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Title: Cylinder expansion test and gas gun experiment comparison

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Cylinder expansion test and gas gun experiment comparison

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6/30/16



Overview



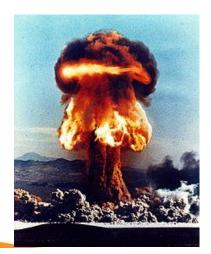
- Introduction
- Gas gun experiment
 - Applications
- Cylinder expansion test
 - Applications
- Comparison of methods
 - Pros & Cons
 - Limitations
- Summer project
- Future work



Introduction



- Explosives energetic material that release their chemical energy in a short time interval
 - "Instantaneous" production of hot gas at 3000°C (6000°F) and over 20 GPa (10,000 atm).
 - Military Operations
 - Mining
 - Building Demolition
 - High explosives: heat and pressure are generated by shock driven chemical decomposition reactions D_v = 3,000 to 9,000 m/s







Brown, G.. "High Explosive Science & Technology at Los Alamos National Laboratory". Naval Academy. (2014). LA-UR-14-27728

Understanding Explosives



- Irreplaceable tool that must be understood
 - Suitability for use
 - Expectation of power, performance, and strength
- Determine the performance behavior of explosives:
 - Test Methods Gas Gun, Cylinder Expansion
 - Empirical Formulae
 - Software Packages- i.e. FLAG, xRAGE, PAGOSA
- Equation of state needed in order to define a relationship between the parameters of the explosive

Ex: Jones-Wilkins-Lee (JWL)- relates pressure and specific volume ratio of gaseous products

$$P_s(V) = A \mathrm{e}^{-R_1 V} + B \mathrm{e}^{-R_2 V} + \frac{C}{V^{1+\omega}}, \qquad \qquad \text{Parameters:} \\ \text{A, B, C, R1, R2, } \omega$$

Brown, G.. "High Explosive Science & Technology at Los Alamos National Laboratory". Naval Academy. (2014). LA-UR-14-27728



Equations of State



- Tests- Gas gun and cylinder expansion
 - Detonation velocity
 - Determine EOS parameters
- Parameters:
 - Unavailable for new or unknown explosives
 - Available for well known explosives
 - Variation in production and manufacturing process
 - Differences in chemical composition
 - Goal: EOS should fit all test data

Topkaraoglu, E. "Design and Development of a Cylinder Expansion Test." Thesis- Middle East Technical University. 2014



Gas Gun Experiment



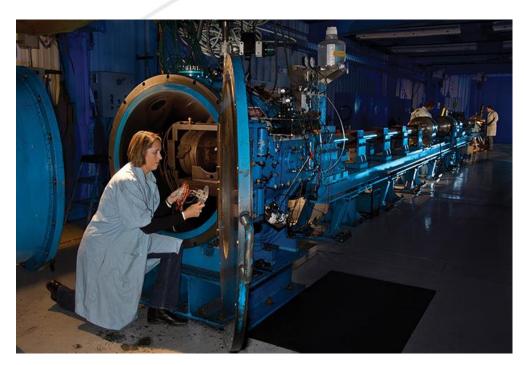


Figure 1: Los Alamos Two-Stage Gas Gun

Gas Gun

Developed:

During WWII - 1940's

Purpose:

- Use a highly specialized gun to generate very high velocities
- Projectile impact creates high pressure to do material research

"Two-Stage Gas Gun at Los Alamos" Los Alamos National Laboratory. Inspiring Women- Dana Dattelbaum. Image.

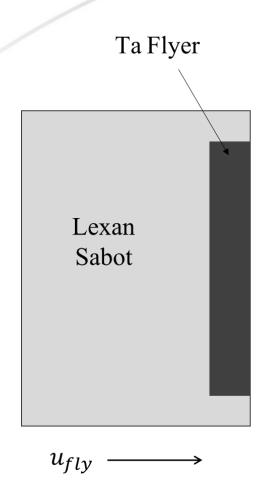
Pittman, E. "Gas Gun Experiments in Developing Equations of State" NTA Working Group. Jun. 2016. PowerPoint.

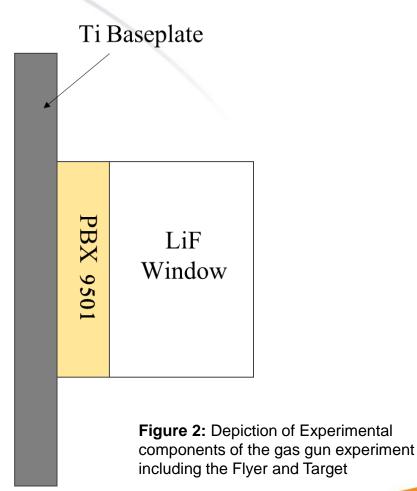
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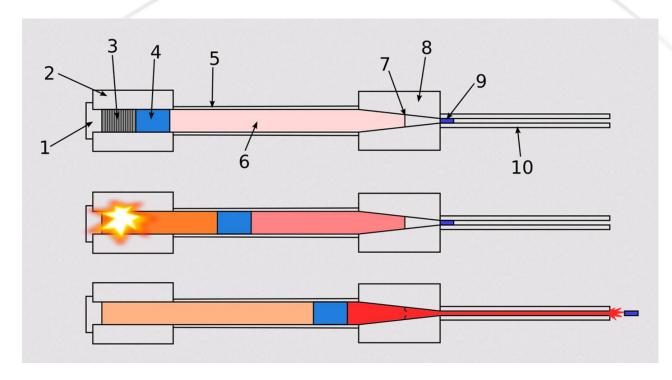


Pittman, E. "Gas Gun Experiments in Developing Equations of State" NTA Working Group. Jun. 2016. PowerPoint. UNCLASSIFIED



Gas Gun: Powder Gun





- 1. Breech block
- 2. Chamber
- 3. Propellant charge
- 4. Piston
- 5. Pump tube
- 6. Light gas
- 7. Rupture disk
- 8. High pressure coupling
- 9. Projectile
- 10.Gun barrel

Figure 3: Mechanism of a Powder Gas Gun

Pittman, E. Gas Gun Experiments in Developing Equations of State. NTA Working Group. June, 2016. Powerpoint. Light-Gas Gun. 15 April, 2016. Wikipedia. URL: https://en.wikipedia.org/wiki/Light-gas_gun **UNCLASSIFIED**



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Los Alamos NATIONAL LABORATORY

Gas Gun- Overdriven data

- Detonation is produced in an explosive under extreme conditions
 - i.e. Impact of the high speed flyer plate
- Propagation of the velocity of the detonation is faster than usual detonation
 - Decays and approaches the normal CJ velocity

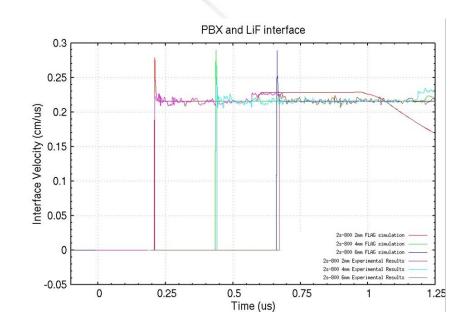


Figure 4: Interface velocities of Shot 2s-800

Pittman, E. Gas Gun Experiments in Developing Equations of State. NTA Working Group. June, 2016. Powerpoint Liu, Z.. "Overdriven detonation phenomenon and its applications to ultra-high pressure generation". Thesis. Kumamoto University. 2001.

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Cylinder Expansion Test





Cylinder Expansion Testalso known as CYLEX

Developed:

1960's by Lawrence Radiation Lab

Purpose:

- Reliable measure of an explosives ability to accelerate metal
- Determine detonation product EOS

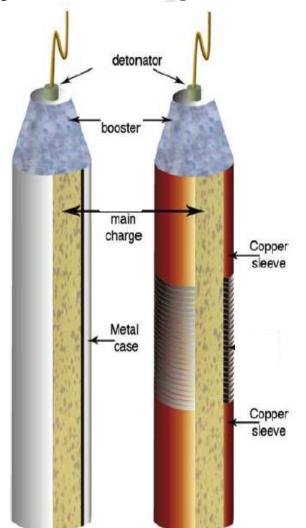
Figure 5: Los Alamos Cylinder Expansion Test

Hill, L., Mier, R., and Briggs, M. E.. PBX 9404 Detonation Copper Cylinder Expansion Test of New and Aged Material. Los Alamos National Laboratory. 2009.

UNCLASSIFIED

Cylinder Expansion Experimental Setup Los Alamos





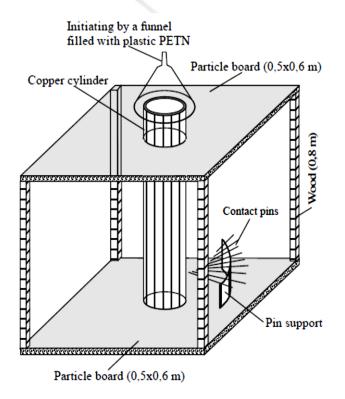


Figure 6: Experimental Components including the explosive filled cylinder and the table assembly

Goto D.M., Becker R. Orzechowski, T.J., Springer H.K., Sunwoo A.J. and Syn C.K., "Investigation of the Fracture and Fragmentation of Explosively Driven Rings and Cylinders", International Journal of Impact Engineering, Vol.35, 2008, pp.1547-1556

Arvanitidis, I. "The Diameter Effect on detonation Properties of Cylinder Test." Swedish Rock Engineering Research. 2004. Report.

Experimental Materials



Plastic Bonded Explosive (PBX)

- PBX 9404: 94% HMX + 3% nitroplasticizer + 3% tris-beta-chloroethylphosphate
 - Very Sensitive Explosive
- **PBX 9501:** 95% HMX + 2.5% estane + 2.5% nitroplasticizer
 - Lower impact sensitivity
 - Less handling problems

Tube Material

- Copper: preferred due to high ductility
 - Enables expansion of the cylinder to a large volume before fracture
 - Can expand twice the amount of steel before rupture
 - Length to Diameter Ratio ~8
 - Obtain steady state detonation velocity and a detonation front with constant curvature

Brown, G.. "High Explosive Science & Technology at Los Alamos National Laboratory". Naval Academy. (2014). LA-UR-14-27728 Topkaraoglu, E. "Design and Development of a Cylinder Expansion Test." Thesis- Middle East Technical University. 2014

Contact Pins





Figure 7: Mounted contact pins

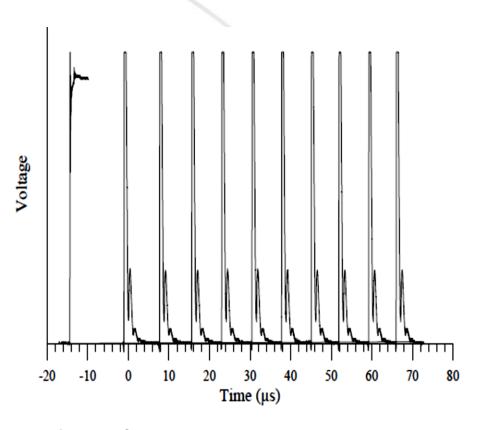


Figure 8: Contact signals vs time

Arvanitidis, I. "The Diameter Effect on detonation Properties of Cylinder Test." Swedish Rock Engineering Research. 2004. Report.



Streak Camera



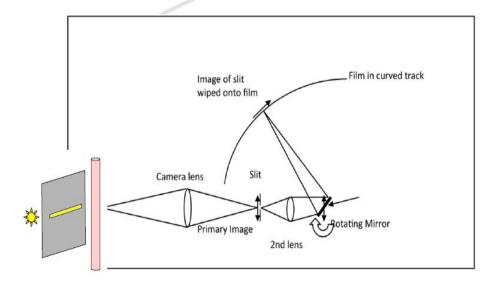


Figure 9: Simple depiction of the streak camera setup

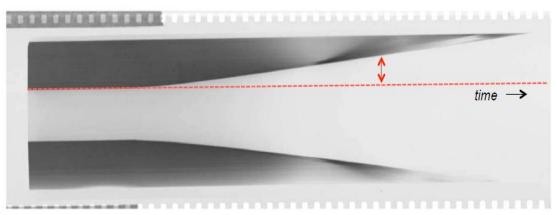


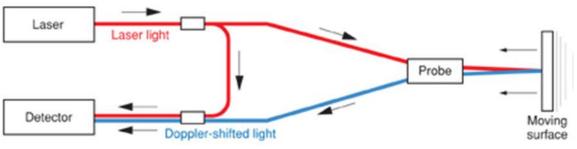
Figure 10:Example of the streak film and the digitized data

Rumchik, C., Nep, R., Butler, G., Breavus, B.. "The miniaturization and reproducibility of the cylinder expansion test". AIP Conference Proceedings, 1426. (2012) Wooten, O. "Preliminary analysis of historical and recent PBX 9404 cylinder tests using FLAG." Primary Physics Seminar. Los Alamos National Laboratory. May, 2016.



Photon Doppler Velocimetry

- Based on mixing the light wave incident onto a moving target, with the reflected light of changed frequency.
- Frequency of the resulting beat wave is proportional to the velocity of the target.



Fourier transform is used to extract f

$$v_{observed} = v_{source} \sqrt{\frac{\frac{v}{-} + 1}{c}} \sqrt{1 - \frac{v}{c}}$$

The reflected light is shifted in frequency, $(v_{observed})$ Where v is the velocity of the moving surface.

$$v^* = \frac{\lambda_0}{2} \overline{f}$$

Where v^* is the apparent velocity of the moving surface, λ_0 is the source wavelength, and f is the signal frequency

Streak vs PDV



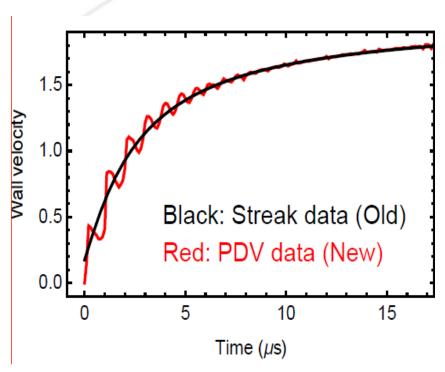


Figure 11: Steak velocity data vs PDV data

Why is it important to redo and remodel the experiments?

- PDV gives more accurate data for wall velocity
- Streak doesn't capture small fluctuations
- EOS parameters depend on the accuracy of our measurements

Wooten, O. "Preliminary analysis of historical and recent PBX 9404 cylinder tests using FLAG." Primary Physics Seminar. Los Alamos National Laboratory. May, 2016. Jackson, S. "Recent PBX 9404 Cylinder Tests and Comparison to Prior Data." Memorandum. Los Alamos National Laboratory. 2015



Gas Gun vs. Cylinder Test



Gas Gun:

- Analyze shock to detonation
- Overdriven data
- High velocity experiments
- Calibrate EOS parameters for hydro codes

Limitations:

 Speed of sound in the working fluid – i.e. Hydrogen, Helium

<u>Cylinder Test:</u>

- Analyze detonation shock
- Simple set-up
- Radial change of confining copper cylinder wall as a function of time
- Calibrate EOS parameters for hydro codes

Limitations:

 Cylinder diameter-explosive diameter has to be larger than the critical diameter



Pros & Cons



<u>Gas Gun:</u>

Pro:

- Overdriven data
- Large Pressure range (kbar to Mbar)
- Variety of targets

Con:

- Expensive
- More complex setup
- Cleanup

Cylinder Test:

Pro:

- Simple set-up
- Does not require Hydrogen
- Completely disposable setup

Con:

- Cannot reach very high velocities
- Copper defects could affect experimental results
- Different sizes and densities of HE



Summer Project



- Model a Cylinder Expansion Test
 - Compare xRAGE and FLAG performance
 - Quantify model deviation from:
 - Normal experimental data-
 - Using JWL EOS Parameters for data set
 - Overdriven data:
 - Determine new parameters that better fit overdriven data

Determine which code & burn model produces computations closest to experimental data

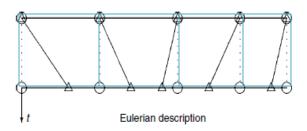


Hydrodynamic Codes



xRAGE

Eulerian

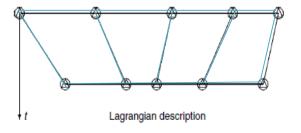


Burn Models:

- Programmed Burn
- SURF- Verification and Validation
- Forest Fire

FLAG

Lagrangian



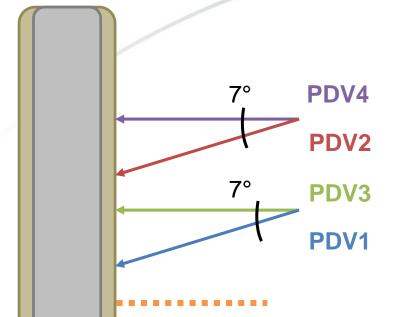
Burn Models:

- LUND- Programmed Burn
- WSD- Reactive Burn



Data Collection





FLAG- PDV function allows for data collection at PDV 1-4

xRAGE- "contact pin" tracers or probes with pressure threshold

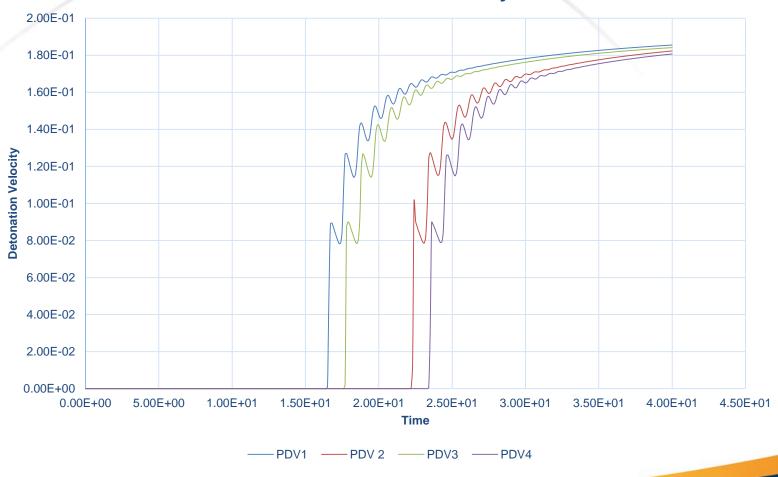
PDV	Position	Direction	Height
1	(10,0,15)	7°	13.7722
2	(10,0,20)	7°	18.7722
3	(10,0,15)	normal	15
4	(10,0,20)	normal	20
UNCLA	SSIFIFD		

Data Trends



FLAG

PDV Detonation Velocity





FLAG



- Programmed Burn- most common
- PDV function

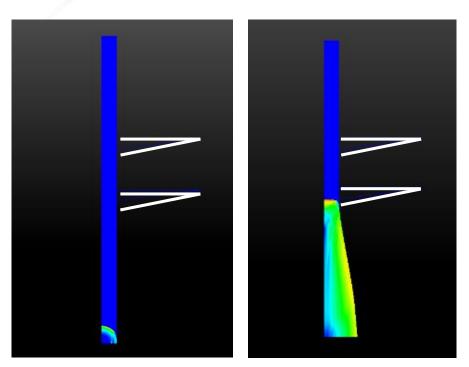


Figure 12: Point Detonation- Shock moving through the HE

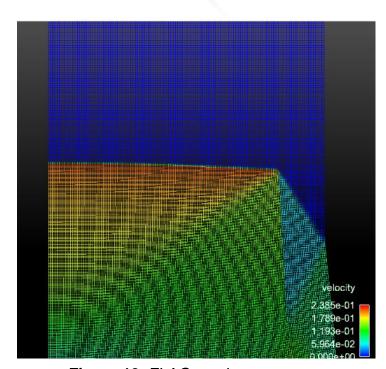


Figure 13: FLAG mesh



xRAGE



- Reactive Burn- most common
- No PDV function → Tracers / Probes

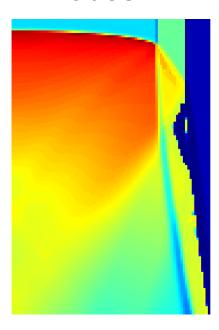


Figure 14: Detonation Velocity-Strange Indentation of wall

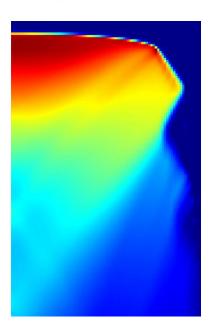


Figure 15: Pressure- (Possible explanation) low pressure in that area. The mesh is also unrefined, so that could be causing the problems as well.





To date:

Created input decks for:

FLAG- LUND (debugged)

WSD

xRAGE- SURF (debugged)

Forest Fire (debugged)

Programmed Burn

Upcoming:

- Increase resolution
- Compare all burn models to experimental data
 - Calculate deviations
- Compare overdriven data to EOS
- Analyze strengths and weaknesses
 - Run time

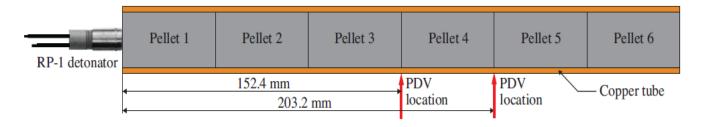


Future Work



See the effect on simulation with variance of

- **Density**
- Diameter



	HE density (g/cc)
min	1.843
mean	1.8452
max	1.847
stdev	0.0012

	HE radius (mm)	Cu-Thickness (mm)
min	12.705	2.535
mean	12.711	2.571
max	12.717	2.608
stdev	0.0106	0.0744

Wooten, O. "Preliminary analysis of historical and recent PBX 9404 cylinder tests using FLAG." Primary Physics Seminar. Los Alamos National Laboratory. May, 2016. Jackson, S. "Recent PBX 9404 Cylinder Tests and Comparison to Prior Data." Memorandum. Los Alamos National Laboratory. 2015





Thank you for your time. **Questions?**

Special thanks to my mentor Julianna Fessenden, my fellow NTA student interns, Scott Ramsey, and NTA staff.

