Validation of Methods for Analyzing Sustainable Aviation Fuels

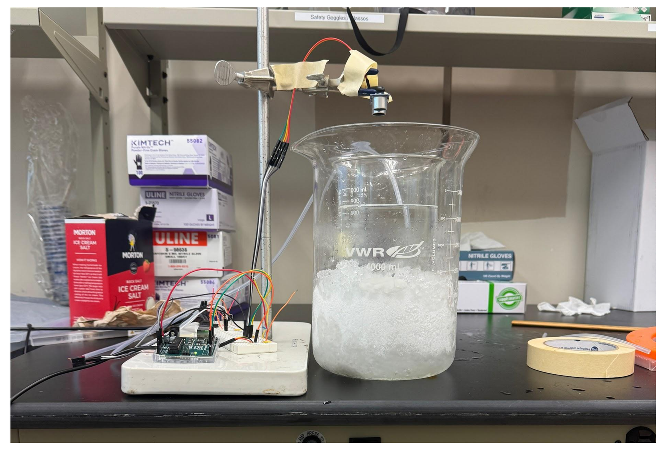
STUDENTS: Nicholas Izutsu, Wenyu Yang, Amy Dao, Minh Nhat Do, Kamala Katta, Grace Vander Griend

Background

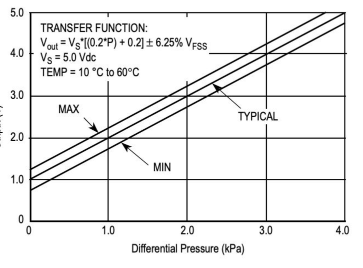
- Commercial aviation industry makes up 2% of total carbon emissions and 12% of emissions from transportation
- Boeing aims to have their aircraft compatible with Sustainable Aviation Fuel (SAF) by 2030
- Current fuel measuring systems incorporate electrical components in the fuel tank, posing potential hazards
- The goal of this project is to create a fully tested mechanism for measuring fuel mass both at cruise altitude and on ground regardless of SAF to fossil fuel ratio
- Our proposed design included a system that can measure the density and height of liquid inside our fixed bottom area fuel tank.
- All measured data will be collected to a microprocessor that represents the aircraft's on-board computer, which will then process all data, cross-check redundant measurements from different subsystems, and evaluate the confidentiality of each measurement

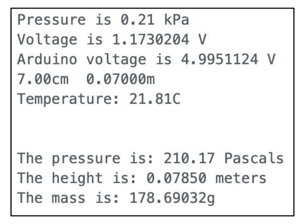
Fuel Quantity Index System - Software

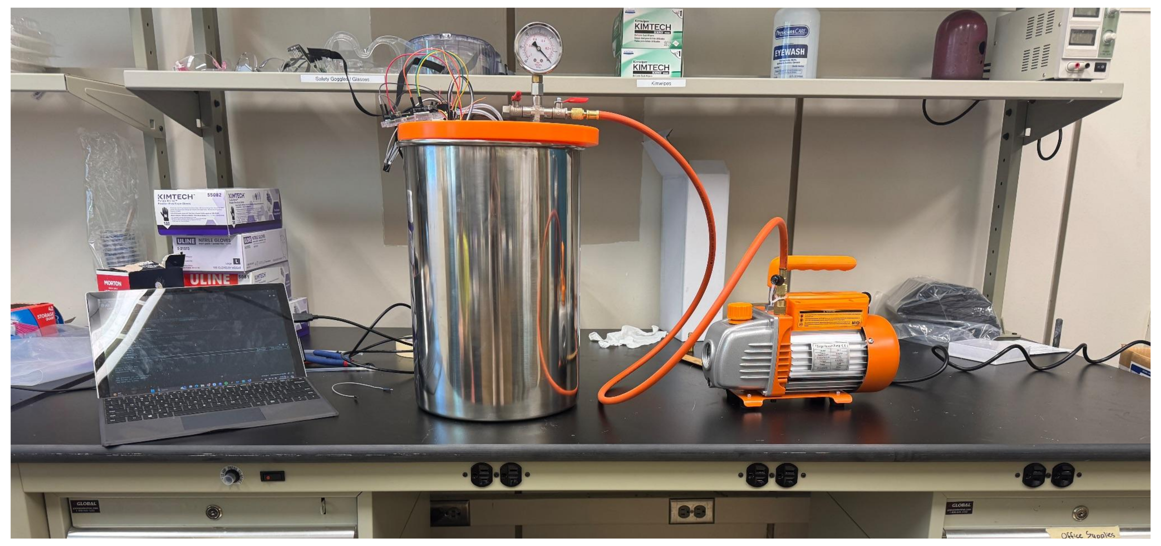
- Data is requested from the pressure, temperature, and ultrasonic sensor every second then sent to the arduino.
- Sensors output signals on a 0-5V scale through analog-to-digital converter.
- Raw ADC values from analog signals are converted to voltages. Voltage values are converted to their respective units celsius, pascals, and meters.
- Pressure and distance values are used to calculate density, from density we can calculate mass of fuel knowing volume of our testing vessel



Salinity (g/L)	0	35	100	300	350
Freezing Point (°C)	0	-1.8	-6	-28	-35



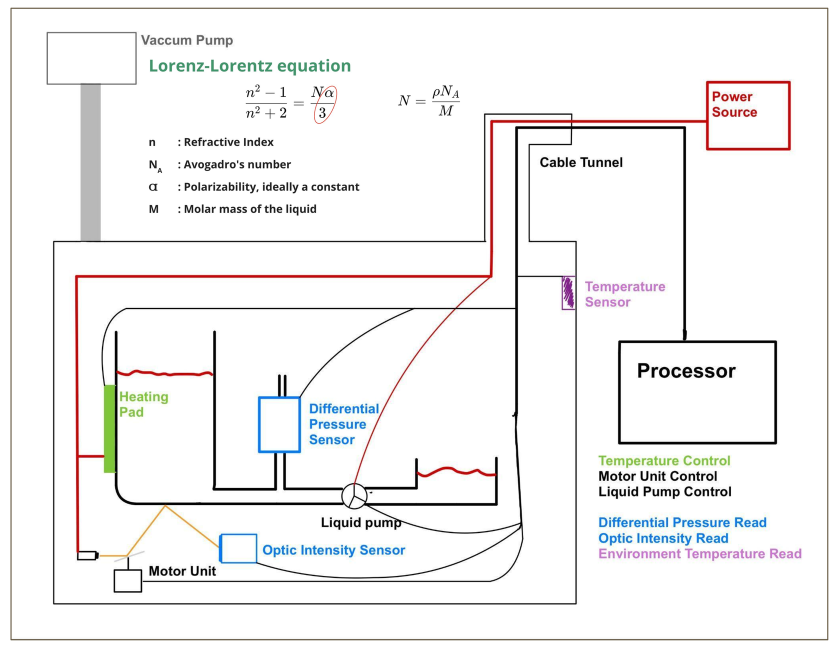




Design

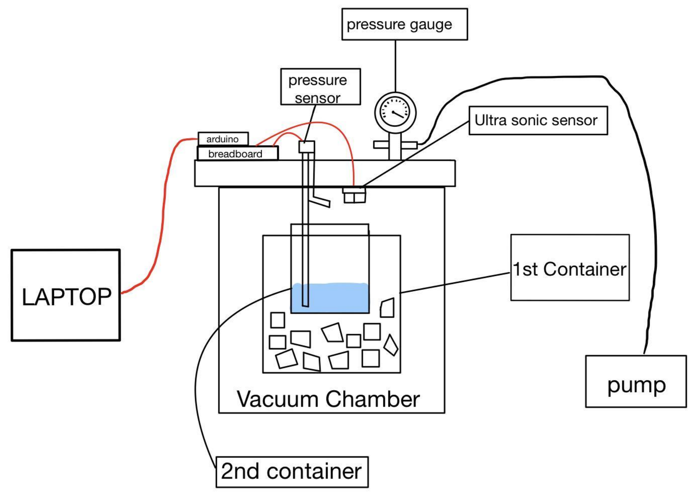
Initial Design

- Refractive index and differential pressure sensors for density and height measurements
- Using heating pads and cooling tanks to simulate a variety of testing environments
- Use a mixture water and ethanol with varying concentrations to simulate different densities
- Limited electrical components in fuel tank



Final Design:

- Ultrasonic and differential pressure sensors for density and height measurements were used to calculate the mass
- Hot plate and cooling baths combined with pump for environmental controls
- Cross-check for percent error across experiments with different pressures, liquid level and temperature



Testing and Experimental Results

- To test the design, three different fluids with varying densities were used. These fluids had to satisfy the criterias of safety, accessibility and cost.
- The selected fluids for testing were DI Water, Cooking Oil and Isopropyl Alcohol.
- These fluids were tested isothermally at nine different pressures from 0.2 to 1.0 bars in increments of 0.1 bars.
- Mass measurements were taken within 30 seconds after changing the pressure environment to ensure the system reaches a steady state and to allow sufficient processing time for the sensors and the code.

DI water	
mass (g)	percent error
200	14.8
500	6.13
700	2.83

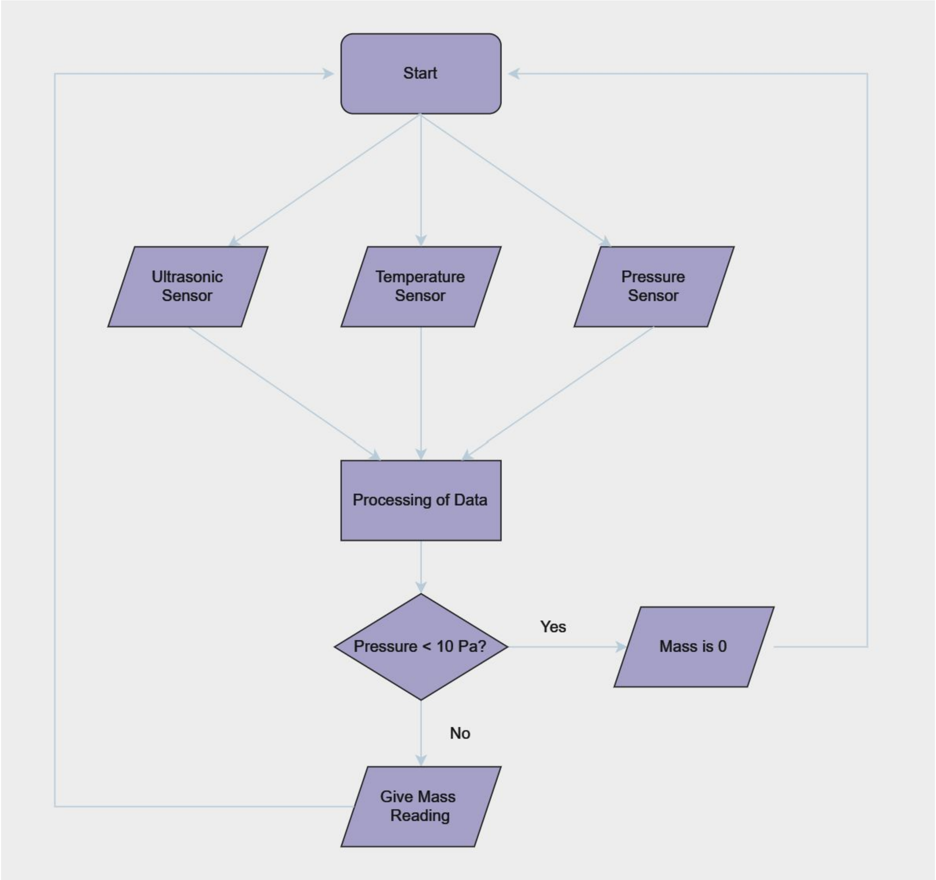
IPA	
mass(g)	percent error
144.49	7.42
500	2.19

Vegetable Oil	
mass(g)	percent error
172.37	4.56
473.83	1.35

- Experimental values show a high level of reliability with most experimental values located under the 10% error value suggesting that the design can accurately measure liquid mass to a significant extent.

Discussion/Conclusion

- Our task was to develop a new system for measuring fuel mass of synthetic alternative fuels.
- Developed an innovative mechanism to measure fuel mass through eliminating electrical components touching the fuel and limiting electrical components in the fuel tank. While ultrasonic sensors were not our initial choice, we found that implementing them allowed for mass determination.
- Our group was able to achieve 1.35 % error this was higher than our targeted 1%. This higher than expected error could be from;
  - rippling of the liquid which would cause our ultrasonic sensor to have an inaccurate reading
  - boiling of water at lower pressures
  - the ultrasonic sensor was not completely vertical due to a lack of support structure
  - the pressure tube was not completely at the bottom of the testing beaker which would result in an inaccurate reading
- From our results we conclude that through further design iterations and refinements this system can be viable for the measuring of fuel mass for different fuel types
- While we came close to implementing the refractive index sensor we were unable to get accurate index values from our sensor. Future groups should focus on the understanding the refractive index sensor and correct implementation of the sensor to get accurate values. This could result in the complete removal of any electrical components within the fuel tank, not just touching the fuel.



Acknowledgments

We would like to thank Boeing as well as all our mentors for their support throughout this project.

ELECTRICAL & COMPUTER ENGINEERING
UNIVERSITY of WASHINGTON

SPONSOR: Boeing
INDUSTRY MENTORS: Callyn Couture, Eva Nee, Jessica Savage, Dean Cox, David Sims
FACULTY MENTOR: Benjamin Rutz