Radiography for a Shock-Accelerated Liquid Layer

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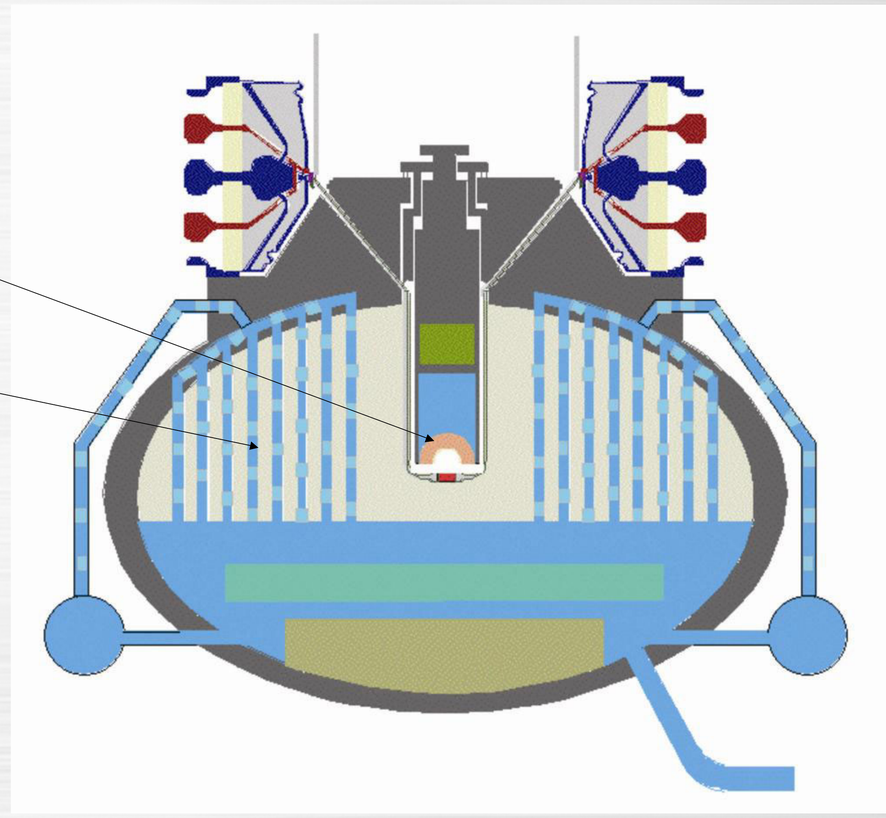
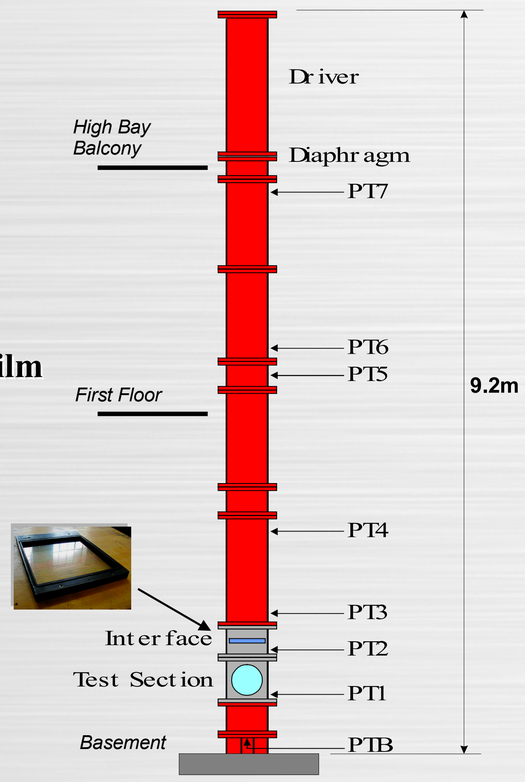
Background

- Inertial fusion energy (IFE) reactor: strong shock propagating from the center of the chamber towards the walls
- Proposed protection: flowing liquid sheets of molten salt to absorb debris, mechanical and thermal energy from fusion reaction
- At first, model flowing molten salt sheet with stationary layer of water (easier to handle; scalable)
- Study breakup/fragmentation of shock-accelerated water sheet(s) and their effectiveness in attenuating pressure load



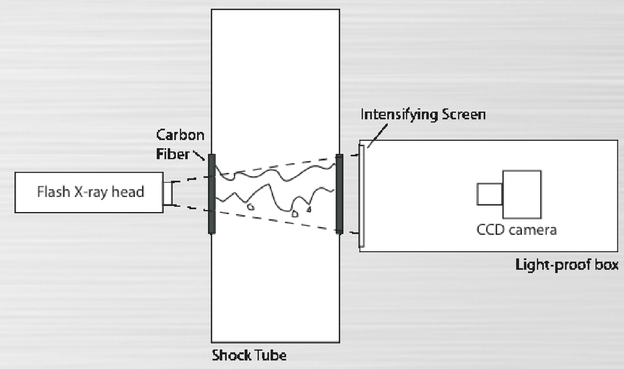
Experimental facility

- 9.2 m long, vertical shock tube
- Square internal cross section, 25 x 25 cm
- Up to Mach 5 into atmospheric air
- Water layer supported in Ar by 1 μm Mylar film

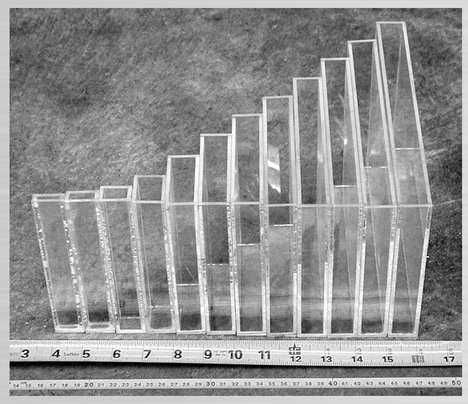


X-ray diagnostics

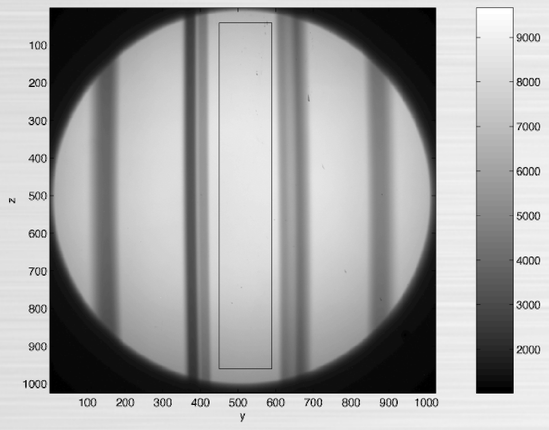
- 70 ns X-ray flash
- max photon energy 150 keV
- Carbon fiber windows
- Kodak Lanex fluorescent screen
- 1024 x 1024 pixels CCD camera



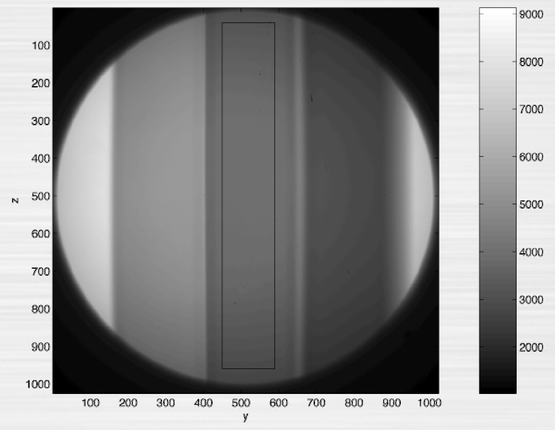
Calibration



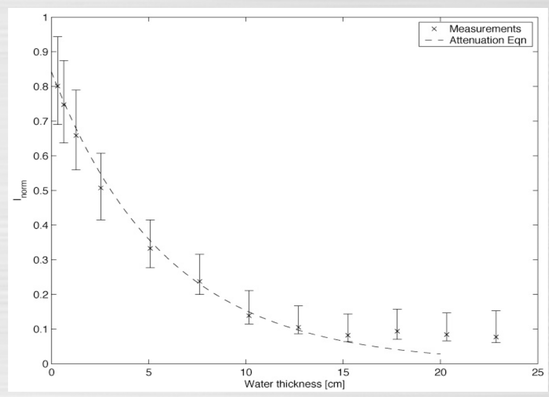
Calibration cells



X-ray image of three empty cells
thicknesses: 25.4 mm, 50.8 mm, 76.2 mm

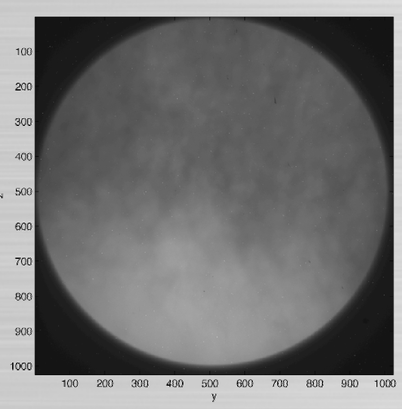


X-ray image of same three cells filled with water

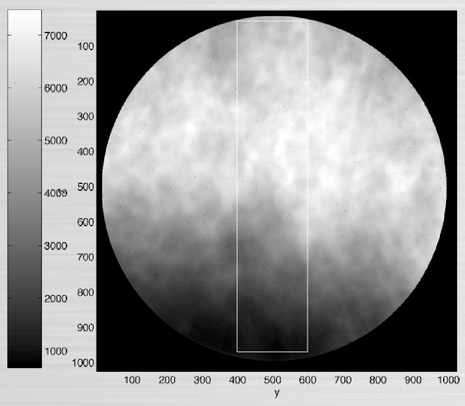


Useful signal up to 130 mm water
(51% volume fraction)

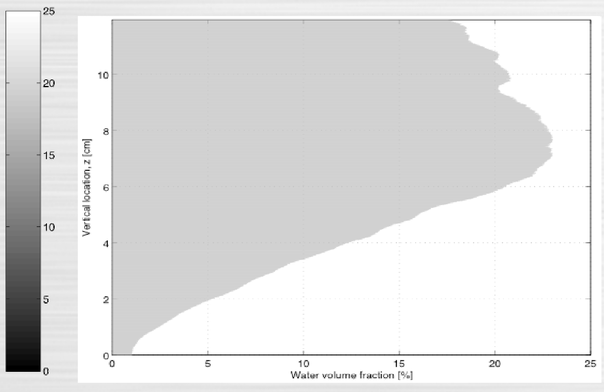
Shock-induced water layer break-up



Raw X-ray Image



Volume Fraction



Average Volume Fraction

$$x_w = \frac{1}{\mu_{Ar} - \mu_w} \ln\left[\frac{I_S - I_D}{I_R - I_D} e^{\mu_{pl} x_{pl}} e^{\mu_{Ar}(x_{st} - x_{pl})}\right]$$

x: thickness	S: signal	pl: Plexiglas
μ: absorpt. coeff.	D: dark current	st: steel
I: pixel value	R: background	w: water

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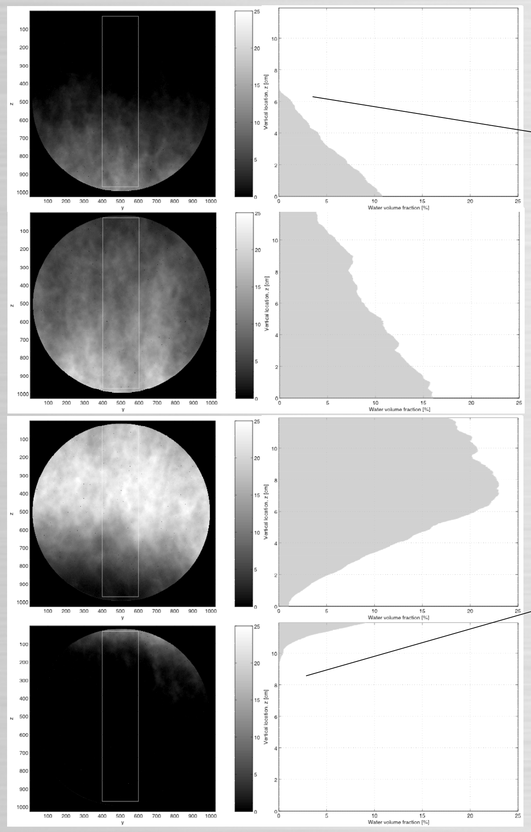
Reconstruction of spread-out layer from sequence of X-ray images

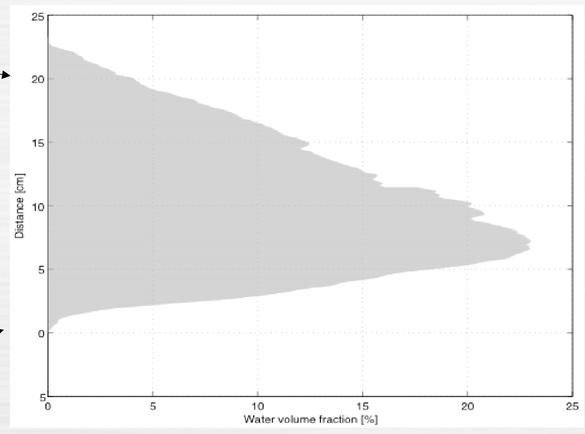


t=3.60 ms "Trailing edge"

t=3.40 ms "Middle"

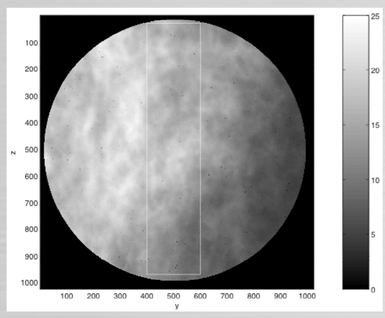
t=3.19 ms "Front"

t=2.98 ms "Leading edge"

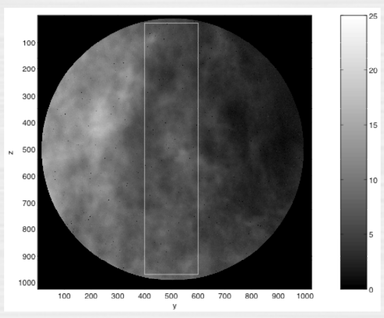


M=2.12, 12.8 mm

Effect of number of layers on break-up

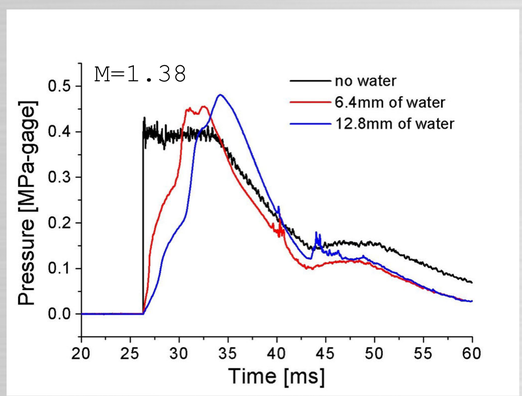


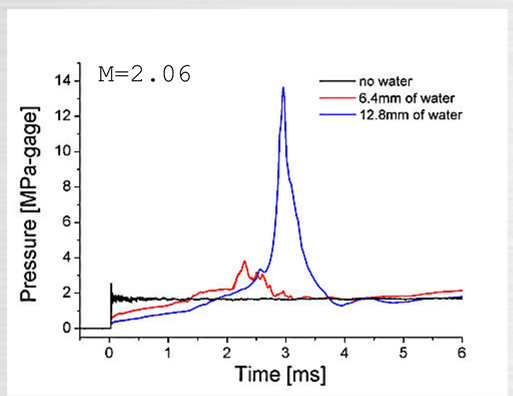
Single layer
z_0=12.8 mm
M=2.13
t=4.93 ms
Image: "Middle"

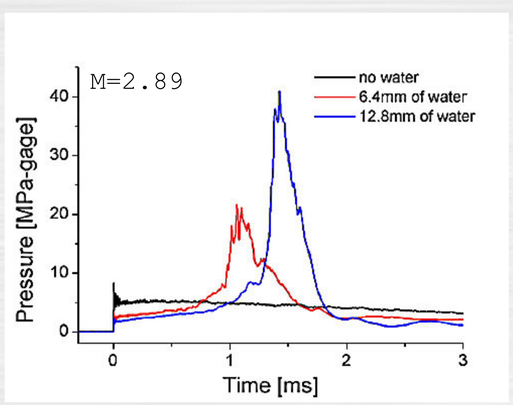


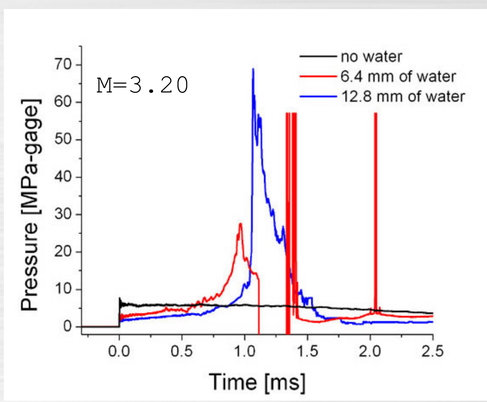
Two layers
z_0=6.4 mm, each
18.3 mm spacing
M=2.12
t=5.18 ms
Image: "Middle"

Effect of water layer break-up upon endwall pressure

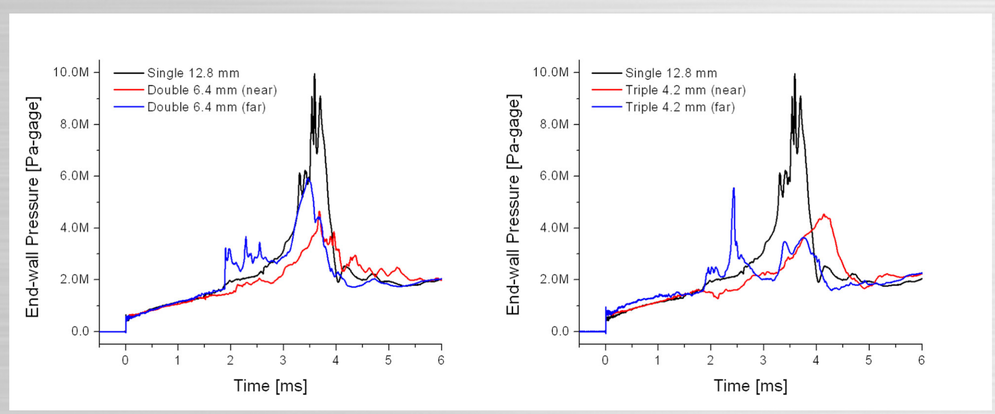






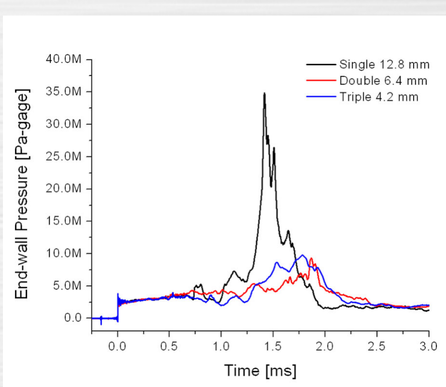


Endwall pressure, single layer, different shock strengths



Effect of layer spacing on endwall pressure

M=2.12
Water volume = 0.8 l in all cases
Double: near = 18.3 mm spacing
far = 92.4 mm spacing
Triple: near = 20.5 mm spacing
far = 94.6 mm spacing



Effect of number of layers on endwall pressure

M=3.20
water volume = 0.8 l in all cases
Double: 18.3 mm spacing
Triple: 20.5 mm spacing