Glass as a Shaped Charge Liner Material

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Outline

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- Highly Ductile Glass Jets
- High Density Glass Investigations
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Introduction

- Glass: non-crystalline (amorphous) solid material typically known to be brittle under ambient conditions and often optically transparent
- Soda-lime glass: ~75% silica (SiO_2), is the most common type of glass used for bottles and windows with a density of ~2.5 gm/cc
- Lead glass: lead replaces the calcium in the glass formulation, typically 18–40% weight lead oxide (PbO), with final densities between 3.1 and 7.2 gm/cc
- Glass as a shaped charge liner material is an old subject
  - Explosively loaded champagne bottles and other conical based bottles for demolition and special applications is very well known and commonly taught for military use. It is believed that such practice dated to a period of improvised munitions used early in World War II.
  - Glass liners have been used in a variety of shaped charge applications, including demolition munitions and as oil well perforators.

Introduction

- Bulk metallic glass has also been investigated as a shaped charge liner material
  - W.P. Walters, L.J. Kecskes and J.E. Pritchett, "Investigation of a Bulk Metallic Glass as a Shaped Charge Liner Material", ARL-TR-3864, August 2006.
- The use of higher density glasses for jet studies has been more recently reported
  - K. Cowan and B. Bourne, "Oxide Glasses as Shaped Charge Liners", Proceedings of the 21st International Symposium on Ballistics, Adelide, South Australia, 2004.
- The US Army ARDEC has undertaken considerable studies of glass shaped charge jet behavior

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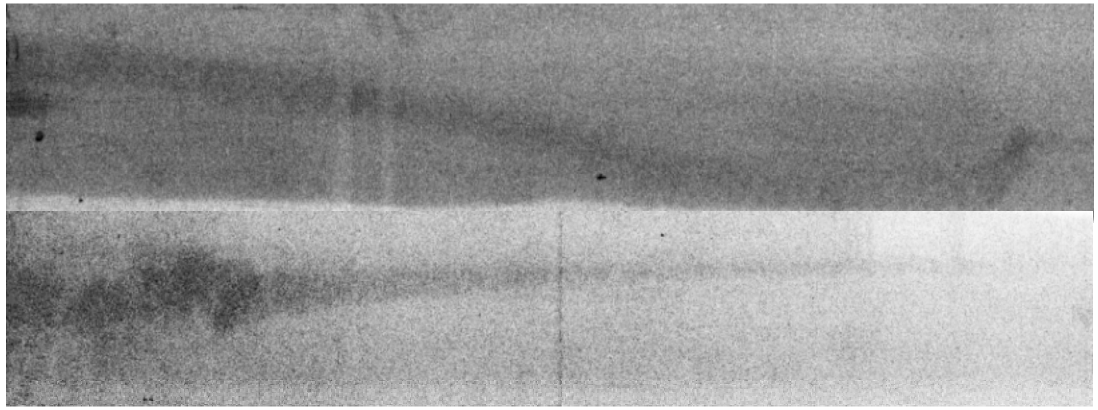
Improvised Shaped Charges

- Hand packing of bottles using moldable plastic explosives to form shaped charges is commonly taught
- Normally the bottle neck would be cut off to reduce the amount of high explosive required and to ease the hand packing operation
- 750 ml wine bottles were hand packed with Composition C-4 explosive
- Flash x-rays were taken of the jets
  - Extremely curved jets
  - Extreme particulate nature
- Steel penetration testing
  - 3.4 CDs (260mm) at a 5.5 CD (460mm) standoff

Improvised Shaped Charges

Jet Flash x-rays



Extremely curved jets, extreme particulate nature

Steel penetration testing

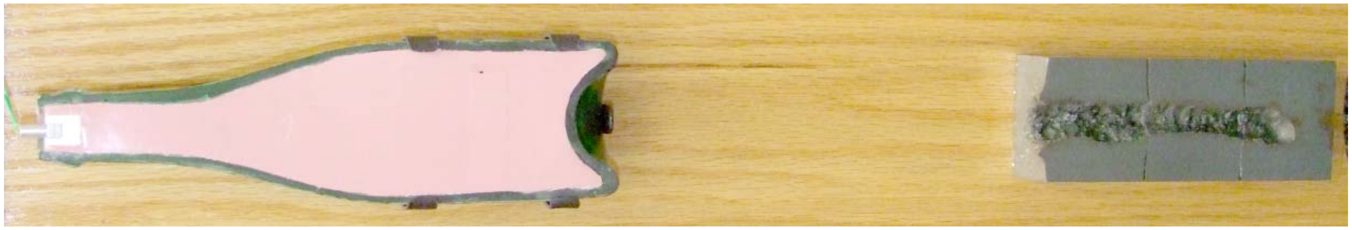
3.4 CDs (260mm) at a 5.5 CD (460mm) standoff

Improvised Shaped Charges

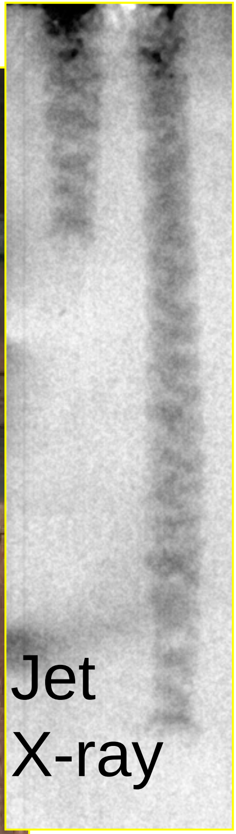
- Beer bottles: 375ml Timmermans Lambic with conical bases
  - Octol 70/30 to a final density of about 1.80 gm/cc
  - Small PBXN-5 booster pellet with an RP87 detonator
  - 150 KV flash x-rays with soft x-ray tubes
  - Jet tip velocity of about 5 km/s with a fairly straight jet
  - Extremely particulated behavior, some repeatable structure
  - Penetration studies against mild steel witness plates
    - 2.6 CD (130mm) of steel at a 6 CD (305mm) standoff
    - 2.25 CDs (114mm) at a 3 CD (152mm) standoff.
- Sparkling wine bottles: 750ml Korbel Extra Dry with conical bases
  - Octol 70/30 to a final density of about 1.80 gm/cc
  - Small PBXN-5 booster pellet with an RP87 detonator
  - 150 KV flash x-rays with soft x-ray tubes
  - Jet tip velocity of about 7 km/s with a fairly straight jet
  - Repeated experiment showed some variation in the jet tip shape and velocity
  - Extremely particulated behavior, some repeatable structure
  - Penetration studies against mild steel witness plates
    - 3.4 CDs (280mm) at a 5.5 CD (460mm) standoff
    - repeated, producing a nearly identical penetration depth.

Improvised Shaped Charges

Beer Bottle



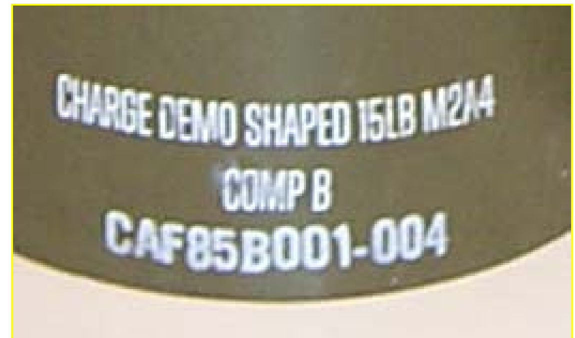
Sparkling Wine Bottle



Penetration

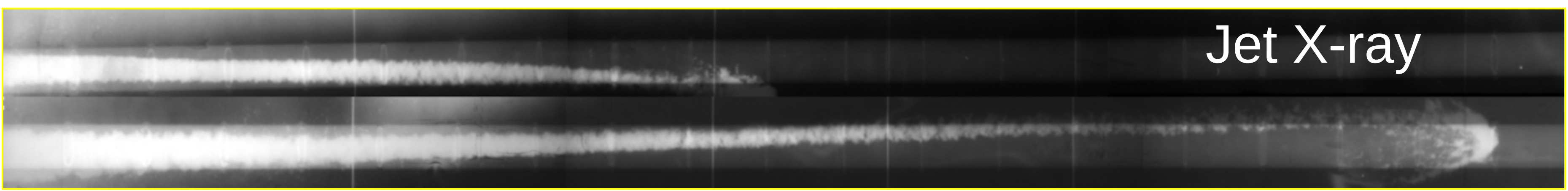
Standard Demolition Charge

M2A3/M2A4 Demolition Charges



- *Originally produced at Picatinny!*
- *Developed in early 1940s!*

~9-1/2 pounds Comp-B main charge
~2 pounds 50-50 pentolite booster

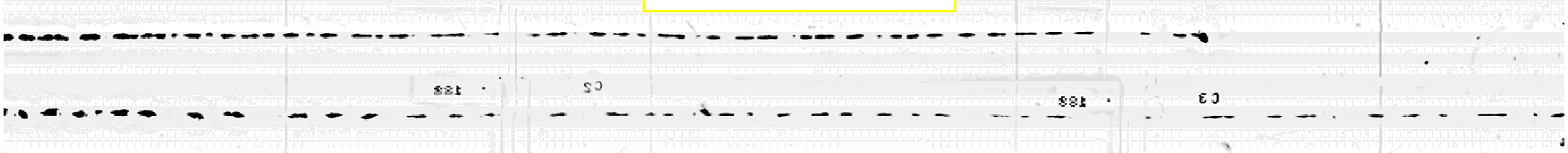


~6.4Km/s Jet Tip Velocity

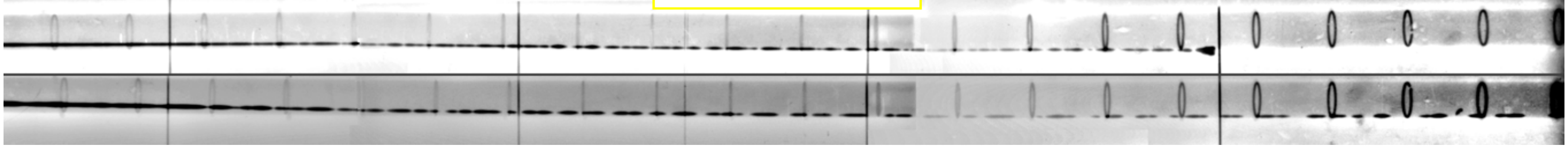
84" Penetration in soil

20 CD flash x-ray comparisons

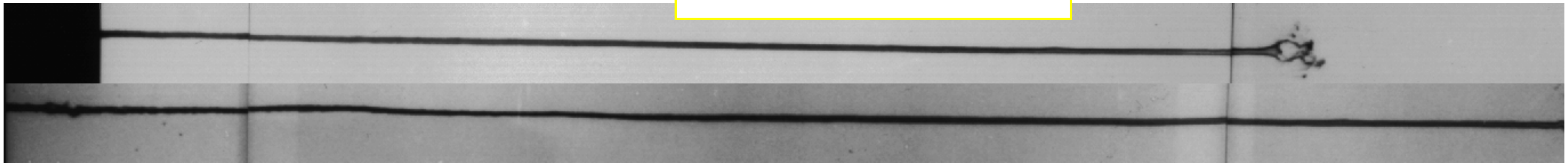
Tungsten Jet



Copper Jet



Ductile Glass Jet



Glass can produce the most ductile shaped charge jets known to date

High Density Glass Investigation

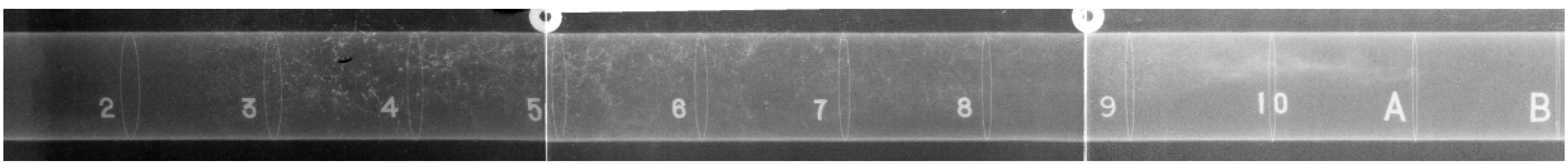
- 70mm shaped charge configuration
- Cast (Octol 70/30, EDC1G) and pressed (LX-14) explosives
- Variety of increased density glasses
  - –up to 5.5 gm/cc glass were identified that were able to produce jets that did not particulate
  - –above this density either could not make the glass or did not form coherent jets

70mm shaped charge

High Density Glass Investigation

Observed Jet Characteristics

- Lower jet velocity shaped charges\tended to produce extreme particulate jet behavior
- May be related to the brittle nature of glasses observed at lower temperatures and pressures
- Similar to jets produced from improvised bottle shaped charges and fielded demolition shaped charges
- Similar jets have been observed from bulk metallic glass lined shaped charge jets

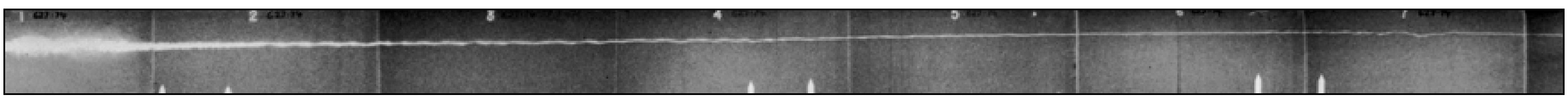


Extremely particulated glass jet

Observed Jet Characteristics

- Extremely ductile jet behavior appears to be associated with higher pressure and resulting glass jet temperatures
- Believed to be a result of traditional glass softening at elevated temperatures

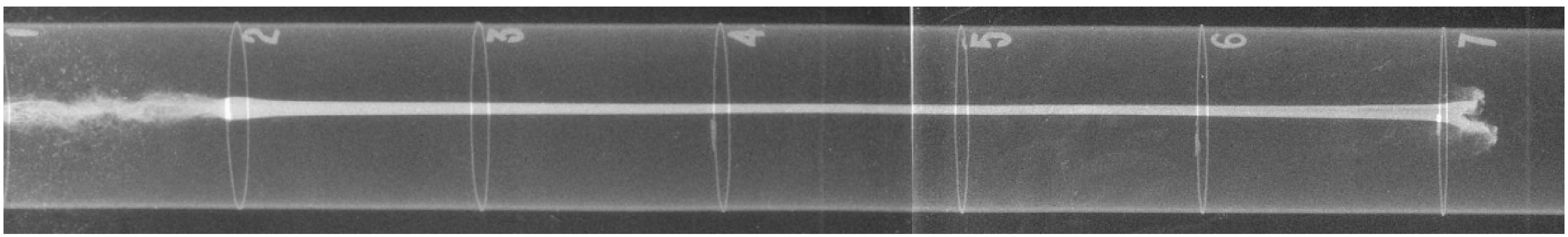
- Very late time jet instability: “wobblization”
- Spiraled into a helical pattern
- Onset of this wobblization: between 40 and 57 CD standoff.



Flash x-ray of a glass jet at 57 charge diameters

Observed Jet Characteristics

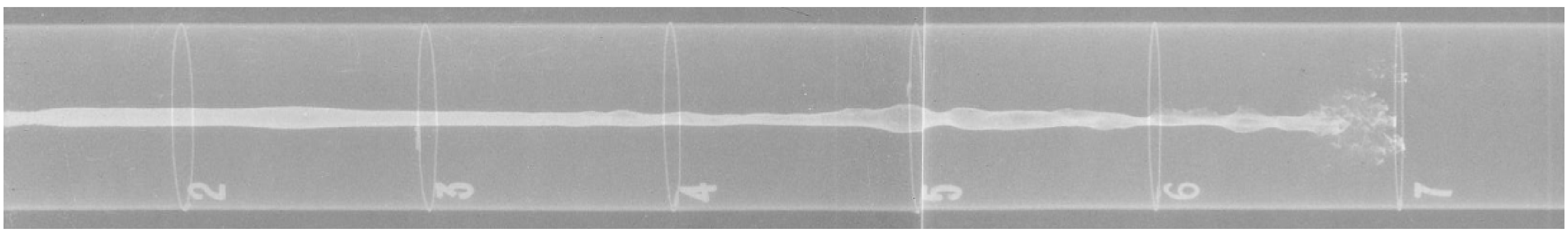
- Jet overdriving was often clearly evident
- Many jet tips looking \like traditional highly overdriven metal jet tips
- Radially dispersed jet mass sprayed in front of the coherent jet
- Long portions of hollow jet tip
- Coherent jet was often noted at a velocity of about 6.5 km/s.



Shaped charge with a hollow section and overdriven jet tip

Observed Jet Characteristics

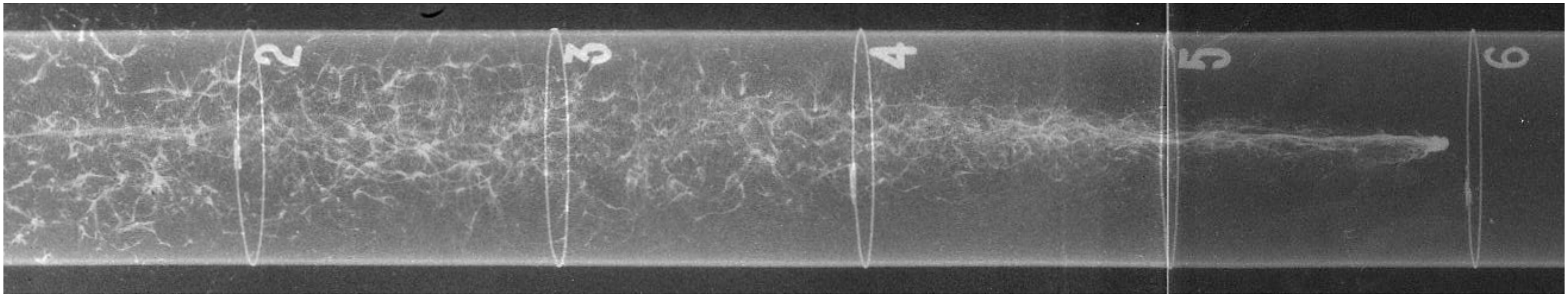
- Radially dispersed jet tip behavior appears to be associated with the classical observed behavior resulting from supersonic flow conditions in the jet formation region
- The degree of radial dispersion was found to vary from slight hollowing of the jet to complete hollowing of the entire jet that became known as “bubble jets”



A glass bubble jet

Observed Jet Characteristics

•Some design and glass combinations appears to push the jet beyond standard overdriven and bubble jet conditions
•Entire jet appeared as a series of fluid sections that became known as a “droplet jet



A glass droplet jet

Conclusions

- A variety of traditional silica based glasses, including higher density lead glasses, have been used as shaped charge liner materials
  - Explosively packed bottles have long been used as improvised shaped charges
  - Standard demolition shaped charges use glass liners for geologic materials penetrations.
  - Shaped charge jet radiography reveals the extreme particulate nature of these jets.
- A series of progressively higher density glasses have also been explored.
  - Jet radiography results from these tests show distinct regions of resulting jet behavior with extreme particulate, ductile or radially dispersed behaviors.
  - The resulting jet behavior appears to be both material and design dependent.

Acknowledgements

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