Cooling and Packaging of Batteries for Formula SAE Electric Racecar

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I. Four Motors, 75kw

II. 120 Battery Cells, 198V Nominal Voltage
Battery Cell

- Cell configuration

I. LiFePO4

II. Prismatic Cell

III. 3.3V Nominal Voltage
Battery Pack

- Pack Configuration

I. 20 Cells per Pack

II. Corrugation Aluminum as Heat Sinks
Battery Cooling

I. Three Packs in One Container

II. Heat Dissipation: 1200W

III. Cooling: Forced Convection
Minimum Flow Rate

\[
\dot{m} = \frac{\dot{Q}}{C_p(T_{out} - T_{in})}
\]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Dissipation of Three Packs</td>
<td>(\dot{Q})</td>
<td>1200 W</td>
</tr>
<tr>
<td>Inlet Temperature</td>
<td>(T_{in})</td>
<td>30 °C</td>
</tr>
<tr>
<td>Outlet Temperature</td>
<td>(T_{out})</td>
<td>50 °C</td>
</tr>
<tr>
<td>Volumetric Flow Rate</td>
<td>(\dot{V})</td>
<td>127 CFM(ft^3/min)</td>
</tr>
</tbody>
</table>
### Flow Region

#### 264 Trapezoidal Channels

![Trapezoidal Channel Diagram]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Area</td>
<td>$A$</td>
<td>36</td>
</tr>
<tr>
<td>Wetted Perimeter</td>
<td>$P$</td>
<td>16</td>
</tr>
<tr>
<td>Hydraulic Diameter</td>
<td>$D_h$</td>
<td>9</td>
</tr>
</tbody>
</table>
### Laminar Flow

<table>
<thead>
<tr>
<th>Volumetric Flow Rate (CFM)</th>
<th>Velocity (m/s)</th>
<th>Reynolds Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>127</td>
<td>6</td>
<td>2700</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Symbol</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Laminar Pressure Drop</td>
<td>$\Delta P_L$</td>
</tr>
<tr>
<td>Head Loss</td>
<td>$\Delta P_O$</td>
</tr>
<tr>
<td>Total Pressure Drop</td>
<td>$\Delta P_T = \Delta P_L + \Delta P_O$</td>
</tr>
</tbody>
</table>
System Resistance Curve

(One Pack)

Static Pressure Drop (Pa)

Volumetric Flow Rate (CFM)
Flow Experiment

- Pressure Drop VS Flow Rate
System Resistance

- Flow Experiment Result
- Numerical Result
Operating Point

170 CFM, 280 Pa (45°C)

127 CFM (50°C)
- Simulation: 276 Pa
- Calculation: 280 Pa
Pressure Drop (Turbulent)

- Simulation: 288 Pa
- Calculation: 280 Pa
Pressure Drop Across One Channel (Laminar)
Pressure Drop Across One Channel (Turbulent)
Flow Speed (Laminar)

- Simulation: 13.2 m/s
- Calculation: 8 m/s
Flow Speed (Turbulent)

- Simulation: 8.25 m/s
- Calculation: 8 m/s
Battery Temperature (Laminar)

- Simulation:
  Average 49°C  Peak 55.7°C

- Calculation: 45°C
Battery Temperature (Turbulent)

- Simulation:
  Average 43.2°C  Peak 50.6°C

- Calculation: 45°C
Air Temperature (Laminar)
Peak 39°C
Air Temperature (Turbulent)
Peak 42°C
Accumulator Container
(Battery Box)

I. Two Containers

II. Six Battery Packs

III. Other Components
Packaging

Accumulator
Isolation
Relays

Energy Meter

Motor Fuse

Main Fuse
Good Luck to E-16

Thank You