Assignment 4, Team Project 2 – "Methanol Combustion"

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1 Objective

The objective of this project was to visualize the fluid dynamics of a methanol combustion reaction. This was accomplished using an methanol vapor and air mixture ignited within a polycarbonate cylinder. The aesthetic qualities of flame color and motion during combustion can be captured using long exposure photography and the resulting photograph visualizes pure methanol combustion and combustion of methanol with impurities.

2 Setup and methods

The methanol combustion was photographed using a Canon Digital Rebel XT mounted on a tripod approximately 18" from the flame. The exposure time was 8 seconds with an f-stop of 5.6 and a focal length of 18mm at ISO 400. The long exposure allowed for the capture of the blue flame from the initial methanol vapor combustion and the yellow flame from subsequent impure liquid methanol combustion.

The methanol combustion setup consisted of a polycarbonate tube centered over a sheet steel plate with a .5" hole and .25 mL of methanol (Figure 1). The procedure involved randomly distributing the methanol in drops on the steel plate and allowing the methanol to evaporate for 30 seconds. After evaporation, a flame was passed under the opening of the steel plate, igniting the mixture of methanol vapor and air within the polycarbonate tube. The tube served to contain the vapor and combustion, providing for a controlled reaction and a well defined image. After combustion of the methanol vapor, the remaining unevaporated methanol on the surface of the steel plate was consumed within several seconds.

The initial photographed image is shown in Figure 2. The objects in the background and the reflections in the polycarbonate tube distract from the image, so the following was performed in photoshop. First, the flame within the tube and the tube bottom were selected and created as a separate image with edge blurring. Second, the reflections were eliminated using the healing brush. Third, the textures from the healing brush were removed using the smudge tool. The resulting final photo is shown in Figure 3. The photoshop modification did not change any of the information within the image; rather, the information within the image is more readily apparent and well defined.

3 Discussion

Combustion dynamics are extremely complex and largely beyond the scope of the class. The fluid dynamics of this project were limited, but from observation of the photograph, it is apparent that methanol remains settled in the bottom of the tube, as expected. The molecular weight of methanol is 32 amu and the molecular weight of dry air is 28.8 amu (assuming air is approximately 80% N_2, 20% O_2), which limits the transport mechanism of the methanol to mass diffusion, rather than buoyancy. A similar setup using a lower molecular weight hydrocarbon, such as methane (16 amu), would likely result in combustion distributed through the entire height of the tube.

Another observation is confirmation that methanol vapor burns without soot, as evidenced by the pure blue flame. Mechanistic physical chemistry studies have modeled the lack of C_2 formation, the primary component of soot, which accounts for the lack of yellow coloration in methanol combustion[1]. Knowledge of the lack of soot in pure methanol combustion leads to the conclusion that the yellow flame observed in the photograph is from the combustion of the remaining liquid methanol on the surface of the steel mixed with residual impurities from the metal processing of the sheet stock, such as lubricants used during forming. The resulting combination of colors from the pure and impure methanol combustion is an interesting evidence of chemical combustion reactions and aesthetically pleasing.

4 References

1. Li, J.; Zhao, Z. W.; Kazakov, A.; Chaos, M.; Dryer, F. L.; Scire, J. J., A comprehensive kinetic mechanism for CO, CH2O, and CH3OH combustion. *International Journal of Chemical Kinetics* **2007,** 39, (3), 109-136.

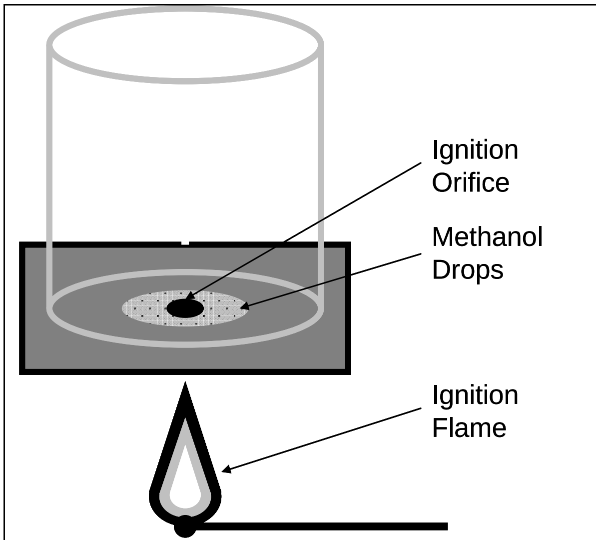

Figure 1 - Setup for methanol combustion

Figure 2 – Original image

Figure 3 – Final image after photoshop retouching