Warren J. Baker Endowment
for Excellence in Project-Based Learning
***Robert D. Koob Endowment** for Student Success*

PROPOSAL NARRATIVE

I. Project Title

Sensor Systems For Combustion Control

II. Abstract

Energy demand is constantly growing. The world has approximately 50 years of oil reserves left, making the search for a sustainable and effective fuel source very urgent [1]. Convenient traits of fossil fuels include high energy output and ease of storage. A fossil fuel that does not produce any carbon emissions is the ideal solution to the world's energy crisis. The combination of air, water, and energy creates liquid regenerable fuels[1], including ammonia. Ammonia can serve as a green alternative to fossil fuels due to its zero-carbon emissions. However, the combustion of ammonia results in NOx emissions. The sensor systems for combustion control project will aim to monitor the contents of the combustion emissions.

III. Introduction

In the post-fossil-energy era regenerable fuels are needed. These are substances that can be made by adding energy to air and water, and that return to air and water when the energy is released. Hydrogen is simplest such substance, but is a gas very difficult to liquefy. Liquid alternatives are ammonia and methanol. Ammonia is attractive because it is made from nitrogen (the main component of air) and water. An early application of ammonia as fuel will be to power marine gas turbines that drive ammonia tanker ships. To enable this application it remains to show that ammonia can be burned in air with low NOx and NH_3 emissions [2].

It is well-known that NOx emission is suppressed by NH_3, through reactions such as $NH_3 \rightarrow NH_2 + H$ followed by $NO + NH_2 \rightarrow N_2 + H_2O$. If sufficient NH_3 is present, these reactions suppress NOx emission. But if too much NH_3 is present there is ammonia slip, meaning that NH_3 appears in the exhaust. It is necessary to get the amount of NH_3 exactly right. When NH_3 is the fuel, this means adjustment of the fuel/air ratio. If NOx and NH_3 in the exhaust can be monitored, that information can be fed back to control fuel/air ratio. Surprisingly, this has not been tried even though ammonia combustion has been studied for nearly a hundred years. This project will lay the foundation upon which a future ammonia combustion control experiment can be built [3].

1. ARPA-E, a government organization, uses the terminology liquid regenerable fuels instead of liquid renewable fuels.

IV. Objectives

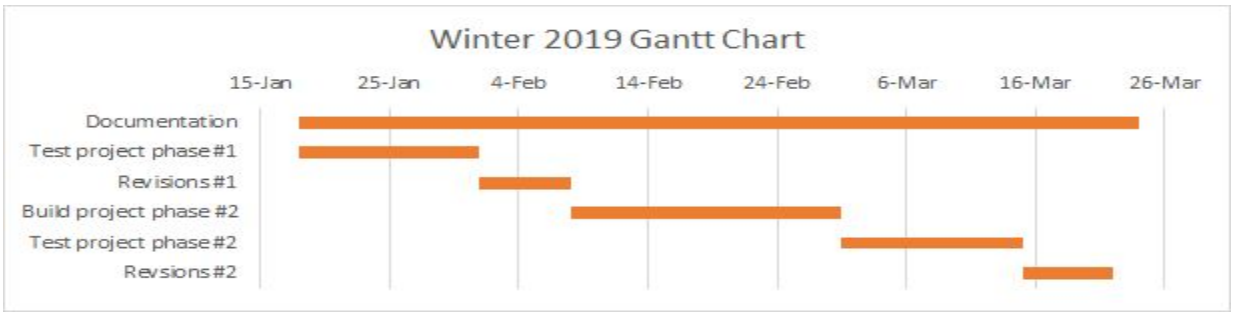
The main objectives that the sensor systems for combustion control project will reach during the allotted timeline are as follows:

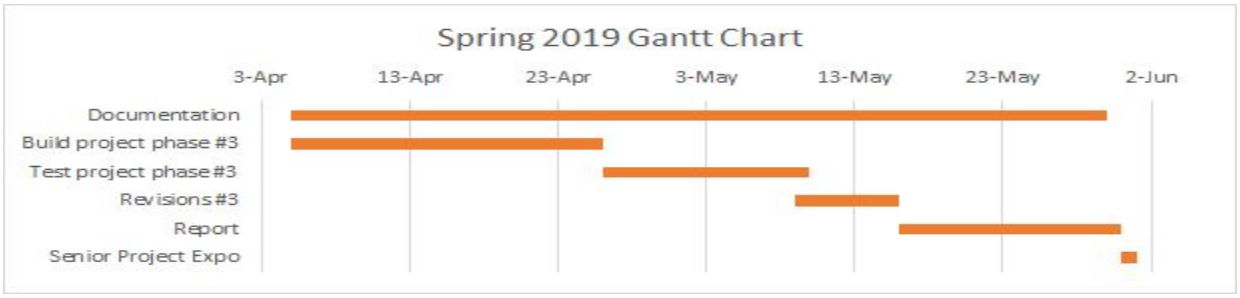
1. Drafting the Design of Mechanical and Electrical Systems: Team drafts the mechanical and electrical systems for advisors to observe and analyze. Advisor feedback will be provided to critique team drafts. Critiques will be used for improvement until design is agreed upon.
2. Safety and Peripheral Training: Team obtains training from Chemistry Department to technically prepare for proper and safe use of sophisited devices such as Electrochemical Impedance Spectroscopy.
3. Ordering Raw Materials: Team acquires various pollutant sensors, microcontrollers,, containment units, and gas tankers from various manufacturers. The team will contact various suppliers recommended by NOx researchers.
4. Assembly of Mechanical and Electrical Systems: Team assembles the mechanical apparatus to supply air and various gaseous. The team will also assemble the electrical system that will detect and monitor present gases in the exhaust stream.
5. Testing and Verification: Team tests the entire system in the Electrochemistry Lab under a chemical fume hood. Testing validates different variations of gaseous concentrations under different conditions by using electrochemical test equipment, microprocessors, and LCD display.

V. Methodology

During Fall 2018, the project team will be researching the production and suppression of NOx emissions by looking at credible references such as books, US patents, IEEE journals, and professional websites. First, the project team will be drafting mechanical and electrical designs with consultation from the project advisors: Dr. William Ahlgren, Dr. David Zigler and Dr. Leta Woo. Once mechanical and electrical design drafts have been chosen and the necessary materials have been acquired, the project team will assemble the systems. The system will be subjected to various tests to verify the accuracy of the NOx sensors and the effectiveness of the established feedback loop. Mechanical and electrical construction of the project can occur out of the testing environment. However, chemical and combustion tests will occur in a fume hood located in the Baker Science and Math Building apart of the Chemistry department.

VI. Timeline





VII. Final Project and Dissemination

Project completion results in a system that will detect NOx emissions and suppress the pollutants. The project and its plans, logistics, and experimental data will be showcased in Cal Poly's Electrical Engineering Senior Project Expo in Spring 2019.

VIII. Budget Justification

The proposed budget is composed of operating expenses. The mechanical aspect of the project comprises of tubing, materials to construct the physical apparatus, and swagelok fittings which approximates to a sum total of **$650**. The electrical aspect of the project comprises of microcontrollers, specialized sensors, and gas control approximates to a sum total of **$4350**. The total cost of this project aims to use a total of **$5000**.

IX. References

[1] British Petroleum, "Oil Reserves," *British Petroleum*, 2017. [Online]. Available:https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy/oil/oil-reserves.html. Accessed: [October 15, 2018].

[2] William L. Ahlgren, "The Duel-Fuel Strategy: An Energy Transition Plan," *IEEE*, November 2012. [Online]. Available:https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6235977. Accessed: [October 23, 2018].

[3] "Nitrogen Oxides (NOx), Why and How Are They Controlled." *United States Environmental Protection Agency*, 1999. [Online]. Available: https://www3.epa.gov/ttncatc1/dir1/fnoxdoc.pdf. [Accessed: October 30, 2019].

Proposed Budget

Student Applicants: Joeny Zhen Joshua Wong	
Faculty Advisor: Dr. William Ahlgren	
Project Title: Sensor Systems For Combustion Control	**Requested Endowment Funding**
Travel/Contractual Services subtotal:	**$0**
Travel: In-State	**$0**
Travel: Out-of-State	**$0**
Travel: International	**$0**
Contracted Services	**$0**
Operating Expenses subtotal:	**$5000**
Mass Flow Controllers	**$3370**
Lambda sensor	**$200**
¼ ” Tubing	**$60**
Materials for Mixing Chamber	**$75**
Materials for Containment Unit (Metal)	**$175**
Needle Value	**$100**
NOx Sensor	**$600**
Arduino	**$40**
CAN-BUS Shield	**$40**
Swagelok fittings	**$340**
TOTAL	**$5000**