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The Penetration Process of Jets And Long Rods in Water

D. Yaziv, M. Mayseless, Z. Cooper, Y. Reifen, E. Hirsch

1. Penetration of Jets in Water

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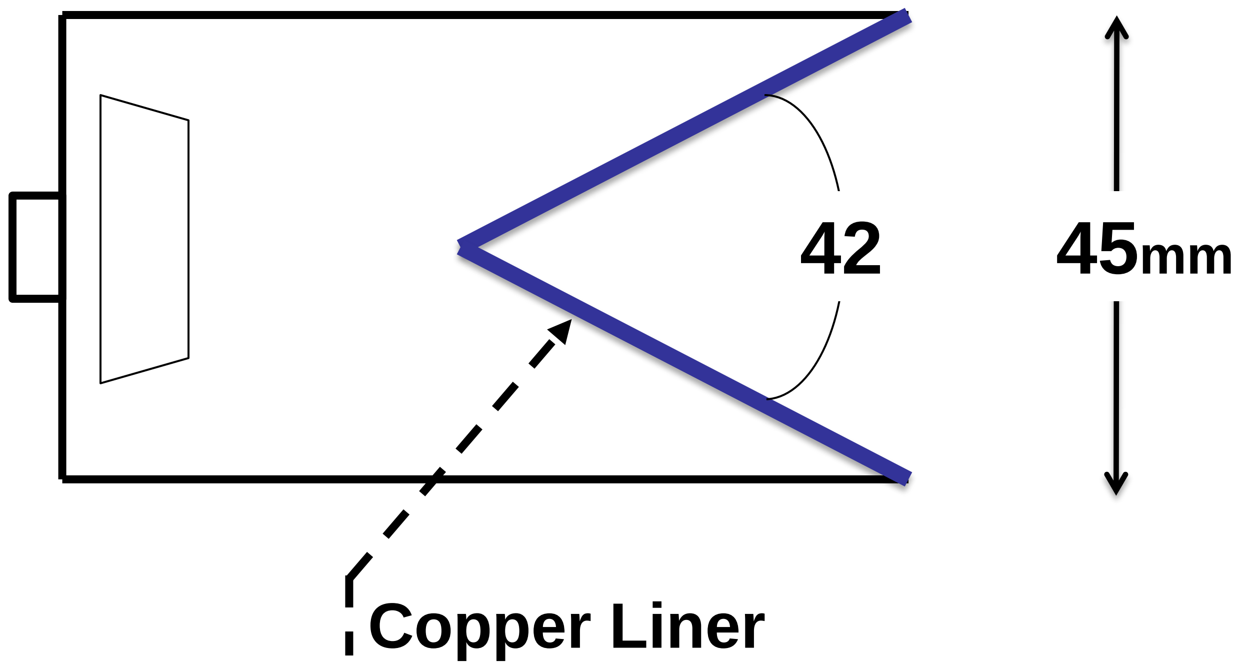
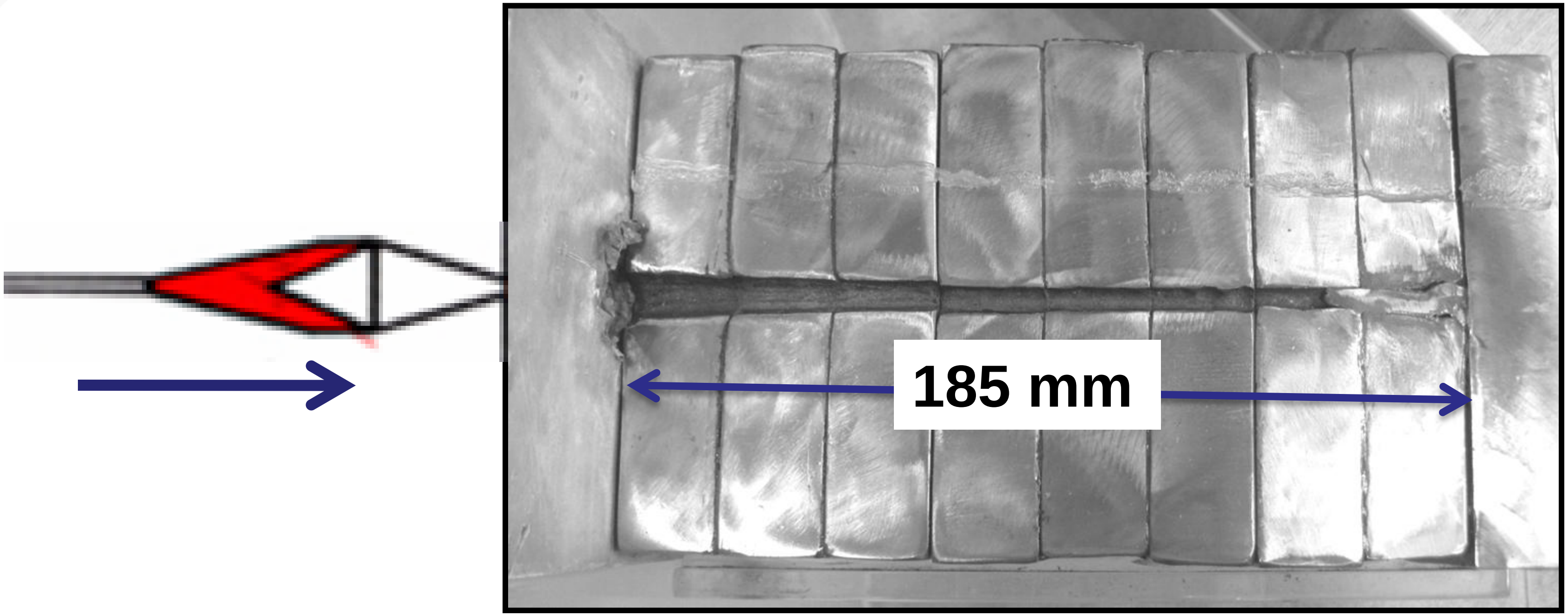
Shaped Charge Type "R"



Liner Cone Angle: **42**
Diameter (D): **45 mm**
Standard Standoff: **1.5 D**



Baseline penetration in RHA : **185 mm**

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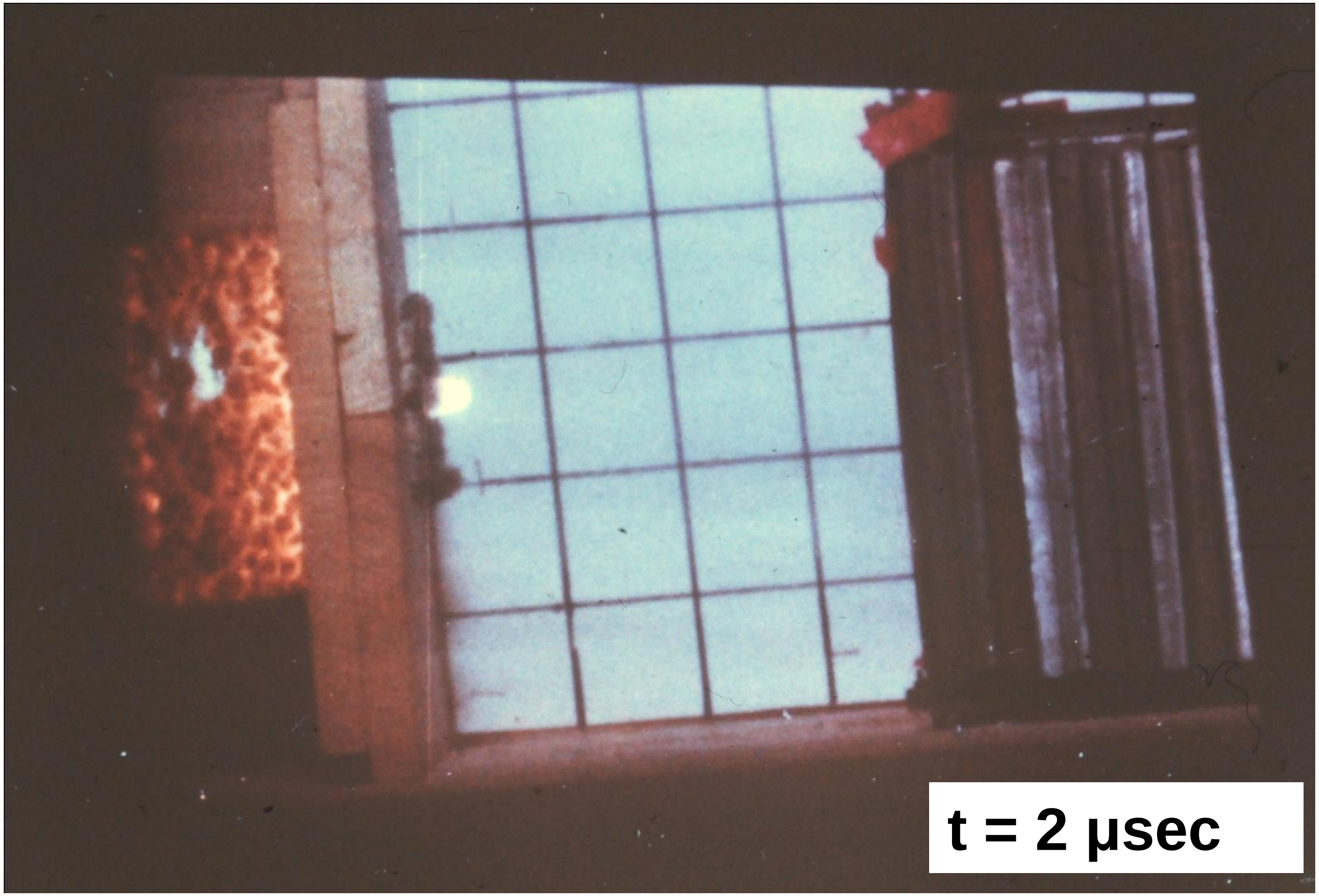
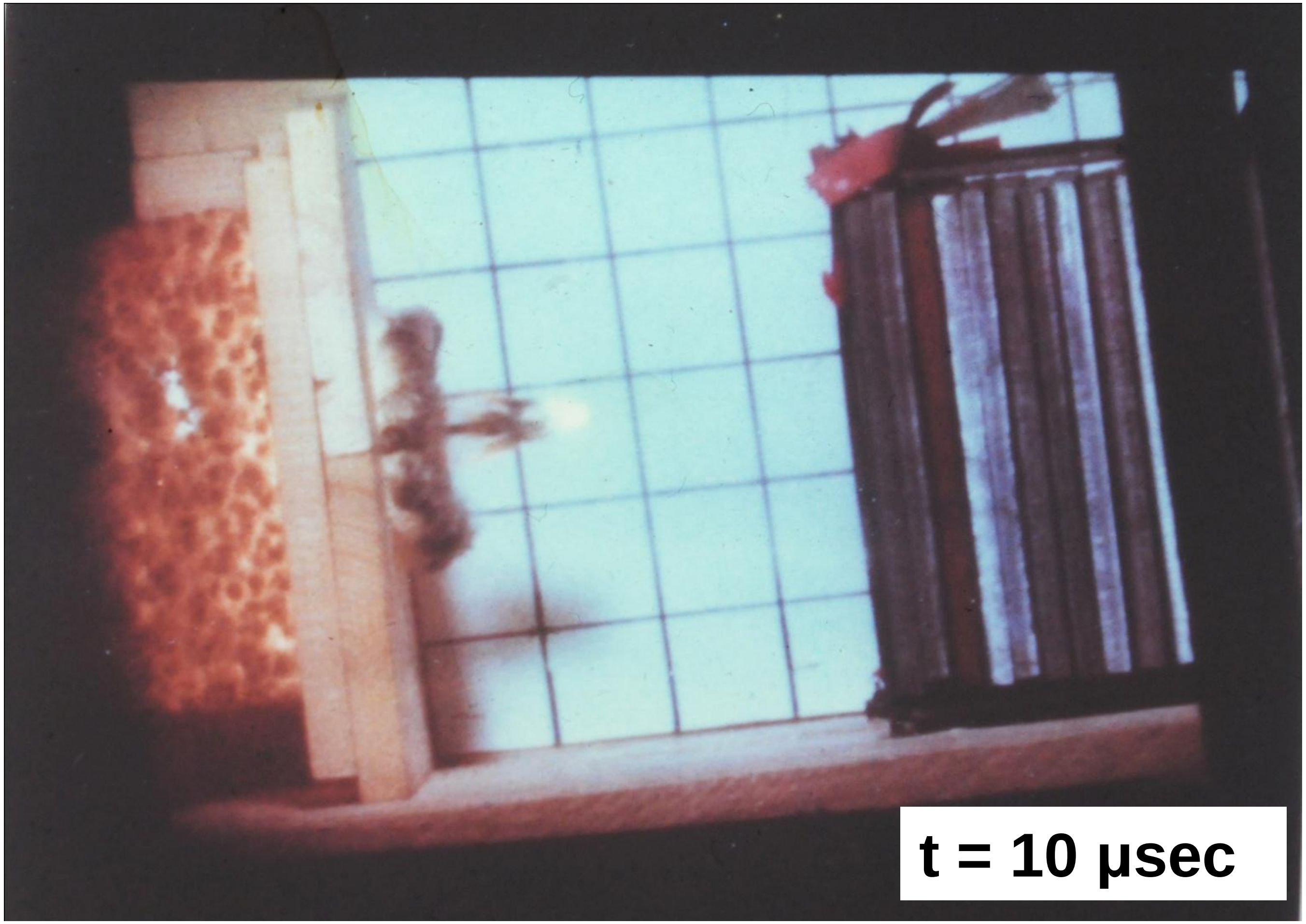
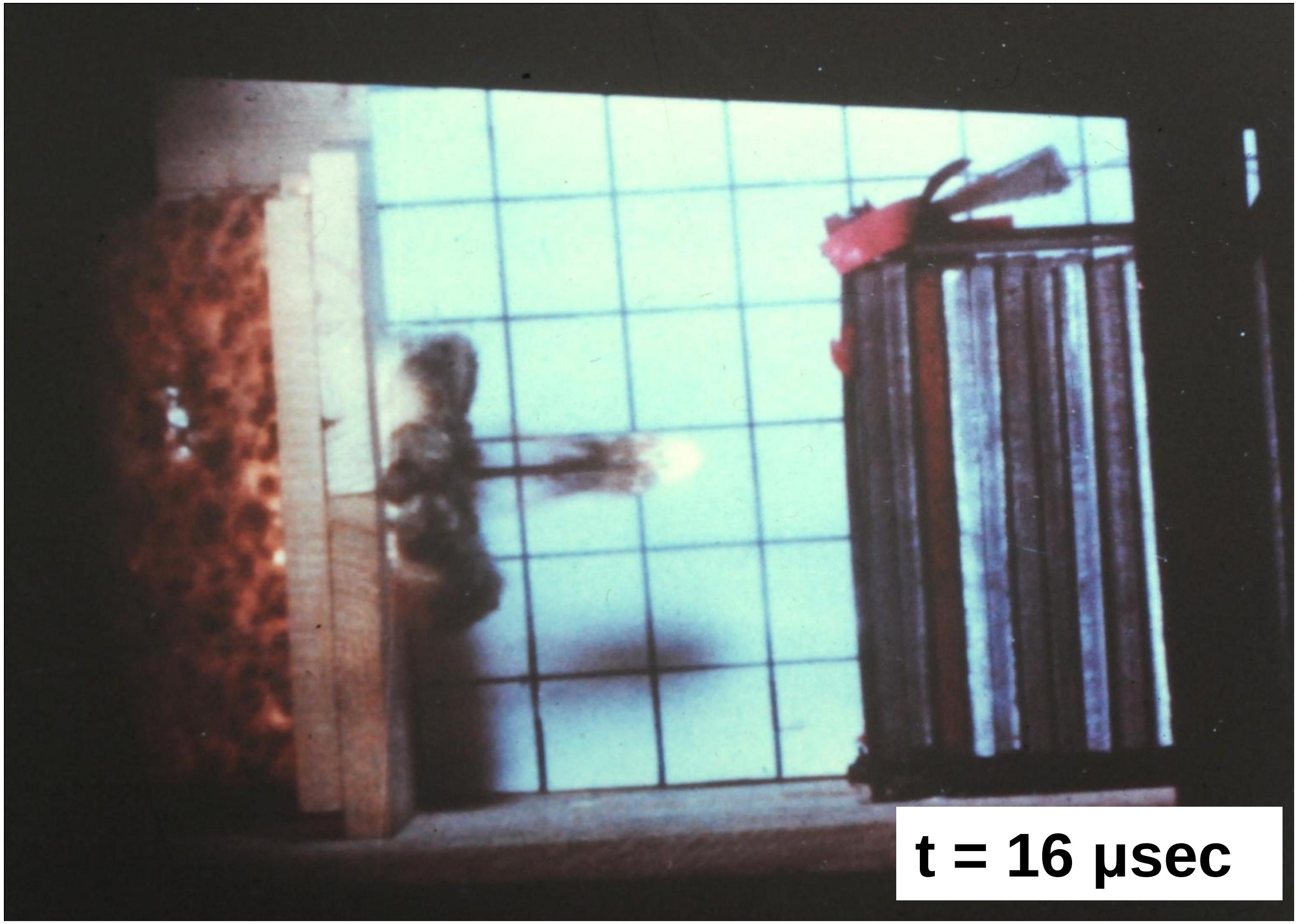
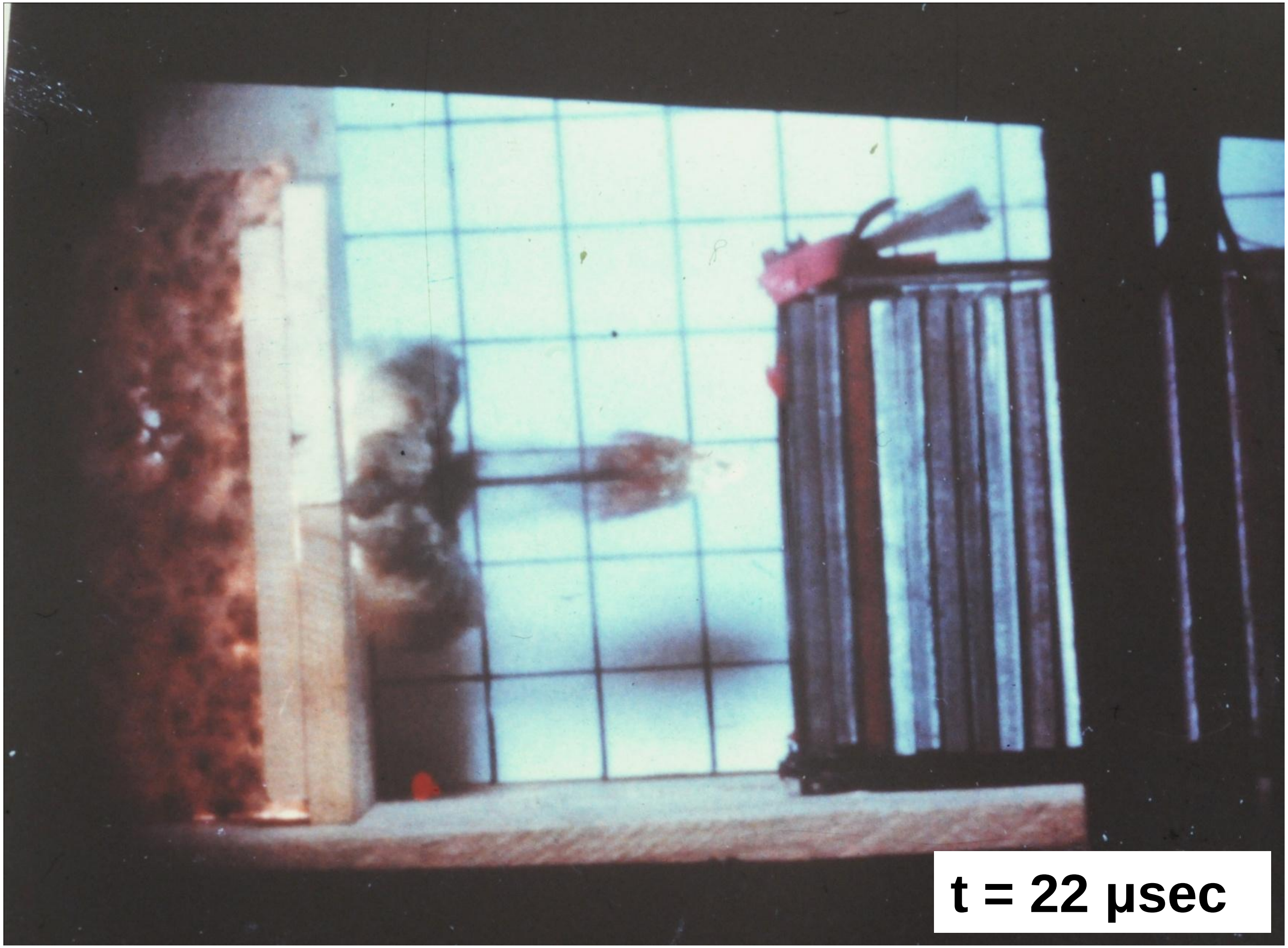
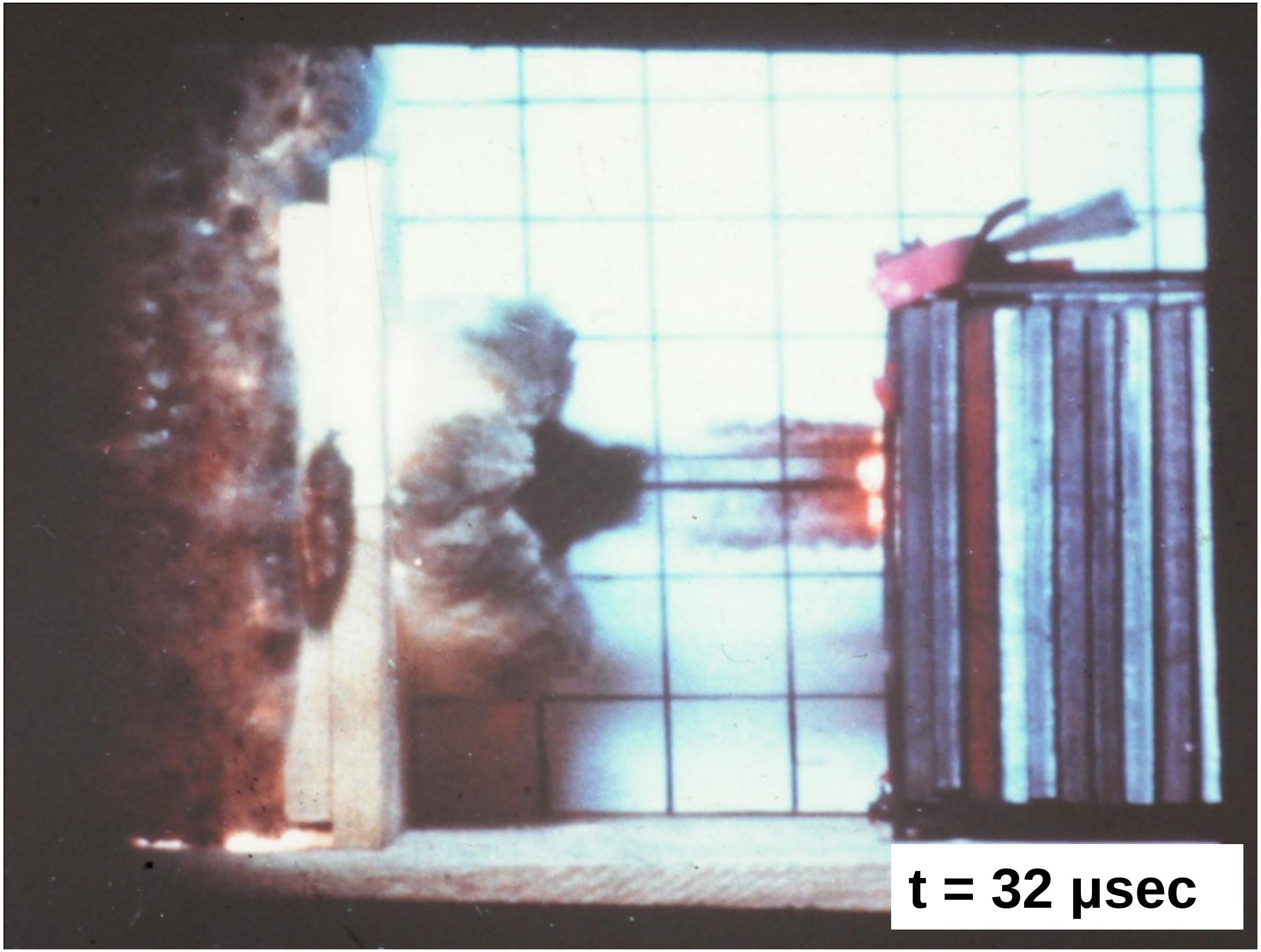



t = 10 µsec


t = 16 μsec



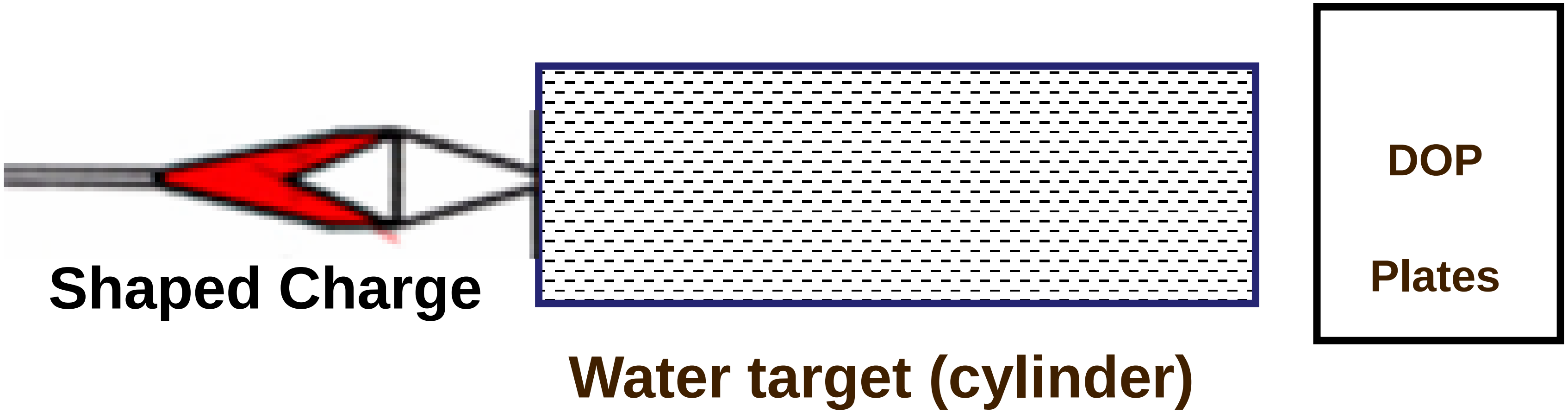
t = 22 μsec


t = 32 µsec

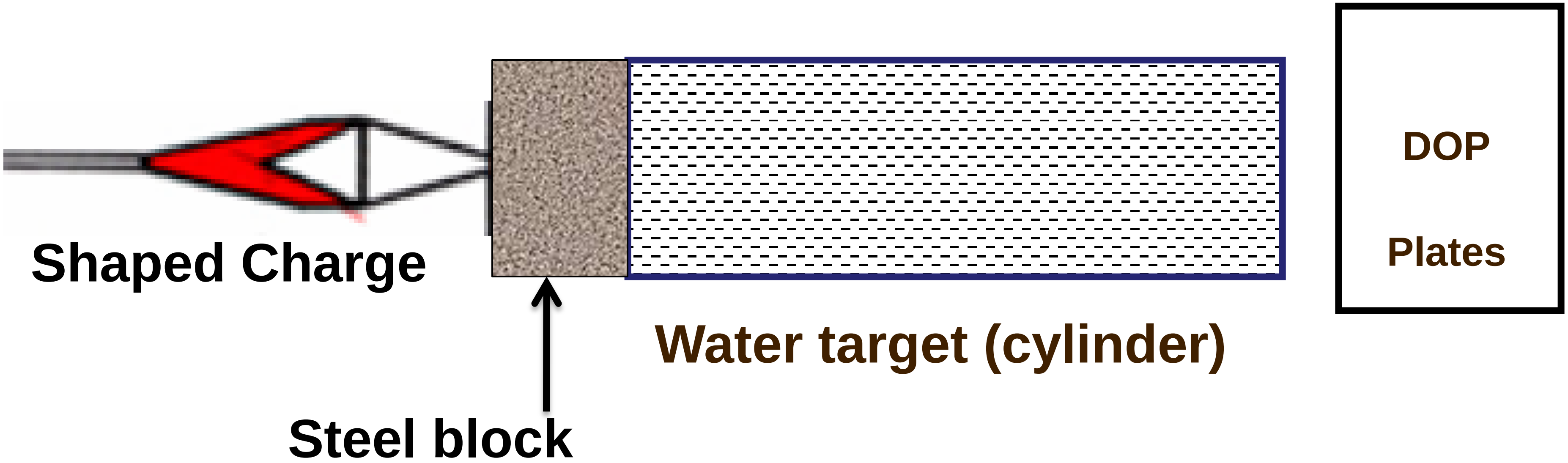
Jet tip velocity = **7,250 m/sec**

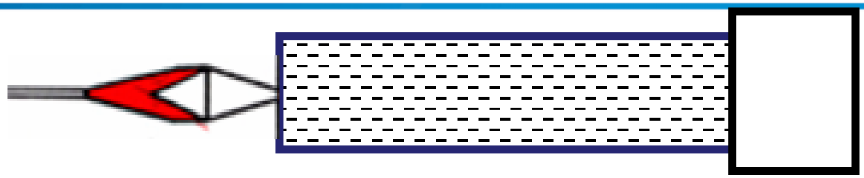
Diameter = **1.5 mm**

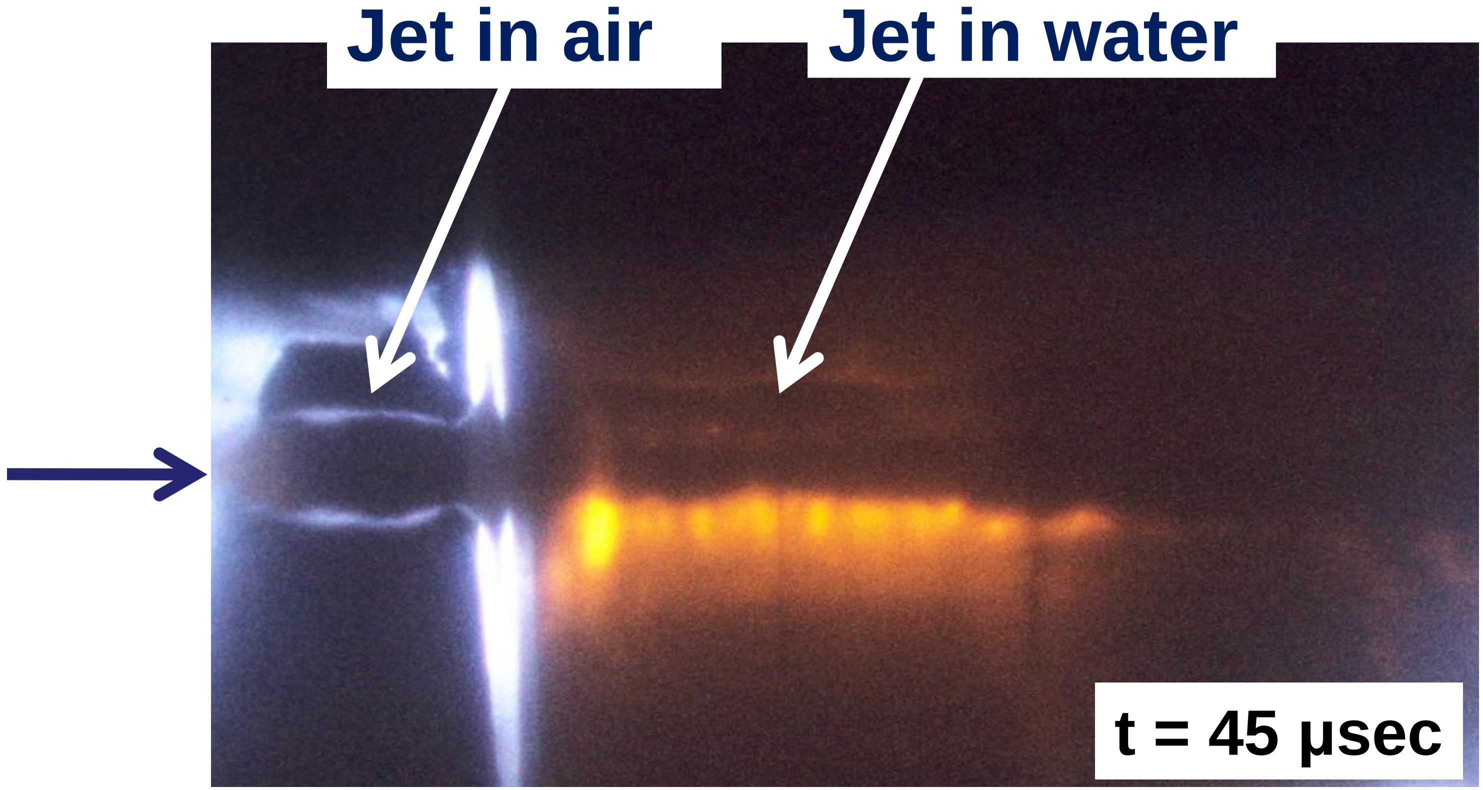
Experimental Set-up



Experimental Set-up



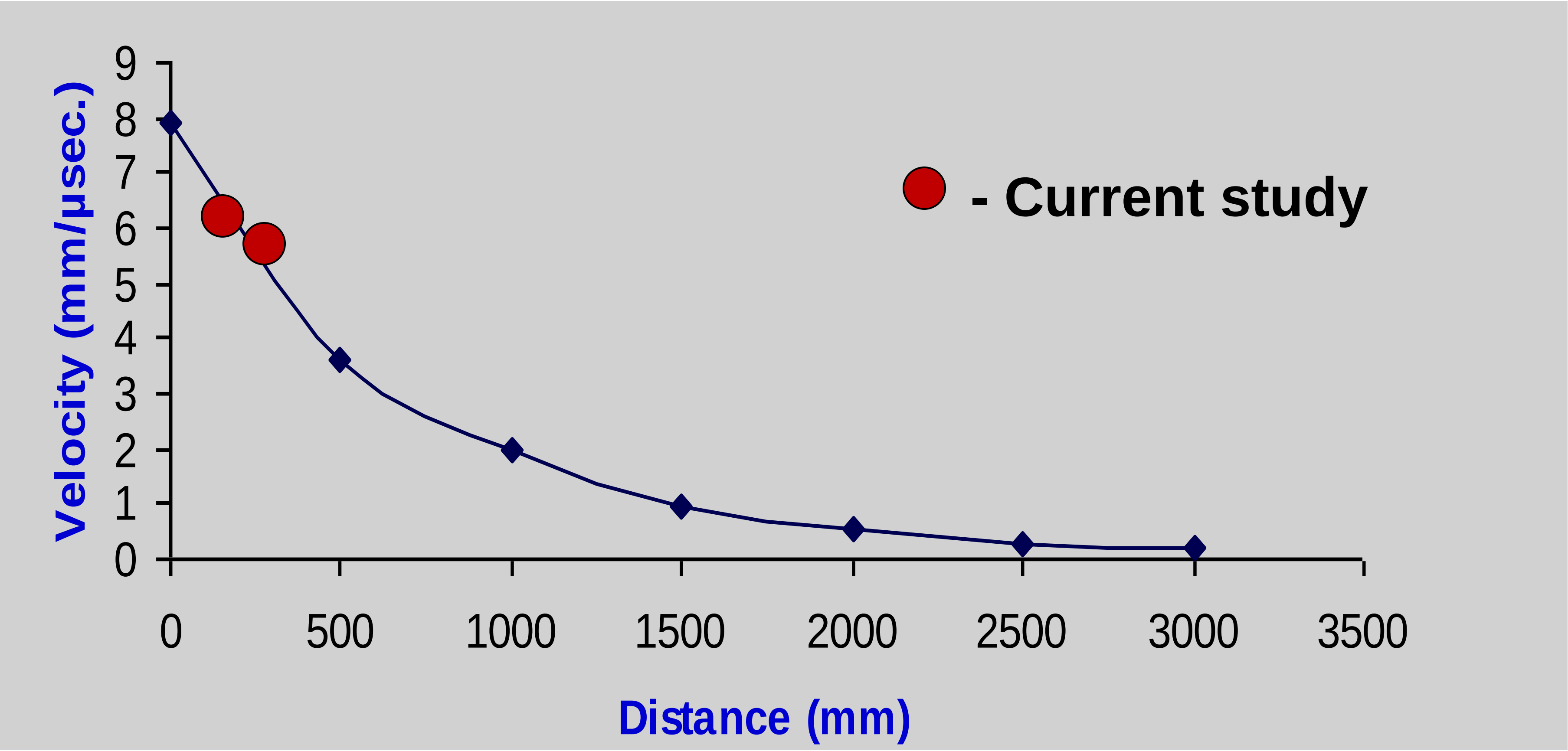




Jet tip velocity

In air=**7,250**m/sec; In water$_{\text{at 250mm}}$ **5,500**m/sec

Velocity of Jet in Water



D.R. Saroha et al, 24th Int. Sym. on Ballistics (2008)

Shaped Charge

Steel block

Steel cylinder filled with Water

Steel plates

Penetration Capability in water

Measured

P_{RHA} = 185mm

P_{water} = 680mm

$= P_{water}/P_{RHA} = 3.6$

Hydrodynamic penetration

$$P_1/P_2 = \sqrt{(\rho_2/\rho_1)}$$

$$P_{Water}/P_{RHA} = \sqrt{(\rho_{RHA}/\rho_{Water})} = 2.8$$

$$P_{Water} = 520\ mm$$

2. Penetration of Long Rods in Water

Experimental Set-up

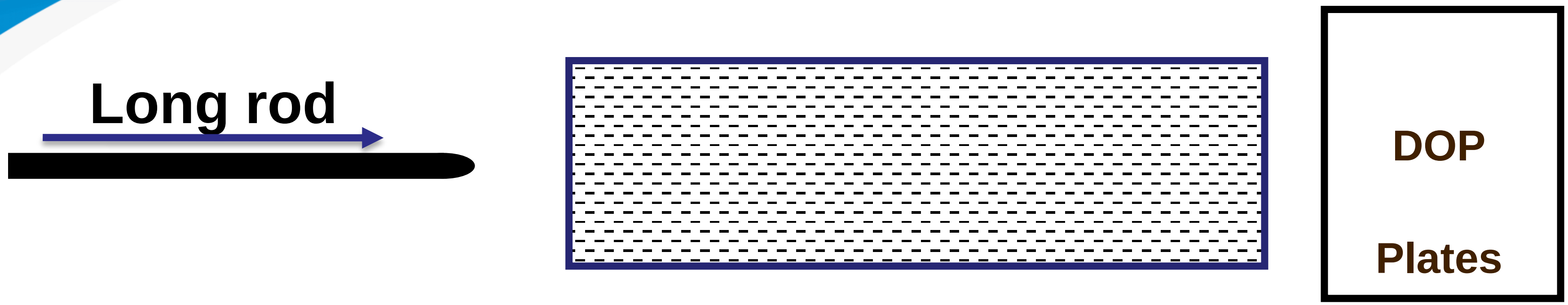
Long rod

Tungsten Alloy
L = 100 mm
L/D = 10
V = 1,430 – 1,475 m/sec

Water target (cylinder)

DOP

Plates



Water target (cylinder)

Obliquity = 90 , 60 , 45

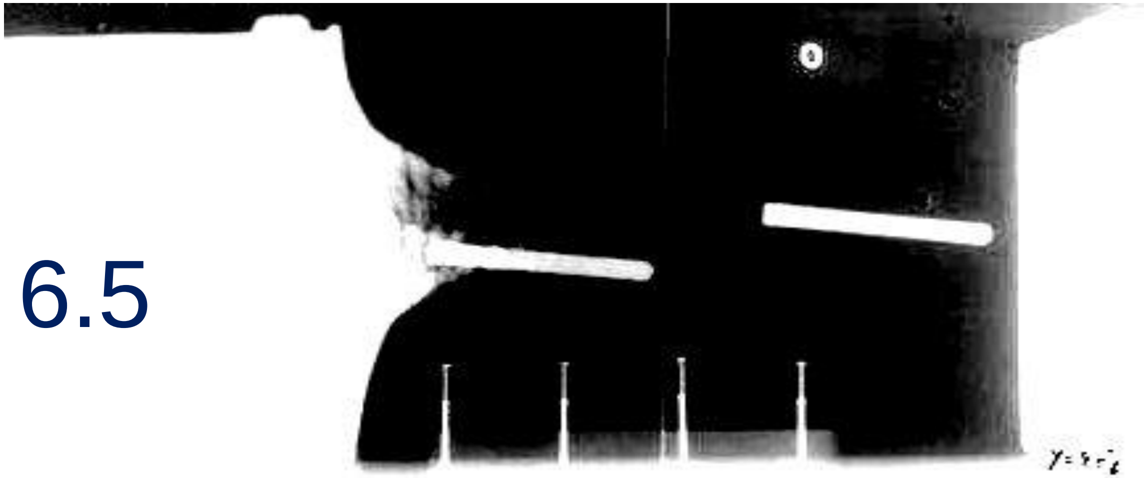
C. E.J Anderson, J. S. Wilbeck, et al., *Long-Rod Penetration into Highly Oblique, Water-Filled Targets* Int. J. Impact Eng. (1998)

Shot DM3

Exit Yaw: 4.5

Shot DM6

Exit Yaw: 6.5



3. Calculations and Analysis

The penetration process in water

can be divided into two phases:

1st Phase:

The classical hydrodynamic penetration

2nd phase:

The inertia of the water influence on the final penetration

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C.P. Woidneck "*Rod Penetration in Liquids*", 9th Int. Sym. Ball.

The SCAN Model

Based on the classical hydrodynamic jet penetration theory with Tate's correction

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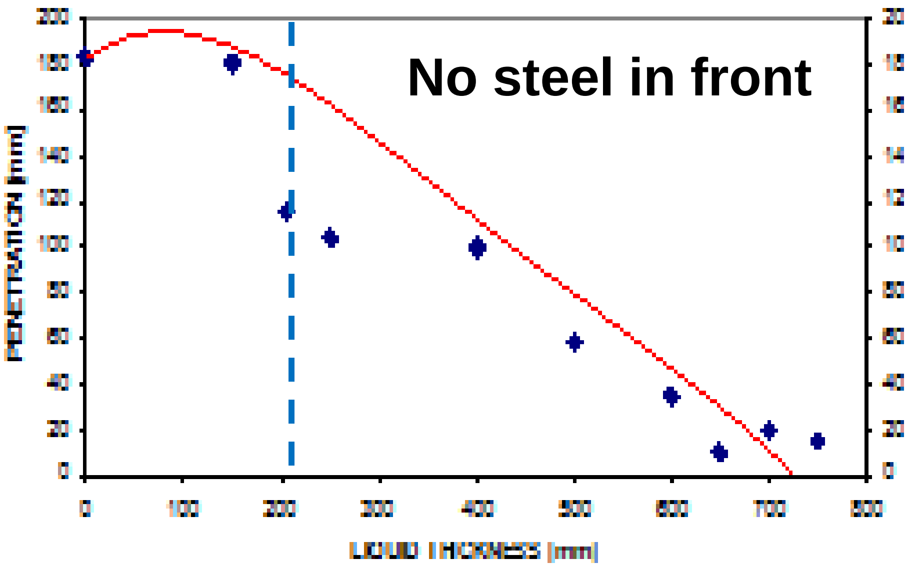
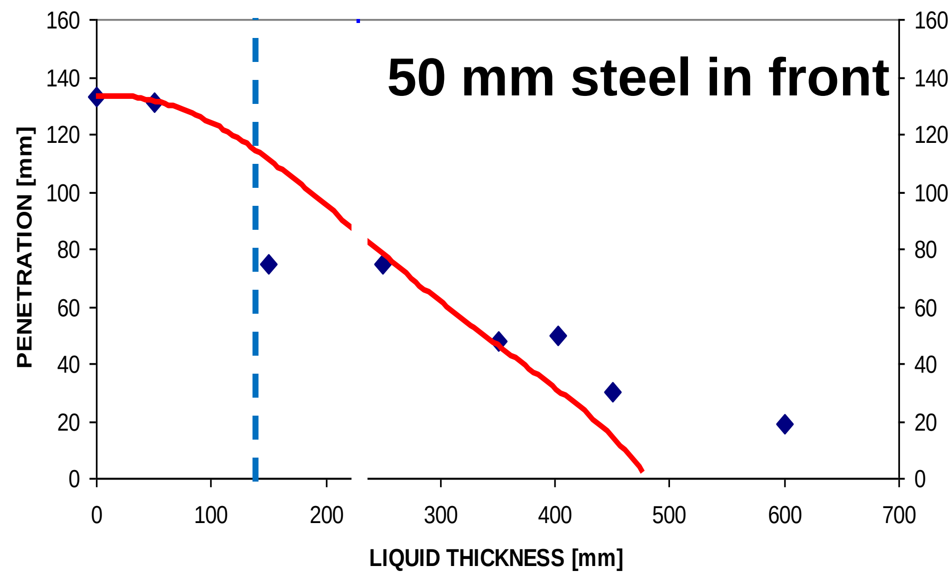
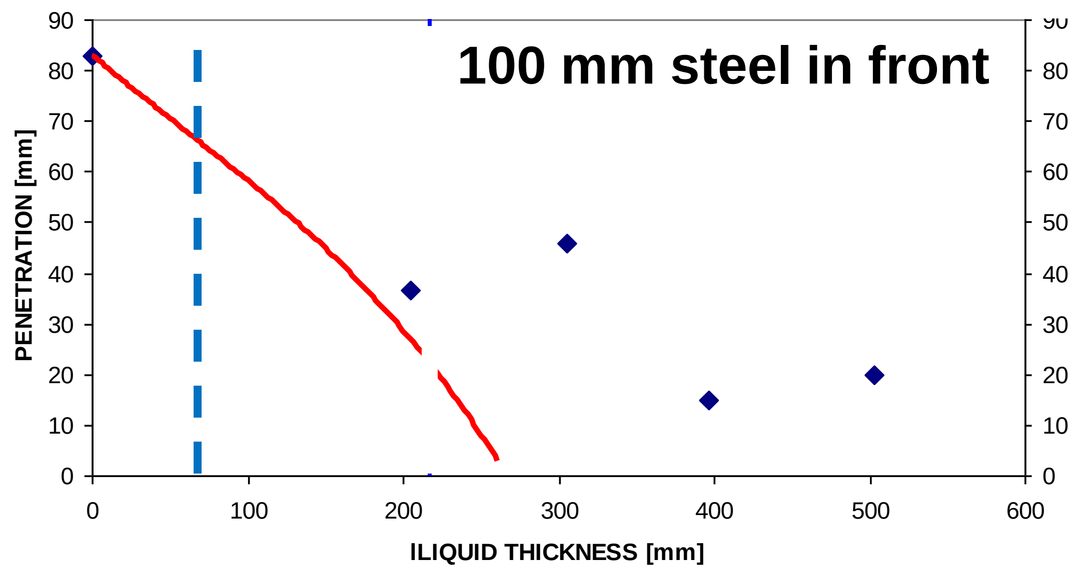
E. Hirsch, D. Goodlin, T.R. Sharon, SCAN, "*Shaped Charge Analyzer Model. Computer Program User Manual"*

No steel, 50 mm and 100 mm steel in front of the water

SCAN predictions





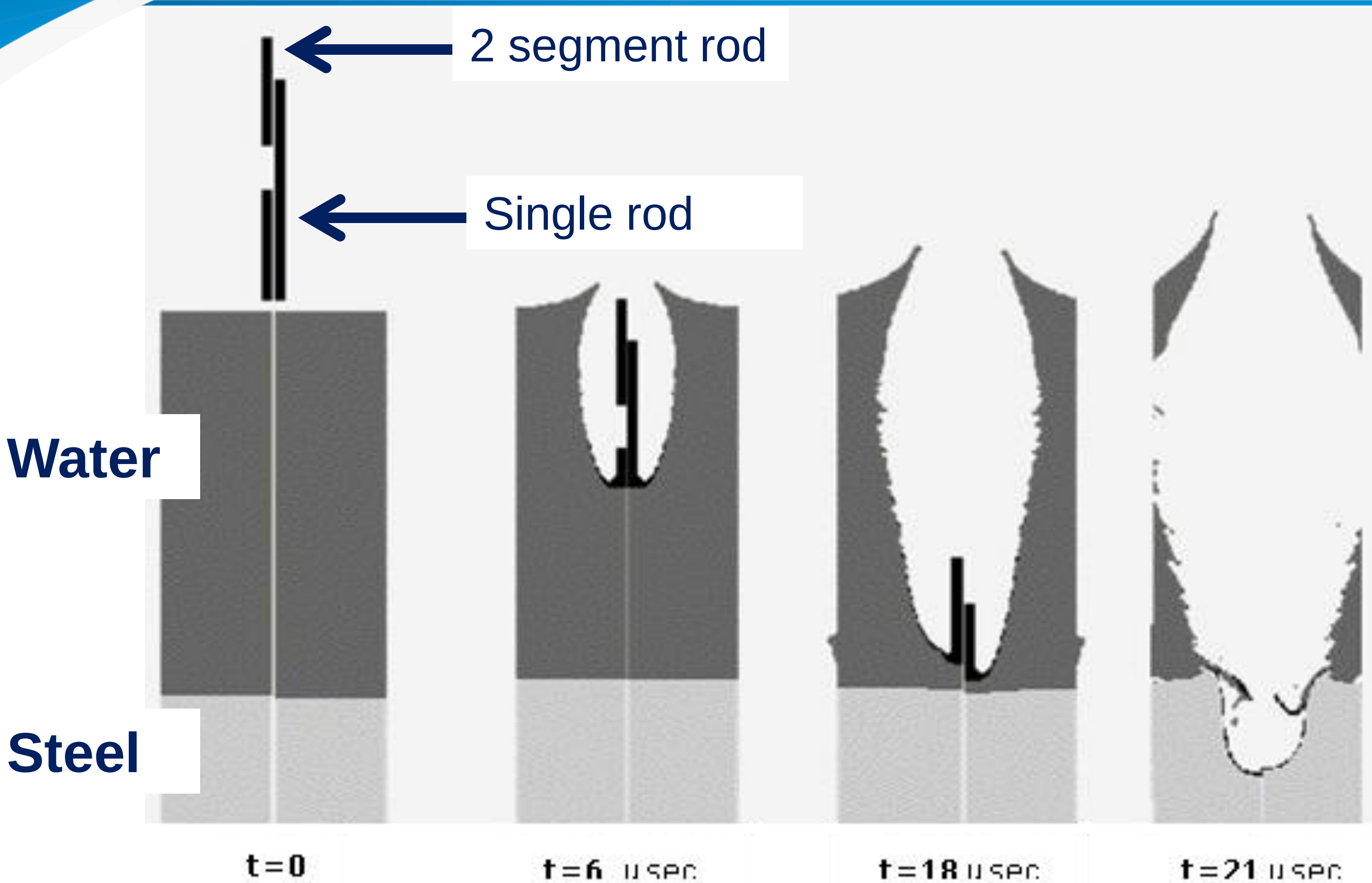


2nd Phase

The Autodyne 2D hydrocode was employed

ASSUMPTIONS:

- The jet was simulated by a rod at a speed of 4,000 m/sec, representing the central part of the jet after particulation
- The rod is eroded during the penetration similarly to the jet
- The water has no strength
- The diameter of the water cylinder is wide enough



<u>Jet - 2nd Phase</u>

Rod: Cupper; L = 20 mm; V = 4,000 m/sec

DOP = 8 mm (single); 10 mm (segmented)

CONCLUSIONS:

1. The total penetration capability of a jet is larger when the jet is particulated
2. The residual DOPs in steel are greater than predicted by the ideal hydrodynamic theory by approximately 25%

2. Penetration of Long Rods in Water
- Analytical Model

The yaw angles at the exit of the water targets were predicted using an analytical model

ASSUMPTIONS:

1. Rigid projectile
2. Incompressible fluid with shear strength
3. The path of the projectile is integrated numerically

Z. Cooper, M. Mayseless, Y. Reifen, D. Yaziv, “Deflecting and Rotating Rigid Projectiles Hitting Plate Edge“ – **Poster Session 12033**

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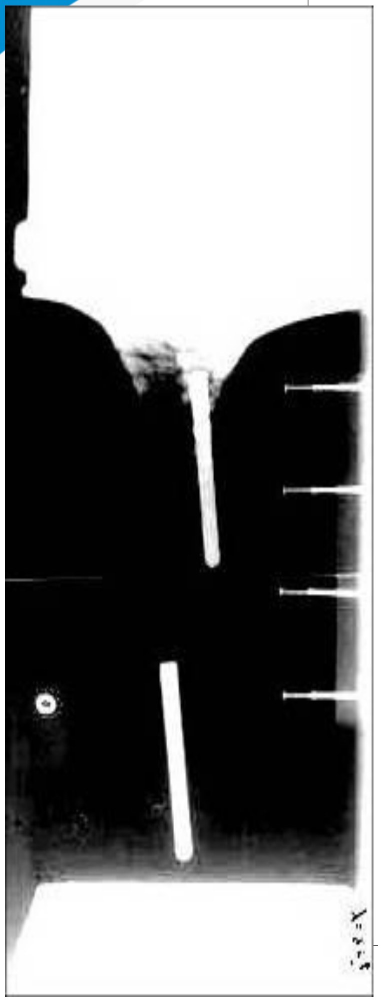

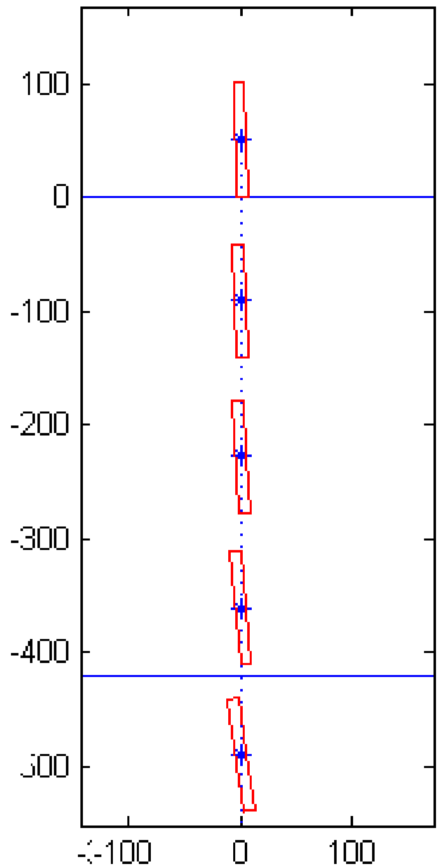

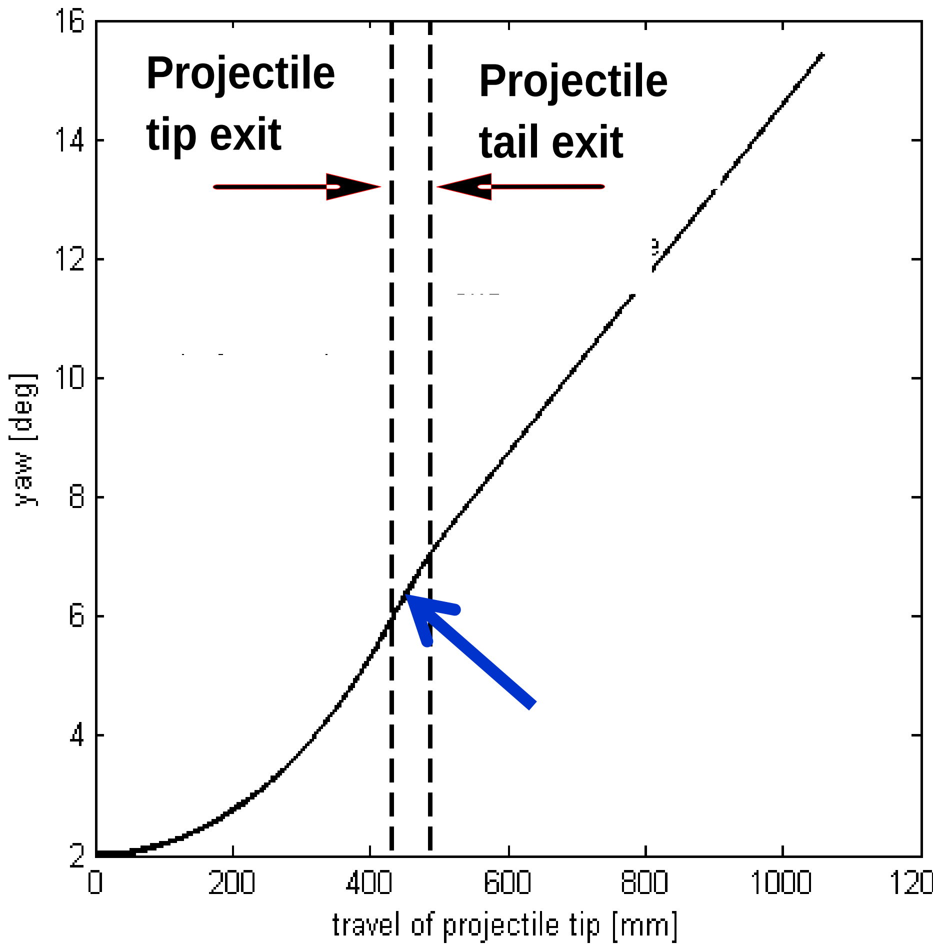

Rod: Tungsten Alloy; L = 100 mm; V = 1,475m/sec;
Water length: 420 mm

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Roecker – Ricchiazzi (R & R) Model

$$yaw\ \ s = yaw\big|_{s=0} \exp\left(\frac{b}{R} s\right)$$

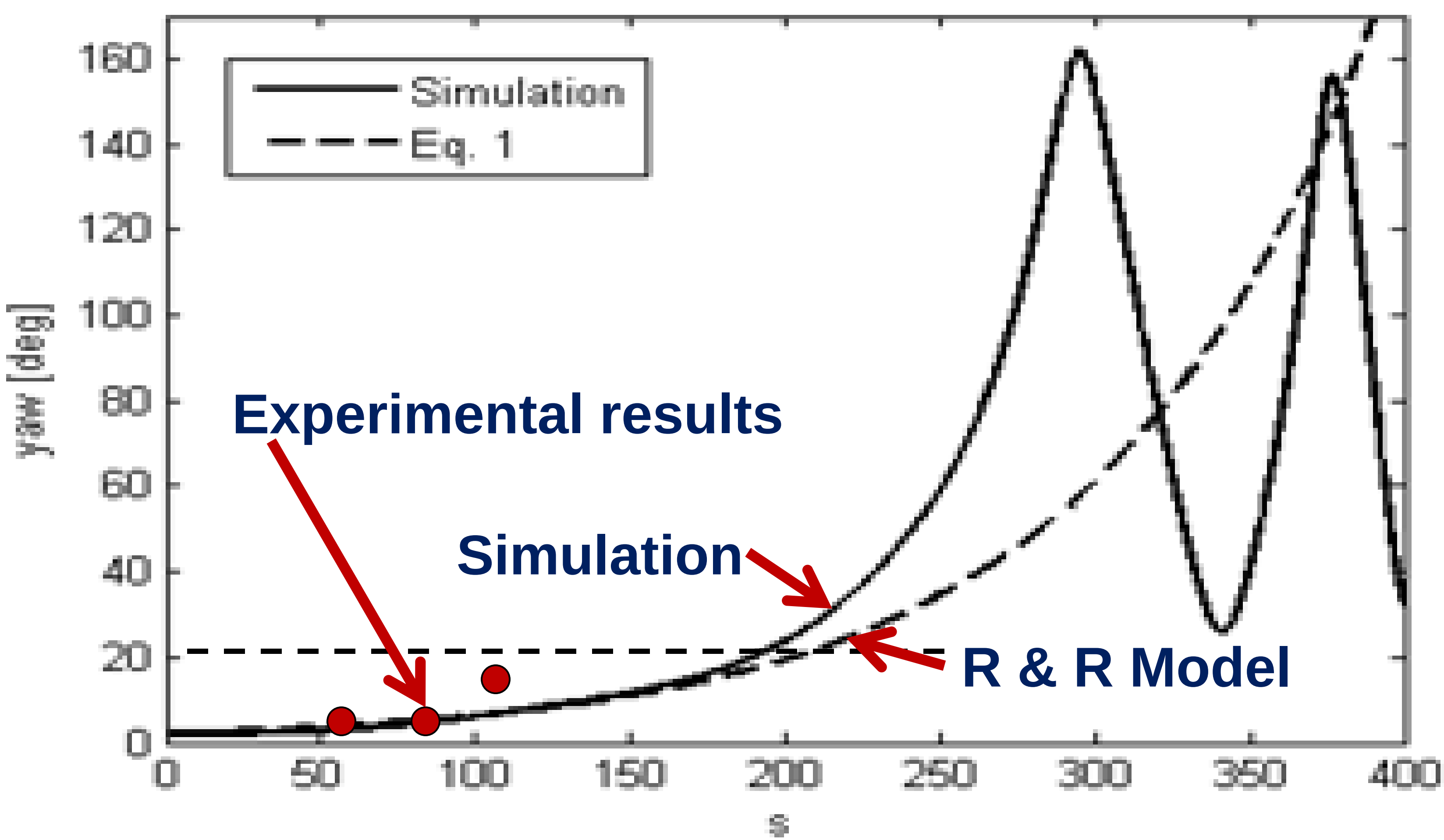
R - *Radius*

s - *Distance (normalized by R)*

b - *Constant related to the turning moment acting on the projectile.*

E.T. Roecker and A.J. Ricchiazzi, "Stability of Penetrators in Dense Fluids", Int. J. Engng. Sci, Vol 16

Rigid Projectile penetrating into water



Conclusions

Jet Penetration in Water

- Two major phases: a hydrodynamic phase followed by an inertial phase
- The penetration capability of a jet in water is larger than predicted by the ideal hydrodynamic theory
- The total penetration capability of a jet is larger when the jet is particulated

Long Rods Penetration in Water.

- The Yaw angle is affected mainly by the DOP in water, the velocity and by the initial yaw
- The impact obliquity has an insignificant effect on the penetration, orientation and yaw of the rod in water

Both

- The differential weight efficiency of water is 0.70 to 0.75 (relative to RHA).