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Chemical Simulants CLP/MDC Efforts

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Sandia TSLGG - EOS facility

DSTL Aero breakup facility

MDA BMDS Lethality
Program Review
ITT, Huntsville, AL
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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

MDA/SISI Case No.

Outline

- Review what was planned in May for this reporting period
  - Release states, high pressure experiment on neat
- Report on test results
  - Show analysis methodology
  - Show results
  - Discuss interpretation
- Conclude with timeline on final report, mention end of EOS effort

Motivation

- ***Develop technique to investigate "material" properties of liquids***
- ***reverberation technique evaluates average release states to provide an understanding of expansion behavior***
- ***provide not only hugoniot data but off-hugoniot (expansion) information for extended model development for liquids***
- ***The measurements, therefore, provide the basis for a detailed equation of state and model development.***

Comparison of "EOS" compression curves

$$B = -V(\partial P / \partial V) = \rho C^2$$

$$-\partial V / V = \partial P / B$$

$$-\int \partial V / V = \int \partial P / B$$

Compression inversely proportional to bulk modulus
High bulk moduli compress less than low moduli

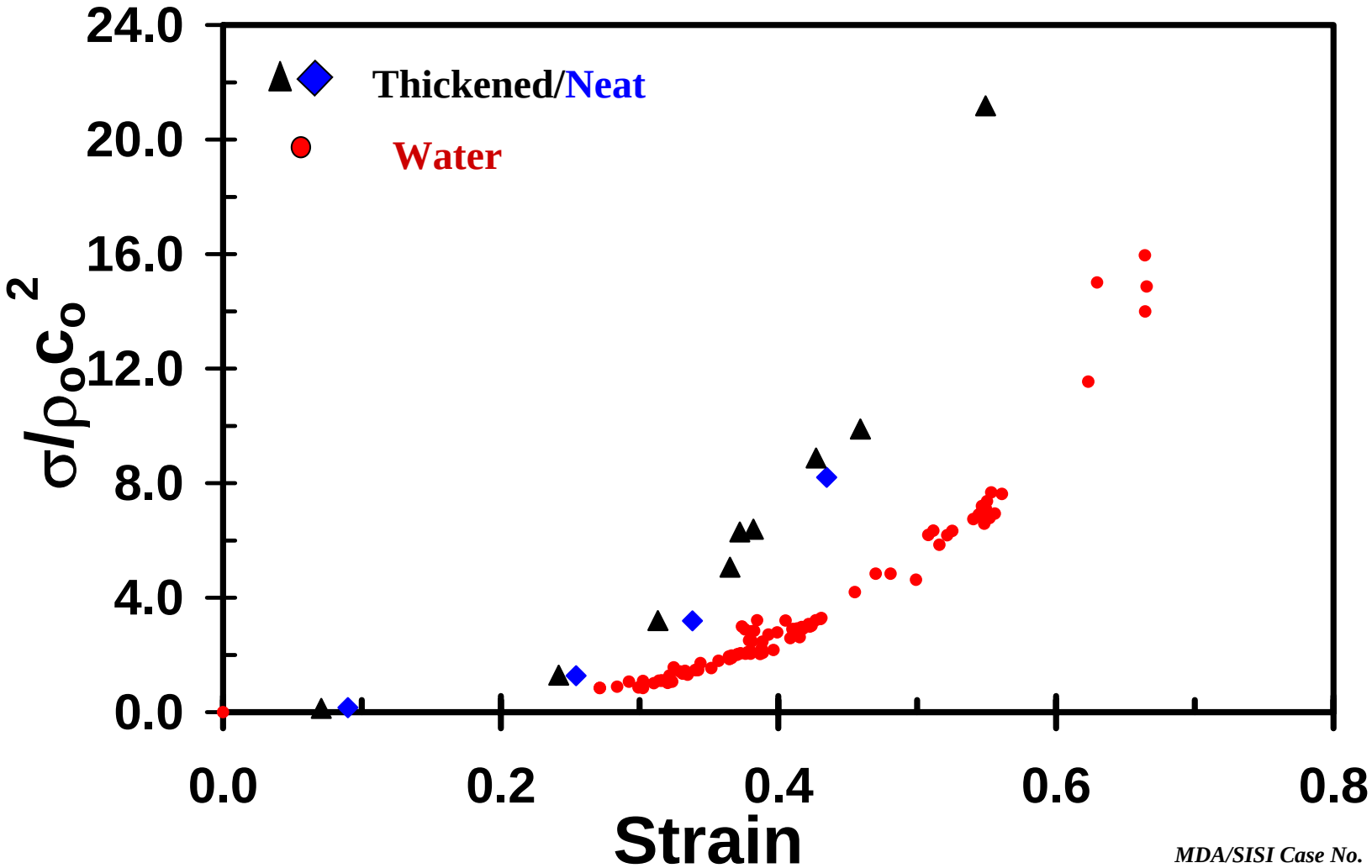
To compare compression – reference to their respective initial bulk modulus

Results indicated for both neat and thickened TBP

Results indicated for thickened TBP and water

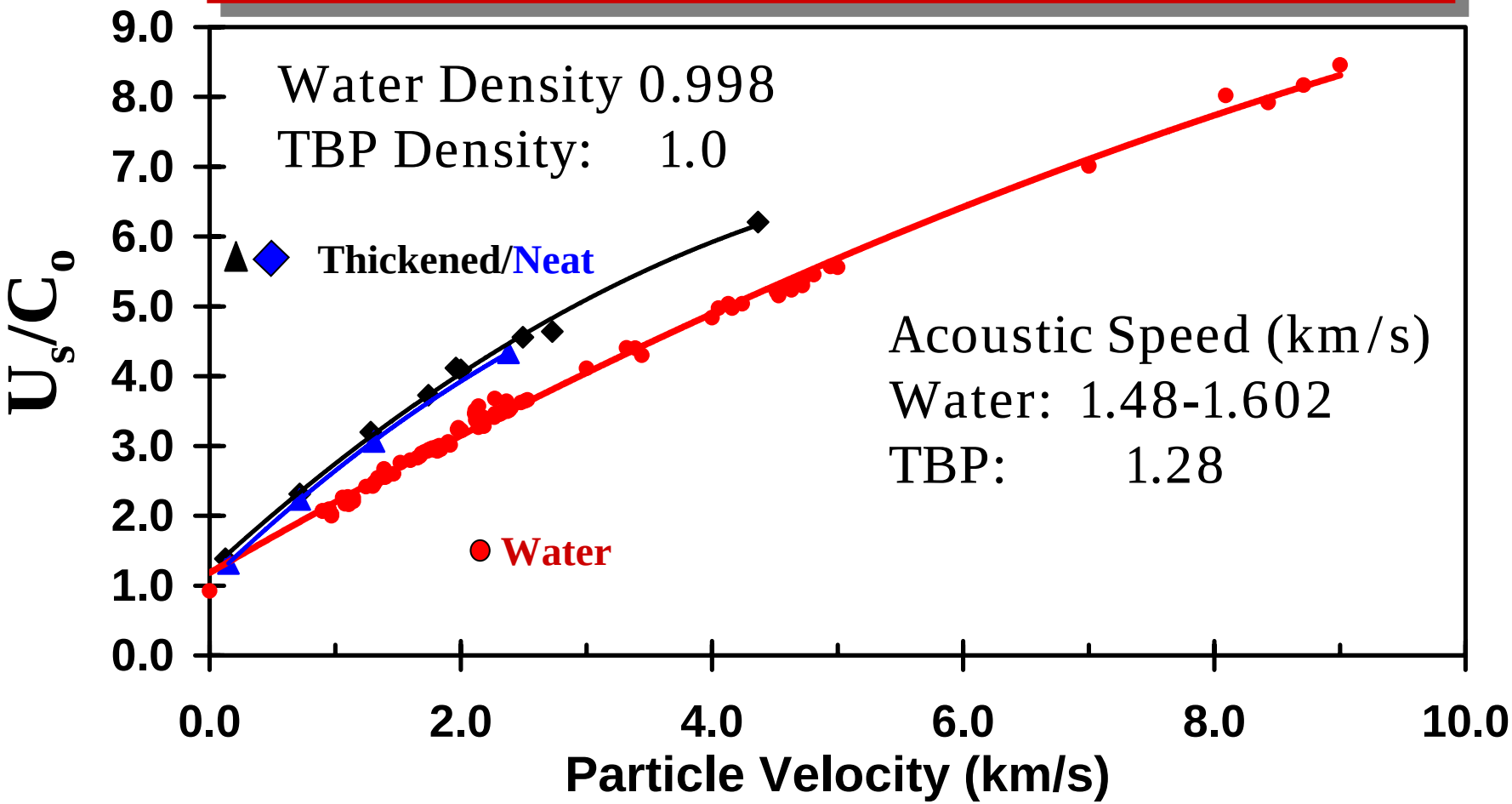
Not all Liquids are created equal

normalized stress_strain modulus



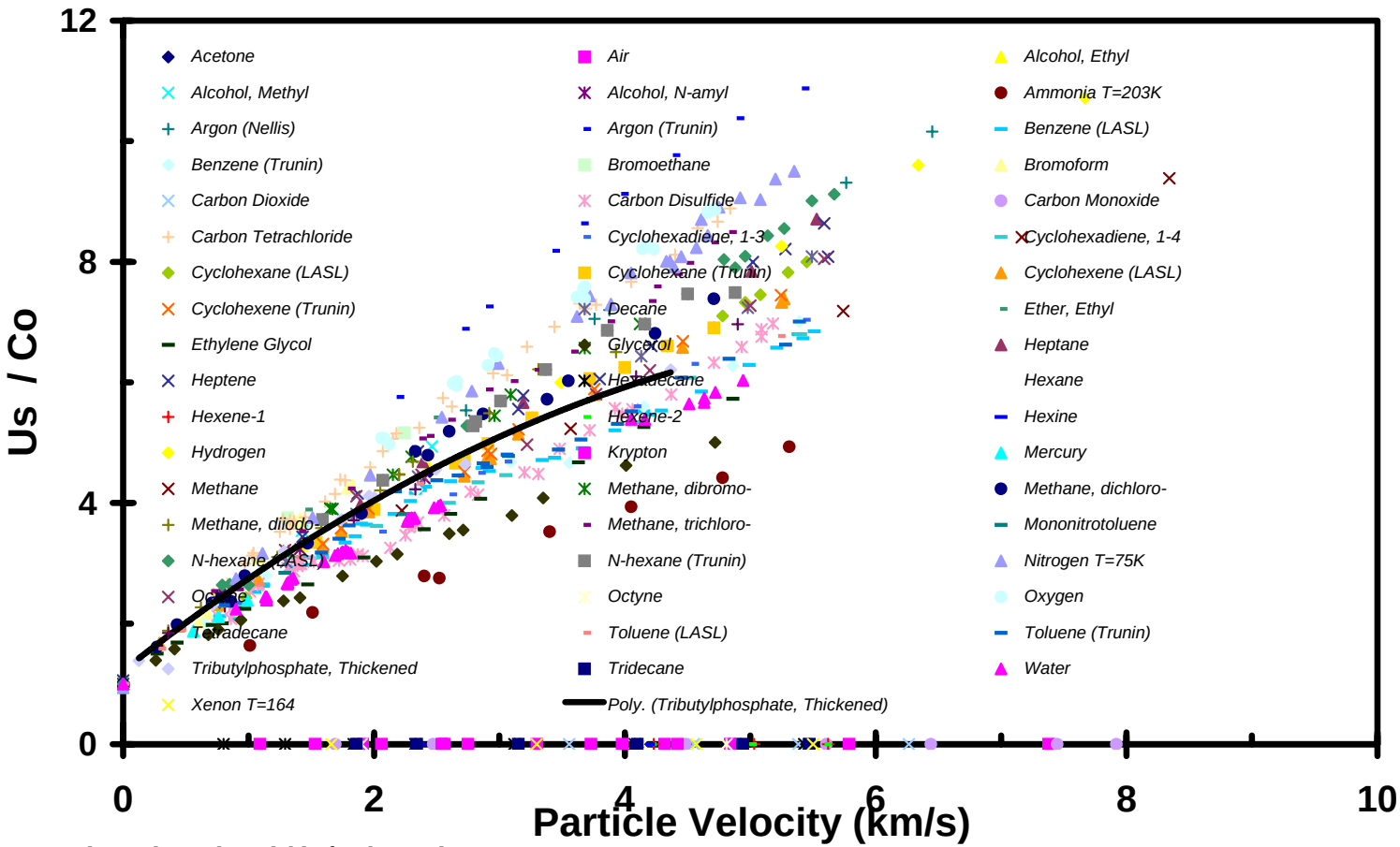
Not all Liquids are created equal

Shock velocity vs. particle velocity normalized with acoustic wave velocity



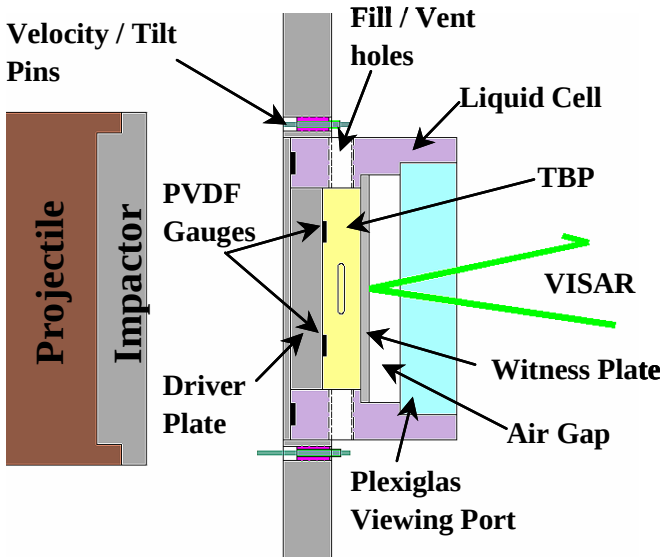
Not all Liquids are created equal

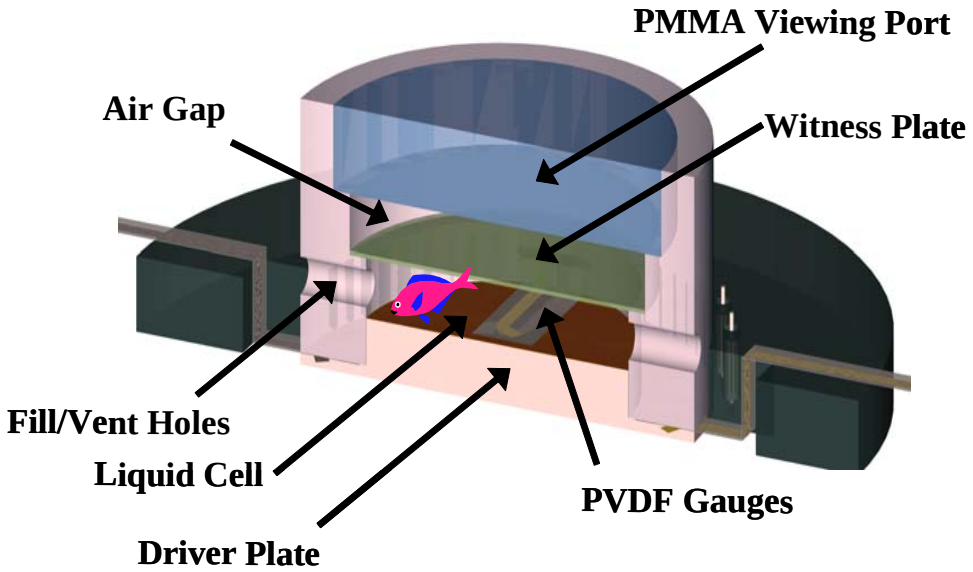
Shock velocity vs. particle velocity normalized with acoustic wave velocity—for all liquids*



*liquids with Hugoniot and sound speed available for this study

Experimental Technique





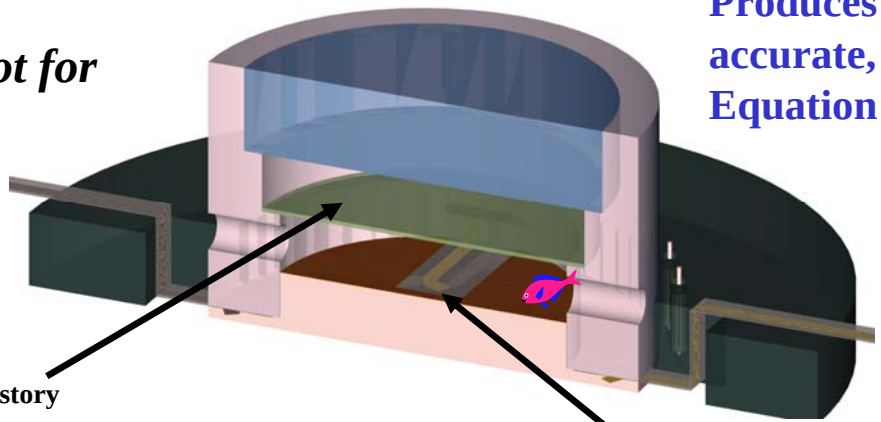
Depiction of experimental target configuration

Experimental Technique

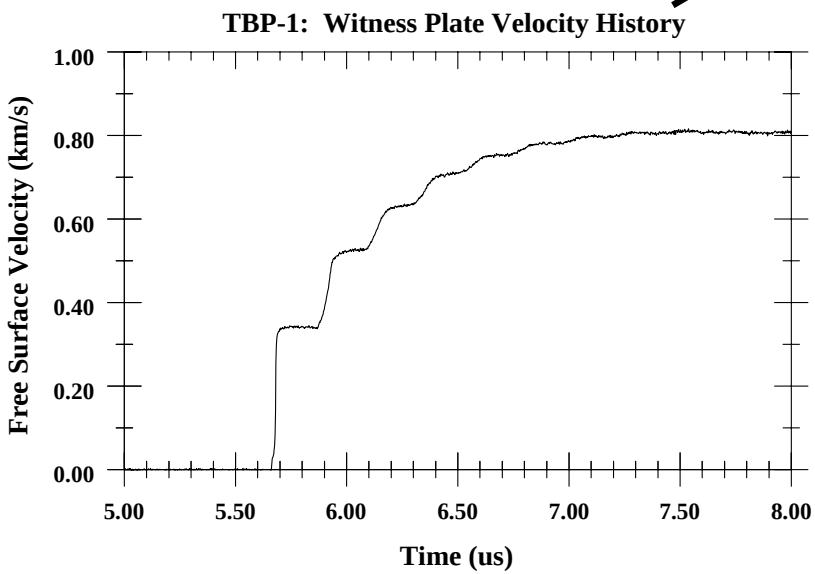
Diagnostic Location,

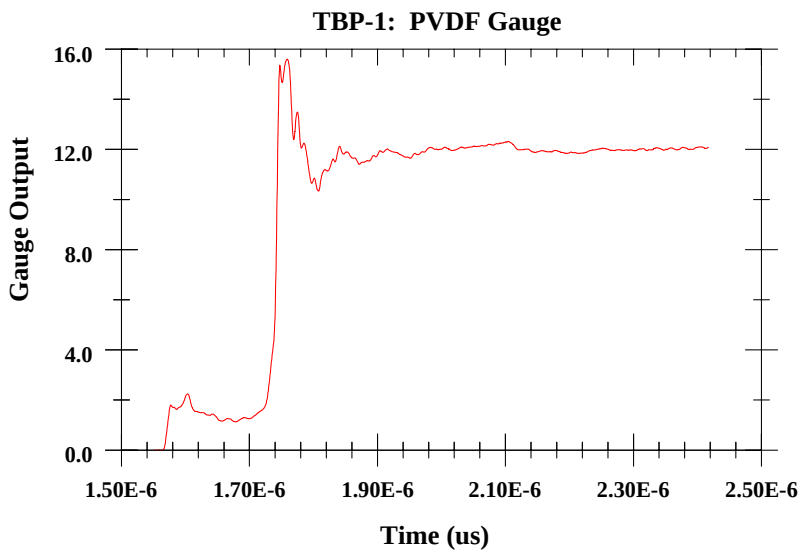
Extremely well-known Hugoniot for Boundary/Standard Materials,

Common fiducial tied to impact plane - Extremely Valuable



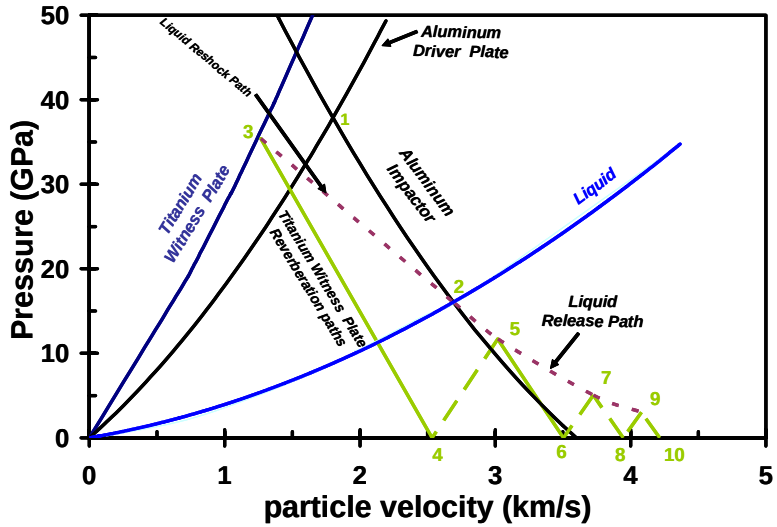
Produces extremely accurate, time-resolved Equation of State of TBP

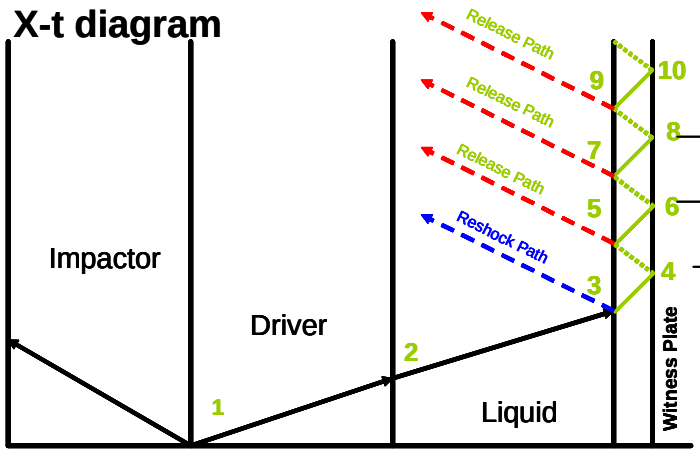


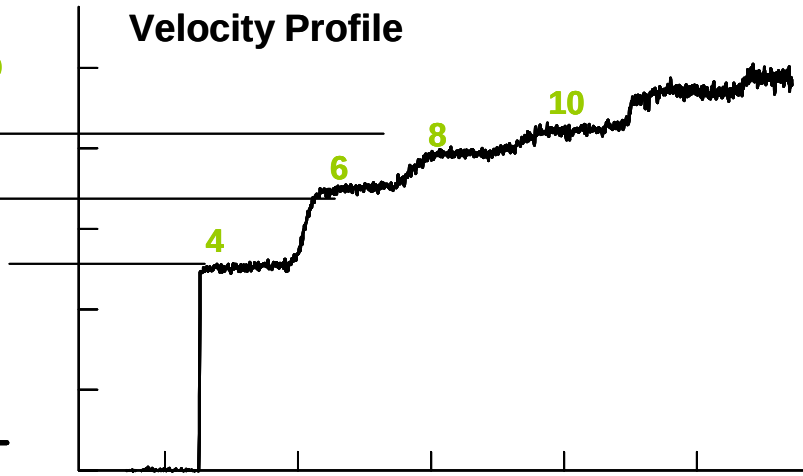


Principle of Technique: Hugoniot

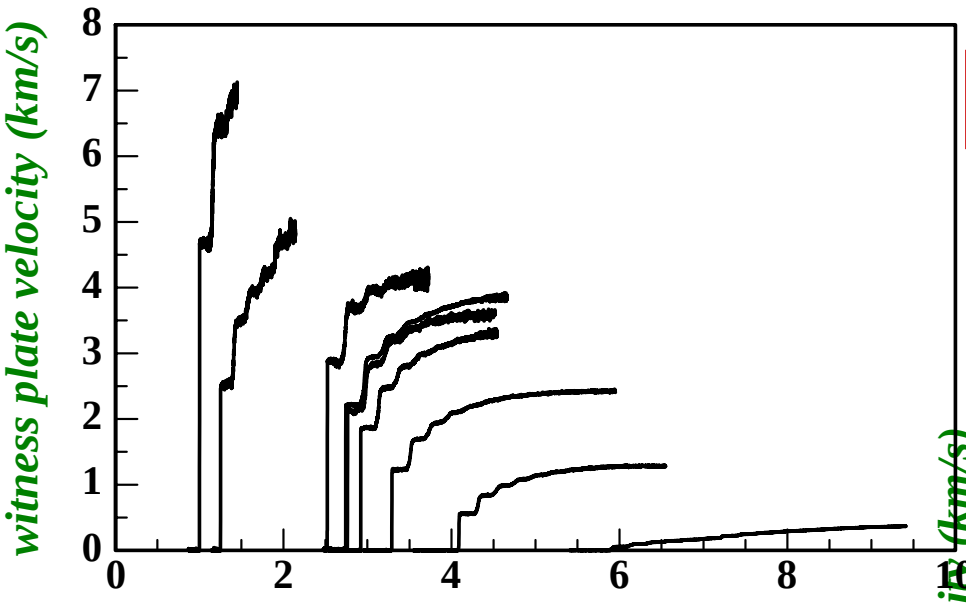
Single experiment gives information on the Hugoniot, Reshock, and Release States





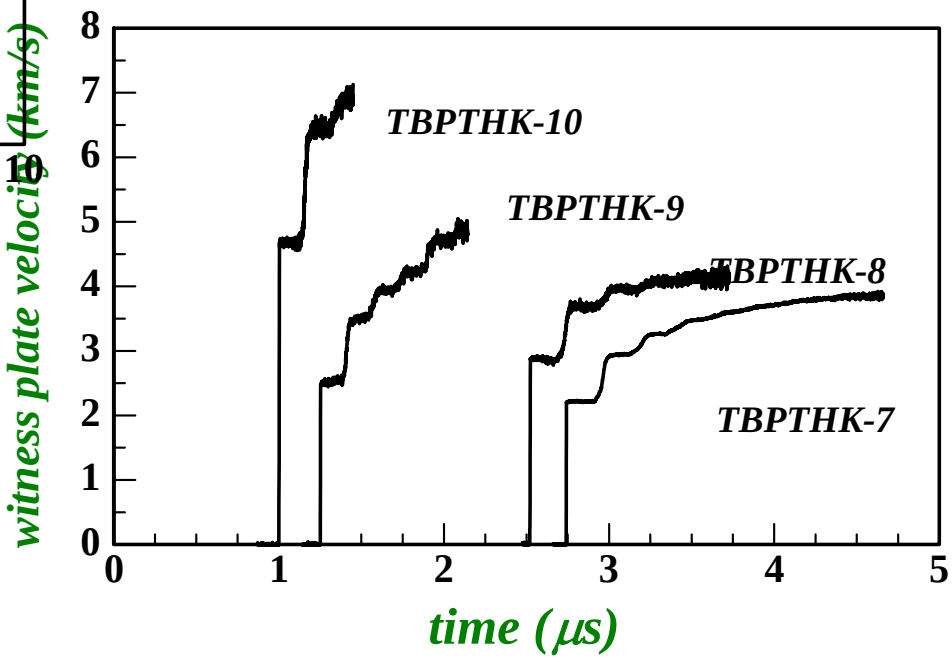


High Pressure Thickened TBP - 35 GPa -



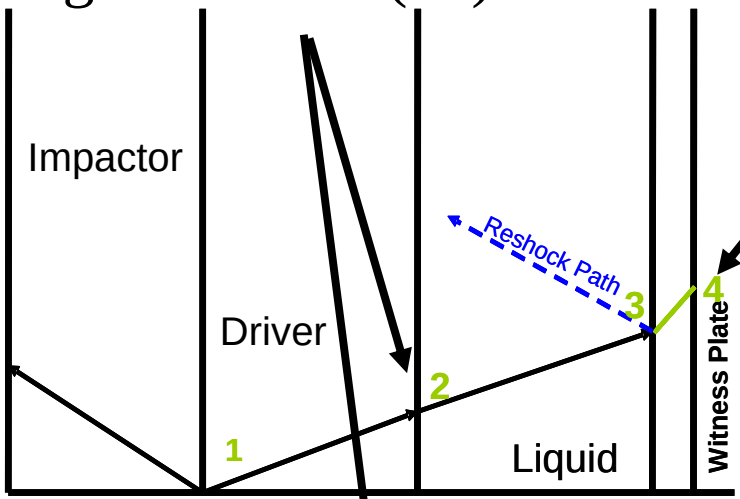
- *All Experiments to 35 GPa*

- *Latest Experiments to 35 GPa*



Principle of Technique: Hugoniot

Hugoniot State (#2)

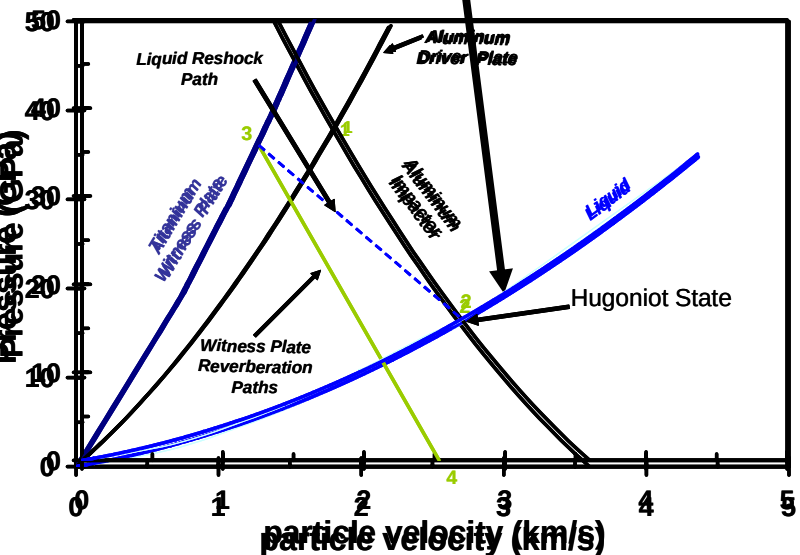


VISAR

Hugoniot state determined:

- ***impedance matching techniques.***
- ***Initial values.***
- ***Direct shock velocity measurements:***

PVDF & VISAR for time of arrival



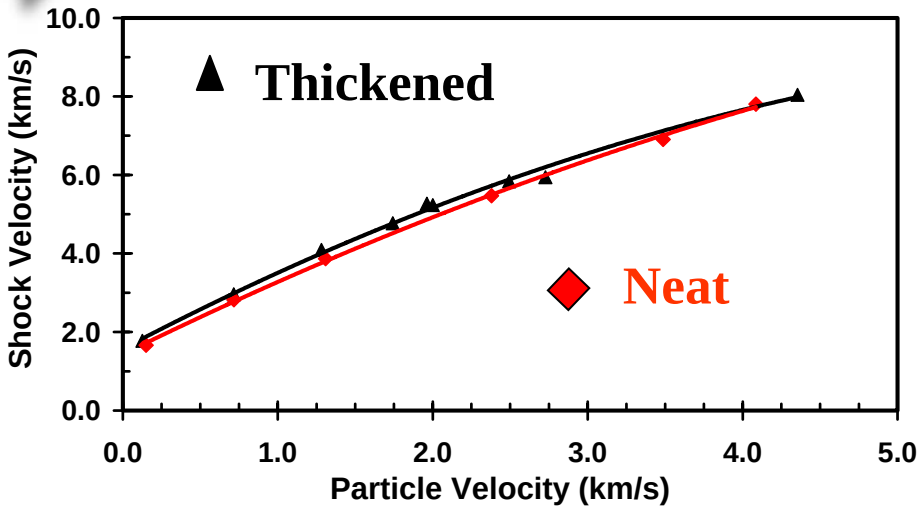
Hugoniot States of Liquid is inferred from impedance of liquid,

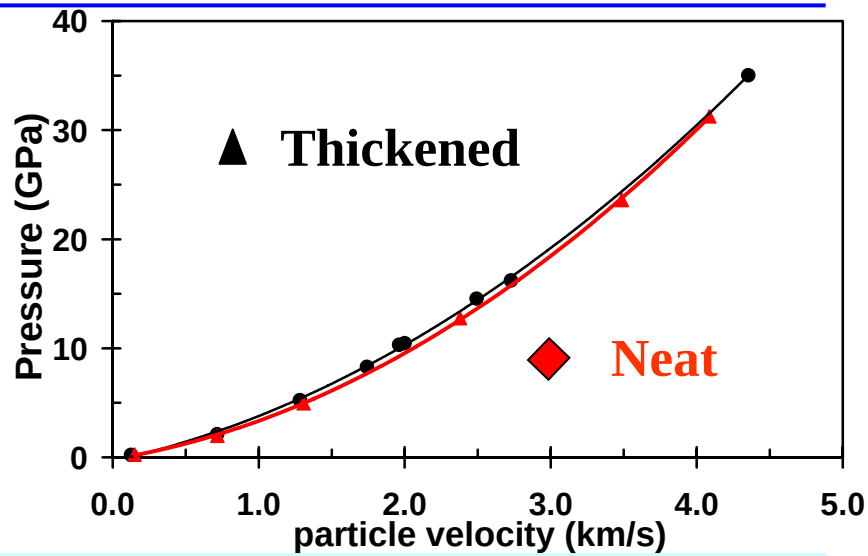
$$z_L = \rho_{oL} U_{sL};$$

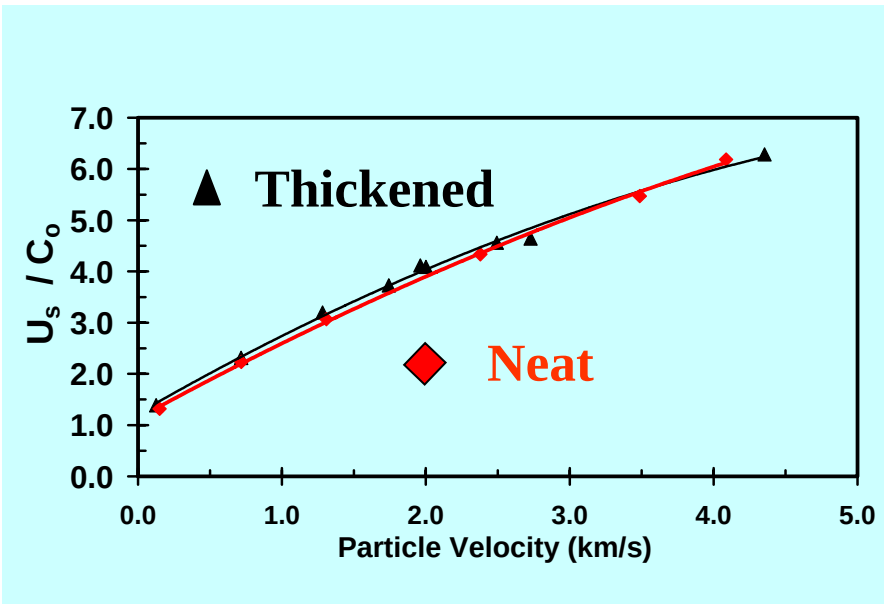
hugoniot of driver and witness plate (Aluminum)

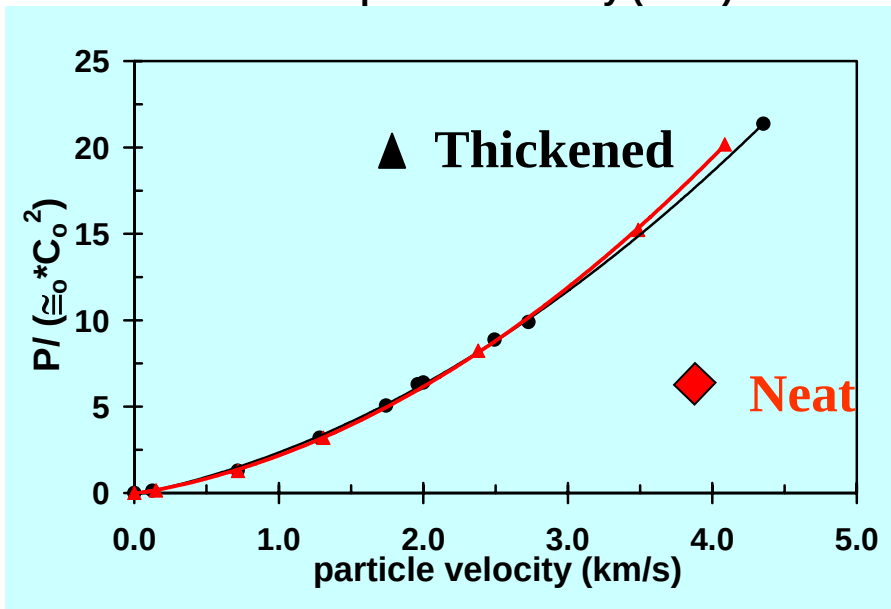
Stress is the same at Aluminum/Liquid interface

neat & thick TBP referenced to ambient sound speed/modulus

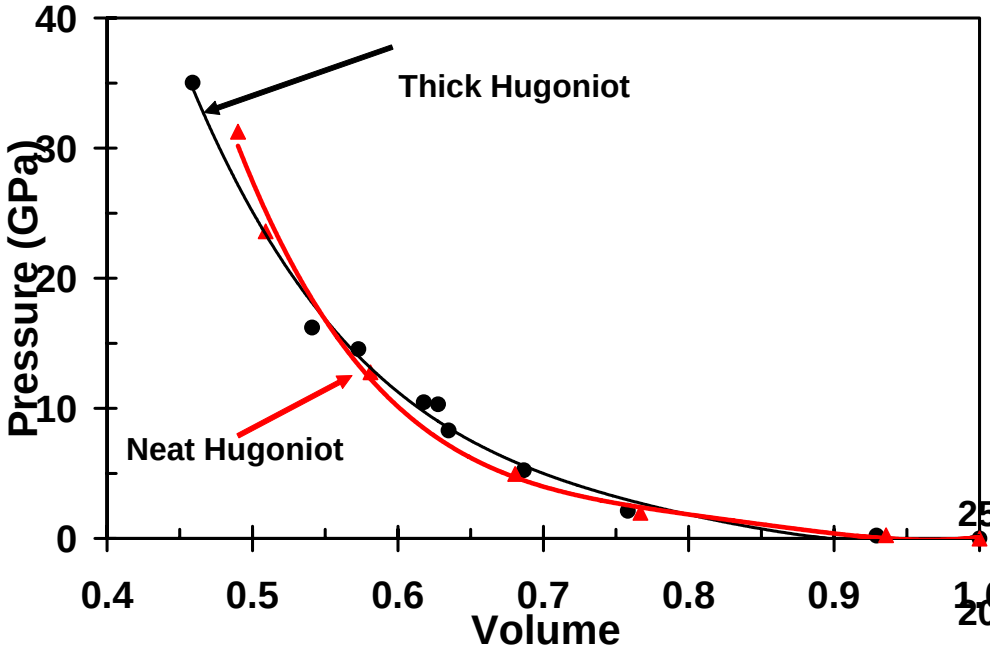


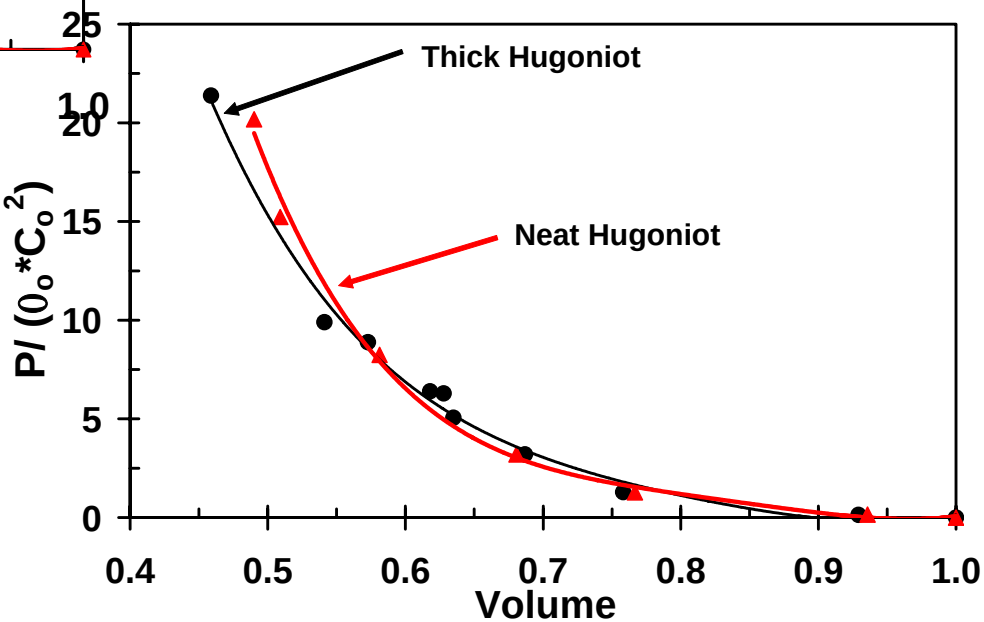






neat & thick TBP

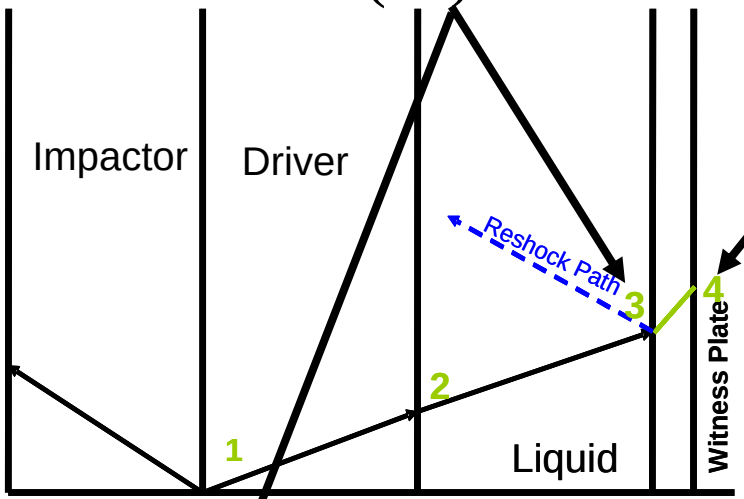




Principle of Technique: Reshock

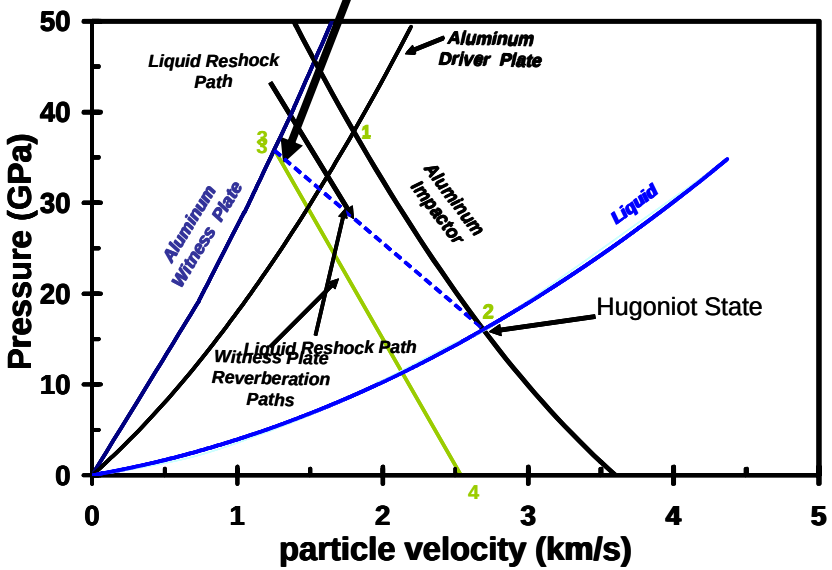
Reshock State (#3)

VISAR



Recompression/Reshock occurs at the witness plate/liquid interface:

- ***Witness plate is higher impedance***



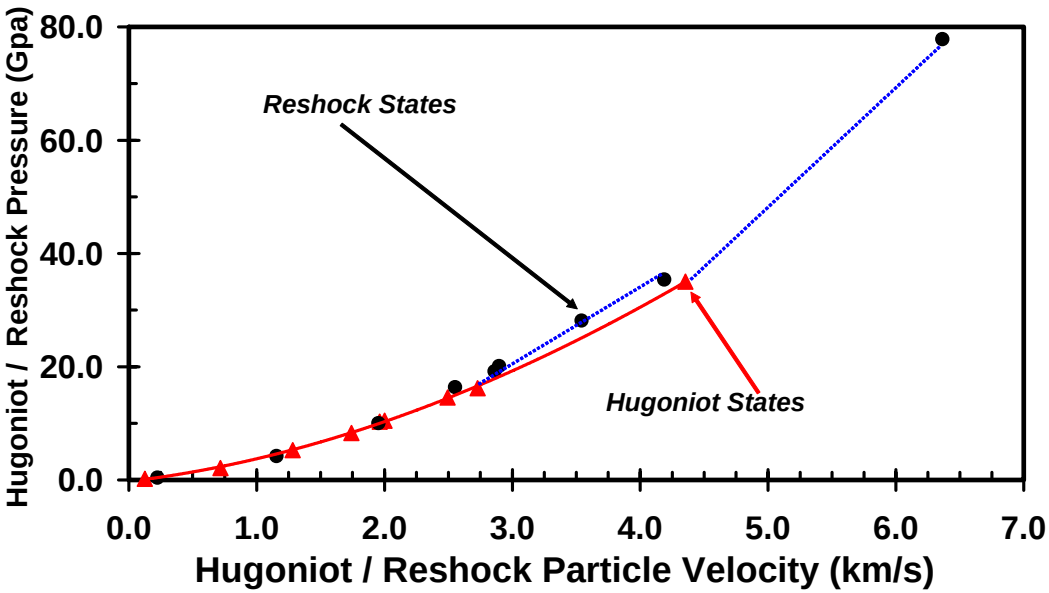
Reshock stress state:

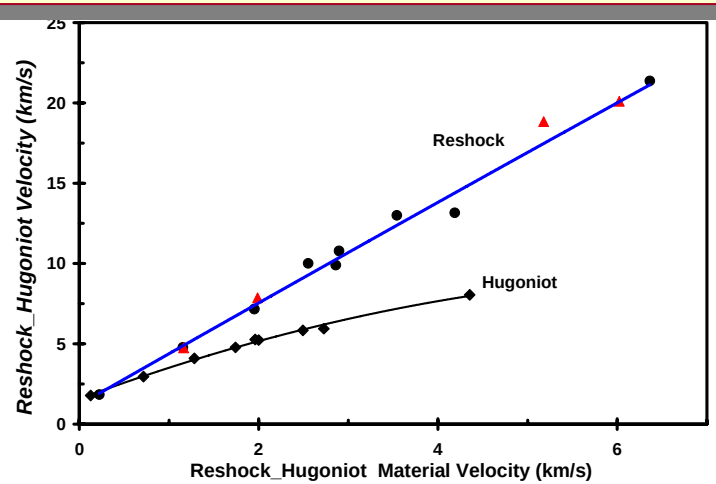
- ***calculated from in-situ particle velocity, and hugoniot of witness plate***

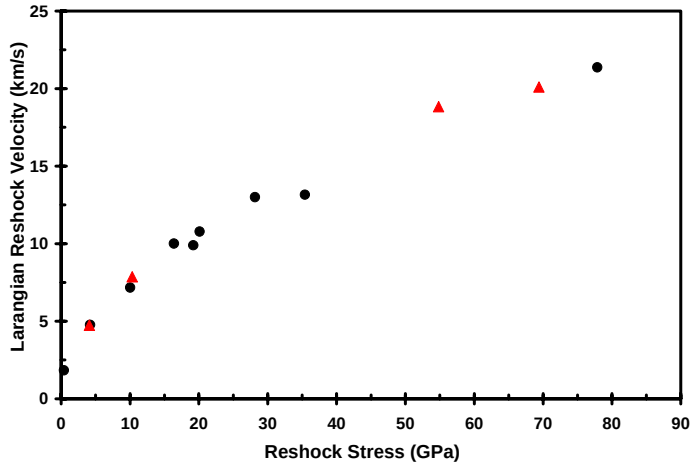
Wave Speed and total strain:

- ***Total strain, $\varepsilon_{RS} = \varepsilon_h + (\Delta u / C_{LRS})$***
- ***wave speed, $C_{LRS} = \Delta_s / (\Delta_u \rho_L)$***

Reshock Results

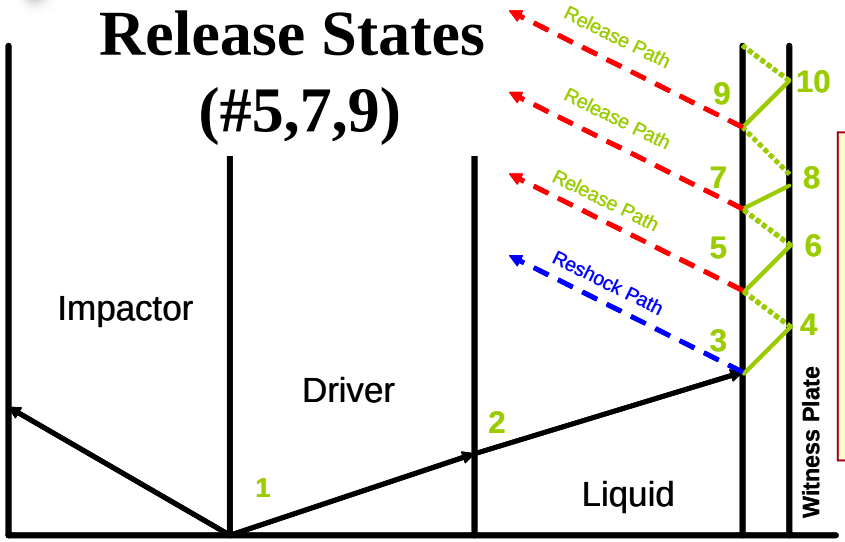






Principle of Technique: Release

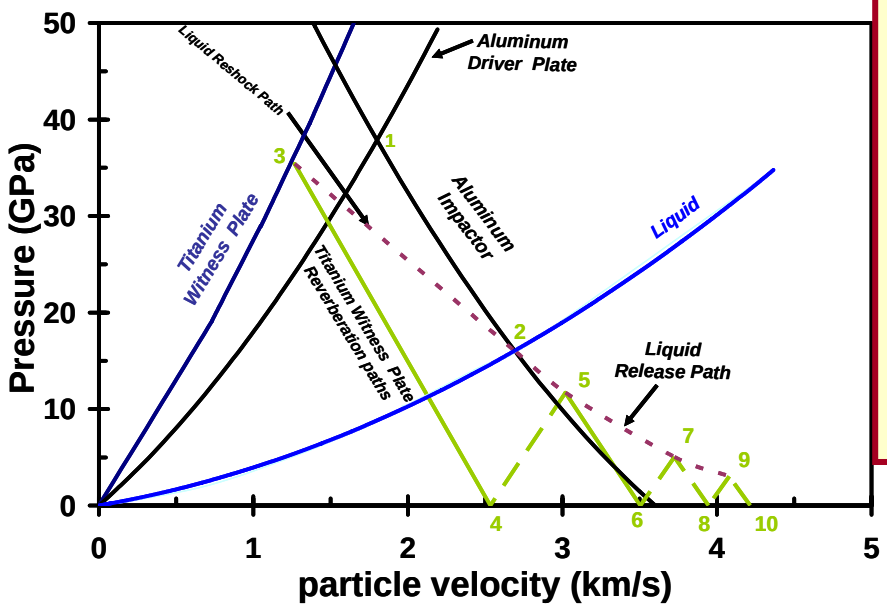
Release States (#5,7,9)



VISAR

Release occurs at the witness plate/liquid interface:

- ***Liquid is lower impedance than witness plate***



Release states:

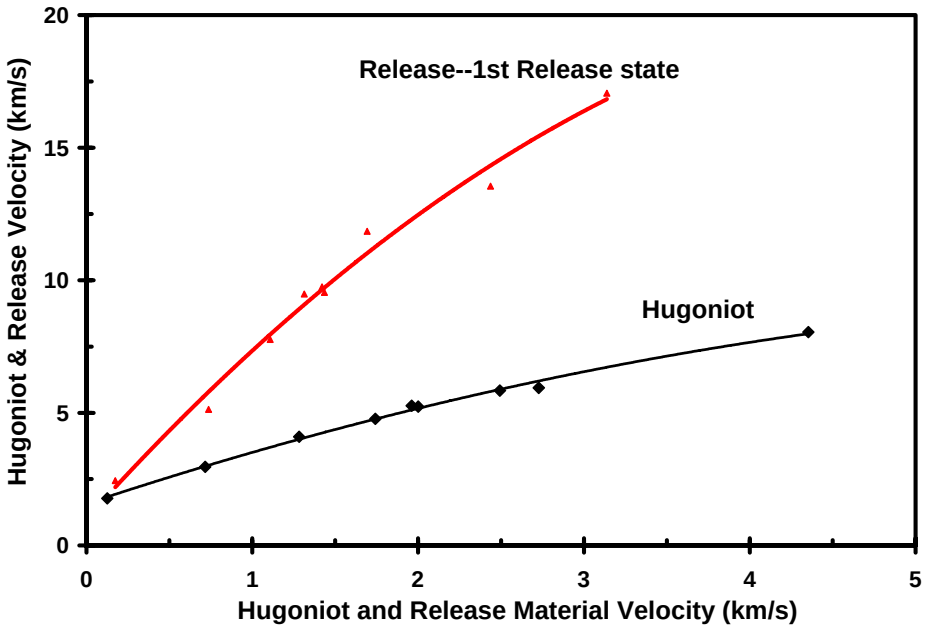
- ***free surface velocity contains detailed information of the expansion of the liquid***
- ***Material velocity and stress determined along the liquid release path***

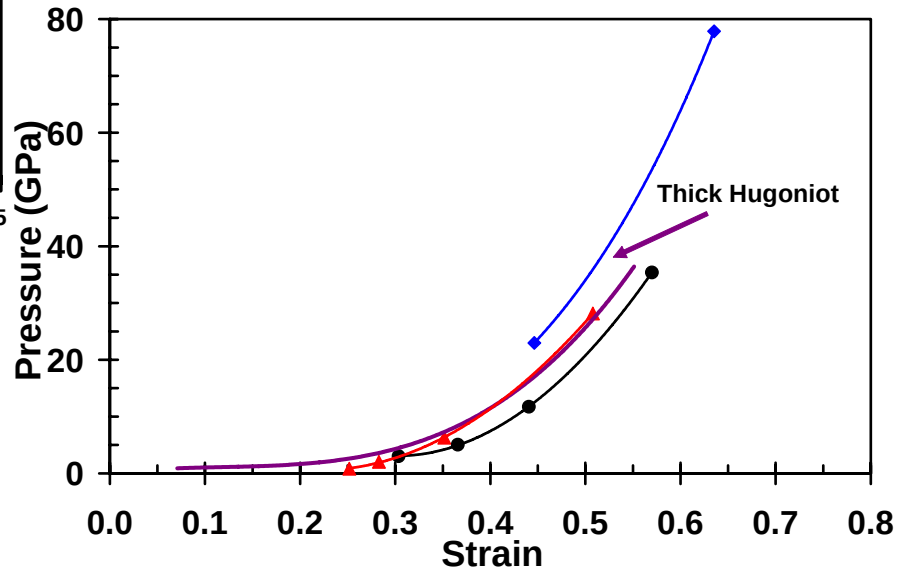
$$u_i = \tfrac{1}{2}(u_{i+1} + u_{i-1})$$

$$\sigma_i = \rho_{wit}\, C_{wit}\, \Delta u_i; \quad i = 5, 7, 9 \text{ etc.}$$

Release Results

Release from the Reshock State: depicts average release paths





Observations:

- TBP Thick shows a stiffer response upon reshock than that of Neat.

- As the liquid is released and pressures decrease it should be noted that all the liquids are converging toward their respective hugoniot.
  - It should be again noted that the starting point is from the off-hugoniot reshock state.

Summary

- *There is very little experimental work performed to ascertain release properties of liquids.*
- *The results reported are the first measurements on any liquid.*
- *Our technique has been used to obtain average release states of liquids.*
- *Changing the witness plate to a high impedance metal, such as tungsten, can modify this technique by increasing the number of release states.*

Current Accomplishments-'04

- *Additional experiments performed on Thickened TBP—Total of 10 experiments*
- *Additional experiments (high pressure) on Neat*
- *Extended pressure study to 35 GPa (both Thick & Neat).*
- *Research of previous liquids provides insight that liquids behave different*
- *Evidence for using same EOS for both "Neat" and "Thickened" may be plausible.*
  - *Current theoretical models simulate experimental hugoniot data very well*
  - *With 4% thickening agent, no surprises*