# Design and Analysis of a Cooling System for High Voltage Battery Pack of a Formula Student Electric Vehicle

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**Abstract -** *This paper explains how to construct a high-voltage battery pack for a formula student vehicle and how to choose a cooling system, as well as easy analysis tools for developing an efficient cooling model. We can display heat dissipation and cooling flow just like a genuine system using software like Ansys Icepack. This system is designed according to the formula student's handbook and with cost-effectiveness in mind.*

***Key Words***: Air cooling system, thermal model, battery pack, heat generation, energy storage, battery thermal management

## 1.INTRODUCTION

To operate an electric car at a high degree of efficiency, the electric motor, power electronics, and battery pack must all be kept within a certain temperature range. This involves the implementation of an advanced heat management system.

Fig 1-Battery box exploded view

Fig 2- Battery Box

To handle our heat radiations in the accumulator, motor, and motor controller, we use a 'Fan Based Cooling System.' It is dependent on the ambient air, which carries the heat via the batteries.

The A123-AMP20m1HD-A pouch cells feature a nominal voltage of 3.3V, a capacity of 19.6Ah, a total weight of 496g for 96 cells, and a power discharge of 1200W.

An efficient cooling system is required to control the heat dissipation of such power.

## 2. THERMAL DESIGN FLOW

An extremely efficient design flow is required to sustain a basic cooling system. We use active air conditioning to manage heat generation in this system. When the vehicle is driving at high speeds, special air flow channels are built to direct air, and when the vehicle is stationary, fans are employed to force air to the battery accumulator box.

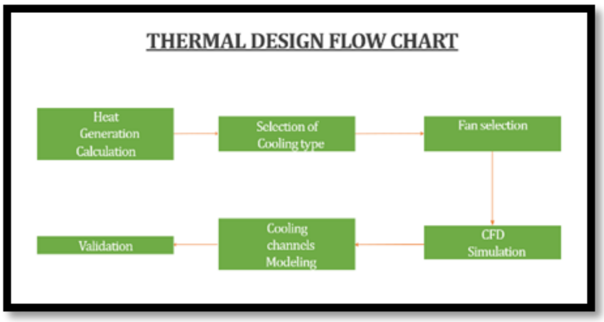


Fig 2- Thermal Design Flow Chart

For active airflow, the accumulator box features three intake and three exhaust fans. By readings from a thermal probe used to monitor battery temperature, special temperature sensors are employed to adjust the fan speed.

## 3. HEAT GENERATION METHODS-

Chemical processes heat, polarization heat, and Joule's heat are the three types of heat created by a lithium ion battery.

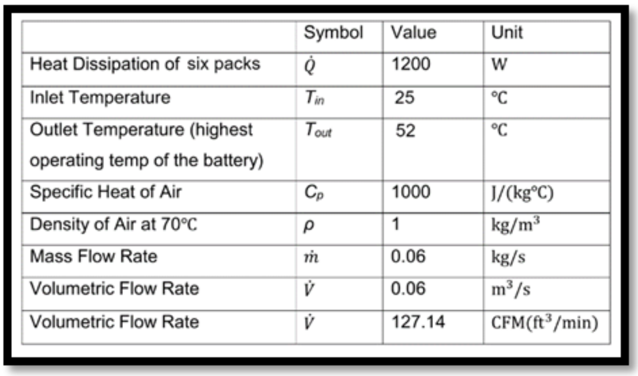
Because characterizing all of the fundamental physical and electrochemical processes that occur in a battery cell is challenging and time-consuming, the battery is evaluated using parametric analysis and characterized using a mathematical model method based on external observable behaviors. All three variables can be measured in real time: voltage at the battery terminal Vt, current A, and temperature C.

- Thevenin Equivalent Method

➢ Vd=I×R

➢ $Q = I^2R$

➢ $Q = \int_0^t I^2 RT\,dx$



| | Symbol | Value | Unit |
|---|---|---|---|
| Heat Dissipation of six packs | $\dot{Q}$ | 1200 | W |
| Inlet Temperature | $T_{in}$ | 25 | °C |
| Outlet Temperature (highest operating temp of the battery) | $T_{out}$ | 52 | °C |
| Specific Heat of Air | $C_p$ | 1000 | J/(kg°C) |
| Density of Air at 70°C | $\rho$ | 1 | kg/m³ |
| Mass Flow Rate | $\dot{m}$ | 0.06 | kg/s |
| Volumetric Flow Rate | $\dot{V}$ | 0.06 | m³/s |
| Volumetric Flow Rate | $\dot{V}$ | 127.14 | CFM(ft³/min) |

Table 1- Heat Dissipation Data

## 4. COOLING MODEL

The cooling method employed is forced convection using six fans to transport heat out of the batteries and improve the surface area of heat convection. There are six stacks, each of which has 16 battery cells. These 16 battery cells are connected in series, and each pack of four battery cells is connected in parallel. The crevices between the stacks are lined with aluminum sheets that act as heat sinks to dissipate the heat.

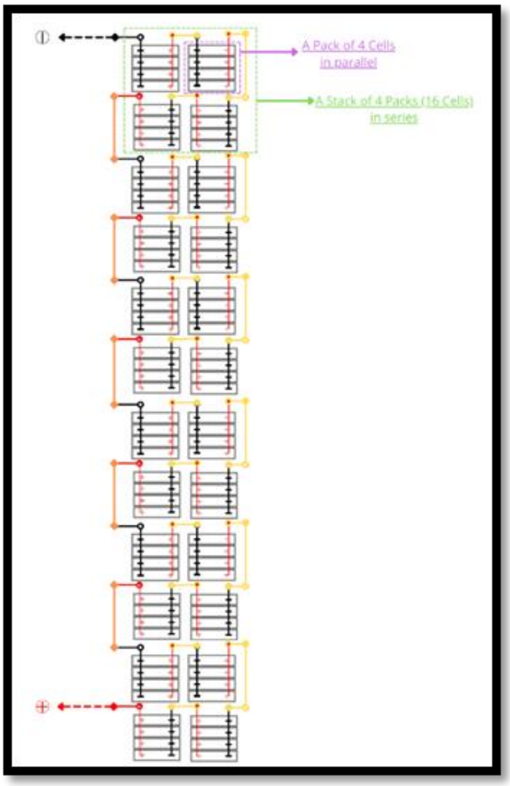


Fig 3- Cell Configuration

The inlet fans are located on the lower half of the battery box's inlet face, while the exhaust fans are located on the upper half. The natural thermal movement of air is aided by this type of positioning.

The air ducts beneath the automobile direct fresh air to the intake fans, which drive airflow to the inlet fans of the battery pack to travel through the cells and heat sinks to dissipate heat and out the exhaust fans at high speeds.

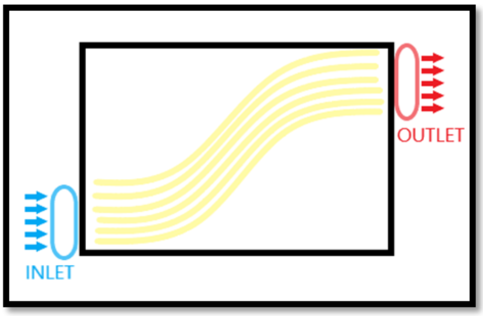


Fig 4-Fan placement & Heat flow

## 5. FAN SELECTION

Choosing the most efficient cooling fan for the system is a critical task. The fan performance curve is simply a static pressure curve created by charting various static pressure points against precise volumetric flow rates at a certain test speed, giving a foundation for flow and pressure calculations. The static pressure curve, which shows the fan's performance at a given speed, can also be used to figure out the pressure capability.

For our method, there were a few criteria for picking fans:

1. Axial fans are used because they can produce a higher flow rate than other types of fans.

2. Because the low voltage system was 12 volts, the fans necessary had to be 12 volts as well.

3. We looked at all of the 12V DC fans on the market and investigated their designs to find the best one.

4. We looked at the fan performance curve and found that 124CFM is the best we could come up with.

5. To make the system basic and stable, we chose a Saneo Denki San Ace 92GV38 E simple fan with dimensions of 92x92x38mm.

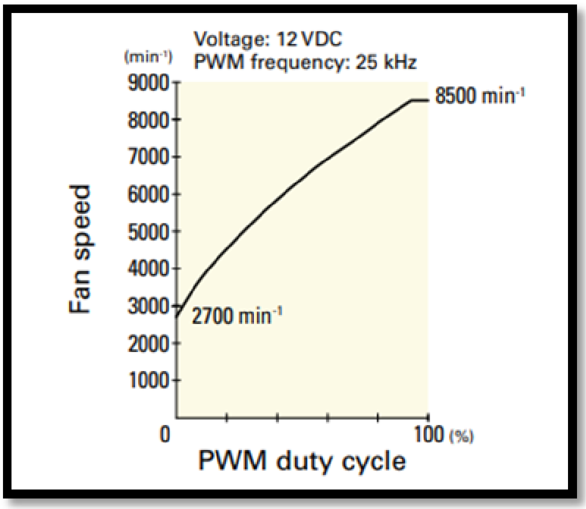


Fig 6- Fan Speed Curve

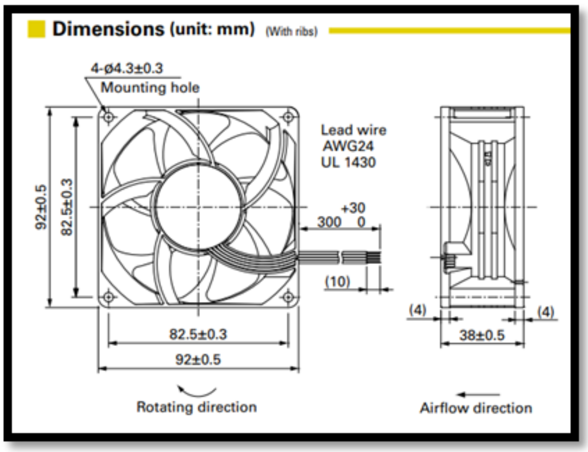


Fig 7-Fan dimensions

## 6. ANALYSIS

The batteries are cooled via forced convection, and six fans are enough to maintain the required temperature at full load, with three parallel fans pushing air into the battery box and three parallel fans pulling air out of the stack.

The system's intake and exit temperatures are depicted in the diagram.

The greatest temperature measured in the hottest section of the battery system was 520 C, which is well within the operational temperature range.

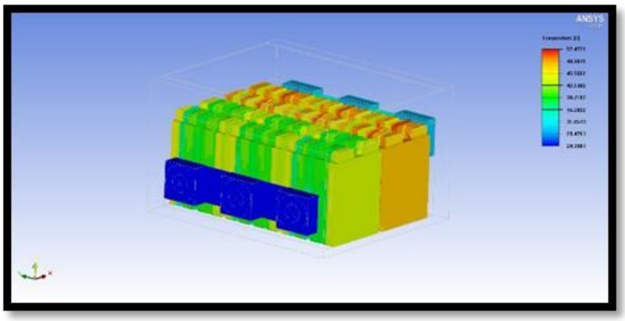


Fig 8-Inlet View

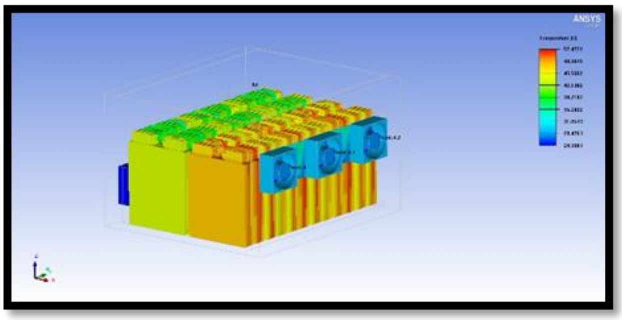


Fig 9-Outlet View

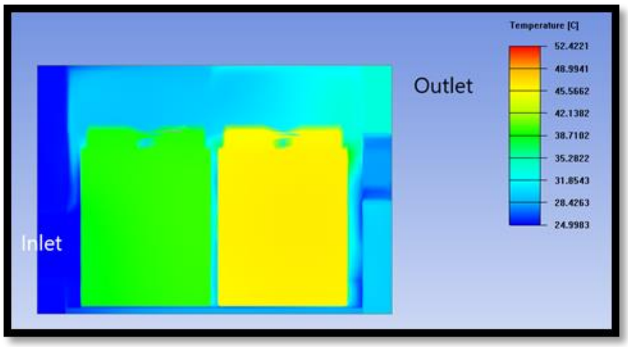


Fig 10-Cross-section View

## 7. CONCLUSIONS

CFD study was performed to figure out how the 96-cell cooling model, which produces 1200 W of power, works. A better cooling system allows the system to run more efficiently and increases its longevity. This straightforward concept will boost cooling system efficiency while lowering costs. Finally, with the proportions of the fan employed, this type is the most efficient.

This battery pack was constructed according to the rules of a formula student competition, and the best performing cells were used in its construction.

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