Interaction of a Planar Shock with a Spherical Gas Inhomogeneity

Part I: Experiments

D. Ranjan, J.H.J. Niederhaus, M.H. Anderson, J.G. Oakley, R. Bonazza

Department of Engineering Physics
University of Wisconsin-Madison

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Wisconsin Shock Tube Laboratory
University of Wisconsin-Madison

Overview

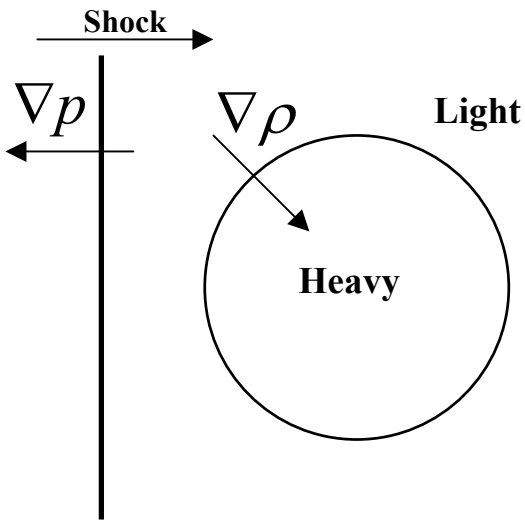
- Planar shock wave accelerates a spherical soap bubble:
  Ar inside, N_2 outside, A=0.176

- Mach numbers
  - M=3.38, u_p=907 m/s
  - M=2.88, u_p=745 m/s
  - M=1.33, u_p=170 m/s

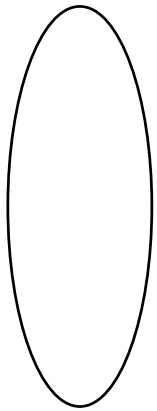
- Previous shock-bubble work

- Time evolution of large scale features

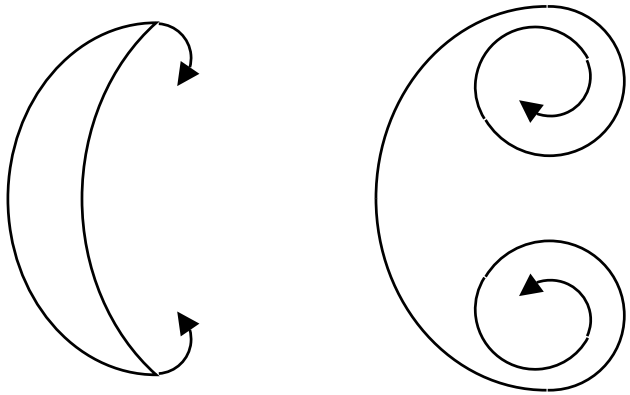
Shock-Bubble Interaction



Compression



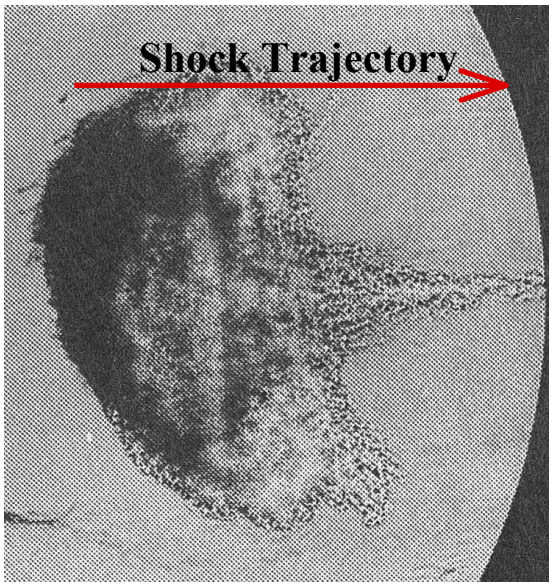
Vortex ring formation

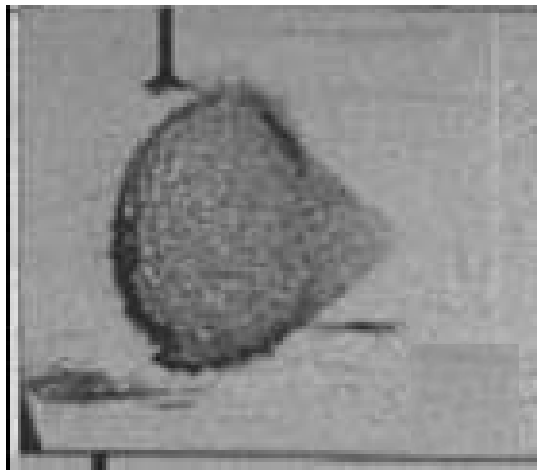


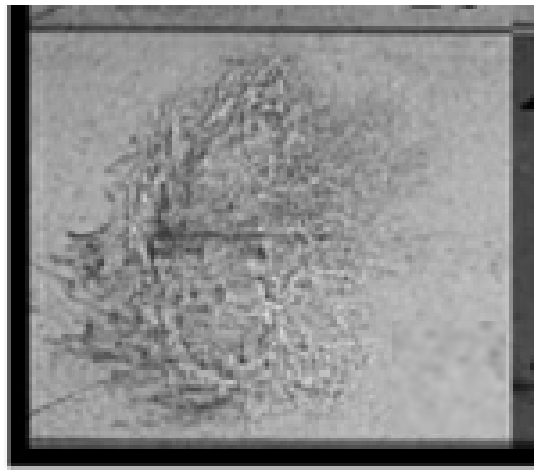
Baroclinic vorticity generation on bubble surface

$$\frac{d\omega}{dt} = \frac{\nabla\rho \times \nabla p}{\rho^2}$$

Previous Shock-Bubble Work



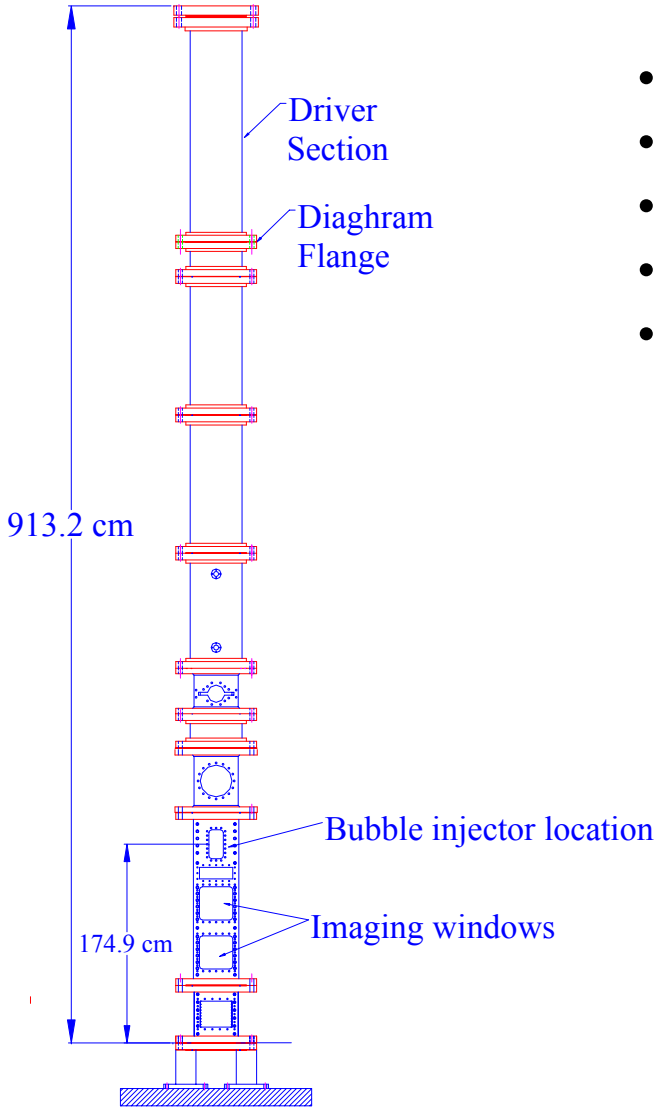




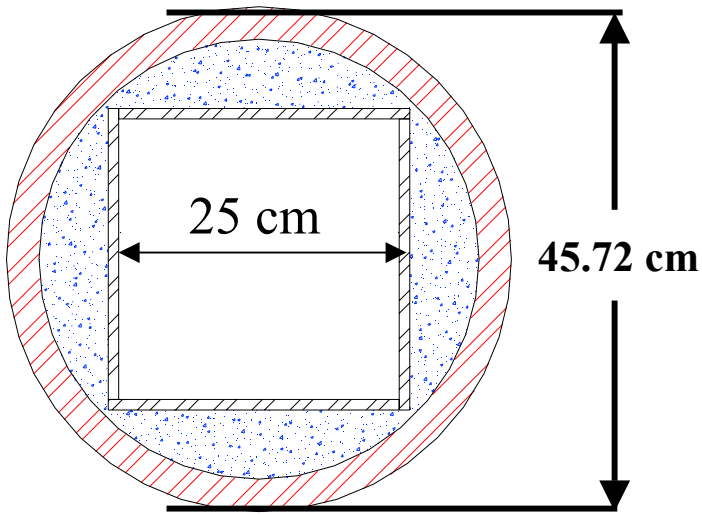
- M =1.25, R22 bubble
- Shadowgraphy
- t = 507 μs
- Haas & Sturtevant, JFM(1987) **181**, 41-76

- M=1.1, Kr bubble, Shadowgraphy
- t =350 μs & t =1330 μs
- From: G. Layes , G. Jourdan &L.Houas, PRL(2003)Volume **91**, Number **17**

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



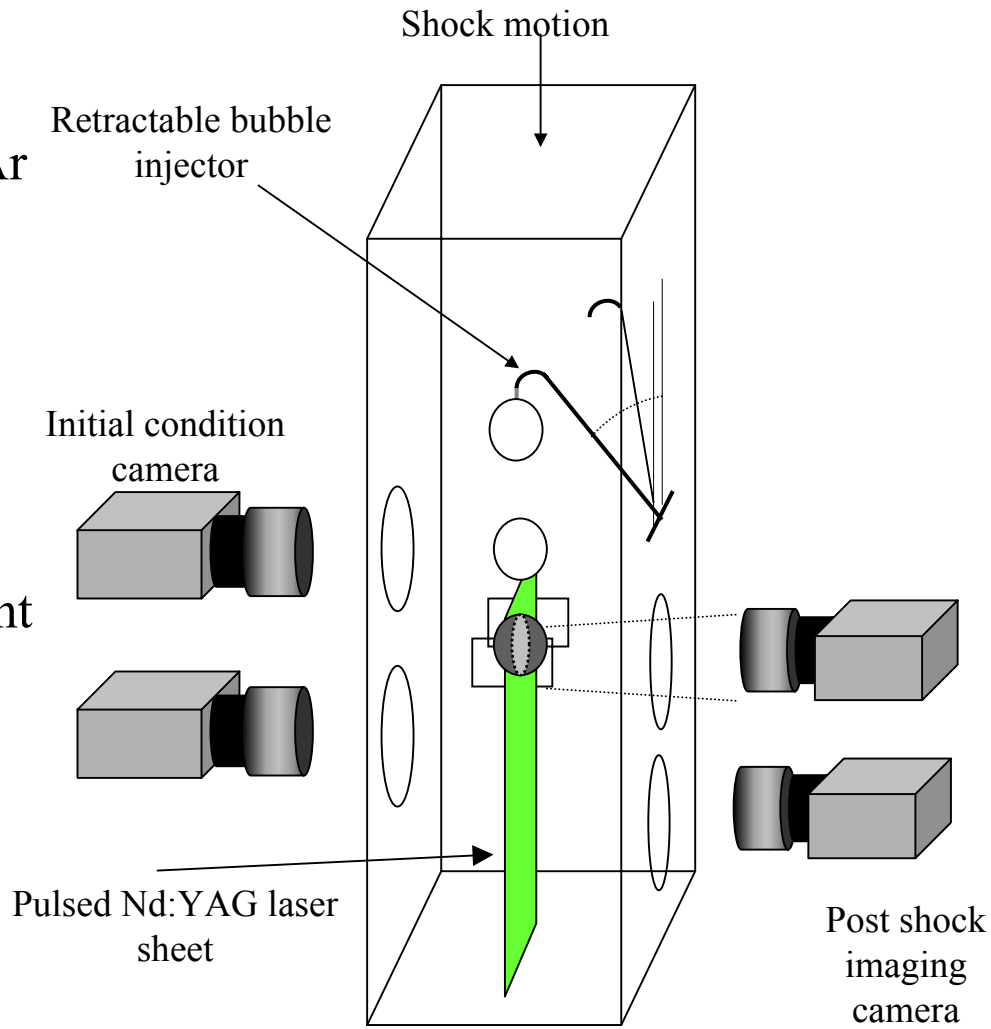
Details of R-M Experiment

Planar shock wave
Spherical soap bubble $D = 5$ cm
Driver: He Driven: N_2 Test: Ar
Atwood Number, $A = 0.176$

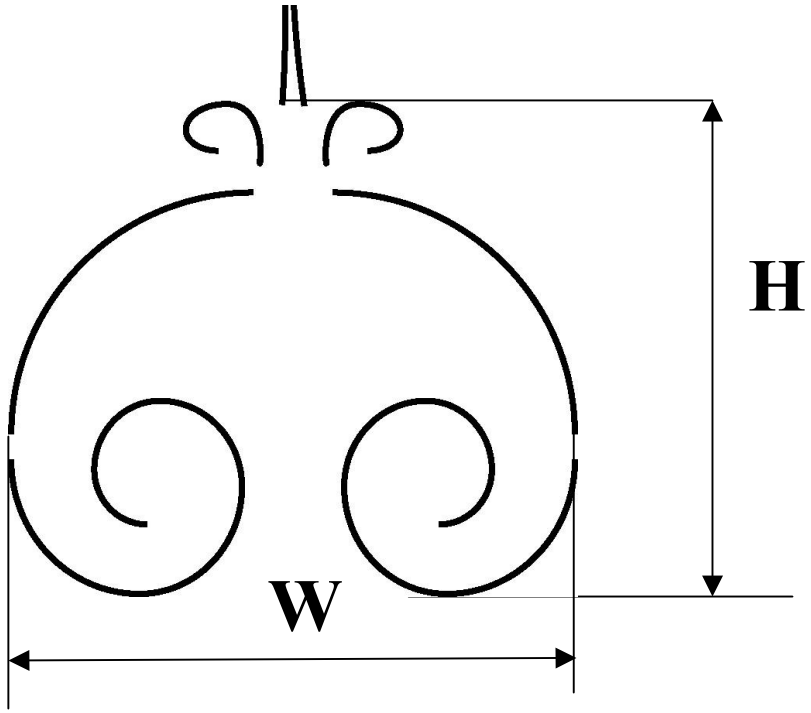
$$A = \frac{\rho_2 - \rho_1}{\rho_2 + \rho_1}$$

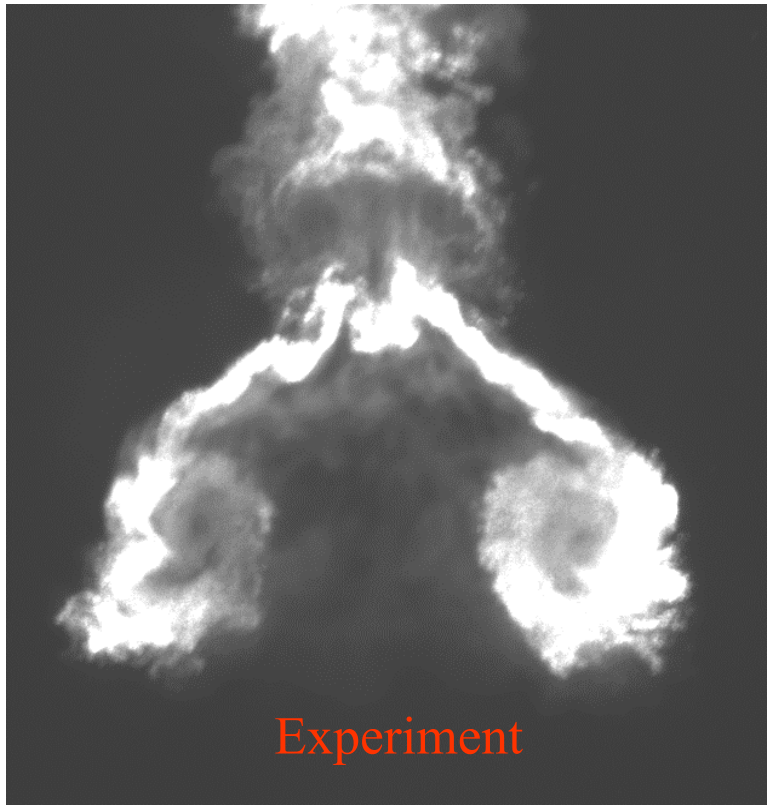
Initial conditions:
Continuous white light from the front
Motion picture at 260 fps
Resolution (514×532)

Post shock:
Mie-scattering from the soap film acting as flow tracer
Planar Imaging
Resolution (1024×1024)



Salient Geometrical Features

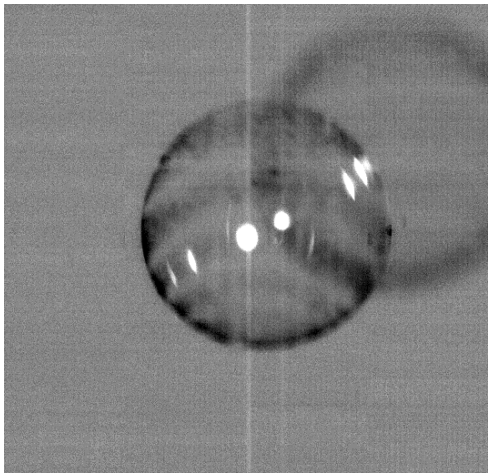




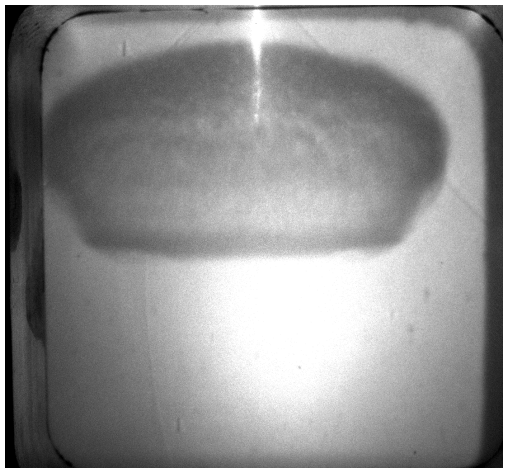
- Length scale: bubble diameter *D*
- Time scale: $\tau = D/(2*W_t)$

  (W_t= Transmitted shock wave speed in bubble)

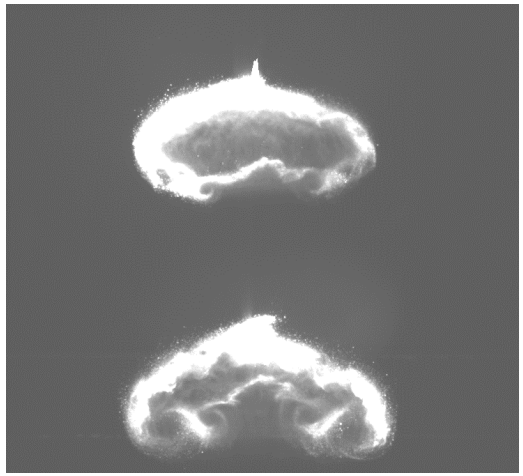
Shock-Bubble Development: M=1.33



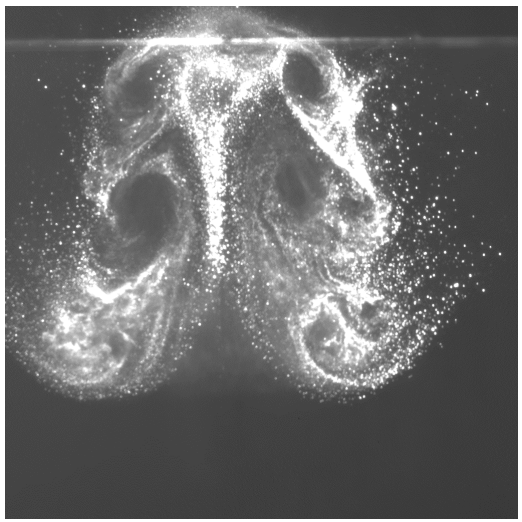
t = 0 ms



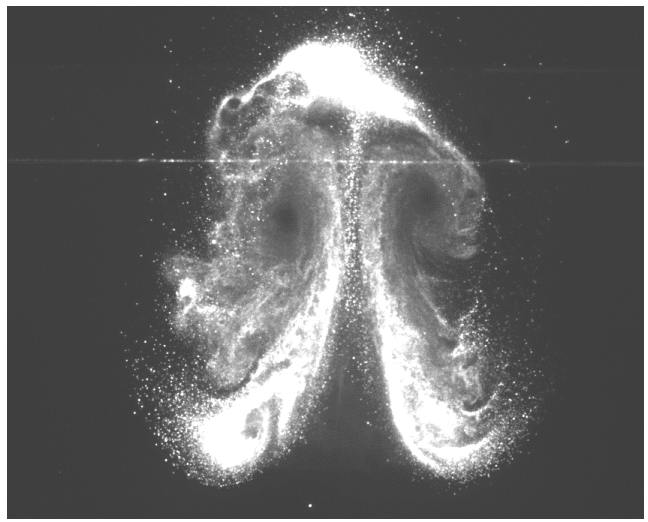
t = 0.55 ms



t = 0.76 & 1.25 ms

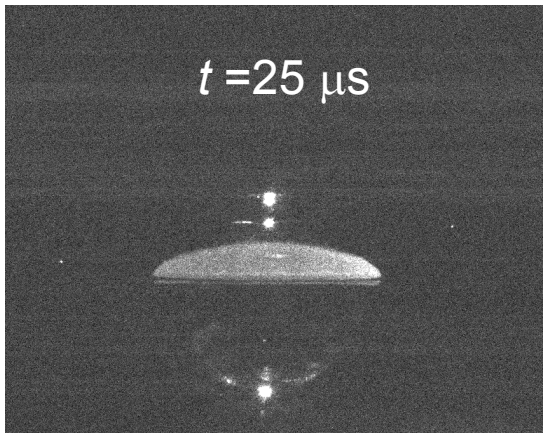


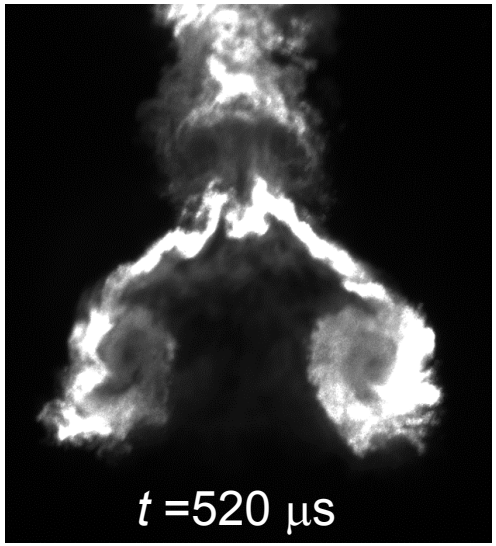
t = 2.70 ms

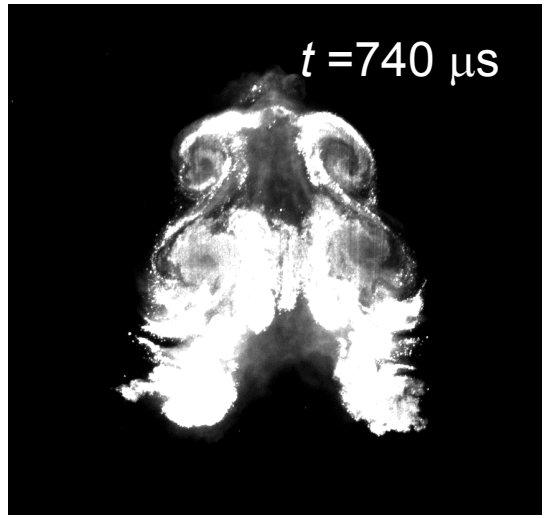


t = 4.15 ms

Shock-Bubble Development: M=2.88



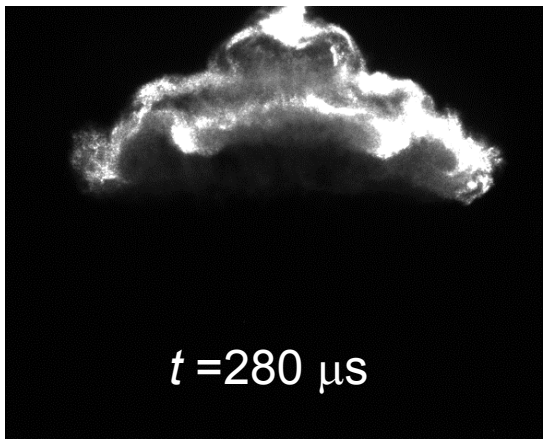


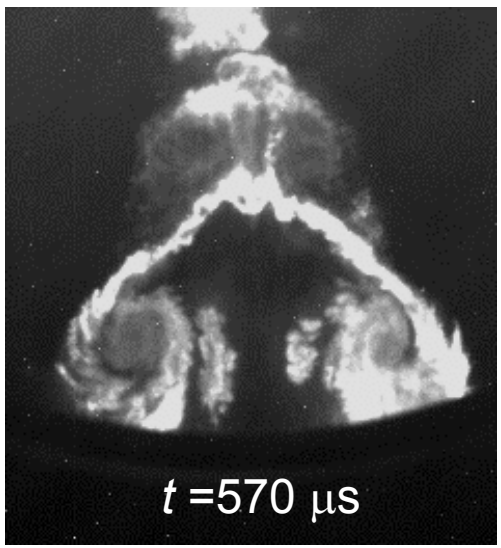


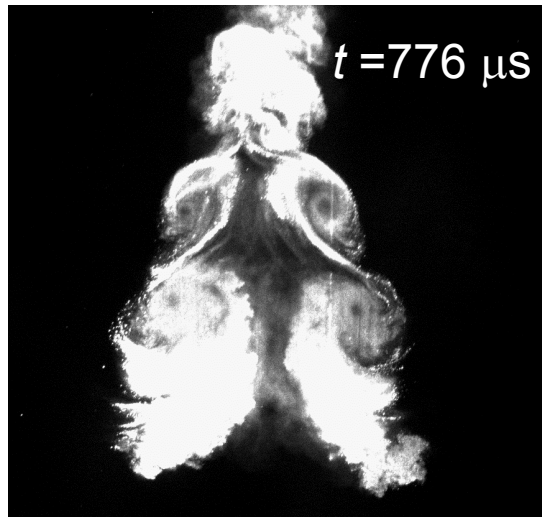
12.07 cm

9.52 cm

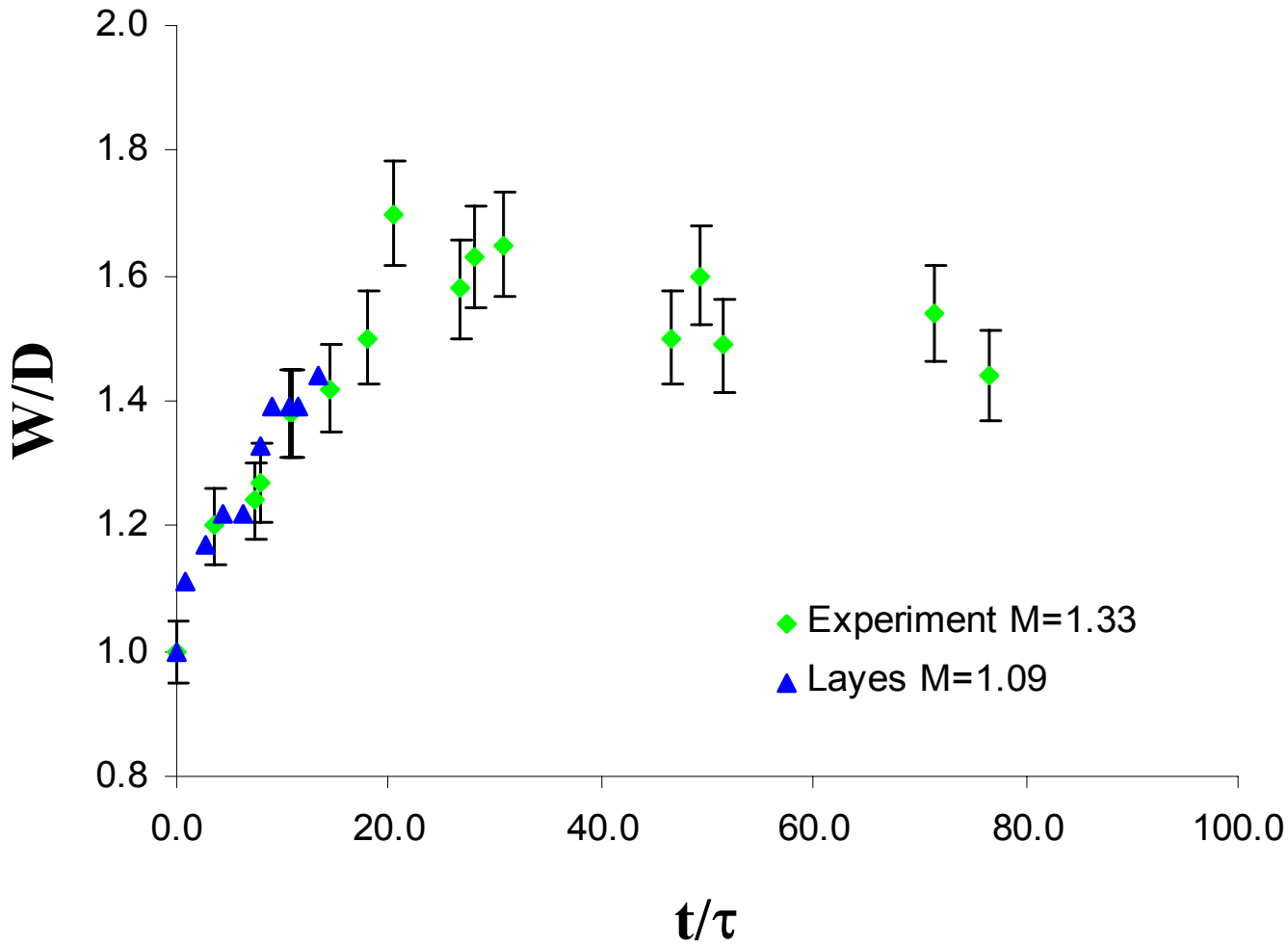
15.24 cm



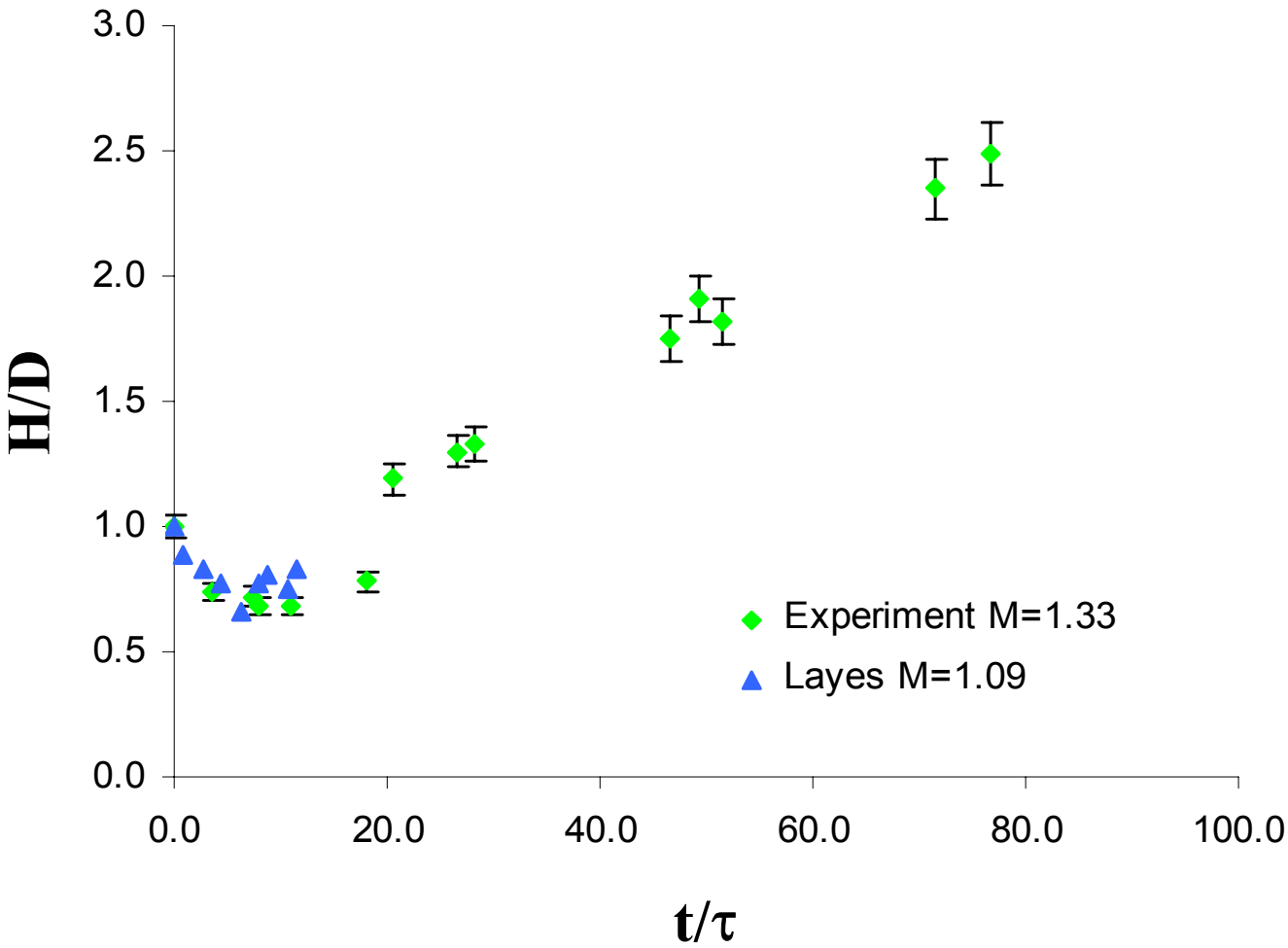




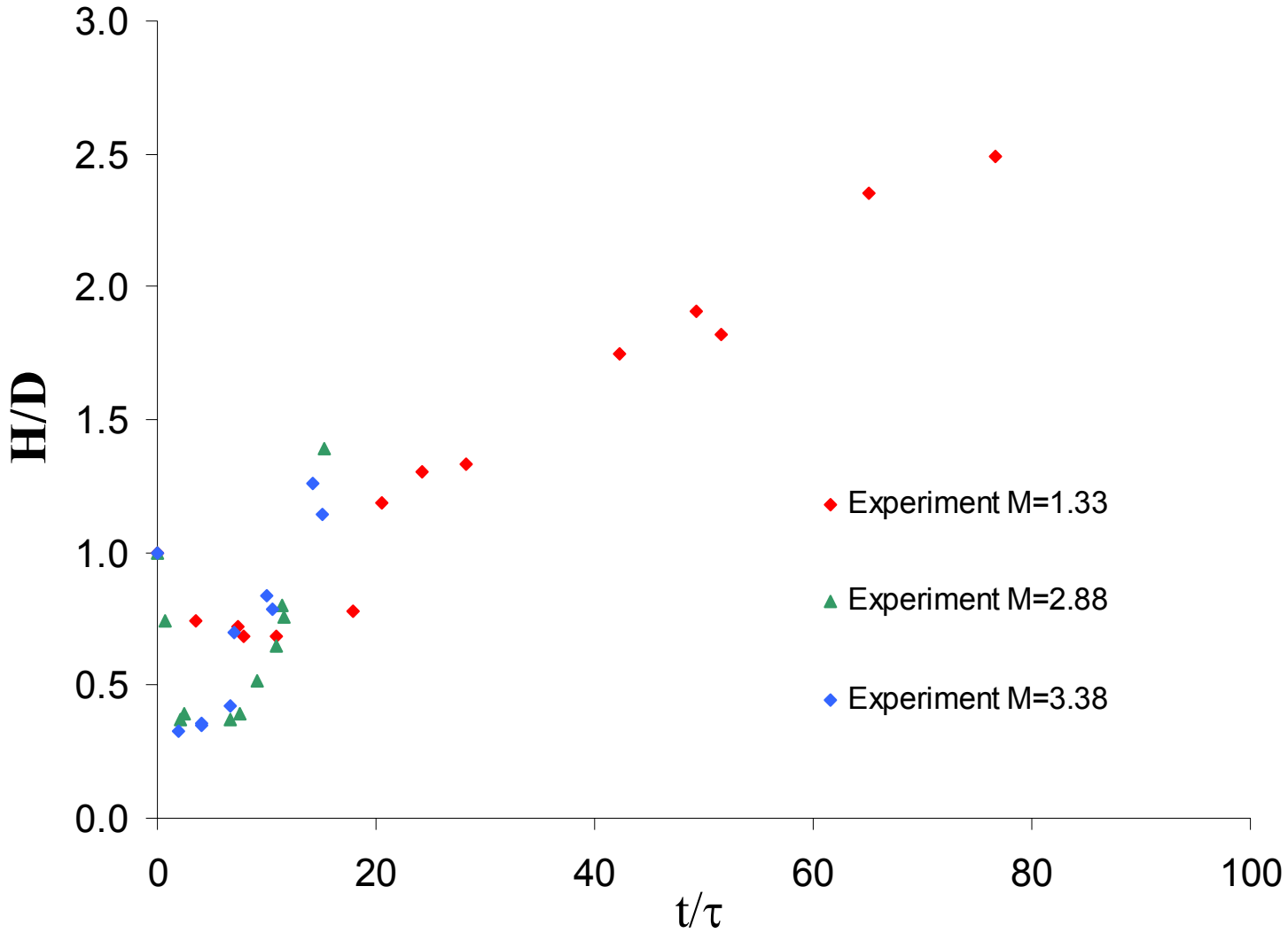
Time Evolution : Width , *M*=1.33



Time Evolution : Height , M=1.33



Comparison: Height (M=1.33, M=2.88, M=3.38)



Conclusions

- Free flow bubble, no holder in flow field
- Wide range of Mach number and planar imaging
- Observed bubble distortion, formation of vortex ring
- Measured growth rates of relevant large scale features
- $\tau = D/(2*W_t)$ appears to be appropriate time scale

Future Work :

- Develop experiment to measure species concentration
- Conduct experiments with different Atwood number

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