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*Title:* Gas Gun Experiments to Measure the Shock Compression Behavior of High Performance Propellant (HPP)

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*Intended for:* Shock Compression of Condensed Matter Conference



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SCCM Abstract

*high performance*  
GAS GUN EXPERIMENTS TO MEASURE THE SHOCK COMPRESSION BEHAVIOR OF AN ~~AMMONIUM-PERCHLORATE/ALUMINUM~~ BASED PROPELLANT *(HPP)* N. J. Sanchez, R. L. Gustavsen

, L. L. Gibson and D. E. Hooks Shock & Detonation Physics Group, WX-9 Los Alamos National Laboratory Los Alamos, NM USA 87545 Gas-gun driven plate impact experiments were performed on High Performance Propellant (HPP) to measure the shock compression behavior and Hugoniot. HPP is a proprietary blend of ammonium-perchlorate, aluminum, and plastic binder. A small amount of FeO<sub>2</sub> gives the propellant a rust color. The primary diagnostic was embedded magnetic particle velocity gauges. The Hugoniot was determined by performing multiple experiments using different impactors and a range of impact velocities. Impact stresses ranged from 0.3 GPa to 15 GPa. Even at the highest stress no reaction was observed; none was expected. At low stress HPP exhibits viscoelastic behavior with rounded wave profiles. Hugoniot data can be described using a model based on a Murnaghan isotherm with a small amount of porosity.

# Gas Gun Experiments to Measure the Shock Compression Behavior of High Performance Propellant (HPP)

**N. J. Sánchez, R. L. Gustavsen, L.L.  
Gibson, & D. E. Hooks**

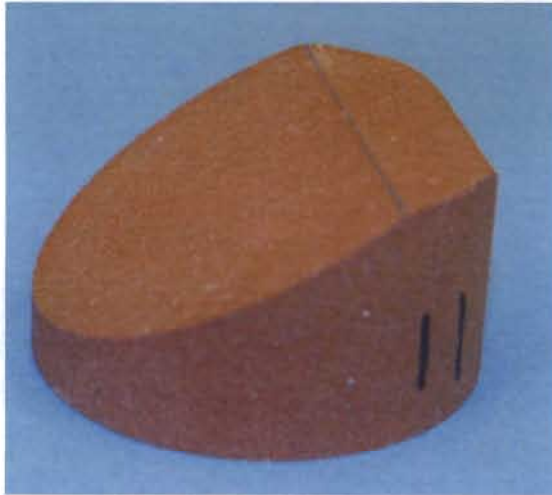


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DOD/DOE Munitions Technology  
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## Goals of this study

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**HPP composition: Ammonium-Perchlorate/Aluminum & plastic binder**

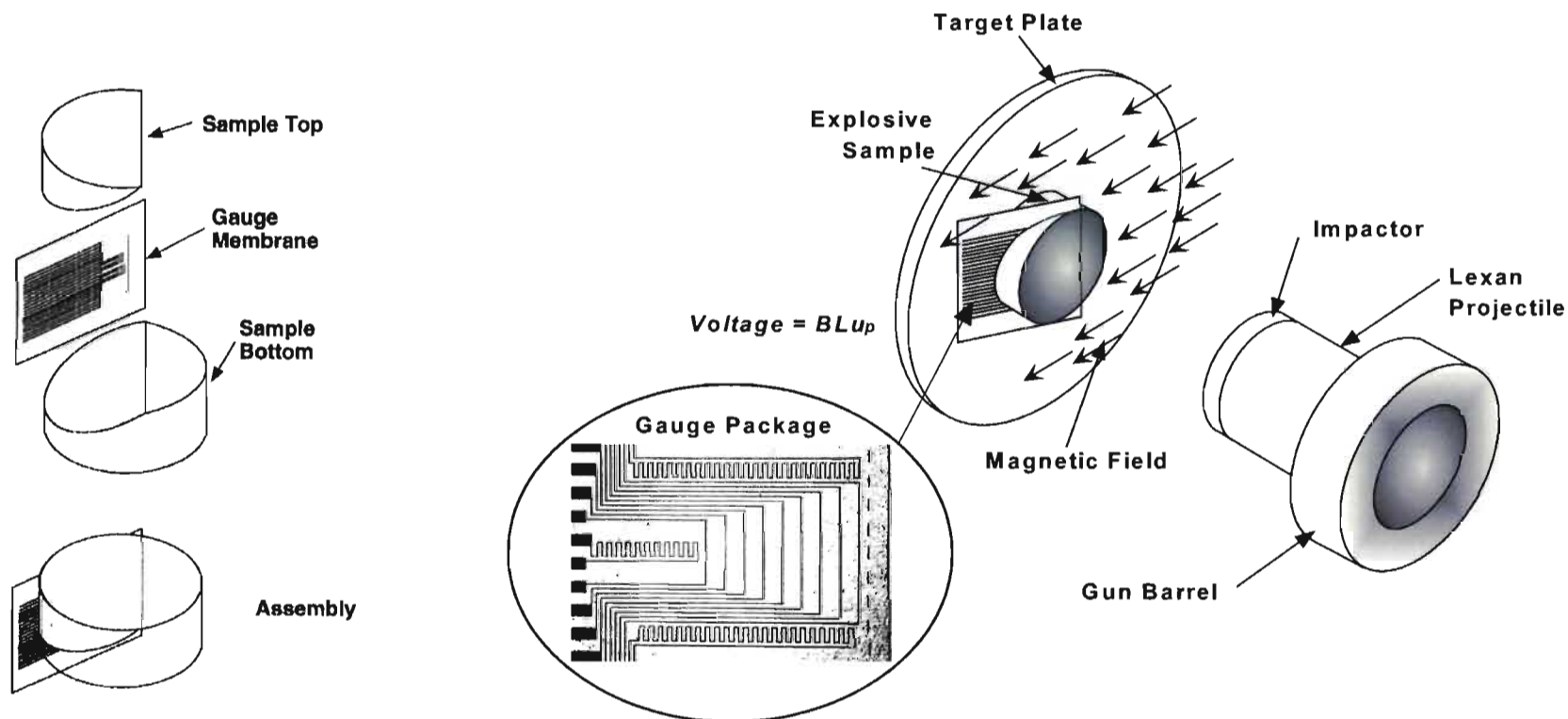


HPP test wedge

- Measure a possible shock to detonation transition (Safety)
- Measure Hugoniot (P-V curve reached by shocks) Equation of State
- Provide “wave profiles” at high pressure (mechanical response)

# Gas gun driven plate impact experiments were used to measure shock properties of HPP

- Magnetic gauges based on Faraday's Law of Induction measure in-material motion

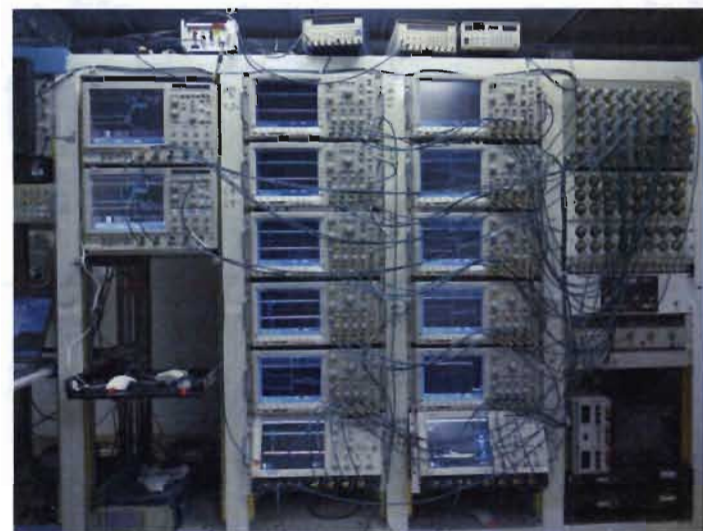




## Finished HPP target



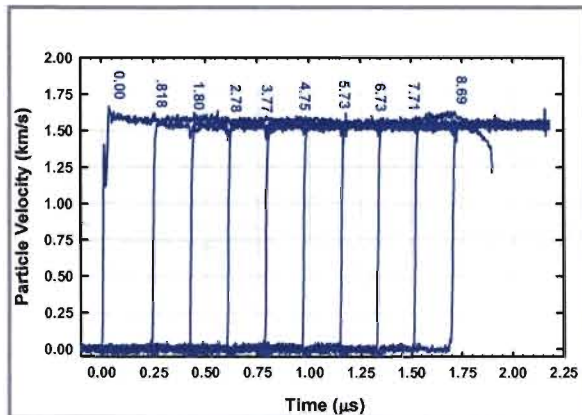
Large amount of data collection



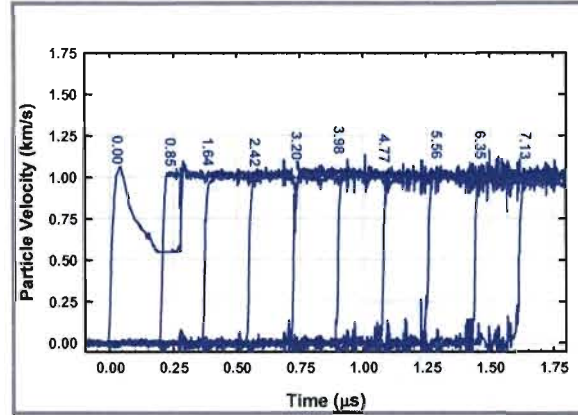
Target assembly was difficult due to the eraser like texture of HPP

# In-situ wave profiles provide material response at high pressure

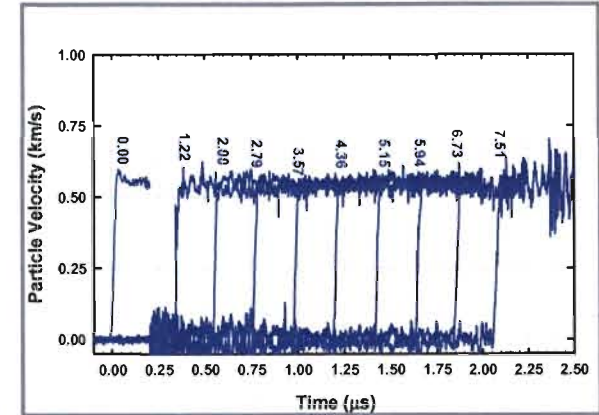
15.1 GPa



8.48 GPa

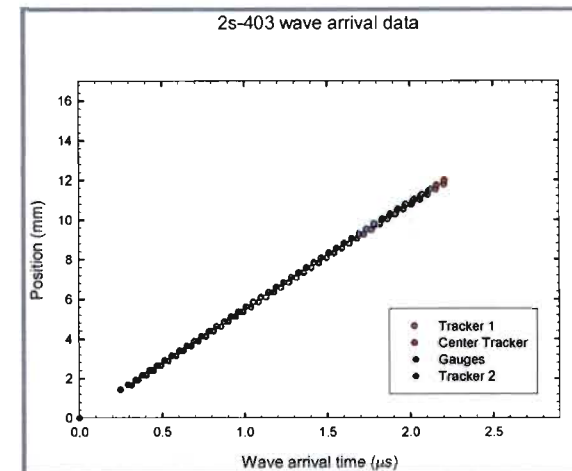


3.83 GPa

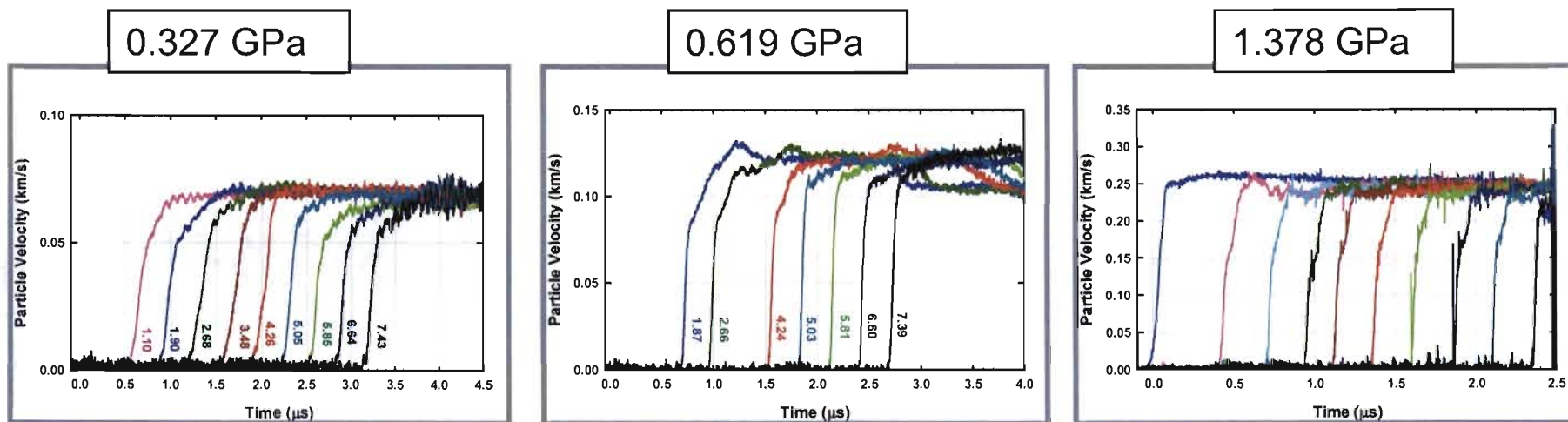


HPP inert up to 15 GPa

Particle velocity ( $U_p$ ) & shock velocity ( $U_s$ ) are measured for Hugoniot data



## Viscoelasticity was observed at low pressures



Rounded wave profiles indicate viscoelastic behavior

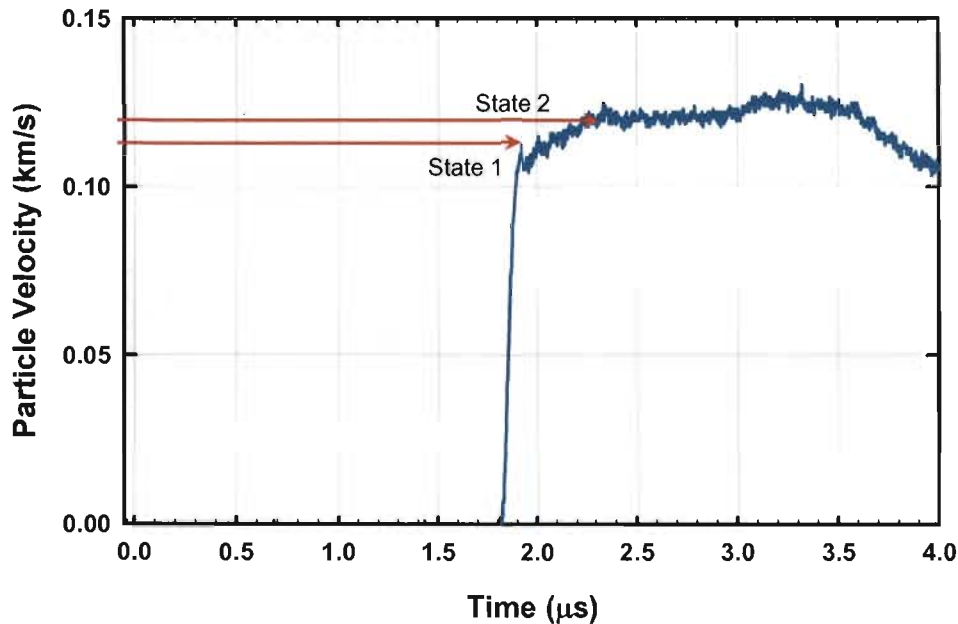
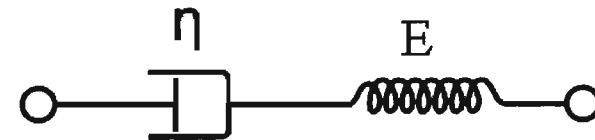


# Viscoelastic materials exhibit both viscous & elastic characteristics when undergoing deformation

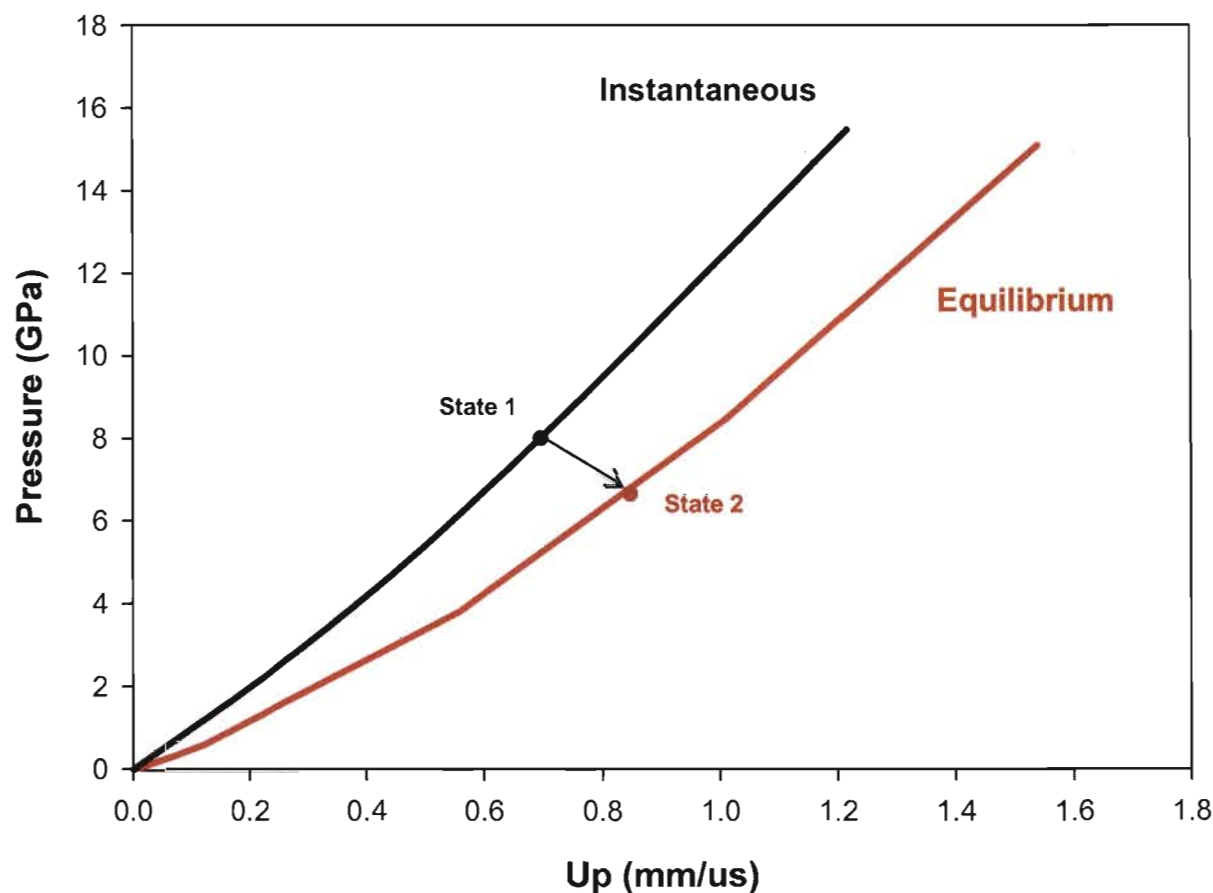
- Slow transition from state 1 to state 2 caused by viscous damping

## ■ Maxwell Model

$$\frac{d\epsilon_{Total}}{dt} = \frac{d\epsilon_D}{dt} + \frac{d\epsilon_S}{dt} = \frac{\sigma}{\eta} + \frac{1}{E} \frac{d\sigma}{dt}$$

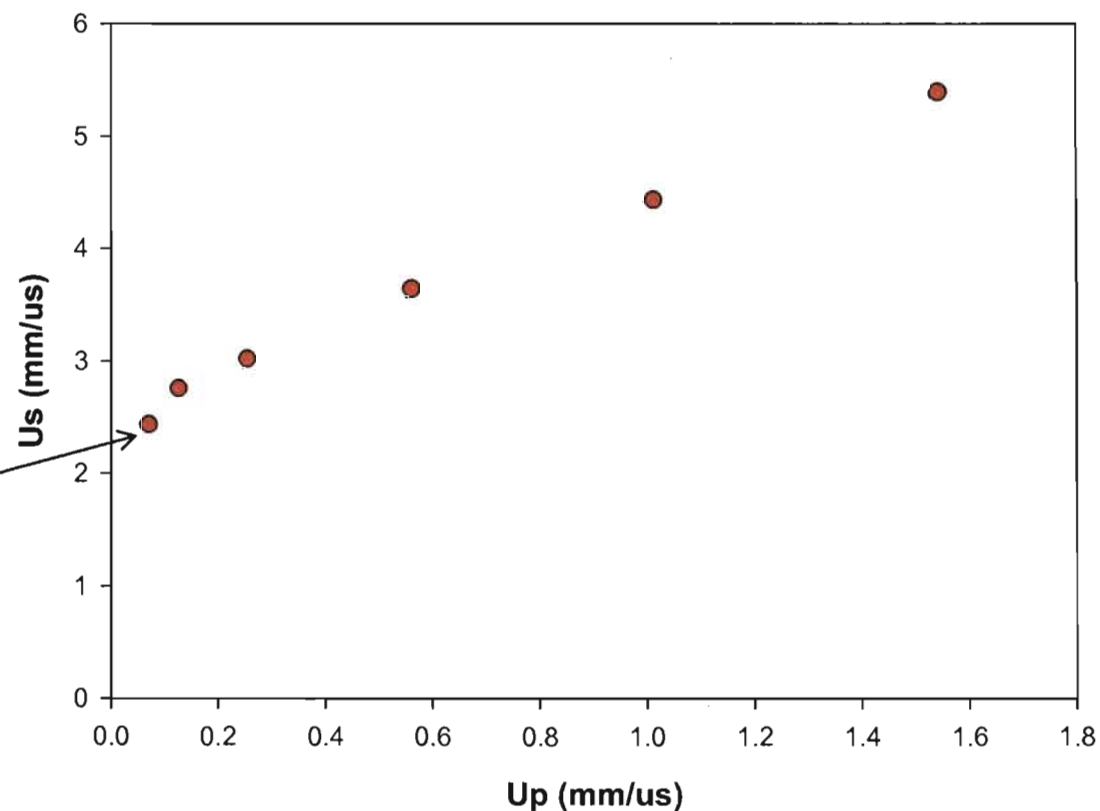


## Viscoelastic materials are difficult to model because they have an instantaneous Hugoniot & equilibrium Hugoniot



# Hugoniot seems to soften at low pressure due to crush out of voids

HPP Hugoniot



Is the nonlinear behavior real?

Symmetric Impact to verify gauges were reading correctly

## Equation of State for porous energetic materials

Constructing a complete thermodynamic potential function based on the Helmholtz Free Energy

$$F(T, V) = C_V \left[ (T - T_o) \left( 1 + \frac{\Gamma}{V} (V_o - V) \right) + T \ln \left( \frac{T_o}{T} \right) \right] + \frac{K_{To} V_o}{N(N-1)} \left[ \left( \frac{V_o}{V} \right)^{N-1} - (N-1) \left( 1 - \frac{V}{V_o} \right) - 1 \right]$$

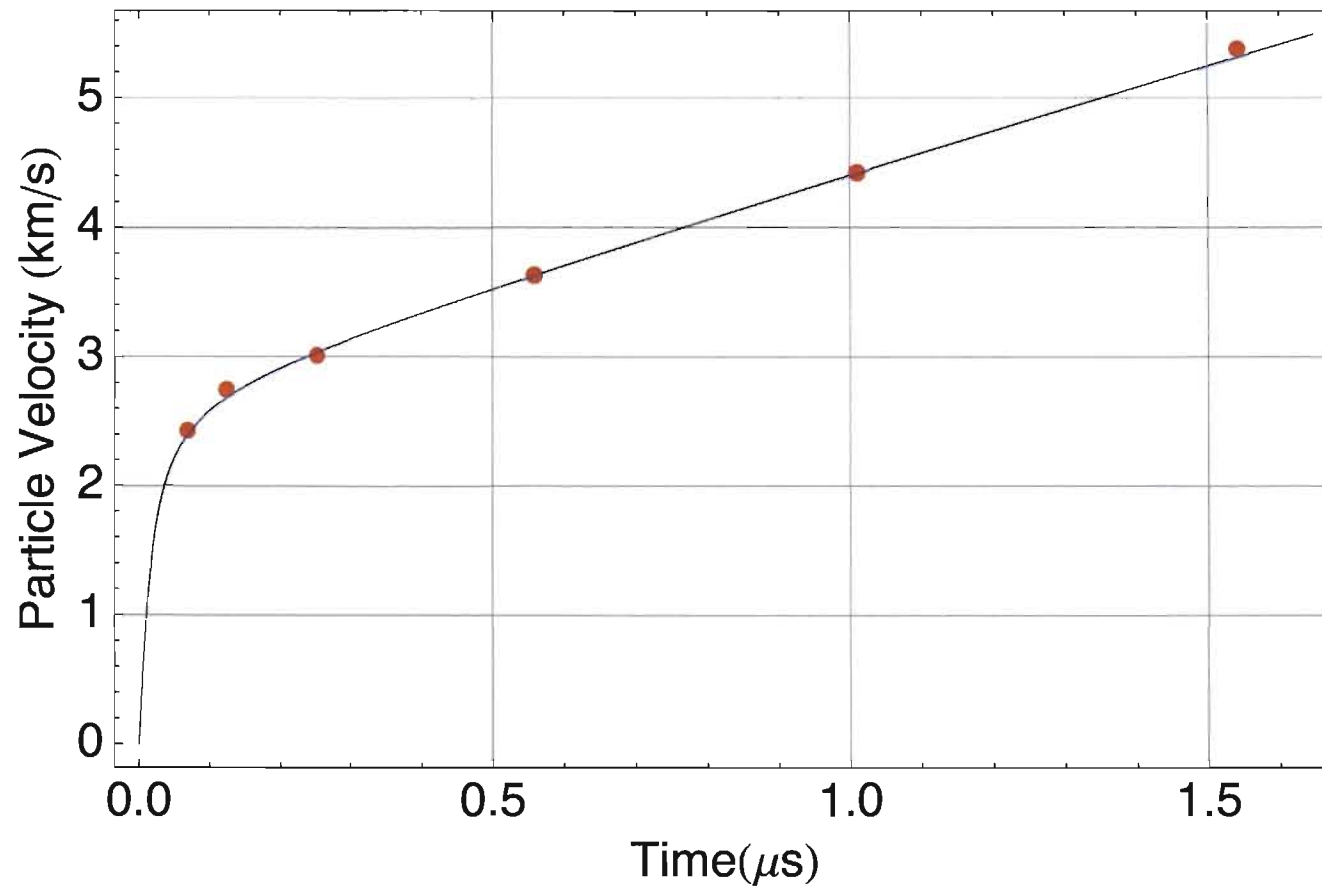
$$K_T = K_{To} \left( \frac{V_o}{V} \right)^N$$

Transforming it to the form of E(P,V)

$$E(P, V) = \frac{P}{\frac{\Gamma}{V}} - \frac{\Gamma}{V} C_V T_o (V_o - V) - \frac{K_{To}}{N \frac{\Gamma}{V}} \left[ \left( \frac{V_o}{V} \right)^N - 1 \right] + \frac{K_{To} V_o}{N(N-1)} \left[ \left( \frac{V}{V_o} \right)^{1-N} - (N-1) \left( 1 - \frac{V}{V_o} \right) - 1 \right]$$

$$E = \frac{1}{2} P (V_{oo} - V)$$

## Analytic function fits the data well





## Summary

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- Concluded that HPP is inert up to 15.1 GPa
- Provided in-situ wave profiles for mechanical response at high pressure
- Provided an equation of state at high pressures

# Questions?

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