Cone Calorimeter for Material Flammability Testing

SDSU San Diego State University

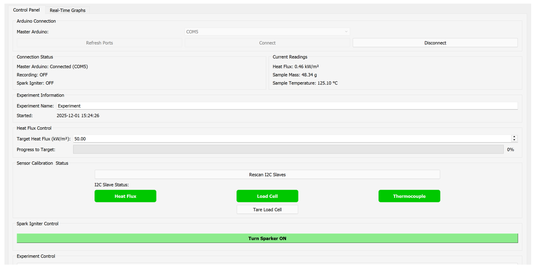
FIAMMA Fire Investigations & Advanced Modeling of Multi-scale Applications

Abstract & Motivation

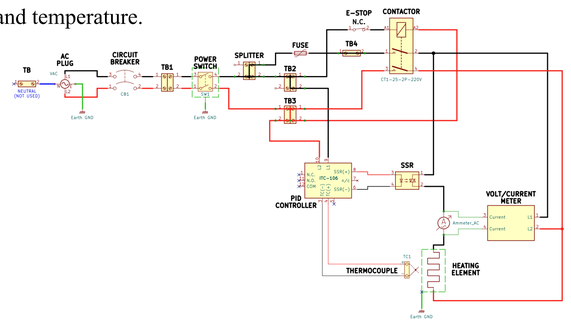
California faces increasingly frequent and severe wildfires, making accurate vegetation flammability data essential for modeling fuel behavior and improving fire management strategies. However, commercial cone calorimeters are costly and difficult to adapt for specialized research.

The FIAMMA lab directed by Dr. Carmignani was in need of a cone calorimeter that is affordable, portable, and customizable in order to conduct flammability tests on vegetation samples for wildfire research. To make the cone calorimeter reliable to similar research conducted, it closely adheres to the ISO 5660 and ASTM E1354 standards for cone calorimeter testing. To achieve the desired heat flux of 50 kW/m², the cone calorimeter uses a heating coil powered by 250V AC operated by a Proportional-Integral-Derivative (PID) controller delivering current up to 15 amps. Additionally, it is equipped with various sensors to measure mass loss, heat flux, temperature and gas emissions as testing is being conducted.

Data Acquisition & Electrical System

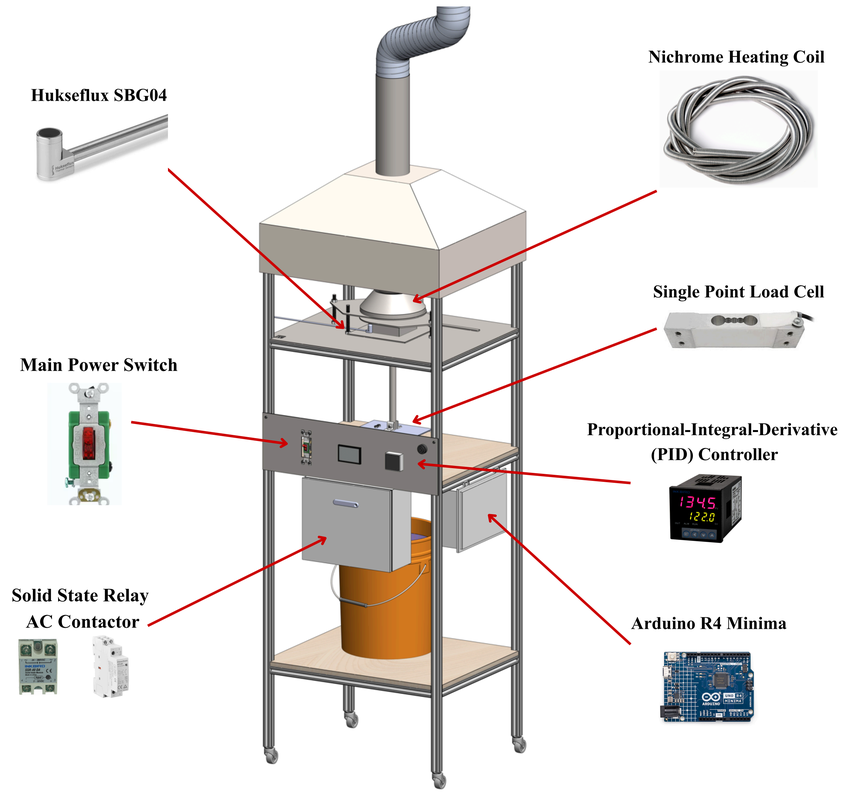


A Graphical User Interface (GUI), shown above, was implemented to monitor data gathered by the master-slave Arduino configuration. The master Arduino gathers data using SCL and SLA pins of three slave Arduinos. An Arduino UNO and three Arduino R4 Minimas are used, each with a designated sensor to capture mass loss, heat flux and temperature.



A high voltage power supply is required to provide the necessary current to power the heating coil. The circuit included various safety mechanisms in case the of a power failure, such as an emergency stop, a breaker and a fuse. The circuit uses a Proportional-Integral-Derivative (PID) monitoring the temperature inside the cone and comparing it to the set point temperature. Based on the error, the PID sends an output to the solid state relay (SSR). The SSR is used to control the current running through the coil.

Cone Calorimeter Design



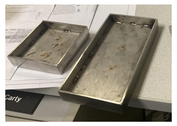
Manufacturing

Manufacturing Processes

Waterjet
TIG and MIG Welding
Mill and CNC Mill

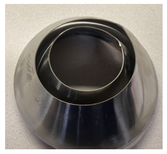
Sample Holders:

Square Sample Holder: 100mm x 100mm
Rectangular Sample Holder: 100mm x 200 mm
Sides - 11 Ga Stainless steel
Bottom - 7 Ga Stainless steel



Inner and Outer Cones:

20 gauge Stainless Steel



Cart:

80/20 T-Slot Aluminum Extrusion
22 x 18 x 68 in.

Coil:

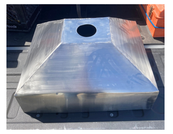
Nichrome wire: Type 675 NiCr60

Coil Holder:

Indented Clay Holder

Hood:

18 Ga Stainless Steel



The Team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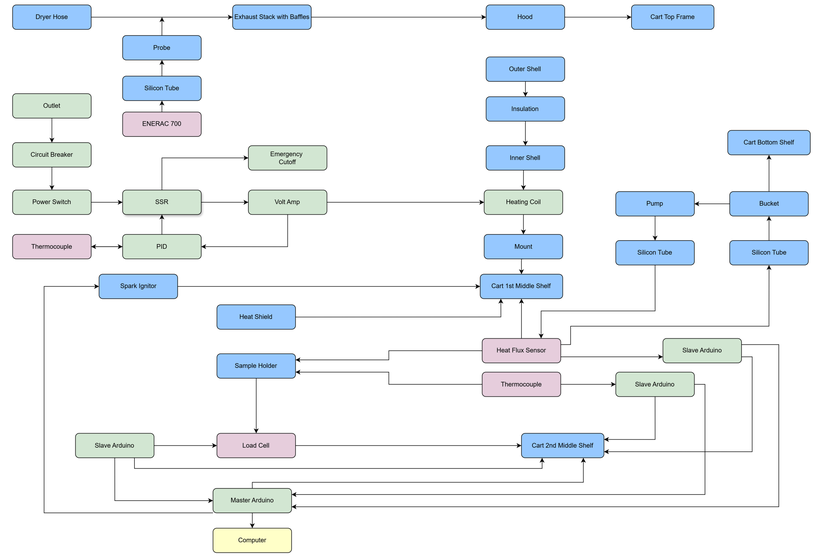
System Level Diagram



Testing

1. Data Acquisition System

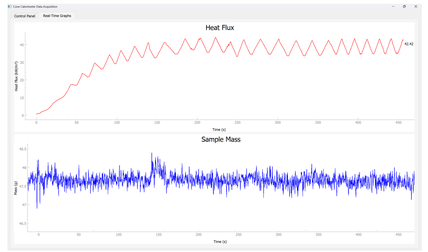
Each sensor was calibrated and tested individually with its designated microcontroller and signal amplifier to ensure reliable data was captured.

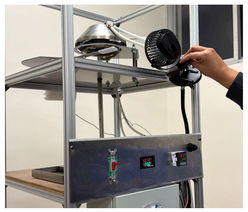
2. Electrical & PID System

Before testing, the wiring was tested for continuity to ensure proper current supply. Then, the PID controller was tuned through iterative testing to minimize temperature overshoot and stabilize the desired setpoint.

3. Full System Integration

Once all subsystems were validated, a full integration test was conducted to ensure the subsystems were operating as a cohesive unit.





Acknowledgements

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