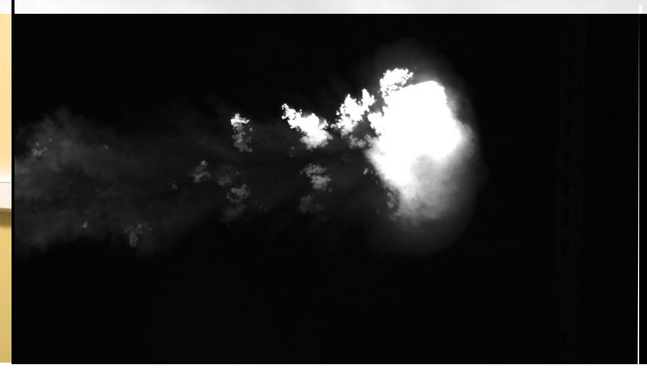
Flow Visualization of an Airzooka Blast

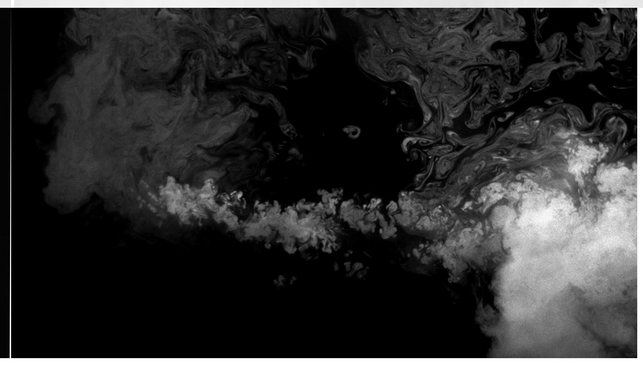
What is an Airzooka?

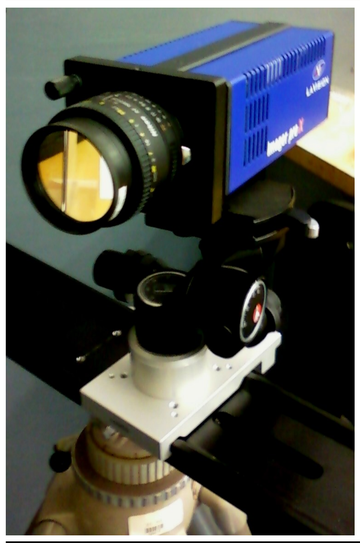
An airzooka is a toy which shoots a blast of air. Most commonly, a handle attached to several elastic chords is pulled back and released, causing a sheet of plastic to be forced rapidly forward, propelling air out of a hole in the front, causing a blast capable of hitting targets over 30 feet away.

What is Flow Visualization?

Flow visualization refers to any technique used to "see" the movement of a fluid. Flow visualization is used both qualitatively and quantitatively in conjunction with computational fluid dynamics (computer simulations) to improve and design products such as airplanes and automobiles.

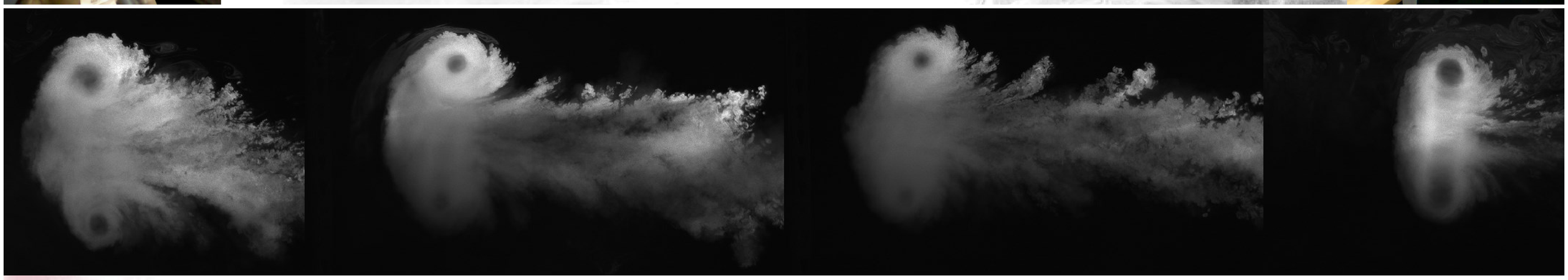






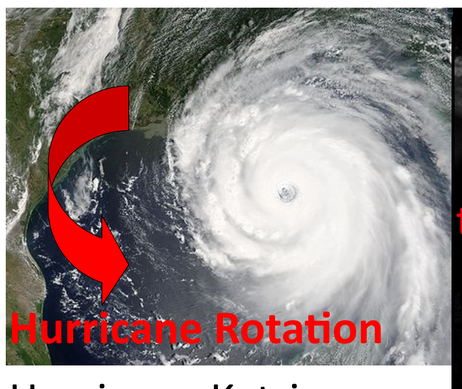
Procedure

In this experiment, a LaVision Particle Image Velocimetry station was used to observe the blast from an airzooka. The airzooka was filled with smoke and subsequently fired through a laser sheet created by passing the laser through two lenses designed for this purpose. This technique allowed the camera to capture a "slice" of the airzooka blast. The camera captured 15 images per second, sending the data to a computer running DaVis (software used for flow visualization). It was then necessary to modify the brightness gradient for the images, in order for the pictures to convey sufficient detail.

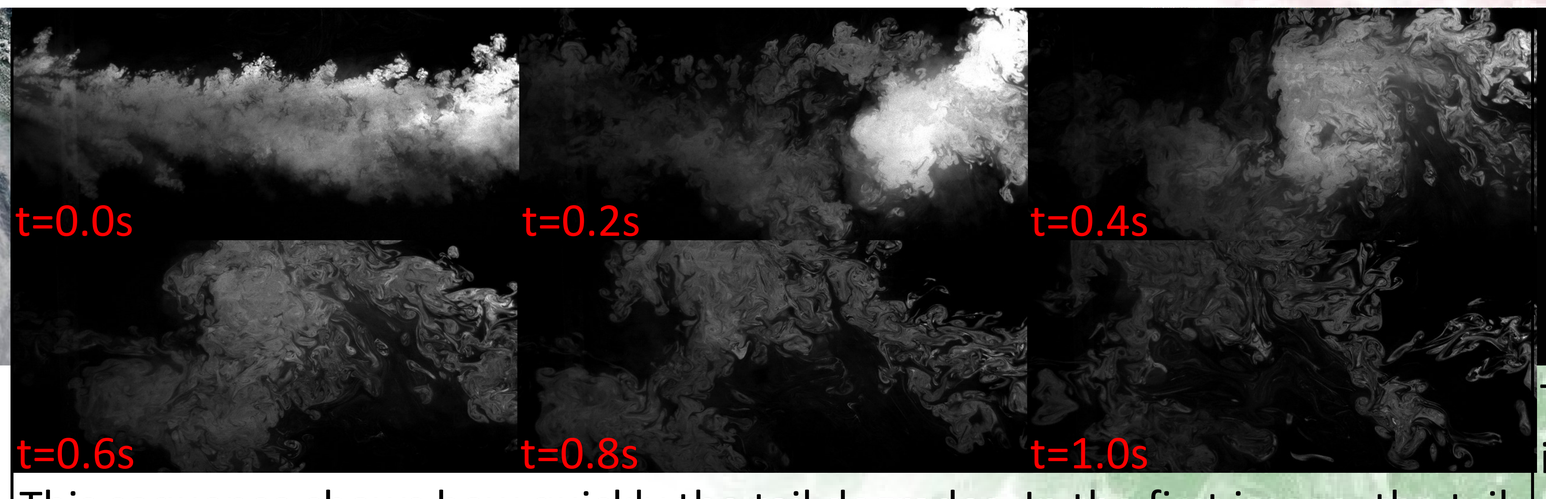


These pictures depict the front of the air blast. Note the vortices on the top and bottom; while they appear to be separate, they are, in fact, part of the same vortex ring. Evidence of this can be seen in the right most picture. Note the stripe connecting the two dark circles; this appears because the laser was slightly off the center of the blast, allowing a view that shows the areas with fewer particles that occur as one nears the vortex center (as can be seen from the pictures, there is a gradient from bright to dark approaching the center of the visible vortices).

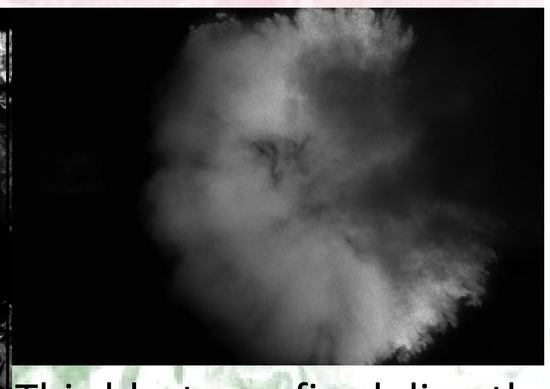
Also note the bulbous front. Although this might seem to be a trivial detail, it gives a clue as to the direction of spin of the ring vortex. The front observed suggests that air is propelled forward from the tail, then curves around the ring (meaning the observed top vortex would spin clockwise). When the air propelled from the tail hits the stagnant air in its path, it must curve off to the side, forming the bulging front, and propagating the vortex. This also allows for smoke that detaches from the vortex to be sucked back in, allowing for smoke rings to be visible for a considerable distance. The direction in which the arms of the vortices extend also lends support to this hypothesis, as the arms of hurricanes extend in a similar fashion (spiral inwards).



Hurricane Katrina: Note how the arms follow the same behavior of those from vortices of the airzooka blast.(Image Source: NASA)



This sequence shows how quickly the tail degrades. In the first image, the tail has a definite structure. At t=1.0 s, however, the air is almost entirely without structure. This demonstrates how important the ring vortex is in maintaining the air blast: without it, the structure quickly degrades to complete disorder.



This blast was fired directly into the laser sheet. Note the circular shape and the darker edge, both of which are formed because of the vortex ring.

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