Accumulator Thermal Management System for Formula SAE Electric Race Car

Project Proposal for Senior Design Project

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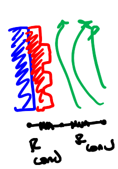
- Insulated accumulator? Beneficial if batteries can get too cold, is this a concern?
- General concept is OK, but two different versions of the target design in two segments
- Fin geometry is HUGE ultimately, how did you make your flow assumptions?
  - 24 mph of flow isn't that challenging, we'll need to define total ΔP through the system to solve for ducted flow
  - ? benefit of not having flow on BOTH sides of the accumulator?
  - need to specify assumptions for convection relationships
- Some [cloud] language about the heat transfer problem
  GOOD assumption to find airflow w/ steady state
  but dynamic process will be more interesting



need to solve the energy balance here

7.5/10

Not approved.... but only b/c your fin geometry & convection this don't mesh
with that fixed we can easily move forward

Contents

are we also considering charging loads, either while parked or from regenerative braking?

1. Introduction and Historical Background

Global warming is a driving force of engineering and innovation, resulting in an increased demand for eco-friendly products, green energy, and sustainability [1] [2]. Electric and hybrid vehicles have seen tremendous growth and popularity since the introduction of the Prius in 2003, with major automotive companies offering hybrid or electric models.

Apart from companies, college students are also contributing to the effort of innovating efficient and high-performance hybrid and electric vehicles. An electric vehicle (EV) is being designed and built by SC Formula Electric, a USC Viterbi design team founded in 2019, for a variety of events at the FSAE competition held in June at Fontana, CA.

Each event at the competition creates a specific demand on the vehicle's battery. The performance of an EV depends on the battery operating performance and it is crucial to regulate its temperature. The battery cooling system is responsible for maintaining an operational temperature while the battery generates heat from the charging and discharging of the vehicle's acceleration. In today's industry there are two types of cooling systems commonly used: air-cooled system and liquid-cooled system. Both systems have their advantages and disadvantages, mostly centered around their efficiency and cost. The goal of this project is to design a cooling system that will best fit the SC Formula Electric vehicle's lithium-ion battery pack and maintain the optimal operating temperature range.

There is a trade here between efficiency gains & water pump load

Aside: you CAN design a water cooling system WITHOUT a circulation pump. Search THERMOSIPHON

1.1. Cooling System Background

There are two types of liquid cooling systems: direct and indirect. Both types are advantageous for the high specific heat and thermal conductivity of the coolant, its compact size, and better uniform temperature distribution than air. Direct liquid cooling immerses the battery in a ~~high-resistance~~ coolant. However, this system is more prone to electrochemical corrosion and an electrical short [3]. Indirect cooling uses a system of channels to flow the liquid coolant, however, it requires a circulator pump that will draw power from the battery and reduce the vehicles travel. Additionally, both types have drawbacks, this type of system adds extra weight to the vehicle, is expensive and complex, and requires more maintenance.

dielectric or non-conductive

an The air-cooling system can be used through two methods, forced or natural convection. Natural convection is less effective than forced convection because it is only highly efficient for low energy density batteries. On the other hand, the addition of a fan and/or blower enhances the heat transfer coefficient during forced air flow to improve heat dissipation. An air-cooling system offers different heat sink designs mainly having to do with the geometry and number of fins that can be incorporated. When the vehicle is in use, the heat generated will flow to the fins which will help heat dissipate because of the increased surface area. Comparing rectangular, circular, and curved fins while changing the thickness of each fin affects the efficiency of the system [4]. Through an experiment it was found that reducing the thickness of the fin and using a curved shape fin decreased the overall weight of the system, improving the system's effectiveness. The material of a fin is another factor to consider increasing the system's productivity. In a comparison of aluminum alloy 6061 and magnesium alloy, aluminum alloy with a small thickness seems to be a better choice to optimize the system. Comparing the number of fins, it was found that using many fins with small thickness was most beneficial for high-performance vehicles because it reduces turbulence while increasing the heat transfer [4]. The challenge with an air-cooled system is that it's not as efficient as other systems, especially in vehicles where air is not fully in direct contact. Yet, the positive side of this system is that there is less weight added to the system as opposed to

effective?

when traveling at low speed

??

Depends on overall fin design + other ducting requirements what about available airflow

using the liquid system while also avoiding leaks. The air-cooled system thus presents itself as a malleable solution because it would be possible to modify the heat sink as needed.

Table 1. Comparison of liquid cooling and air cooling. On a scale basis, 1, 2 and 3 represent great, good, okay, respectively. Table from research paper [3].

what defines these? w/o some quantitative rankings, these tables are quite vague....

	Liquid Cooling		Air Cooling
	Direct	Indirect	
Cooling Efficiency	1	1	2
System Complexity	3	3	1
Energy Loss	3	3	1
Maintenance	3	3	1
Short Circuit	3	3	1
Lifespan	3	3	1
Cost	3	3	1

As shown in the table above, an air-cooling system performs better in mostly all aspects compared to a liquid based system. Moving forward, our cooling system will be air based with some fin modifications made later in our design.

2. Theory and Basic Equations

The accumulator, also known as the battery, has a watt-hour capacity of 6.3kWh. A cylindrical, lithium-ion cell, known as 18650, has been selected for the design, but the specific chemical composition has yet to be determined. Regardless of composition, the 18650 is of standard size and average voltage, allowing the team to begin physical modelling of the accumulator. The accumulator will be composed of modules, segments of cells isolated within a casing. Within each module will be 28 groupings of 4 clustered cells in series and parallel, respectively. The accumulator will be composed of 5 modules, with each module having a charged voltage of 100.8 volts, for a total of 504 volts. Table 2 below shows calculated and estimated values from the design thus far.

Table 2: Accumulator Specification Data

Specification	Value	Unit
Cell Nominal Voltage	3.7	[V]
Cell Capacity	3500	[mAh]
Cell Internal Resistance	20	[mΩ]
Accumulator Nominal Voltage	504	[V]
Accumulator Capacity	6.3	[kWh]

We will rely on basic assumptions regarding the space and behavior of the system, allowing for simplifications in calculations and modeling. These assumptions are defined as either boundary conditions of the system or as variable values within the system. Furthermore, FSAE rules and regulations define a set of design constraints that ensure and maintain safety of the vehicle, as described below in Sec. 2.1. Lastly, the design parameters for this project only reflect the demands placed on the vehicle at the FSAE competition.

2.1. Assumptions and Constraints

The following table identifies the assumptions made regarding the behavior of the vehicle and surrounding environment. Within the scope of this project, we will conduct a more thorough analysis of each of these assumptions or disregard entirely. ...? so why do we care about these?

Table 3: Boundary Conditions and Variable Behavior – Assumptions proposed for the initial calculations of this project.

Property	Condition	Magnitude
Temperature	Ambient Air	27°C
Geometry	Specific internal geometry of battery modules will be ignored	Internal geometry treated as a heat generating box OK
Insulation	Unknown final coverings of vehicle	Accumulator container will be fully insulated, no heating or cooling ability
Intake Air Speed	Intake air speed aerodynamically encouraged w/a scoop and fan	Air speed will range from minimum airflow from driving and maximum from fan max speed
Heat Source	Accumulator modules function as black box heat source	Specific geometry and composition of module will be not be addressed within this proposal
Internal Air Flow	Behavior of air flow within heat sinks	Air flow within the internal channel of the accumulator is assumes to be frictionless and incompressible
Internal Battery Resistance	Average internal resistance value of well-known 18650 lithium-ion battery cells	20 mΩ

! careful here... possibility of to much cooling

Does internal air flow conflict with the "black box" assumption

The table below presents the rules our design is required to comply to as obtained from the 2021 FSAE rulebook.

Table 4: FSAE rules project must comply with *[5]*.

Rule	**Description**
T.1.6.3	Design must address heat transfer between the heat source and the panel that the driver contacts
T.5.5.1	Cooling or lubrication system must be sealed to prevent leakage.
T.5.6.4	Cooling system catch can must vent through hose w/minimum internal diameter of 3mm down to the bottom levels of the Chassis.
EV.7.5.4	...cooling fans must not be inside the Accumulator Container. Ok
EV.8.5.2	Temperatures must remain below the max cell temperature on the cell data sheet or 60°C.

60°C max, what's the minimum cell temperature

Different than the max positive power draw + steady state assumptions we discussed
Still ok but need to now consider thermal transients

Lastly, the power demand estimate used in the calculation of heat generation within the accumulator was visually estimated using motor telemetry supplied by the Beijing Institute of Technology. This data was obtained from what is considered to be the longest and most demanding event at competition, the endurance event. The use of this data supplies us with an expected average and peak demand of power throughout the race which will be considered a sufficient estimate to demonstrate the feasibility of the project submitted within this proposal. Once approved, as this project progresses, research into event simulation and telemetry data will enable a more thorough analysis of the final design.

2.2. Heat Generation

Using the average sustained power demand from the motor telemetry of 15 kW, and the nominal accumulator voltage from Table 1, the maximum sustained current was found, shown in Eqn. 1 below.

$$I_{max} = \frac{P_{max}}{V_{nom}} = \frac{15000\ W}{504\ V} = 29.762\ A \qquad [1]$$

To determine the heat generated within the accumulator the maximum sustained current and internal resistance of the battery modules were considered. Using the knowledge of the internal resistance and connection sequence of the cells, Eqns. 2-3 describes the calculation of the accumulator internal resistance.

$$Series: R_{Total} = R_1 + \cdots + R_n \qquad [2]$$

$$Parallel: R_{Total} = \left(\frac{1}{R_1} + \cdots + \frac{1}{R_n}\right)^{-1} \qquad [3]$$

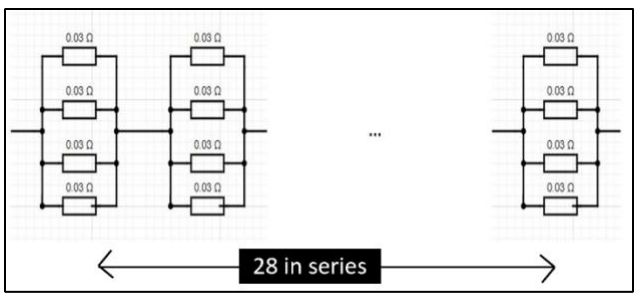


Figure 1: Diagram of internal resistance circuitry on one module

Implementing the data from Table 1 and the previous equations, the total internal resistance of the accumulator was found to be:

$$R_{Total} = 0.7\ \Omega \qquad [4]$$

Combining the information from Eqns. 1-4 the maximum heat generated was found using Eqn. 5 below.

$$\dot{Q} = I^2 R = 29.762^2 * 0.7 = \boxed{620\ W} \qquad [5]$$

whats the contribution from battery chemistry? Does the internal resistance dominate?

Careful "dissapation" implies to the environment

This is the working estimated heat to be dissipated by the thermal management system design proposed.

2.3. Heat Transfer

So a water style system w/ air as the coolant.... air cooled system will have a different architecture

The heat transfer system of the accumulator consists of the heat generated by the accumulator system components, the heat dissipated through conduction via heat sinks, and the convection of heat via the forced air through the heat sink channel. The radiator and hoses function as the primary disposal of heat generated by the motor and motor controller. Additionally, all wiring, sensors, and other high-voltage electrical components will be assumed to produce negligible heat transfer through either conduction or convection for the purposed of this proposal but will be considered throughout the remainder of this study.

ok

The first law of thermodynamics dictates that the rate of heat transfer leaving the heated fluid within system must be equal to the rate of heat transfer to the cooling element. Similarly, this rate of heat transfer must also be equal to the amount of heat generated by the system.

$$\dot{Q}_{gen} = \dot{Q}_{cond} = \dot{Q}_{conv} \quad [6]$$

not the case! If $\dot{Q}_{gen} > \dot{Q}_{conv}$ you'll see a net rise in accumulator temp

Need to assume @ steady state

The heat transfer rates shown in Eqn. 5 can be expanded as follows:

what's different here ?

$$\dot{Q}_{cond} = \frac{-\mathrm{K\,A}\,\Delta\mathrm{T}}{t} \quad [7]$$

$$\dot{Q}_{conv} = \mathrm{h\,A}\,\Delta\mathrm{T} \quad [8]$$

$$\dot{Q} = \dot{m}\, c_p\, \Delta T \quad [9]$$

$$\dot{Q} = h\, A_s\, \Delta T \quad [10]$$

Where K in Eqn. 7 is the thermal conductivity of the heat sink material and h in Eqn. 8 is the convection heat coefficient to be calculated for the design.

ok Air flow within the system takes place in two parts, the intake through the scoop and flow through the heat sink. Air flow into the system includes a sucking fan housed within a scoop. The fan is required because while the vehicle may travel at many speeds, the faster the vehicle travels, the more likely radial outflow of incoming air is to occur as the vehicle passes through space. Suction from the fan will ensure consistent flow to reach the heat sinks. It is assumed the flow of air into the system is turbulent, due to the fan and shape of the ducting. Once the flow reaches the heat sinks, laminar flow will be assumed and verified, calculated in the following equations.

?

Can't assume this, nothing to re-smooth the flow

$$Nu = \frac{hL}{k} \quad [11]$$

$$D_h = \frac{4A_c}{p} \quad [12]$$

$$Re = \frac{V_{avg}\, D_h}{v} \quad [13]$$

$$V_{avg} = \frac{\dot{m}}{\rho\, A_{chan}} \quad [14]$$

$$Nu = 0.664\, Re_L^{0.5}\, \mathrm{Pr}^{1/3} \quad [15]$$

$$Nu = 0.037\, Re_T^{0.5}\, \mathrm{Pr}^{1/3} \quad [16]$$

at high speed you want to ensure that your duct provides ram air cooling

fan provides flow at low speeds when air isn't forced

Duct placement + design will be critical. Need to balance drag vs. cooling air flow

under what assumptions are these relations valid?

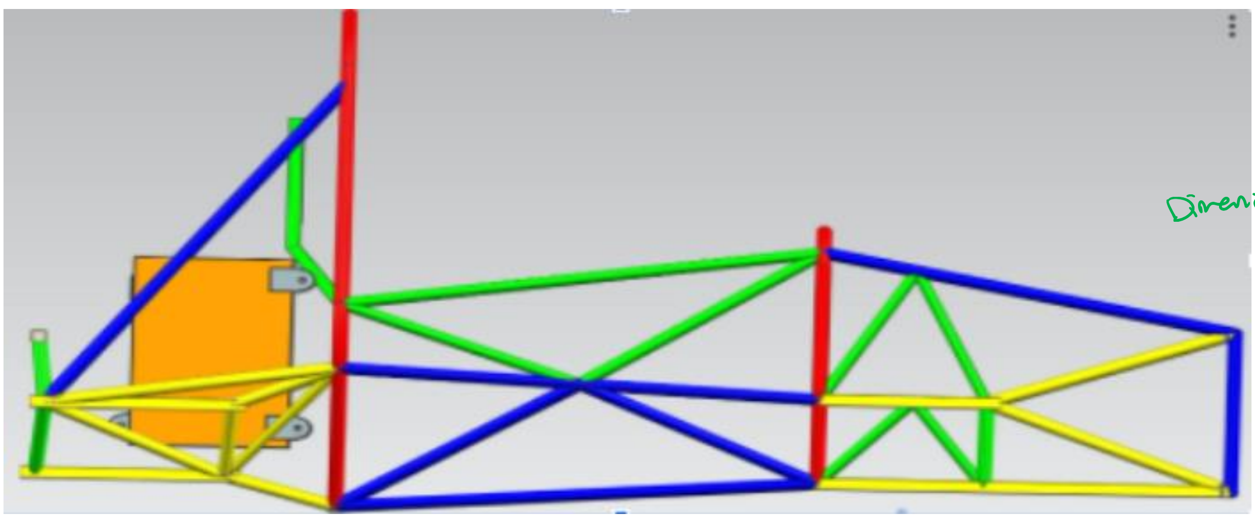
Once the range of thermal cooling needs has been determined later within our project, a range of cooling ability can be established and actualized by controlling the volumetric flow by a variable speed suction fan.

3. Concept and Analysis Plan

This section highlights the design concepts and plan of analysis for the design of a thermal management system. The design for heat dissipation will be an air-cooled system which uses the assistance of fans and a heat sink. The design will consider the physical design, placement within the existing accumulator design, build material selection, air flow properties within the system, and optimization of heat dissipation within the budget constraints set out in Section 5.

3.1. Concept Description

Our design goal is to create an accumulator thermal management system capable of maintaining the optimal temperature range of a lithium-ion battery pack and its subsequent components in an electric race vehicle while performing at a competition. The battery pack is a part of a larger subassembly also known as the accumulator. The accumulator consists of the packaging of individual battery cells, various high-voltage (HV) components, wiring, and a controller (not housed within the accumulator container). A draft of the current accumulator design is shown below in Fig. 2, prior to our additions.



Dimensions?

Figure 2: The frame of the vehicle is shown above with the accumulator container, shown in orange, located in the rear of the vehicle.

The accumulator consists of 5 modules, each containing 112 cells. The final geometry of the internal layout of the modules has been completed by the powertrain team of SC Formula Electric, shown below in Fig. 3.

Is the [illegible] the proposed heat transfer surface?

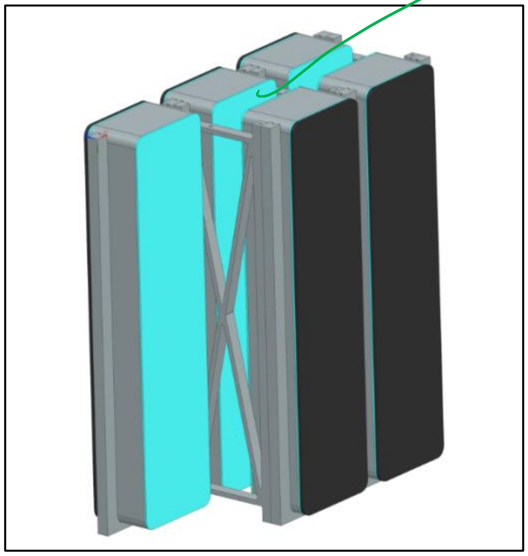
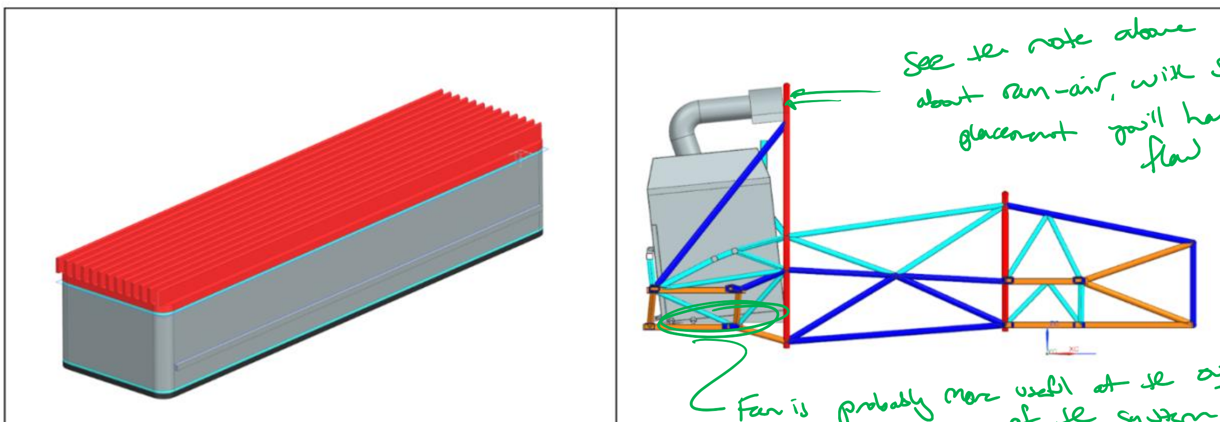


Figure 3: Complete geometry of accumulator, consisting of 5 modules (container not shown)

A working model sketch of the proposed heat sink attachment and scoop channel are shown below in Fig. 4. The heat sinks attach to the backs of the accumulator modules, a surface shared by all cells.



See the note above about ram-air, with scoop placement you'll have forced flow

Fan is probably more useful at the outlet of the system less disruption to the scoop

Figure 4: Heat sink attached to singular module (left). Accumulator container with scoop attached behind roll bar (right)

3.2. Proto-Design

Our thermal management system will include the integration of multiple components to achieve an optimized system. Fig. 5 below outlines the strategy to be employed.

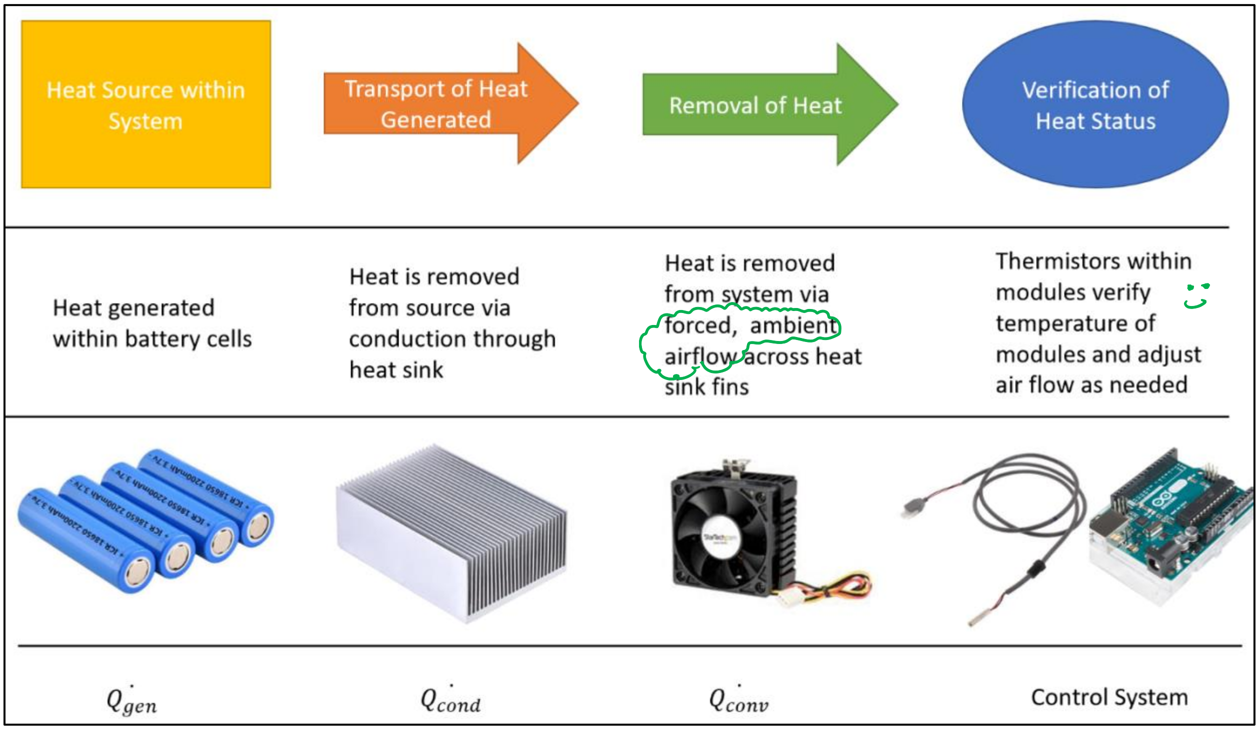


Figure 4: Process flow diagram of the heat dissipation system proposed from this study.

only if there is a ΔT

need to consider a balance

The heat dissipation of 620 W is expected to begin with the heat sink pulling heat from the module. The heat sink will be inserted between the walls of the current module model through which the heat sink will be able to draw heat from. The Accumulator Management System (AMS) is a controller which allows for safe operation of the HV cells. This controller monitors the temperature of every cluster of 4 battery cells. In addition, the main controller of the vehicle (MC) monitors the temperature as well which will cause the cooling system to initiate when needed. The system will consist of a hood scoop and PWM fan to draw air from the outside to be directed to the fins. Through forced convection, the fins will assist by dissipating heat to cool down the battery. When the vehicle is stationary, it is expected that outside air will still flow through the system to maintain the system at a stable temperature. via what mechanism?

3.3. Analysis Methods

To ensure the accumulator is running at the optimal temperature range for the input heat we will calculate the heat dissipated from the battery at steady state during the endurance test (i.e., lap

Different target assumption than above

25 of 50). This will give us the amount of heat dissipated required to ensure our design is sufficient to keep the battery from overheating.

By using the results from the CFD analysis, we will figure out the amount of heat dissipated using our air-cooled system. From the heat profile, we can easily calculate the max and minimum temperature of the battery pack. Using the maximum acceleration will result in the maximum power that the battery will have to perform under. This power then converted to heat generation will need to match the amount of heat dissipated, that the heat sink can perform, to confirm the capability of the system. Seeing that the heat generation of the accumulator is 620 W, while the dissipated heat amounts to 620 W, it is safe to assume that the cooling system will be able to cool the system given the conditions of the competition. Refer to the analysis section to see thorough breakdown of limitations.

Our design is $1,240.71 below the budget, meeting our budget criteria which allows us to have sufficient funds for more purchases in the case of a design change, mistake during manufacturing, or additional tool. For a full breakdown of the cost, refer to Section 5.

4. Analysis

A preliminary analysis was completed to determine the feasibility of this project. This section will walk through the calculations and assumptions introduced in Section 2 and provide additional supporting information to justify feasibility of the air-cooled heat dissipation as well as support for the basic assumptions. The table below lists the variables used in the following equations.

Table 5: Properties of Air at 27 degrees Celsius

Property	Value
Density	1.184 kg/m^3
Specific Heat	1007 J/kg-K
Thermal Conductivity	0.02551 W/m-K
Kinematic Viscosity	1.562×10^{-5} m^2/s
Prandtl Number	0.7296

4.1. Calculation Summary

Using a common internal resistance of the 18650 cells and the nominal voltage of the accumulator, the heat generated was determined to be 620 W. Heat dissipation from the accumulator modules occurs through heat sinks, which are attached to the external surface of the modules within the accumulator, creating a finned channel flowing between the modules as seen in Fig. 3. In the table below are the working dimensions of our design.

Table 6: Heat Sink Specifications and Dimensions

Dimensions are HUGE

Heat Sink Specification	Value
Height of Fin	500 mm
Width of Fin	400 mm
Length of Fin	520 mm

about 25 mph....
reasonable.... depending on duct geometry

Number of Fins	13
Heat Sink Material	Aluminum

The average manufacturer-specified ideal operating temperature range for the cells is 20-40ºC, with a maximum of 60ºC. The heat sink calculations to follow use the maximum ideal operating temperature of 40ºC. Using the surface area of the fins, the temperature differential between ambient air and the maximum ideal, and the known dissipated heat, Eqn. 8 finds the coefficient of heat transfer to be 46.81 W/m^2-C. Assuming laminar flow, Eqn. 11 results in a Nusselt number of 954.219. Using Eqn. 15 the Reynolds number was found to be 2.56 x 10^6, which is not laminar. Calculating using Eqn. 16, the Reynolds number was found to be 3.73 x 10^5. Using this number within Eqn. 17, the free stream velocity was found to be 11.2261 m/s. While this number is a bit high, it is still plausible for a variety of fans to accomplish. Additionally, this velocity is likely much higher than is actually required, as there are surfaces within the accumulator container that are likely to additionally dissipate heat not taken into account within this proposal.

laminar vs. turbulent flow is determined by geometry. based on the heat sink fins, assume turbulent

As is shown in Fig. 6 below, the Reynold's number vs Velocity graph is plotted to verify turbulent behavior and determine the air compressibility in the heat sink. From the graph and calculations, we can see that the flow will always be turbulent. The maximum flow speed that air can remain incompressible is 102 m/s, which can satisfy our assumption that air is incompressible.

yes, you've got turbulence trips everywhere

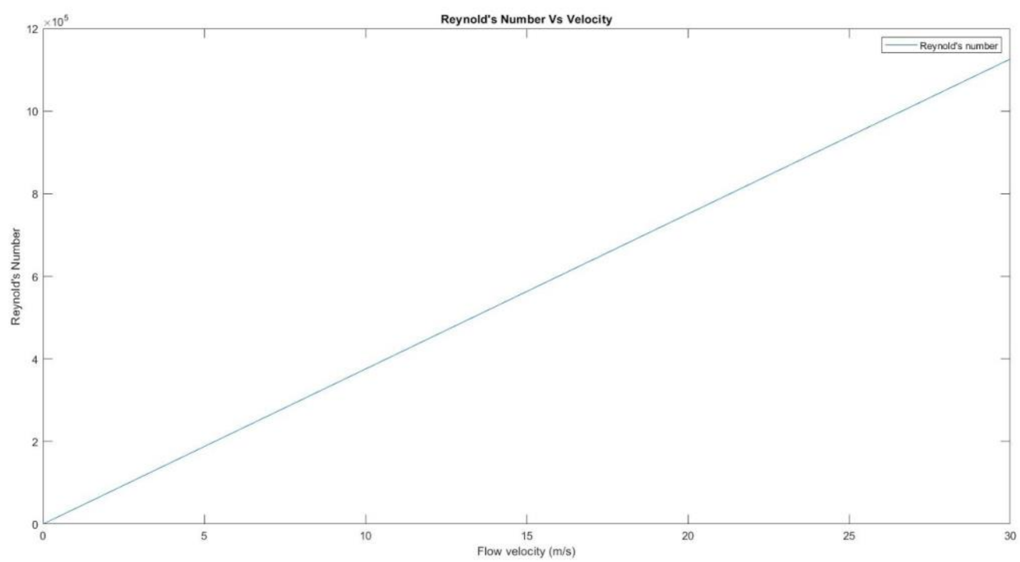


Figure 5. Reynold's number vs flow velocity

Through Fig. 7 below, we can see a log relationship between forced air convective coefficient and amount of heat it is able to dissipate. The forced air convective coefficient will vary depending on the speed it reaches the fins and the rate the fin tips will be able to transfer heat. From the graph, we can obtain the maximum amount of heat that can be dissipated given a certain air-flow speed. In order to satisfy our design conditions, it is optimal to keep heat dissipated below this maximum capacity.

we'll need to analyze the time dependence of $\dot{Q}$ vs heat removal
that's really where this gets interesting

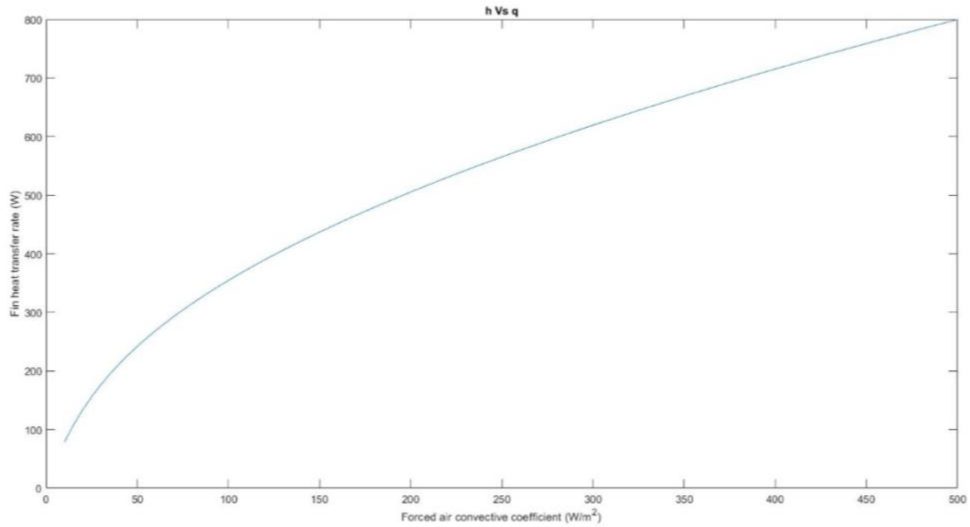


Figure 6: Fin tip heat transfer rate vs forced air convective rate

4.2. Proposed Analysis Procedure and Method

all about weight vs. effectiveness
for air based system
will need LARGE + powerful
fans to sustain high volumetric airflow

For air-cooled battery pack, first we will calculate the optimal wind speed *v* using MATLAB. By varying *v* from CFD analysis, we will compare *v* with an amount of heat dissipated (using Eqn. 3), using assumed boundary conditions. Furthermore, we are assuming the shape of the battery pack acts as a fully insulated box. For a water-cooled battery pack, the core concept is to equate Eqn. 6 to Eqn. 7 and find the optimal mass flow rate. However, we will vary the material and therefore varying terms h, in the above equations. A graph will be shown comparing mass flow rate vs temperature change, together with their cost comparison.

4.3. Design Box

The vehicle will experience a myriad of thermal conditions during competition as there are different events within which the vehicle will be used. Designing around a worst- or best-case scenario is limiting within this process, as it may result in a product which undercools when placed under strenuous conditions or becomes over-engineered, resulting in an accumulator that performs well under stress, but otherwise runs at suboptimal temperatures. Through the course of our project, we will develop a model based on the conditions set forth in Section 2 but add robustness to this design by testing our products ability to perform well at intermittent peak power demands and during charging, while the vehicle is stationary.

ok we'll simplify

5. Cost Estimate

The budget for this project is constrained by the allocated resources of SC Formula Electric. Part of the competition focuses on the business aspects of the team, rewarding manufacture over purchase. To follow this strategy, we've proposed a budget that is mainly manufactured, only purchasing components when necessary. Shown in Fig. 8 below is the estimated budget with component-specific sourcing of all required items and services. The budget given by SC Formula Electric is located on the bottom of the figure. In addition to the working budget for the development of this study, the team currently owns several items not listed in the budget to be used within this project, such as Arduinos, sensors, wiring supplies, and basic hand tools to build the final design.

AME-441 Group 8 - Cost Estimate
FSAE Battery Cooling System
as of 2/5/2021

	Vendor/Manufacturer	Model/Part No.	Qty.	Unit Price	Item Price
EXPENSES FOR ITEMS AVAILABLE IN LAB					
Materials					
3D Printer Material ($0.20/cm3)	AME-441 Lab	DWG-GRP-8-01R3	5000	$0.20	$1,000.00
Manufacturing custom heat sinks?					
Milling ($70 per hour)	AME-441 Machine Shop	DWG-GRP-8-01R1	10	$70.00	$700.00
Laser Cutting ($50 per hour)	AME-441 Machine Shop	DWG-GRP-8-01R2	1	$50.00	$50.00
3D Printer ($20 per hour)	AME-441 Lab	DWG-GRP-8-01R3	3	$20.00	$60.00
				Sub-total Cost:	**$1,750.00**
EXPENSES FOR ITEMS REQUIRED FOR PURCHASE		is 47 cfm sufficient?			
Equipment					
PWM Fan	McMaster-Carr	$\boxed{1976K56}$	1	$70.10	$70.10
Air Regulator	McMaster-Carr	41735K11	1	$42.74	$42.74
Thermistors	McMaster-Carr	8000K4	1	$6.83	$6.83
					$0.00
Materials					$0.00
Aluminum Sheets (36x36 in)	Home Depot	57000	6	$21.98	$131.88
Heat Sink Compounds	McMaster-Carr	76645A14	1	$82.74	$82.74
Miscellaneous Hardware	McMaster-Carr	N/A	1	$25.00	$25.00
				Sub-total Cost:	**$359.29**
				TOTAL PROJECT EXPENSES:	**$2,109.29**
BUDGET					
AME-441 project budget ($100 per student)			4	$100.00	$400.00
SC Fornula Electric Battery Cooling Budget			1	$1,200.00	~~$1,200.00~~
				TOTAL BUDGET:	**$1,600.00**

Figure 8. Cost estimate of consumables and services required for the manufacture of the final product.

6. Timetable

To complete this project for the duration allotted, a Gantt chart will be used to keep track of project milestones and course deliverables, as shown below. Each major task is broken into corresponding subtasks assigned to individual team members. To view the full chart, refer to Appendix A.

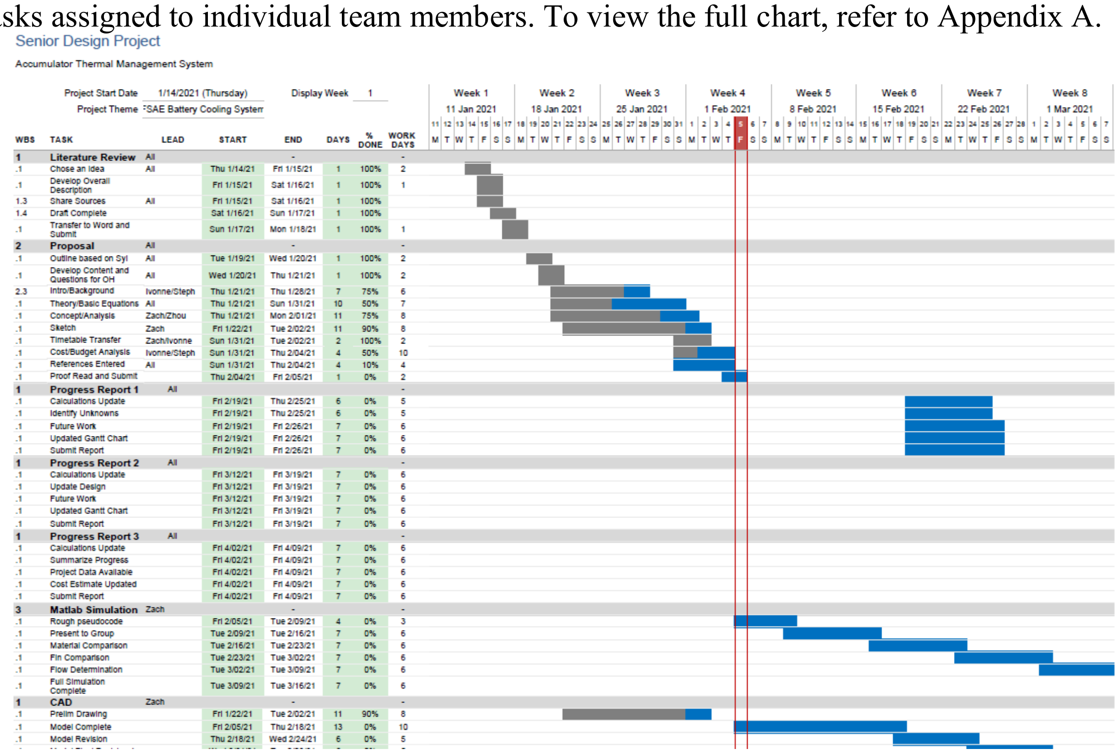


Figure 9. Gantt Chart for battery thermal management system project.

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Senior Design Project

Accumulator Thermal Management System

Project Start Date: 1/14/2021 (Thursday) Display Week: 1

Project Theme: SAE Battery Cooling System

Week 1: 11 Jan 2021 | Week 2: 18 Jan 2021 | Week 3: 25 Jan 2021 | Week 4: 1 Feb 2021 | Week 5: 8 Feb 2021 | Week 6: 15 Feb 2021 | Week 7: 22 Feb 2021 | Week 8: 1 Mar 2021

WBS	TASK	LEAD	START	END	DAYS	% DONE	WORK DAYS
1	**Literature Review**	All		-			-
.1	Chose an idea	All	Thu 1/14/21	Fri 1/15/21	1	100%	2
.1	Develop Overall Description		Fri 1/15/21	Sat 1/16/21	1	100%	1
1.3	Share Sources	All	Fri 1/15/21	Sat 1/16/21	1	100%	
1.4	Draft Complete		Sat 1/16/21	Sun 1/17/21	1	100%	
.1	Transfer to Word and Submit		Sun 1/17/21	Mon 1/18/21	1	100%	1
2	**Proposal**	All		-			-
.1	Outline based on Syl	All	Tue 1/19/21	Wed 1/20/21	1	100%	2
.1	Develop Content and Questions for OH	All	Wed 1/20/21	Thu 1/21/21	1	100%	2
2.3	Intro/Background	Ivonne/Steph	Thu 1/21/21	Thu 1/28/21	7	75%	6
.1	Theory/Basic Equations	All	Thu 1/21/21	Sun 1/31/21	10	50%	7
.1	Concept/Analysis	Zach/Zhou	Thu 1/21/21	Mon 2/01/21	11	75%	8
.1	Sketch	Zach	Fri 1/22/21	Tue 2/02/21	11	90%	8
.1	Timetable Transfer	Zach/Ivonne	Sun 1/31/21	Tue 2/02/21	2	100%	2
.1	Cost/Budget Analysis	Ivonne/Steph	Sun 1/31/21	Thu 2/04/21	4	50%	10
.1	References Entered	All	Sun 1/31/21	Thu 2/04/21	4	10%	4
.1	Proof Read and Submit		Thu 2/04/21	Fri 2/05/21	1	0%	2
1	**Progress Report 1**	All					-
.1	Calculations Update		Fri 2/19/21	Thu 2/25/21	6	0%	5
.1	Identify Unknowns		Fri 2/19/21	Thu 2/25/21	6	0%	5
.1	Future Work		Fri 2/19/21	Fri 2/26/21	7	0%	6
.1	Updated Gantt Chart		Fri 2/19/21	Fri 2/26/21	7	0%	6
.1	Submit Report		Fri 2/19/21	Fri 2/26/21	7	0%	6
1	**Progress Report 2**	All					-
.1	Calculations Update		Fri 3/12/21	Fri 3/19/21	7	0%	6
.1	Update Design		Fri 3/12/21	Fri 3/19/21	7	0%	6
.1	Future Work		Fri 3/12/21	Fri 3/19/21	7	0%	6
.1	Updated Gantt Chart		Fri 3/12/21	Fri 3/19/21	7	0%	6
.1	Submit Report		Fri 3/12/21	Fri 3/19/21	7	0%	6
1	**Progress Report 3**	All					-
.1	Calculations Update		Fri 4/02/21	Fri 4/09/21	7	0%	6
.1	Summarize Progress		Fri 4/02/21	Fri 4/09/21	7	0%	6
.1	Project Data Available		Fri 4/02/21	Fri 4/09/21	7	0%	6
.1	Cost Estimate Updated		Fri 4/02/21	Fri 4/09/21	7	0%	6
.1	Submit Report		Fri 4/02/21	Fri 4/09/21	7	0%	6
3	**Matlab Simulation**	Zach		-			-
.1	Rough pseudocode		Fri 2/05/21	Tue 2/09/21	4	0%	3
.1	Present to Group		Tue 2/09/21	Tue 2/16/21	7	0%	6
.1	Material Comparison		Tue 2/16/21	Tue 2/23/21	7	0%	6
.1	Fin Comparison		Tue 2/23/21	Tue 3/02/21	7	0%	6
.1	Flow Determination		Tue 3/02/21	Tue 3/09/21	7	0%	6
.1	Full Simulation Complete		Tue 3/09/21	Tue 3/16/21	7	0%	6
1	**CAD**	Zach		-			-
.1	Prelim Drawing		Fri 1/22/21	Tue 2/02/21	11	90%	8
.1	Model Complete		Fri 2/05/21	Thu 2/18/21	13	0%	10
.1	Model Revision		Thu 2/18/21	Wed 2/24/21	6	0%	5
.1	Model Final Revision 1		Wed 2/24/21	Tue 3/02/21	6	0%	5
.1	Completed Model		Tue 3/02/21	Sun 3/14/21	12	0%	9
1	**CFD**	All		-			-

simulation of heat?

Senior Design Project

Accumulator Thermal Management System

I'm missing half of this

Project Start Date 1/14/2021 (Thursday) Display Week 1

Project Theme FSAE Battery Cooling System

Week	Week of	Dates	Days
Week 1	11 Jan 2021	11 12 13 14 15 16 17	M T W T F S S
Week 2	18 Jan 2021	18 19 20 21 22 23 24	M T W T F S S
Week 3	25 Jan 2021	25 26 27 28 29 30 31	M T W T F S S
Week 4	1 Feb 2021	1 2 3 4 5 6 7	M T W T F S S
Week 5	8 Feb 2021	8 9 10 11 12 13 14	M T W T F S S
Week 6	15 Feb 2021	15 16 17 18 19 20 21	M T W T F S S
Week 7	22 Feb 2021	22 23 24 25 26 27 28	M T W T F S S
Week 8	1 Mar 2021	1 2 3 4 5 6 7	M T W T F S S

WBS	TASK	LEAD	START	END	DAYS	% DONE	WORK DAYS
.1	Establish All Conditions		Sun 3/14/21	Mon 3/15/21	1	0%	1
.1	Create Grid		Mon 3/15/21	Thu 3/18/21	3	0%	4
.1	Develop Simulation Strategy		Thu 3/18/21	Sat 3/20/21	2	0%	2
.1	Form Input Paramaters and Files		Sat 3/20/21	Tue 3/23/21	3	0%	2
.1	Perform Simulation		Tue 3/23/21	Mon 3/29/21	6	0%	5
.1	Extract Necessary Info		Mon 3/29/21	Thu 4/01/21	3	0%	4
.1	Analyze Results		Thu 4/01/21	Sat 4/03/21	2	0%	2
1	**Presentation Slide**	All		-			-
.1	Introduction to Project		Sat 3/20/21	Mon 3/22/21	2	0%	1
.1	Introduce Air Cooled System		Sat 3/20/21	Mon 3/22/21	2	0%	1
.1	Theory/Basic Equations		Mon 3/22/21	Fri 3/26/21	4	0%	5
.1	Constraints/Boundary Conditions		Fri 3/26/21	Mon 3/29/21	3	0%	2
.1	Experimental Simulation		Mon 3/29/21	Wed 3/31/21	2	0%	3
.1	Present CFD/MatLab Results		Wed 3/31/21	Sun 4/04/21	4	0%	3
.1	Provide Analysis		Sun 4/04/21	Wed 4/07/21	3	0%	3
.1	Conclusion		Wed 4/07/21	Fri 4/09/21	2	0%	3
.1	Revise		Fri 4/09/21	Sun 4/11/21	2	0%	1
.1	Oral Presentation		Tue 4/20/21	Tue 4/20/21	0	0%	1
1	**Final Report**	All		-			-
.1	Abstract		Tue 4/20/21	Thu 4/22/21	2	0%	3
.1	Introduction		Thu 4/22/21	Sun 4/25/21	3	0%	2
.1	Experimental Technique		Thu 4/22/21	Mon 4/26/21	4	0%	3
.1	Results		Thu 4/22/21	Tue 4/27/21	5	0%	4
.1	Discussion		Tue 4/27/21	Sun 5/02/21	5	0%	4
.1	Conclusion		Sun 5/02/21	Sat 5/08/21	6	0%	5
.1	References Entered		Tue 4/20/21	Tue 5/04/21	14	0%	11
.1	Appendices Completed		Tue 4/20/21	Tue 5/04/21	14	0%	11
.1	Revise		Sat 5/08/21	Tue 5/11/21	3	0%	2
.1	Turn In Report		Tue 5/11/21	Tue 5/11/21	0	0%	1
1	**Other Task**	All		-			-
.1	Complete Lab Notebook		Thu 1/14/21	Tue 5/11/21	3	5%	84
.1			Tue 10/20/20	Fri 10/23/20	3	0%	4
.1			Tue 10/20/20	Fri 10/23/20	3	0%	4
.1			Tue 10/20/20	Fri 10/23/20	3	0%	4
.1			Tue 10/20/20	Fri 10/23/20	3	0%	4
.1			Tue 10/20/20	Fri 10/23/20	3	0%	4
.1			Tue 10/20/20	Fri 10/23/20	3	0%	4