# Wind Tunnel
# Air Flow Visualization

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## Original Objectives

- Investigate various methods for flow visualization
- Incorporating Schlieren and Shadowgraph into the wind tunnel
- Demonstrate the ability to capture and record aerodynamic flow over-determined objects using a high-speed video camera;
- Select an object of interest such as golf balls, wings, bicycles, etc. or CAD model prototype for wind tunnel testing
- Print and test the object of interest then demonstrate how the object may be modified for optimal aerodynamic performance;
- Characterize and model flow for a TBD set of objects by varying parameters such as flow velocity and orientation of the test object with regard to the flow velocity vector.

## Requirements

- Utilize multiple visualization methods ✓
- No emissions ✓
- Low Cost ✓
- Adjustable Lens/Mirror height ✓
- Movable Mirror/Lens Mounts ✓
- Light source Heat dissipation ✓
- Safe evacuation ✓
- No cleanup ✓

## Concepts

- Finding the focal length ($f$):

$$\frac{1}{f} = \frac{1}{Image\ Distance} + \frac{1}{Object\ Distance}$$

- Snell's Law:

$$n_1 \sin\theta = n_2 \sin\theta$$

- Schlieren photography is a visual process that is used to photograph the flow of fluids of varying densities.
- Schlieren Imaging:
  - Systems detect changes to the first derivative in density.
- Shadowgraph Imaging:
  - Shadowgraphs are sensitive to changes in the second derivative in density

## Problem Statement

A method is needed to visualize and characterize aerodynamic flow over-scaled models in the wind tunnel. The wind tunnel has a small test chamber constructed of acrylic, so that objects mounted in the chamber may be observed as air flows through the chamber. Recently, the College of Engineering and Technology purchased a portable "smoke" generator and a high-speed camera (capable of frame rates in excess of 10,000 frames per second). The generator can inject a fine mist into the airflow, but it dissipates too quickly to easily observe with the human eye. The team will investigate higher contrast visualization methods such as shadowgraphs, Schlieren, oil, tufts, etc.

## Final Design/Results *

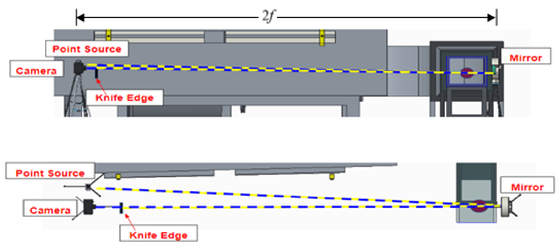


**Figure 1: CAD Model of Schlieren Test Setup**

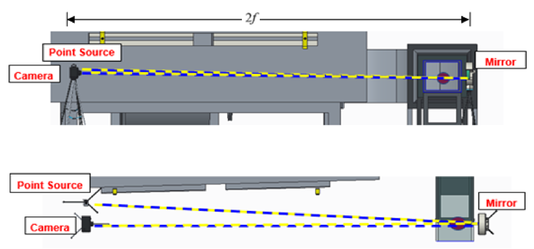


**Figure 2: CAD Model of Shadowgraph Test Setup**

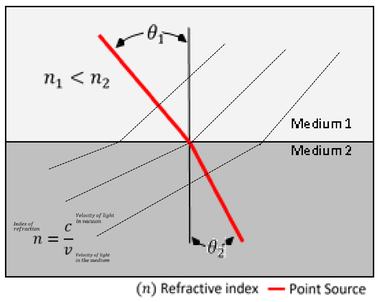


**Figure 3: Refractive Index Concept Diagram**

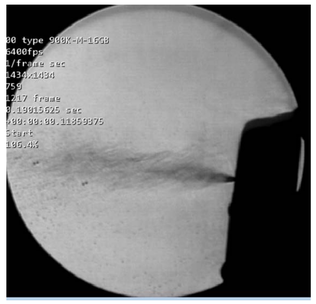

**Figure 4: Mist From Compressed Body Spray (Shadowgraph Imaging)**

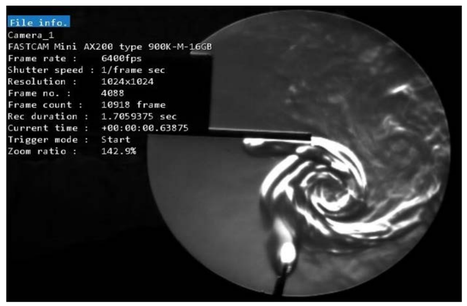


**Figure 5: Vortex Over Flame (Schlieren Imaging)**

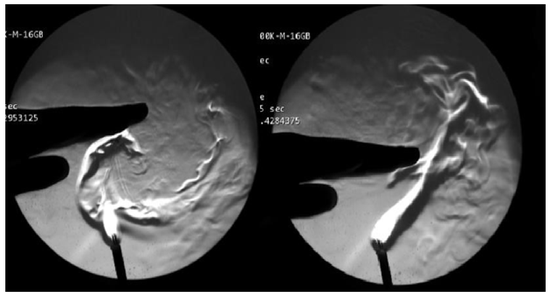

**Figure 6: Hand Feathering a Flame (Schlieren Imaging)**

* On March 16, 2020 classes and labs were closed to students due to the COVID-19 Pandemic. Without access to fabrication and testing equipment, Objectives and Deliverables were modified accordingly.

## Modified Objectives*

- Testing of additional items was halted due to Covid-19
- A manual was created for future use of new users
- After initial testing of Schlieren, all testing was suspended. Western Carolina University's wind tunnel modifications for this project have also been suspended. The team now operates remotely via messaging. The project has been stalled during a crucial point. However, will be resumed during the 2020 fall semester by an independent study consisting of two members of this capstone team.

## Summary

- Successful imaging in the Optics Lab and Wind Tunnel (open Area) of:
  - Alcohol, body spray, body heat, breath, open flame, butane, and Passive heat from electronics (cell phone)
- Comparison of sensitivity between Shadowgraph and schlieren Imaging
  - Schlieren's knife edge is used to block refracted light rays from the imaging. Resulting in more detailed imaging of density change
- Test Section Walls will need to be changed out for optically clear glass before Imaging can be successful inside the test section.. Imaging is very sensitive and picks up the internal structure of plexiglass.

## Team & Acknowledgements

-  Brittany Holloway - ET
-  Jared Beaird - BSE
-  Mitchell Henson - BSE
-  Rankan Aldabas - EE
- Dr. Hayri Sezer - Mentor
- Dr. Patrick Gardner – Sponsor
- Dr. Andrew Ritenour