing is simple in theory, but the practical implementation is often more complex



Resonant Plate Testing Overview

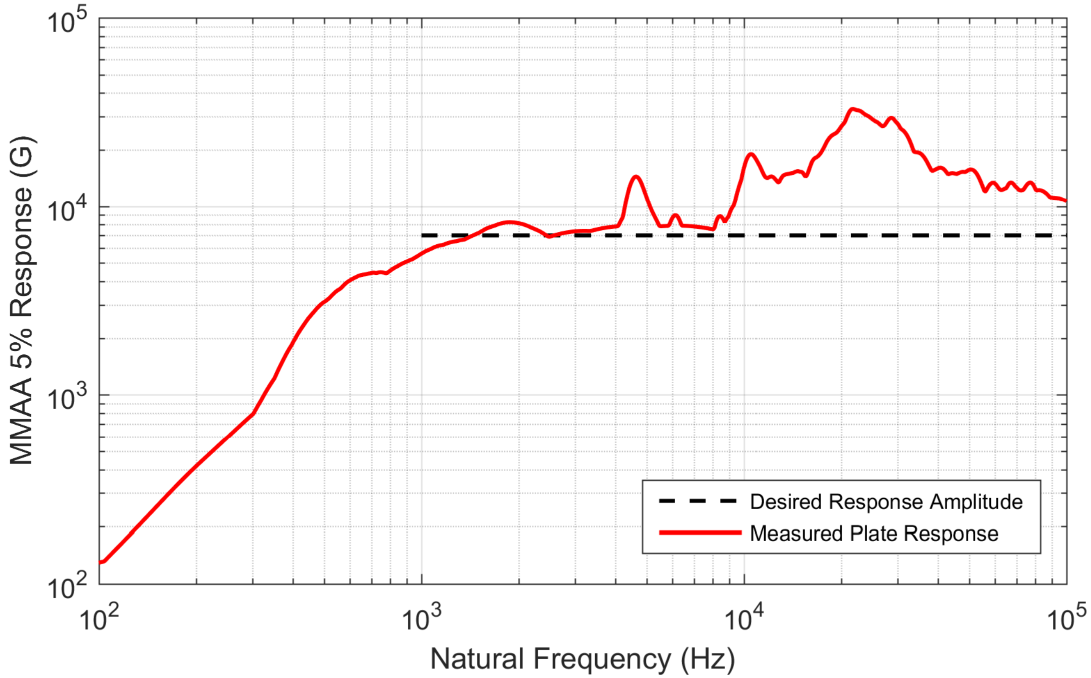
- Plate resonant frequency is tuned to the primary frequency in the SRS test requirement
  - Plate dimensions, thickness, and material
- Additional tuning done by adjusting:
  - Impact mass and velocity
  - Anvil programming material
  - Damping bars and material





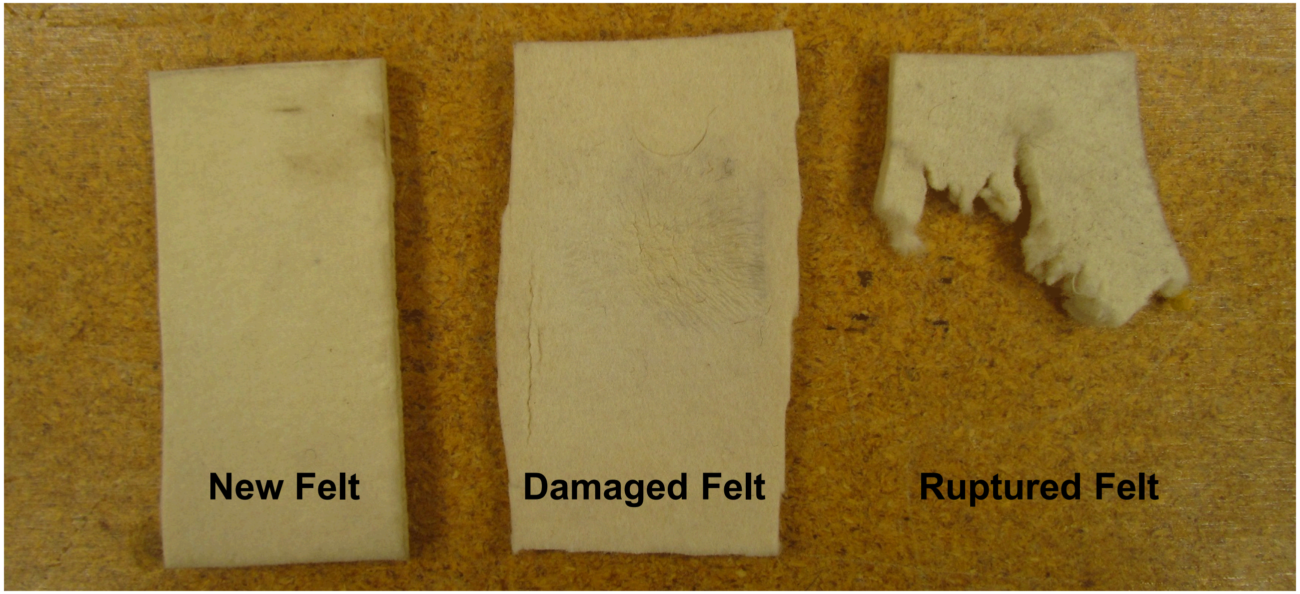
High-Frequency Excitation Problem

- Recent testing revealed undesirable energy input at frequencies above 10kHz
  - Response in the 20 – 30 kHz range is four times the desired level
  - Could have been missed with a poor choice of filters



Experimental Testing Results

- Experiments were conducted to determine the root cause of the excessive high-frequency energy
  - First set of tests performed to reproduce the problem
- Prevalent theory was programming material failure
  - Thin programming material frequently ruptures with high power resonant plate shock tests

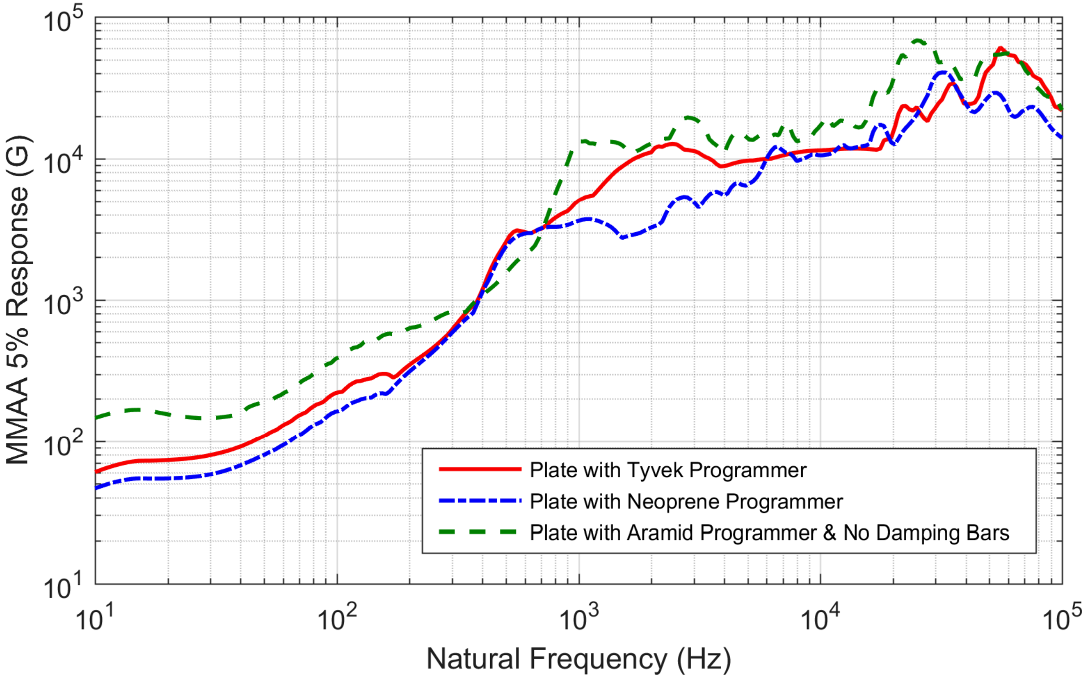


Experimental Testing Results

- Second tests focused on trying new programming materials
  - Cardstock
  - Felt
  - 75D Extra Hard Rubber
  - Brass
  - Delrin Acetal Resin
  - Wear Resistant Nylon
  - 90A Durometer Polyurethane
  - 70A Durometer Ultra-Strength Neoprene
  - Aramid Fabric
  - Tyvek® Fabric
- Some of these materials performed well, some not so well
- None of them corrected the problem

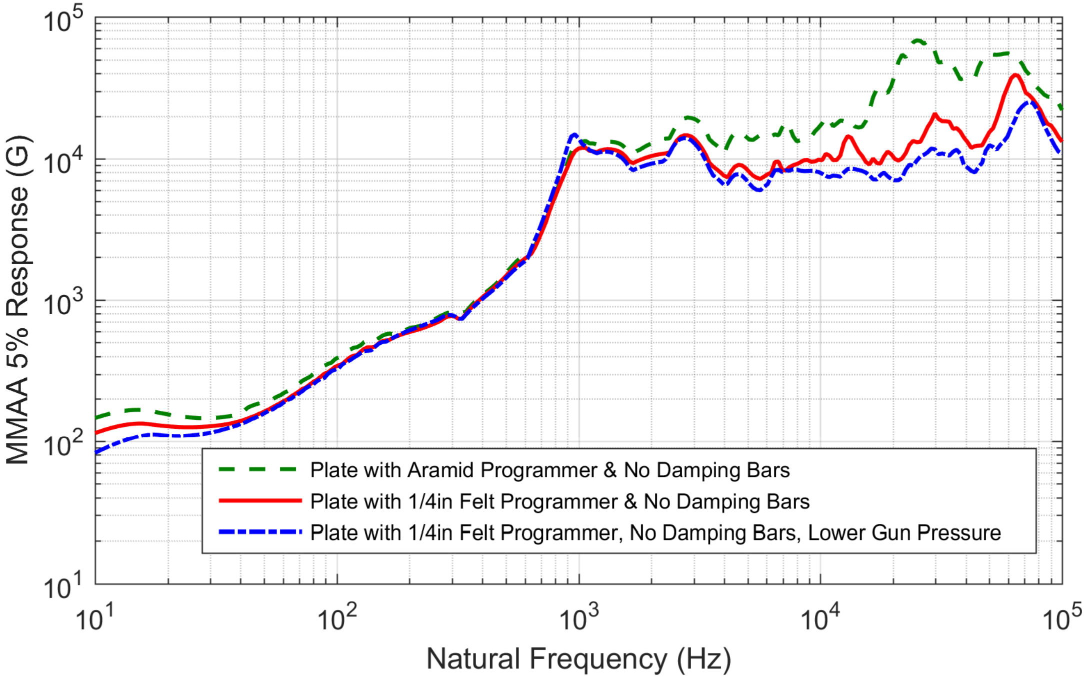
Experimental Testing Results

- All of the programming materials used for this test series were relatively thin and material rupture was common
- Plot shows test results from three programming material tests
  - Tyvek® fabric and Neoprene with the usual set of damping bars
  - Aramid fabric with damping bars removed



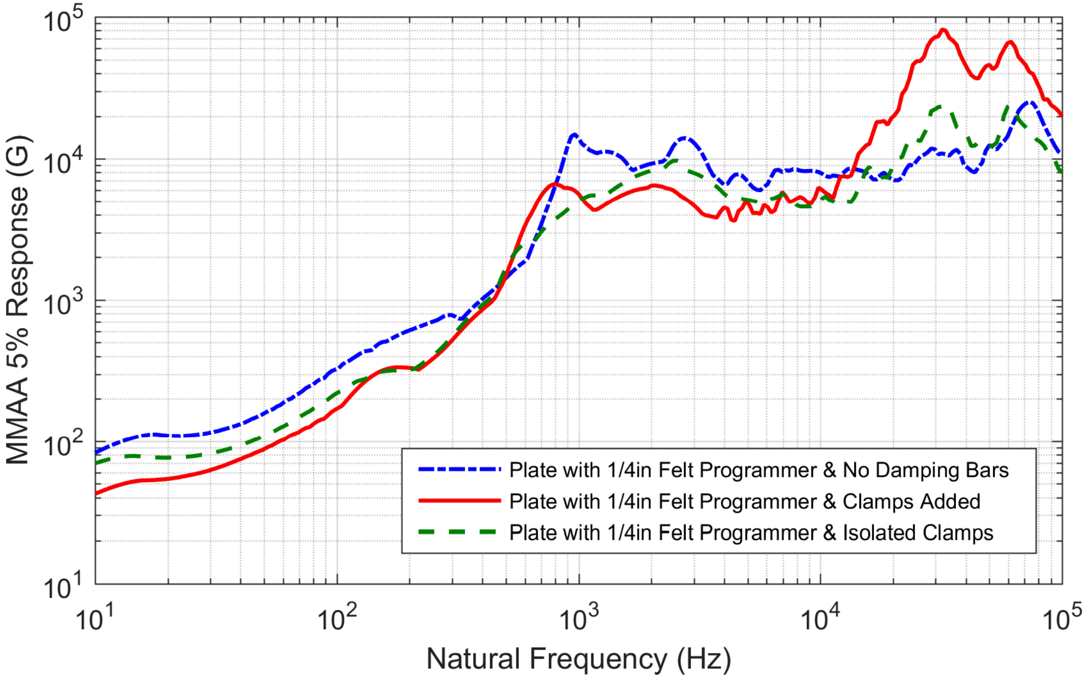
Experimental Testing Results

- Continued testing without damping bars
- Returned to using the traditional thicker felt programmer
  - Results looked immediately better at the higher frequencies



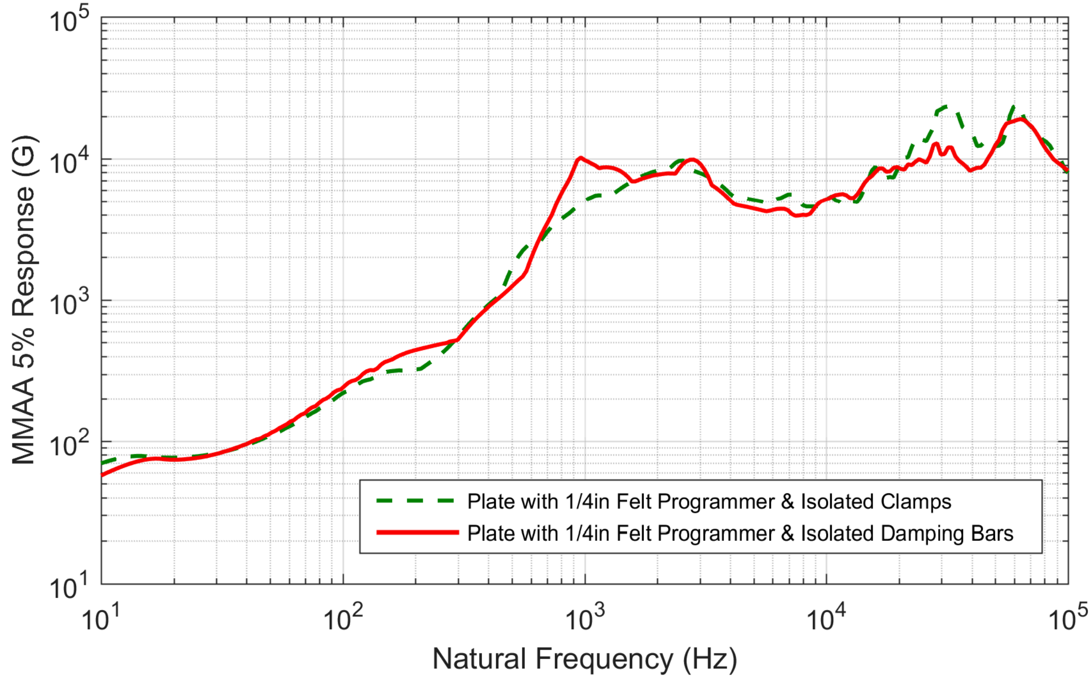
Experimental Testing Results

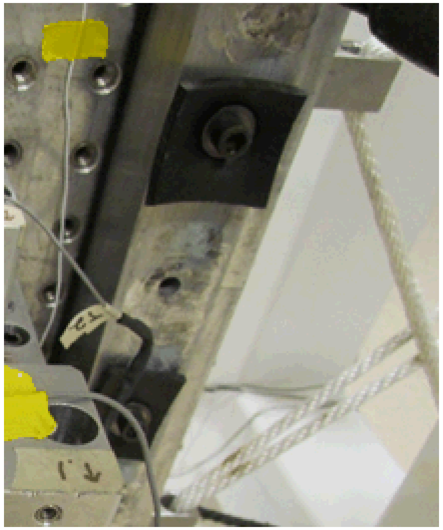
- Wanted to add mass back to the plate
  - Installed four C-clamps at plate corners
  - Significant high-frequency response immediately reappeared
- Repeated test with thin rubber between plate at C-clamp
  - Results significantly improved



Experimental Testing Results

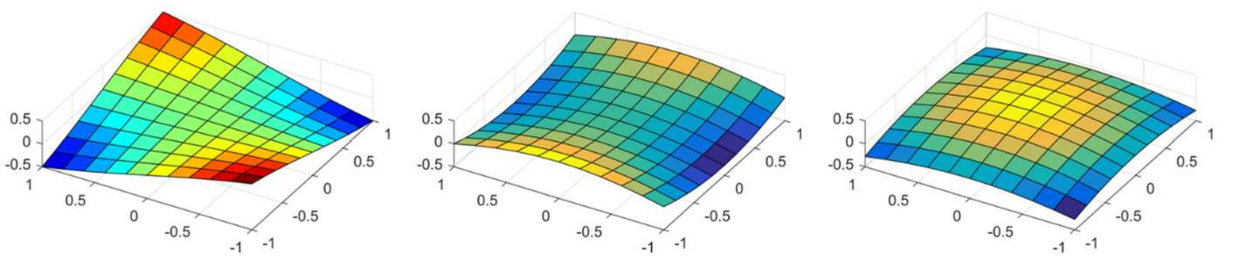
- Removed C-clamps and added damping bars back
  - Made a simple damping bar isolation system
  - Isolated bars top and bottom with polyurethane
- Damping bars gave better knee-frequency response
  - High-frequency response still very well controlled





750Hz Resonant Plate Design

- Shortly after this research, a request for a new 750Hz resonant plate was made
  - Considered a good opportunity to incorporate new design features to help attenuate high-frequency excitation in the 10 – 100kHz range
- Physical size determines primary response
  - Material needed to be aluminum
  - Sized comparable to existing 500Hz and 1kHz resonant plates
  - Frequency can be determined by closed-form techniques
- Design was 19.75 inches square, 1.50 inches thick, 6061-T6 Al

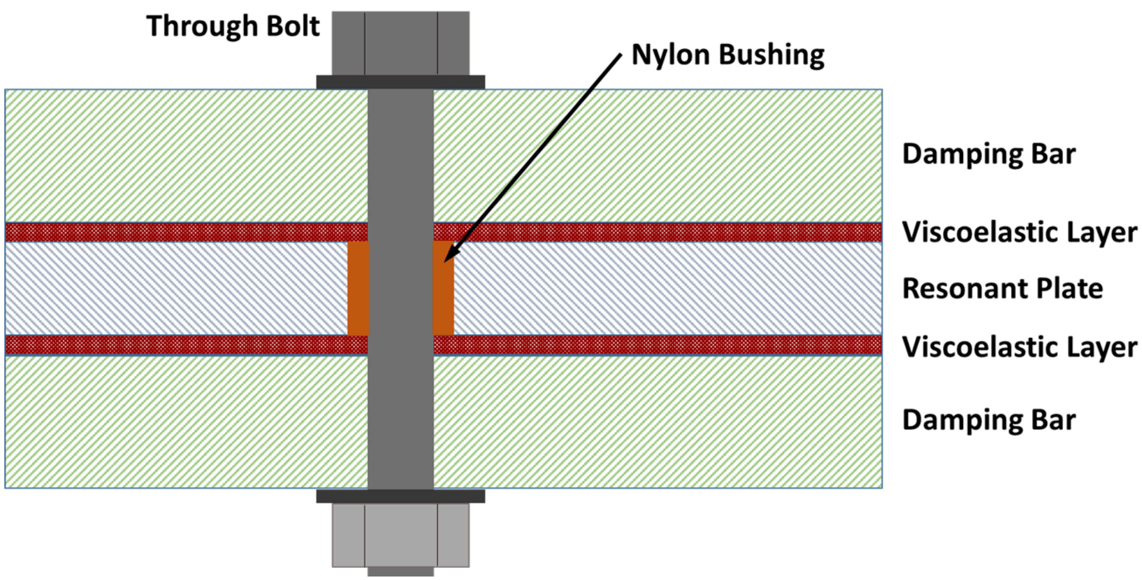


Mode 1 Mode 2 Mode 3

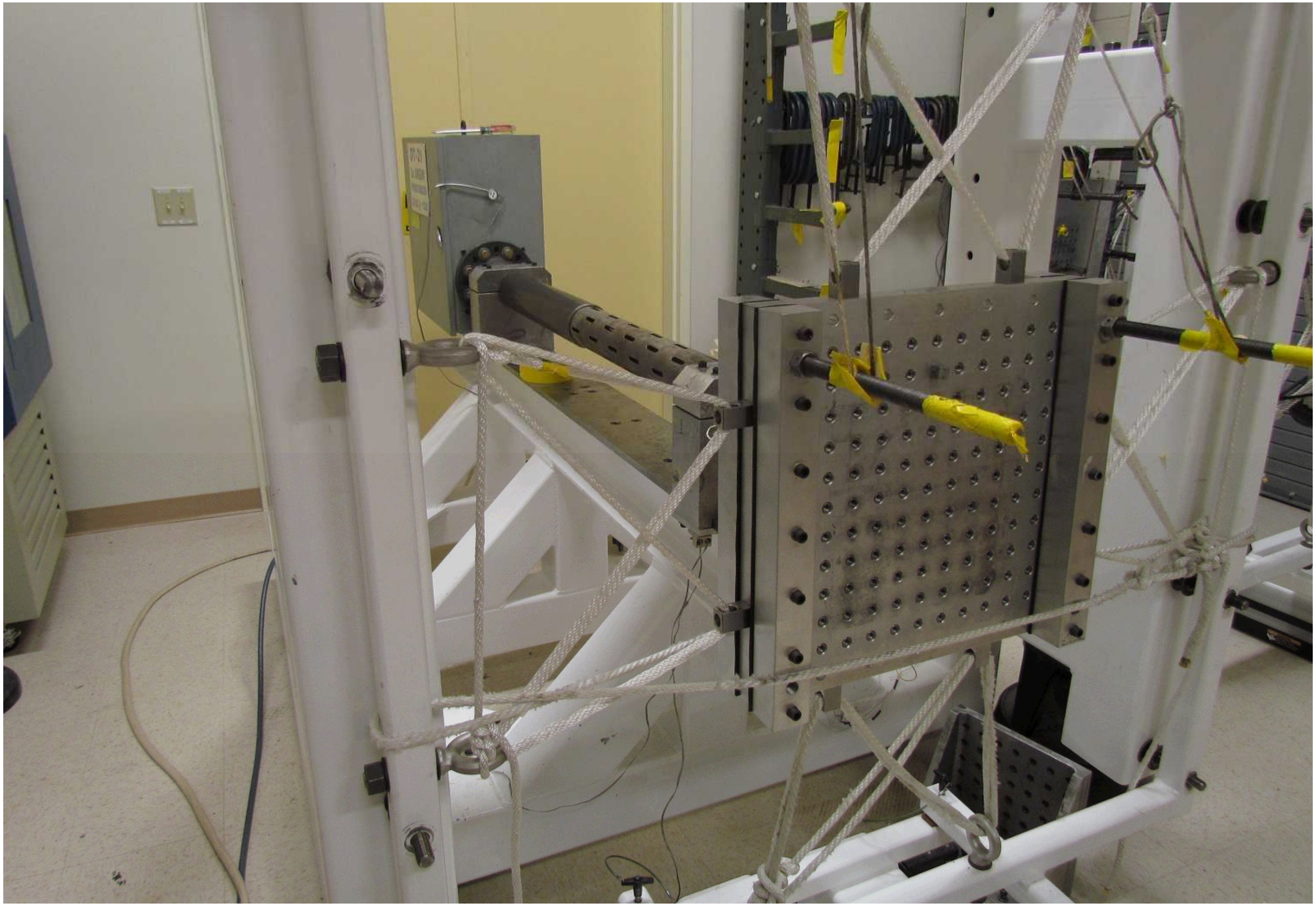
$$f_i = \frac{\lambda_i^2}{2\pi l^2}\sqrt{\frac{Et^3}{12\gamma(1-\nu^2)}}$$

750Hz Resonant Plate Design

- Damping bar attachment methodology
  - Damping bar isolation scheme is a refinement of the
  - Damping bars are bolted in place rather than using C-clamps
  - Nylon bushings used to isolate attachment bolts from resonant plate
  - Viscoelastic layers between damping bars and resonant plate, similar to what was used before



750Hz Resonant Plate As-Built



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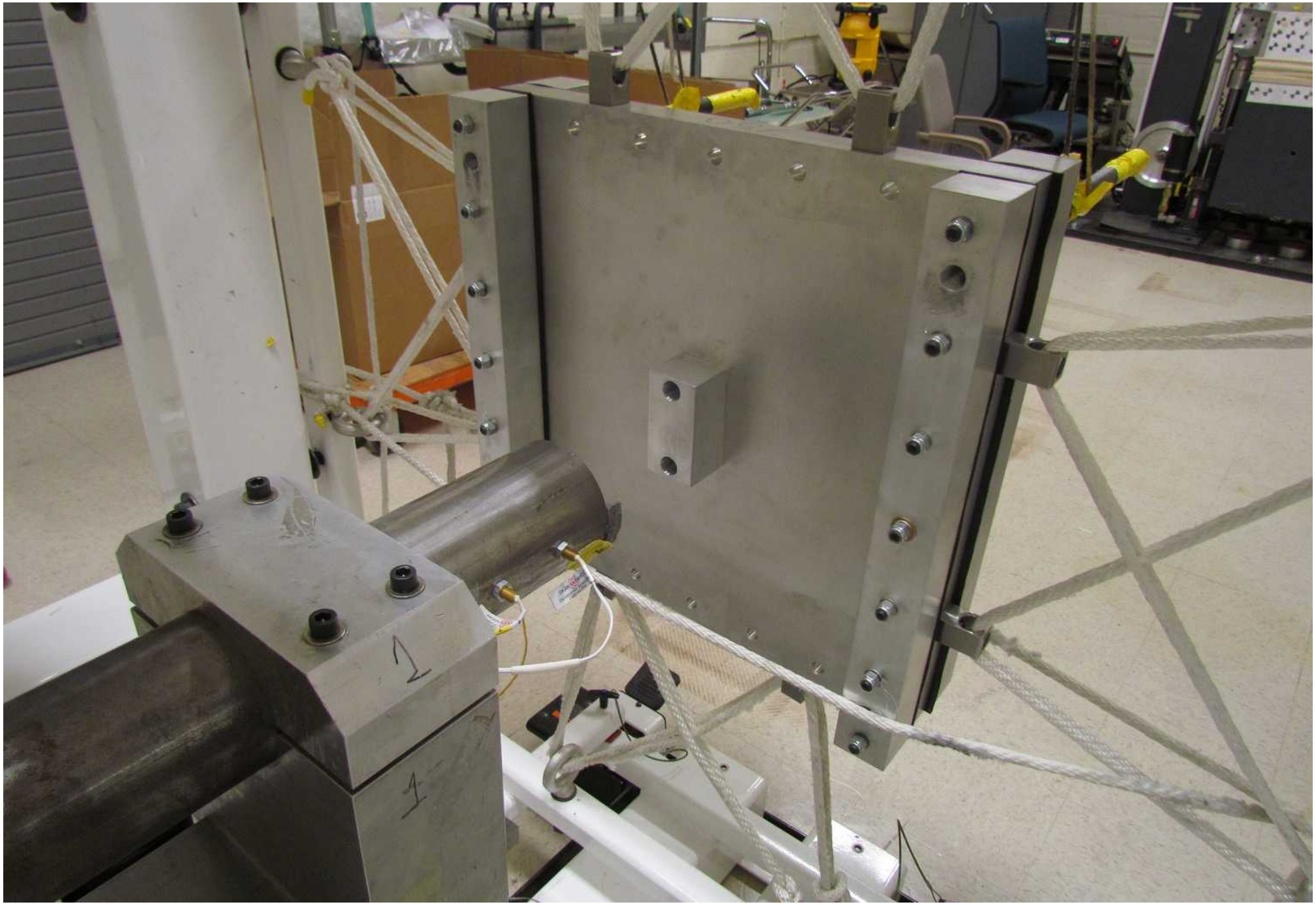
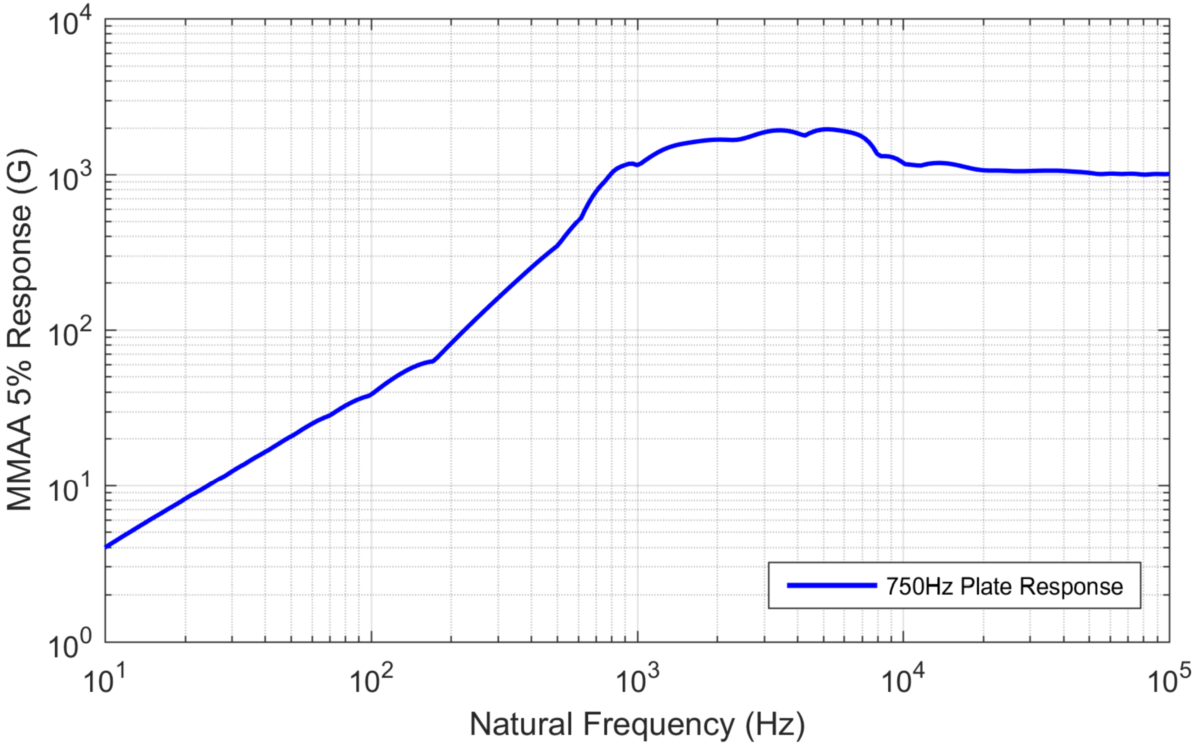


750Hz Resonant Plate Test Results

- Plate response from initial tests using a representative test mass



Conclusions

- Conclusions
  - High-frequency energy beyond 10kHz was causing significant concern with existing resonant plate shock testing
  - An test series was performed to identify and suggest corrections for the high-frequency energy problem
  - A new resonant plate was designed and tested that shows significant attenuation at frequencies in the 10 – 100kHz range