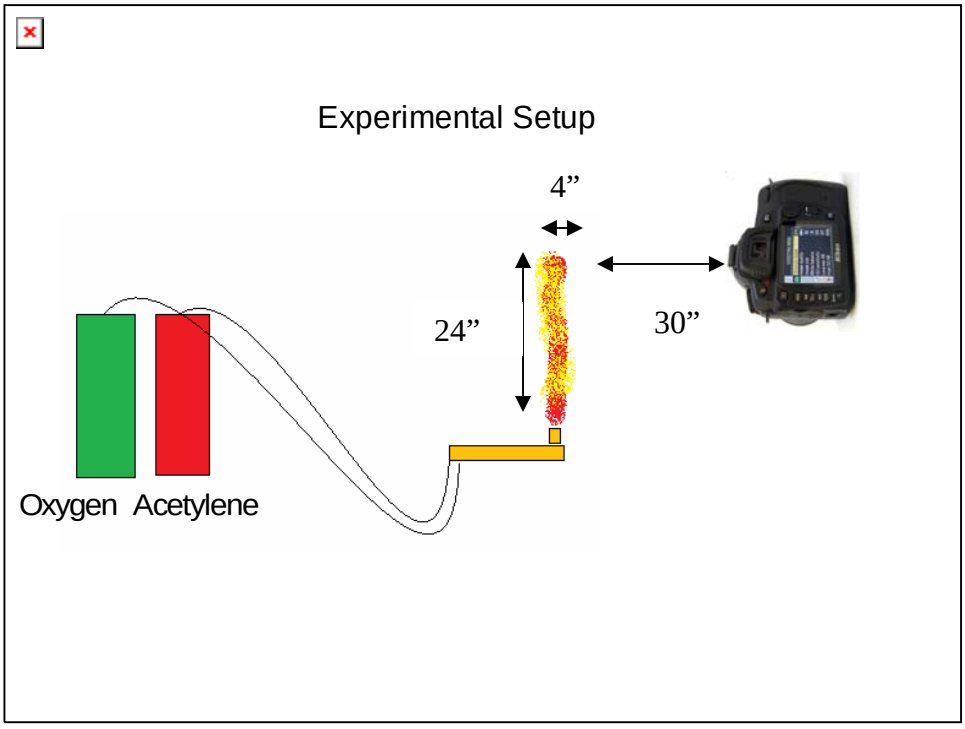
Kevin McCoy
Flow Visualization
Get Wet Project

The image captures a premixed acetylene and oxygen fueled flame traveling vertically. The flame is in a dark room in a natural air environment. The intent of the image was to capture the way the flame reacts to it's neutral surroundings as it exits the torch. The phenomenon of the flame changing from an undisturbed flow to the more random curved flow as the flame travels upward is due to the kelvin-helmholtz instability.

A sketch of the experimental setup can be found below. Oxygen and acetylene tanks feed the torch which produces the flame. The amount of each gas included in the flame's fuel mixture can be adjusted on the torch handle. The setup used for the photo used approximately 90% acetylene and 10% oxygen to achieve the rich colors present. The oxygen and acetylene are mixed inside the torch before exiting and being ignited. The fuel then exits the torch through five small holes. An outside spark is required to ignite the gas, which then stays ignited until the valves on the fuel are turned off. The flame travels vertically. As the ignited gas travels upward it interacts with the non-moving air surrounding it. This velocity difference across the interface of the two fluids, the ignited gas and the surrounding air, generates waves in the flow. These waves cause the instability of the flow shown in the photo. The flame twirls in a more random fashion as it moves upward. The combination of the kelvin-helmholtz instability, the increase in area of the flow decreasing it's velocity, and the loss of energy due to frictional losses and heat losses with the outside environment combine to create a beautiful image of randomized turbulent flow of a flame. The Reynolds number of the flow is estimated to be in the thousands to tens of thousands due to both the high velocity of the fluid, as well as the random flow fluctuations witnesses in the photo indicating turbulent flow. The Richardson's number is estimated to be below .25 due to the instability of the flow. By analyzing the photograph, the distance the flow may have moved during the photograph was around 2 cm in the upper portions of the flame. Since the shutter speed was 1/2000 second this would mean the flow was traveling at approximately 40 m/s in these areas while it was most likely traveling much faster at the beginning of the flame.



The flame was framed in a dark room with a black backdrop, a piece of black foam board. The intent was to have the flame be the only element of focus in the photo. The room was not prepared in any other way, the surrounding environment consisted of room temperature air. The oxygen acetylene torch assembly and igniter were sourced from the University of Colorado mechanical/aerospace welding shop. Similar products can be found at local welding supply stores or on the web at vendors like Harbor Freight. The only lighting present for the photo was the flame. The flash on the camera was not used and there were no other light sources present.

Size of the field of view	30” x 30”
Distance from object to lens	30”
Lens focal length	48mm
Lens specifications	18.0-135.0 mm f/3.5-3.6
Type of camera	Nikon D80 Digital SLR
Original Image Size	3872 X 2592
Final Image size	674 x 2041
Aperture	F/4.8
Shutter Speed	1/2000 second
ISO Setting	100

The original image was cropped so that the flame fills up the image. The only other modification made in Photoshop was trying to get rid of the white spot in the beginning of the flame. The curves tool was used to add yellow to that area, making the photo more consistent and pleasant to view.

The image displays the unstable and chaotic flow properties of the flame interacting with the neutral environment, the intent of the photo, quite well. I like how the image captures an instant in time of the phenomenon but I think a video is really necessary to fully capture the flames flow properties. I believe the image could be improved by experimenting more with the camera's settings to achieve a sharper image and capture even more of the flame's colors without any whiteout which needed to be fixed in Photoshop. To capture even more interesting flows the flame could interact with other objects, redirecting the flow and revealing more information about flame flow properties.

Sources:

Kelvin–Helmholtz instability

http://en.wikipedia.org/wiki/Kelvin%E2%80%93Helmholtz_instability

Reynolds Number

http://en.wikipedia.org/wiki/Reynolds_Number