Apêndice A

Project Requirements

Performance

E1 **(Mandatory)** Maximum power output must be <80 kW DC

E2 **(Desirable)** Maximum Discharge rate should be >10C (C-rate)

E3 **(Optional)** The accumulator should be able to be fully recharged within 4 hours.

E4 **(Desirable)** The accumulator should last through tests and competition without major repairs – 300 life cycles

Cell Chemistry and Limitations

E5 **(Mandatory)** Cell chemistry – Li-ion

E6 **(Mandatory)** Cell temperature range must be – [30;60] ºC

E7 **(Mandatory)** Use cylindrical cells with low failure rates and high life cycle – 18650 or 21700

TSAC Design

E8 **(Mandatory)** Tractive system accumulator Energy capacity – [6;8] kW

E9 **(Mandatory)** The voltage of the accumulator must be within the range – [400;600] V

E10 **(Desirable)** Must respect chassis restriction for tractive system accumulator container (TSAC)– height: 280; width: 600; length: 550 (mm)

E11 **(Desirable)** Tractive system accumulator container (TSAC) must not exceed weight – <60 kg

E12 **(Desirable)** Maintenance time for segment removal should be– <20 min

E13 **(Mandatory)** Must comply with mechanical resistance rules (for critical components and their mountings) – withstand 40 g in the longitudinal direction, 40 g in the lateral direction and 20 g in the vertical direction

E14 **(Mandatory)** Utilize active and/or passive cooling

E15 **(Mandatory)** Must meet the insulation requirements in the rules FSG 2025

E16 **(Mandatory)** Must include an Insulation Monitoring Device (IMD)

E17 **(Mandatory)** Respect the integration of properly rated fuses

E18 **(Mandatory)** TSAC must be sealed from dust and debris

E19 **(Desirable)** TSAC must be resistant to vibration

E20 **(Desirable)** Modulation design should always remember easy maintenance

E21 **(Mandatory)** Tractive System Accumulator Container (TSAC) must be attached to the chassis accordingly to the regulations

Segment Design

E22 **(Mandatory)** Capacity of each segment must be – <6 MJ

E23 **(Mandatory)** Each segment must not exceed a static voltage of 120VDC

E24 **(Mandatory)** Each segment must not exceed a weight of 12 kg

Cost Effectiveness

E25 **(Optional)** Should have an easy and cost friendly manufacturing

E26 **(Optional)** Prioritize components which are affordable

E27 **(Desirable)** Use off the shelf components when possible

Others

E28 **(Mandatory)** Must fulfill all the rules criteria to compete

Apêndice B

PCM test bench consrucion

B.0.1 Materials

- **Cardboard tunnel:** Constructed with a rectangular cross-section.
- **Racks:** To hold PCM plates in specific configurations within the tunnel.
- **Tape:** To ensure minimal air leakage at tunnel joints.
- **Plastic tube:** ensure around 1 meter of constant are to remove any turbulence that the fan might create in the airflow.
- **PCM plates:** 12 plates in total, each with defined heat storage properties.
- **Fan:** To provide controlled airflow through the tunnel. EFACEC BF5 71M 42 Ventilator
- **Thermocouples:** For temperature measurement at the entry and exit points.
- **Thermocouple data acquisition system:** For continuous logging of temperature and pressure data. DeltaOHM HD 32.8 data acquisition system.
- **anemometer:** To measure flow velocity through a tube
- **Pitot tube:** Used to measure flow velocity through a pressure differential between dynamic and static pressure.
- **Pitot tube data acquisition system:** For continuous logging of flow velocity.TSI Airflow PH731 data acquisition system.
- **Stopwatch or timer:** For recording test duration.

B.0.2 Construction Procedure

Due to limited team funds, the development of the testing bench was made using simple materials, with the usage of equipments already present in the workshop like the fan and Data Logger. The next list explains the building process of the test bench.

1. Construction of a cardboard tunnel of uniform cross-section with the accumulator width and height measurements. This tunnel also has a cone that ensures the connection between the outlet of the plastic tube and the rest of the tunnel. The cardboard was also involved with tape in order to not get wet during the tests.

2. Place the fan at the entry of the plastic tube to provide airflow. Ensure the fan speed is adjustable for testing different flow rates by changing the area of the tunnel's entrance cross-section.

3. Design supports to hold PCM plates securely within the tunnel without obstructing airflow excessively.

4. with the usage of the pitot tubes, measure the air speed inside the cardboard cross section for various fan speed.

In Figure B.1, the transitional section between the plastic tube and the cardboard tunnel is shown

Figura B.1: Initial transitional section of the tunnel.

In figure B.2 it is shown the cardboard section where 3 racks for holding the PCMs stay. This section has a **length of 500mm**.

Figura B.2: Middle section of the tunnel, housing PCM shelves.

In Figure B.3 The final assembly of all sections is shown. The PCMs stay on the middle cardboard section, being installed by the back off the test bench. The entry of the fan that can be seen on the right can also be restricted using some cardboard blockers of various dimensions.

PEA-Template/figs/Assembly2.jpeg

Figura B.3: Assembled tunnel with ventilator.

Apêndice C

Airflow measurements

For the measurement of the airflow in the desired area, the first method used was the pitot tube. In this method, as seen in Figure C.1, the cross-sectional area is divided into smaller areas and 4 measurements per area are taken. This method was used in the Cardboard Cross-section Area and in the plastic tube

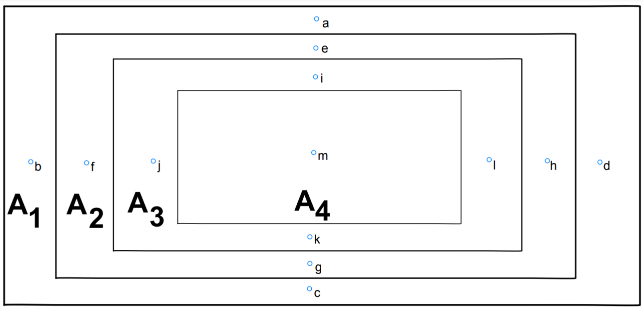


Figura C.1: Transversal area analysis division scheme.

The velocities for each area are calculated as follows:

$$V_{A_1} = \frac{V_a + V_b + V_c + V_d}{4}, \tag{C.1}$$

$$V_{A_2} = \frac{V_e + V_f + V_g + V_h}{4}, \tag{C.2}$$

$$V_{A_3} = \frac{V_i + V_j + V_k + V_l}{4}, \tag{C.3}$$

$$V_{A_4} = V_m. \tag{C.4}$$

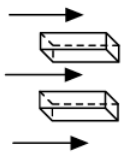
The average velocity across the section is then:

$$\overline{V} = \frac{V_{A_1}A_1 + V_{A_2}A_2 + V_{A_3}A_3 + V_{A_4}A_4}{A_{total}}. \tag{C.5}$$

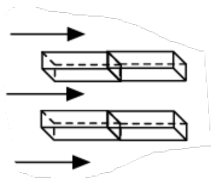
Apêndice D

PCM configurations

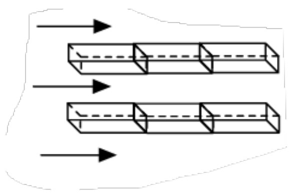
- Configuration 1: 2 PCM in parallel (longer side of the block along the airflow direction)



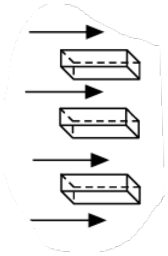
- Configuration 2: 2 PCM in parallel, 2 in series (longer side of the block along the airflow direction)



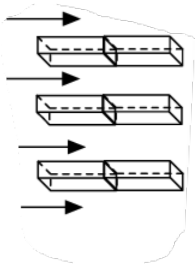
- Configuration 3: 2 PCM in parallel, 3 in series (longer side of the block along the airflow direction)



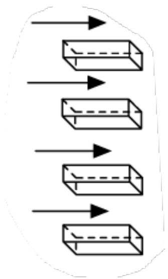
- Configuration 4: 3 PCM in parallel (longer side of the block along the airflow direction)



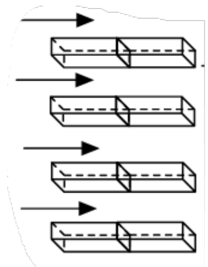
- Configuration 5: 3 PCM in parallel, 2 in series (longer side of the block along the airflow direction)



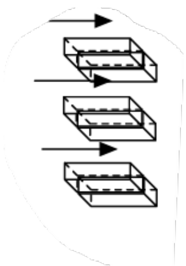
- Configuration 6: 4 PCM in parallel (longer side of the block along the airflow direction)



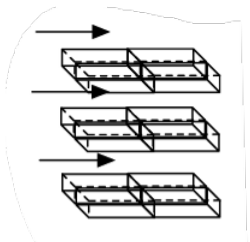
- Configuration 7: 4 PCM in parallel, 2 in series (longer side of the block along the airflow direction)



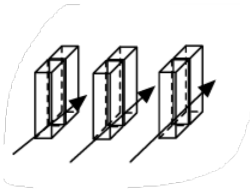
- Configuration 8: 3 PCM parallel, 2 in series vertical (longer side of the block along the airflow direction)



- Configuration 9: 3 PCM parallel, 2 in series and 2 vertical (longer side of the block along the airflow direction)



- Configuration 10: 3 PCM parallel, 2 series (shorter side of the block along the airflow)



- Configuration 11: 3 PCM parallel, 3 series (shorter side of the block along the airflow)