Experimental study of a strongly shocked gas bubble

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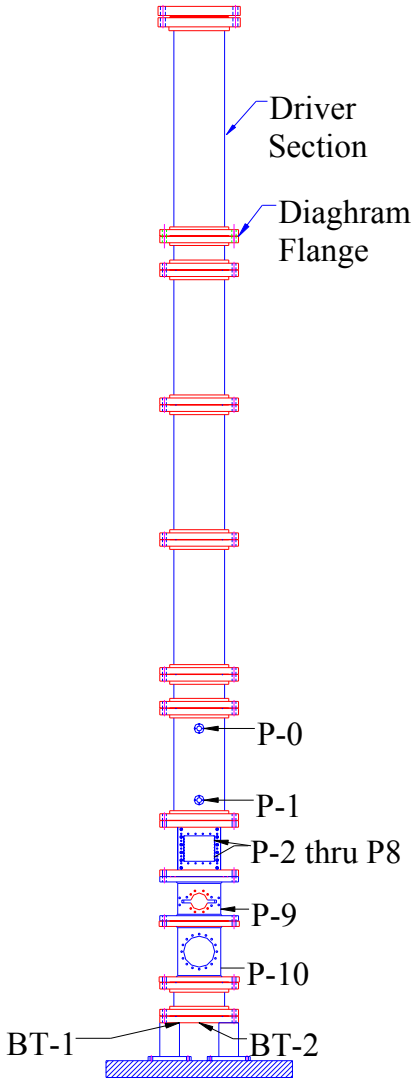
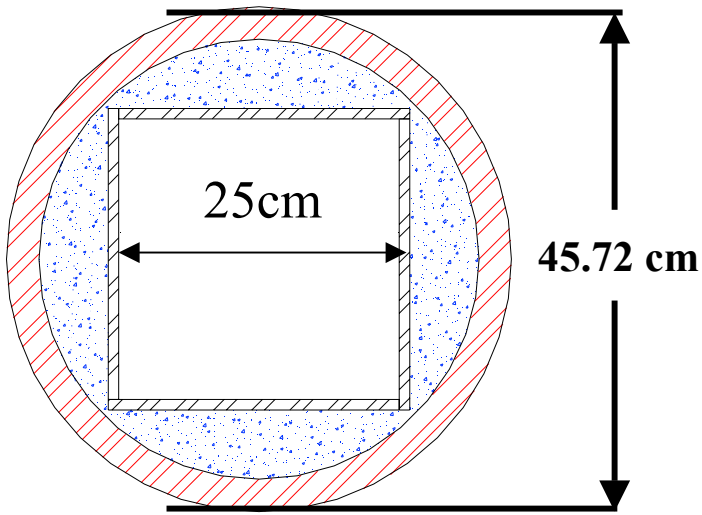
Overview

- Planar shock wave accelerates a spherical soap bubble:
  Ar inside, N_2 outside, A=0.176
- Vortex velocity defect and circulation measurements
- Time evolution of geometrical properties
- Mach numbers
  - M=2.88, u_p=745 m/s
  - M=3.38, u_p=907 m/s

The Wisconsin Shock Tube



- Vertical
- Large internal cross-section (25 cm square)
- Total length 9.2 m, driver length 2 m
- Pressure load capability: 20 MPa
- Modular driven section

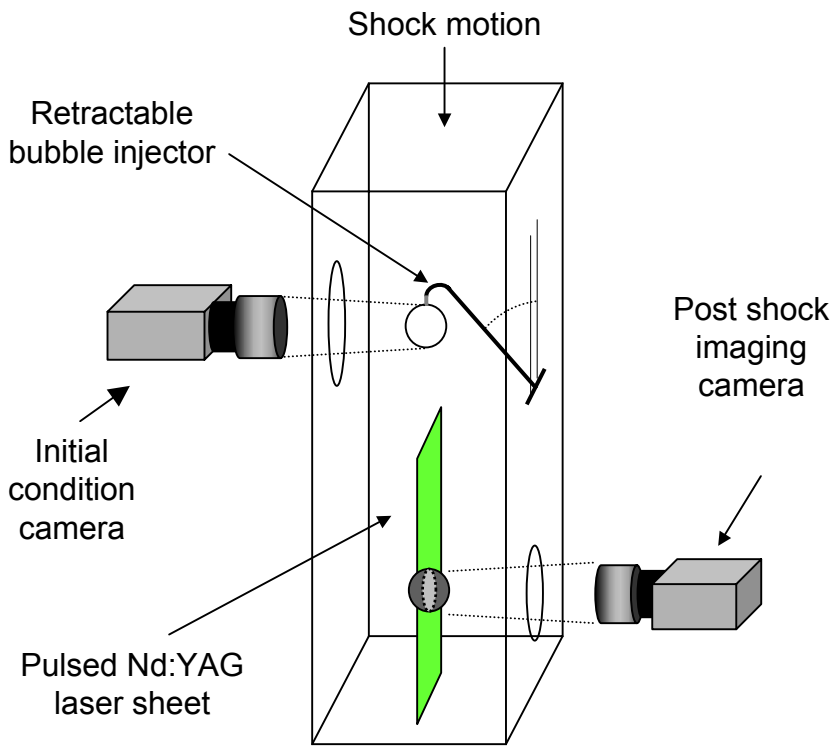


Details of R-M Experiment

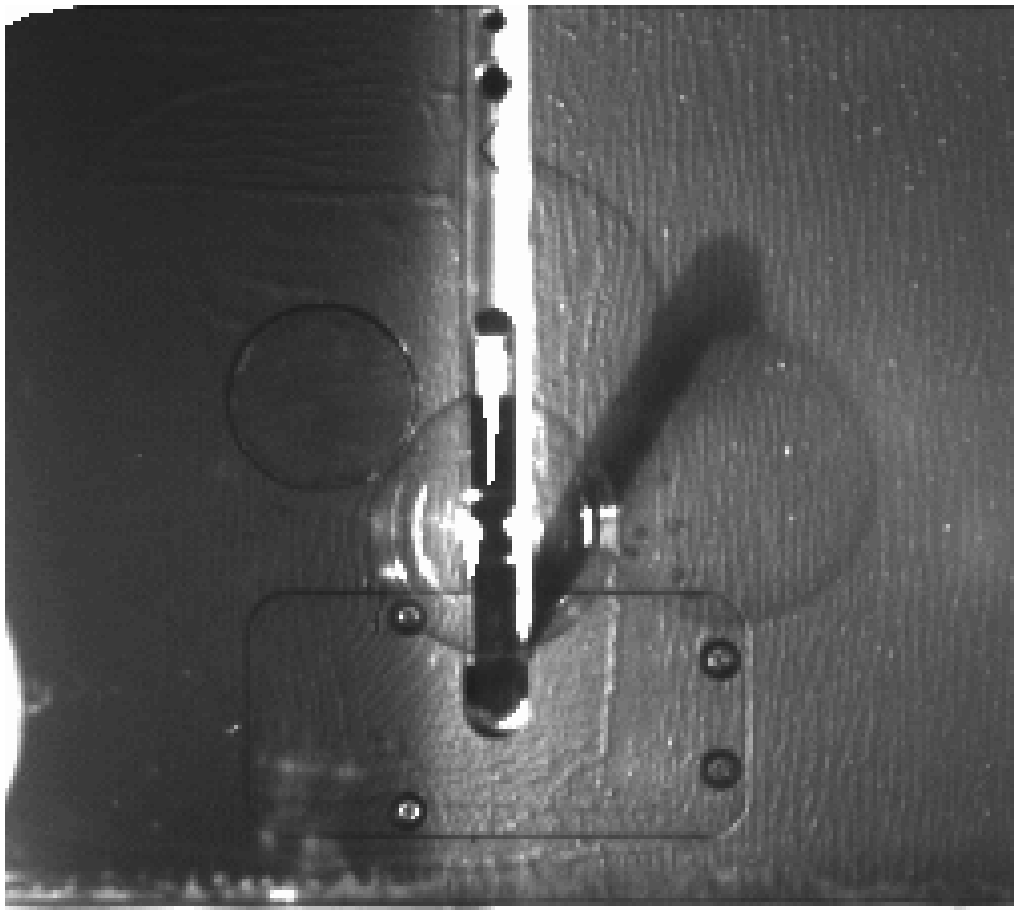
Planar shock wave
Spherical soap bubble $D = 5$ cm
Driver: He Driven: N_2 Test: Ar

Initial conditions:
Continuous white light from the front
Motion picture at 220 fps
Resolution (256×256)

Post shock:
Mie-scattering from the soap
film acting as flow tracer
2 laser pulses
2 images per run on same frame
Resolution (1024×1024)

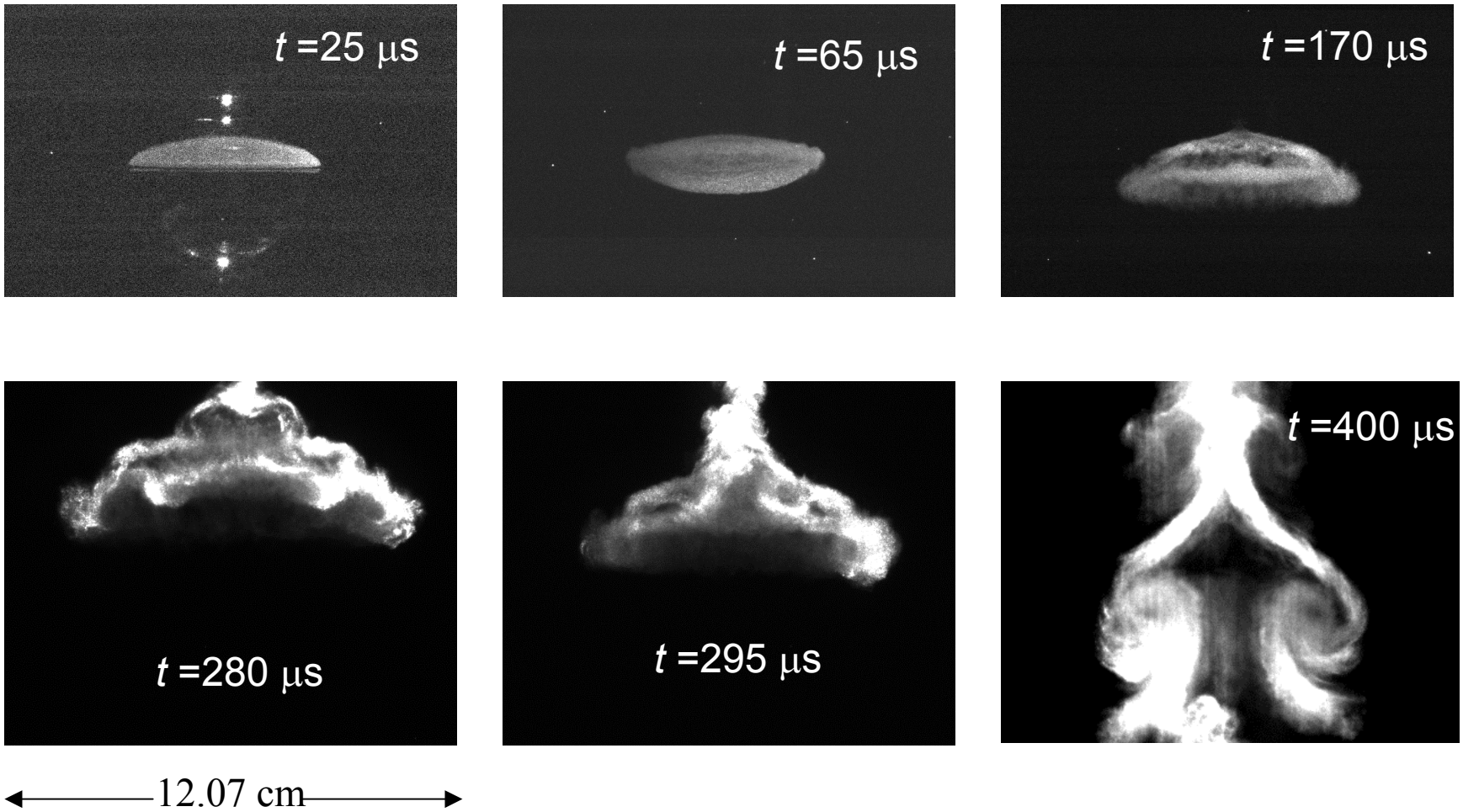


Initial Conditions

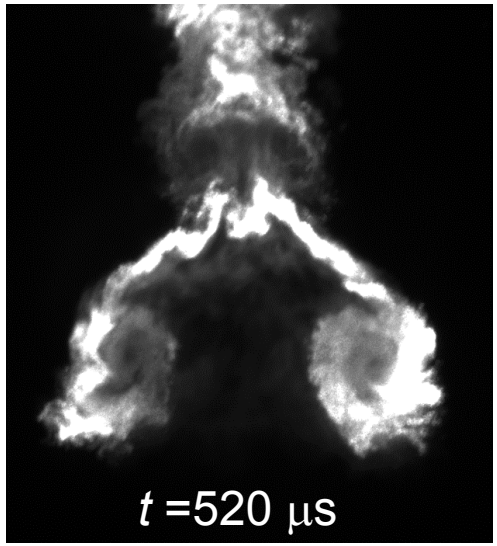


Formation of a ~5 cm diameter bubble and controlled release of bubble

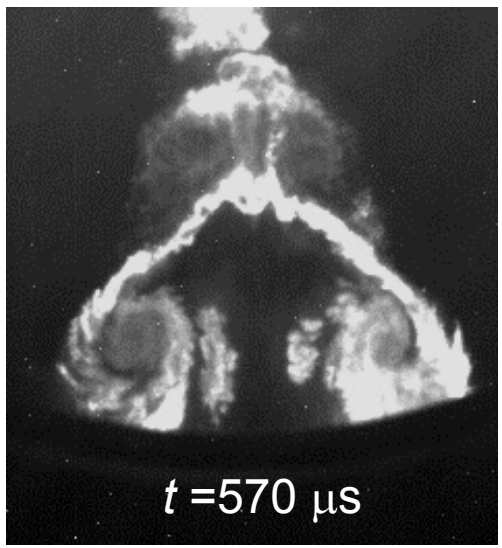
Shock Accelerated Bubble *M*#2.88

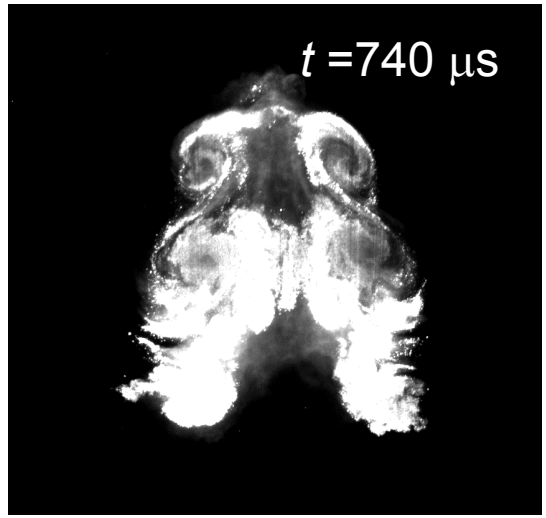


Shock Accelerated Bubble *M*#2.88

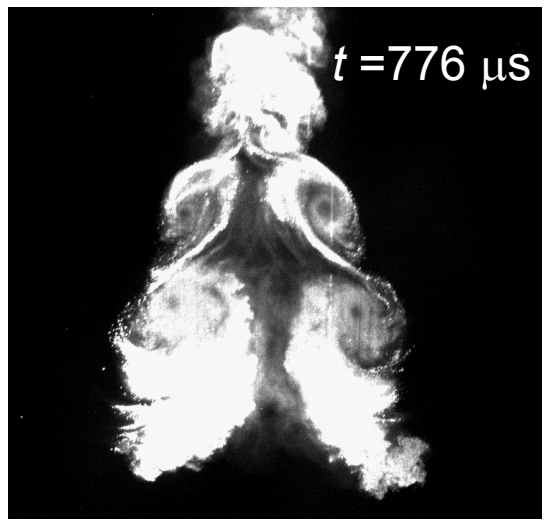


9.52 cm

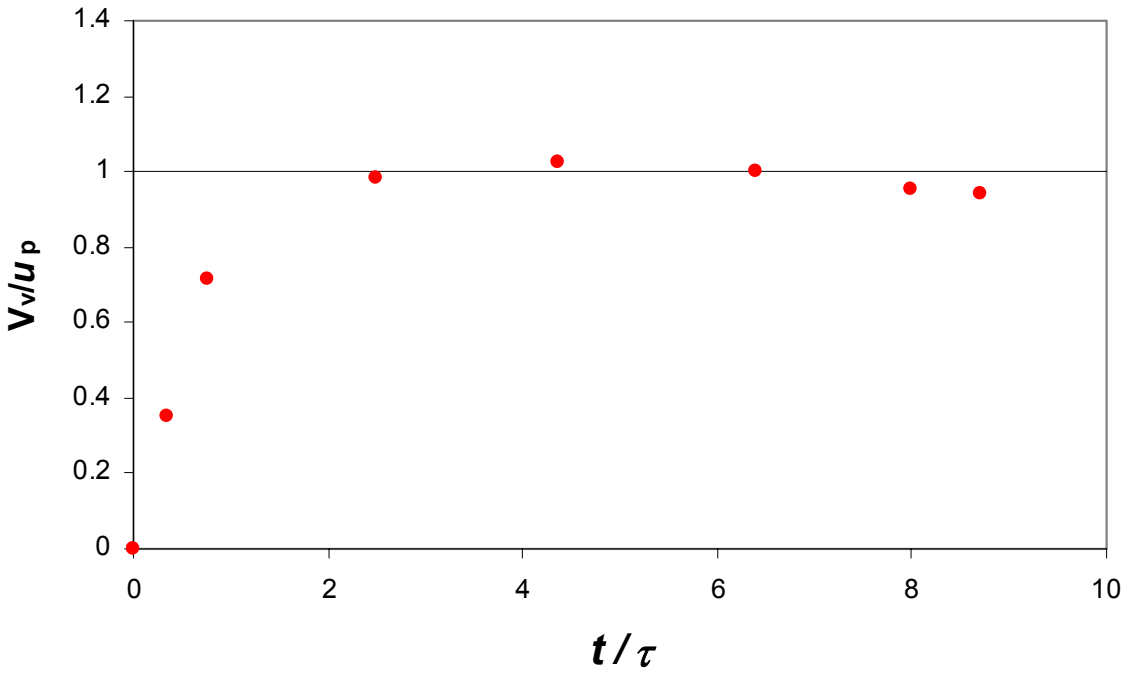


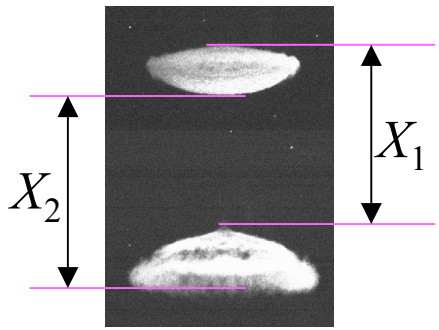


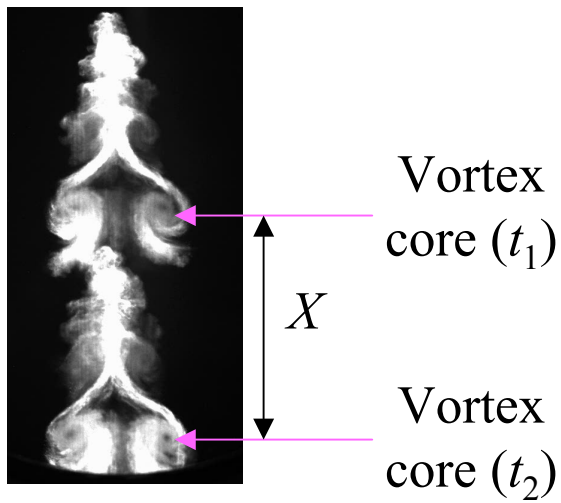
15.24 cm



Vortex Velocity Defect







- Bubble diameter D
- Time scale: $\tau = D/u_p$
  (u_p=particle velocity behind shock)
- $V_v = [(X_1+X_2)/2]/(\Delta t)$ (for early times)
- $V_v = X/(\Delta t)$ (for later times)

Circulation Measurements, *M*#2.88

$$\Gamma \approx u_p \left(1 - \frac{u_p}{2W}\right) D \ln\left(\frac{\rho_\infty}{\rho_b}\right)$$

Picone & Boris (1988)

$\Gamma = -8.6$ m^2/s (D=5 cm)

Initial circulation

$$\Gamma = \frac{4\pi R(V_V - u_p)}{\left[\ln\left(\frac{8R}{r}\right) - \frac{1}{4}\right]}$$

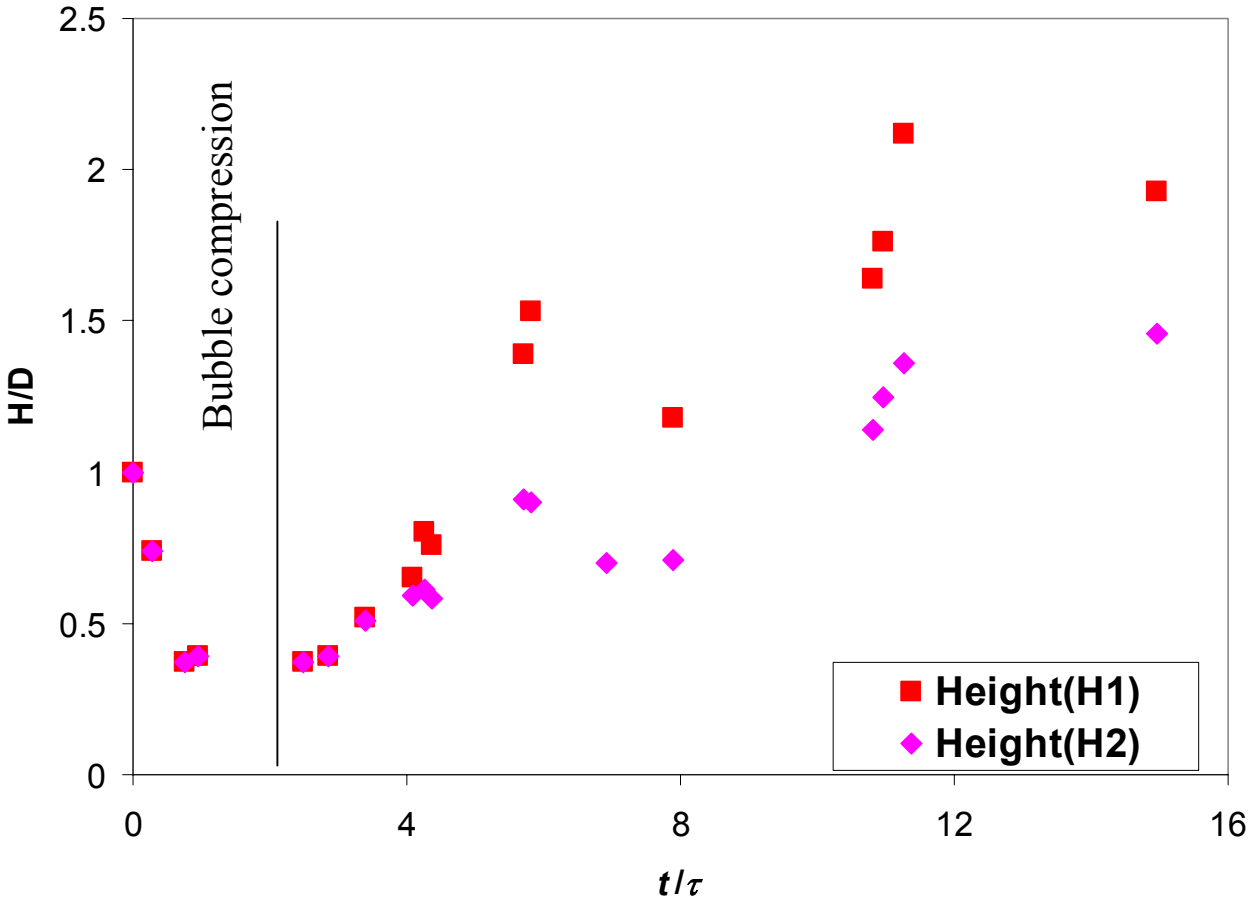
Haas & Sturtevant (1987)

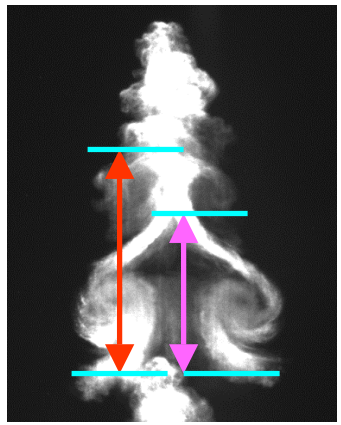
Vortex ring circulation

t/τ	Γ (m^2/s)
8.0	-3.7
8.7	-4.8

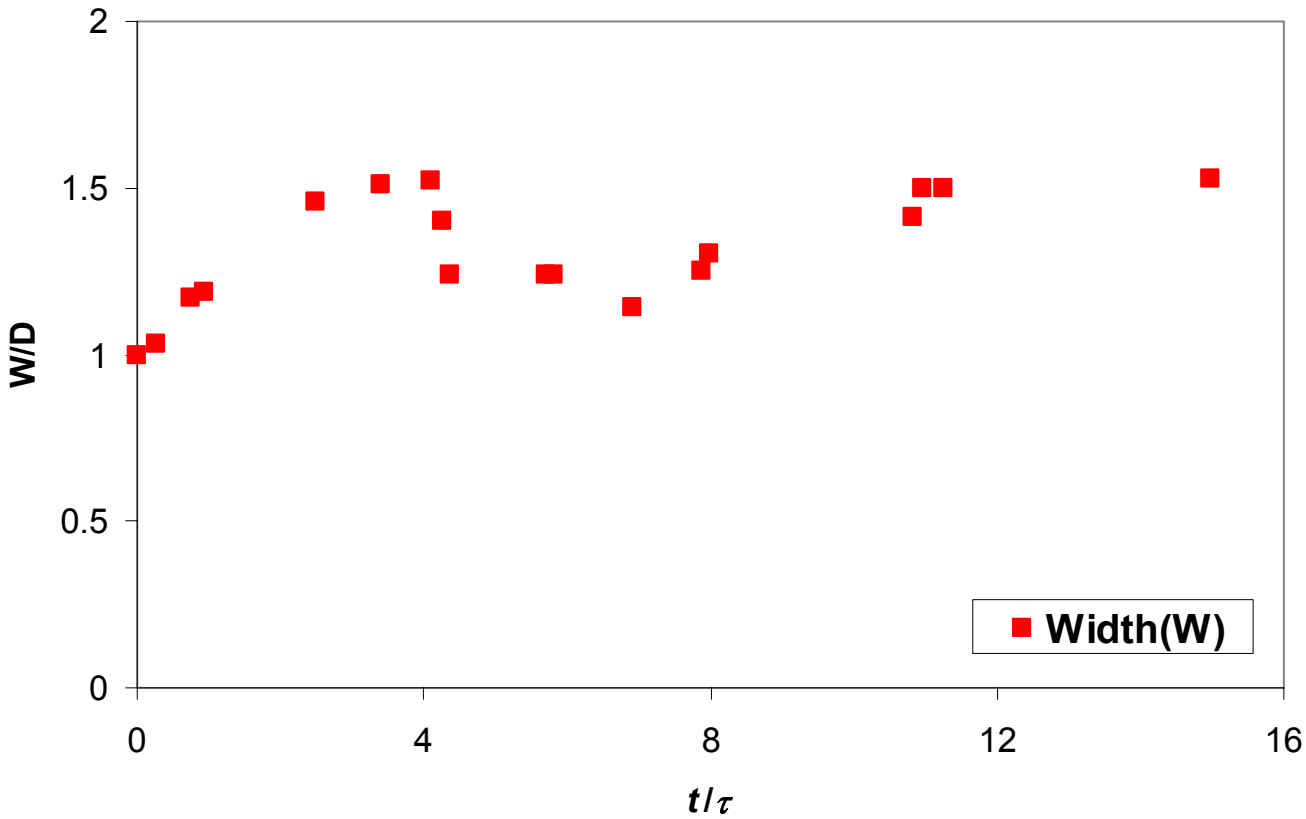
Experimental values

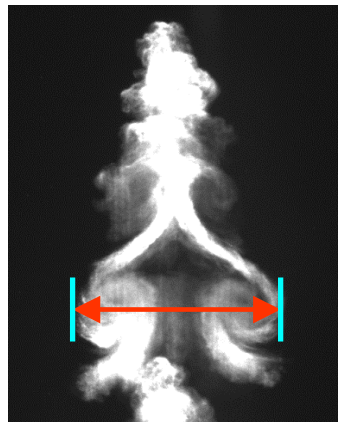
Height Growth Rate, *M*#2.88



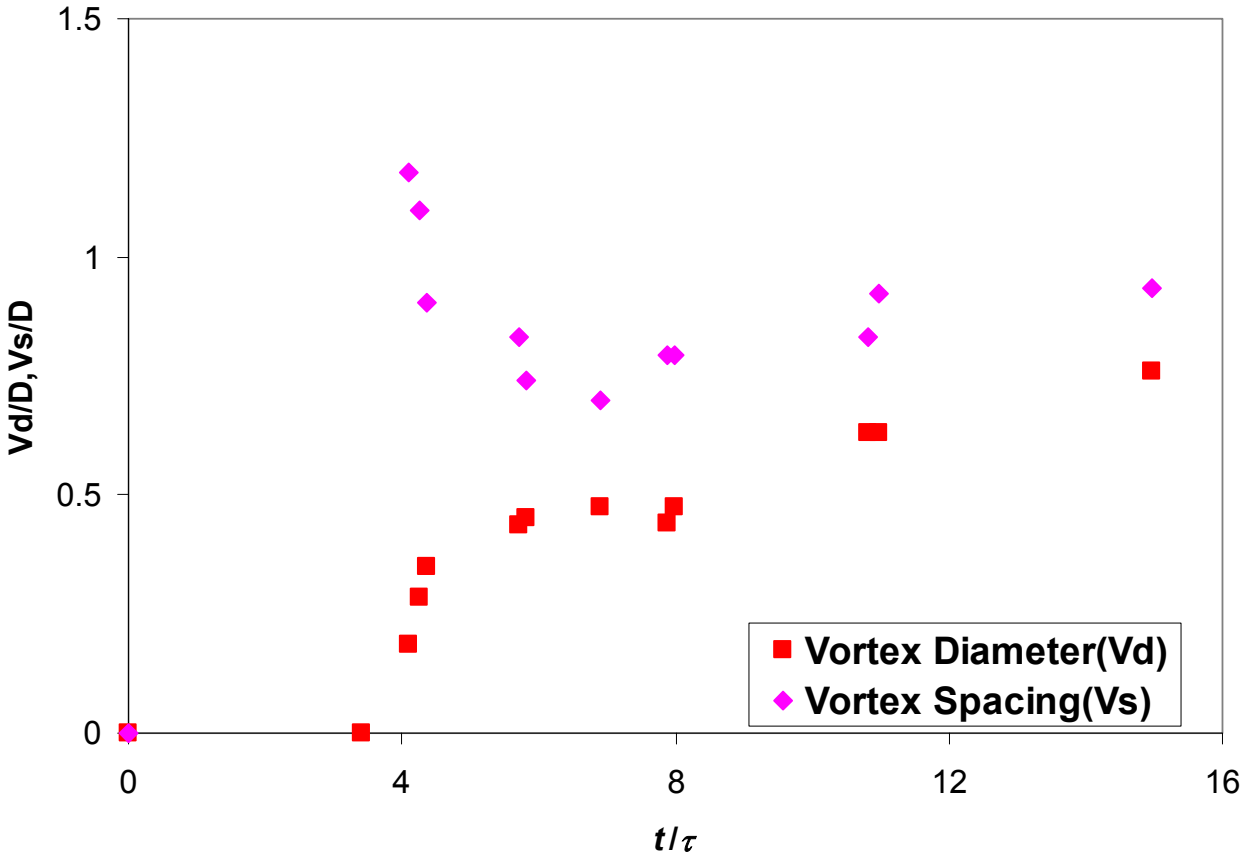


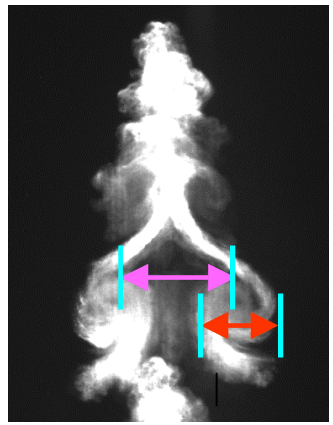
Width Growth Rate, *M*#2.88



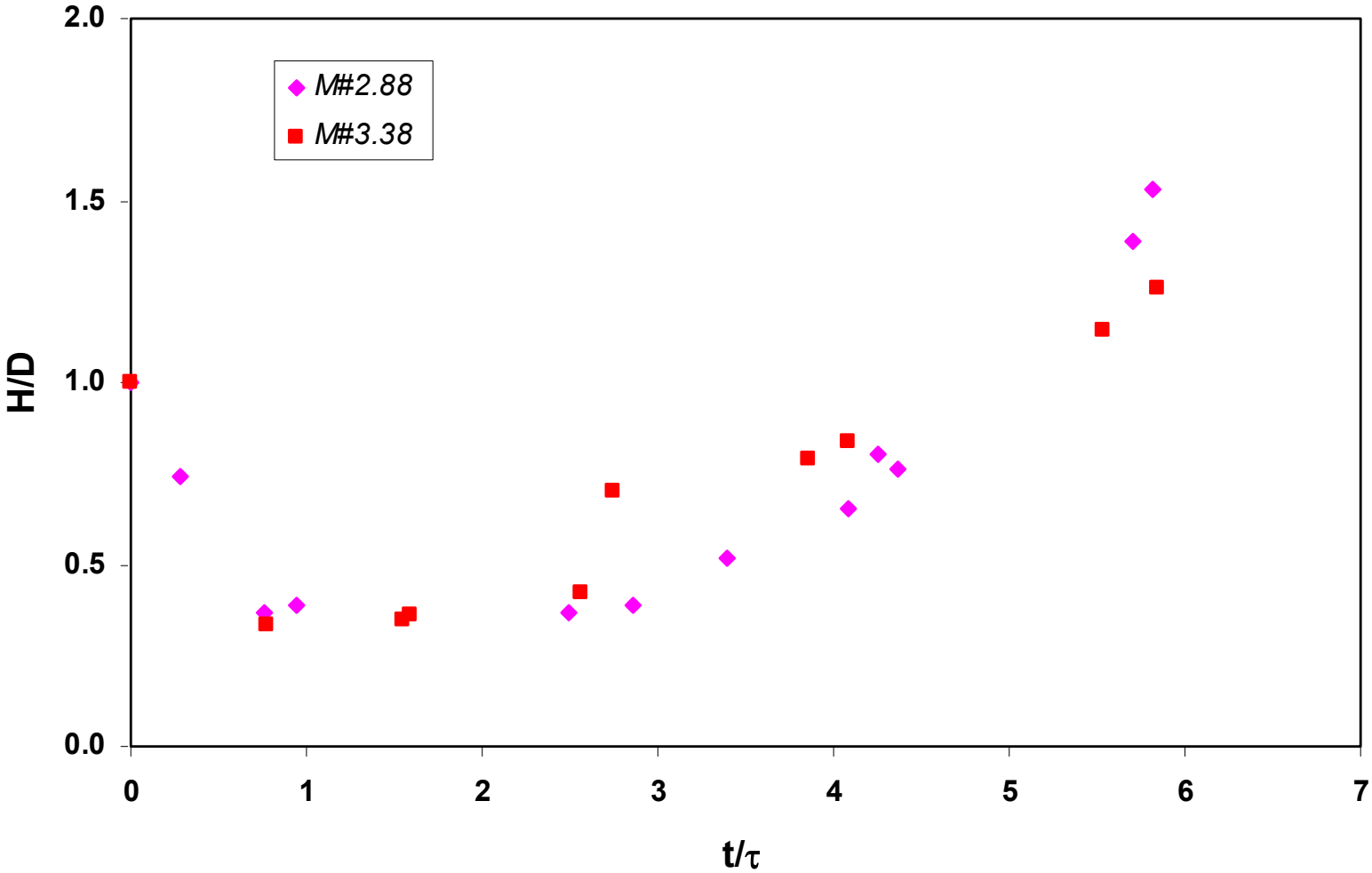


Vortex Growth Rate, *M*#2.88





Comparison(*M#2.88 & M#3.38*)



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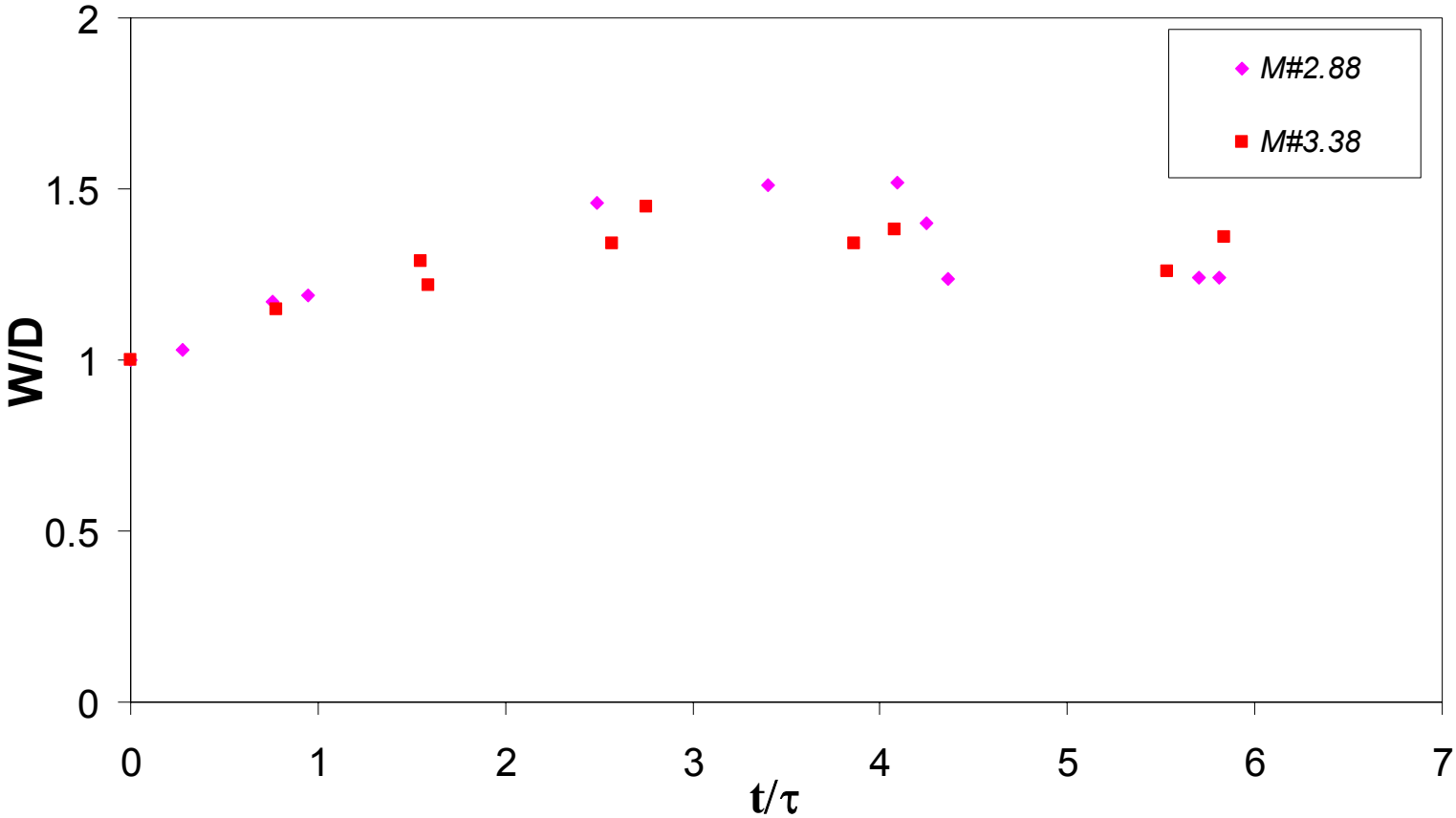

Conclusions

- Developed new bubble-release technique
- Used strong (M>2.5) shocks
- Observed bubble distortion, formation of vortex ring
- Measured growth rates of relevant large scale features
- $\tau = D/u_p$ appears to be appropriate time scale

- Develop experiment to measure species concentration