# Richards, Michael Joseph

## Optical Measurements of Diesel Soot Formation

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### Introduction

The purpose of this project was to aid in the research of Kenth Svensson, PhD. student at BYU. I was able to perform many vital tasks in preparation for data acquisition. The proposal which we submitted named three tasks which were measuring and mapping the temperature gradient within a combustion chamber, mapping the mass of the fuel as a function of injection duration and pressure, and calibrating a CCD camera. A partial summary of Svensson's research topic and objectives is provided below to help others understand the importance of this research.

### Research Topic and Objectives

Diesel engines are known to be among the most efficient engines within the transportation industry. Because they emit particulate matter and nitrous oxides, diesel engines adversely affect the environment. The Environmental Protection Agency has continually lowered legal emission levels. A 90% reduction of the 2004 levels of these emissions is already established for 2010. An improved understanding of pollution formation and technologies, which can reduce emission levels, is necessary before diesel engine designers can meet future emission regulations.

It is known that soot formation is related to the amount of oxygen present during combustion, whether the oxygen comes from entrainment into the fuel jet, or the oxygen content of the fuel. It is, however, unknown what role the source of the oxygen plays in the formation of soot. It is also unknown how the structures of the molecules affect the formation of soot.

The main objective of this research is to determine how the molecular structure of fuel affects soot formation in direct-injection diesel combustion and if the source of the oxygen plays a role. To accomplish these goals a constant volume combustion vessel is used to simulate the combustion within an engine.

### Mapping the Temperature Gradient

In order to compare research data with published data, the density of the gas within the chamber must be known. Density is directly related to temperature. The vessel is heated before the experiments take place to better simulate the conditions of a diesel engine. Because not all of the surfaces are at the same temperature, a temperature gradient exists. Therefore, a temperature map is necessary to compute the density.

To map this gradient we designed and created a thermocouple probe out of an existing window blank. We used a 1/4 in. steel pipe and a k-type thermocouple. The end of the pipe was bent at a 90 degree angle, and a steel cube was placed over the outside end of the pipe and fastened with a cap screw so that the the cap screw corresponded to the position of the bend in the pipe. With this probe we were able to calculate the location of the thermo couple tip within the vessel. The results showed that there was actually circulation within the vessel.

## Mapping the Mass of Fuel as a Function of Injection Duration and Pressure

The mass of fuel injected into the combustion chamber can be used to calculate the overall equivalence ratio, which can be used as an input in simulations or models, and to analyze the energy release compared to that of potential energy within the fuel.

I created a fuel map within the range of 4-10 ms and 15000-25000 psi. Fuel was injected, at each condition, into a small container until it held approximately 2 grams, typically between 40 and 100 250 injections. It was then weighed to calculate the average mass per injection.

## Calibrating a CCD Camera

An important part of the research requires knowing the temperature of the flame. The vessel was constructed to give excellent optical access. Two-color pyrometry will be used to determine the temperature of the flames. A CCD camera will be used to acquire the images of the combusting flame. Because these measurements need to be accurate, calibration of the camera is necessary.

The CCD camera views the flame through a multi-viewer, which splits the image into two images. The images are then amplified as they go through an optical intensifier. The multi-viewer was adjusted in order to produce two precisely separated images in addition to calibrating the camera.

To calibrate the camera, a black body at a known temperature, was be imaged. Images were taken under a variety of conditions in order to calibrate the camera as accurately as possible: the gain of the optical intensifier, the exposure level, and the temperature of the black body were all varied. Several images were be taken at each condition and the mean and standard deviation was be calculated. This procedure was followed numerous times due to various difficulties with the camera. Even at the writing of this report the camera is being serviced for damage. This will need to be repeated once again when the camera is returned.

## Conclusion

Accomplishing these tasks, while working with Kenth Svensson, and Dr. Tree has been an excellent experience. I have learned about the techniques used in research, and how to apply the knowledge I’ve gained in the classroom to a research situation. As mentioned above, in addition to these tasks, a number of other tasks have been accomplished. Some data has already been acquired and analyzed. The knowledge that comes from this research will contribute to understanding the formation of soot within a diesel engine.

When it is all through, this work will result in at least one, and very possibly a number of published papers, to which the applicant will be a co-author. It is estimated that the entire research will take at least another six months. I have learned quite a bit, and will continue to learn as a I continue working with these fine gentlemen.