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

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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)

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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 FeO2 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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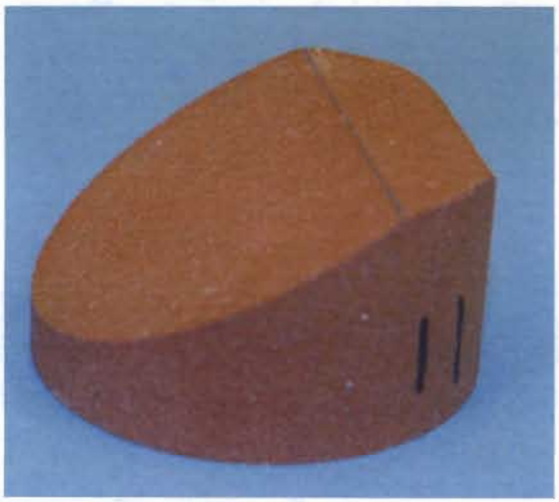
Goals of this study

HPP composition: Ammonium-Perchlorate/Aluminum & plastic binder

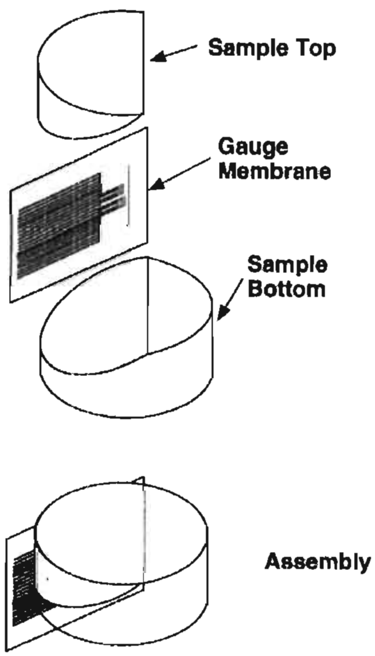


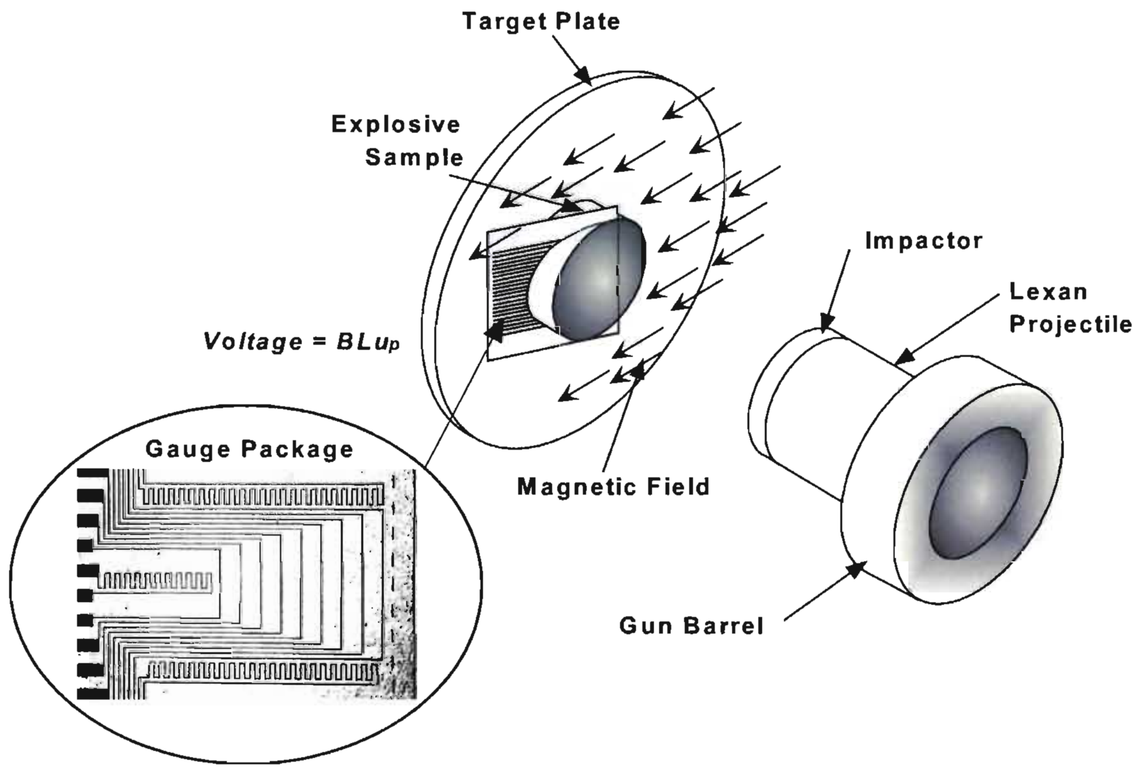
HPP test wedge

- 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

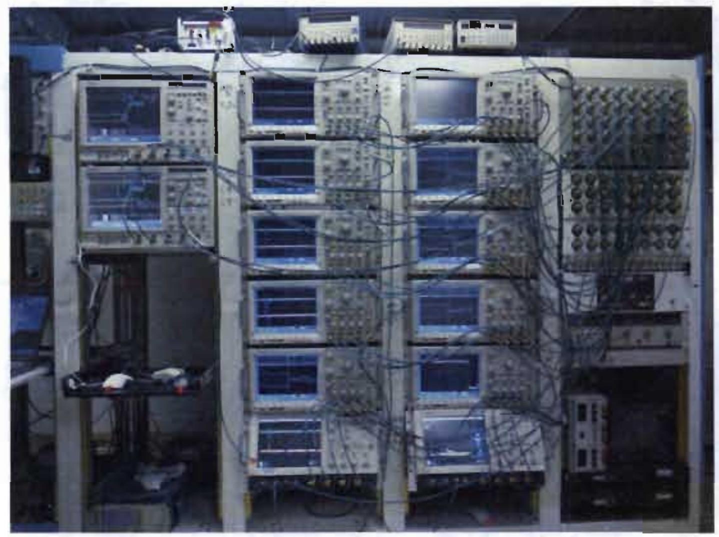




$$V = L \cdot U_p \times B$$

Finished HPP target

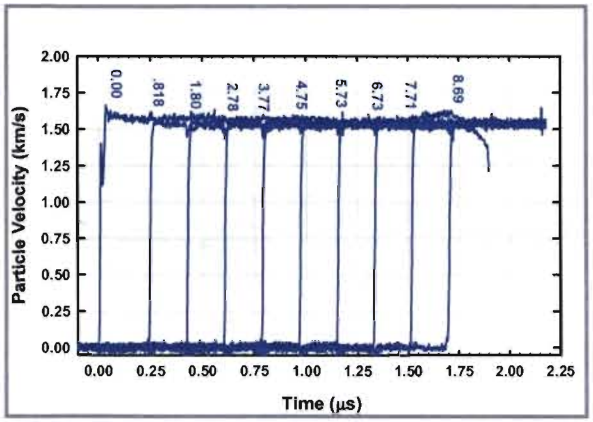
Large amount of data collection



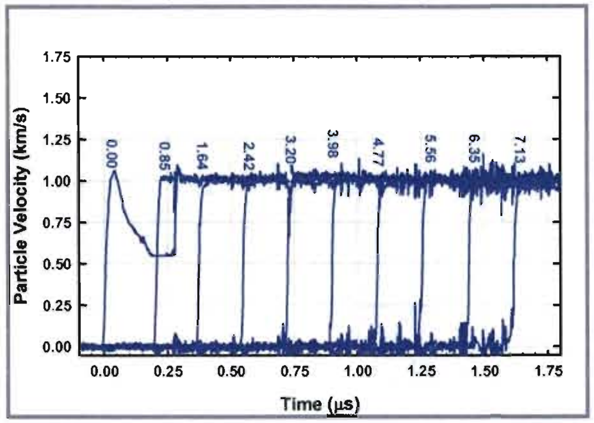
Target assembly was difficult due to the eraser like texture of HPP

In-situ wave profiles provide material response at high pressure

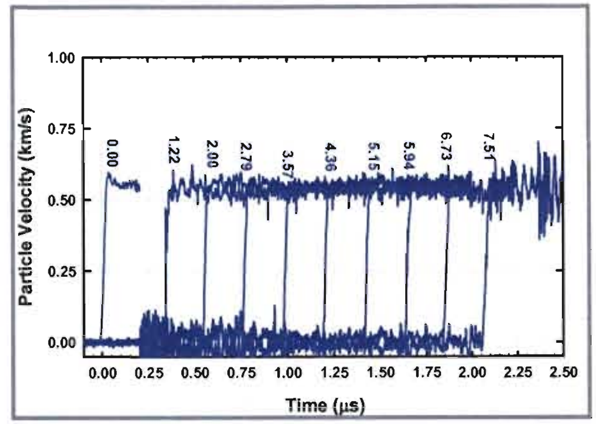
15.1 GPa



8.48 GPa

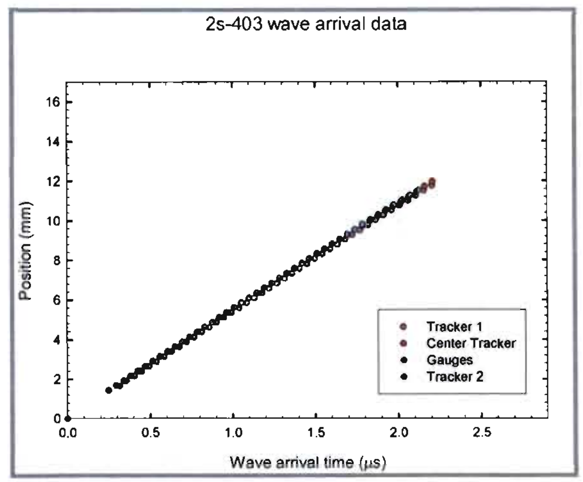


3.83 GPa

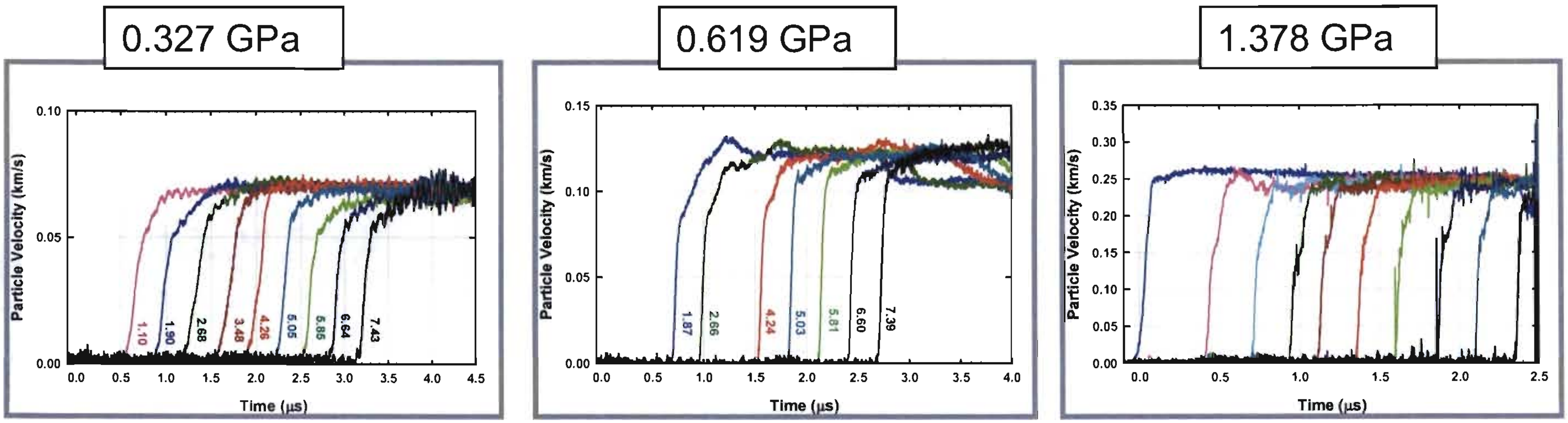


HPP inert up to 15 GPa

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



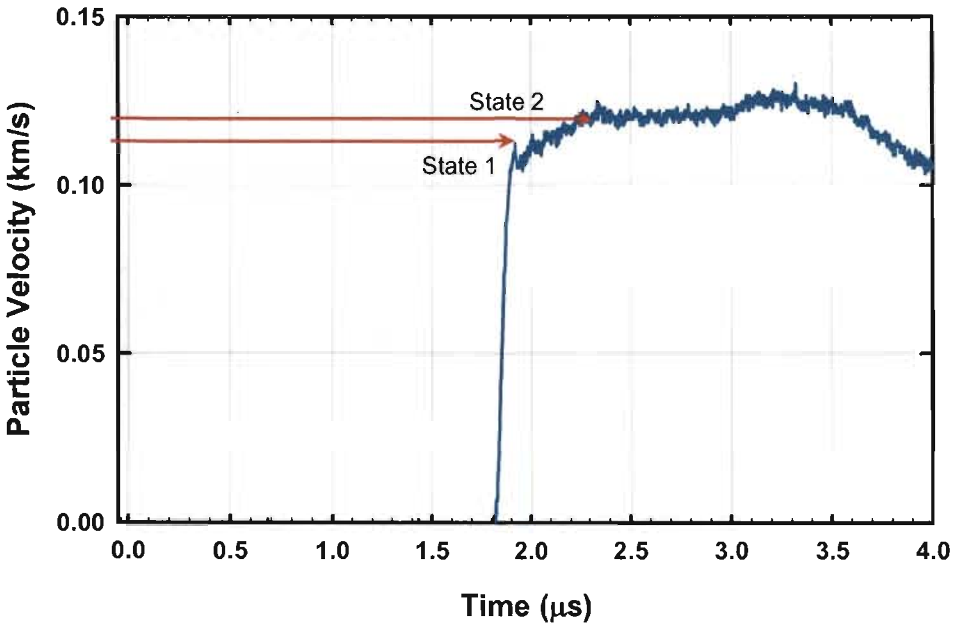
Viscoelasticity was observed at low pressures



Rounded wave profiles indicate viscoelastic behavior

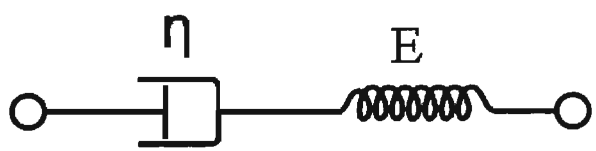
Viscoelastic materials exhibit both viscous & elastic characteristics when undergoing deformation

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

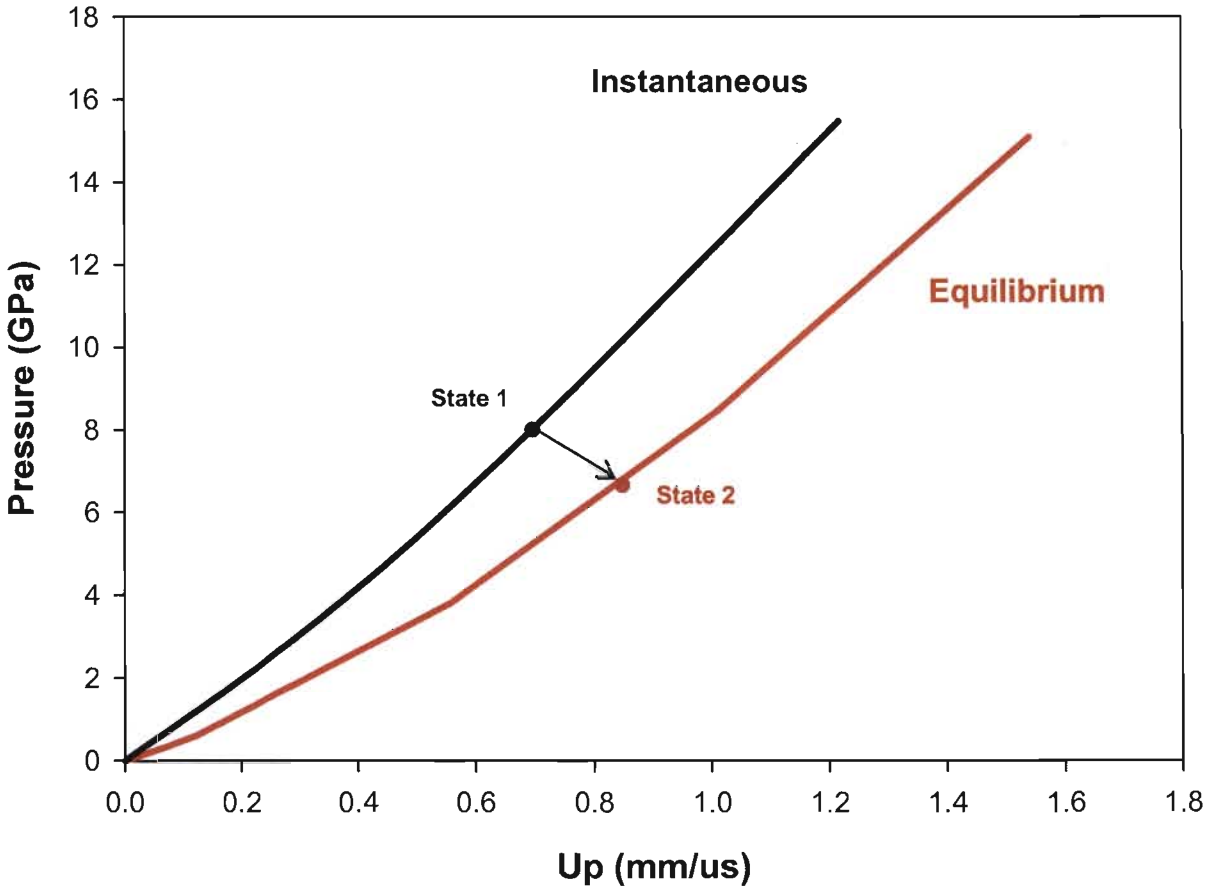


- **Maxwell Model**

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



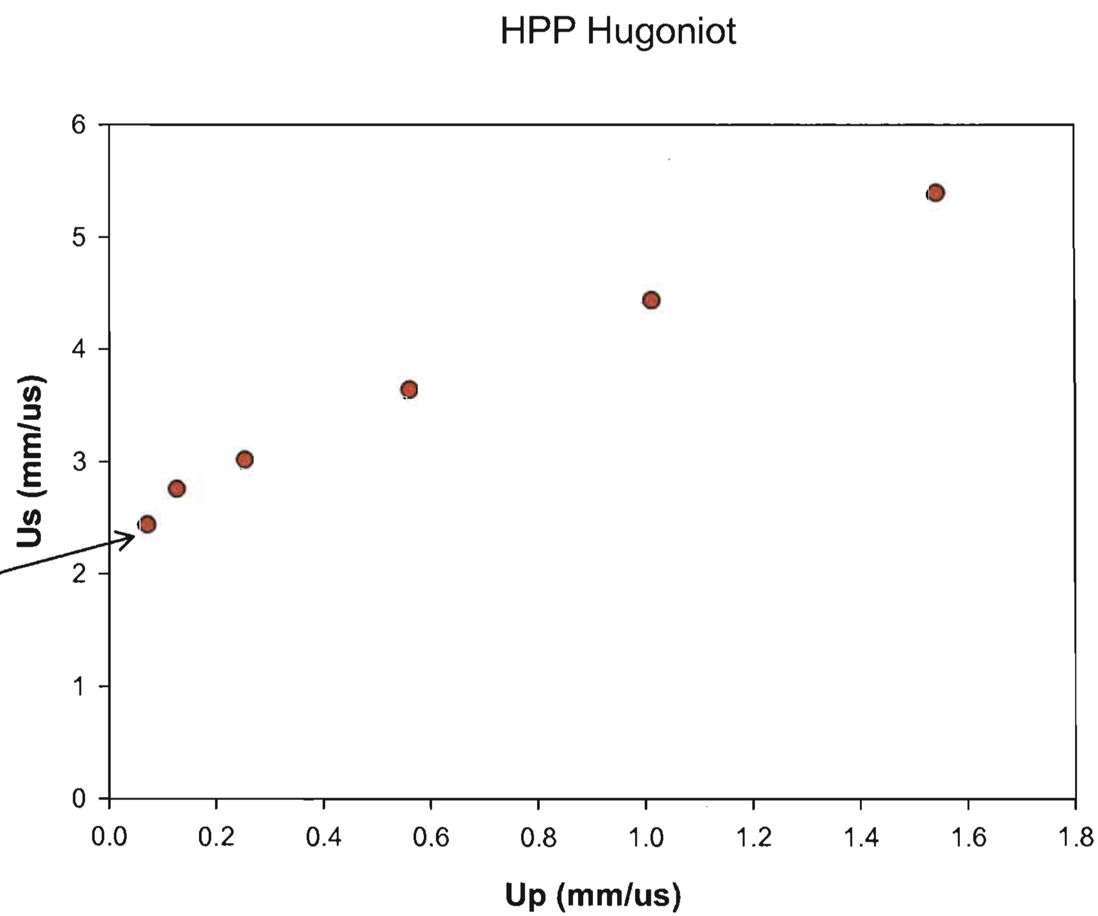
Viscoelastic materials are difficult to model because they have an instantaneous Hugoniot & equilibrium Hugoniot



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

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

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

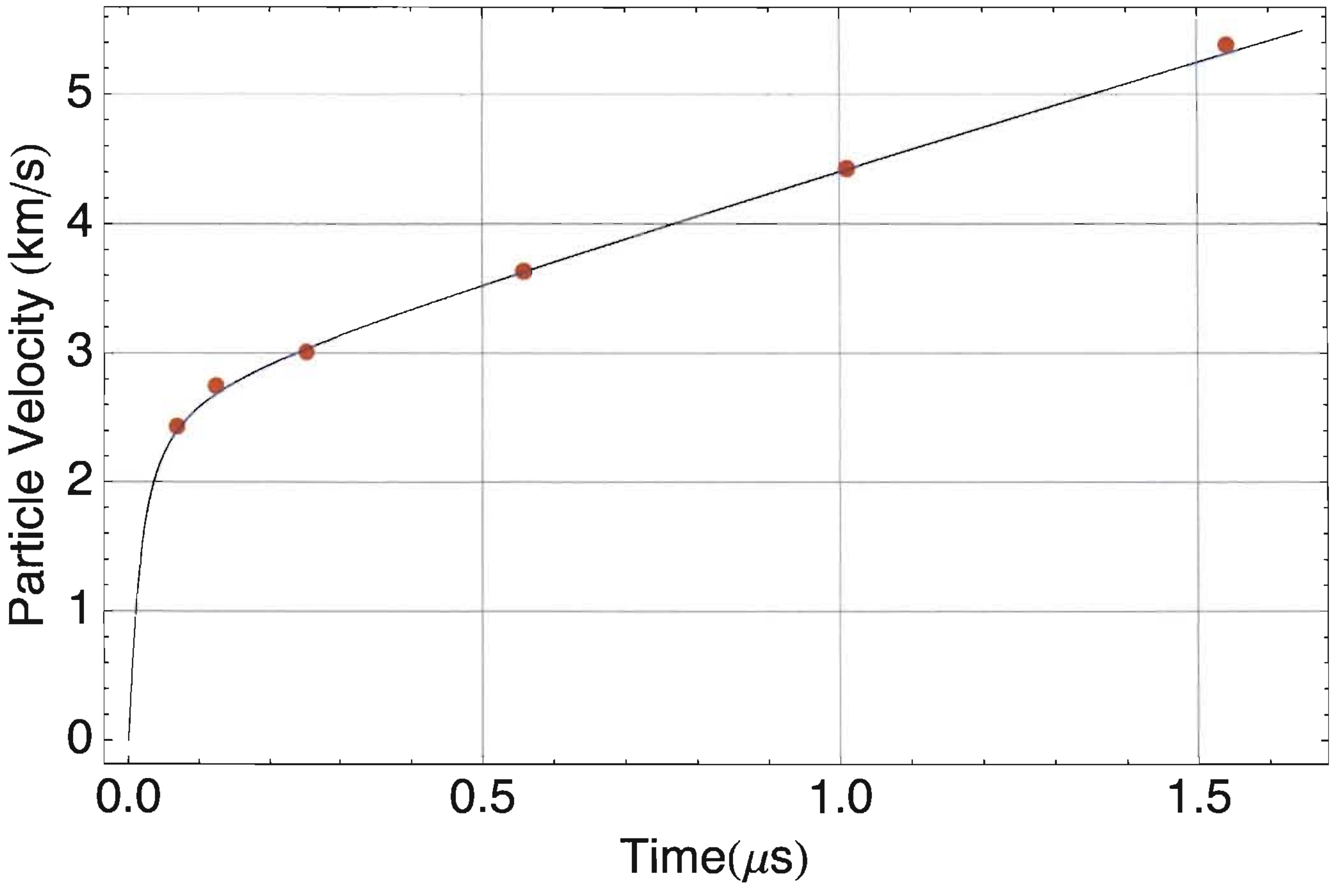
$$K_T = K_{To}\left(\frac{V_o}{V}\right)^N$$

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

- 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?