SAND2024-14696C

Sandia National Laboratories

Exceptional service in the national interest

MINIATURIZED RESONANT PLATE TESTING WITH HIGH SHOCK LOADS

94th Shock & Vibration Symposium, Dallas TX

Carl Sisemore, ShockMec Engineering LLC

Elliott Pelfrey, Sandia National Laboratories

3 – 7 November 2024

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

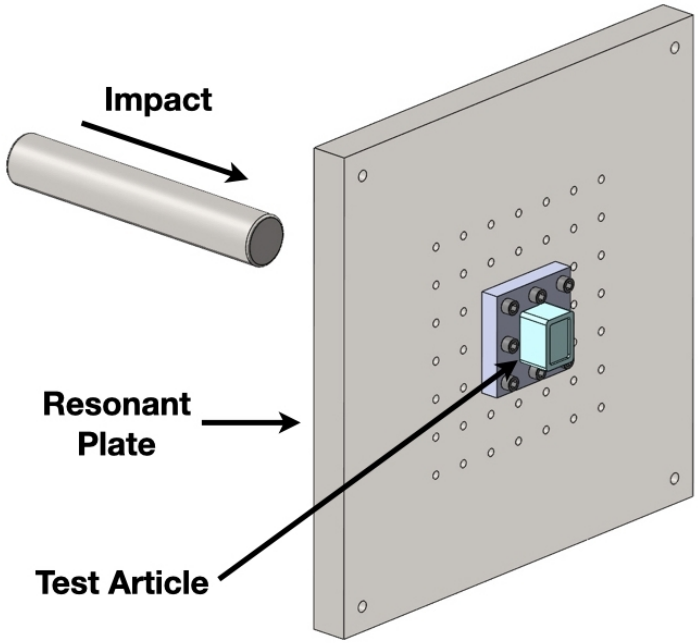
Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525

INTRODUCTION

- Resonant plate shock testing overview
- Overview of experimental testing with short gas guns
- Review of high-frequency resonant plate test data
- Review of low-frequency resonant plate test data
- Comparison of long and short barrel gas gun results
- Estimates of small gun impact velocity
- Conclusions

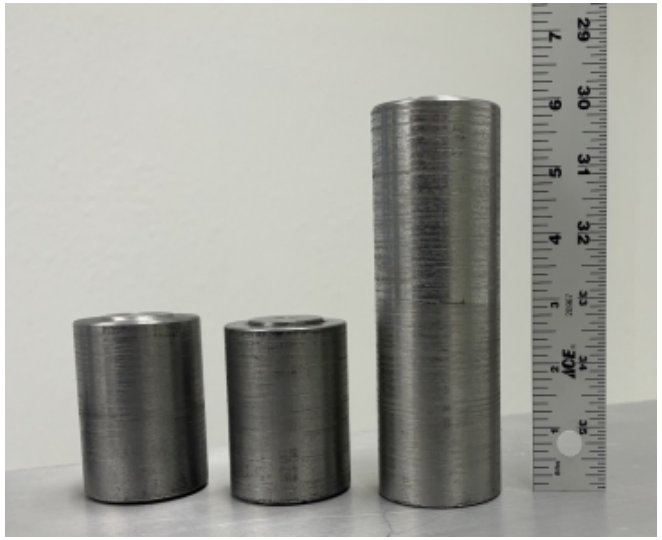
RESONANT PLATE SHOCK TESTING

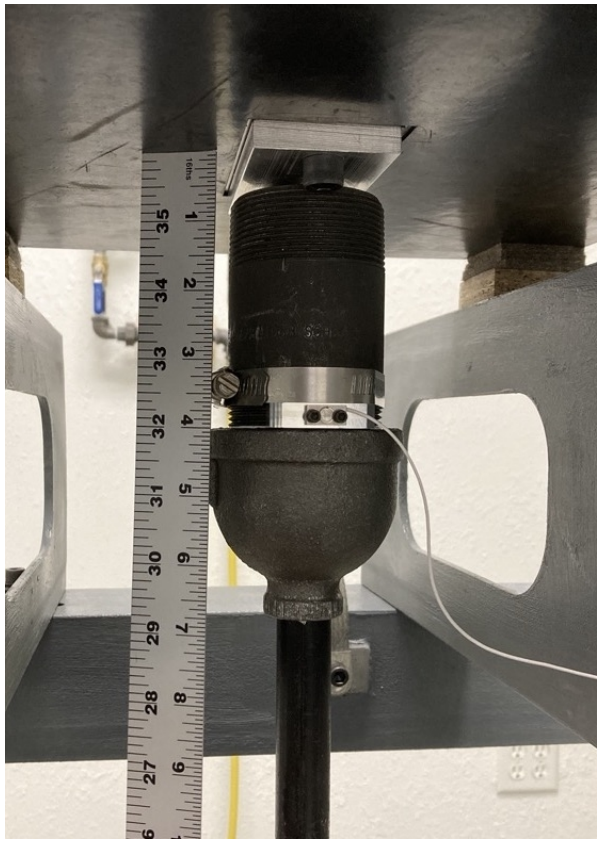
- Resonant plate testing is commonly used to simulate pyrotechnic shock events in the test lab
- Test article is attached to a tuned resonant plate and the plate is struck with a hammer
- Previous work has shown that lightweight projectiles can effectively ring resonant plates
- Can resonant plates also be rung with very short pneumatic hammer systems?
- Testing was performed on the ShockMec Engineering High-G 1 shock machine

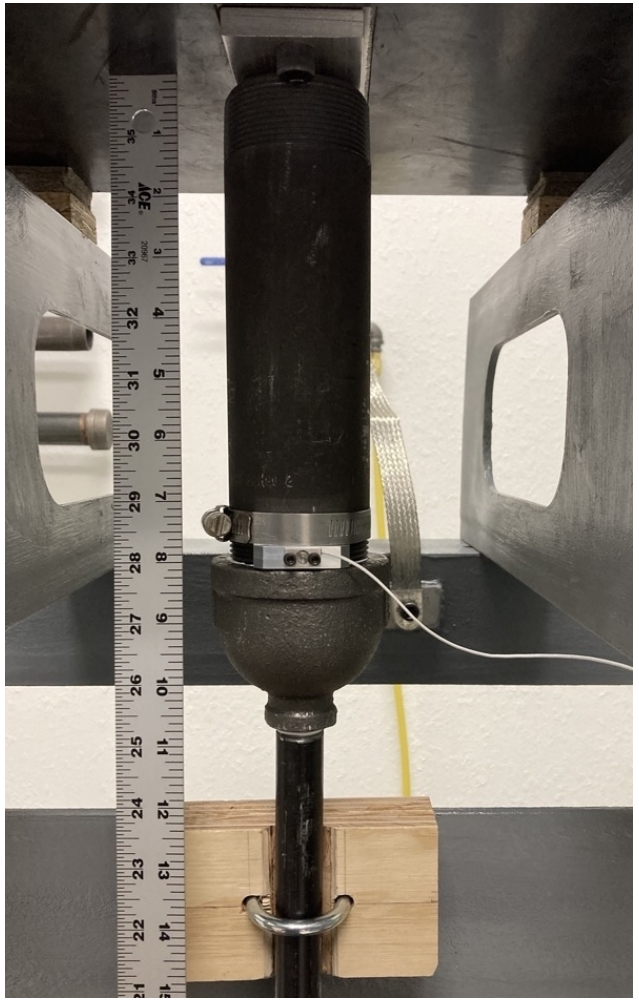


8 INCH AND 4 INCH GUN BARREL CONCEPTS

- Two short prototype gas gun barrels were manufactured for this research
  - Nominally 8 inches and 4 inches long
- Three projectile weights were made to match
  - 5 lbf and 2 lbf
- Tests performed on two resonant plates
  - 3 kHz and 600 Hz resonant plates

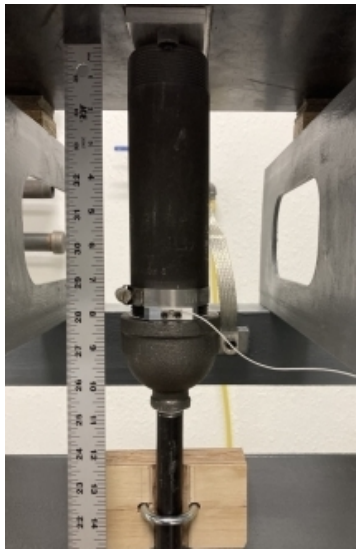


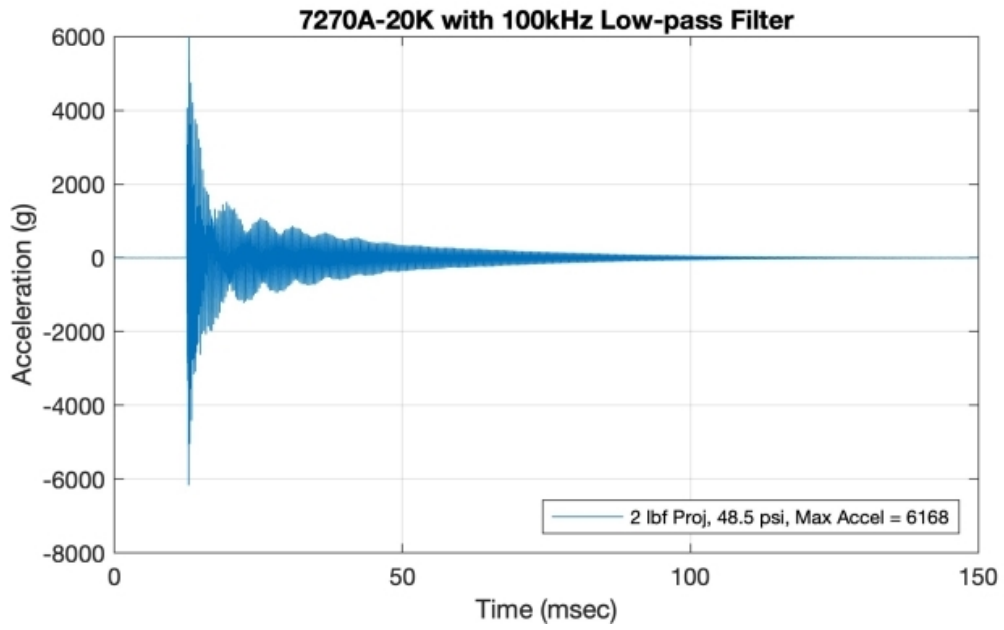


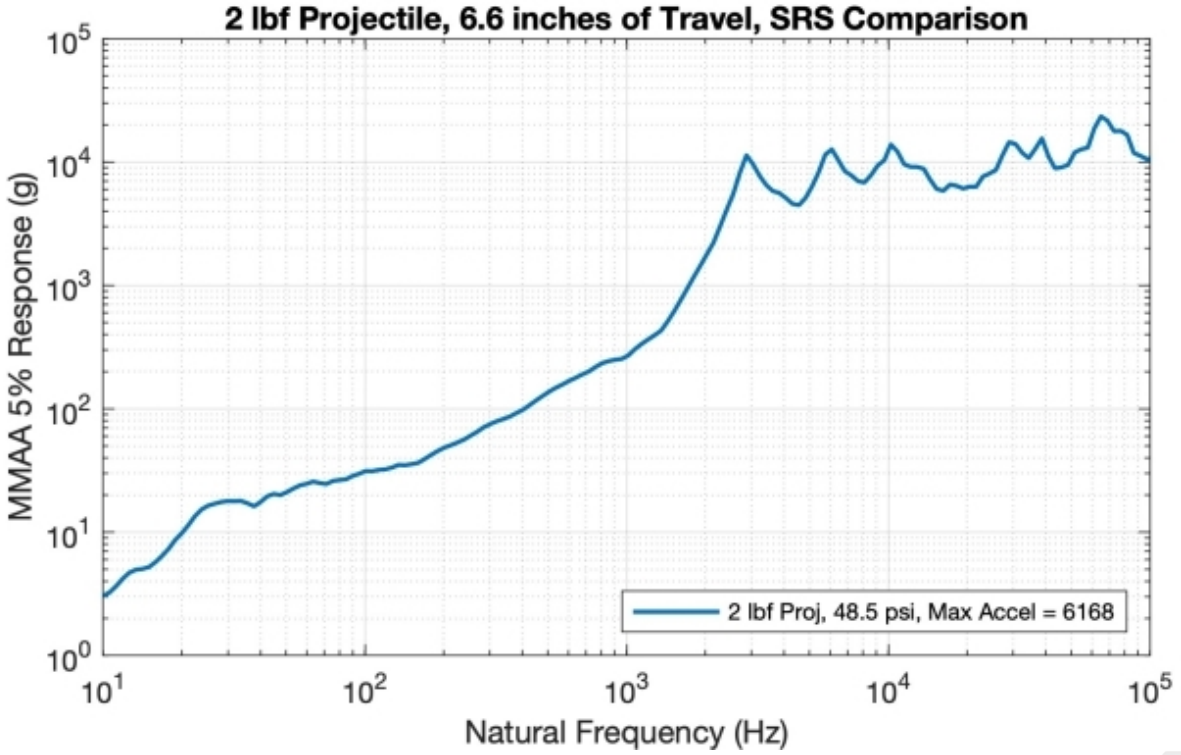


8 INCH GUN HIGH-FREQUENCY RESULTS

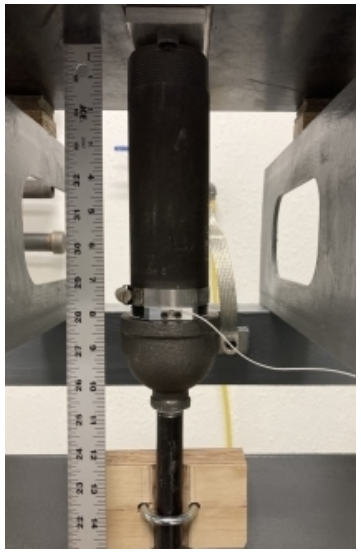
- Initial results from a 2 lbf projectile with 6.6 inches of travel against a 3 kHz resonant plate launched with 48.5 psi gun pressure
- Peak acceleration of 6168g
- SRS peaks exceed 10,000g



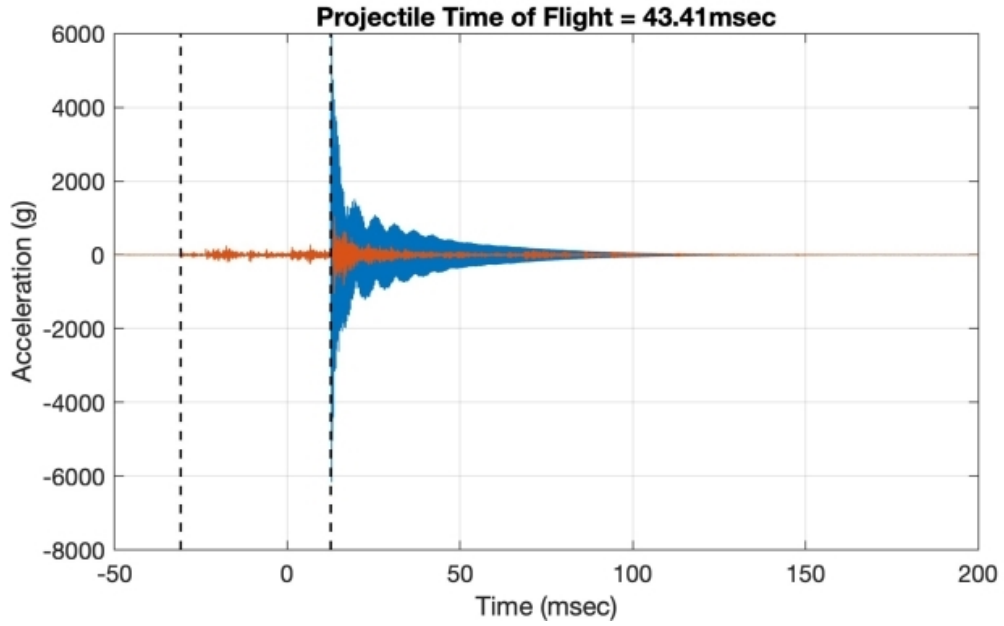


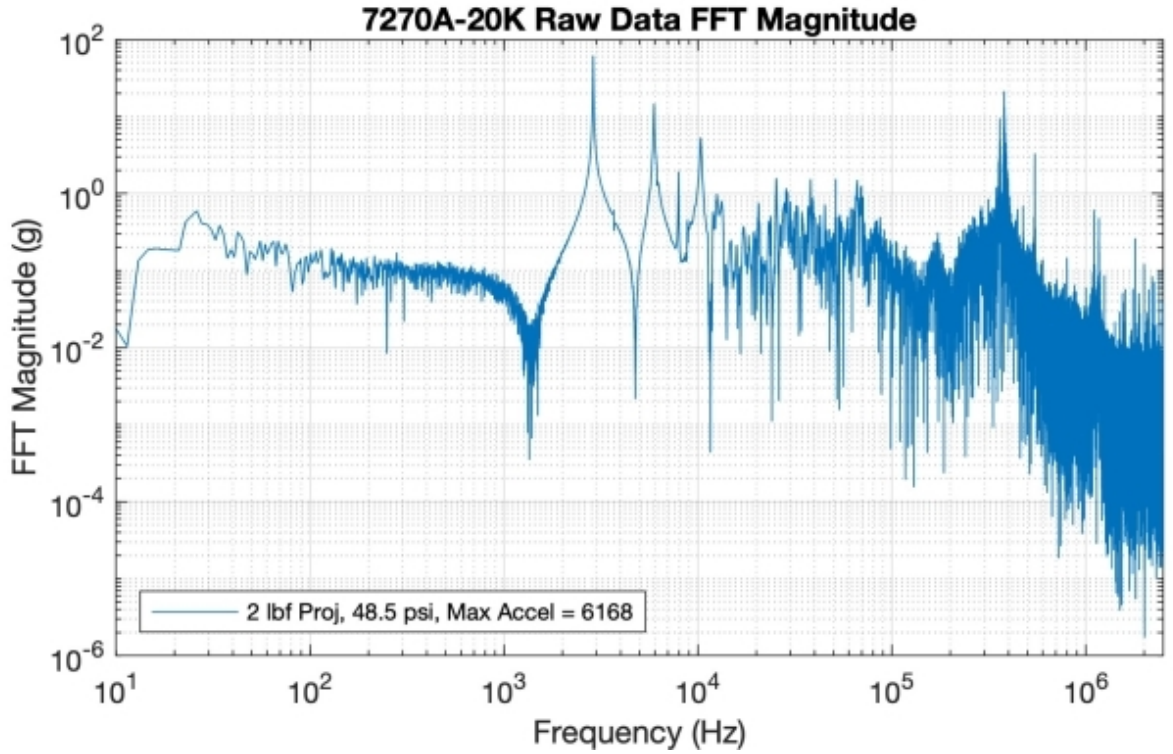


8 INCH GUN HIGH-FREQUENCY RESULTS



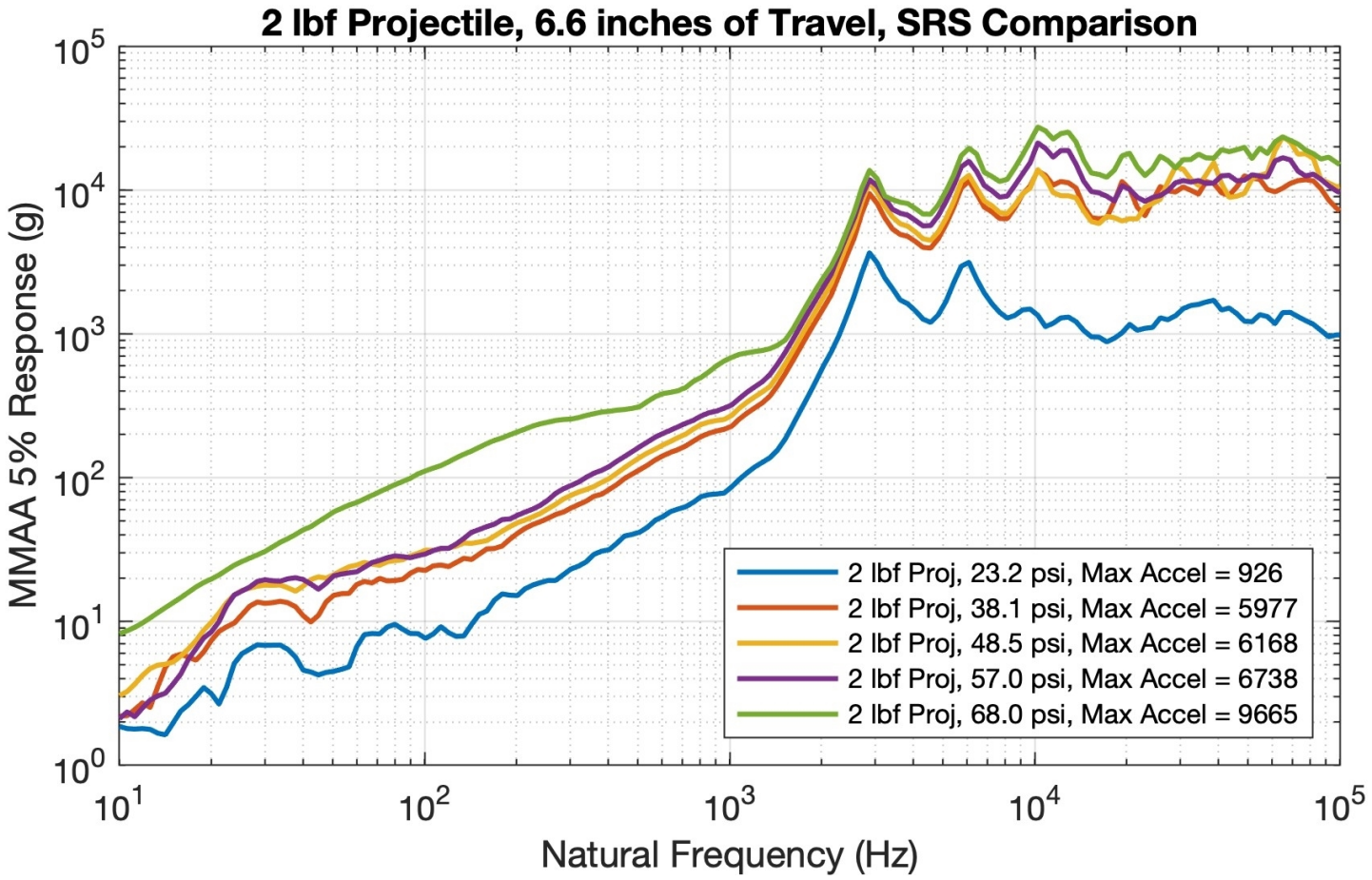
- Fourier transform results indicate that the 3 kHz resonant plate was well rung by the small projectile and the short travel distance
  - 2 lbf projectile, 6.6 inches of travel, 48.5 psi launch
- Time of flight estimated at 43.4 msec
- Estimated impact velocity of 24 ft/s





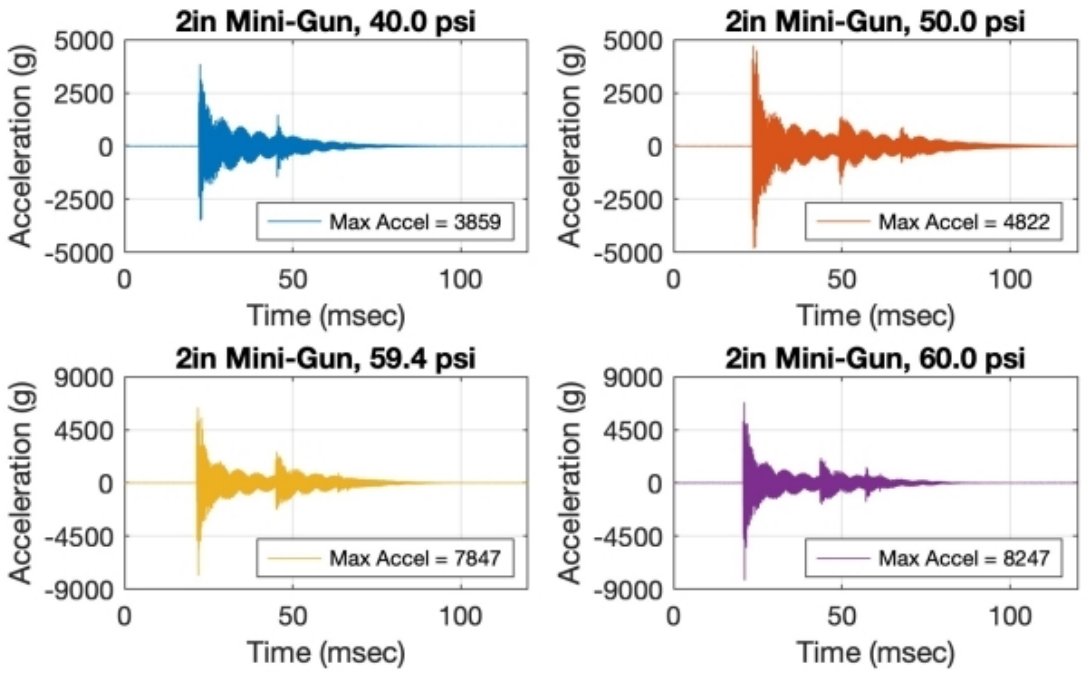
8 INCH GUN VARIABLE PRESSURE SHOT RESULTS

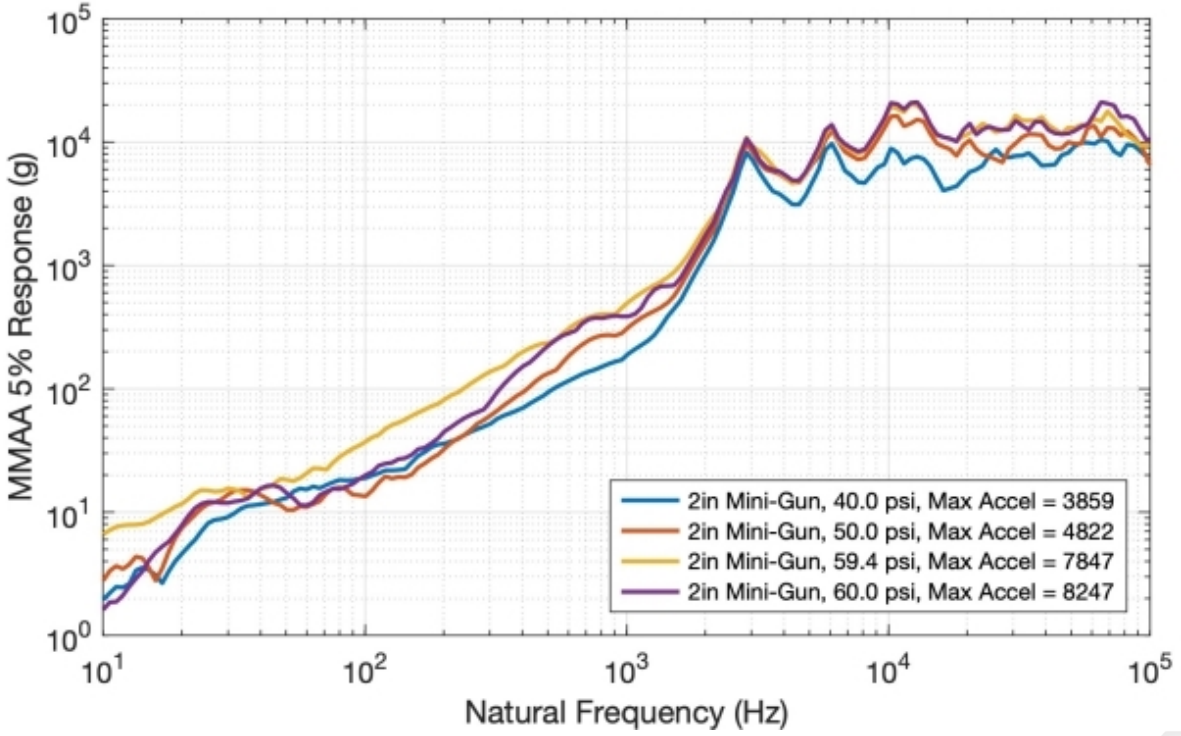
- Tests at various gun pressures using the same short barrel gun, projectile, and 3 kHz plate
- Wanted to verify plate mode consistency and that amplitude increases with pressure



4 INCH GUN HIGH-FREQUENCY RESULTS

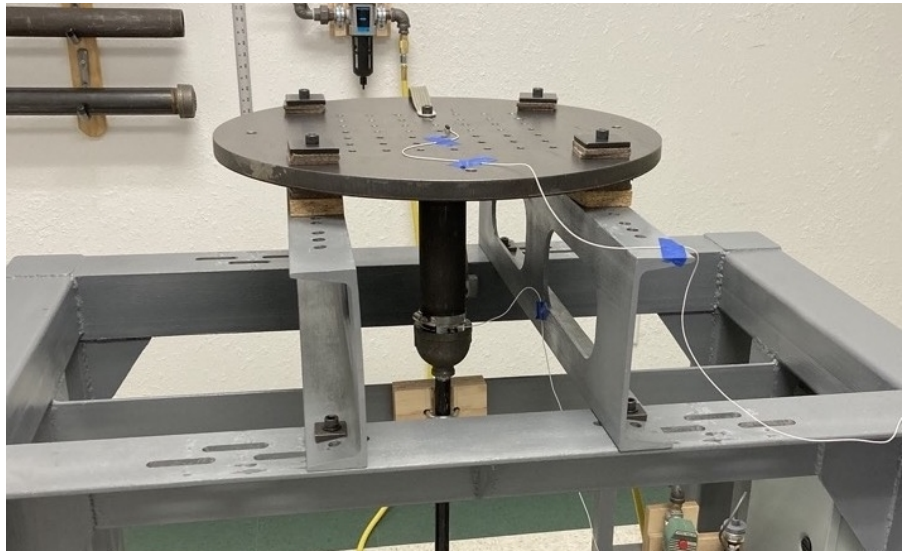
- Results from a 2 lbf projectile with 2.75 inches of travel against a 3 kHz resonant plate launched with various gun pressures
- Peak accelerations ranged from 3859g up to 8247g
- Did have some issues with multiple impacts due to short distance and lack of gas venting in this configuration

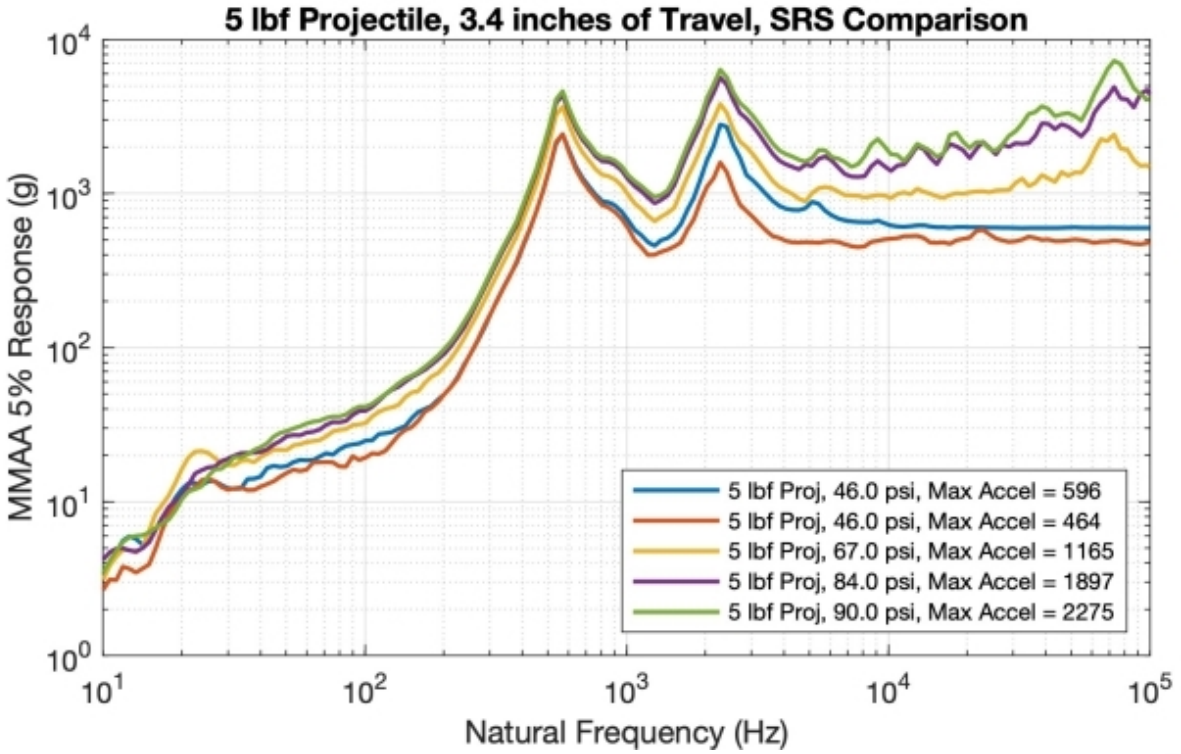




8 INCH GUN LOW-FREQUENCY RESULTS

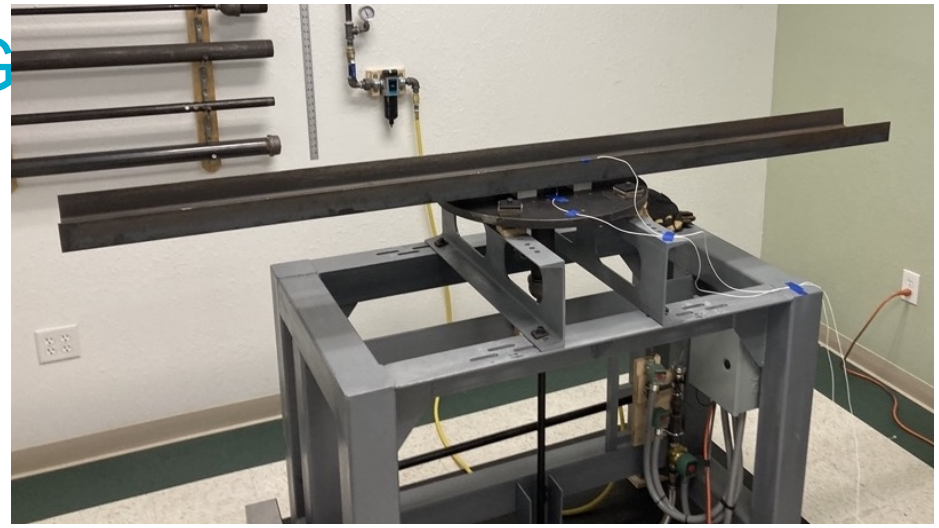
- Switched to a 600 Hz round steel resonant plate to verify low-frequency capability
  - Bare plate is 20 inches in diameter, ¾ inches thick, and weighs 76 lbf
- Used the longer 5 lbf projectile, resulting in only 3.4 inches of travel before impact
- Results are a little lower than what might be obtained with a heavier projectile or a faster impact speed but still quite good

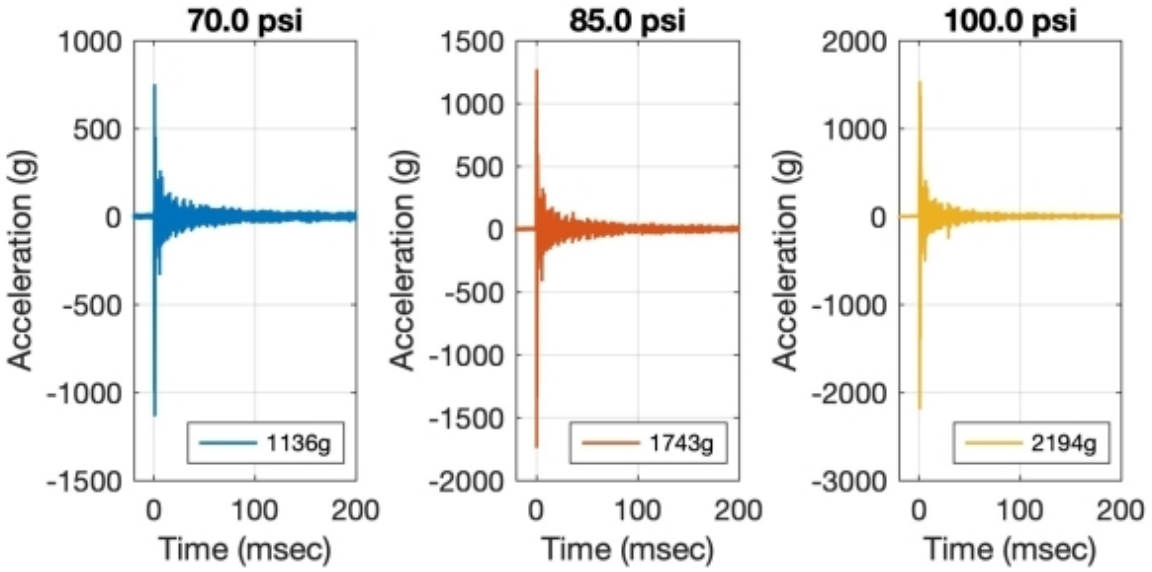


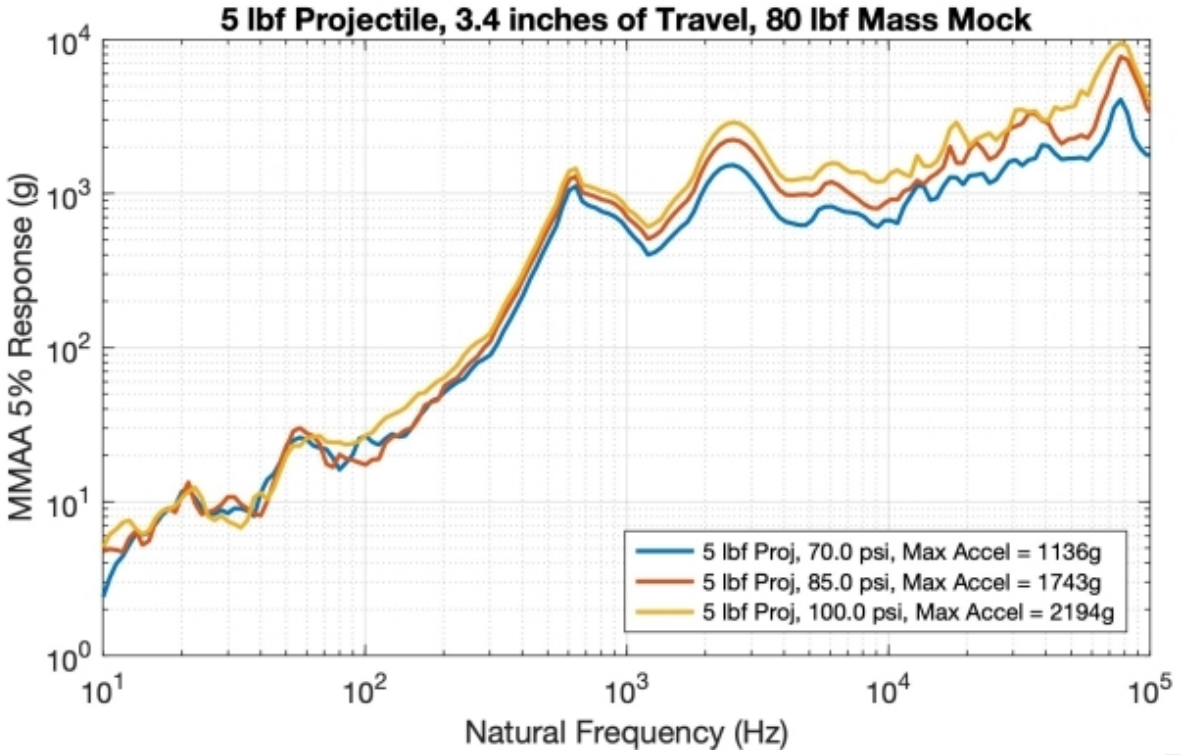


8 INCH GUN HEAVYWEIGHT TESTING

- To push the limits of the short barrel gas guns, an 80 lbf mass was mounted on the 600 Hz round steel resonant plate
- Tests were performed with the 5 lbf projectile with only 3.4 inches of travel prior to impact
- The results achieved are a little low but may improve with a larger, heavier projectile

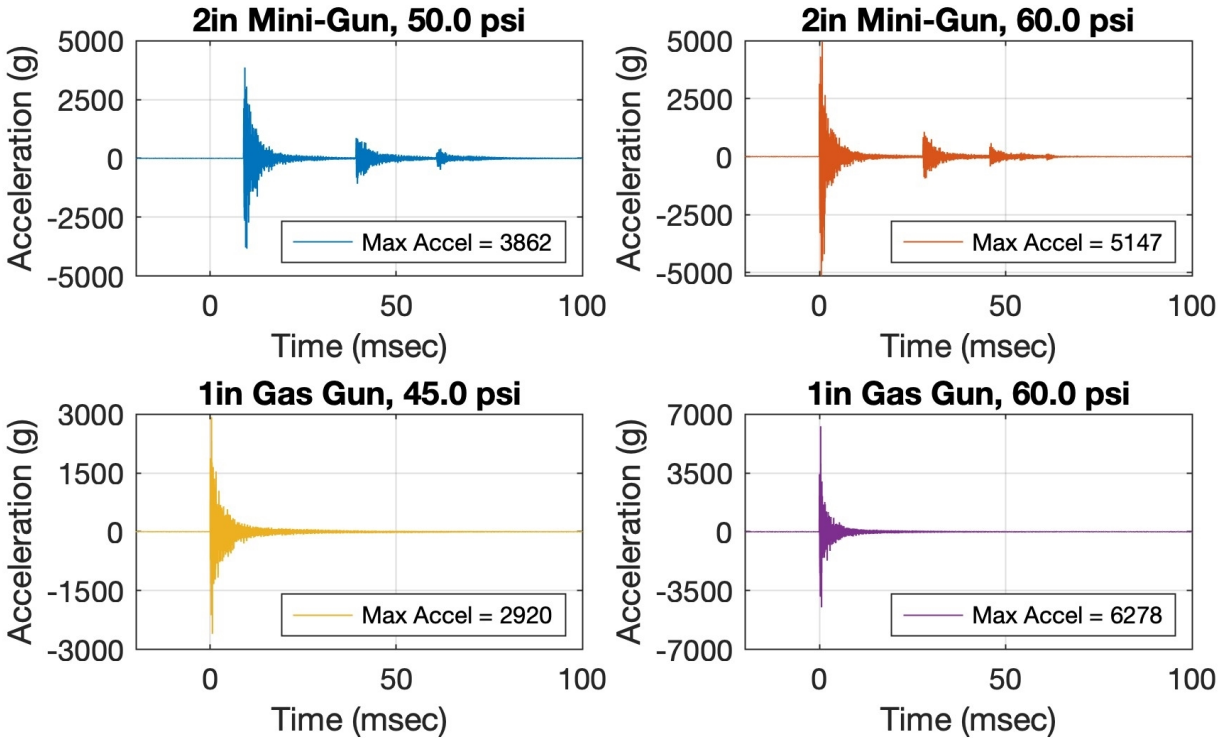


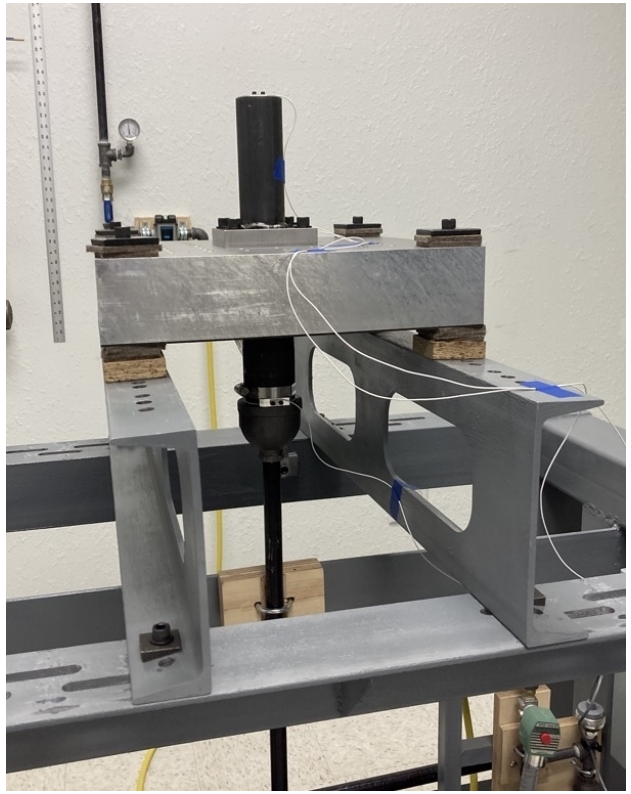




36 INCH AND 4 INCH GUN BARREL COMPARISON

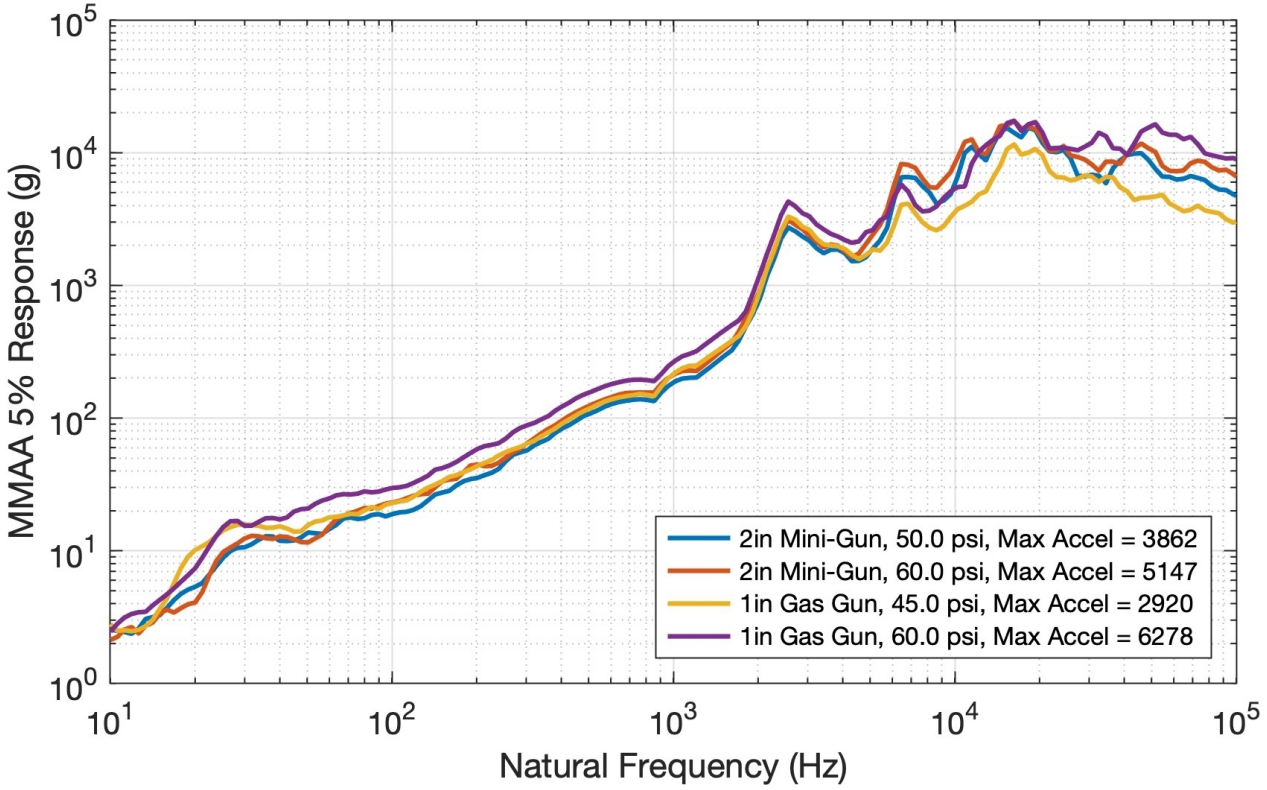
- Do short guns give the same nominal shock excitation as a traditional length gas gun?
- Results shown here compare the 4 inch long, 2 inch diameter gun with a 36 inch long, 1 inch diameter gun against a 3 kHz plate with an 8 lbf mass mock test article
- Measured acceleration signals show a lot of similarity in the initial shock excitation

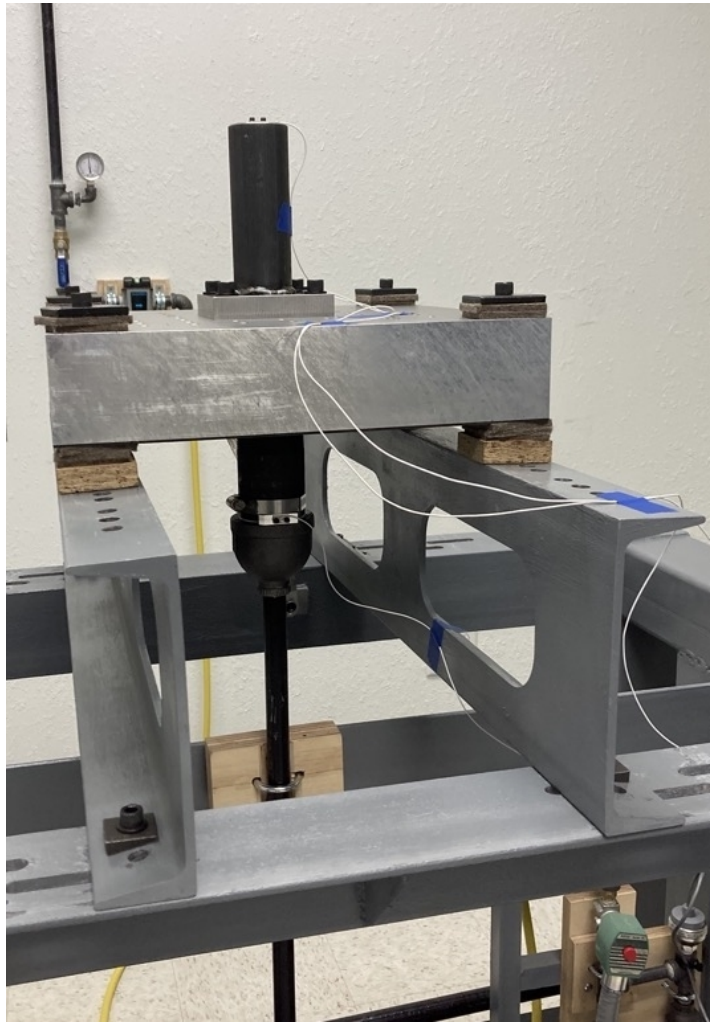




36 INCH AND 4 INCH GUN BARREL COMPARISON

- SRS comparisons between the two gun lengths are very consistent
- Results indicate a consistent modal excitation of the resonant plate
- Equally likely to meet a test specification requirement with either gun configuration

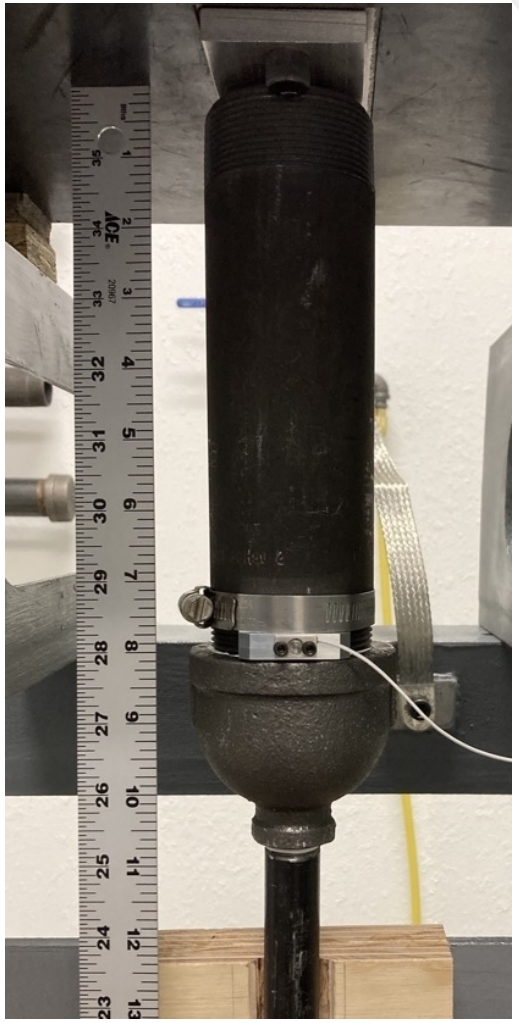




PROJECTILE VELOCITY ESTIMATES

- Estimating impact velocity on a very short barrel gun is challenging due to the rapidly changing velocity of the projectile over the short distance
- The approach used here to was to “listen” for the air entering the base of the gas gun with an accelerometer to estimate first motion
- The accelerometer on the resonant plate records the impact time
- A numerical integration was performed to simulate the air driven motion of the projectile accelerating up the short barrel and into the plate

Gas Gun Configuration	Resonant Plate	Impact Velocity
8 inch Gun 2 lbf Projectile	3 kHz	13 – 37 ft/s
4 inch Gun 2 lbf Projectile	3 kHz	11 – 12 ft/s
8 inch Gun 5 lbf Projectile	600 Hz	11 – 17 ft/s



CONCLUSIONS

- The experiments documented here show that extremely short gas guns can be used to obtain high shock loads on both low and high-frequency resonant plates
- While further optimization of the design is warranted, the concept testing was successful
- This opens the door for the development of extremely small shock test machines for unique applications

ACKNOWLEDGEMENTS

“Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC (NTESS), a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy’s National Nuclear Security Administration (DOE/NNSA) under contract DE-NA0003525. This written work is authored by an employee of NTESS. The employee, not NTESS, owns the right, title and interest in and to the written work and is responsible for its contents. Any subjective views or opinions that might be expressed in the written work do not necessarily represent the views of the U.S. Government. The publisher acknowledges that the U.S. Government retains a non-exclusive, paid-up, irrevocable, world-wide license to publish or reproduce the published form of this written work or allow others to do so, for U.S. Government purposes. The DOE will provide public access to results of federally sponsored research in accordance with the DOE Public Access Plan.”