IMPROVED SHEA NUT ROASTER
ETHOS 2019

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Agenda

1. Background & Objectives
2. Development Overview
3. Initial Field Testing
4. Baseline Laboratory Testing
5. Development Process
6. Next Steps

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Project Background

- Shea is a fruit that grows on trees scattered throughout the shea belt.
- There is no organized farming of shea trees, and the process is quite extensive with many energy, health, and ergonomic issues.
- Women are the primary processors

Project Objectives

- ☐ Acceptability
- ☐ Economics
- ☐ Ergonomics
- ☐ Productivity
- ☐ Health
- ☐ Durability
- ☐ Performance
- ☐ Quality

Figure 1: The Shea Butter Production Process

Development Overview - Schedule

TASK	2018						2019							2020	
Project Scoping initiation and planning															
Baseline Field Testing															
Conceptual designs (P1) Concept development Prototype design, build Test Field / User evaluations															
Improved designs(P2)															
Final Design for Manufacturing (P3)															
Pilot Production & Evaluation															
Durability testing															
Manufacturing System Design															
Production Prep															
PRODUCT LAUNCH															

Initial Field Testing

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Initial Field Testing – continued

- Objective:
  - Gather baseline measurements on fuel consumption, emissions, and productivity for the 2 primary methods for roasting shea kernels
- 13 different sites
  - 10 in Tamale, 3 in Wa
  - 6 co-ops, 7 individual processors
- 15 tests
  - 10 drum roasters
  - 5 pot and paddle

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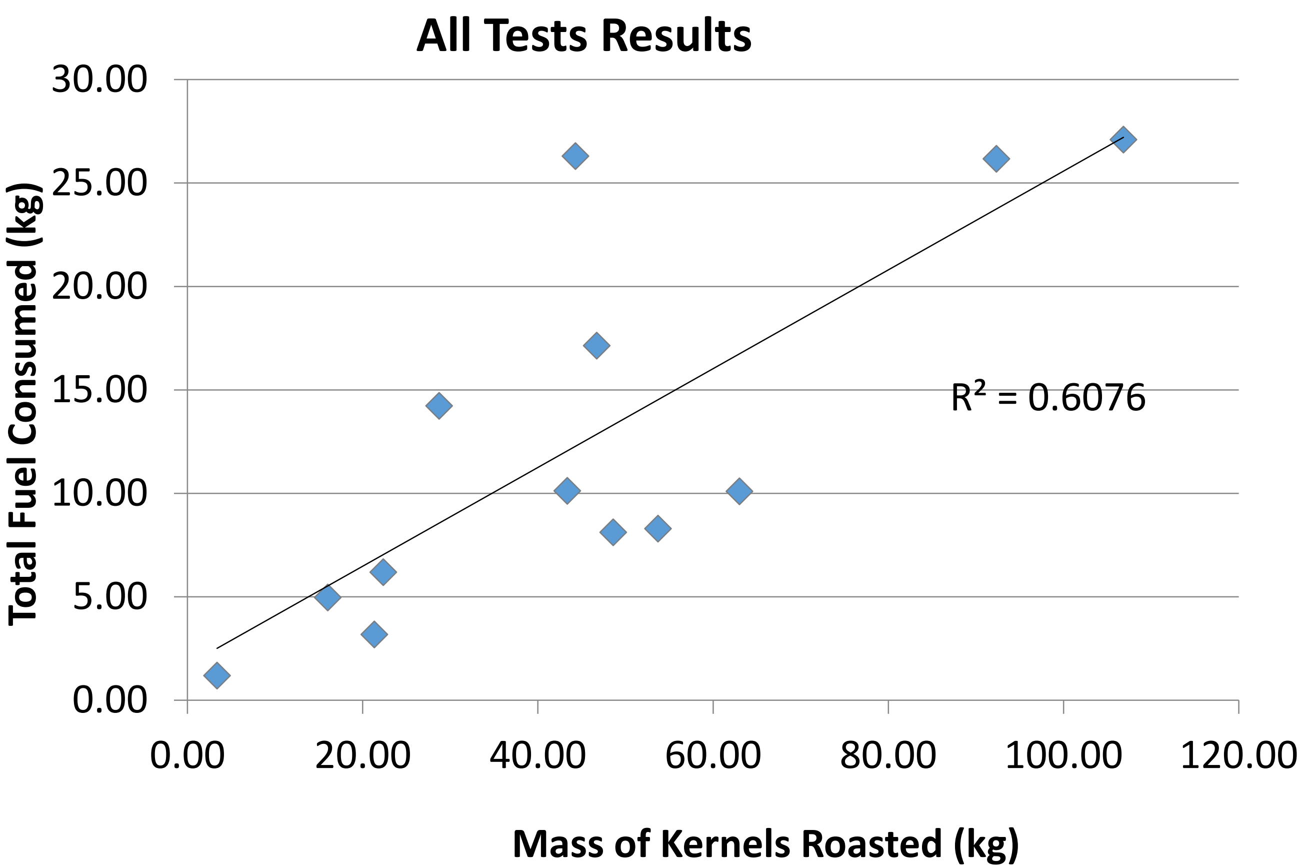
Initial Field Testing – continued



- Variability due to difficulty weighing fuel (wood and shea nut residue) and shea kernels.
- Measuring fuel moisture (hand held conductivity meter)
- Measuring residual char

Initial Field Testing – continued

- What did we learn?
  - The Drum has a significantly higher capacity than the Pot roaster
  - The Specific fuel consumption is nearly identical for both roasters
  - The average final nut temperature (independent or roaster type) was 136°C.
  - No kernels were ever discarded due to burning or over roasting.
  - No consistent method for determining when roasting is completed.
  - Roasting efficiency is very low (<10%)

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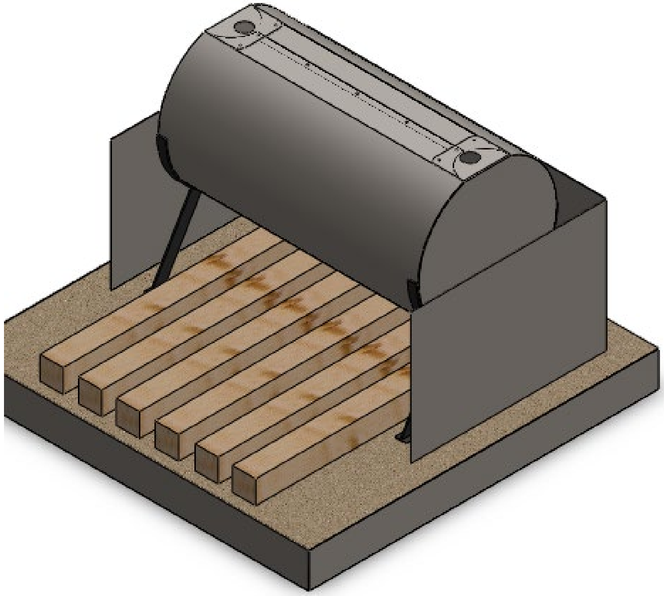
Baseline Laboratory Testing

- Simulation Simplifications
  - Scaled to 50% by volume (79% by length)
  - Heat water vs. Shea Kernels
  - Fixed drum vs. rotating drum
  - Uniform wood fuel



- Issues with simulating in the lab
  - Roaster is too large to fit in testing hood.
  - No shea kernels available to roast
  - Fuel is very irregular

Baseline Laboratory Testing - continued

Baseline Laboratory Test Results

Test #	*High Power Efficiency, %*	*Time to Boil, min*	*Dry Fuel Consumed, g*	*HP Output, kW*	*HP CO, g/MJd*	*Char after Cold Start, g*
1	14.8%	27	1223	14.7	9.2	100
3	15.4%	32	1147	11.6	10.9	92
4	16.2%	28	1093	12.8	10.2	94
5	17.4%	29	1017	11.2	10.4	84
6	14.5%	31	1232	13.0	12.9	163
Average	**15.6%**	**29**	**1142**	**12.7**	**10.7**	**107**
Maximum	17.4%	32	1232	14.7	12.9	163
Minimum	14.5%	27	1017	11.2	9.2	84
COV, %	7.56	7.0	8	10.7	12.6	30

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Preliminary Design Process

Sheet Use -- See Note

[Link to Design Brief]

Click the [+] or [-] button above column B to show/hide the scoring columns

	Acceptability	Economics	Health	Ergonomics	Productivity	Roast Quality	Fuel Flexibility	Maintenance	Durability	Versatility	Fuel Use	Item 12	Item 13	Item 14	Item 15
Parameter Scaling Factor Input:		10	10	8	4	4	2	2	2	2	7				
Pass/Fail:	Y	N	N	N	N	Y	N	N	N	N	N	N	N	N	N
As Percentages:	0%	20%	20%	16%	8%	8%	4%	4%	4%	4%	14%	0%	0%	0%	0%

1 [Baseline]

Design Parameter	Acceptability	Economics	Health	Ergonomics	Productivity	Roast Quality	Fuel Flexibility	Maintenance	Durability	Versatility	Fuel Use	Item 12	Item 13	Item 14	Item 15
Whit	3	2	1	1	4	4	4	2	3	4	1				
Carol	4	2	1	1	3	4	5	2	4	5	1				
Serwaa	3	4	3	3	3	4	4	1	3	2.5					
Kaci	4	3	1	2	3	4	4	2	3	3	1				
Brian	4	1	1	2	4	4	5	2	2	3	1				
Paul	3	2	1	3	3	3	3	2	2	2	1				
Peter	3	1	0	1	3	4	5	2	4	2.5	1	0	0	0	0
Raw Average (1-5)	3.4	2.1	1.1	1.9	3.3	3.9	4.3	1.9	3.0	3.1	1.0	0.0	0.0	0.0	0.0
passfail	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Weighted Totals	0	21.4	11.4	14.8	13.1	15.4	8.57	3.71	6	6.28	7	0	0	0	0

Scaled Average Score (1-5)	Key Features	Percieved Benefits	Potential Risks	BOM Estimation (1-5)	Shea Batch Capacity	Additional Comments	Next Steps
2.1 42% (+ 0) Chill	Enclosed drum, metal handles,open fire chamber with 3-sided mild steel enclosure	increases productivity over banku pot, enclosed slightly more than banku pot	Smoke & heat exposure, burns, heavy to load and unload (requires 2 people), no more fuel efficient than banku pot	2	10-25 bowls of shea nuts	[Text]	Example: Create Prototype, test heat transfer properties, with lab tests.

2 [Wok over Rocket Stove]

Design Parameter	Acceptability	Economics	Health	Ergonomics	Productivity	Roast Quality	Fuel Flexibility	Maintenance	Durability	Versatility	Fuel Use	Item 12	Item 13	Item 14	Item 15
Whit	2	3	3	3	1	4	3	2	3	2	4				
Carol	3	3	3	3	1	5	2	2	4	5	4				
Serwaa	3	2		2	1	4	3	2	3	5					
Kaci	3	3	3	3	1	4	3	4	4	5	4				
Brian	3	4	3	4	1	4	2	2	4	4	4				
Paul	2	2	2	1	1	3	2	3	3	4	4				
Peter	3	3	4	3	1	4	3	4	3	5	4	0	0	0	0
Raw Average (1-5)	2.7	2.9	3.0	2.7	1.0	4.0	2.6	2.7	3.4	4.3	4.0	0.0	0.0	0.0	0.0
passfail	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Weighted Totals	0	28.5	30	21.7	4	16	5.14	5.42	6.85	8.57	28	0	0	0	0

Scaled Average Score (1-5)	Key Features	Percieved Benefits	Potential Risks	BOM Estimation (1-5)	Shea Batch Capacity	Additional Comments	Next Steps
3.0 61% (+18%) Chill	Large shallow round pot (pan) over a side fed rocket stove or a batch fed stove for shea **could be used for other processing steps	Fast roasting for small batch or nuts, high efficiency and low emissions, loaded and unloaded by 1 person, a rocket stove would be straightforward for BDL to design and optimize	Low productivity does not meet co-op needs or match roasting drum	2	<10 bowls	Rocket stove would likely be a totally new design. Stability would be a key consideration, as would the ability to handle larger wood.	CAD concept

3 [Batch-fed Shea Cake Burner]

[image]

Design Parameter	Acceptability	Economics	Health	Ergonomics	Productivity	Roast Quality	Fuel Flexibility	Maintenance	Durability	Versatility	Fuel Use	Item 12	Item 13	Item 14	Item 15
Whit	2	3	4	4	3	4	1	2	3	2	5				
Carol	2	3	2	3	1	5	1	3	3	3	5				
Serwaa															
Kaci	3	3	2	3	2	4	1	2	3	3	5				
Brian	3	2	2	3	1	2	1	3	3	3	5				
Paul	3	3	4	4	3	3	1	3	3	3	1				

Scaled Average Score (1-5)	Key Features	Percieved Benefits	Potential Risks	BOM Estimation (1-5)	Shea Batch Capacity	Additional Comments	Next Steps
3.1	A batch feed stove, similar to a charcoal stove, designed to burn shea cake briquettes (in the shape of balls)	Eliminates use of other fuels in roasting process, Batch fed provides consistent time and energy delivered to kernels, smaller quantity requires only 1 person	Heating Value of shea cake is unknown, cost to briquette is unknown, consistency of shea cake is unknown. Risk that batch feeding shea cake will not work- it may result in an	2	5-15 bowls (compara ble to	What are we assuming here? a) this is just a shea cake burner that has similar efficiency to other burners, and so burns much more shea cake per kg of	1) attempt to burn shea cake in batch mode - compare to charcoal. 2)Research Briqette making, determine HHV of shea cake

Sheet1 | Sorted Scores Matrix | 1 | 2 | 3 | 4 | 5 | 6 | 9 | 7 | 15 | 8 | 10 | 11 | 12 | 13 | 14 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26

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Preliminary Design Process

No.	Name	Design Parameter	Accept	Econon	Health	Ergono	Product	Roast C	Fuel Fle	Mainten	Durabili	Versatil	Fuel Us	Scaled Average Score (1-5)			Pass/Fail
	See Attached Note	Scaling Factor		10	10	8	4	4	2	2	2	2	7				
		Pass/Fail?	Y	N	N	N	N	Y	N	N	N	N	N				
4	Gari Elephant		2.9	2.4	4.7	2.9	3.1	4.0	3.1	4.3	3.6	4.4	3.9	3.5	71%	(+29%)	Chill
10	Improved Combustion Chamber [FEATURE]		3.8	3.3	3.8	3.0	3.2	3.7	3.7	3.0	3.2	4.5	4.2	3.5	71%	(+28%)	Chill
11	Front-Fed Enclosed drum w/top stack and pedal dri		3.4	2.6	4.6	3.4	3.3	3.7	3.6	2.0	2.6	3.8	3.9	3.5	70%	(+27%)	Chill
12	Front Fed 3-chamber enclosed drum w/ side-stack		3.1	2.7	4.6	2.6	3.1	3.7	3.7	2.4	2.6	3.5	4.1	3.4	68%	(+26%)	Chill
8	Stacked Drums w/exhaust stack		3.7	2.1	4.1	2.7	4.7	3.8	3.4	2.0	3.0	3.4	4.5	3.4	68%	(+26%)	Chill
19	Retrofitted Enclosure		3.9	3.0	4.6	3.0	3.3	3.7	3.7	2.7	2.7	3.6	2.4	3.3	67%	(+24%)	Chill
16	Batch Fed Enclosed Drum Roaster		2.9	1.9	4.9	2.4	3.4	3.7	3.7	1.7	2.7	3.6	4.3	3.3	66%	(+24%)	Chill
20	Banku Pot Cookstove		3.1	3.4	3.4	2.6	2.1	3.9	2.9	2.7	3.4	4.3	4.0	3.3	66%	(+23%)	Chill
13	Side fed enclosed drum w/ top-stack		3.1	2.3	4.4	2.3	3.0	3.7	3.3	2.3	2.6	3.5	4.0	3.2	64%	(+22%)	Chill
22	Continuous Feed Auger		2.3	1.1	4.3	3.6	4.7	3.6	3.9	1.6	2.4	1.7	4.0	3.2	64%	(+22%)	Chill
7	Oven Type		2.3	2.1	4.1	3.7	2.6	3.7	3.1	2.1	2.7	2.9	3.1	3.2	63%	(+21%)	Chill
14	Crank-driven intake fan [FEATURE]		3.3	2.0	4.4	1.9	3.2	3.9	3.9	1.1	2.6	3.5	4.3	3.1	63%	(+20%)	Chill
3	Batch-fed Shea Cake Burner		2.8	3.0	2.8	3.3	2.3	3.7	0.8	2.7	3.2	2.8	4.3	3.1	62%	(+19%)	Chill
2	Wok over Rocket Stove		2.7	2.9	3.0	2.7	1.0	4.0	2.6	2.7	3.4	4.3	4.0	3.0	61%	(+18%)	Chill
6	Sand Medium [FEATURE]		2.1	3.7	2.1	2.1	3.7	4.6	3.9	2.4	2.9	2.5	2.7	3.0	59%	(+17%)	Chill
17	Whole Nut Roasting [FEATURE]		2.3	4.1	1.6	2.6	4.6	3.4	4.3	2.4	3.0	3.2	1.7	2.9	58%	(+16%)	Chill
9	Twin Nut Roaster		3.0	1.9	3.9	1.9	4.0	3.6	5.0	1.7	2.3	3.2	2.7	2.9	57%	(+15%)	Chill
15	Treadle-Driven Rotation [FEATURE]		3.3	2.5	2.5	4.2	3.2	3.8	4.3	1.7	2.3	3.4	1.5	2.8	57%	(+15%)	Chill
5	Kitchen Aide		2.6	2.6	3.4	2.3	1.7	3.0	2.4	2.7	2.6	2.7	3.4	2.8	56%	(+13%)	Chill
18	Tip-empty drum [FEATURE]		2.9	2.1	1.9	3.9	3.7	3.7	4.3	2.1	2.9	3.4	1.7	2.7	54%	(+12%)	Chill
23	Shea Cake Briquette Press		3.0	2.3	1.5	2.6	3.3	3.8	3.5	2.3	3.5	2.9	3.8	2.7	54%	(+11%)	Chill
24	Improved Drum Door [FEATURE]		4.5	2.7	1.8	3.0	3.3	3.7	4.3	2.2	2.8	3.3	1.1	2.5	51%	(+9%)	Chill
25	Drum Transport System [FEATURE]		3.2	2.0	1.6	3.6	3.2	3.8	4.4	2.0	3.0	3.3	1.0	2.5	49%	(+7%)	Chill
21	Cantilevered Fuel [FEATURE]		2.3	2.4	1.3	1.9	3.1	3.7	2.9	2.4	2.9	3.6	2.9	2.4	48%	(+6%)	Chill
1	Baseline		3.4	2.1	1.1	1.9	3.3	3.9	4.3	1.9	3.0	3.1	1.0	2.1	42%	(+ 0)	Chill

Sheet1 | Sorted Scores Matrix | 1 | 2 | 3 | 4 | 5 | 6 | 9 | 7 | 15 | 8 | 10 | 11 | 12 | 13 | 14 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23

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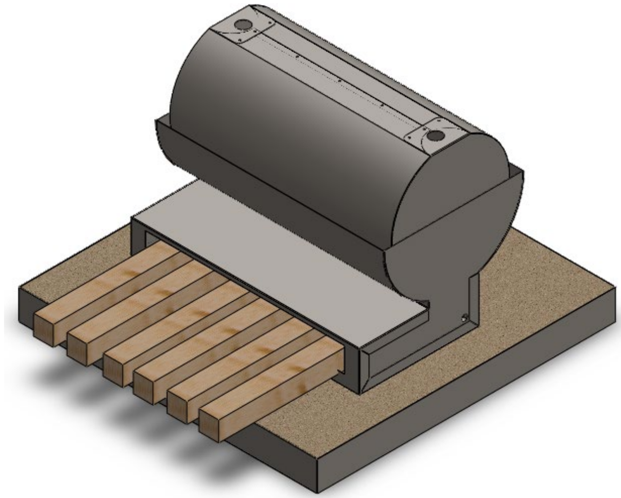
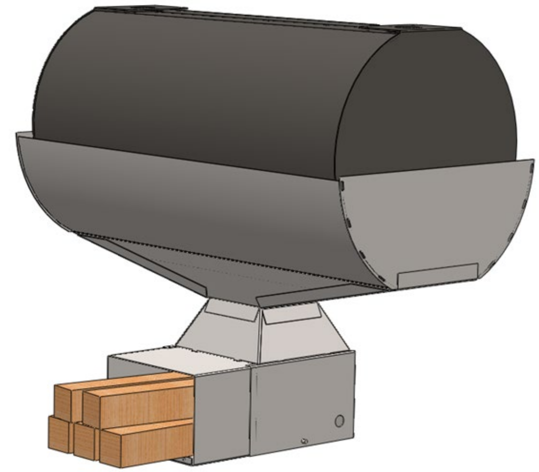
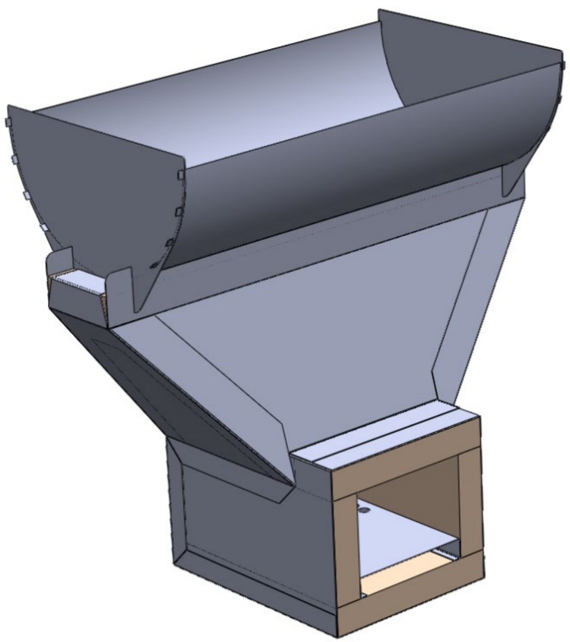
Prototypes

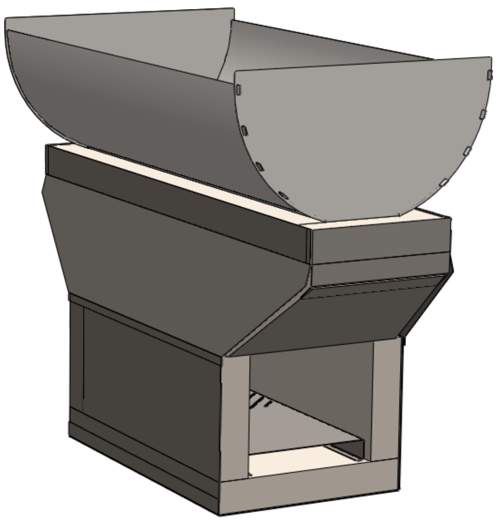
Round 1





Round 2





Prototypes

Round 1

Round 2

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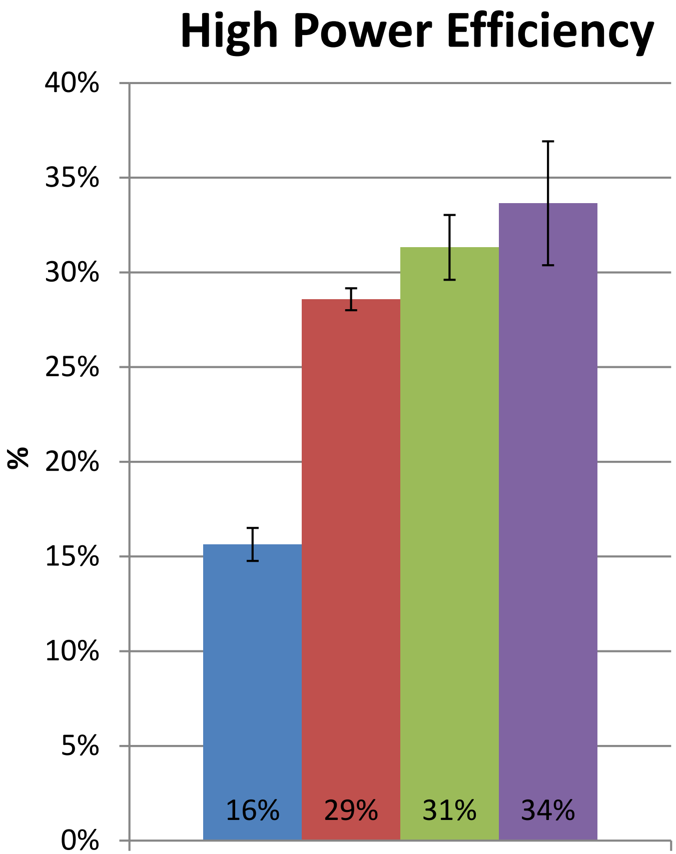
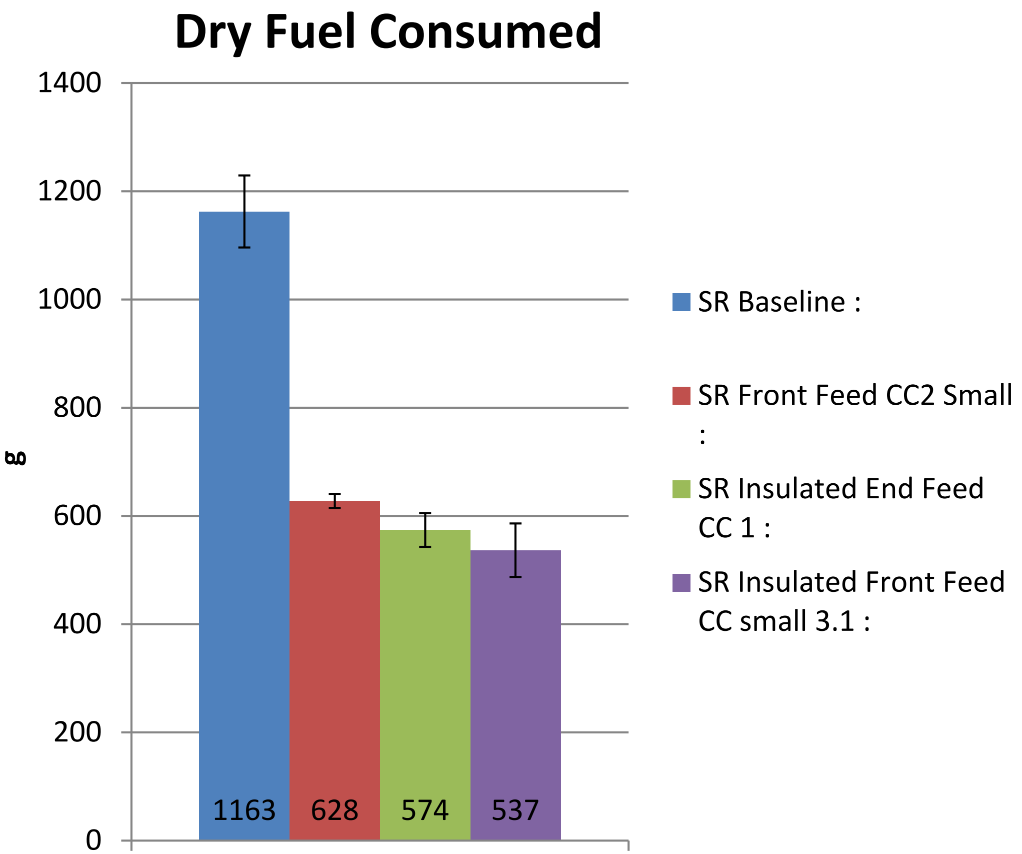
Testing Results





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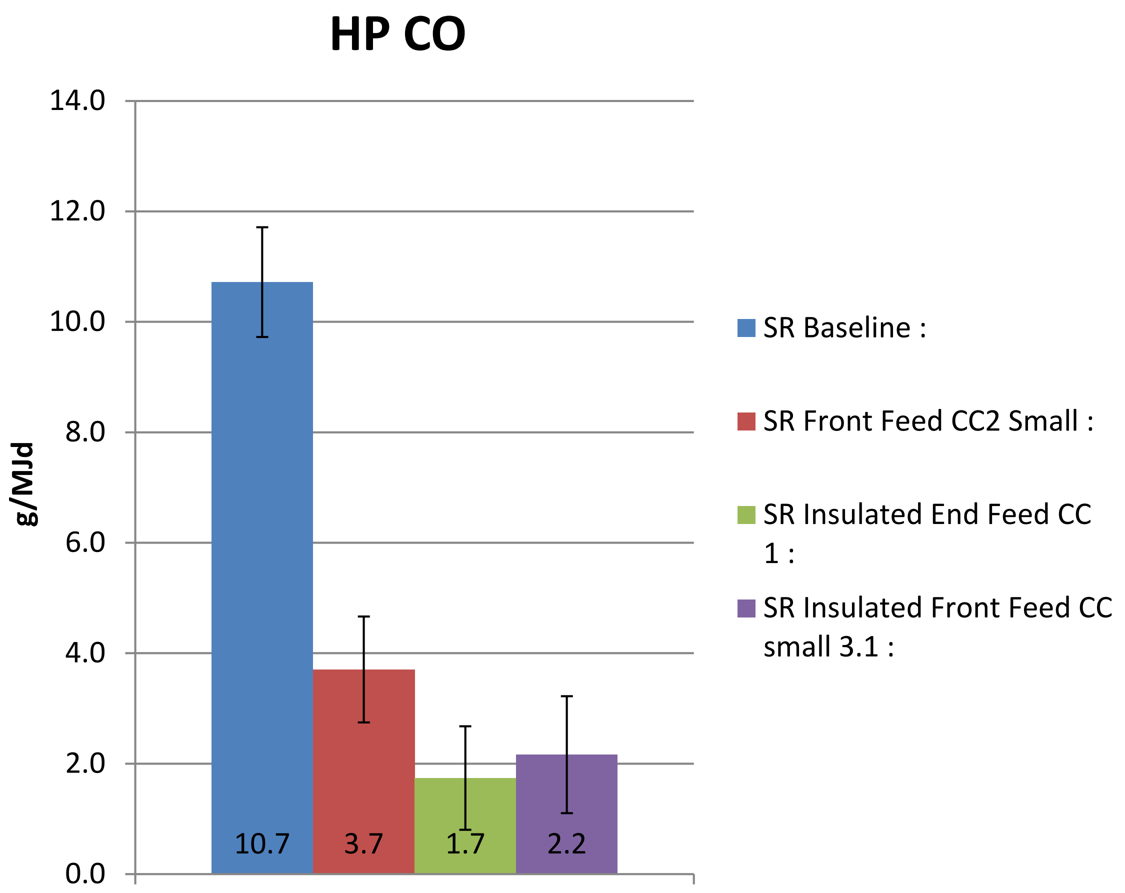
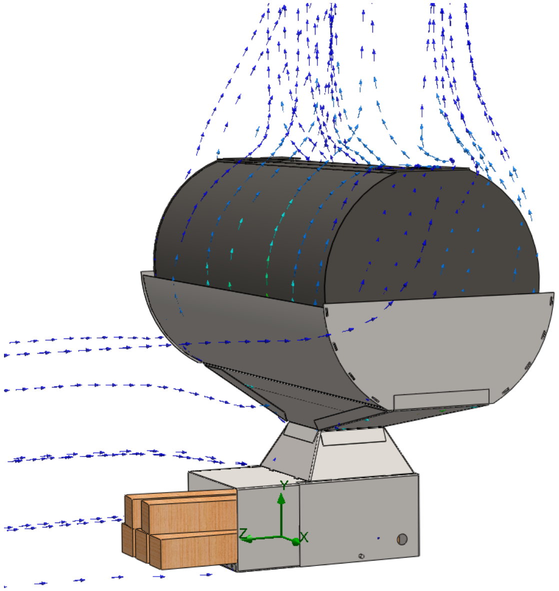
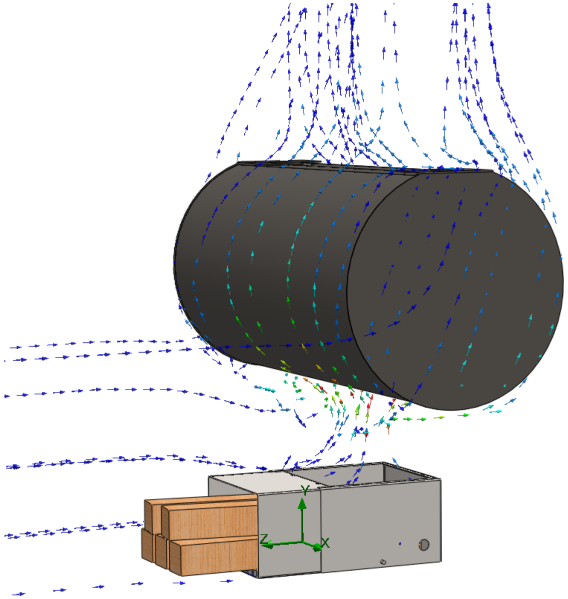
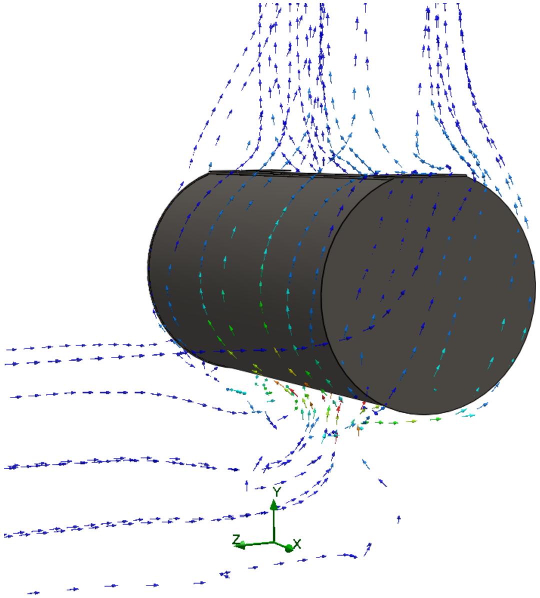


Development Process -Flow Simulation

- Research Phase
- Assist in rapid iteration for heat distribution







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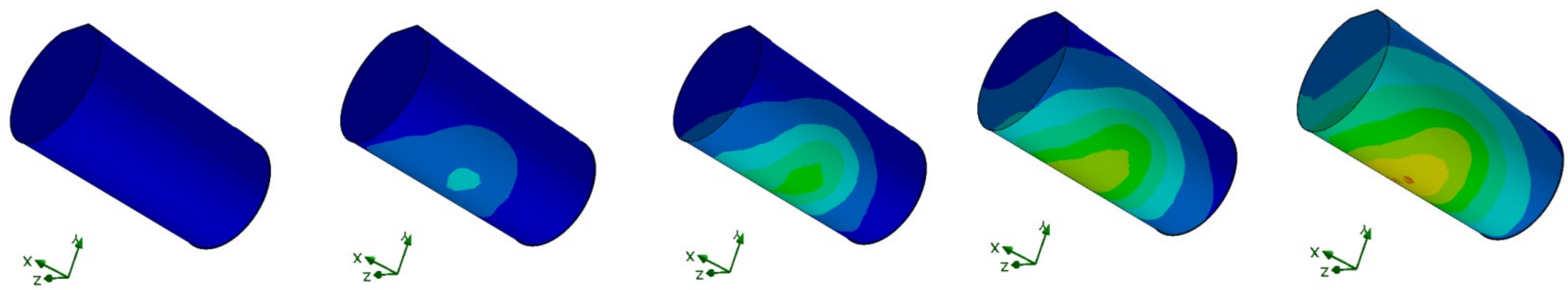
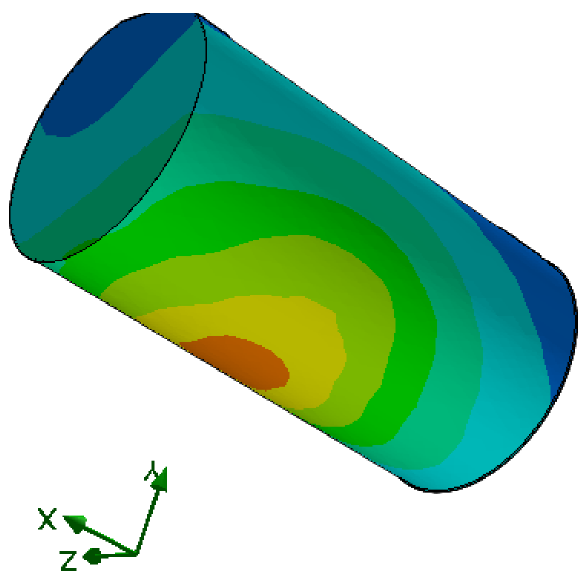




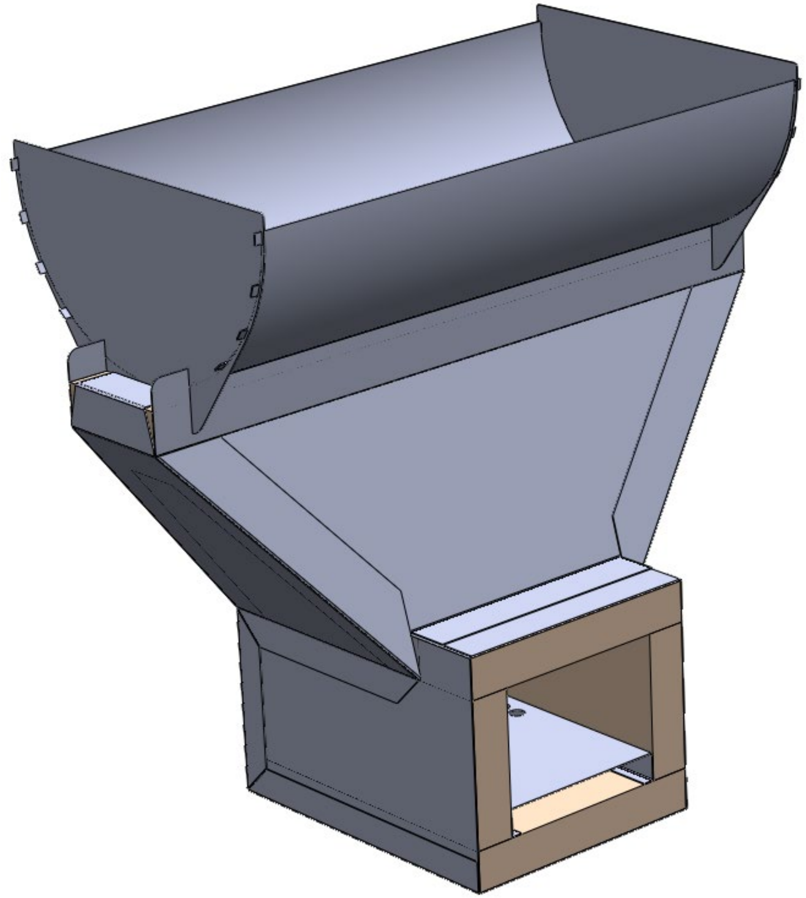
Development Process – Heat Distribution

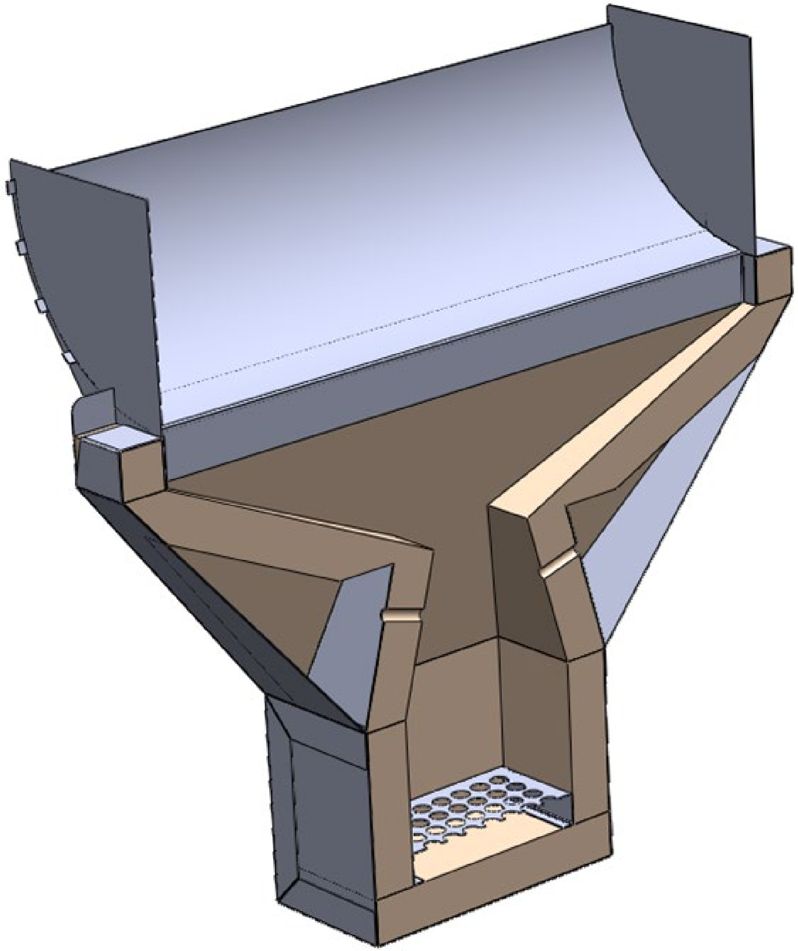
DAQ – 6 channel

5 New High-Temp TC (fixed to drum bottom)

Same Roaster Setup

Development Process – Heat Distribution





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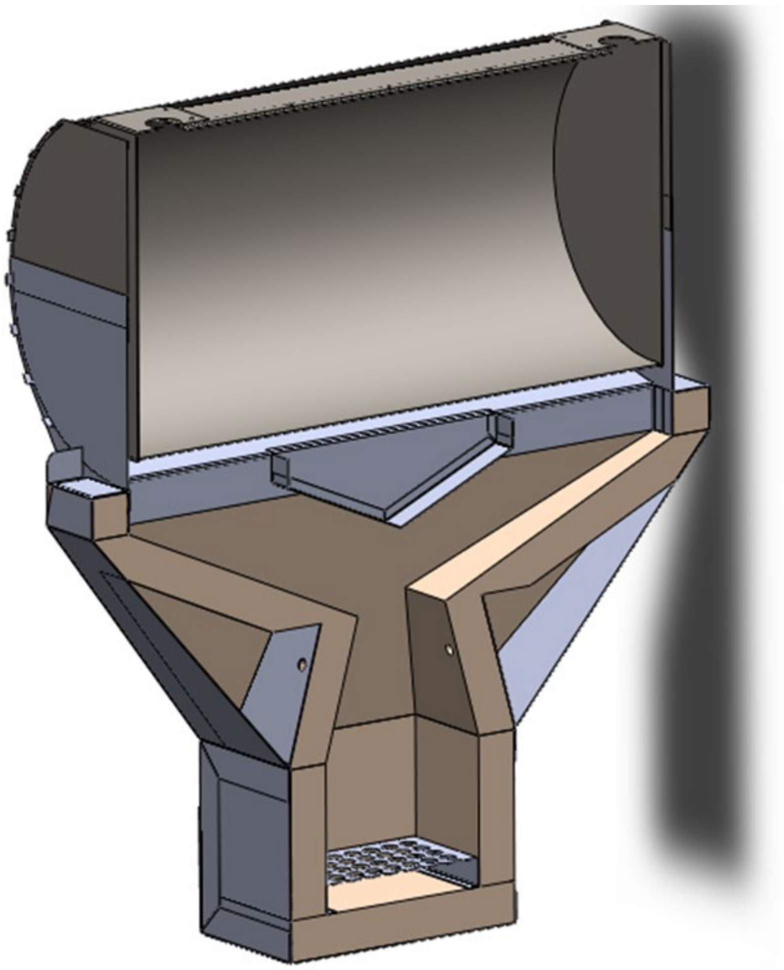
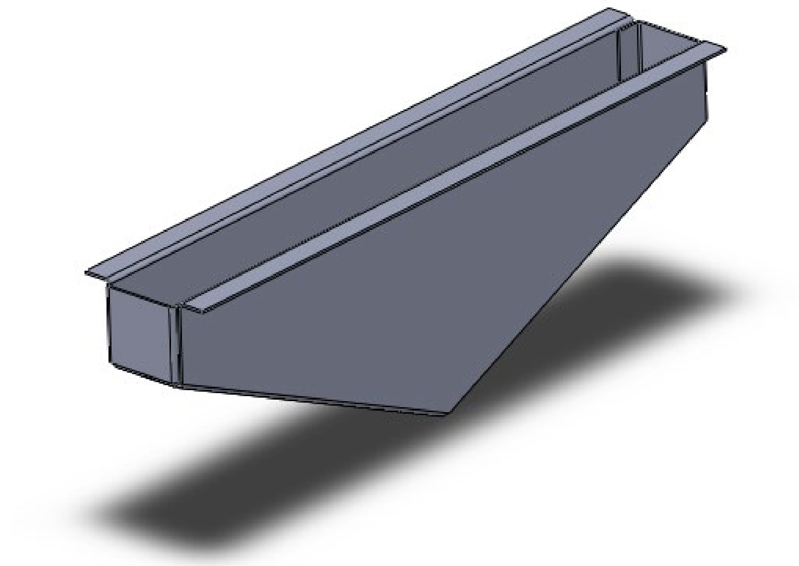
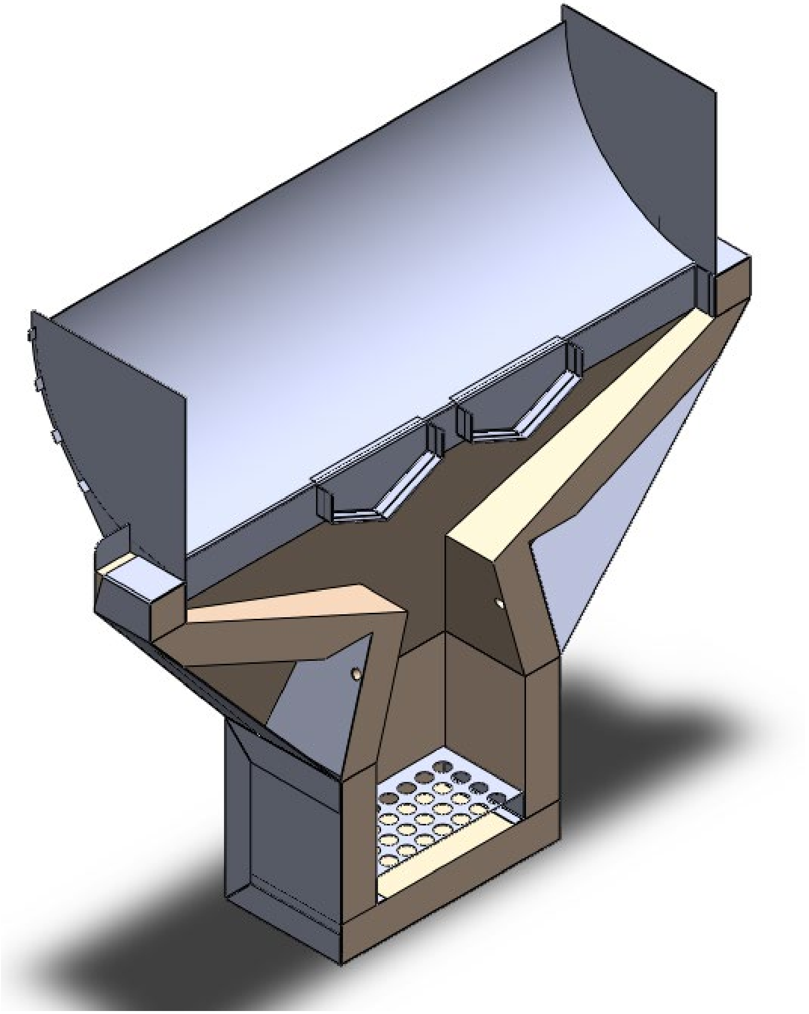
Development Process – Heat Distribution

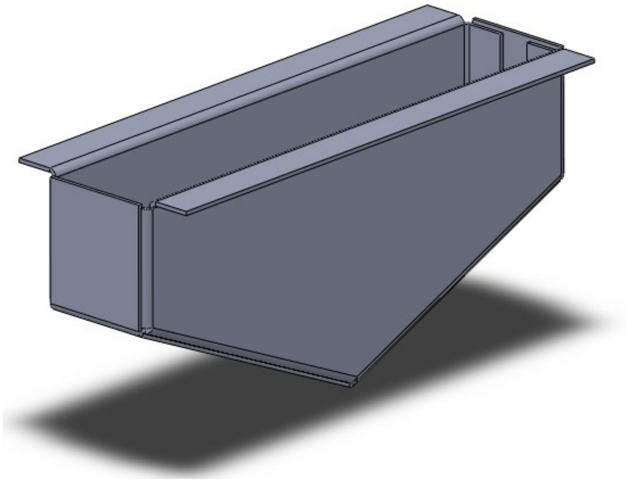




24 cm deflector

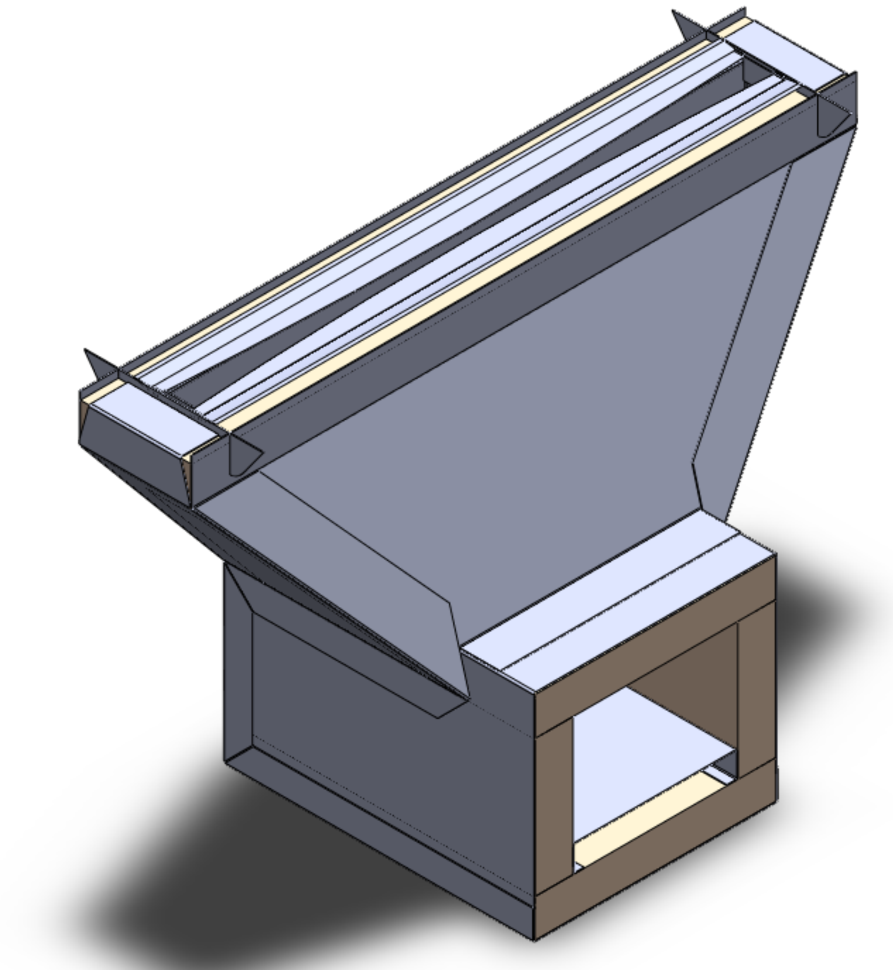
Development Process – Heat Distribution

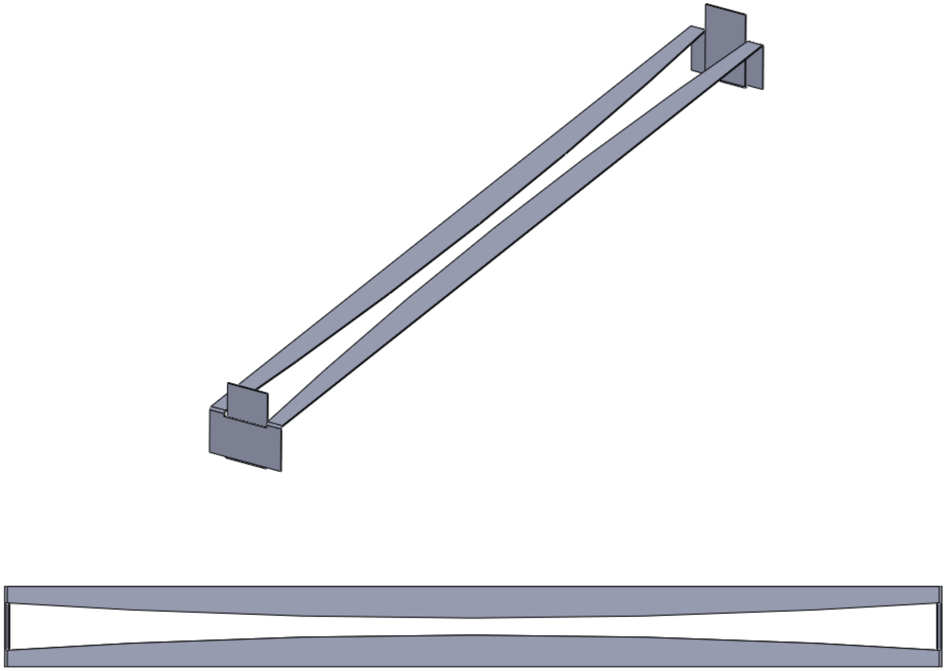




2 x 12 cm Deflector with 3 cm gap at center

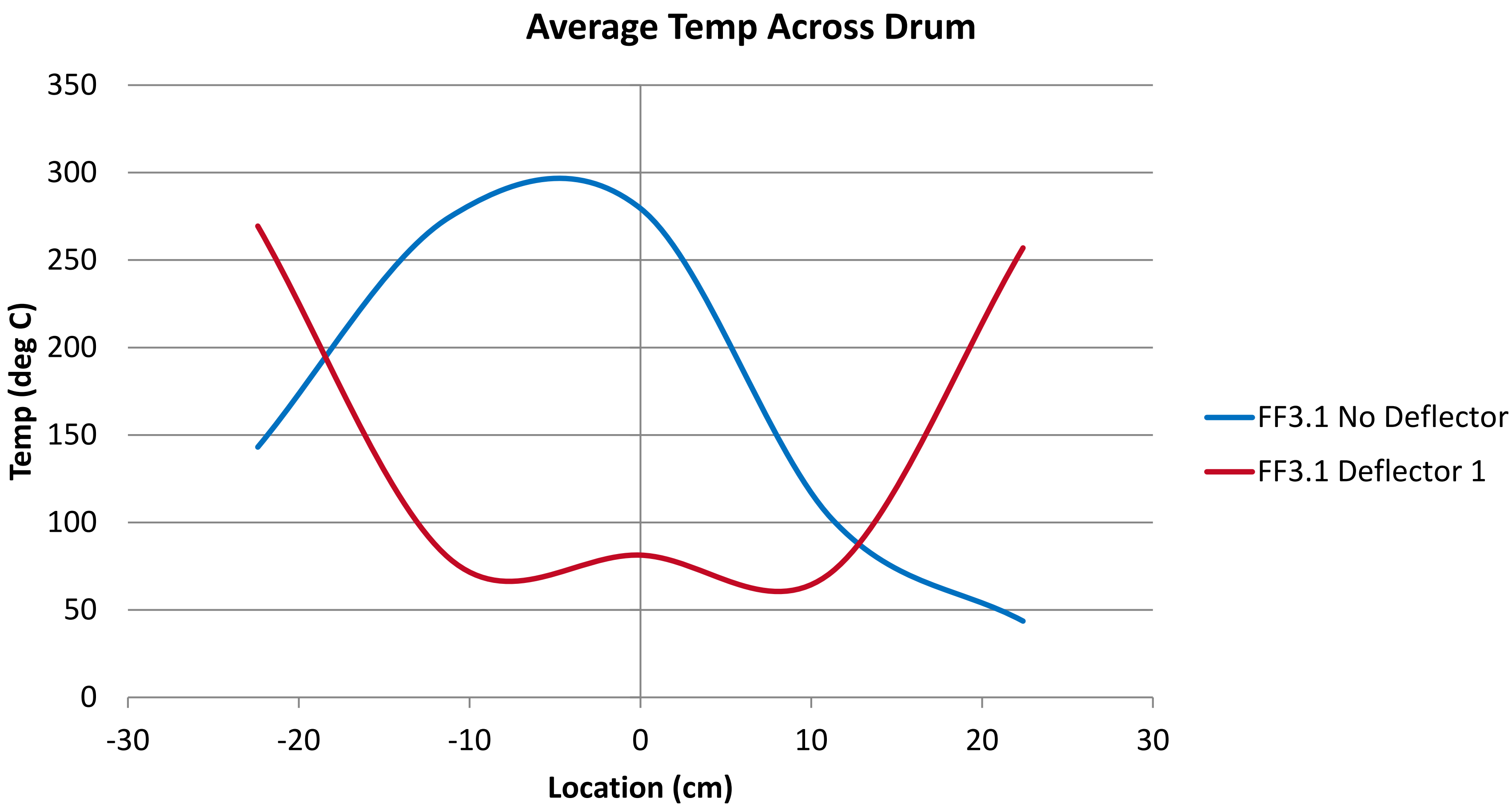
Development Process – Heat Distribution





Deflector 3 – same open area as Deflector 1 constrained by end points of hour glass shape

Analyzing Temp Data



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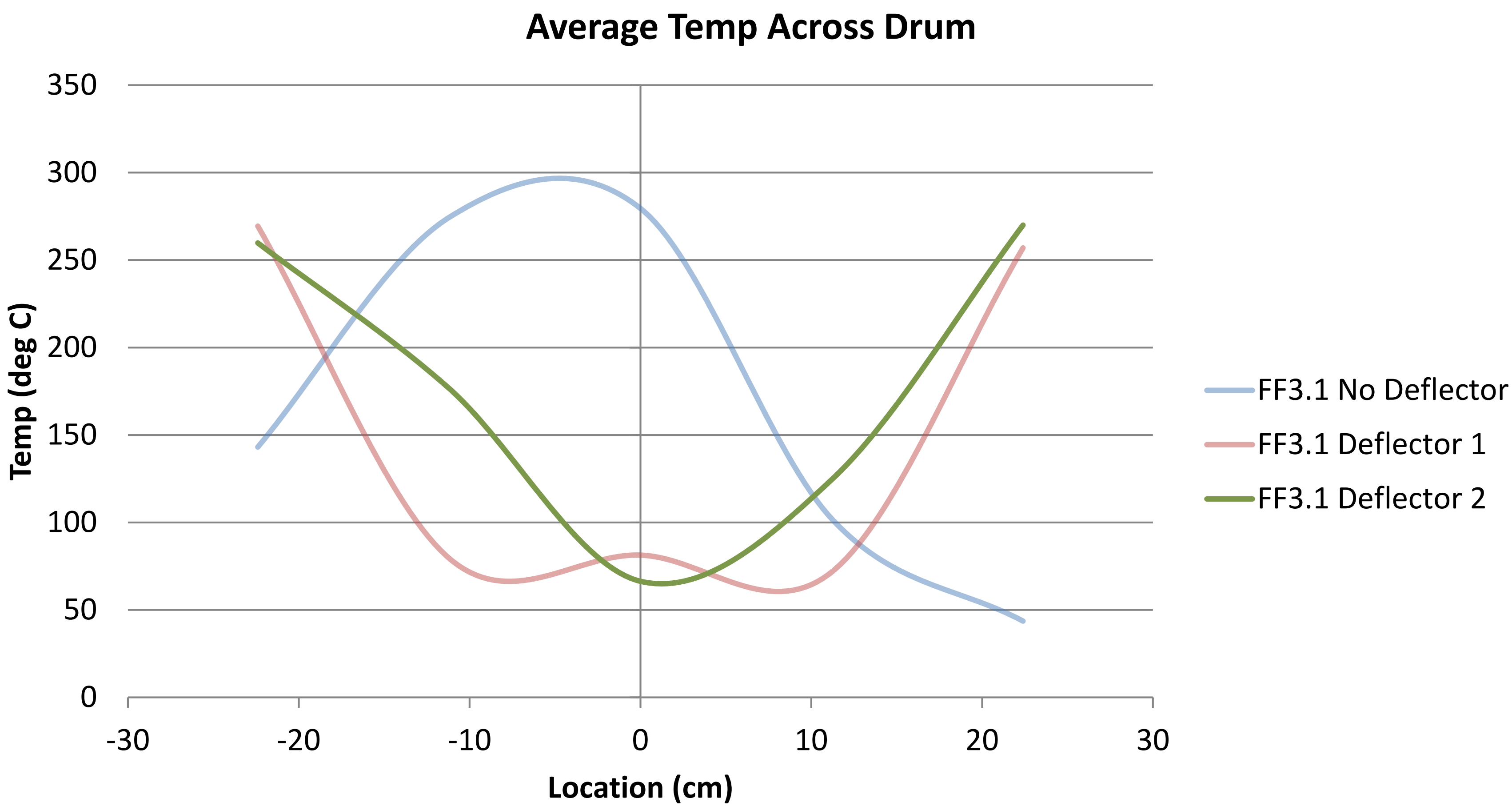
Analyzing Temp Data



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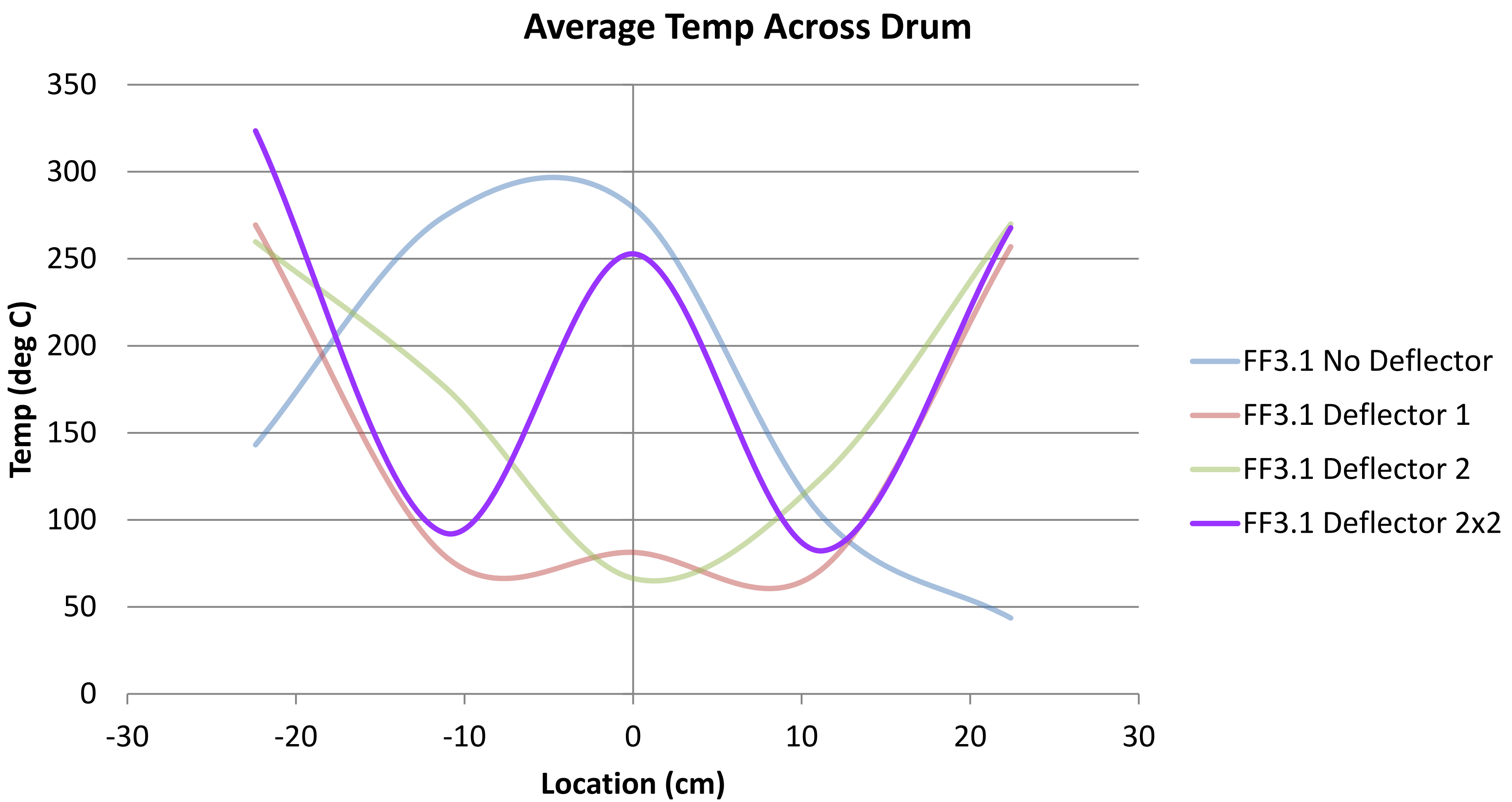
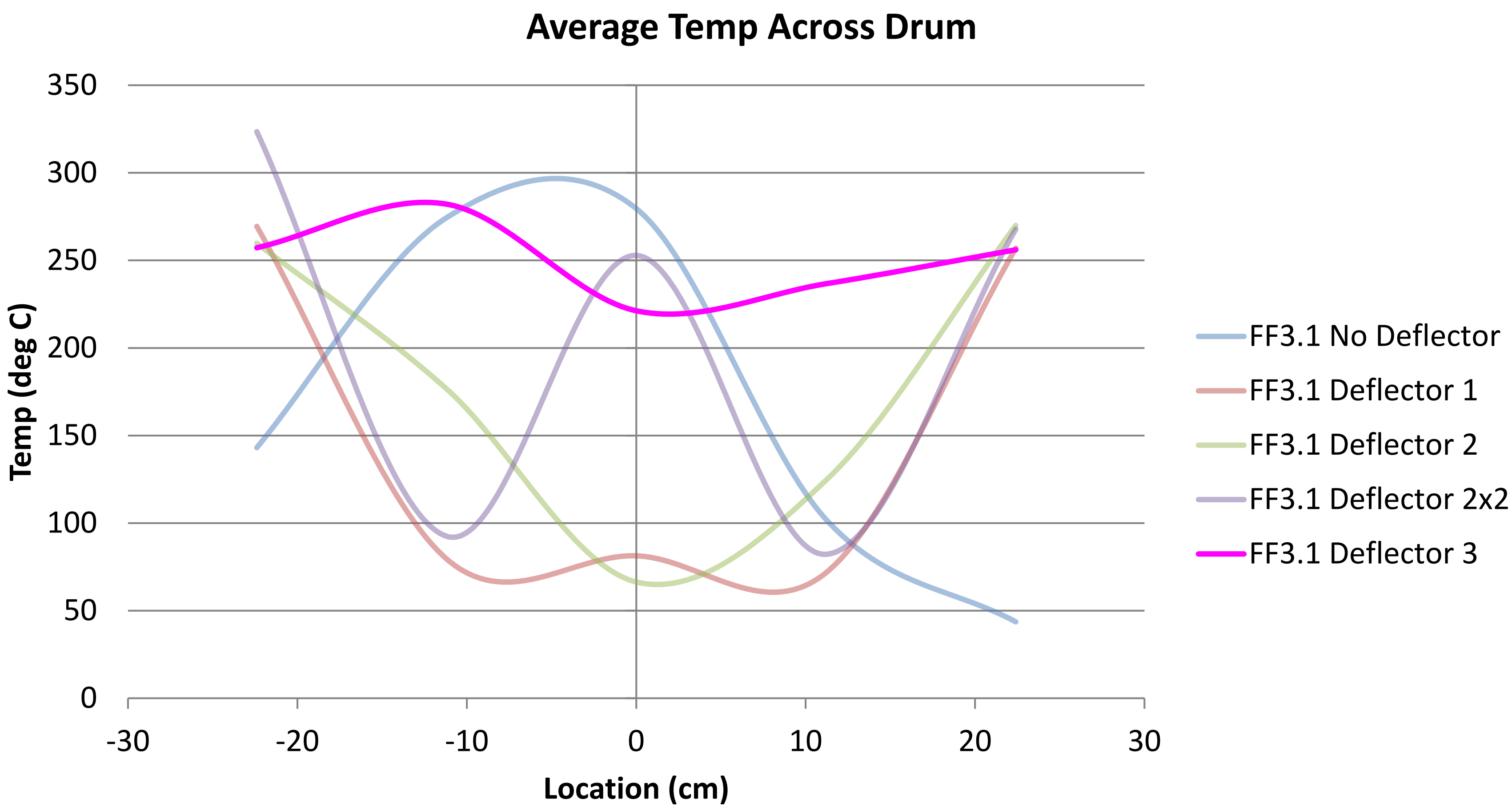


Analyzing Temp Data



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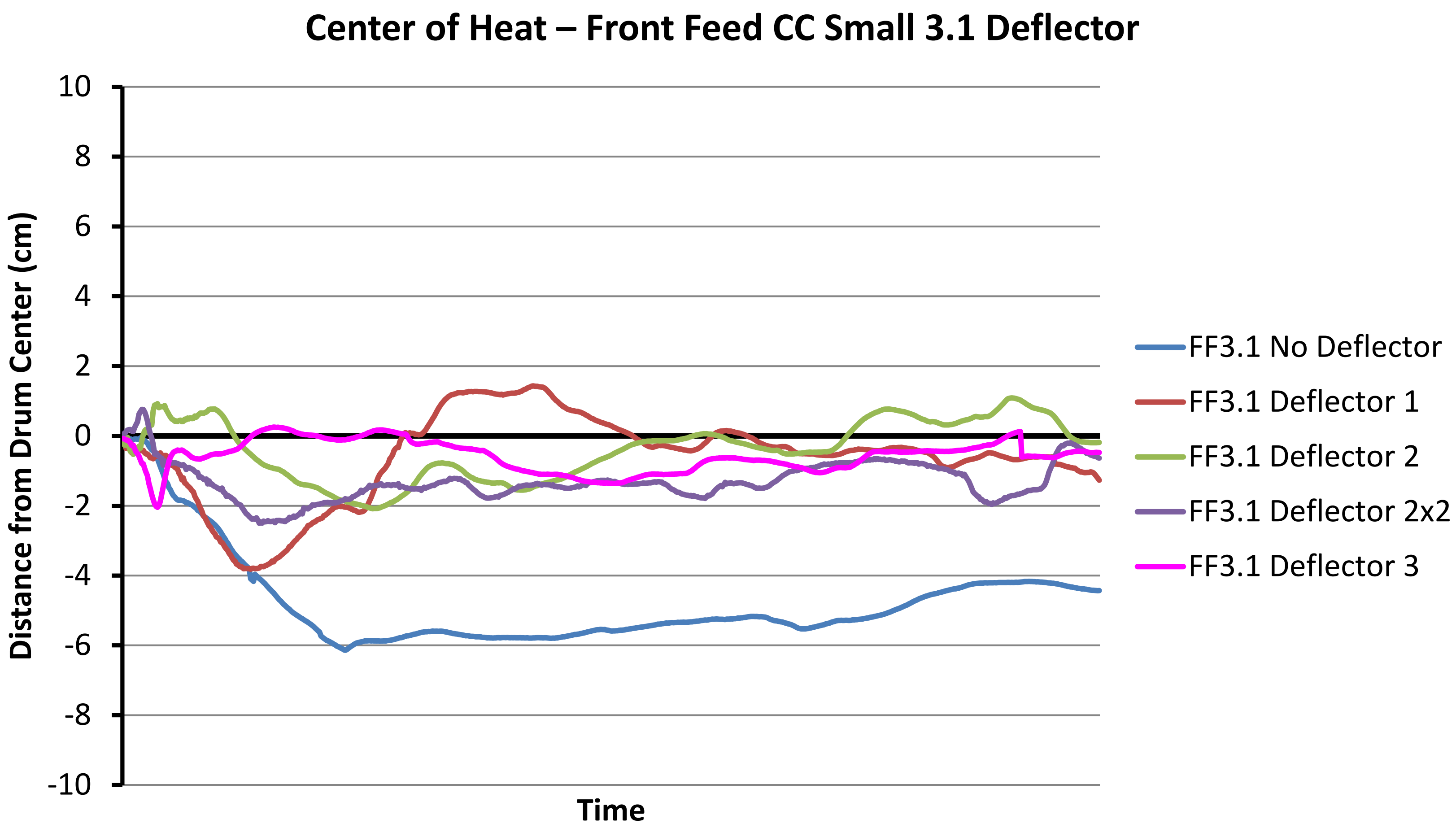
Analyzing Temp Data



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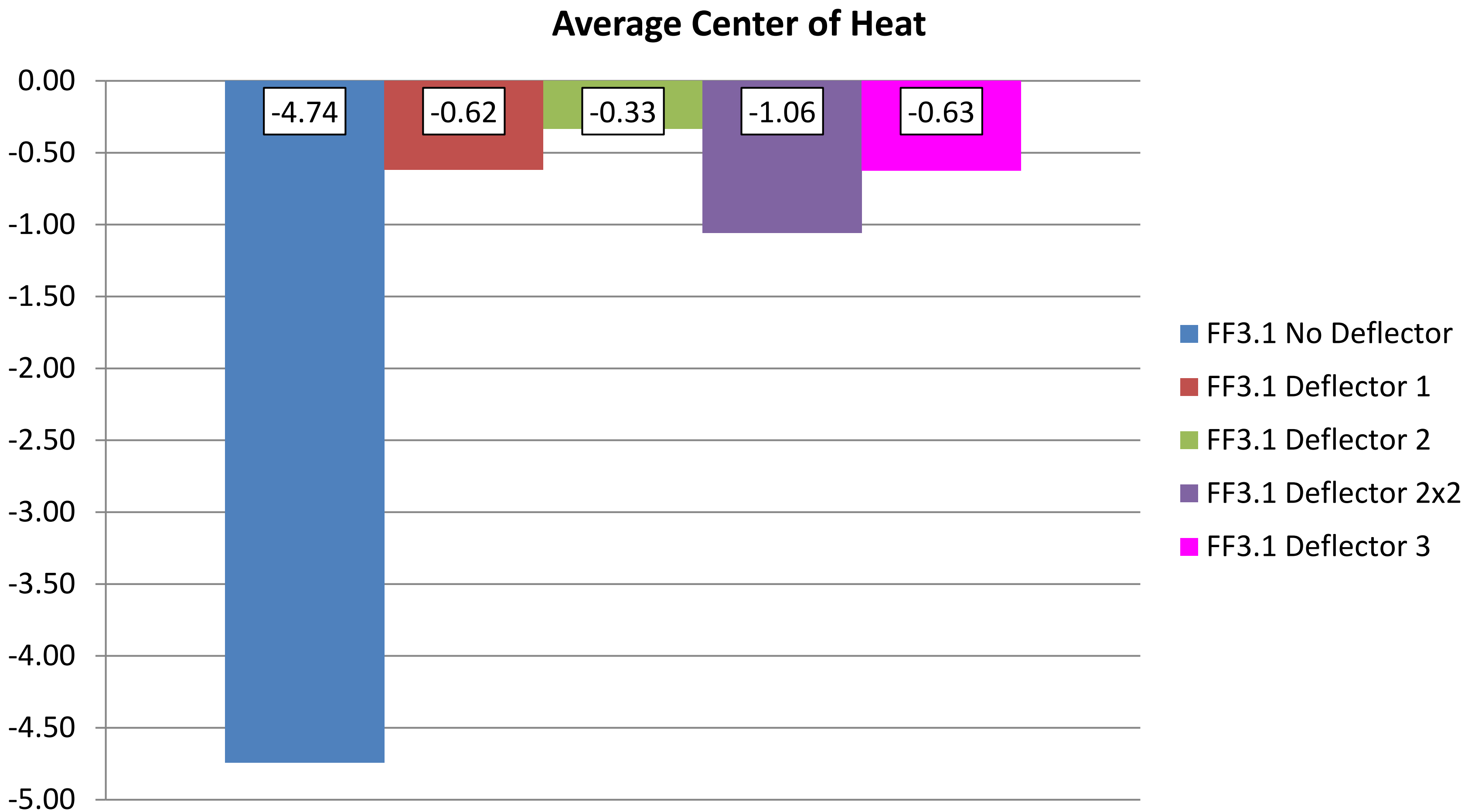
Analyzing Temp Data



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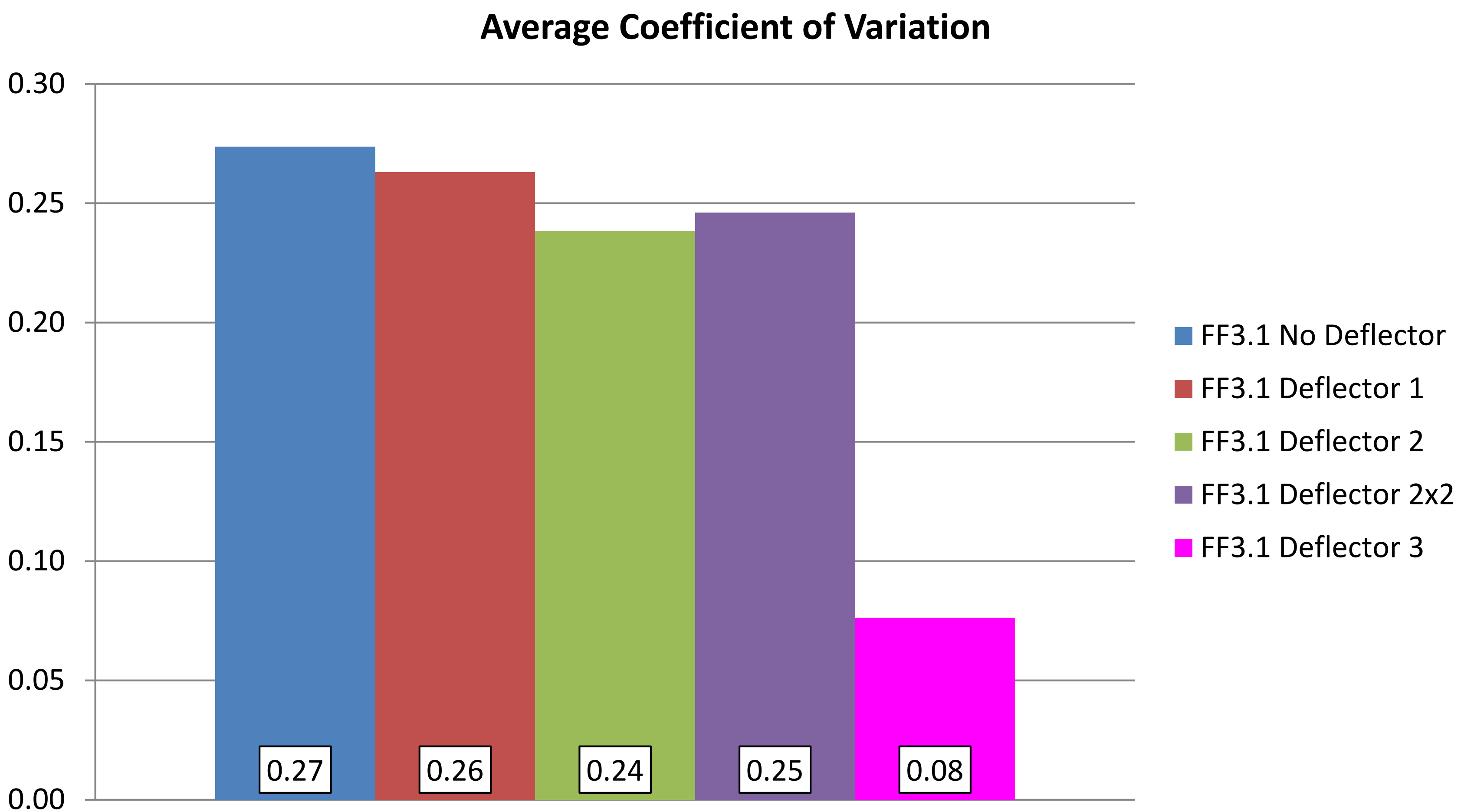
Analyzing Temp Data



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Next Steps

- Scaling up of Prototypes and sending to Ghana for user feedback and verification of performance.
  - Structural design
  - Material selection for performance/cost/durability
  - Implementation strategy and logistics

- Thank You!