Combustion Diagnostics Method with Planar Laser Induced Fluorescence (PLIF) Method

Faculty Mentor: Dr. Hameed Metghalchi, Mechanical and Industrial Engineering
Graduate Students: Kian Eisazadeh Far and Colin Fredette
YSP Participants: Roger D. Cruz, Boston Latin School and Cassandra C. Fach, The Winsor School

Abstract
The project's focus is the study and measurement of intermediate species, specifically hydroxyl (OH) concentration. The PLIF system allows for the concentration of OH to be measured in various conditions and fuels. Through a series of tests and calculations in regards to the concentration of OH in a premixed hydrogen-air flame, it was found that the intensity of the flame [counts] is lineally proportional to the concentration of OH. More tests will be conducted to verify results and the data will be used in a later study of JP8.

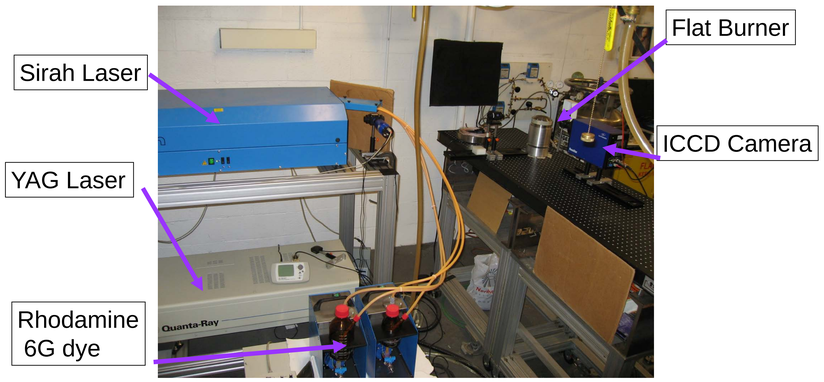

Figure 1

Introduction
Measurements of the concentration of hydroxyl in a hydrogen-air flame were calculated through a series of experiments and calculations utilizing a flat flame burner, a YAG laser, a Sirah Dye Laser (tunable dye laser) with Rhodamine 6G Dye, and an ICCD camera. The YAG laser emits a beam of light at 532 nm that is sent through the Sirah Dye Laser. The Rhodamine 6G dye is fluoresced, emitting wavelengths between 559-576 nm, with a peak at 566 nm. Hydroxyl in the hydrogen-air flame is fluoresced at the (1,0) quantum transition (band). Upon calibration of the hydrogen meter, tests were run with the lasers. The ICCD camera captured fluorescence of the hydroxyl. Upon completion of a series of tests at different flow rates and equivalence ratios, the conversion between counts and parts per million (concentration) was calculated.

Methods
The basic set up of the lab is seen in Figure 1. The set up is composed of two lasers, the YAG laser and the Sirah Laser (tunable dye laser), 2 dye pumps, a flat burner for the hydrogen-air flame, and an ICCD camera. In order to perform experiments in the right equivalence ratio, the hydrogen meter needs to be calculated. To do so, Stanjan is used to calculate the adiabatic temperature (Figure 2). Based on the maximum value, we assume the measured temperature of the flame to peak at the same equivalence ratio. Once this is found, the temperature at different flow rates can be measured and plotted (Figure 3). Once plotted, the calibration can be recalculated in accordance to the data found (Figure 4). Pictures of the flame can be taken at different flow rates and equivalence ratios (Figure 5). Furthermore, the temperature at each data point can be measured (Figure 6). The data collected is then plugged into Stanjan and the calibration curve can be calculated (Figure 7).

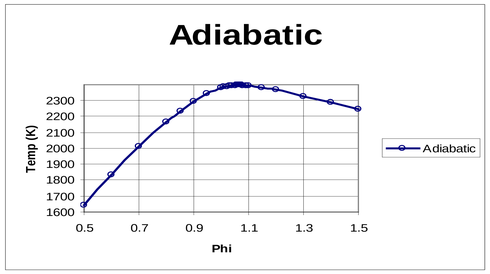

Figure 2

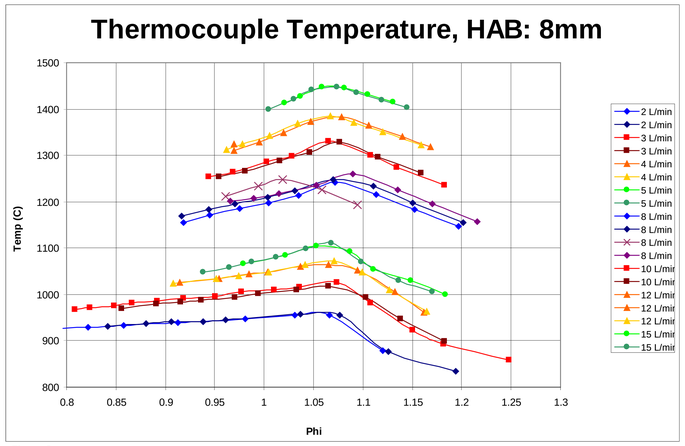

Figure 3

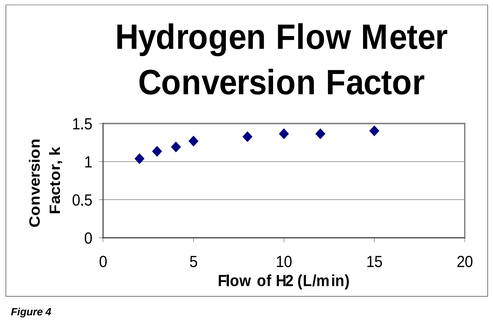

Figure 4

References

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Thank you John Doughty and Mimmo Elia for all of your help!

Results
1. Based on the adiabatic temperature graph's peak, the actual temperature of the flame's peak is at the same equivalence ratio: $\varphi \approx 1.07$
2. The factory conversion factor for H_2 (1.01) did not work at high flow rates. A new calibration curve was calculated (Figure 4) so that the temperature for each flow rate peaks at the correct equivalence ratio.
3. Very low flow rates result in an unstable flame and very high flow rates result in the flame going out

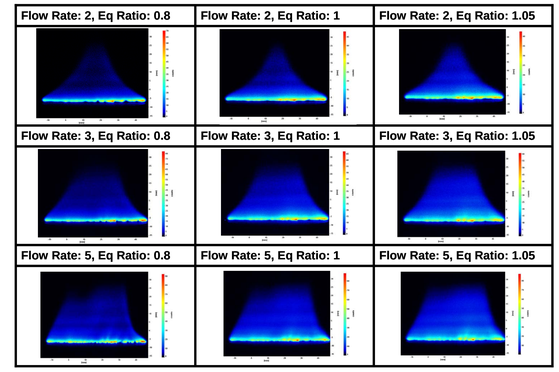

Figure 5

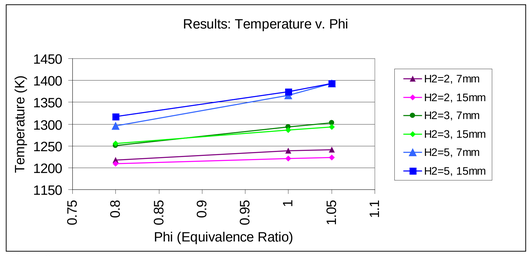

Figure 6

4.The higher the flow rate, the higher the temperature that may be obtained at a certain point in the flame
5. The higher the equivalence ratio, the higher the temperature that may be obtain at a certain point in the flame.
6. Generally, the temperature is higher at 7mm than 15 mm because it is closer to the flame.

Conclusion
The results demonstrate that there is a direct coloration between the hydroxyl (OH) in the hydrogen (H_2) flame and the temperature vs. equivalence ratio graph (Figure 5 and 6). Despite the general positive trend of data, the concentration calibration seems incorrect. Generally it is expected that at 15 mm the temperature would be lower than at 7mm; however, the temperature was occasionally higher. The error could be a result of an error in the thermocouple reading. Figure 7's trend line starts at 4.3 rather than 0 due to the error. Nevertheless it can be interpreted that the higher the concentration of OH the higher the intensity of the flame (measured in counts), thus correlating with temperature. It is found that the higher the temperature, the higher the concentration of OH in the H_2 flame will be. Overall, the results provide a base line for future testing; however, more tests must be run before determining the concentration conversion.

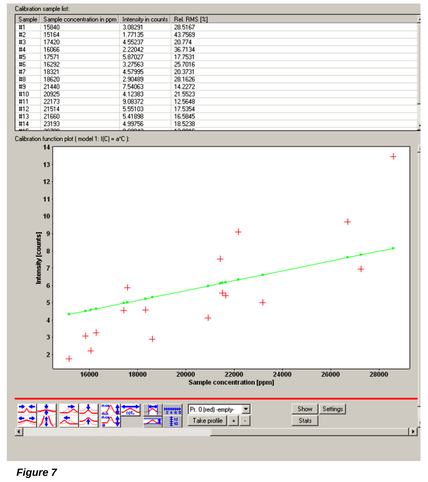

Figure 7

Connections
The study of hydroxyl proves to be useful in current "green" projects. Since hydroxyl is present in all flame fronts, it could be used to study the combustion process of different fuels. Although a current project focuses on the study of JP8 for the military, if tests prove to be successful, other fuels could be studied in a hope to better understand this complex reaction leading to more efficient equipment design and lower emissions.