EXPERIMENTAL HYDRODYNAMICS LABORATORY

Shallow Angle Water-Entry of High-Speed Projectiles

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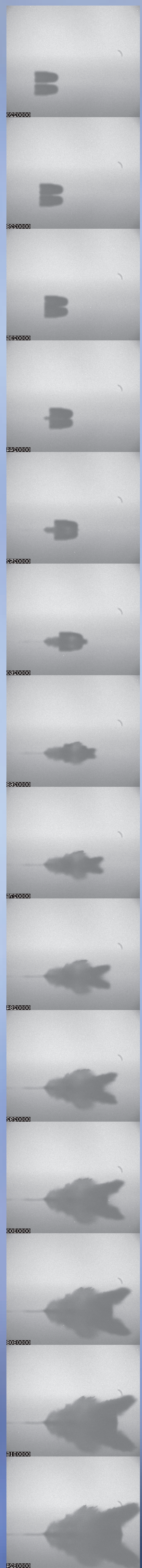
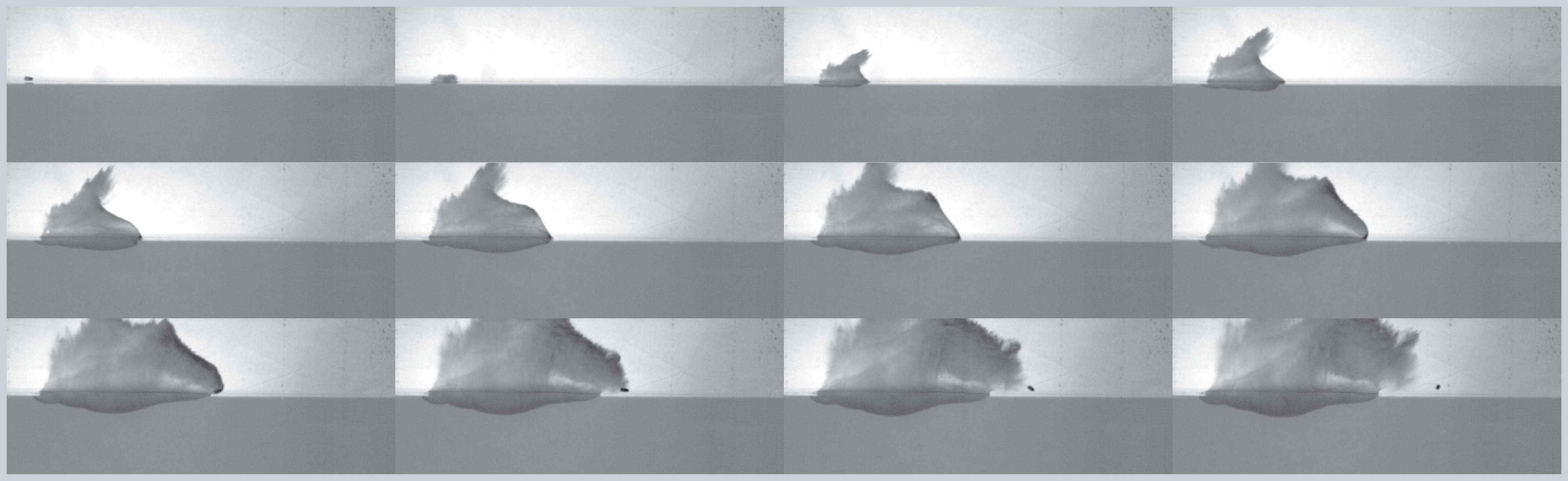
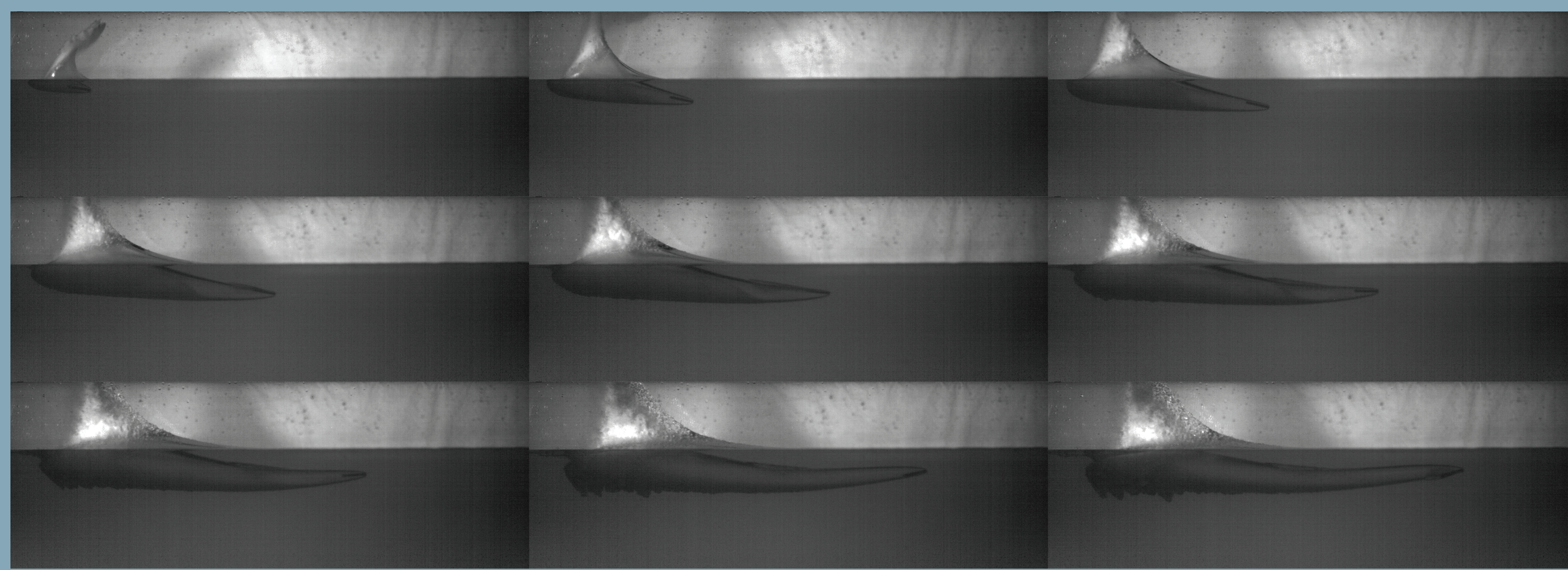


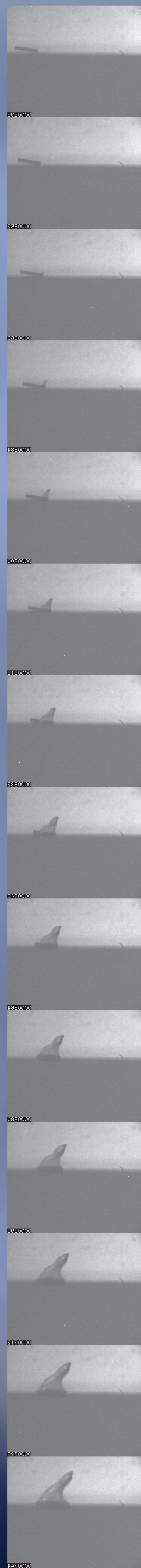


Contrary to popular belief, a bullet can be fired into water at a shallow angle and enter the water without skipping off of the surface under the right conditions. The contrasting phenomena is dominated mainly by the tip shape of the projectiles. On the left a standard *.22 caliber* ogive projectile *L/D = 2.17* enters the water at an angle of nearly *0°* with a velocity of *349 [m/s]*, eventually skipping off of the surface resisting water entry. Images are spaced *4μs* apart. On the right a modified *.22 caliber* projectile *L/D = 8.30* with a blunt tip enters the water at an angle of *8°* and entry speed of *331[m/s]*. Images are *8μs* apart. The modified projectile enters the water creating a cavity and enters the water without skipping. Although the modified projectile presented here enters at a higher angle than the standard bullet at left our research shows that these projectiles can enter the water without skipping up to angles as small as *6°*.

The shallow water entry angle causes the bullet to form a distinct splash arching both outward and upward. For the case on the left the bullet continues to travel underwater and begins to tumble causing the cavity to vary in size in the vertical direction. As the bullet tumbles it loses both velocity and the ability to maintain a proper heading. The force of water against the bullet as it tumbles eventually causes it to bounce and leave the cavity. Images above illustrate the cavity formation and bouncing of the bullet with a larger view and larger time span between images (*133μs*). It is interesting to note that bullets of this type can enter the water successfully without skipping at an angle of 11°.



A longer modified .22 caliber bullet is used to contrast the affect of nose shape on water-entry. The longer projectile has a similar splash formation to the standard projectile, but once underwater it is able to resist the tumbling nature of the standard bullet. The modified tip allows the projectile to create a super cavity large enough to contain the bullet without tumbling. The tip creates the cavity by forcing the water around the 90° face, which forces the fluid to accelerate around the infinite jump, which in turn causes the water to decrease in pressure enough to create the vaporous cavity. The images below show a larger view of the modified bullet and a larger time span between images (869μs). The modified length allows the projectile to lean against the cavity walls for stability and helps reduce the tendency for the bullet to tumble. For example, the fourth image in the series shows the bullet leaning against the cavity wall at the top of the cavity. It is then forced back into the cavity and begins to pitch bending the cavity towards the surface. The final image shows the bullet once again leaning against the cavity for stability. Further images (not shown) show the bullet pitching down again and heading deeper below the surface.



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