KGCOE MSD Technical Review Agenda

P11462: Thermoelectric and Fan System for Cook Stove

Meeting Purpose:

1. Finalize Engineering Specification and Customer Needs
2. Receive feedback on critical technical issues
3. Receive approval to complete design as presented
4. Receive approval to purchase parts as presented

Materials to be reviewed:

1. System Level Design Review Action Items
2. Customer Needs
3. Engineering Specifications
4. System Design
5. Risk Assessment
6. Proposed MSD2 Schedule
7. Engineering Analysis
8. Detailed Drawings and Schematics
9. Bill of Materials
10. Test Plan
11. Next Steps

Meeting Date: February 11, 2011

Meeting Location: 78-2150

Meeting Time: 8:00 – 10:00 am

Timeline:

Meeting Timeline		
Start Time	**Topic of Review**	**Required Attendees**
8:00	Introduction	Dr. Stevens/Dr. Hoople
8:02	System Level Design Review Action Items	Dr. Stevens/Dr. Hoople
8:03	Customer Needs	Dr. Stevens/Dr. Hoople
8:05	Engineering Specifications	Dr. Stevens/Dr. Hoople
8:09	System Design	Dr. Stevens/Dr. Hoople
8:14	Risk Assessment	Dr. Stevens/Dr. Hoople
8:19	Proposed MSD2 Schedule	Dr. Stevens/Dr. Hoople
8:22	Engineering Analysis	Dr. Stevens/Dr. Hoople
8:52	Detailed Drawings and Schematics	Dr. Stevens/Dr. Hoople
9:35	Bill of Materials	Dr. Stevens/Dr. Hoople
9:39	Test Plan	Dr. Stevens/Dr. Hoople
9:43	Next Steps	Dr. Stevens/Dr. Hoople
9:45	Questions, Concerns, Ideas	Dr. Stevens/Dr. Hoople

Project Description

Project Number	Project Name	Project Track	Project Family
11462	Thermoelectric power system for first generation of improved cook stove	Sustainable Design and Product Development	Sustainable Technologies for the Third World
Start Term	Faculty Guide	Project Sponsor	Customer Organization
Winter 2010-2011	Rob Stevens and Ed Hanzlik	Corning Sustainability Funds	H.O.P.E (Haiti Outreach-Pwoje Espwa)

Project Overview:

According to the World Health Organization more than three billion people depend on biomass fuels (wood, dung, or agricultural residues) primarily for cooking. The practice of cooking with biomass has decimated many ecosystems and requires an enormous amount of human effort to gather. In addition, there is considerable evidence that exposure to biomass smoke increases the risk of common and serious diseases in both children and adults. According to the WHO studies, indoor smoke from solid fuels causes an estimated 1.6 million deaths annually.

To minimize these harmful effects associated with cooking more efficient cook stoves have been proposed. These new stoves are significantly more biomass fuel efficient and thus reduce deforestation rates. These enhanced stoves also reduce indoor air pollution, thereby reducing deaths and illnesses due to biomass cooking.

Project Objective:

The goal of this project is to develop a thermoelectric power system for the first generation of RIT cook stove (project P10461). The thermoelectric power unit should convert heat directly into electricity to power a fan and provide power for auxiliary loads.

Name	Discipline	Role / Skills
Jared Rugg	ME	Team Leader
Brad Sawyer	ME	Lead Engineer
Jeff Bird	ME	Team Member
Tom Gorevski	EE	Team Member
Fahad Masood	EE	Team Member

System Level Design Review Action Items

Item #	Action	Owner
1	For ES #3 Unit price subtract $2.50 to account for inability to quantify manufacturing costs.	Jared
2	For ES #8 Aux charging reduce number of phones able to be charged with stove off from 3 to 2.	Fahad
3	For ES #8 Aux charging recompute energy requirements for phone charging.	Fahad
4	For ES #9 Battery size recompute energy requirement for startup operation period.	Fahad
5	For ES #11 Volume take another look at volume estimates. Appear too large.	Jared
6	For ES #17 Maximum temperature of hot side of TEG increase temperatures. Data sheet specs maximum continuous hot side temp of 300 degC.	Tom
7	More explicitly state assumptions. Example is stove runs for 2 hours/day 3 times/day.	Jared
8	Stick to simple transient modeling	Jared

Customer Needs

Needs	Importance	Description	Comments/Status
1	9	Provide forced air flow to fire in current RIT stove design	
2	3	System easily removed from stove	
3	9	Cheap cost of system	
4	3	5 year life span (3x use per day)	
5	9	No user interaction for system protection	
6	3	Variable flow rate control	
7	3	User-friendly operation	
8	1	Well packaged system	
9	3	Operational in harsh environments	
10	9	Works with charcoal fire	
11	3	Ability to charge auxiliary device	
12	3	Plan to apply to team 11461's stove	
13	1	Fan runs at start-up	
14	9	Safe to operate	
15	9	System must be transportable	
16	9	Thermoelectric use	

Importance Scale: 1 – Low Importance, 3 – Moderate Importance, 9 – High Importance

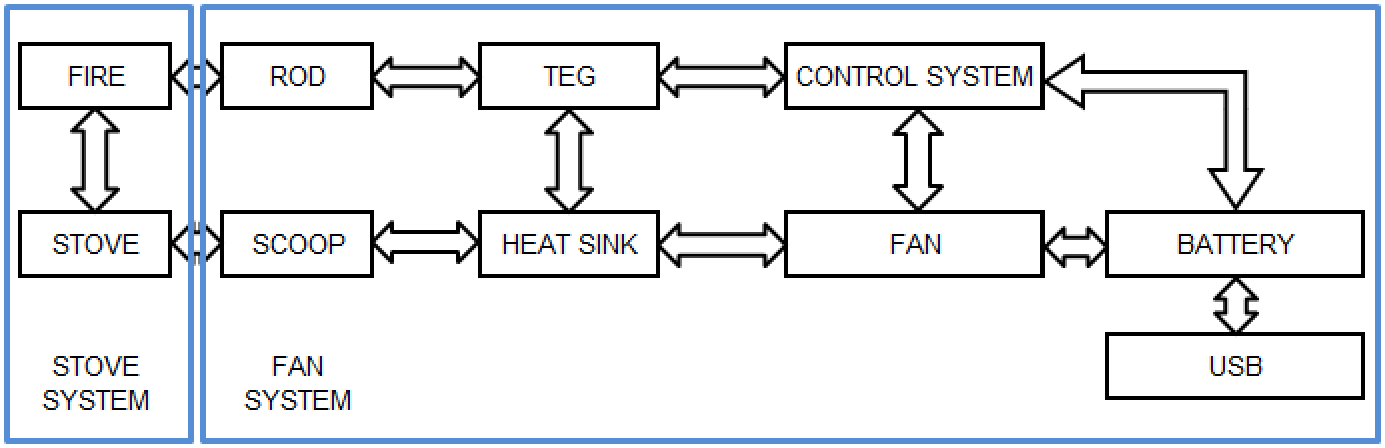
Engineering Specifications

Spec	Description	Importance	Relates to CN	Units	Marginal	Target	Comments/Status
1	Flow rate of air into stove	9	1,6,13	kg/min	0.3-0.7	0.2-0.8	
2	Flow control settings	3	6,13	#	2	3	Evenly distributed across the flow range
3	Unit price	9	3	$	27.5	12.5	Material cost
4	Coupling time with no tools	1	2,7,12	min	10	5	
5	Removal time with no tools	1	2,7,12,15	min	10	5	
6	Product life span	3	4, 9	years	3	5	Assume 2 hr/use and 3 uses/day
7	Replaceable component life span	3	4, 9	years	1	2	Rod, Fan, Battery
8	Aux charging	3	11,16	Wh		2	Being able to charge ~2 cell phones throughout the day
9	Battery size	3	11,13,16	Ah	1.5-3	2	Energy storage of 1 battery (Keep in mind energy required for 5 product startup cycles)
10	Weight	1	7,8,12,15	kg	<2.5	<2	
11	Volume	1	7,8,12,15	cm^3	3000	1000	
12	Time to reach peak performance	1	13,16	min	15	10	Within 90% of SS assuming charcoal ignites instantly
13	User actions during operational cycle	3	6,7,13	#	6	4	
14	User actions to protect system	3	5,7	#	1	0	
15	Maximum temperature inside enclosure	3	1,4,9,14	°C	60	50	
16	Maximum external temperature of housing	3	7,8,14	°C	54	45	
17	Maximum temperature of hot side of TEG	9	9,16	°C	275	300	

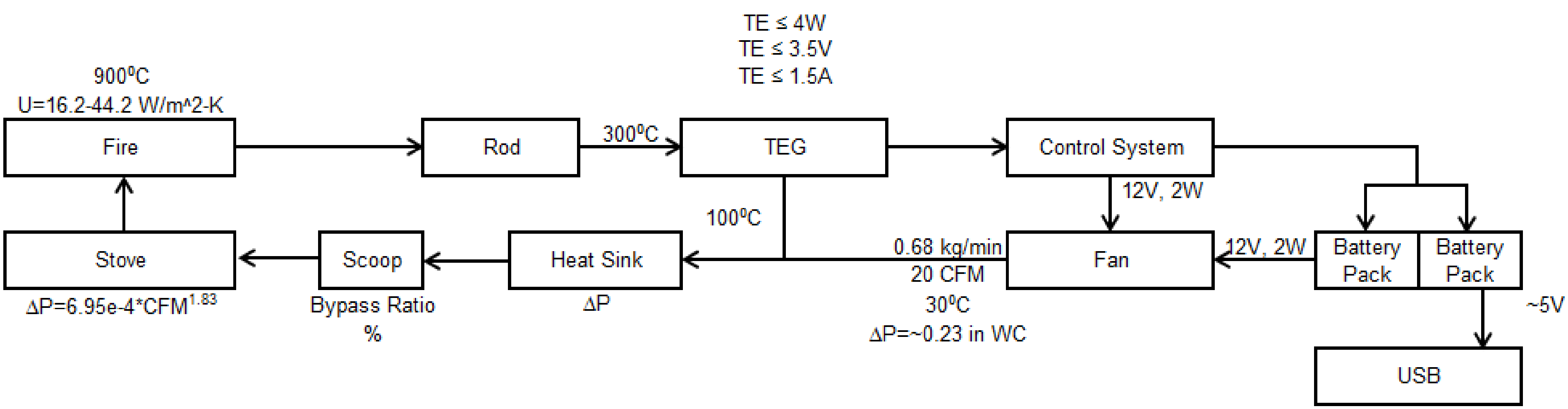
Importance Scale: 1 – Low Importance, 3 – Moderate Importance, 9 – High Importance

System Level Design

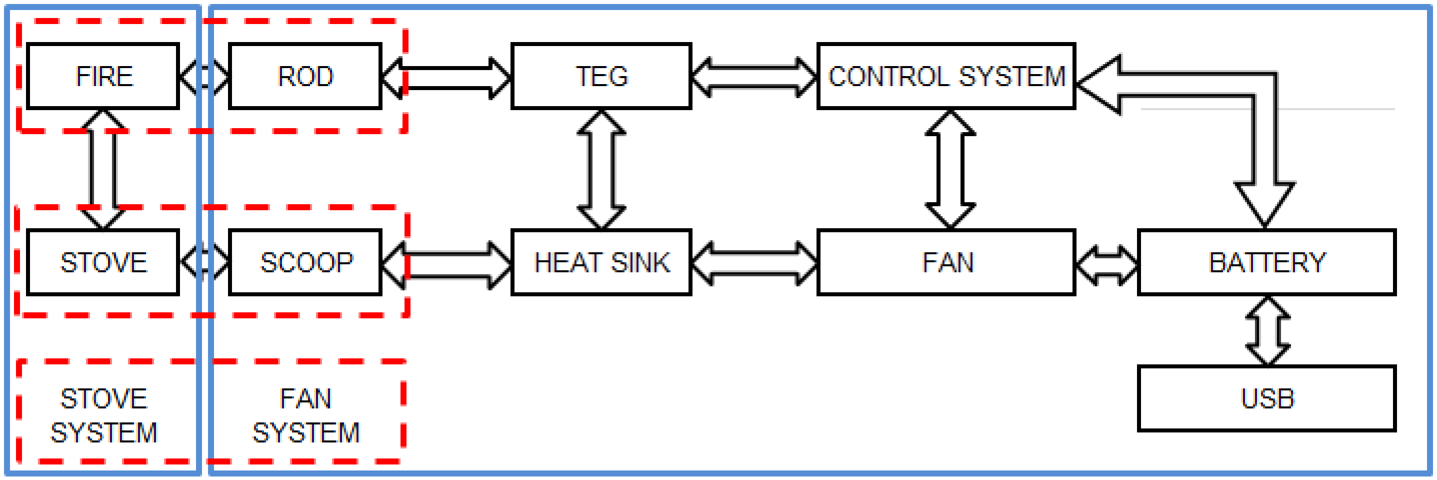
Subsystem Interfaces



Energy Flow



Project Interfaces



	11462 INTERFACE	STOVE INTERFACE	DEFINING FEATURES	CRITICAL SPECS			
INTERFACE 1	Heat Rod	Fire	Heat rod will take energy from fire. Heat rod will penetrate stove walls.	Diameter of rod	Fire Temperature		
INTERFACE 2	Duct Coupling	Stove Housing	Ducting will provide air flow at a given pressure. Duct will provide air into stove through square shaped hole in the outer wall of stove.	Dimensions of ducting	Location of entrance	Flow Rate	Pressure Drop
INTERFACE 3	Device Attachment	Stove Housing	The fan system will attach to the outside wall of the stove	Location of device on exterior of stove	Method of attachment	Architecture of exterior of stove	

Risk Assessment

ID	Risk Item	Effect	Cause	Likelihood	Severity	Importance	Action to Minimize Risk	Owner
Risks Involved with Thermoelectric Generator								
1	TEG overheat	Total System Failure	Inadequate heat transfer control	2	3	6	In-depth heat transfer including FEM, testing	Jeff
2	Insufficient TEG cooling	Unsustainable operation	Heating up of TEG cold side	2	2	4	In-depth heat transfer including FEM, testing	Brad
3	Unable to maintain max TEG efficiency	TEG capabilities not optimized	Transient effect on components	2	2	4	In depth analysis(TEG I-V characteristics), Testing	**Tom**/Jeff
4	Inability to accurately model TEG	Optimal power not being used	TEG model changes as heat is consistently applied	2	2	4	In depth analysis(TEG I-V characteristics) / Testing	**Jeff**/Tom
5	TEG power producing capacity too small	Underpowered system	Unable to meet required ΔT or TEG incapable of producing required power	1	3	3	Design with minimal power consumption / Design to required specs using amplifiers.	**Jeff**/Tom

ID	Risk Item	Effect	Cause	Likelihood	Severity	Importance	Action to Minimize Risk	Owner
Risks Involved with Battery/Charging System								
6	Battery failure/destruction	Total system failure	Poor battery sizing, excessive heat	2	3	6	Proper battery sizing, means to bypass battery	Fahad
7	Electrical components fail/overheat	System Failure	Excessive heating to components. Complicated design.	2	3	6	Keep components insulated and distant from heat. Simplify design to incorporate as little components as possible.	Fahad
8	Faulty design of control system	System failure	Components not sized properly or break due to overheating from fire	2	3	6	Design system in insulated location / In depth analysis of design requirements.	Tom/**Fahad**
9	Battery doesn’t charge	Fan won't start immediately. Aux. device won't charge.	Poor battery sizing, too little current to battery, battery malfunction	2	2	4	Size the battery more accurately through better testing. Allow TEG to charge aux device.	Fahad
10	Battery is drained	Fan won't start immediately. Aux. device won't charge.	Battery too small and doesn't hold charge well. Excessive user interaction	3	1	3	Test battery many times to ensure charge is held. Incorporate an LED warning system to tell user that battery is drained.	Fahad

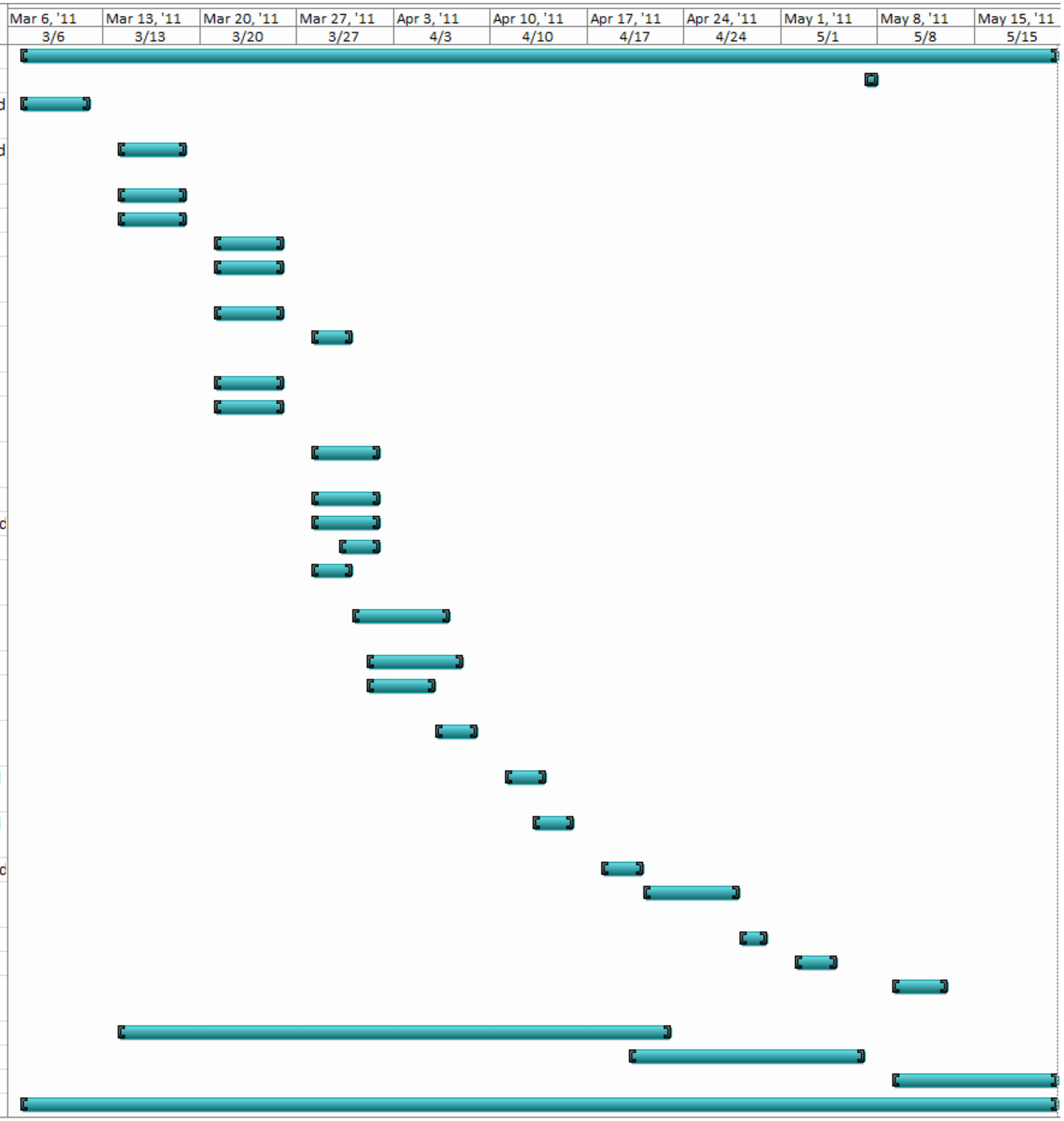
ID	Risk Item	Effect	Cause	Likelihood	Severity	Importance	Action to Minimize Risk	Owner
Risks Involved with Fan								
11	Fan produces insufficient pressure drop	Forced air unable to reach fire	Poor modeling/testing of stove	2	2	4	Increase flow rate, Provide more power to fan.	Jared
12	Fan melts	Loss of airflow, main system failure	Fan placed too close to stove, stove heat estimated	1	3	3	Testing to correctly estimate temperatures at proposed location	Jared
13	Fan requires too much power	Fan will drain power from battery, overdraw TE	Poor fan selection or design, fan failure	1	2	2	Apply margin on battery size or fan sizing	Jared

ID	Risk Item	Effect	Cause	Likelihood	Severity	Importance	Action to Minimize Risk	Owner
Risks Involved with Conduction Rod								
14	Heat conduction rod melting	Possible loss of heat transfer to thermoelectric	Inadequate analysis of stove operating temperatures and material properties	2	3	6	Analyze stove operating temperatures. Carefully select material to suit	Brad
15	Heat conduction rod conducts too much/not enough heat	Possible overheating of thermoelectric/ Insufficient power generation	Inadequate heat transfer analysis	2	3	6	Complete analysis of heat transfer characteristics of rod/block. Average stove operating temperatures taken into consideration	Brad
16	Rod takes too long to heat up	Improper system function. Fan may not operate at start-up	Inadequate transient heat transfer analysis. Inadequate understanding of transient temperatures in combustion chamber.	2	2	4	Test stove to get understanding of transient temperatures. Model transient temperature characteristics of rod.	Brad

ID	Risk Item	Effect	Cause	Likelihood	Severity	Importance	Action to Minimize Risk	Owner
Risks Involved in General System/Project Management								
17	Transient modeling	Forced induction to fire may fail at start-up or battery will be drained	Insufficient transient heat transfer modeling. Insufficient energy storage capabilities	3	2	6	Rigorous transient heat transfer analysis. Careful selection of heat transfer method and materials. Testing of stove (transient temps)	Brad/Tom
18	Inadequate means to prototype (tooling)	Failure to provide prototype for testing. Failure to deliver product.	Complex components, exotic manufacturing methods (CNC), insufficient thought given to lead times.	2	3	6	Consider means of production when in design process. Plan ahead for lead times.	Brad
19	Casing conducts too much heat	Jeopardize user safety	insufficient insulation	2	3	6	Testing for the radiant heat near controls / Design for better flow control	Jeff
20	Product Cost	Over acceptable/affordable value for Haitians	Excessive component cost	2	2	4	Design based on cost, Accurately log expenditures.	Jared
21	Insufficiently connects to stove	Failure to meet CN 9,10. Possible damage to unit.	Poor design planning	2	2	4	Decide on robust design early in design process and test design. Tests should include durability testing.	Brad

Proposed MSD2 Schedule

ID	Task Name	Duration	Start	Finish	Owner
1	MSD 2 Timeline	55 days	Mon 3/7/11	Fri 5/20/11	Jared
2	Imagine RIT	1 day	Sat 5/7/11	Sat 5/7/11	Jared
3	Write test plans for each component	5 days	Mon 3/7/11	Fri 3/11/11	Jeff/Fahad
4	Write test plans for each subsystem	5 days	Mon 3/14/11	Fri 3/18/11	Jeff/Fahad
5	Test fan	5 days	Mon 3/14/11	Fri 3/18/11	Jared
6	Test heat sink	5 days	Mon 3/14/11	Fri 3/18/11	Brad
7	Machine thermal beam	5 days	Mon 3/21/11	Fri 3/25/11	Jeff
8	Machine and assemble housing	5 days	Mon 3/21/11	Fri 3/25/11	Brad
9	Machine bypass	5 days	Mon 3/21/11	Fri 3/25/11	Jared
10	Integrate bypass into housing	3 days	Mon 3/28/11	Wed 3/30/11	Jared
11	Assemble breadboard	5 days	Mon 3/21/11	Fri 3/25/11	Tom
12	Assemble battery housing	5 days	Mon 3/21/11	Fri 3/25/11	Fahad
13	Test heat conduction beam	5 days	Mon 3/28/11	Fri 4/1/11	Jeff
14	Test electronics	5 days	Mon 3/28/11	Fri 4/1/11	Tom
15	Test battery system	5 days	Mon 3/28/11	Fri 4/1/11	Tom/Fahad
16	Test bypass scoop	3 days	Wed 3/30/11	Fri 4/1/11	Jared
17	Combine heat sink, TE, and beam	3 days	Mon 3/28/11	Wed 3/30/11	Brad
18	Test combined thermal subsystem	5 days	Thu 3/31/11	Wed 4/6/11	Brad
19	Assemble circuitboard	5 days	Fri 4/1/11	Thu 4/7/11	Tom
20	Integrate fan into housing	3 days	Fri 4/1/11	Tue 4/5/11	Jared
21	Test integrated fan-bypass assembly	3 days	Wed 4/6/11	Fri 4/8/11	Jared
22	Integreate thermal subsystem into	3 days	Mon 4/11/11	Wed 4/13/11	Jeff/Brad
23	Test integrated fan-thermal assembly	3 days	Wed 4/13/11	Fri 4/15/11	Jeff/Brad
24	Integrate electronics	3 days	Mon 4/18/11	Wed 4/20/11	Tom/Fahad
25	Test fully integrated system	5 days	Thu 4/21/11	Wed 4/27/11	Jared
26	Integrate into stove	2 days	Thu 4/28/11	Fri 4/29/11	Jared
27	Test fan-stove system	3 days	Mon 5/2/11	Wed 5/4/11	Jared
28	Write plan to apply to P11461 stove	4 days	Mon 5/9/11	Thu 5/12/11	Brad
29	Document Test results	30 days	Mon 3/14/11	Fri 4/22/11	Brad
30	Create Poster	13 days	Wed 4/20/11	Fri 5/6/11	Jared
31	Write Paper	10 days	Mon 5/9/11	Fri 5/20/11	Jared
32	Keep EDGE up-to-date	55 days	Mon 3/7/11	Fri 5/20/11	Jared



Engineering Analysis

Divided into two sections: Mechanical Analyses and Electrical Analyses

Mechanical Analyses:

Main goal of analyses is to size several components:

- Heat conduction beam
- Heat sink
- Fan
- Housing
- Bypass scoop

Steps necessary to size components:

- Characterize overall heat transfer rate of fire to beam
- Characterize current impedance of stove
- Understand effect of flow rate variation on heating of pot

Final Sizing:

Heat conduction beam	--	0.5” X 2.75” X 6.94”		
Heat sink	--	3.15” X 4” X 2.875”	7 Fins	
Fan	--	80 X 80 X 25 mm	Max CFM: 41	Max ΔP: 0.23 inH2O
Housing	--	3.15” X 3.15” Duct	Thermal, Electrical, and Bypass system attached	
Bypass scoop	--	2.75” X 3.55”	Attached at base to 0.25” rod	

Overall Heat Transfer Coefficient Determination

A test was conducted to determine the U value for fire. This test was necessary due to the lack of information characterizing the heat transfer behavior of a fire. The test was based on the amount of energy transferred through a known and perfectly insulated distance in a rod of known material. For this test a rectangular piece of 1018 steel was used and the temperature difference over a 2 inch nearly perfectly insulated section was taken to determine energy flux. This allowed for a quantification of the energy transferred to the rod with the equations below. The method of calculations was similar to that used for the sizing of the beam, with the difference coming from rearranging the formula to solve for h.

$$q = \frac{-k(T_B - T_H)A}{\Delta x}$$

Conductive heat equations used for perfectly insulated rod section

$$q = M\tanh(mL_c)$$

Adiabatic tip condition used for fin calculation

$$m = \sqrt{UPkA_c} * \theta_b$$

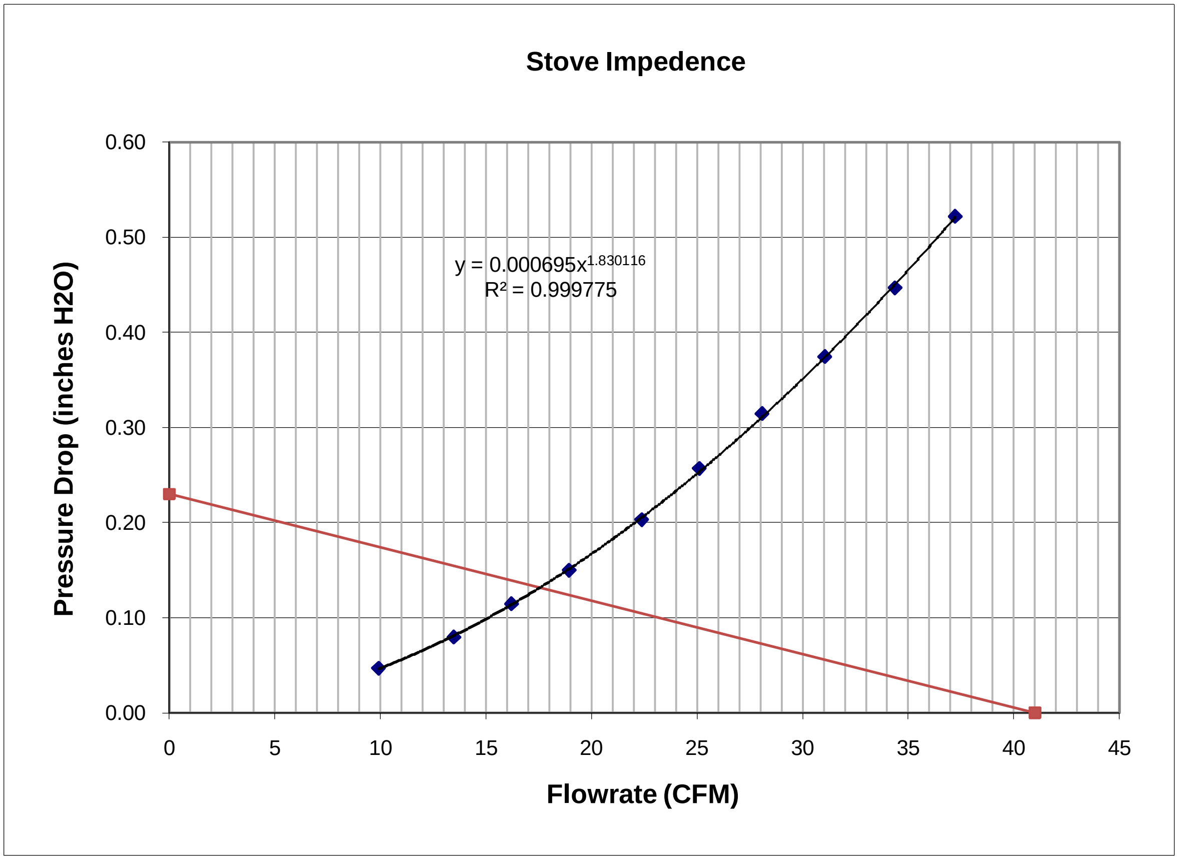
Equation where U was made a variable and solved for

Rod Length (m):	0.132
Rod CSA (m^2):	0.0006048
1018 CRS (W/mK):	51.9
Length between TC (m):	0.0508
Resistance of TC section (C/W):	1.6183952
Length of Rod between walls(m):	0.0254
T Fire (Deg C):	750
Rod Thickness (m):	0.01905
Rod Width (m):	0.03175
Perimeter (m):	0.1016
Lc (m)	0.141525

Delta T (Deg K)	Location of Charcoal	Hot TC (Deg C)	Cold TC (Deg C)	Q (W)	Approx. Tbase (Deg C)	U (W/m^2K)
97.00	close to bottom of stove	358.00	261.00	59.94	406.50	16.2
120.00	at rod	380.00	260.00	74.15	440.00	24.8
141.00	one inch above rod	431.00	290.00	87.12	501.50	44.2

Pressure Drop through Stove System

A test was performed to analyze the pressure drop needed across the fan to provide the proper airflow to the combustion chamber. The first generation stove was used for this test. A pressure tap was inserted into the wall of the inlet section of the stove to measure the pressure of the air just before it enters the combustion chamber. The fan speed was varied to alter the flow rate and pressure measurements were taken with a pressure sensor. Due to the limited number of holes for airflow, the pressure increased much quicker than originally expected. The conclusion drawn from this test was the need for either a lower flow rate or more holes in the stove to increase the flow and lower the pressure.



*Red Line approximates the current fan capacity

Flow Rate Considerations

A water boil test was performed to better understand the added effect of the forced air. The time for 2 Liters of water to boil was recorded at 3 different flow rates: 20, 30, and 40 CFM. Before the tests were run the stove was run for 20 minutes to allow it to reach a thermal steady state.

Water Temp (°F)	Flow Rate (CFM)	Time to boil (min)
51.1	20	3:54
48.6	30	3:15
50.9	40	3:13

Beam Sizing Sizing Calculations

$$q = \frac{-k(T_B - T_H)A}{\Delta x}$$

Used for calculating heat loss on the rod section that penetrates the stove wall

$$M^2 = \frac{hP}{kA_c}$$

$$q = Mtanh(mL_c)$$

Adiabatic tip condition for fin calculation, used in sizing the heat harvesting devices

$$m = \sqrt{hPkA_c} * \theta_b$$

$$L_c = L + \delta$$

Corrected length to account for area of the fin tip

$$\delta = \frac{t}{2}$$

Factor for corrected length

$$R = \frac{(T_b - T_\infty)}{q}$$

Thermal resistance equation used to back out size feasibility

$$R = thermal\ resistance$$

$$k = thermal\ conductivity\ constant$$

$$h = heat\ transfer\ coefficient$$

$$P = perimeter$$

$$A_c = cross\ sectional\ area$$

$$\theta_b = temperature\ difference$$

$$\theta_b = T_b - T_\infty$$

$$q = 130w$$

$$h = 30.2\ \frac{w}{m^2 * K}(Fire)$$

$$T_H = 300℃$$

$$k = 51.2\ \frac{w}{m * K}(Steel)$$

$$T_\infty = 900℃$$

$$T_H = temperature\ of\ TE\ hot\ side\ interface$$

$$q = heat\ energy\ transfered$$

To size our thermal energy harvesting apparatus we assumed adiabatic tip condition and moved forward. This assumption allowed for the base equation to be used in our analysis. To start, the heat loss through conduction in the section between the inner and outer stove was calculated assuming perfect insulation allowing us to find a temperature at the inner wall needed to maintain a 300 degree Celsius temperature at the thermal electric. The temperature at the stove wall was used to size out ruler shaped steel beam to conduct the heat energy into the thermal electric. Using Matlab a program was constructed to first calculate the temp at the inner wall of the stove and them vary both length of the beam and width given a user defined thickness. This allowed the optimum sizes to be obtained for each individual length.

Heat Sink Sizing Calculations

In order to calculate the heat transfer characteristics of the heat sink the convection coefficient (h) must be calculated. The flow between the fins of the heat sink will the modeled as internal, fully developed flow.

$$h = .023(Re)^{\frac{4}{5}}(\mathrm{Pr})^{0.3} \qquad \text{For air at STP Pr=.707}$$

In order to use this equation the Reynolds number for the flow across our heat sink must be calculated.

$$Re_D = \frac{4\dot{m}}{\pi D_h \mu}$$

Hydraulic diameter is calculated as such:

$$D_h = \frac{4A_c}{P} = \frac{4(6.45E^{-4})}{.1372} = .0188\text{m}$$

For flow rate:

$$20\text{ CFM} = 0.730\text{ kg/min} = .0122\text{ kg/s} = \frac{.0122\ kg/s}{7\ (channels)} = .00174\text{ kg/s}$$

The Reynolds number can now be calculated.

$$\mu = 208.2E^{-7}\ \text{N*s/m}^2$$

$$Re_D = \frac{4(.00174\frac{kg}{s})}{\pi(0.188\ m)\mu}$$

$$Re_D = 5660$$

Now that we have a Reynolds number the 'h' value can be calculated

$$h = .023(5660)^{\frac{4}{5}}(.707)^{0.3}$$

$$h = 20.85\ \frac{W}{m^2K}$$

The equations for calculating the thermal resistance of the heat sink are as follows:

Lc=L+(t/2)
Ap=t*L
Af=2*W*Lc
Ac=W*t

Ab=Total Area-(N*Ac)   (Area of the base)
At=(N*Af)+Ab

P=(2*W)+(2*t)

m=sqrt((h*P)/(K*Ac))

Nf=((tanh(m*Lc))/(m*Lc))

No=1-(((N*Af)/At)*(1-Nf))

The thermal resistance of the given heat sink is calculated as:

Rh=1/(No*h*At)

The proposed heat sink:

Fin height: 2.5 in.
Fin length: 4.0 in.
Fin thickness: 0.124 in.
Fin spacing: 0.400 in.
Fins: 7
Heat sink dimensions: 4 in. x 3.15 in.

R_T=0.52

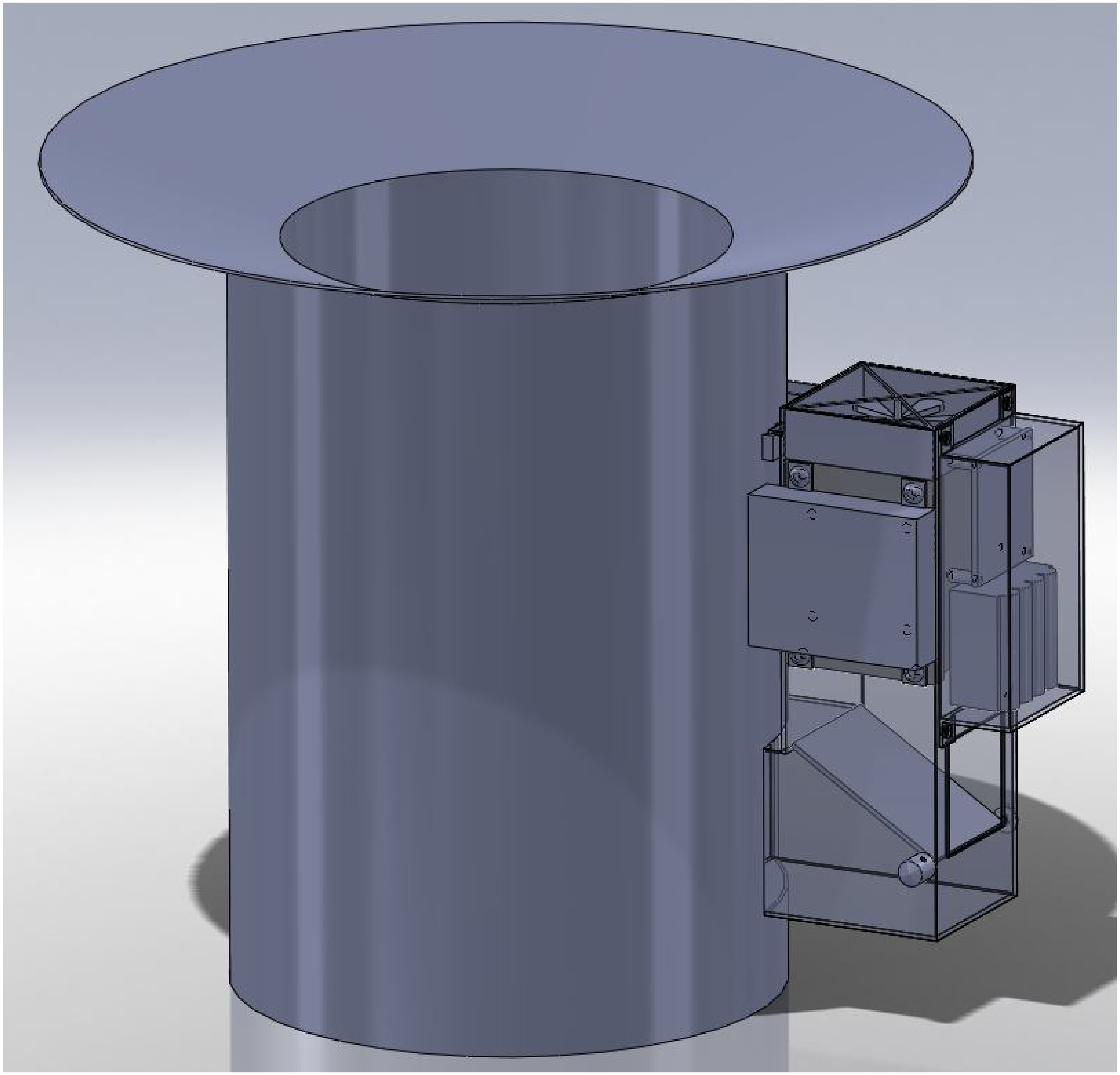
Additional Considerations

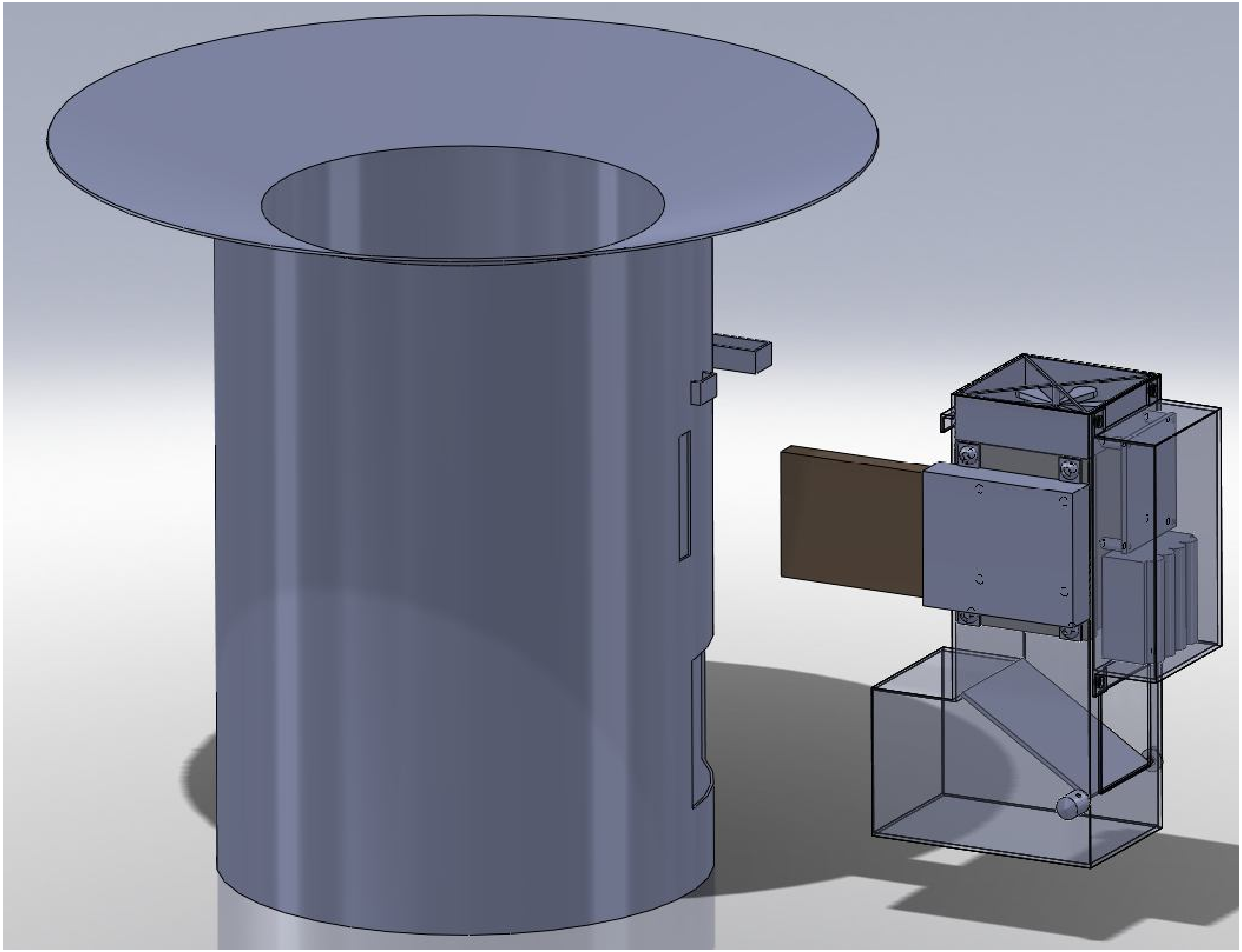
Based on a lumped capacitance analysis:

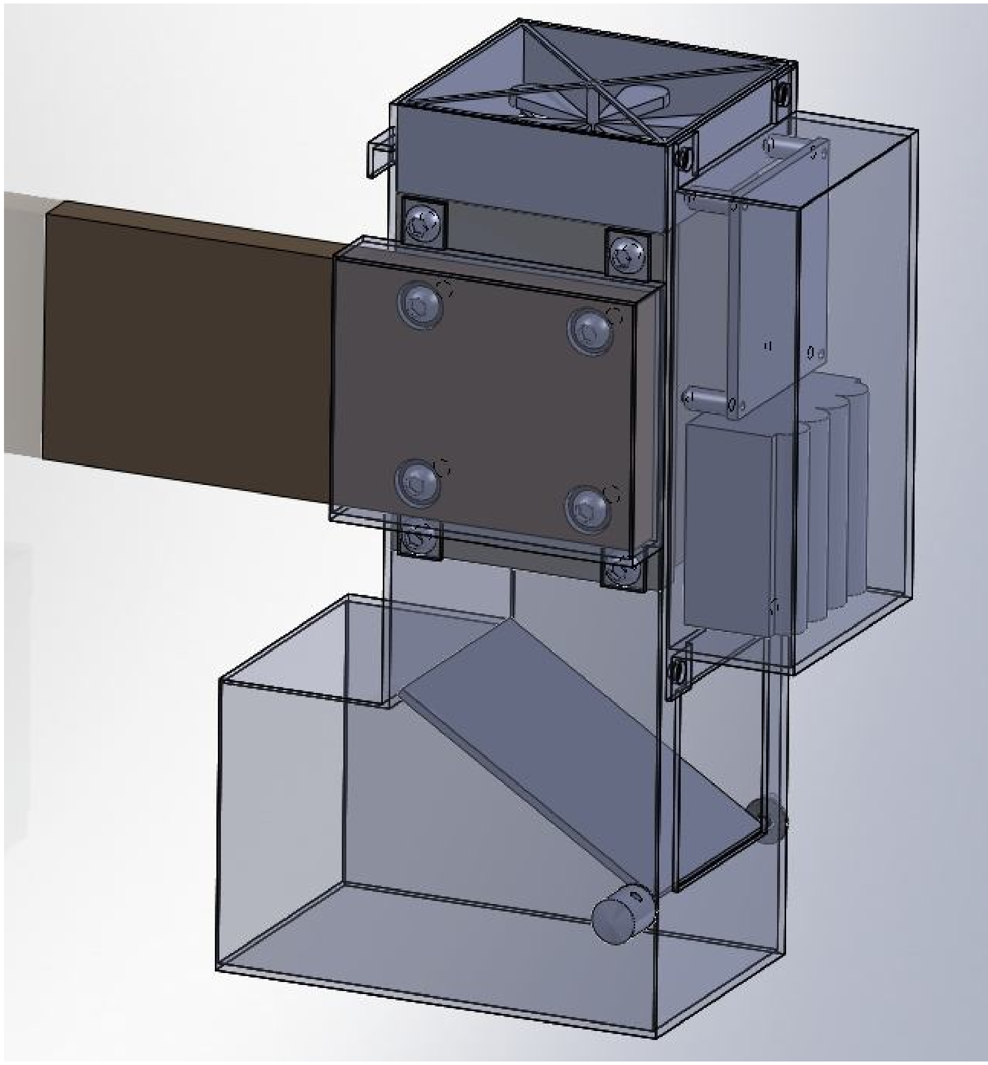
Time to reach a 300 deg C steady-state temperature – 10.42 min

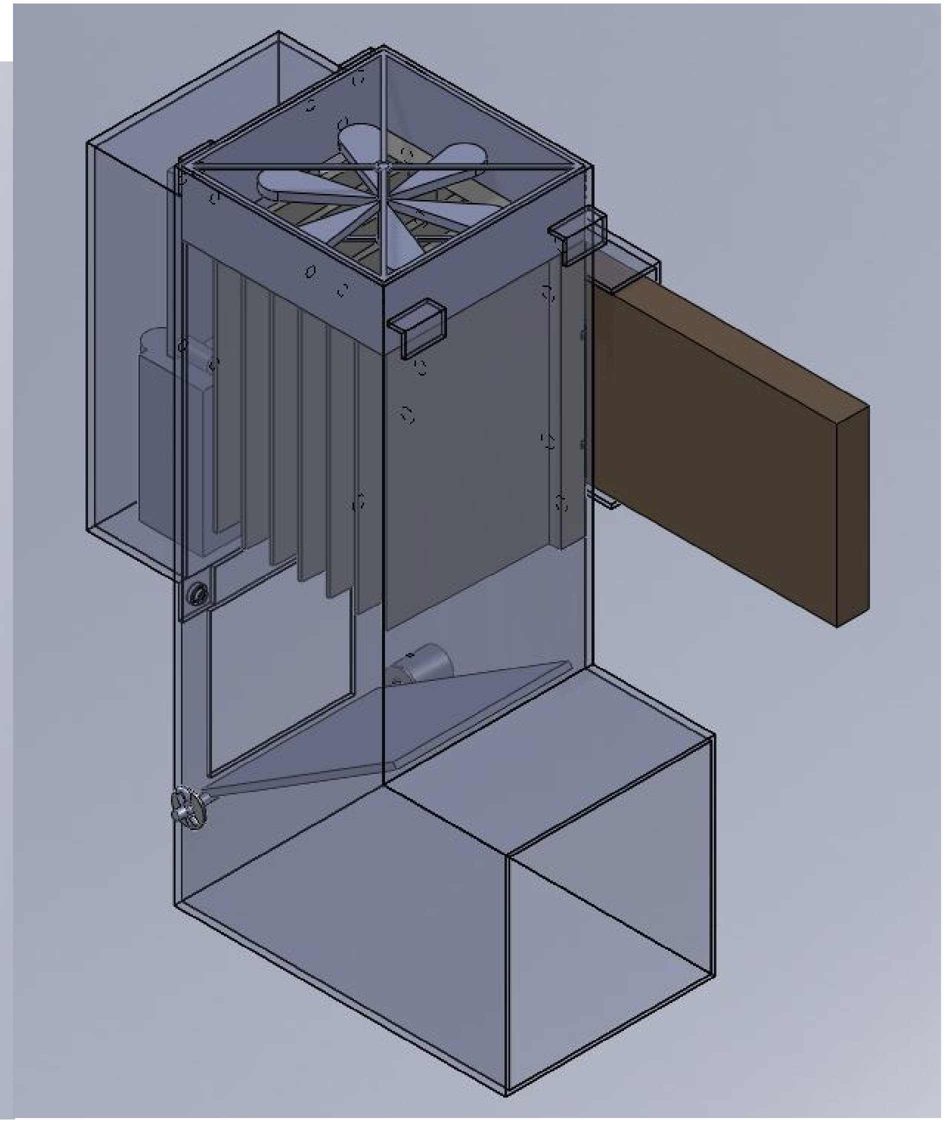
Variation of hot-side temperature of thermoelectric:

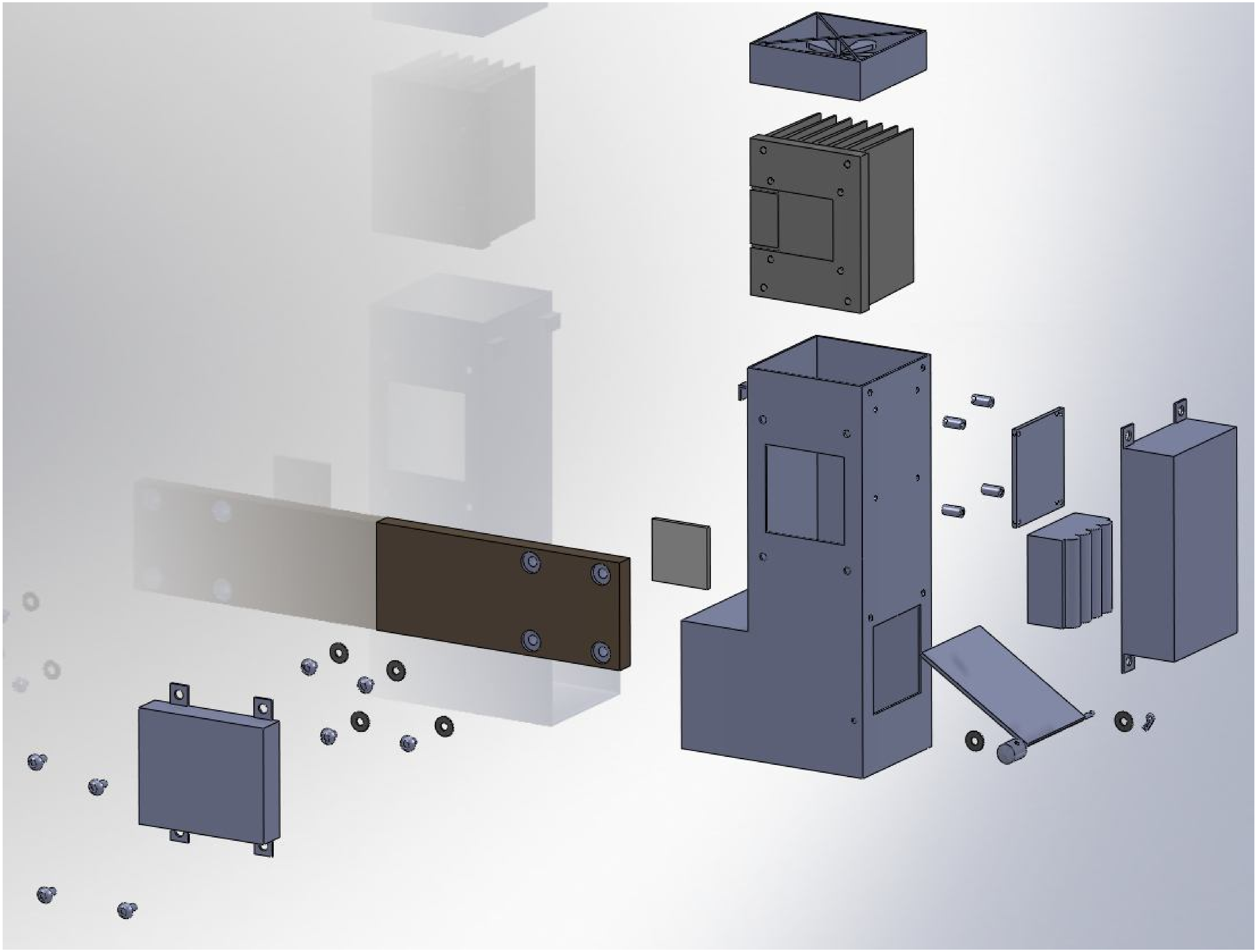
With low value of U = 24.2 W/m-K	--	190 deg C
With high value of U = 44.2 W/m-K	--	380 deg C
With low fire temp = 700 deg C	--	75 deg C
With high fire temp = 1100 deg C	--	475 deg C





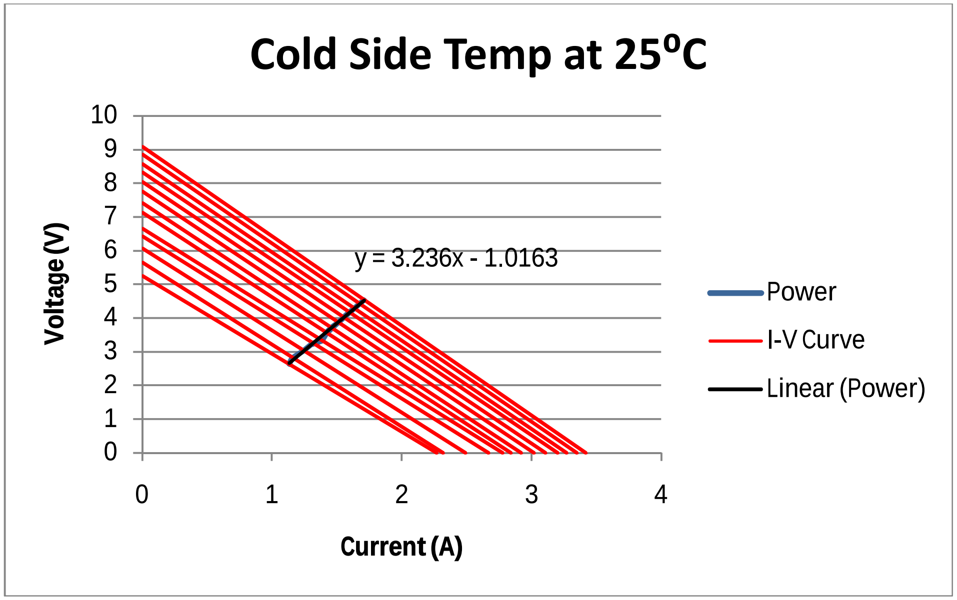


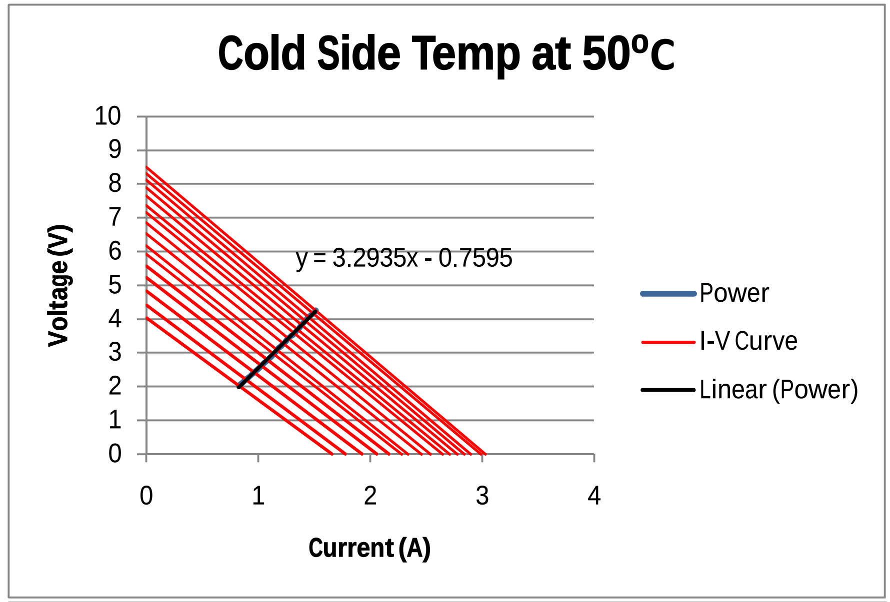


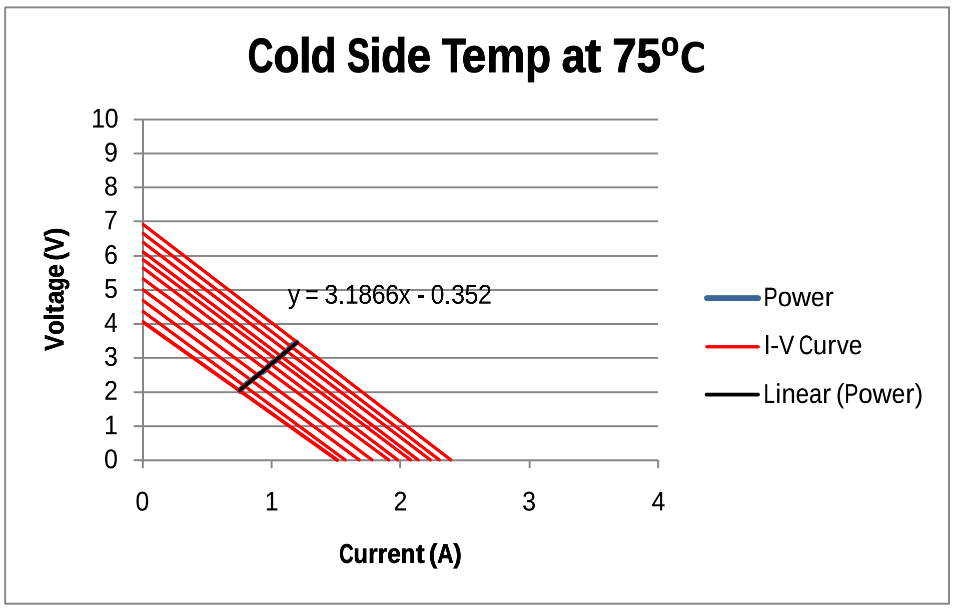


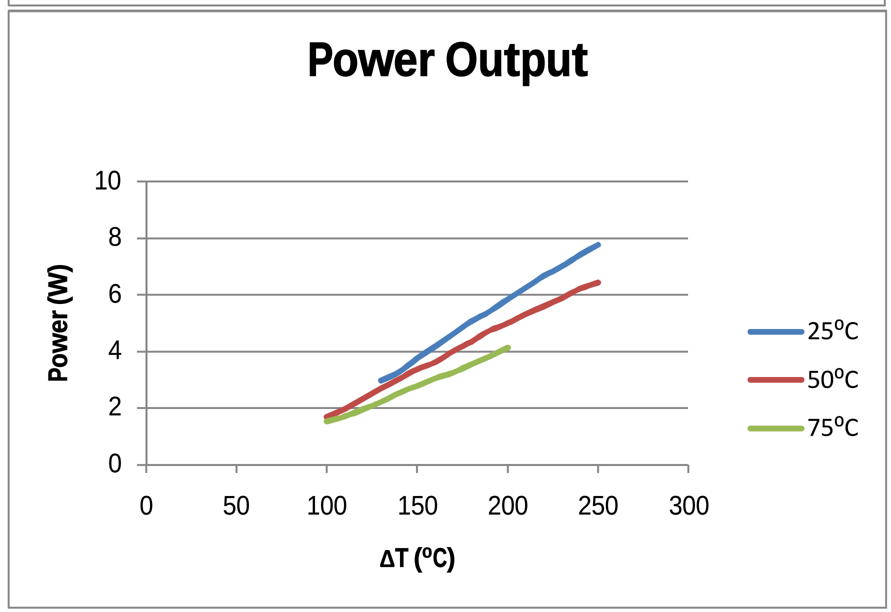
Electrical Analyses:

I-V and Power Curves



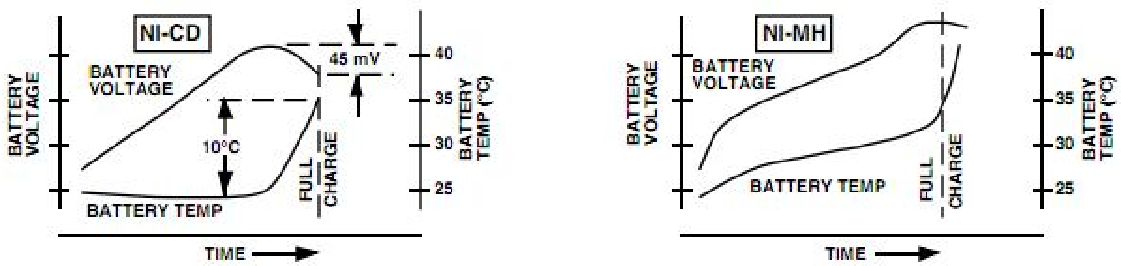






Battery Sizing Considerations

	NiMH	NiCd
Capacity (mAh)	1100-3000	500-1000
Energy Density (Wh/L)	140-300	50-150
Service Life (Figures from manufacturers)	Up to 1000 Cycles	Up to 750 Cycles

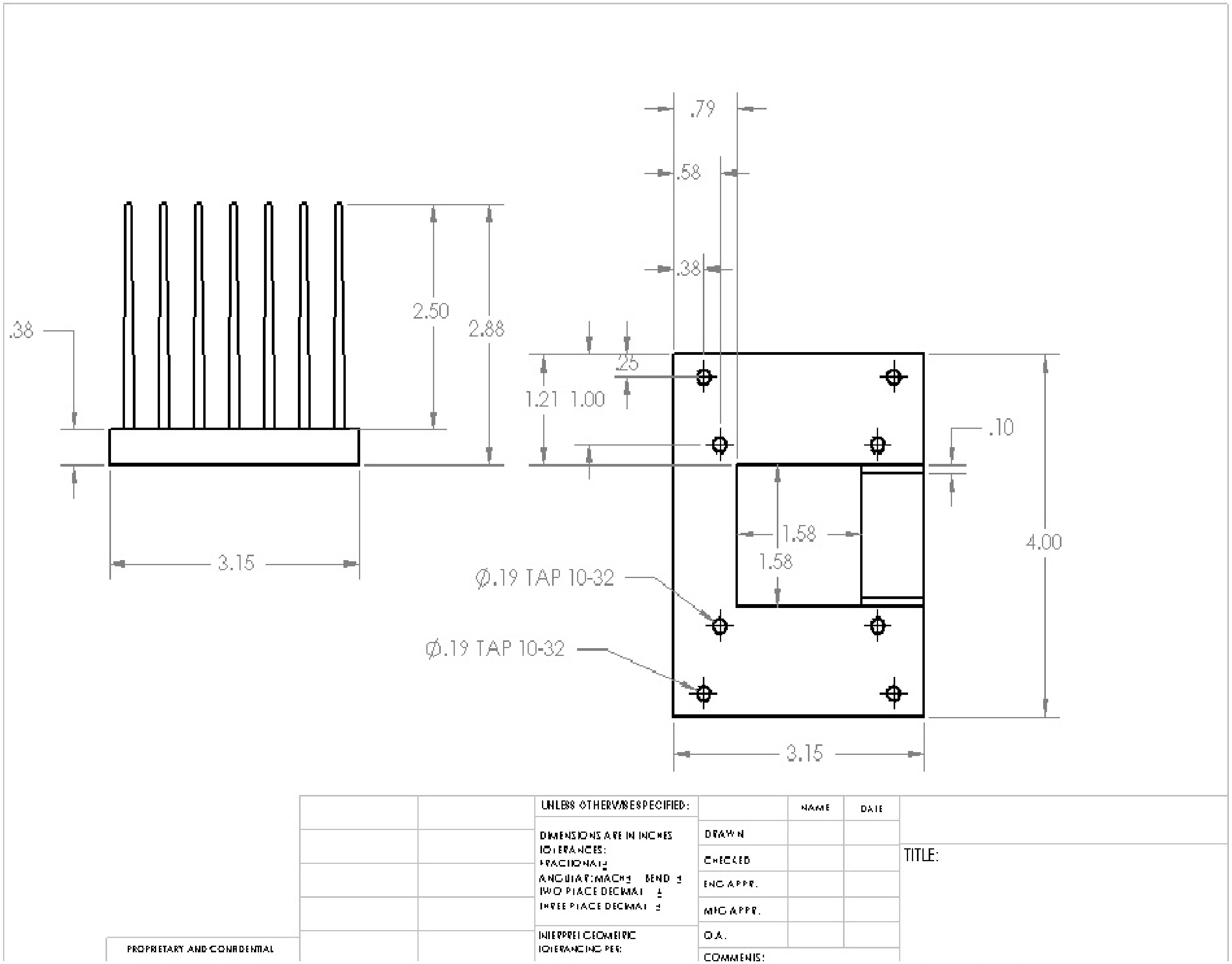


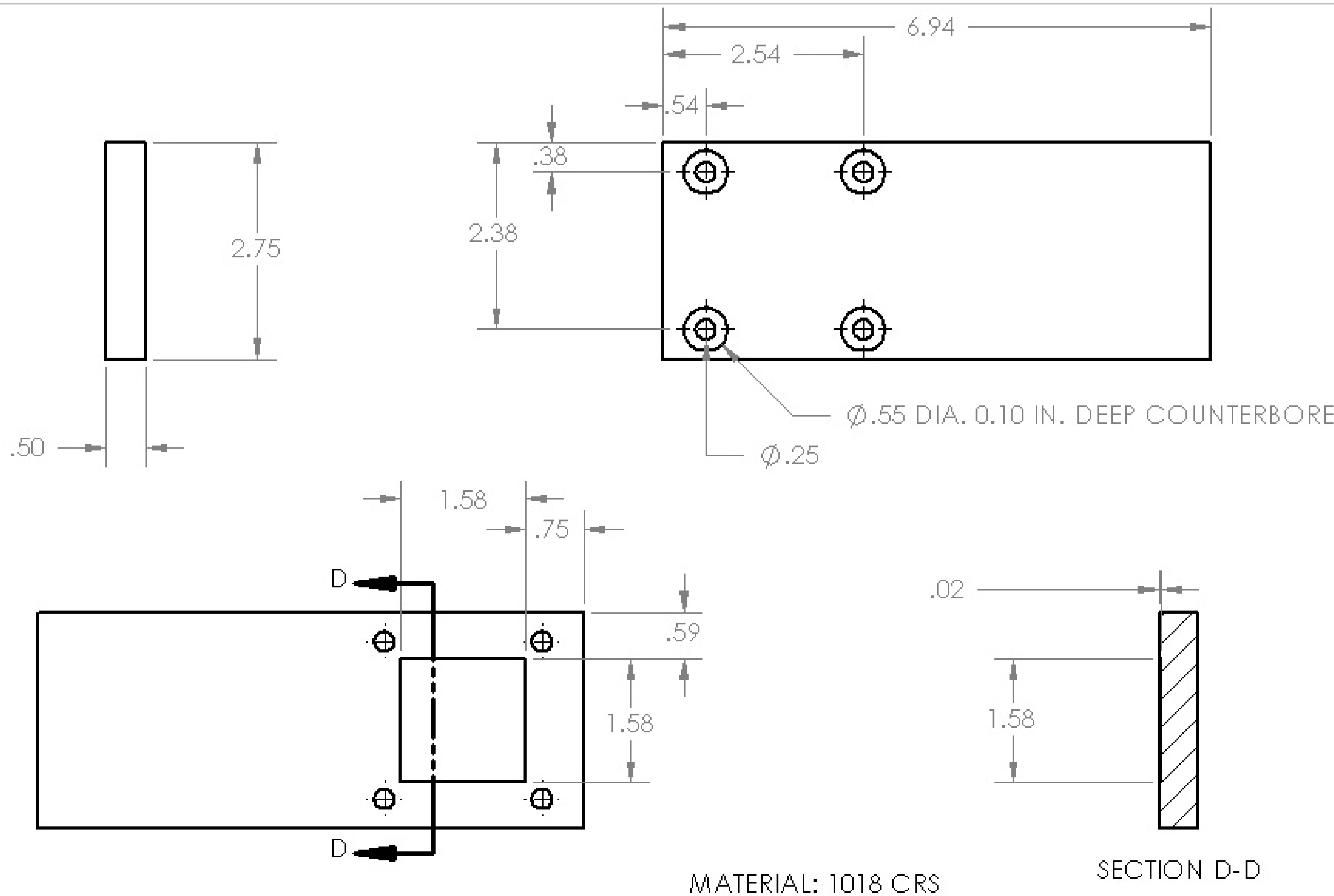
NiCd and NiMH voltage and temperature for 1C charge rate.

NiMH batteries are newer than NiCd batteries and are rapidly replacing NiCd batteries in consumer electronics. NiMH batteries are more environmentally friendly than NiCd batteries because they do not produce a toxic substance as they degrade. NiCd batteries have a longer shelf life as the self discharging rate for NiMH batteries is larger; however for our application this has little effect. For these reasons and because NiMH batteries are cheaper than NiCd batteries, we have chosen to move forward using NiMH batteries. To satisfy our customer’s needs we will use five AA cells; two for the fan and three for the auxiliary devices. However, as we move forward we must keep in mind that overcharging can make the NiMH battery volatile so we might possibly need to implement an intelligent charging system.

Detailed Drawings and Schematics

MECHANICAL DRAWINGS





MATERIAL: 1018 CRS

		UNLESS OTHERWISE SPECIFIED:		NAME	DATE
		DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN		
			CHECKED		
			ENG APPR.		
			MFG APPR.		
		INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
		MATERIAL	COMMENTS:		
NEXT ASSY	USED ON	FINISH			
APPLICATION		DO NOT SCALE DRAWING			

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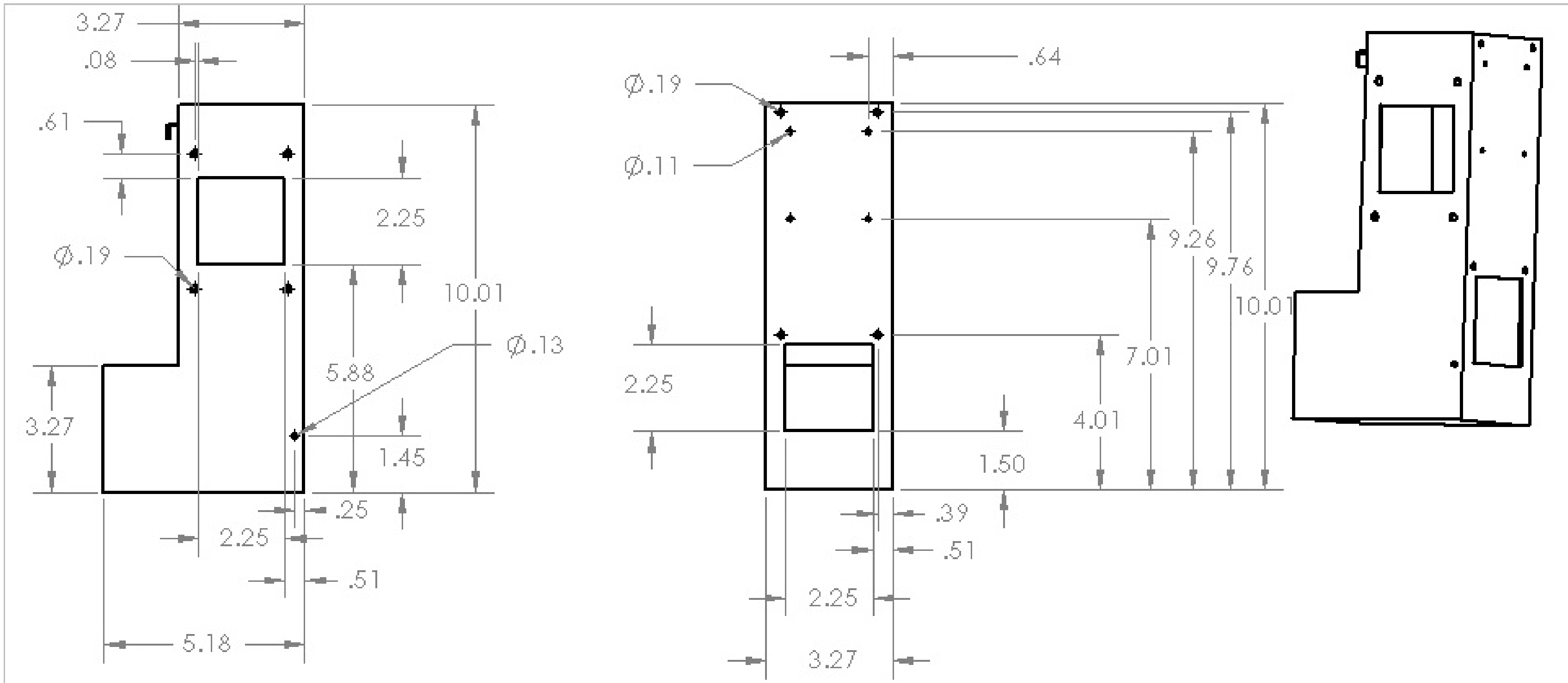
TITLE:

SIZE	DWG. NO.	REV
A	BDS_Ruler	

SCALE: 1:2	WEIGHT:	SHEET 1 OF 1

5 4 3 2 1



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NEXT ASSY	USED ON
APPLICATION	

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

FINISH

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

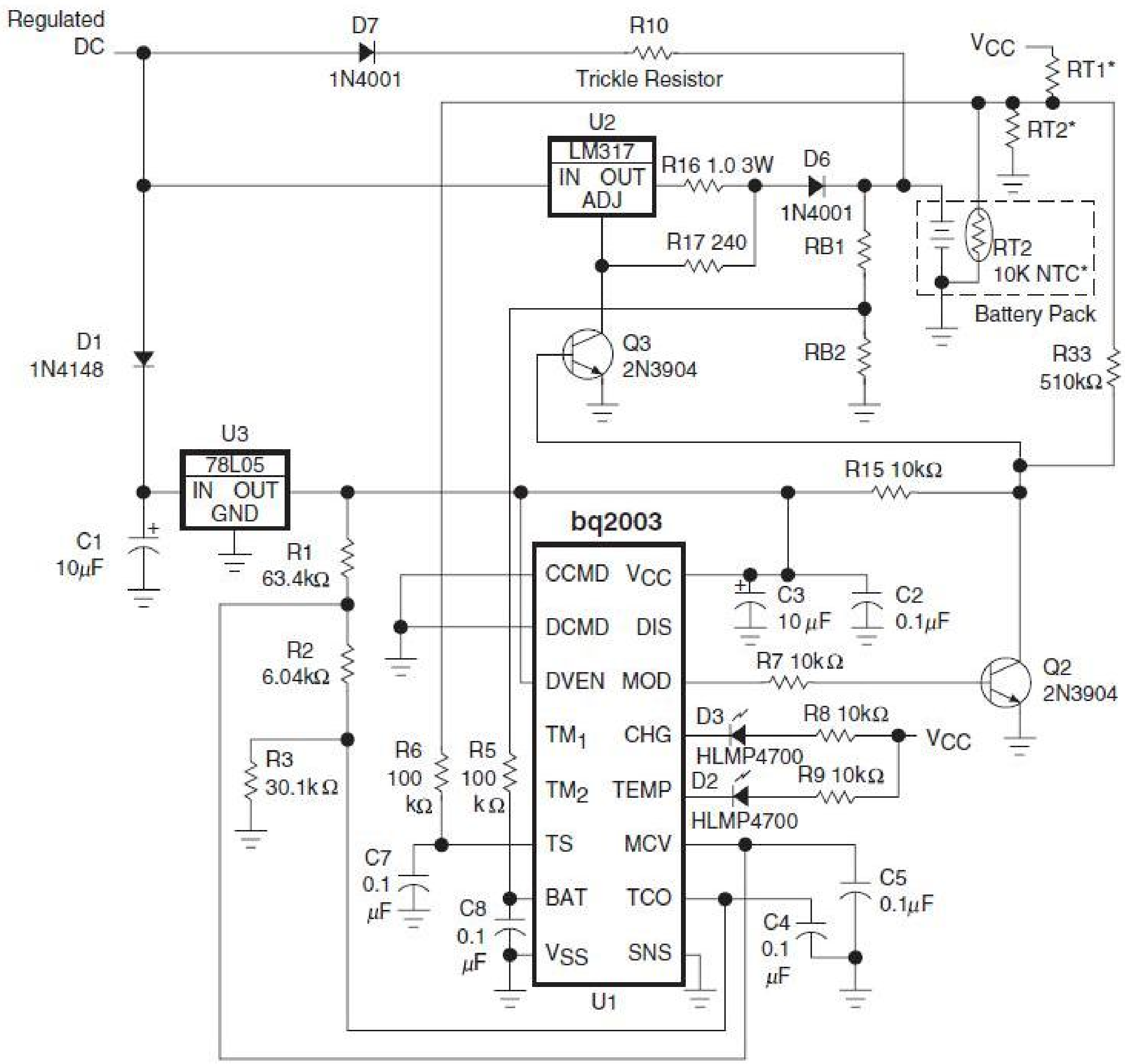
TITLE:

SIZE	DWG. NO.	REV
A	Housing_V3.0	

SCALE: 1:4	WEIGHT:	SHEET 1 OF 1

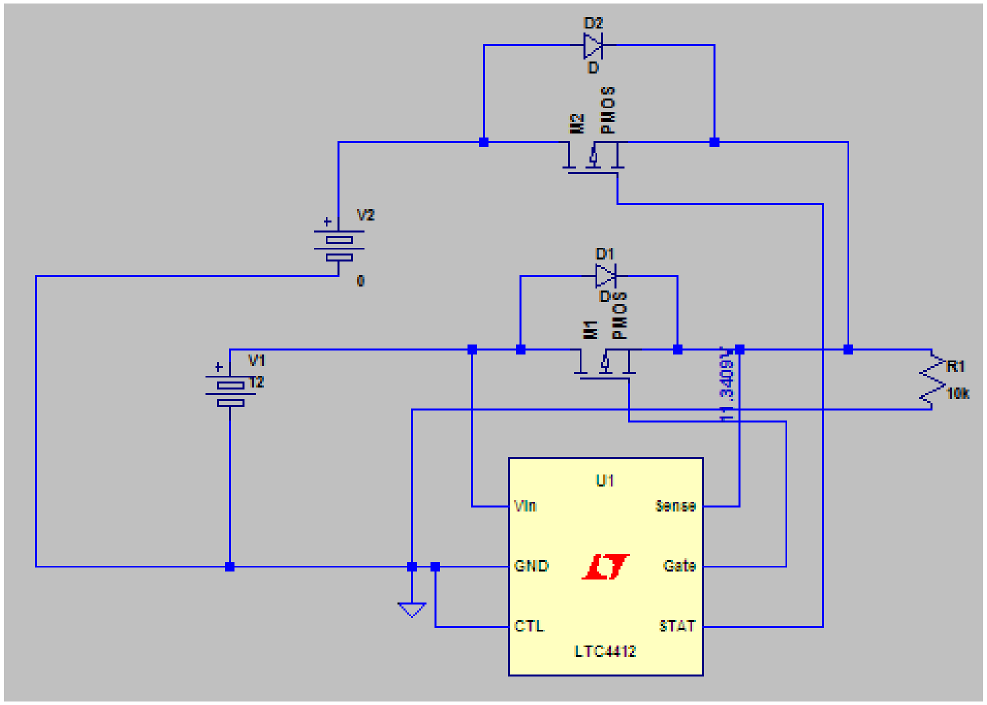
ELECTRICAL DRAWINGS

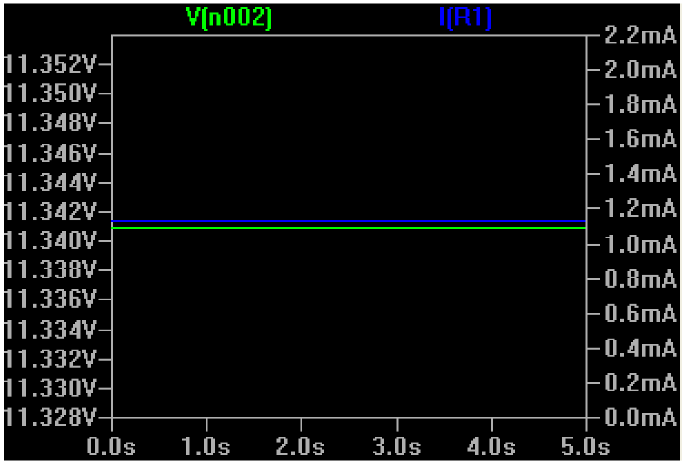
Electrical Charging Schematic – With Trickle Charge and Thermal Detector



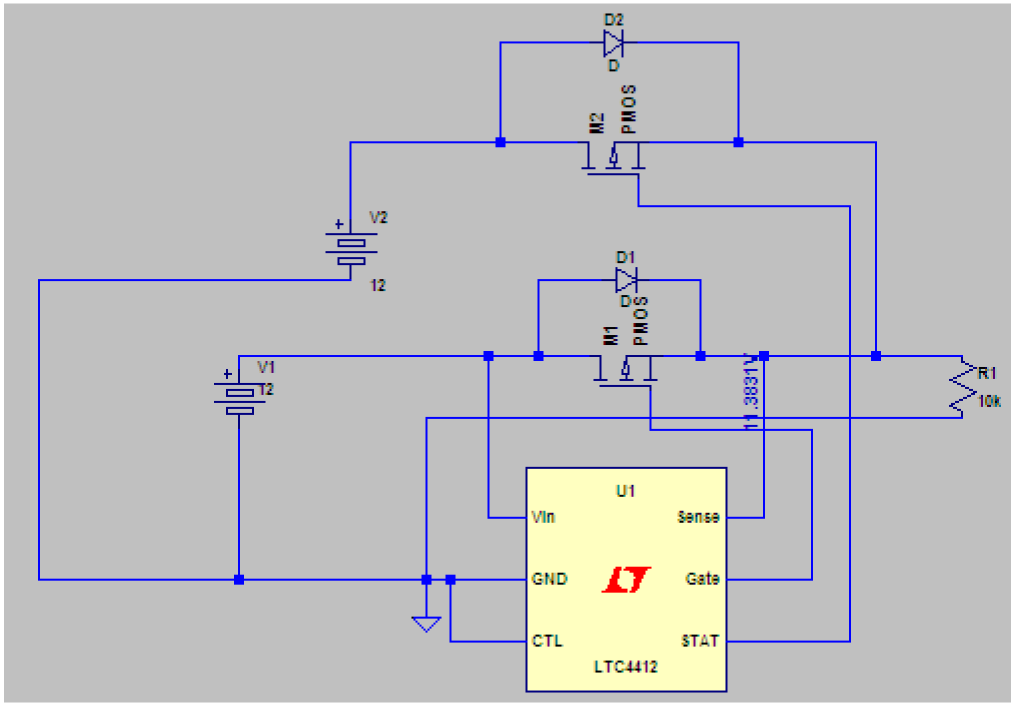
Power Source Switching Schematic

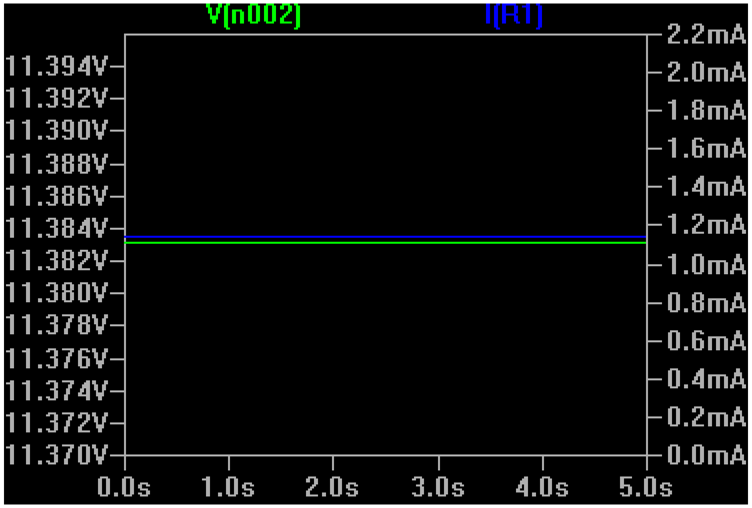
Schematic and Capture of Battery Running with TEG OFF (Fan Powered by Battery)



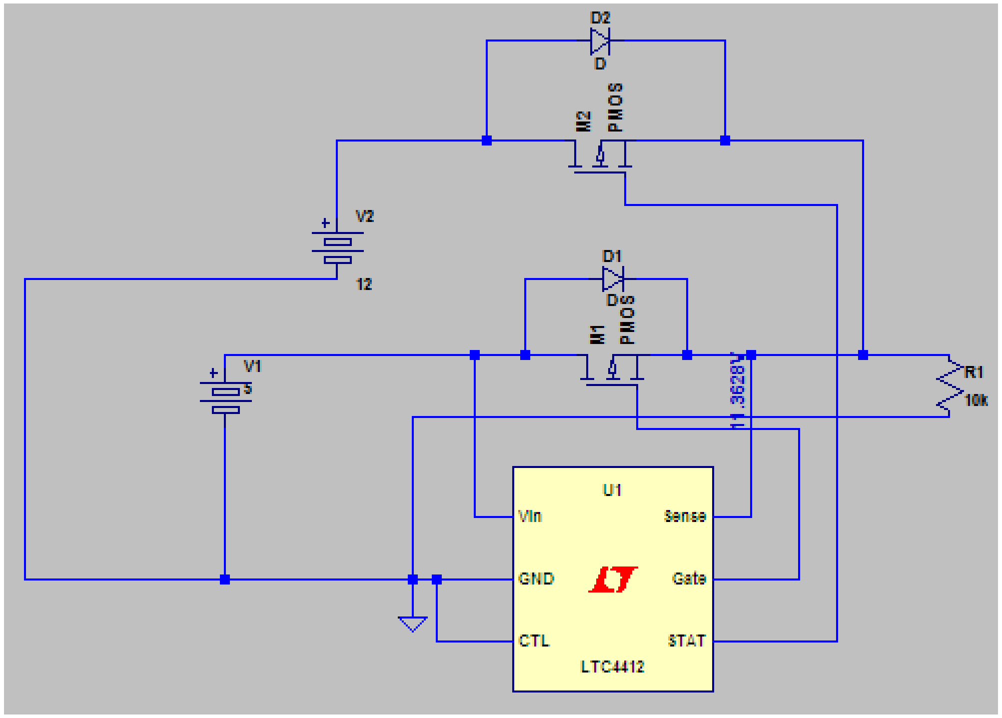


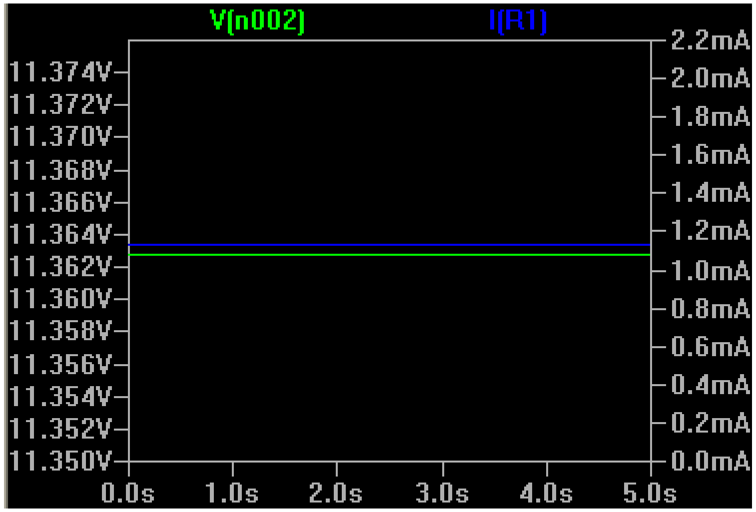
Schematic and Capture of Battery and TEG ON (Fan Powered by TEG)



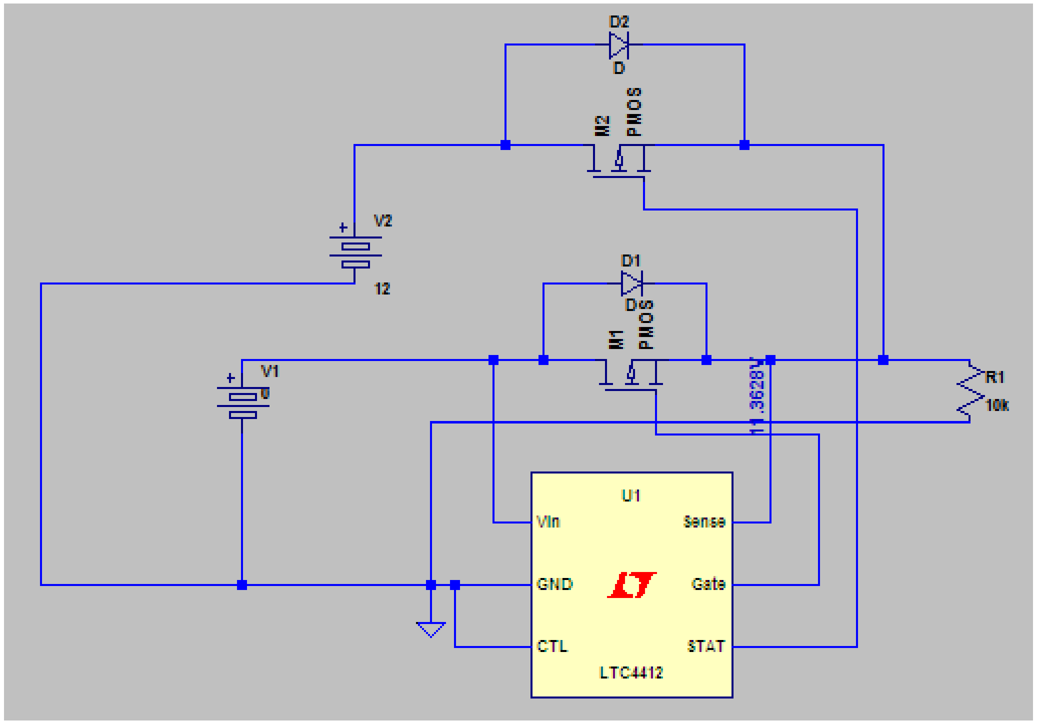


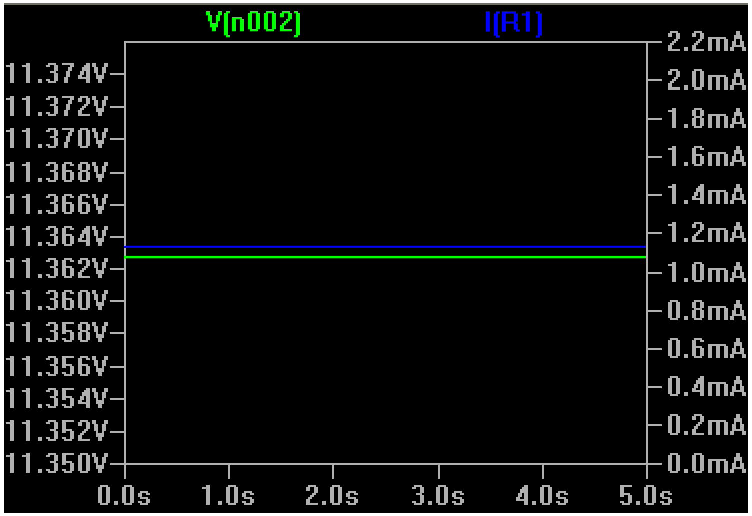
Schematic and Capture of Battery Partially Drained and TEG ON (Fan Powered by TEG)



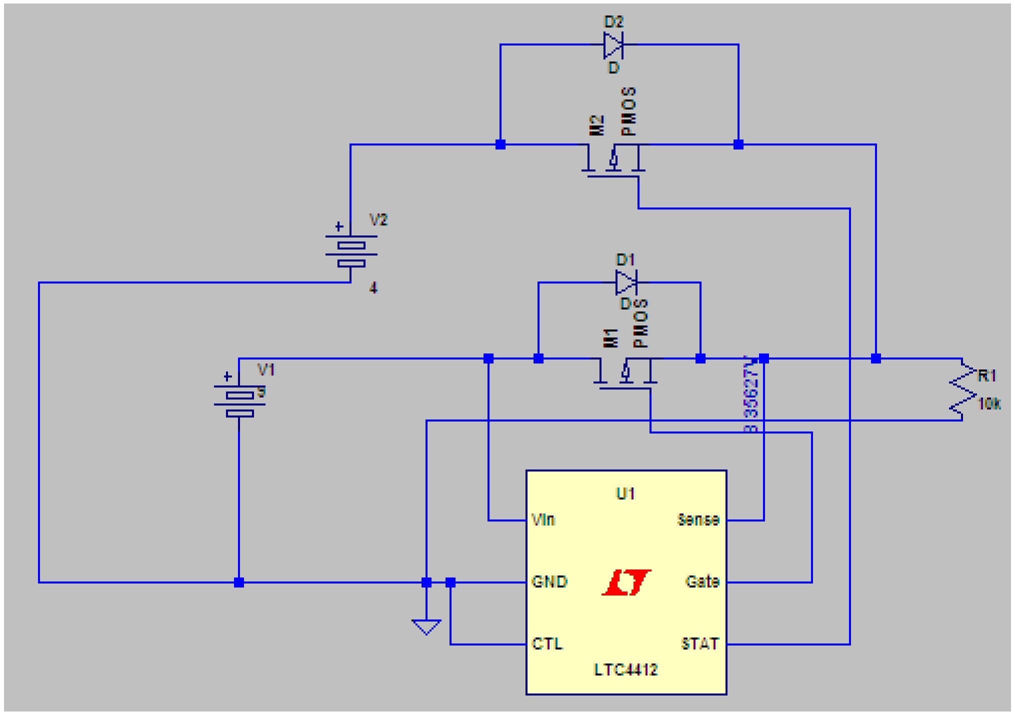


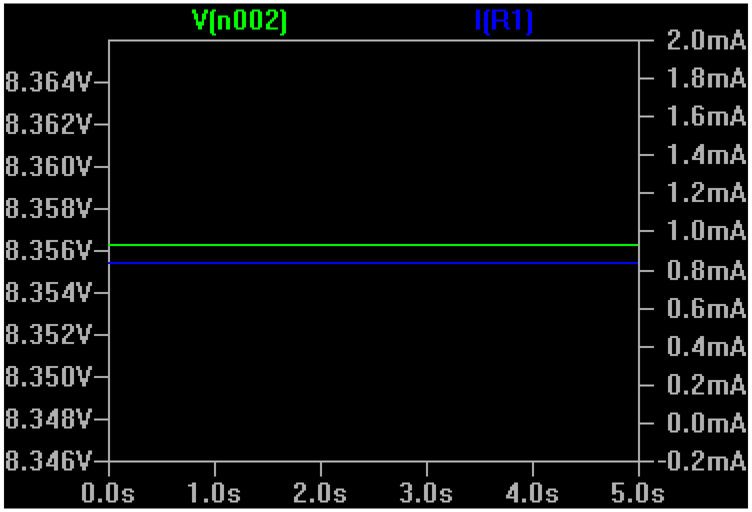
Schematic and Capture of Battery Fully Drained and TEG ON (Fan Powered by TEG)



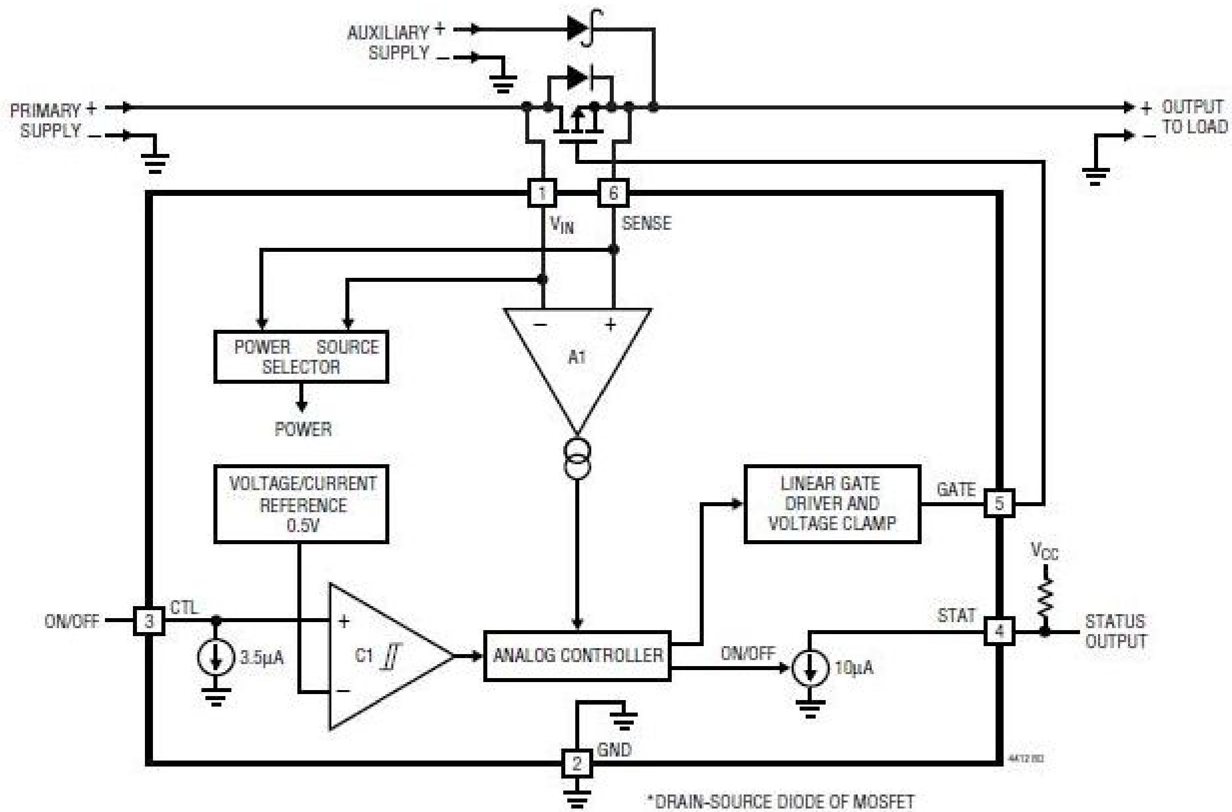


Schematic of Battery Partially Drained and TEG Powering Up (Fan Powered from Battery)





Internal Block Diagram of LTC4412



Bill of Materials
Team: P11462
Revision: 1

	Item	Part Description	Supplier	Part #	Quantity	Prototype Unit Price	Prototype Total Price	Prototype As Used	10,000 Unit Lot Unit Price	10,000 Unit Lot Total Price	Lead Time	Owner	Status	Comments
Mechanical	1	Beam Material (0.5x2.75x12 1018CRS)	McMaster	8910K961	1	$22.44	$22.44	$13.09		$0.00	2 weeks	Jeff		
	2	Heat Sink	Heatsink USA	E004	1	$16.33	$16.33	$5.44		$0.00	2 weeks	Brad		
	3	10-32 Cap Screw (.75 in. long) (Pack of 25)	McMaster	91355A079	1	$8.31	$8.31	$3.99		$0.00	2 weeks	Brad		
	4	Thermal Blanket (24" x 25' x 1/8")	Cotronics Corp	370-1	1	$79.95	$79.95	$0.00		$0.00	4 weeks	Jared		
	5	18 gauge sheet metal	SMC Metal		1		$0.00	$0.00		$0.00	4 weeks	Brad		
	6	Fan	Allied Electronics	997-0881	1	$4.20	$4.20	$4.20		$0.00	2 weeks	Jared		
	7	Thermal Paste	AOS Technologies	52039 (XT-3)			$0.00	$0.00		$0.00	3 weeks	Jeff		
			Timtronics	Red Ice 611			$0.00	$0.00		$0.00	2 weeks	Jeff		
	8	Stainless Steel Washers (Per 100)	McMaster	90313A200	1	$6.89	$6.89	$0.48		$0.00	2 weeks	Brad		
	9	1/4 in. diameter rod (5 in. long)	McMaster	1327K115	1	$3.68	$3.68	$3.68		$0.00	2 weeks	Brad		
	10	Control Knob	McMaster	6094K88	1	$2.36	$2.36	$2.36		$0.00	2 weeks	Brad		
	11	Cotter Pin (.042 in. wire diameter - fits 1/4 shaft)	McMaster	98335A034	1	$5.17	$5.17	$0.05		$0.00	2 weeks	Brad		
	12	Spring - 1.25 in. long - 5.22 lb/in. (pack 12)	McMaster	9657K155	1	$6.58	$6.58	$0.55		$0.00	2 weeks	Brad		
	13	4-40 Cap Screw (.25 in. long) (Pack of 50)	McMaster	91306A311	1	$8.10	$8.10	$0.32		$0.00	2 weeks	Brad		
Electrical	1	Thermoelectric	China	TEP1-1264-1.5	1	$8.00	$8.00	$8.00	$8.00	$8.00	6 weeks	Tom		
	2	Rechargable AA Ni-MH Battery (4 pack)	Zeikos (Amazon.com)	ZE-4AA	2	$2.49	$4.98	$3.11	$2.49	$4.98	2 weeks	Fahad		
	3	Low Loss Power Path Controller	Linear Technology	LTC4412ES6#TR	1	$1.93	$1.93	$1.93	$1.36	$1.36	3 weeks	Tom		
	4	P channel MOSFET	Digikey	FDN306P	2	$0.55	$1.10	$1.10	$0.24	$0.49	2 weeks	Tom		
	5	Diode	Allied Electronics	1N914	2	$0.01	$0.03	$0.03	$0.01	$0.02	2 weeks	Tom		
	6	Capacitor 10µF 50V electrolytic	Rubycon	50YK10M5X11	1	$0.04	$0.04		$0.03	$0.03	2 weeks	Fahad		C1
	7	Capacitor 0.1µF ceramic	Vetco	SMBCAP-CER0603-0.1UF50V	5	$0.49	$2.45		$0.06	$0.30	2 weeks	Fahad		C2, C4, C5, C7, C8
	8	Capacitor 10µF 7V electrolytic			1		$0.00			$0.00	2 weeks	Fahad		C3
	9	Diode	Tayda	1N4148	1	$0.01	$0.01			$0.00	2 weeks	Fahad		D1
	10	HLMP 4700 red LED			2		$0.00			$0.00	2 weeks	Fahad		D2, D3
	11	Diode	Allied Electronics	1N5400	1	$0.09	$0.09		$0.05	$0.05	2 weeks	Fahad		D6
	12	Diode	Allied Electronics	1N4001	1	$0.08	$0.08		$0.03	$0.03	2 weeks	Fahad		D7
	13	NPN General Purpose Amplifier	Talon Electronics	2N3904	2	$0.09	$0.18		$0.06	$0.12	2 weeks	Fahad		Q2, Q3
	14	Resistor 63.4KΩ	Galco Industrial Electronics	RN55D6342F	1	$0.06	$0.06			$0.00	2 weeks	Fahad		R1
	15	Resistor 6.04KΩ	Galco Industrial Electronics	RN55D6041F	1	$0.06	$0.06			$0.00	2 weeks	Fahad		R2
	16	Resistor 30.1KΩ	Galco Industrial Electronics	RN55D3012F	1	$0.26	$0.26			$0.00	2 weeks	Fahad		R3
	17	Resistor 100KΩ (Qty 10)	Tayda	100K OHM 1/4W 5%	1	$0.10	$0.10	$0.02		$0.00	2 weeks	Fahad		R5, R6
	18	Resistor 10KΩ (Qty 10)	Tayda	10K OHM 1/4W 5%	1	$0.10	$0.10	$0.02		$0.00	2 weeks	Fahad		R7, R15
	19	Resistor 1.0KΩ	Jameco Electronics	CF1/2W102JRC	1	$3.00	$3.00	$0.03		$0.00	2 weeks	Fahad		R8, R9
	20	Resistor 2KΩ	Galco Industrial Electronics	2W-68K-5%-MO	1	$0.07	$0.07			$0.00	2 weeks	Fahad		R10
	21	Resistor 1Ω (Qty 10)	Tayda	1 OHM 1/4W 5%	1	$0.10	$0.10	$0.01		$0.00	2 weeks	Fahad		R16
	22	Resistor 240Ω (Qty 10)	Tayda	240 OHM 1/4W 5%	1	$0.10	$0.10	$0.01		$0.00	2 weeks	Fahad		R17
	23	Resistor 510 KΩ (Qty 10)	Tayda	510K OHM 1/4W 5%	1	$0.10	$0.10	$0.01		$0.00	2 weeks	Fahad		R33
	24	Resistor 562 KΩ	Newark	26R4203	1	$0.03	$0.03		$0.03	$0.03	2 weeks	Fahad		RB1
	25	Resistor 187 KΩ	Newark	01P3731	1	$0.05	$0.05		$0.03	$0.03	2 weeks	Fahad		RB2
	26	Keystone RL0703-5744-103-S1			1		$0.00			$0.00	2 weeks	Fahad		RT
	27	Resistor 3.57KΩ (Qty 100)	Jameco Electronics	MFR-25FRF-3K57	1	$0.90	$0.90		$0.80	$0.80	2 weeks	Fahad		RT1
	28	Resistor 2.67KΩ	Galco Industrial Electronics	RN55D2671F	1	$0.06	$0.06			$0.00	2 weeks	Fahad		RT2
	29	Fast Charge IC	Texas Instruments	bq2003	1		$0.00		$2.20	$2.20	3 weeks	Fahad		U1
	30	Voltage Regulator	Tayda	LM317T	1	$0.21	$0.21			$0.00	2 weeks	Fahad		U2
	31	Voltage Regulator	Newark	72K8848	1	$0.16	$0.16		$0.08	$0.08	2 weeks	Fahad		U3

	Prototype	10,000 Unit Lot
Sub Cost	$188.25	$18.51
Shipping:		
Tax		
Total Cost	$188.25	$18.51

Legend

(green)	**Ready to order**
(yellow)	**Know what needs to be done and have XX hrs of work**
(red)	**Do not know all info and estimate time is XX hrs.**

Test Plans

Engineering Spec 1: Flow rate of air entering the stove

The flow rate of air entering the stove between 0.3 and 0.7 kg/s and will be tested using a fan test rig and flow sensor to characterize the rate at which the fan is set to run.

Engineering Spec 2: Flow control settings

The flow control should have at least 2 settings for flow rates corresponding with boil and simmer. This will be a true or false condition base on the setting available on our unit.

Engineering Spec 3: Unit price

The unit price should be no greater than $27.50. This will be tested by summing the costs of all components with best estimated values based on 10,000 unit orders.

Engineering Spec 4: Coupling time with no tools

The unit will take no longer than 10 minutes to attach to the stove without the use of any tools. This will be tested by timing an untrained persons attachment time over a series of trials to ensure a person with no prior knowledge of the system can attach it in the allowed time.

Engineering Spec 5: Removal time with no tools

The unit must be able to be removed in under 10 minutes without the use of any tools. The test procedure for this will be the same as spec 4.

Engineering Spec 6: Product life span

The base unit without taking into account replaceable components will be able to function for 3 years. This will be tested through life cycle analysis due to the limited time available on this project.

Engineering Spec 7: Replacement component life span

Replaceable components in the unit shall function for a minimum of 1 year before needing replacement. This will be tested in the same way as spec 6. Estimates for MTBF for specific parts will be used.

Engineering Spec 8: Aux Charging

The unit shall provide power to charge and auxiliary device. The first section of the test will be composed of a true or false assessment of the unit’s ability to provide auxiliary power. If the statement proves true then the amount of power will be measured and compared to the target power requirements.

Engineering Spec 9: Battery Size

The unit shall be able to run the fan from a cold start to aid in initial lighting of the stove. This will be tested through trial runs with cold starting the stove.

Engineering Spec 10: Weight

The unit shall weight no more than 2.5 kilograms. This will be tested by simply weighing the final unit to assess the overall weight.

Engineering Spec 11: Volume

The volume of the unit shall not exceed 3000 cc. This will be tested by calculating the volume of the unit based on outer dimensions.

Engineering Spec 12: Time to reach peak performance

The unit shall reach predetermined peak performance within 15 minutes of the initial starting of the stove. This will be tested through trial runs cold starting the stove with the unit in place. Similar to spec 9

Engineering Spec 13: User actions during operational cycle

The unit shall require no more than 6 user interaction during the entire operational cycle. This will be tested through trials conducted with the working unit similar to spec 9 and 12.

Engineering Spec 14: User action to protect system

The unit shall not require any intervention by the user to protect the system from damage from normal operation. This will be tested through trial runs and assessing the stability of system through complete operational cycles.

Engineering Spec 15: Maximum temperature inside enclosure

The temperature inside the enclosure due to convection of ambient air and heat given off by electrical components shall not exceed 60 degrees Celsius. This will be tested through monitoring the temperature inside the enclosure during stove operation using thermocouples inserted into the chamber.

Engineering Spec 16: Maximum external temperature of housing

The external temperature of the unit shall not exceed 54 degrees Celsius. This will be tested using an infrared temperature sensor during the course of a test run to measure the external temperature of the unit.

Engineering Spec 17: Maximum temperature of the hot side of TEG

The hot side of the TEG shall not exceed 275 degrees Celsius. This will be tested through analysis as well as trial runs monitoring the temperature at the hot side of the thermoelectric to monitor for over temp. Temperatures will be assessed with thermocouples which will be inserted in a groove in the conducting apparatus and will be located between the conducting apparatus and TEG.

Next Steps

- Complete Charging Circuit
- Complete BOM
- Address action items from DDR
- Project Management Review
- Order Parts
- Start writing test plans