

Crumbler Head Temperature Sensor Array

Objective:

The objective of this project is to develop a method of monitoring the temperature of two rotating biomass grinding drums (crumblers). This is both for research and to prevent potential damage to product. The design must be robust, cost effective, accurate, and cheap to make or easily transferrable between different crumblers.

Requirements:

Project Deliverables	Metric no.	Quantification
Customer Needs		
Sensors for P-Series head translatable to other crumblers	1	self-contained sensor apparatus not specific to P series head
Digital Output readable by PLC	2	0-5V output, 4-20mA output, Serial output
temperature reading across head length	3	Sensor Array (6 sensors per head)
Accuracy	4	(+/-) 15 degrees F
Notification of overheating	2	Personell monitoring PLC will be able to read this
Not too hot to damage material	5	display critical temp at 200F
Verification of effectiveness	6	Prototype testing/emissivity calibration with Thermocouple
Our Needs		
modifying existing casing		OK to drill holes into side sheet
CAD Files		Stored in Google Drive

Alternatives:

Thermocouple rod on end product:

Pros:

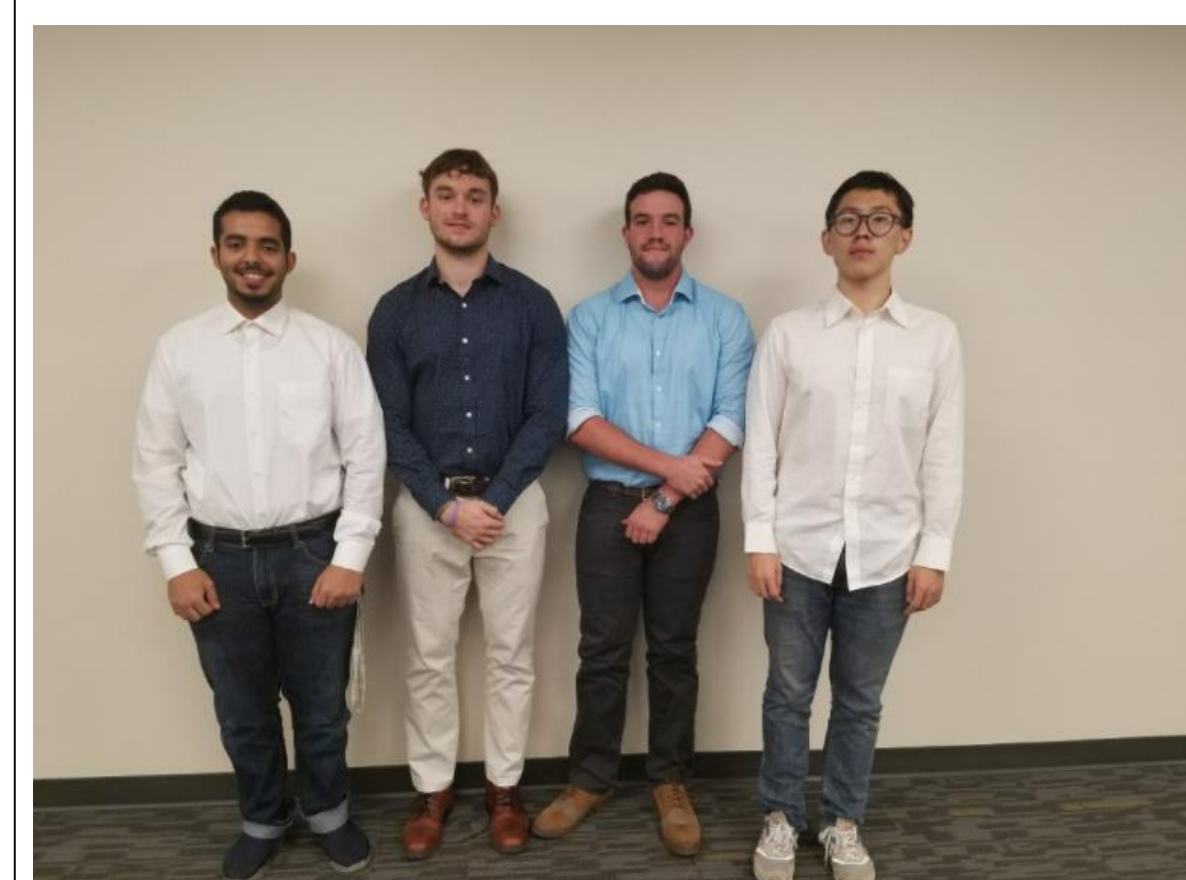
- Directly measuring the product rather than the crumbler head drum
- Simple to setup and install
- Low Cost
- Is a permanent fixture on the system

Cons

- Hard to make sure your temperature readout function is accurate
- The time between the product leaving the crumbler head and where the thermocouple is at may give the product time to cool down, introducing further uncertainties.

Summary/Acknowledgements

Upon completion of the circuitry and circuit housing, Forest Concepts will have the ability to monitor the surface temperature of their crumbler heads. Special thanks to Dev Shrestha, Coleton Bailey, and all of the members at Forest Concepts!



Team Members (left to right)

- Abdulaziz Alazhemi - Mechanical Engineering
- Anthony Ponzini – Biological Engineering
- Jacob Miller – Mechanical Engineering
- Feifan Deng – Electrical Engineering
- Dev Shrestha – Lead Instructor

The Design

Infrared Sensor array pointing at the rotating drums controlled using Arduino Mega and Labview with Ethernet cables for data transmission

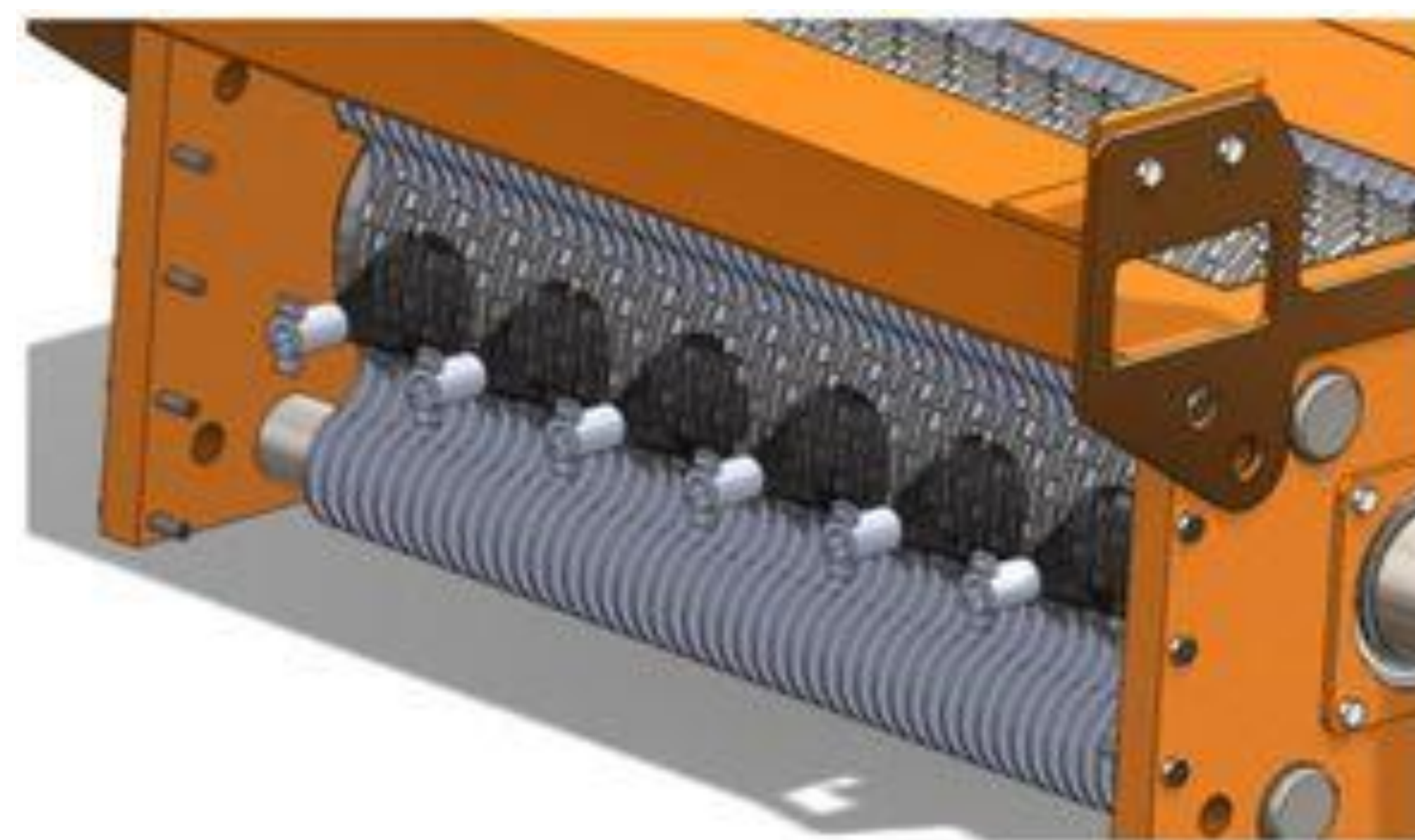


Figure 1: Sensors mounted in side plate of crumbler

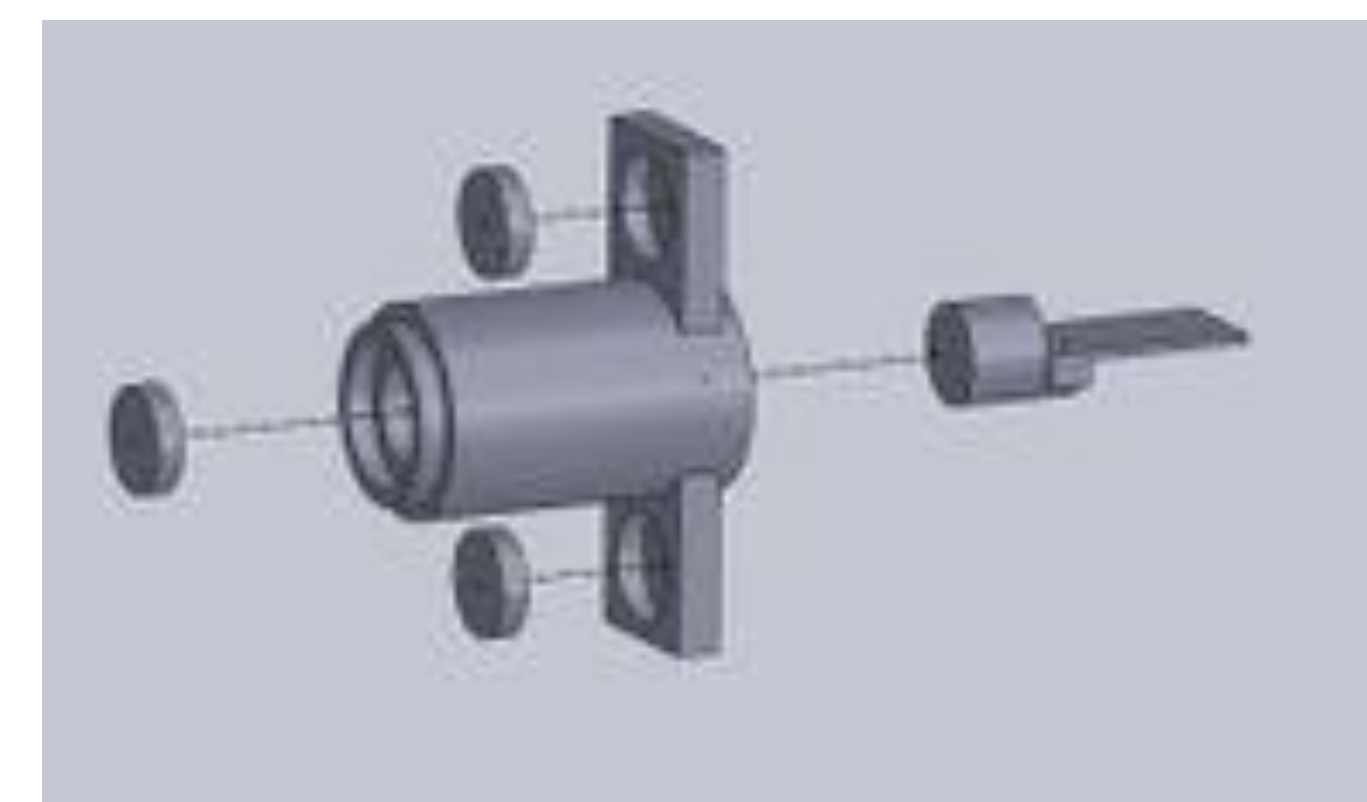


Figure 2: 3D printed ABS Sensor housing with magnets to hold the sensors and housings to the crumbler walls

A custom PCB was designed to make the packaging of the Arduino much more efficient.

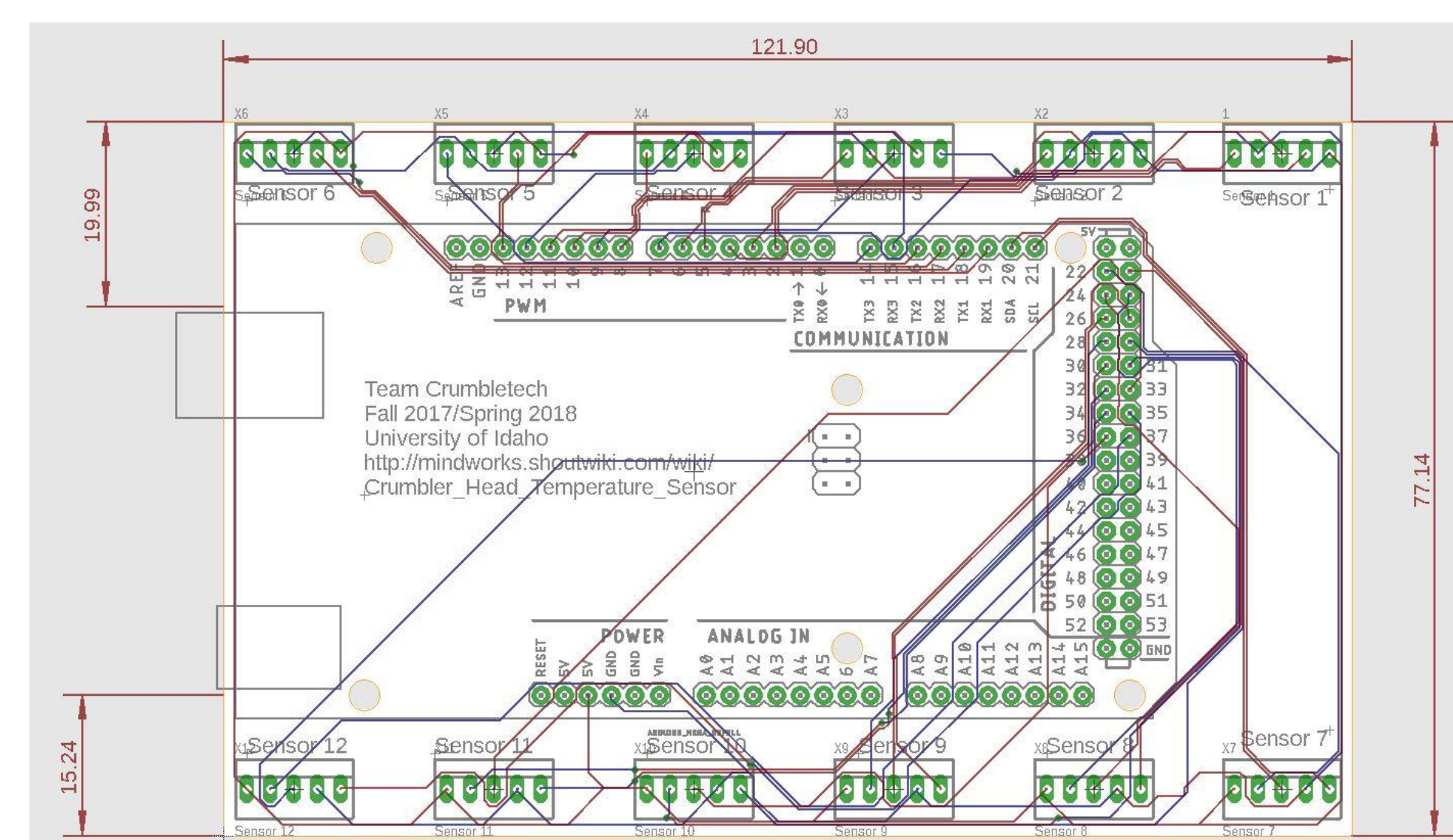


Figure 3: PCB board design

Calibration

A K-type thermocouple was used to measure the temperature of a sample of a crumbler tooth that FC sent us. Those values were then compared to the values read by the sensors.

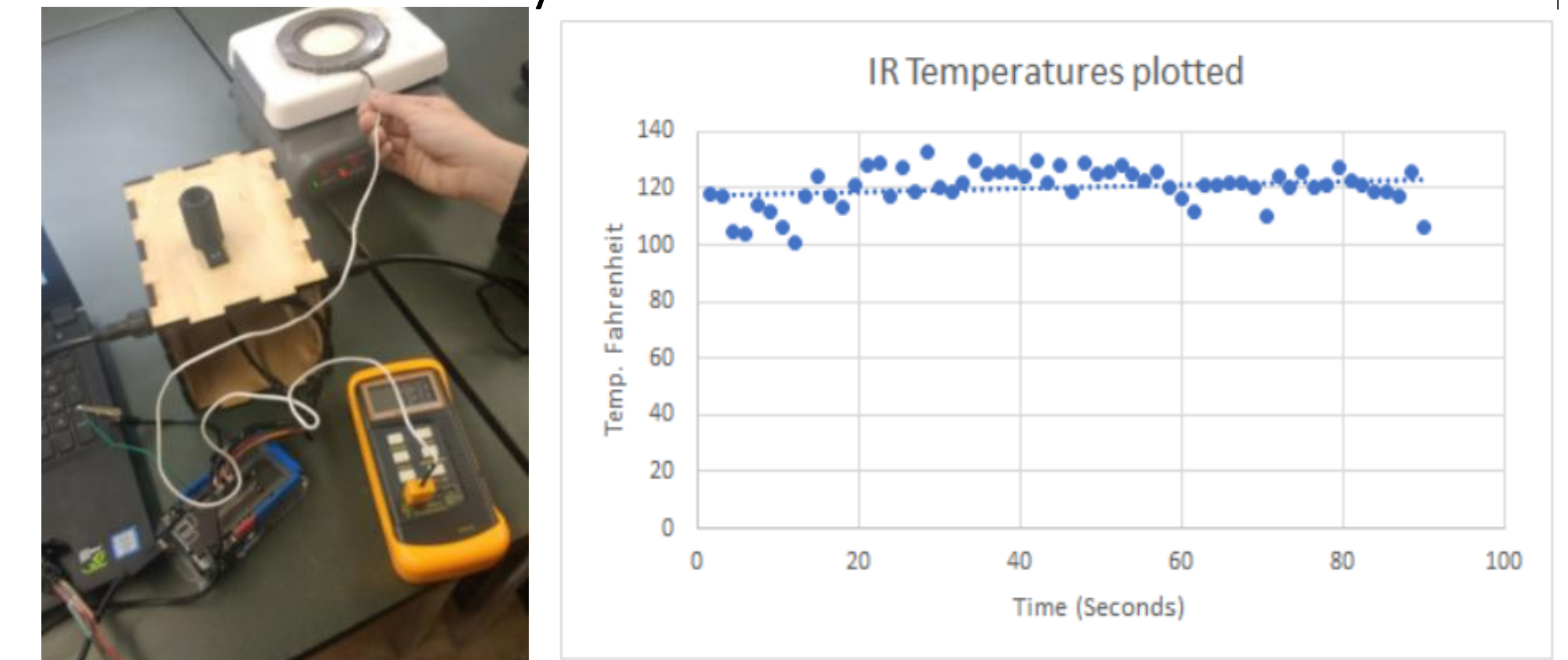


Figure 4: IR sensor and thermocouple comparison

Also, our prototype was sent to Forest Concepts for preliminary testing:



Figure 5: Prototype testing at Forest Concepts

Once the thermocouples and IR readings could be compared, we could find the emissivity of the Crumbler teeth using the Stefan-Boltzmann law:

$$\epsilon_1 * \frac{T_1^4}{T_2^4} = \epsilon_2$$

Where ϵ_1 is the set emissivity reading of the sensors from the manufacturer (.95), T_1 is the temperature reading from the IR sensors, and T_2 is the reading from the thermocouple.