IS HIGHER DETONATION VELOCITY *NEEDED* FOR SHAPED-CHARGES *?*

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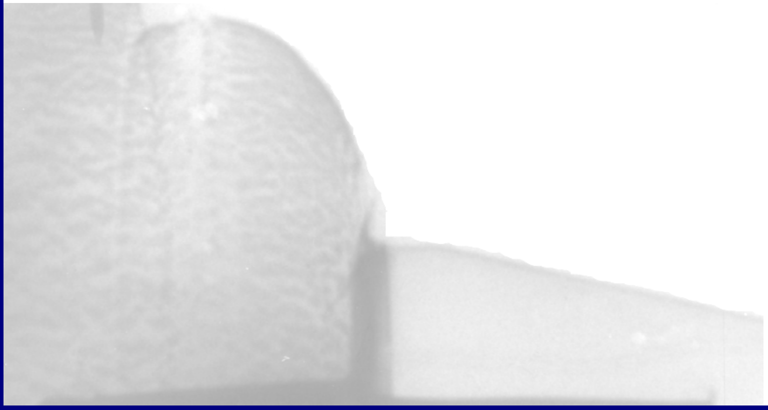


אוניברסיטת בן-גוריון בנגב
Ben-Gurion University of the Negev

BAKER HUGHES

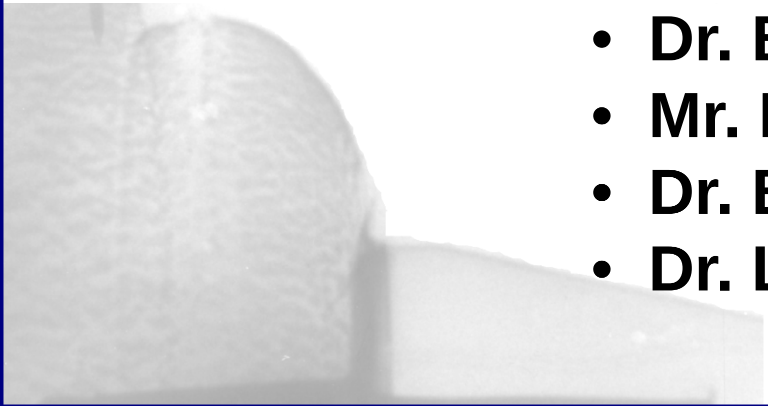
Dedicated to:

Prof. Dr. Manfred Held

who asked many questions and had a direct interest in this topic since at least the late-1970s.

Also presented to honor others who also worked with us since those times on modeling, experiments and applications:

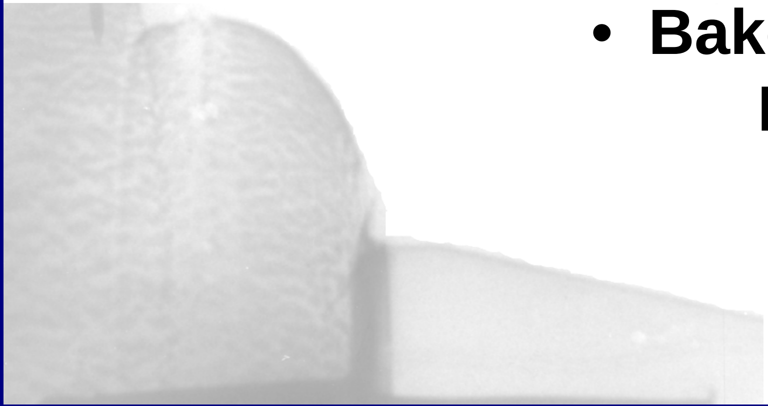
- **Mr. Don Butz**
- **Dr. Bob Eichelberger**
- **Mr. Don Kennedy**
- **Dr. Bob Sedgwick**
- **Dr. Lou Zernow**



Approach

"*Partial Differential*" look into a multi-parameter, multi-process explosive application … :

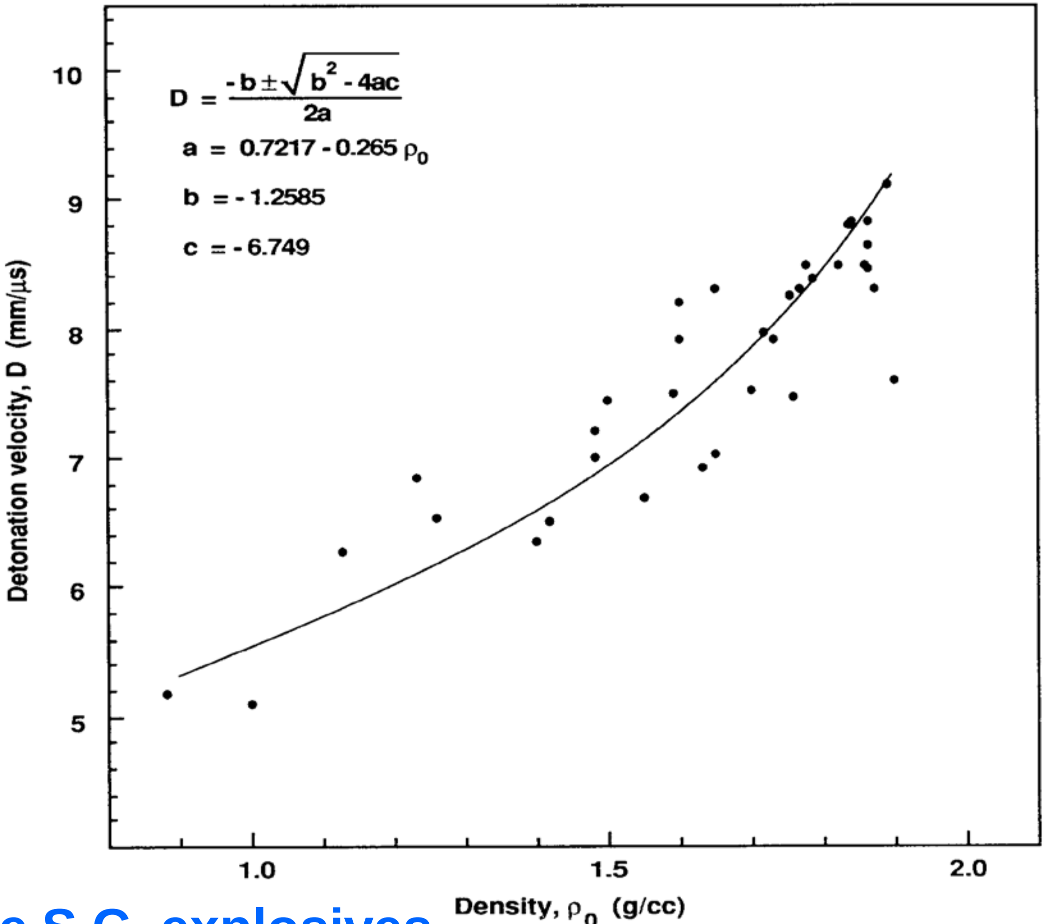
- **Effects of explosive performance are envisioned and modeled consistently,**
- ***Two* different modeling methods were <u>validated</u> and <u>extrapolated</u>:**
  - **SCAN analytical model code**
  - **Baker Hughes 2-D 2^{nd} Order Eulerian Grid Code**



Earlier work using BRIGS is not presented in the paper or presentation.

Detonation Velocity -- *Key* Characteristic of Explosive *Mass* & *Energy Densities*

For an individual energetic material $D = A + B\rho_o$ **describes performance versus pressed or cast density at less than crystal density**



Urtiew & Hayes **provided formula for D from 34 energetic materials and binders.**

Using gas expansion to define propulsion

$$\gamma_{average} = 2.77\ *$$

$$\gamma = -d \ln P / d \ln V$$

for constant γ **expansion**

*** 2.8+ for high performance S.C. explosives**

Different Explosives in Shaped-Charges

SCAN used to reverse-engineer performance of 10 explosives in BRL 81-mm S-C using Gurney formulas where

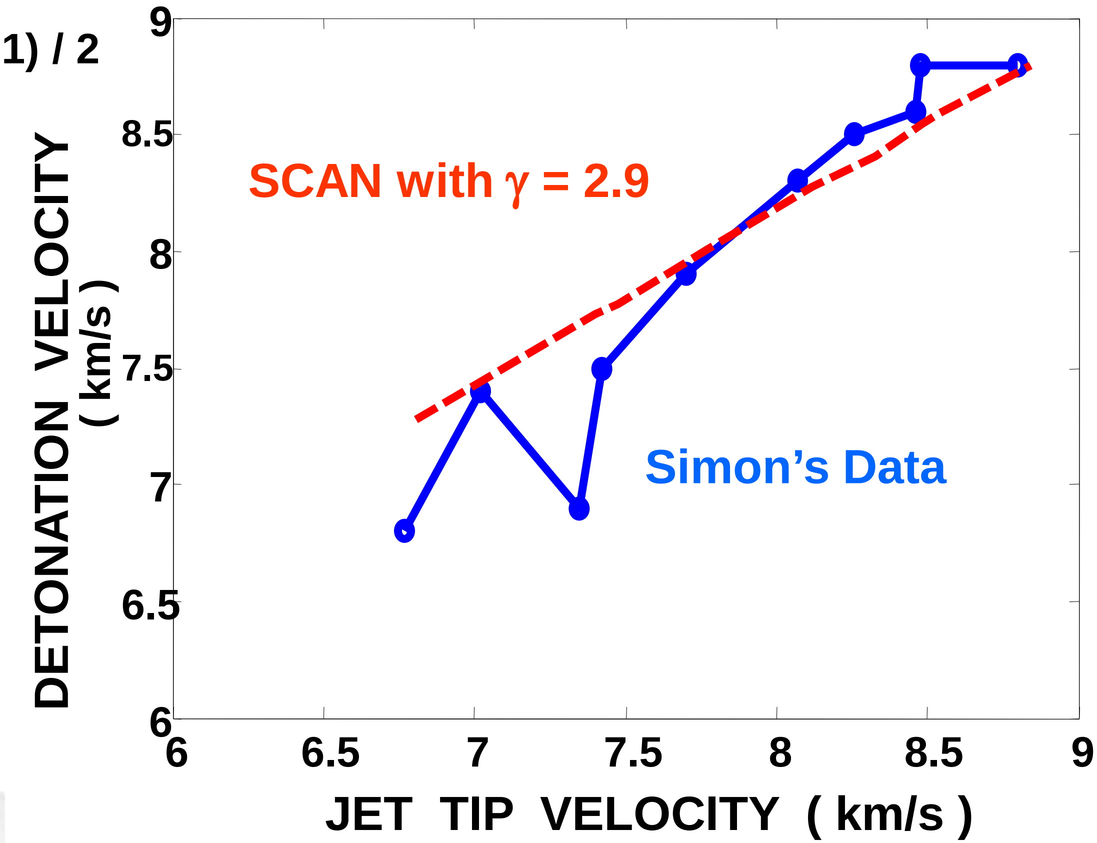
$$(2E)^{1/2} = D\left((2/\gamma^2-1)(\gamma/\gamma+1)^{\gamma} \right)^{1/2}$$

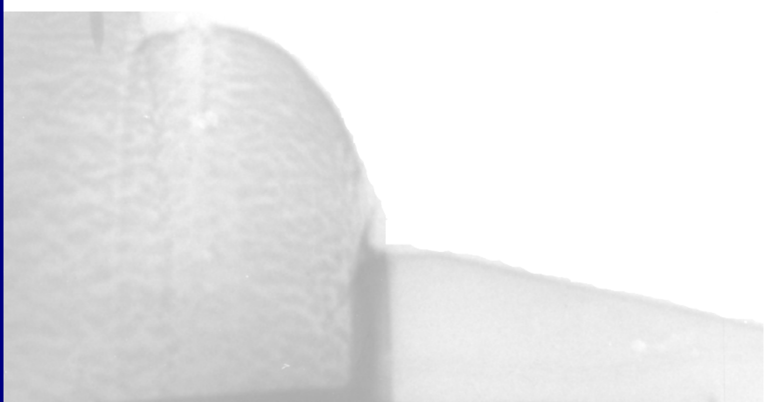
and

$$D = 8.8\,(\rho_o/1.856)^{(\gamma-1)/2}$$

$\gamma = 2.9$

fit to published jet tip velocities





Extrapolating Explosive Performance using a JWL Equation of State

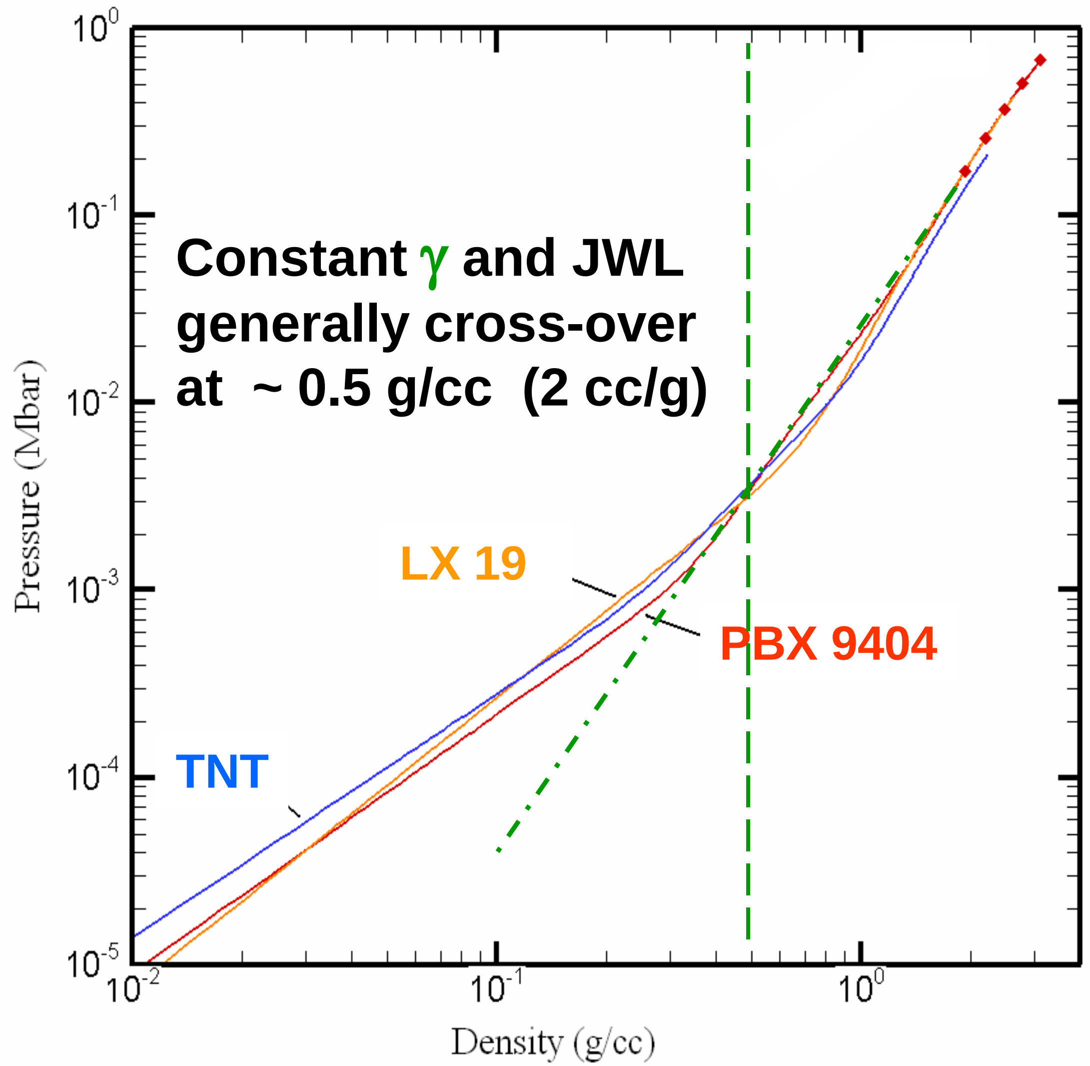
Assumptions:

- expansion isentrope does not change
- initial position for pressure / density changes
- PBX 9404 baseline

  D = 8.8 km/s

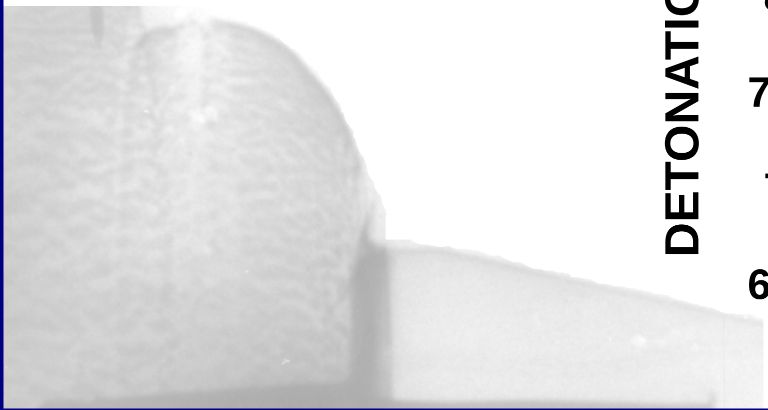
  ρ_o = 1.84 g/cm^3

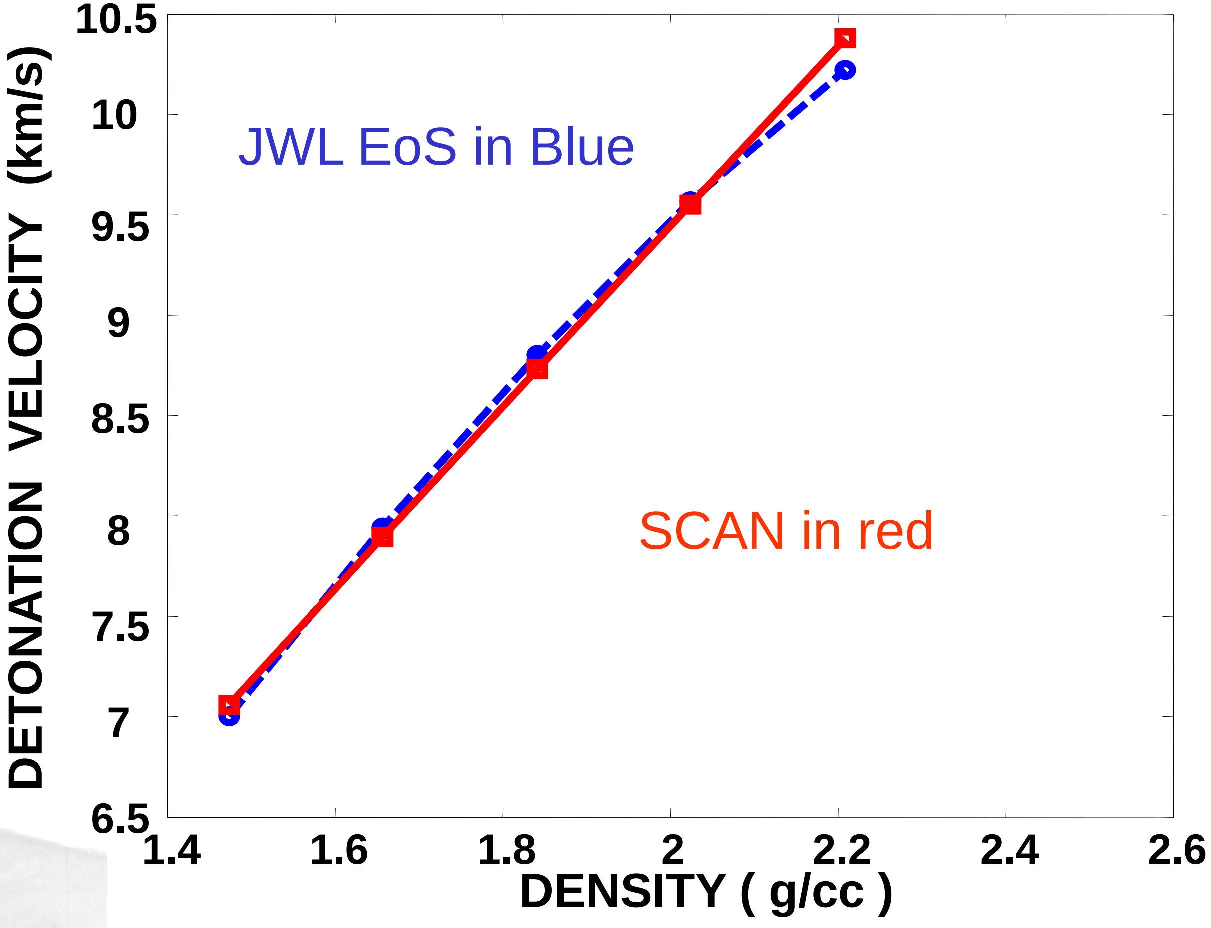
  γ = 2.85



Detonation Velocity *versus* Explosive Density --- JWL & SCAN Models

Comparable **over the range of simulations**



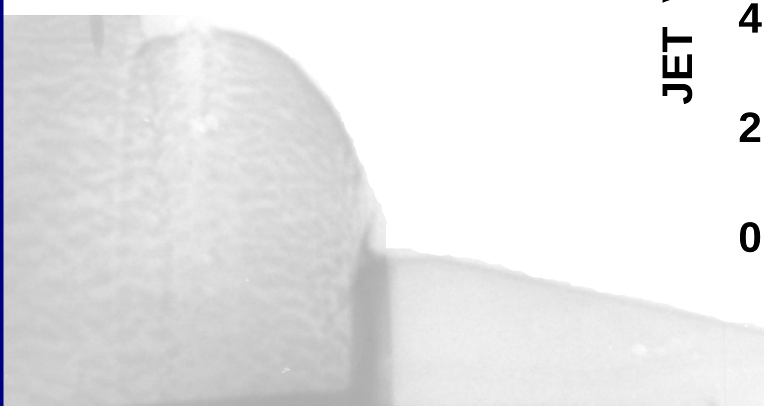


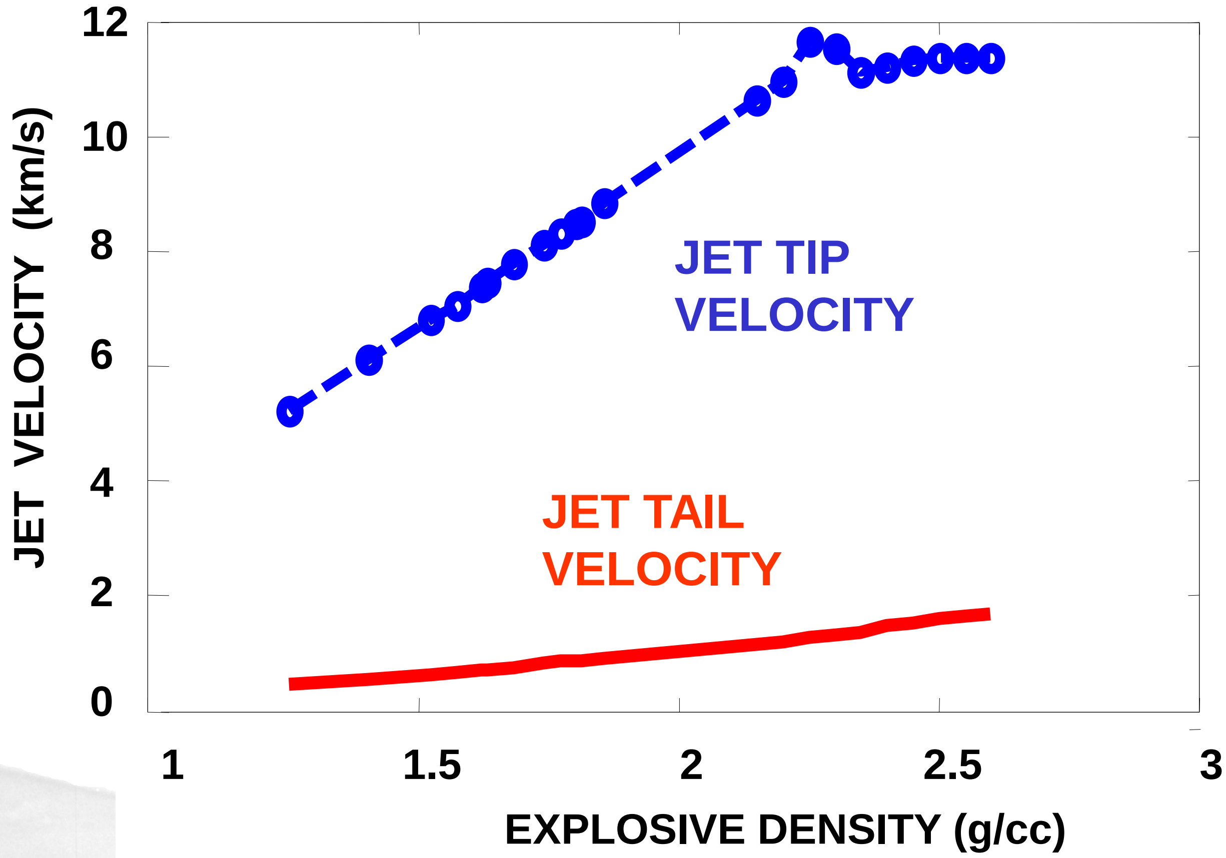
SCAN Modeling using BRL 81mm Configuration

Jet Tip Velocity *increases* <u>until</u> jet formation process reaches *supersonic limitation* at

~ 10.12 km/s at explosive density ~ 2.15 g/cc

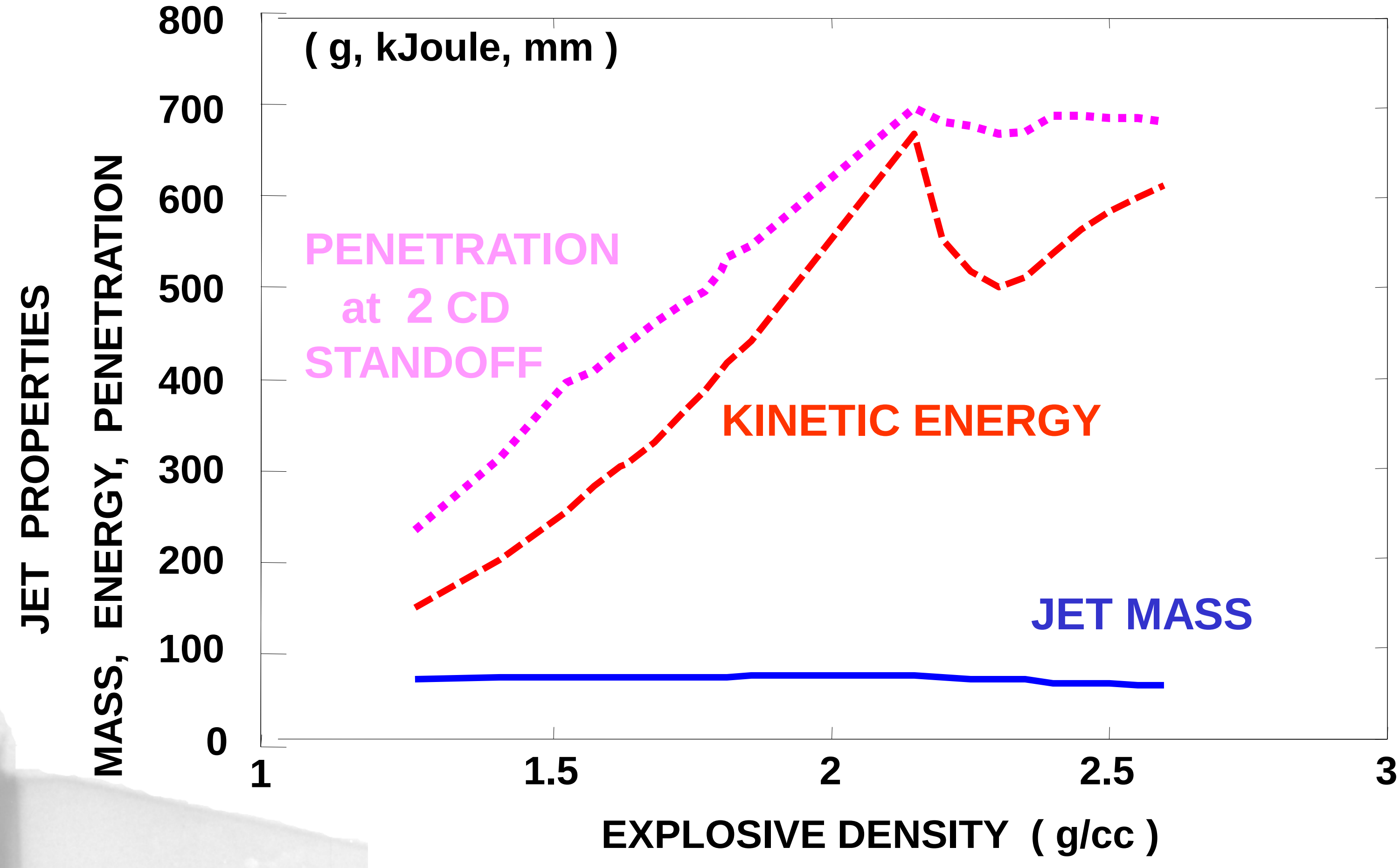
then *Jet Tip* disperses as non-coherent expanding tube





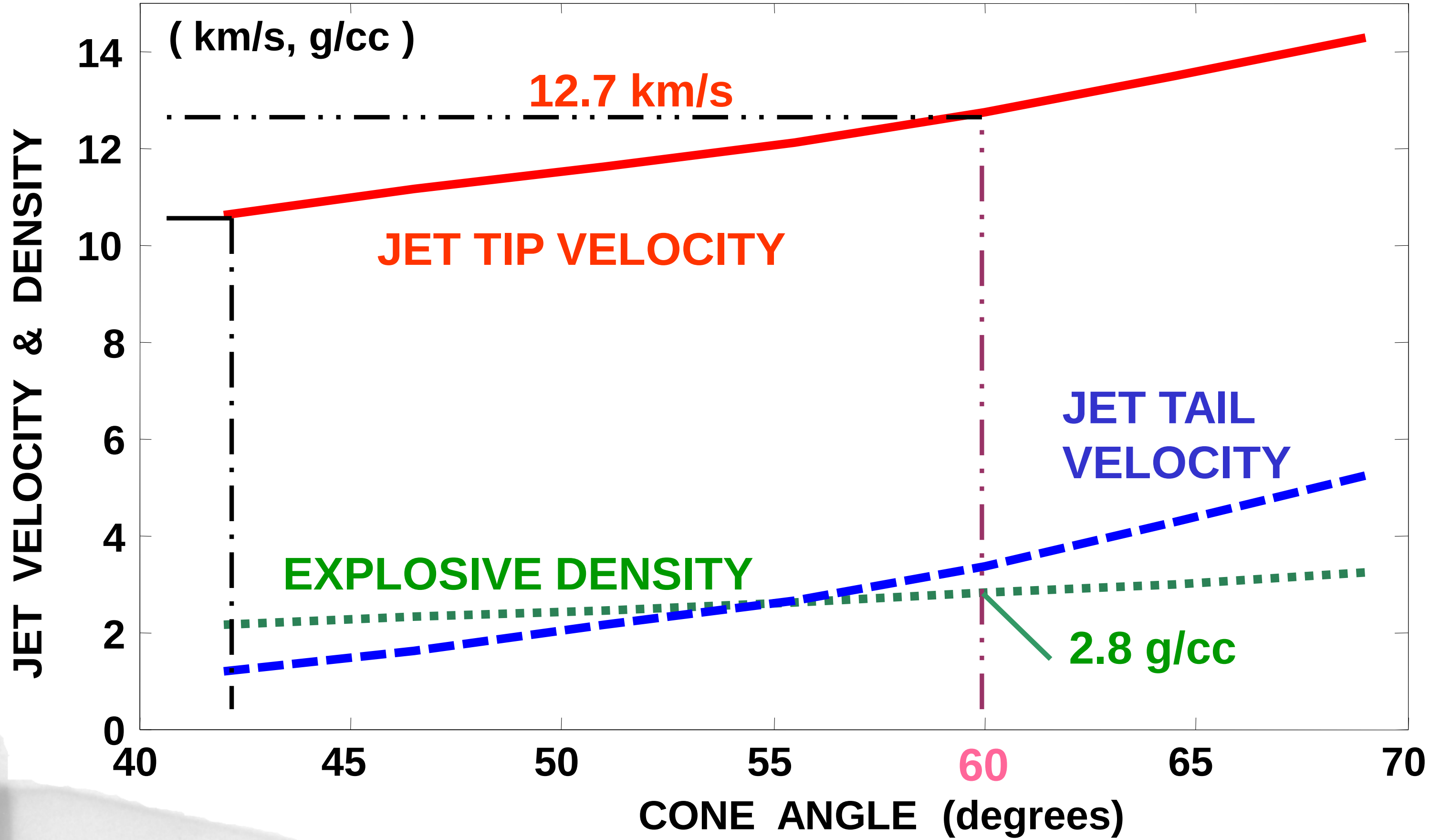
SCAN Modeling using BRL 81mm Configuration

Supersonic collapse *limits* Jet Length, Velocity Gradient and Target Penetration

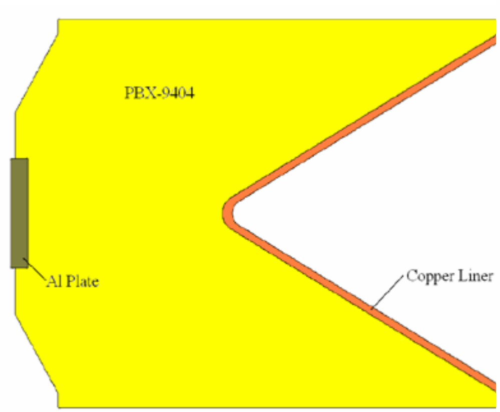


SCAN Modeling using BRL 81mm Geometry

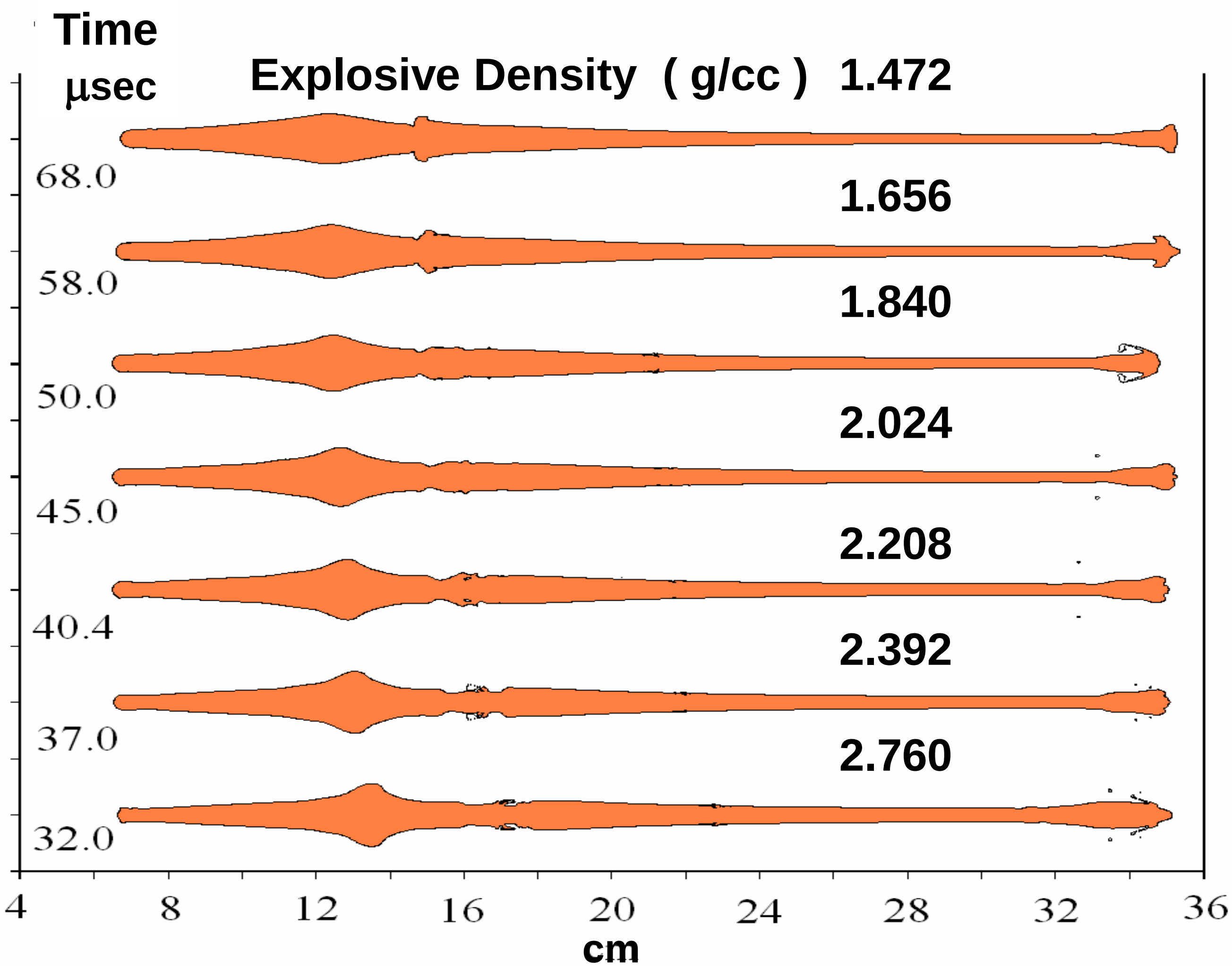
Supersonic jet formation *criterion* applied to combinations of cone angle and explosive density

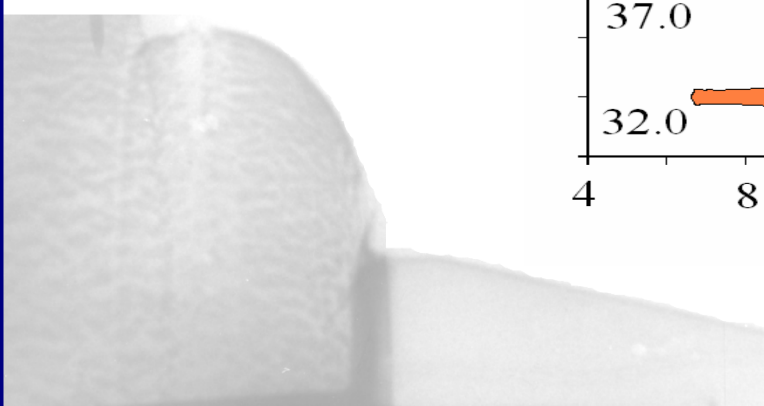


Baker Hughes 2-D 2nd Order Eulerian Code Simulations



60⁰ Cu, t_{liner} 1.65 mm
point initiated





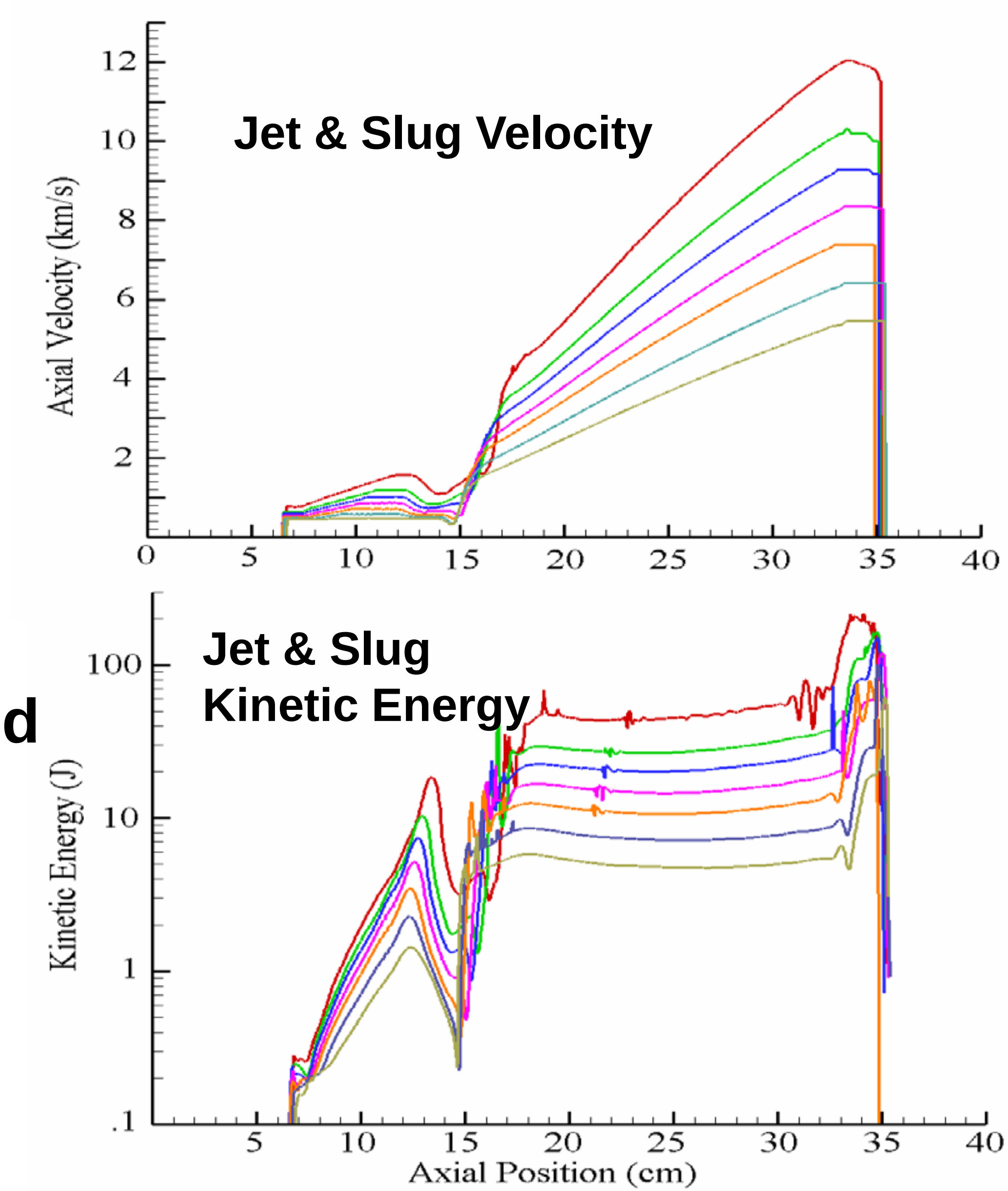
Simulations were stopped when jet tip reached ~ 24 cm from charge face

Baker Hughes 2-D 2nd Order Eulerian Code Simulations:

Increased Density and Detonation Velocity lead to:

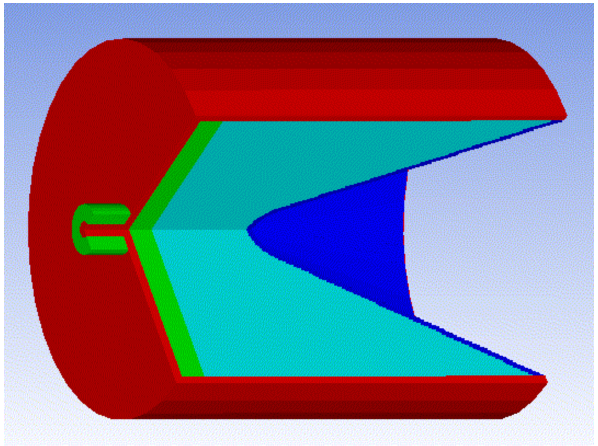
- **increased Jet:**
  - **velocities,**
  - **gradients, and**
  - **kinetic energy**
- ***dramatically* increased Slug velocity**

From 600 to 700 m/s to ~ 1500 m/s

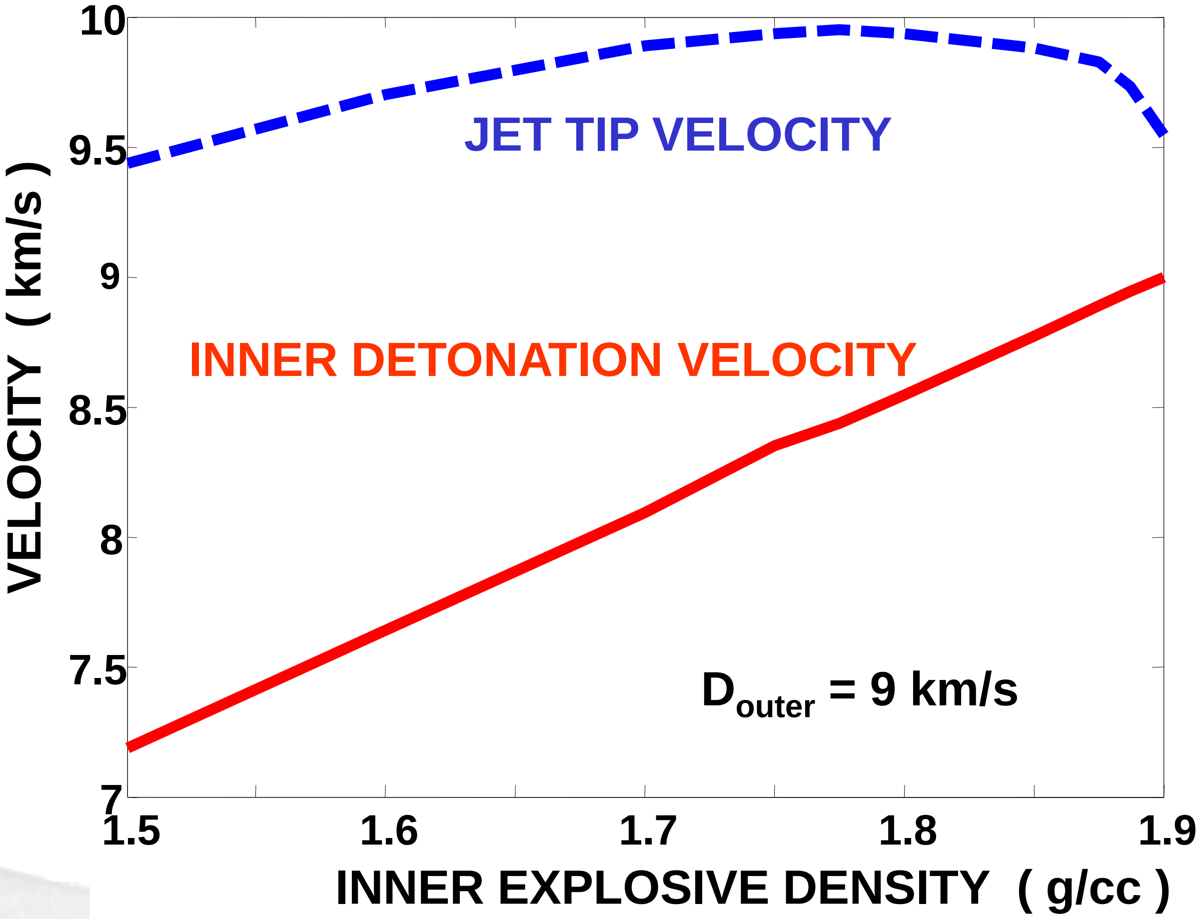


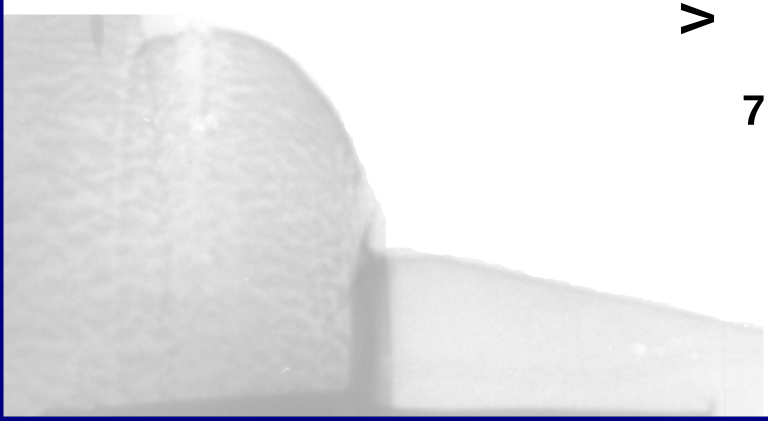
SCAN Modeling of Cone-Shaped Detonation

Detonation wave half angle Θ is determined by the ratio of outer to inner detonation velocities



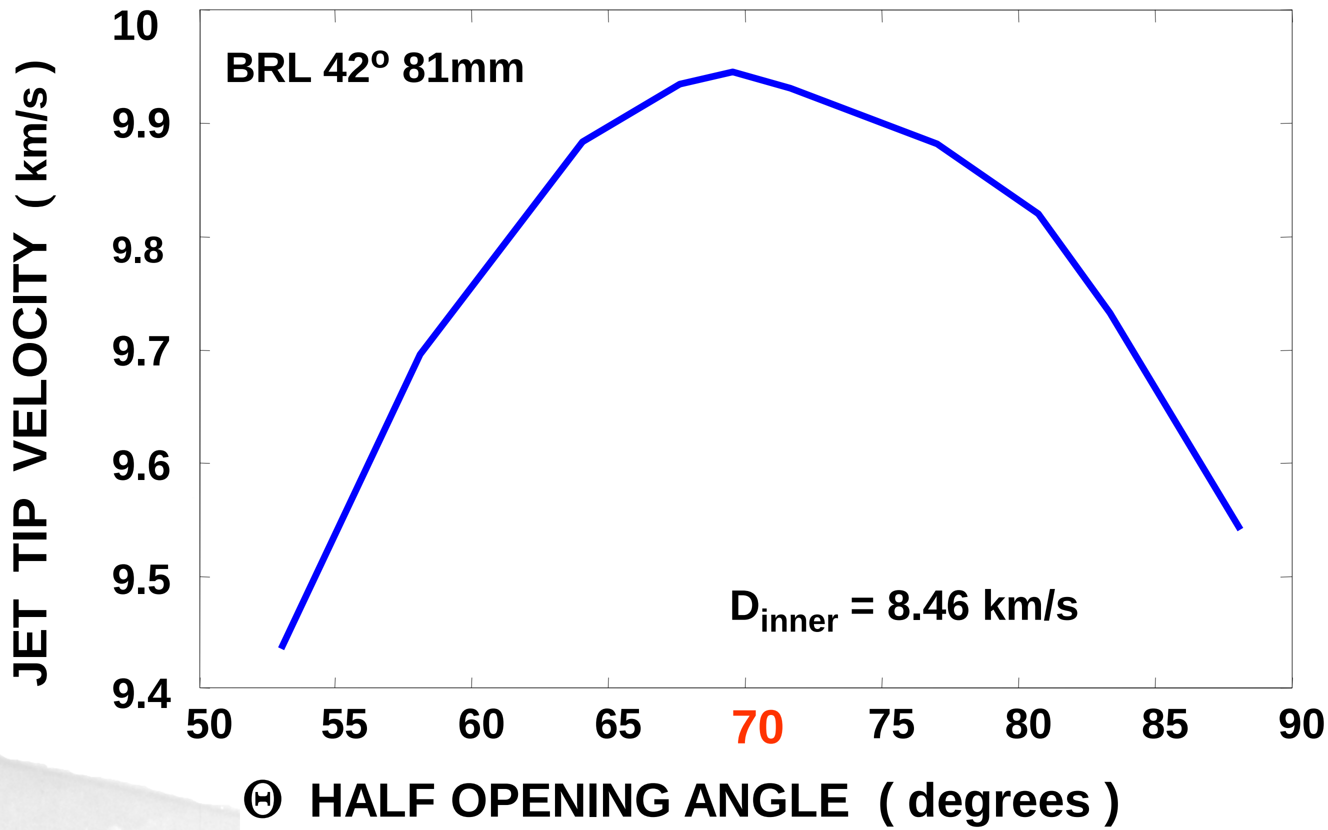
81.3 mm diameter

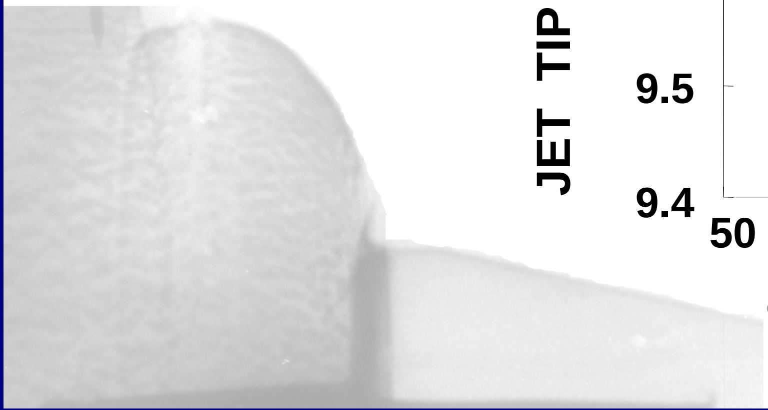




SCAN Modeling of Cone-Shaped Detonation in a BRL 81 mm Shaped Charge

Optimum jet formation (*supersonic criterion*) using lower performance explosive for majority of charge





LIFT Charge (1980)

[Cone-Shaped-Wave Shaped Charge]

United States Patent [19] **Petrousky et al.**

[11] **Patent Number: 4,955,939**

[45] **Date of Patent: Sep. 11, 1990**

[54] **SHAPED CHARGE WITH EXPLOSIVELY DRIVEN LIQUID FOLLOW THROUGH**

[75] Inventors: **James A. Petrousky**, Port Tobacco, Md.; **Joseph E. Backofen**; **Donald J. Butz**, both of Columbus, Ohio

[73] Assignee: **The United States of America as represented by the Secretary of the Navy**, Washington, D.C.

[21] Appl. No.: **471,381**

[22] Filed: **Mar. 2, 1983**

[51] **Int. Cl.**[5] **F42B 12/10**

[52] **U.S. Cl.** **102/476**; 102/306; 102/307; 102/308; 102/309; 102/310

[58] **Field of Search** .... 102/306-310, 102/476; 86/1 B, 1.1; 89/1 A, 1.11

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Primary Examiner—Charles T. Jordan
Assistant Examiner—Richard W. Wendtland
Attorney, Agent, or Firm—Kenneth E. Walden; Donald J. Breh

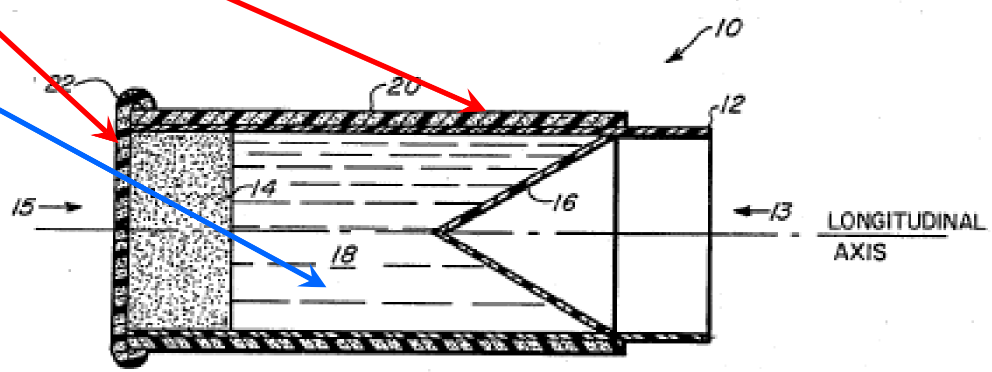
[57] **ABSTRACT**

Disclosed is a non-fragmenting explosive device for perforating a target and injecting a material through the perforation to disrupt structure behind the target. The device is particularly adapted to safely disarm unexploded explosive devices such as bombs without detonation of the bomb. The device includes an outer covering of explosive material for explosively confining the disruptive material to a well defined shape for total injection into the target.

1 Claim, 2 Drawing Sheets

Explosive

Water-Based **or** *Organic* **Material**



Drs. L. Zernow, M. Held, R. Brown and others have designed and built “over-wrap” devices

Summary and Conclusions

Higher Detonation Velocity Explosives
can still provide more **shaped charge performance**

Jet & Slug *Velocities* and *Kinetic Energy increased*

as a result, Jet & Slug can be tailored for
increased **target penetration and effect**

Higher Detonation Velocity Explosive
can be used as an "*outer-wrap*" to provide:

- **Conical detonation wave**
- **Optimization**
- **Insensitive explosive charge designs**

IS HIGHER DETONATION VELOCITY *NEEDED* FOR SHAPED-CHARGES *?*

NO **…. but, it can be very beneficial**

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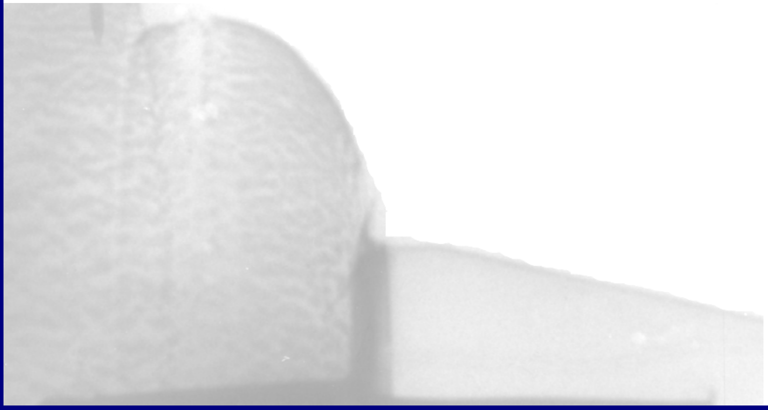
[4] BRIGS Co., USA.



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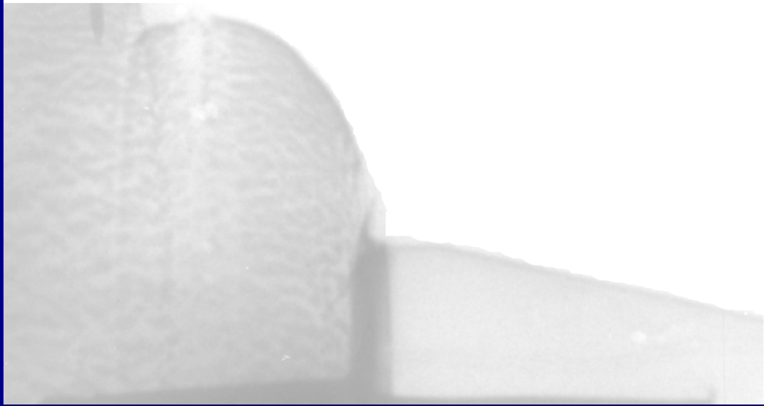

Gurney Velocity / Detonation Rate relationships:

$Vg / D \cong 0.337$ (P.W. Cooper)

$Vg / D \cong (0.605 / [\Gamma - 1])$ (J. Roth per J.E. Kennedy)

where Γ = the adiabatic exponent for the gaseous products

$Vg / D \cong (0.60\, \phi^{-1/2} + 0.648\, \rho_o^{1/2}) / (1.01 + 1.313\, \rho_o)$

where $\phi = N M^{1/2} Q^{1/2}$; N = moles of gaseous detonation products
M = average weight of gases, and Q = chemical energy of detonation

(Hardesty & Kennedy / Kamlet & Hurwitz)

Copper Cylinders

Vg / D	Exp. (Licht)	Cooper	Roth	HK/ KH
TNT	0.346	0.346	0.350	0.351
Comp B	0.345	0.343	0.355	0.385
Octol	0.335	0.330	0.331	0.328
LX-14	-----	0.326	0.348	-----
PETN	0.359	0.355	0.369	0.331

at γ = 2.9, SCAN formula ==> $Vg / D \cong 0.338$

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