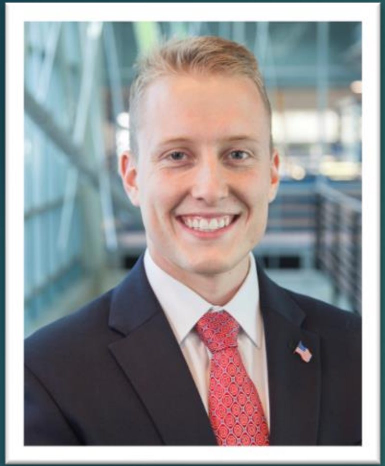
EML4551-2

Temperature-Sensitive Medication Storage for Natural Disasters

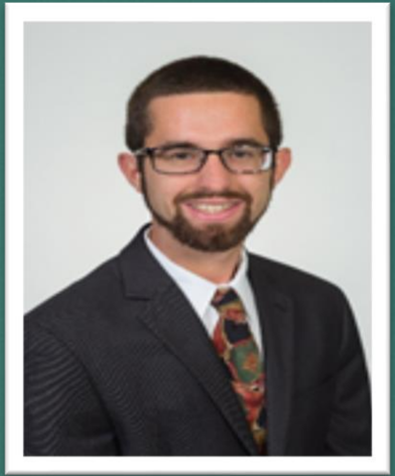
12-NOV-19

Meet the Team



Jesse Arrington
Design Engineer

Christian Torpey
Technical Engineer



Matthew Israel
Thermal Process Engineer

Tyler White
Energy Systems Engineer

Timothy Willms
Production Engineer

Sponsor

Tom Derzypolski
President of BowStern Marketing

- Florida State University graduate
- Bachelor's in Communications with an emphasis on Public Relations
- Decorated veteran of the U.S. Navy
- Member of:
  - Florida Public Relations Association
  - American Advertising Federation
  - Veterans of Foreign Wars

BowStern
MARKETING COMMUNICATIONS

Overview

- Project Brief Summary
- Targets and Metrics
- Concept Generation
- Concept Selection
- Bill of Materials
- Current Prototyping Efforts

Project Brief Summary

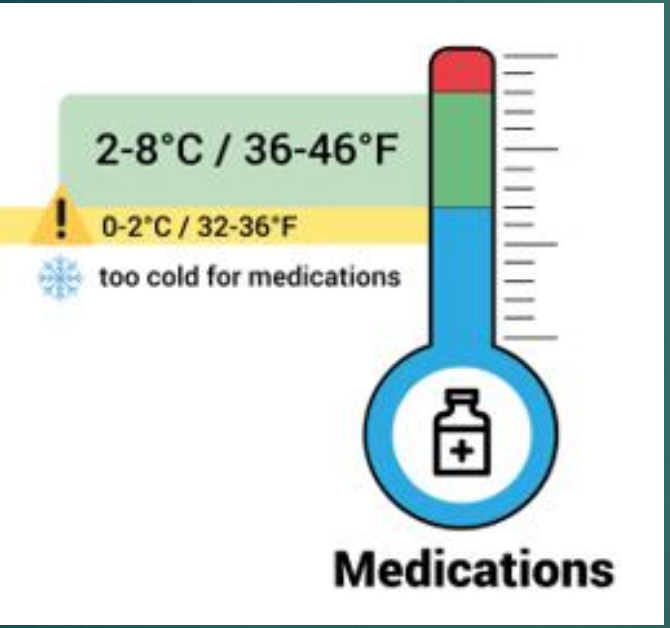
Objective

The objective of this project is to provide an affordable and accessible means to keep temperature sensitive medications cool during natural disasters and the days following.

Motivation

- Puerto Ricans were out of power for an average of 84 days following Hurricane Maria
- 46% spike in diabetes related deaths
- Inability to keep insulin medication chilled

Background Information



Medication	Storage Temperature Range (°C)
Insulin	2 - 8°C
Penicillin	3 - 15°C
Byetta	3 - 15°C
Victoza	3 - 15°C
Pulmozyme Nebuliser	2 - 8°C

Targets & Metrics

Targets & Metrics

Function	Metric	Target
* Receive Medication	* Medicine storage internal volume	* Height = 50mm Diameter = 22mm
	Wall thickness	Thickness <= 0.05m
	Total external size	Volume = 0.0625 - 0.25m³
* Eject Medication	* Dimensions for device that removes the medicatio n from the device body	* Height = 50mm Diameter = 22mm
* Secure Medication	* Number of medication vials broken	* Vial number = 0
	Impact resistance	Force = 27N
Convey device status	The user is notified whether the device is operating properly	Yes

Function	Metric	Target
Transfer power	Voltage	120V/240V outlets
Generate power	Voltage	1.5V, 9V, 3V, 3.7V
Store power	Voltage	1.5V, 9V, 3V, 3.7V
* Convert power	* Voltage	* 1.5V, 9V, 3V, 3.7V
* Supply power	* Voltage	* 1.5V, 9V, 3V, 3.7V
* Sense temperature	* Medication temperature	* T = 3.5-6 °C
* Rectify temperature	* Medication temperature	* T = 3.5 or 6 °C
	* Container cooling time	* Time <= 15 minutes
	* Cooling rate	50.97 mW/°C
Initiate cooling system	On/Off	On
Halt cooling system	On/Off	On
* Prevent heat transfer	* Net heat transfer rate going into and out of the container	* ΔQdot = 0W

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Team & Sponsor | Background | Targets & Metrics | Generation | Selection | Bill of Materials | Prototyping

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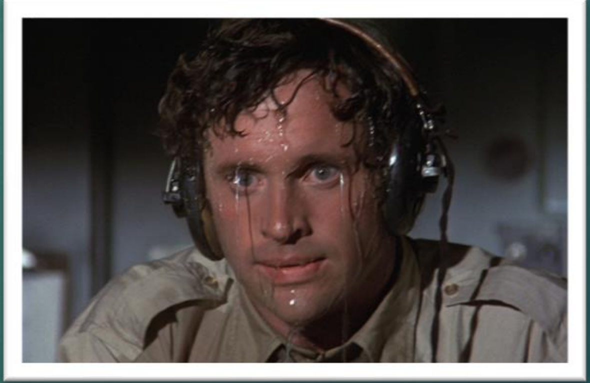
Concept Generation

Methods of Concept Generation

- Morphological Chart
- Biomimicry
  - Stegosaurus/Elephant – Cooling Fins
  - Tortoise – Protective Exoskeleton
  - Mammals – Evaporative Cooling through Sweating
  - Reptiles – Burying/Shade
  - Seals – Blubber Insulation
- Scamper List
- Total Concepts Generated > 900,000



Medium Fidelity Concept #1

- Liquid cooling system
  - Vials will be placed in sleeves with small tubes running throughout
  - Pumps circulate water/coolant through tubes
  - Water/coolant circulated through external fins for evaporative cooling
  - Internal volume of device will be evacuated with reasonable range to reduce convection
- Single, large internal rechargeable battery to power:
  - Pumps
  - Thermocouples
  - Microcontroller
- Integrated solar panels and hand cranks to charge battery

Medium Fidelity Concept #2

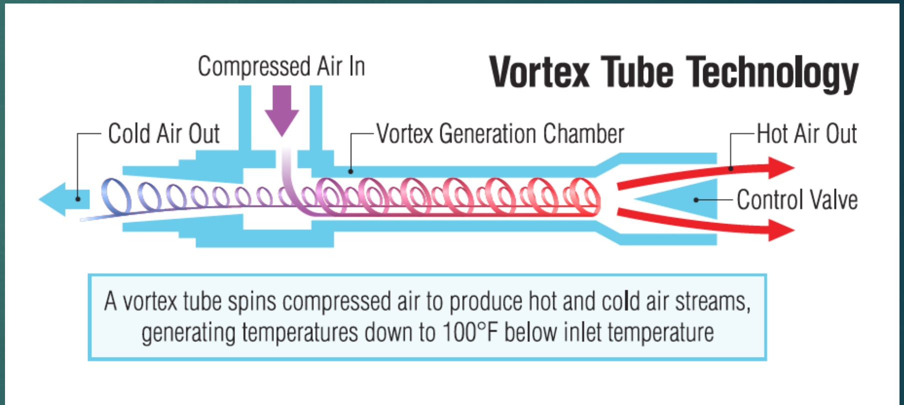
- Immersion cooling system
  - Coolant will be cooled to below normal system temperatures with incorporated cooling system
- Battery pack using conventional batteries to power:
  - Coolant cooling system (pump, condenser, compressor)
  - Temperature sensors
  - Microcontroller
- Conventional batteries will be cycled through
  - Charged while not in use using an external power generation source

Medium Fidelity Concept #3

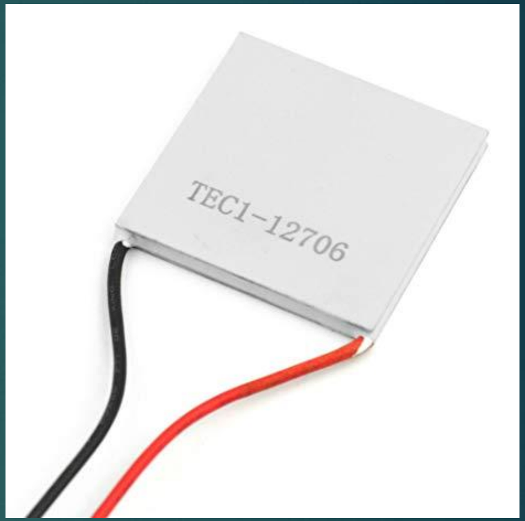
- Miniaturized refrigeration system
  - Evaporator, compressor, condenser, expansion valve
- Large, integrated solar panel array to power:
  - LCD display
  - Thermocouple
  - Microcontroller
  - Miniaturized refrigeration system
- Single, large internal battery to collect excess power from solar panel array
- Standard double-walled insulated cooler
  - Vials placed in individual padded protective sleeves
  - Vials kept in rigid mesh drawer which seals off internal volume from exterior when opened

Medium Fidelity Concept #4

- Ranque-Hilsch vortex tube cooling system
  - Device that separates compressed gas into hot and cold streams
  - Cold end inside the device, hot end outside the device
- Single, large, internal rechargeable lithium battery to power:
  - LCD display
  - Thermocouple
  - Microcontroller
  - Control valve
  - Compressor
- Cord to plug into various power generation sources
  - No integrated power generation
- Standard double-walled insulated cooler
  - Airtight locking cylinder for each vial



Medium Fidelity Concept #5



- Thermoelectric Cooling System (TEC)
  - Peltier effect: opposite of Seebeck effect
  - Induced current causes heat on one side and cooling on the other
- Single, large, external emergency battery to power:
  - LCD display
  - Thermocouple
  - Microcontroller
  - TEC system (TEC plate & fans)
- Large solar panel which is integrated into the external emergency battery
- Standard double-walled insulated cooler
  - Airtight locking cylinder for each vial
  - Each vial is held in place with zip-tie like clamps

High Fidelity Concept #1

- Miniaturized refrigeration system
  - Evaporator, compressor, condenser, expansion valve
- Single, large, internal rechargeable lithium battery to power:
  - LCD display
  - Thermocouple
  - Microcontroller
  - Miniaturized refrigeration system
- Cord to plug into additionally external emergency battery & other power generation sources
  - No integrated power generation
- Standard double-walled insulated cooler
  - Airtight locking cylinder for each vial

High Fidelity Concept #2

- Compressed gas cooling system
  - Release of compressed gas into the device will cool medication
  - Compressed gas will be stored in external tank(s)
- Single, large, internal rechargeable battery to power:
  - LCD display
  - Thermocouple
  - Microcontroller
  - Control valve for compressed liquid
- Cord to plug into various power generation sources
  - No integrated power generation
- Standard double-walled insulated cooler
  - Airtight locking cylinder for each vial
  - Each vial is wrapped in "cool towel" material

Department of Mechanical Engineering

Presented By: Timothy Willms

FAMU-FSU Engineering

High Fidelity Concept #3

- Endothermic chemical reaction cooling system
  - Ammonium chloride (NH4CL) mixed with water (H2O) reacts endothermically
  - Fan to circulate air
- Single, large, internal rechargeable lithium battery to power:
  - LCD display
  - Thermocouple
  - Microcontroller
  - Servo which will dispense NH4CL
- Cord to plug into various power generation sources
  - No integrated power generation
- Double-walled, vacuum-sealed cooler
  - Vacuum-sealed individual cylinders for each vial

Concept Selection

Concept Selection

- 5 concepts chosen to be analyzed:
  - Concept 1: High Fidelity Concept #1 – Miniaturized Refrigeration System
  - Concept 2: High Fidelity Concept #2 – Compressed Gas Cooling System
  - Concept 3: High Fidelity Concept #3 – Endothermic Chemical Reaction Cooling
  - Concept 4: Medium Fidelity Concept #5 – Thermoelectric Cooling System (TEC)
  - Concept 5: Medium Fidelity Concept #4 – Ranque-Hilsch Vortex Tube Cooling

Binary Comparison Matrix

- Used to compare our customer needs and determine which are of higher priority. Ranked each need against each other need
  - 0 – less important
  - 1 – more important
- Totals added up along each row and down each column
- The need with the highest total is the most impactful to our design

Binary Pairwise Comparison Chart of Customer Requirements

	The device is intended to store and maintain chilled medication.	The device sustains a desired temperature without the use of ice.	The device is durable in all environmental conditions.	The device is easily portable.	The device can be transported by individuals of every age.	The device visually displays the storage temperature to the user.	The device prohibits unauthorized access.	The device generates and uses minimal power to keep the medication refrigerated.	The device maintains a temperature range suitable for refrigerated medicines.	The device features multiple sources of power generation based on environmental conditions.	The device will maintain power without being connected to the grid.	The device controls the temperature of the system for a target of three months without being plugged into an external power source.	Total
The device is intended to store and maintain chilled medication.	|	0	0	0	0	0	0	0	1	0	0	0	1
The device sustains a desired temperature without the use of ice.	1	|	0	0	0	0	0	1	1	0	1	0	4
The device is durable in all environmental conditions.	1	1	|	1	0	0	0	1	1	0	1	0	6
The device is easily portable.	1	1	0	|	0	0	0	1	1	0	1	0	5
The device can be transported by individuals of every age.	1	1	1	1	|	0	0	1	1	1	1	0	8
The device visually displays the storage temperature to the user.	1	1	1	1	1	|	0	1	1	0	1	0	8
The device prohibits unauthorized access.	1	1	1	1	1	1	|	1	1	1	1	1	11
The device generates and uses minimal power to keep the medication refrigerated.	1	0	0	0	0	0	0	|	1	0	1	0	3
The device maintains a temperature range suitable for refrigerated medicines.	0	0	0	0	0	0	0	0	|	0	0	0	0
The device features multiple sources of power generation based on environmental conditions.	1	1	1	1	0	1	0	1	1	|	1	0	8
The device will maintain power without being connected to the grid.	1	0	0	0	0	0	0	0	1	0	|	0	2
The device controls the temperature of the system for a target of three months without being plugged into an external power source.	1	1	1	1	1	1	0	1	1	1	1	|	10
Total	10	7	5	6	3	3	0	8	11	3	9	1	
Check (TRUE if properly filled out)	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	

Binary Pairwise Comparison Chart of Customer Requirements

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The device is easily portable.	1	1	0	|	0	0	0	1	1	0	1	0	5
The device can be transported by individuals of every age.	1	1	1	1	|	0	0	1	1	1	1	0	8
The device visually displays the storage temperature to the user.	1	1	1	1	1	|	0	1	1	0	1	0	8
The device prohibits unauthorized access.	1	1	1	1	1	1	|	1	1	1	1	1	11
The device generates and uses minimal power to keep the medication refrigerated.	1	0	0	0	0	0	0	|	1	0	1	0	3
The device maintains a temperature range suitable for refrigerated medicines.	0	0	0	0	0	0	0	0	|	0	0	0	0
The device features multiple sources of power generation based on environmental conditions.	1	1	1	1	0	1	0	1	1	|	1	0	8
The device will maintain power without being connected to the grid.	1	0	0	0	0	0	0	0	1	0	|	0	2
The device controls the temperature of the system for a target of three months without being plugged into an external power source.	1	1	1	1	1	1	0	1	1	1	1	|	10
Total	10	7	5	6	3	3	0	8	11	3	9	1	
Check (TRUE if properly filled out)	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	TRUE	

House of Quality

- Used to determine how well engineering characteristics satisfy customer needs
  - Our team generated 14 engineering characteristics for analysis
- Each customer need was given a relative weight of importance
  - Weights used from the results of our Binary Comparison Matrix
- Engineering characteristics given scores based on relation to each customer need
  - 1 – weak relation
  - 3 – moderate relation
  - 9 – strong relation
- Engineering characteristics given final ranking of importance

		Engineering Characteristics													
Improvement Direction		↑	↑	↓	↓	↑	↓	↓	↓	↓	↓	↑	↑	↑	↑
Units		W	W	W	m3	#	kg	W	sec	m3	$	#	N	----	----
Customer Requirements	Importance Weight Factor	Power Capacity (Storage)	Generated Power	Power Consumption	External Size	Number of Power Generation Sources	Weight	Heat Transfer Rate	Cooling Time	Excess Internal Volume	Cost	Number of Vials Stored	Durability (Impact Resistance)	Ease of Operation	Safety of Medication
The device is intended to store and maintain chilled medication.	10			1		3		9	9	3	9	1			
The device sustains a desired temperature without the use of ice.	7		9	1		3		9	1	1		1			
The device is durable in all environmental conditions.	5				1		1				3		9	3	3
The device is easily portable.	6				9		9				1	9	1	9	
The device can be transported by individuals of every age.	3				9		9						1	9	
The device visually displays the storage temperature to the user.	3	1	1	3							1				
The device prohibits unauthorized access.	0														3
The device generates and uses minimal power to keep the medication refrigerated.	8	3	9	9		3		3	9	1	1				
The device maintains a temperature range suitable for refrigerated medicines.	11	3	9	9			1	9	9		1	3			3
The device features multiple sources of power generation based on environmental conditions.	3	3	9	3		9					9				
The device will maintain power without being connected to the grid.	9	9	9	9		9					3				0
The device controls the temperature of the system for a target of three months without being plugged into an external power source.	1	9	9	9		3		9	9	1	1				0
Raw Score	2276	159	354	296	86	186	97	285	277	46	188	104	54	96	48
Relative Weight %		6.985940246	15.55360281	13.00527241	3.778558875	8.172231986	4.261862917	12.52196837	12.17047452	2.021089631	8.260105448	4.569420035	2.37258348	4.21792619	2.108963093
Rank Order		7	1	2	11	6	9	3	4	14	5	8	12	10	13

		Engineering Characteristics													
Improvement Direction		↑	↑	↓	↓	↑	↓	↓	↓	↓	↓	↑	↑	↑	↑
Units		Wh	W	W	m3	#	kg	W	sec	m3	$	#	N	----	----
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The device is intended to store and maintain chilled medication.	10			1		3		9	9	3	9	1			
The device sustains a desired temperature without the use of ice.	7		9	1		3		9	1	1		1			
The device is durable in all environmental conditions.	5				1		1				3		9	3	3
The device is easily portable.	6				9		9				1	9	1	9	
The device can be transported by individuals of every age.	3				9		9						1	9	
The device visually displays the storage temperature to the user.	3	1	1	3							1				
The device prohibits unauthorized access.	0														3
The device generates and uses minimal power to keep the medication refrigerated.	8	3	9	9		3		3	9	1	1				
The device maintains a temperature range suitable for refrigerated medicines.	11	3	9	9			1	9	9		1	3			3
The device features multiple sources of power generation based on environmental conditions.	3	3	9	3		9					9				
The device will maintain power without being connected to the grid.	9	9	9	9		9					3				0
The device controls the temperature of the system for a target of three months without being plugged into an external power source.	1	9	9	9		3		9	9	1	1				0
Raw Score	2276	159	354	296	86	186	97	285	277	46	188	104	54	96	48
Relative Weight %		6.985940246	15.55360281	13.00527241	3.778558875	8.172231986	4.261862917	12.52196837	12.17047452	2.021089631	8.260105448	4.569420035	2.37258348	4.21792619	2.108963093
Rank Order		7	1	2	11	6	9	3	4	14	5	8	12	10	13

Pugh Chart

- Used to compare how well a concept performs in relation to an engineering characteristic
  - Used top five engineering characteristics from HOQ
- Datum design (store-bought cooler) used as baseline for comparison of concepts
  - Concept given (+1) if better than datum, (-1) if worse, and (0) if equal
  - Columns totaled to given ranking of concepts, with highest being the best
- Second Pugh chart made to compare top three concepts from initial Pugh chart
  - Concept with a total of zero from initial Pugh chart was used as new Datum
  - Highest total from this chart determines the best concept for selection

Selection Criteria	Datum	Concepts				
	Dcol Battery Powered Insulin Cooler	1	2	3	4	5
Generated Power	0	1	1	1	1	1
Power Consumption	0	-1	1	1	S	S
Heat Transfer Rate	0	1	1	1	1	1
Cooling Time	0	S	1	-1	S	S
Cost	0	-1	-1	-1	-1	-1
# of pluses	0	2	4	3	2	2
# of minuses	0	2	1	2	1	1

Selection Criteria	Datum	Concepts		
	1	2	3	4
Generated Power	0	S	S	S
Power Consumption	0	2	2	1
Heat Transfer Rate	0	S	S	S
Cooling Time	0	1	-1	S
Cost	0	S	S	S
# of pluses	0	3	2	1
# of minuses	0	0	1	0

Selection Criteria	Datum	Concepts				
	Dcol Battery Powered Insulin Cooler	1	2	3	4	5
Generated Power	0	1	1	1	1	1
Power Consumption	0	-1	1	1	S	S
Heat Transfer Rate	0	1	1	1	1	1
Cooling Time	0	S	1	-1	S	S
Cost	0	-1	-1	-1	-1	-1
# of pluses	0	2	4	3	2	2
# of minuses	0	2	1	2	1	1

Selection Criteria	Datum	Concepts		
	1	2	3	4
Generated Power	0	S	S	S
Power Consumption	0	2	2	1
Heat Transfer Rate	0	S	S	S
Cooling Time	0	1	-1	S
Cost	0	S	S	S
# of pluses	0	3	2	1
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Selection Criteria	Datum	Concepts				
	Dcol Battery Powered Insulin Cooler	1	2	3	4	5
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Heat Transfer Rate	0	1	1	1	1	1
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Cost	0	-1	-1	-1	-1	-1
# of pluses	0	2	4	3	2	2
# of minuses	0	2	1	2	1	1

Selection Criteria	Datum	Concepts		
	1	2	3	4
Generated Power	0	S	S	S
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Cost	0	-1	-1	-1	-1	-1
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	1	2	3	4
Generated Power	0	S	S	S
Power Consumption	0	2	2	1
Heat Transfer Rate	0	S	S	S
Cooling Time	0	1	-1	S
Cost	0	S	S	S
# of pluses	0	3	2	1
# of minuses	0	0	1	0

AHP

- More in-depth analysis of concepts in relation to the top five engineering characteristics
  - Consistency checks for accuracy
- First compares engineering characteristics to determine relative weights
- Then concepts are compared to one another, in relation to each characteristic
  - Concepts given relative weights for each characteristic
- Finally, a table of concepts vs. characteristics is generated
- From this table, a list of alternate values is calculated
  - Highest value is the best design

Criteria Comparison Matrix [C]					
	Generate Power	Power Consumption	Heat Transfer	Cooling Time	Cost
Generate Power	1	3	5	5	0.333333333
Power Consumption	0.333333333	1	3.000000003	5	0.333333333
Heat Transfer	0.2	0.333333333	1	3	0.2
Cooling Time	0.2	0.2	0.333333333	1	0.2
Cost	3	3	5	5	1
Sum	4.733333333	7.533333333	14.33333334	19	2.066666666

Normalized Criteria Comparison Matrix [NormC]						
	Generate Power	Power Consumption	Heat Transfer	Cooling Time	Cost	Criteria weights {W}
Generate Power	0.211267606	0.398230089	0.348837209	0.263157895	0.161290322	0.276556624
Power Consumption	0.070422535	0.132743363	0.209302326	0.263157895	0.161290322	0.167383288
Heat Transfer	0.042253521	0.044247788	0.069767442	0.157894737	0.096774194	0.082187536
Cooling Time	0.042253521	0.026548673	0.023255814	0.052631579	0.096774194	0.048292756
Cost	0.633802817	0.398230089	0.348837209	0.263157895	0.483870968	0.425579795
Sum	1	1	1	1	1	1

Consistency Check		
{Ws}=[C]{W}	{W}	Cons={Ws}./{W}
Weighted Sum Vector	Criteria Weights	Consistency Vector
1.572967881	0.276556624	5.687688322
0.88945515	0.167383288	5.313882645
0.423287518	0.082187536	5.150264105
0.249592543	0.048292756	5.168322611
2.409800994	0.425579795	5.662395206

RI Values for Consistency Check	
# of criteria	RI value
3	0.52
4	0.89
5	1.11
6	1.25
7	1.35
8	1.4
9	1.45
10	1.49
11	1.51

Average consistency	5.396510578
Consistency Index	0.099127644
Consistency Ratio	0.089304184

Consistency Check		
{Ws}=[C]{W}	{W}	Cons={Ws}./{W}
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7	1.35
8	1.4
9	1.45
10	1.49
11	1.51

Average consistency	5.396510578
Consistency Index	0.099127644
Consistency Ratio	0.089304184

Final Rating Matrix					
	Design 1	Design 2	Design 3	Design 4	Design 5
Generate Power	0.087895628	0.255766093	0.230469886	0.337972765	0.087895628
Power Consumption	0.057818035	0.457562648	0.283175483	0.121938596	0.079505239
Heat Transfer	0.09025974	0.261255411	0.467965368	0.09025974	0.09025974
Cooling Time	0.065409262	0.504406831	0.134526811	0.260760699	0.034896396
Cost	0.063215889	0.351477677	0.17415269	0.351477677	0.059676066

[Final Rating Matrix]^T					
	Design 1	Design 2	Design 3	Design 4	Design 5
Generate Power	0.087895628	0.057818035	0.09025974	0.065409262	0.063215889
Power Consumption	0.255766093	0.457562648	0.261255411	0.504406831	0.351477677
Heat Transfer	0.230469886	0.283175483	0.467965368	0.134526811	0.17415269
Cooling Time	0.337972765	0.121938596	0.09025974	0.260760699	0.351477677
Cost	0.087895628	0.079505239	0.09025974	0.034896396	0.059676066

Concept	Alternative Value
Design 1	0.071466316
Design 2	0.34273508
Design 3	0.230210274
Design 4	0.283471966
Design 5	0.072116363

Final Rating Matrix					
	Design 1	Design 2	Design 3	Design 4	Design 5
Generate Power	0.087895628	0.255766093	0.230469886	0.337972765	0.087895628
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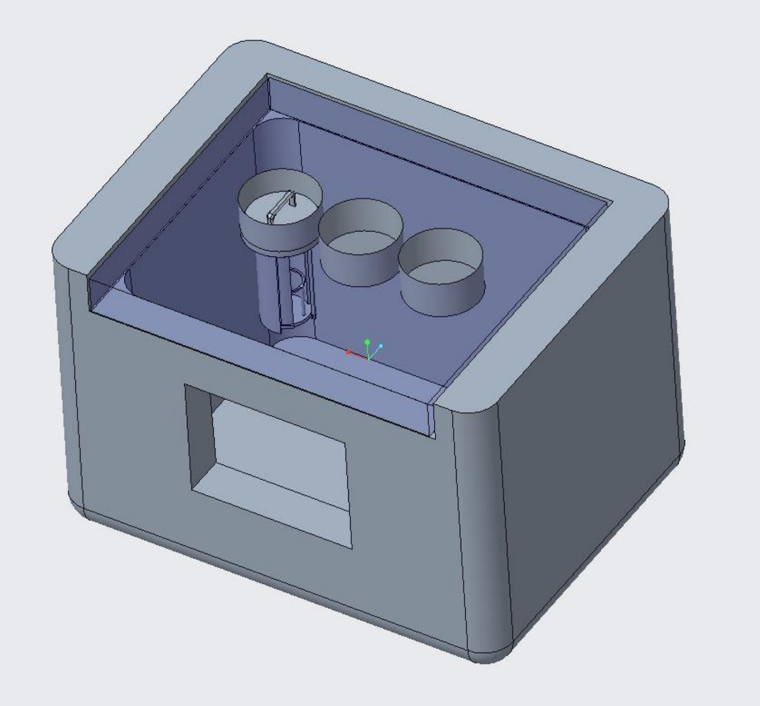
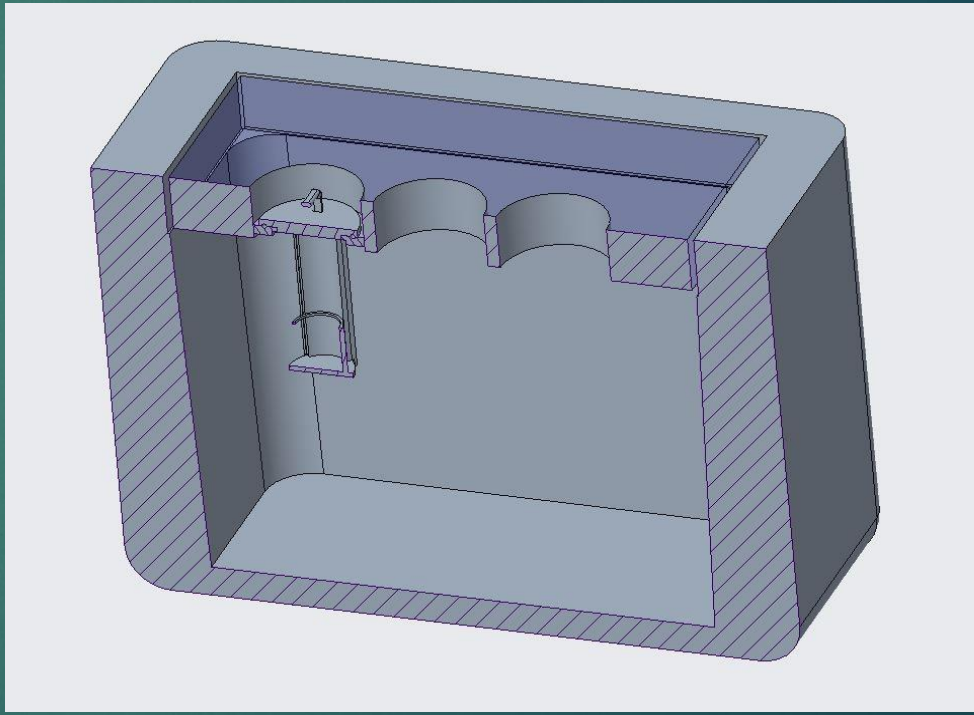
Design 1	0.071466316
Design 2	0.34273508
Design 3	0.230210274
Design 4	0.283471966
Design 5	0.072116363

Final Selection

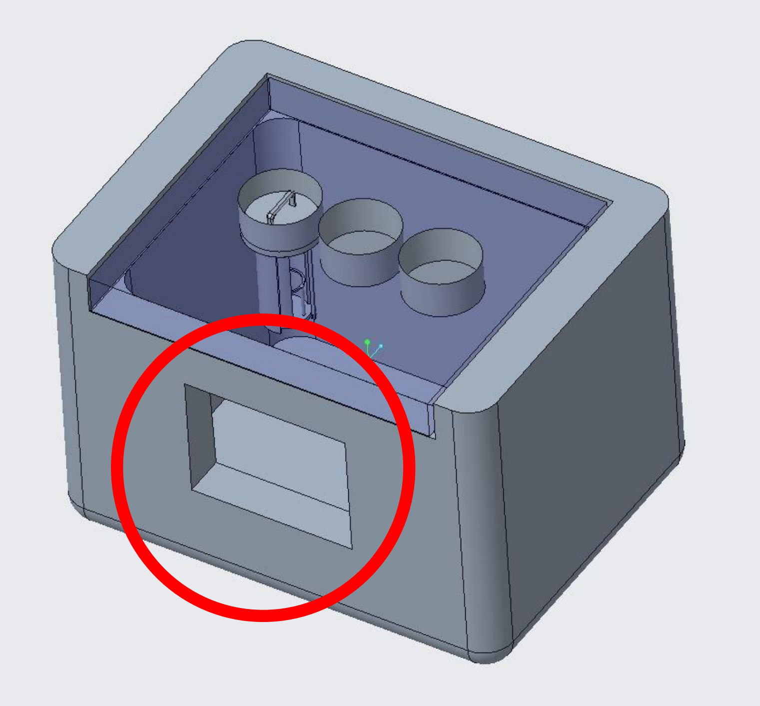
- Pugh chart & AHP determined Concept 2 would be the optimal selection
  - In practicality, this concept is infeasible due to:
    - Difficulty obtaining large quantities of compressed gas
    - High safety risk in handling compressed gases
- Therefore, Concept 4 (TEC System) was selected as the final design
  - Second lowest cost & consumption of power
  - TEC can be powered with AA batteries if necessary

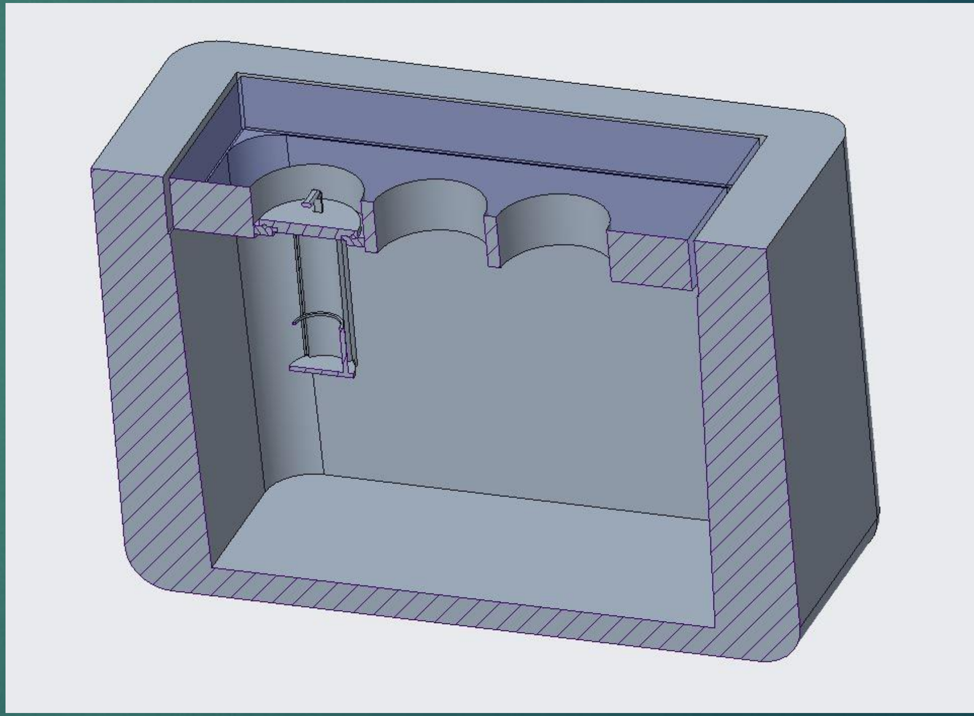
Final Design



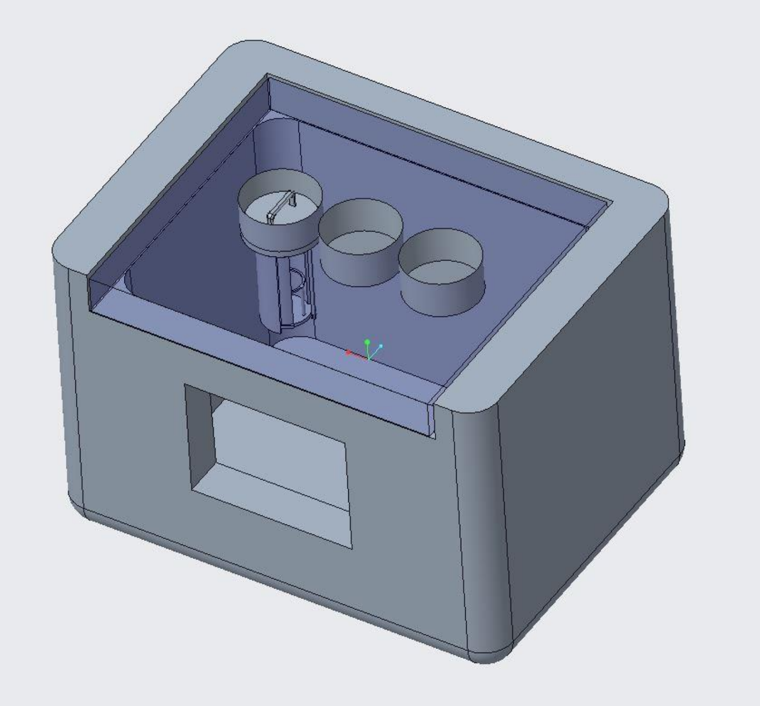


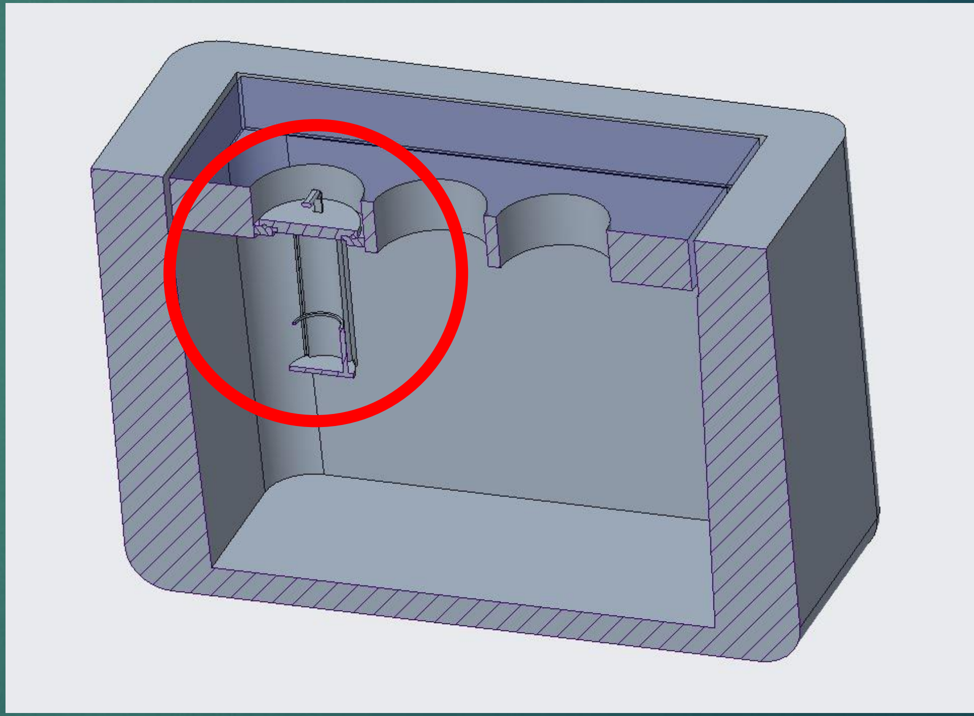
Final Design



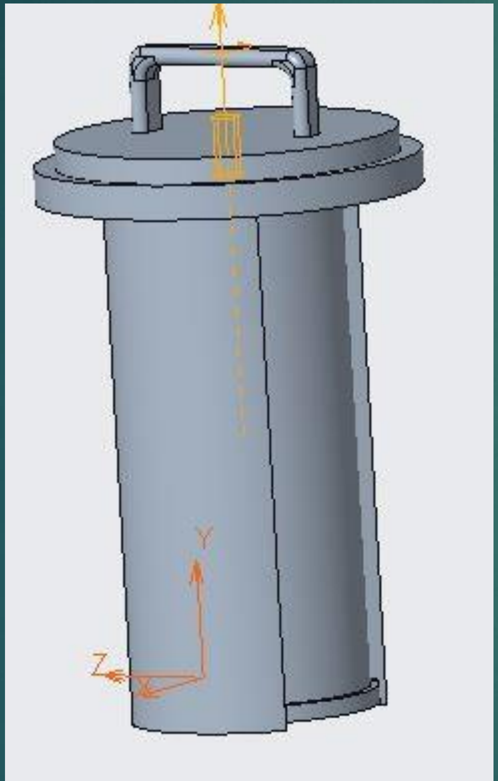


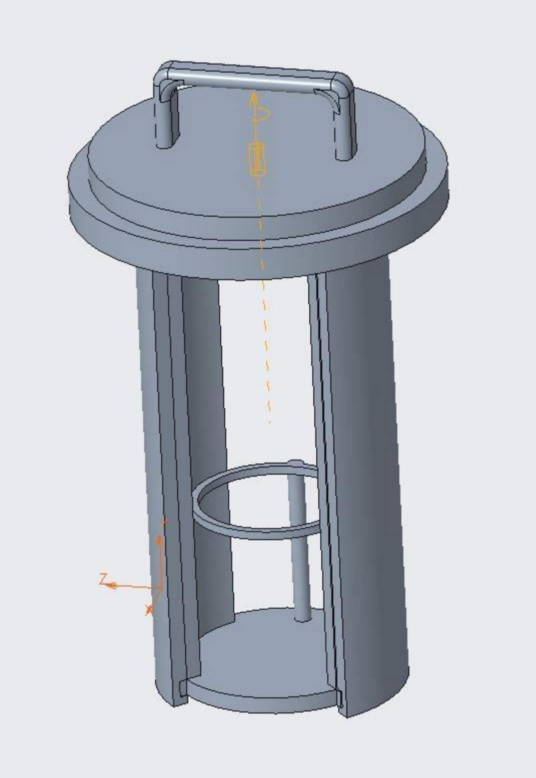
Final Design

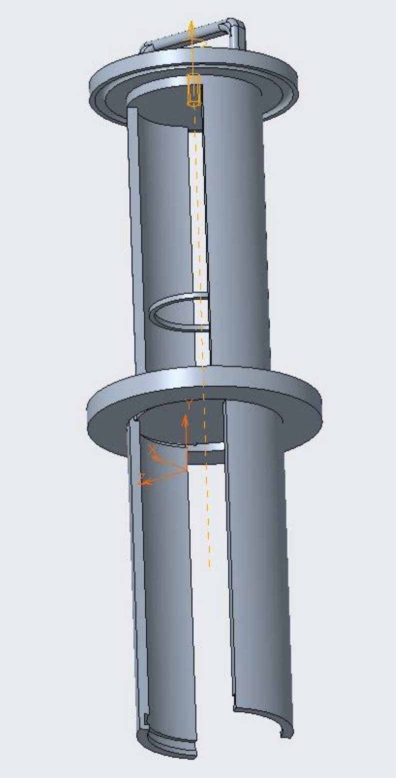




Locking Cylinders







Bill of Materials

- Early stages of purchasing
- Optimizing purchasing for benefit of prototyping and final product

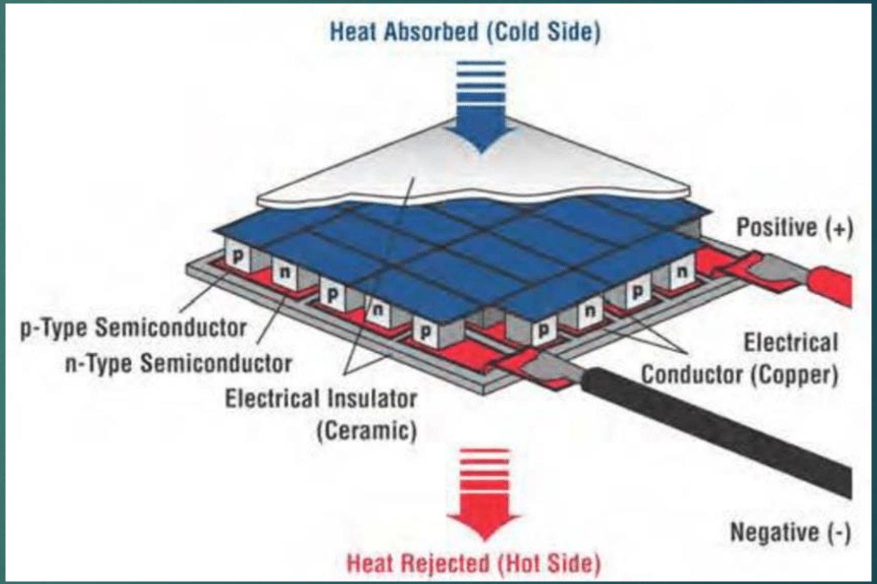
KEY:	Do not order - more information needed	Do not order - free from school	In stores	Received

T512 Part Number	Item	Description	Quantity	Manufacturer	Supplier Contact	Unit Weight	Specifications	Unit Cost	Cost Shipping	Total Cost	Shipping times	Purchase Order #	Ordered (Yes)	Arrived (Yes)	Unit Maturity (%)	Project Weight (out of 100%)	Unit Total
1	Void-Filling Spray Foam Insulation	1.8lbs./cu. ft Density. Heat Flow Rate: 0.16 Btu @ 75F	1	n/a	McMaster-Carr	1.04 kg	1.04 kg can	$40.00	$40.00	$40.00			NO	NO	0%	5%	0.0%
2	Buna-N O-Ring	34mm ID, 2mm Thickness, 38mm OD	1	n/a	McMaster-Carr	n/a	Pack of 50	$10.23	$10.23	$50.23			NO	NO	0%	1%	0.0%
3	Legend 6-Can Cooler	5 qt cooler	1	Igloo	Igloo	1 kg	EXT DIM: 27.5*20.5*18.7 cm. INT DIM: Top: 21.6*16.2*14.9 cm. Bottom: 20.5*15.2*14.9 cm	$22.49	$22.49	$72.72			NO	NO	0%	30%	0.0%
4	Explorer 240 Portable Power Station	240Wh (14.4V, 16.8Ah). Charging Input:12V-30V(42W Max). DC Output: 13.3V, up to 10A. USB Output: 5V 2.4A	1	Jackery	Jackery.com	3 kg	13.2*23.1*19.6 cm	$249.99	$249.99	$322.71			NO	NO	0%	12%	0.0%
5	Explorer 50W Solar Panel	Equipped with 1* USB-A output port (5V/2.4A) and 1*USB-C output port (5V/3A) in addition to 1* DC port (16.2V/3.15A/50W)	1	Jackery	Jackery.com	2.46 kg	56.5*39.5*1 cm	$199.99	$199.99	$522.70			NO	NO	0%	4%	0.0%
6	Super Silicone Sealant	3oz Tube. Temperature Range: -75F to 400F. 325 psi Tensile Strength. 24hr Hardening Time	1	3M	McMaster-Carr	n/a	88.72 mL Tube	$11.60	$11.60	$534.30			NO	NO	0%	3%	0.0%
7	Mini Nano V3.0 ATmega328P Microcontroller Board	Arduino Nano. Digital I/O Pins 14 (of which 6 provide PWM output). Flash Memory 32 KB (ATmega328) of which 2 KB used by bootloader	1	Makerfire	Amazon.com	0.0227 kg	3.3*1.8 cm	$8.29	$8.29	$542.59			NO	NO	0%	5%	0.0%
8	USB Battery Pack	2200mAh Capacity. 5V 1A Output	1	Adafruit	Adafruit	0.073 kg	2.5*91*2.5 cm	$14.95	$14.95	$557.54			NO	NO	0%	5%	0.0%
9	USB Male to Male Cable	USB 2.0 Cable, 45.7cm Long	1	Monoprice	Amazon.com	0.0045 kg	45.7 cm	$4.94	$4.94	$562.48			NO	NO	0%	5%	0.0%
10	Large Sized Heat Sink set	12V Thermoelectric Peltier Cooler Refrigeration Cooling System Heat Sink Conduction Module	2	n/a	Amazon.com	354.88 mL	14.9 x 13.9 x 8.9 cm	$23.49	$46.98	$609.46			NO	NO	0%	21%	0.0%
11	Digital Thermocouple	Proster Digital Thermocouple Temperature Thermometer with Two K-Type Thermocouple	1	Proster	Amazon.com	236.59 mL	-200℃ to 1372℃	$22.99	$22.99	$632.45			YES	YES	100%	5%	5.0%
12	Locking Cylinders	SLA Printed	3	Ciscor	n/a	n/a	4.5 cm OD, 7.0 cm Length	$0.00	$0.00	$632.45			NO	NO	0%	3%	0.0%
13	Exterior Protective Grate	ABS Printed In Sections	1	Innovation Hub	n/a	n/a	20.0 cm Width, 12.5 cm Height, 2.5 cm Depth	$0.00	$0.00	$632.45			NO	NO	0%	1%	0.0%

Current Prototyping

Current Prototyping

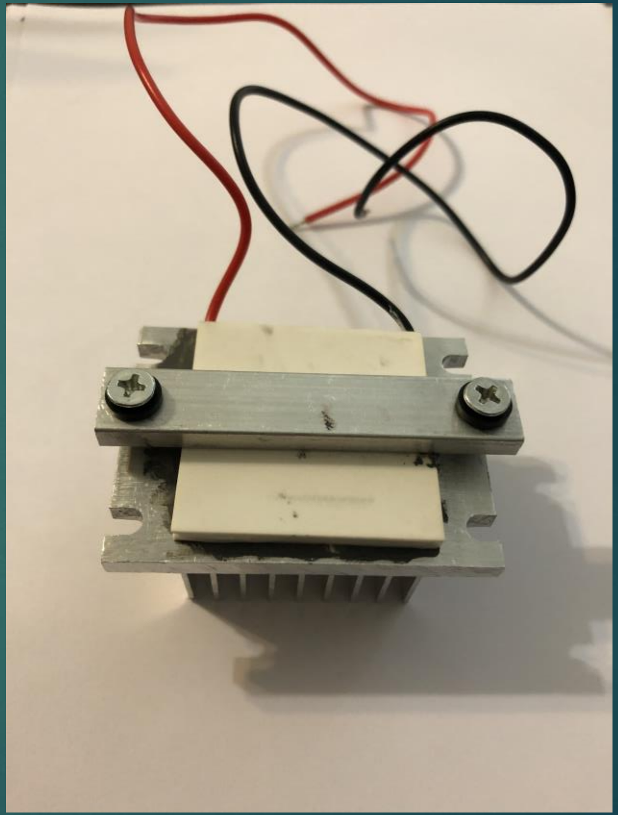
Thermoelectric Modules:



Current Prototyping

Testing:

- Modeling of 1-D Heat Transfer for TEC system
- Analyzing current vs heat transfer rate
  - i.e. Single module at higher current compared to multiple modules at a lower current
- Optimizing fin efficiency



References

- BowStern Marketing Communications. (n.d.). BowStern : Desire to Communicate. Retrieved October 7, 2019, from http://www.bowstern.com/.
- Derzypolski, T. (2018, June 16). An option for the Children's Services Council that could satisfy many: Opinion. Retrieved October 6, 2019, from https://www.tallahassee.com/story/opinion/2018/06/16/option-childrens-services-council-could-satisfy-many/705225002/.
- Federal Emergency Management Agency FEMA Seal Plaque (Round). (n.d.). Retrieved October 6, 2019, from https://americanplaquecompany.com/product/federal-emergency-management-agency-fema-seal-plaque-round/.
- Fink, S. (2018, June 3). Puerto Rico: How Do We Know 3,000 People Died as a Result of Hurricane Maria? Retrieved October 6, 2019, from https://www.nytimes.com/2018/06/02/us/puerto-rico-death-tolls.html.
- Medication Storage at Home. (n.d.). Retrieved October 6, 2019, from https://medangel.co/medication-storage-at-home/.
- Moye, D., & McGonigal, C. (2018, March 9). These Stunning GIFs Show St. Martin's Miraculous Recovery From Hurricanes Irma And Maria. Retrieved October 6, 2019, from https://www.huffpost.com/entry/watch-st-martins-hurricane-recovery-in-these-stunning-before-and-after-images_n_5a9ecb1be4b002df2c5e3165.
- Polley, N. (n.d.). Red Cross Helps Missouri Flood Victims. Retrieved October 6, 2019, from https://www.ktts.com/2019/03/31/red-cross-helps-missouri-flood-victims/.
- Pulmozyme (dornase alfa) Uses, Dosage, Side Effects. (n.d.). Retrieved October 6, 2019, from https://www.drugs.com/pulmozyme.html.
- Reports: Hurricane Maria makes landfall in Puerto Rico with 155 mph winds. (n.d.). Retrieved October 6, 2019, from https://www.accuweather.com/en/weather-news/reports-hurricane-maria-nears-virgin-islands-puerto-rico-as-winds-reach-175-mph/70002762.
- Taking BYETTA. (n.d.). Retrieved October 6, 2019, from https://www.byetta.com/taking-byetta.html.
- U.S. Department of Defense (DOD). (n.d.). Retrieved October 6, 2019, from http://www.milbadges.com/corps/USA/dod.
- Victoza (Liraglutide [rDNA] Injection): Side Effects, Interactions, Warning, Dosage & Uses. (n.d.). Retrieved October 6, 2019, from https://www.rxlist.com/victoza-drug.htm.

References

- https://the-isle-dinosaur-game.fandom.com/wiki/Stegosaurus
- https://animalcorner.co.uk/animals/tortoise/
- https://www.gqmiddleeast.com/grooming/how-to-deal-with-excessive-sweating
- https://www.earth.com/news/seals-regulate-oxygen-diving/
- https://www.amazon.com/YKS-TEC1-12706-Thermoelectric-Cooler-Peltier/dp/B007H2IXV2
- https://www.alibaba.com/product-detail/Mini-refrigerator-with-lock-mini-fridge_60539764431.html
- https://www.vortec.com/vortex-tube-short-course

Questions?

- Contact Us!
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  - Timothy Willms (Production Engineer) - tjm15m@my.fsu.edu