

Development of a Method for Conducting Short-Circuit Test Under UN38.3 Standard for Batteries Composed of Primery Lithium Metal Cells

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Lithium batteries have been utilized in a wide range of applications, from land vehicles and aircraft to isolated systems such as underwater equipment and space satellites, where autonomy is a crucial factor. However, these batteries pose significant risks in cases of external damage, malfunction, or exposure to environments that interfere with their internal chemical reactions. This has led to the creation of specific standards to regulate their transport and storage. Therefore, this work proposes a methodology for conducting a short-circuit test, a component of the certification process for the UN38.3 standard on the safe transportation of lithium batteries.

Keywords: UN38.3. Transport and Safety. Battery. Metallic Lithium.

Embedded electronics is a field of great prominence in the development of autonomous systems, allowing the integration of sensors, actuators, and control algorithms into compact and efficient devices [1]. Systems designed to operate in isolated and extreme environments, such as orbiting satellites and underwater devices, depend on energy sources that ensure their operation for long periods [2]. In this sense, autonomy becomes a relevant aspect, as the system must operate continuously and independently, without external intervention.

For these systems to remain operational without external interaction, one option is the use of batteries. Among the battery technologies currently available on the market, lithium batteries are widely mentioned in the literature due to their high voltage per cell, high energy density (around 500 Wh/kg), and low self-discharge rate—characteristics that favor long service life and optimization of space occupied by the cells, making them a relevant choice for applications demanding extended autonomy [3-6].

However, lithium batteries are susceptible to temperature variations and overcharging. Due to lithium's reactivity, under certain conditions—such as exposure to high temperatures, physical damage, or short circuits—these batteries may undergo uncontrolled chemical reactions, resulting in the leakage of toxic substances, fire, and explosion [7]. To mitigate these risks, international safety standards were established, among them UN38.3, a regulation developed by the United Nations that defines a series of rigorous tests to ensure the safety of lithium batteries during transport and storage [8]. In this context, this work aims to present a methodology for conducting one of the qualification tests for safe transport under the UN UN38.3 standard, for batteries assembled with tested lithium cells, totaling a mass equal to or less than 500 g of Li.

Theoretical Foundation

The air transport of lithium batteries has become increasingly common, mainly due to the high speed of this mode, which allows cargo to reach its destination faster than other transport options. However, when the lithium content exceeds 1 g or the capacity surpasses 20 Wh, it is necessary to meet the regulatory requirements for the air transport of hazardous goods [7]. UN38.3 establishes eight distinct tests that evaluate the behavior of batteries under various

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adverse conditions, including exposure to high and low temperatures, vibration, impact, external short circuits, and overcharge.

Certification under this standard significantly reduces the risk of accidents, thereby protecting both logistics operators and end-users.

For batteries assembled with tested cells totaling less than 500 g of lithium, three tests are required: vibration (T3), mechanical shock (T4), and external short circuit (T5). Although UN38.3 requires that this type of battery undergo all tests (T3, T4, and T5) to ensure transport and handling safety, this work focuses exclusively on the short-circuit test. This choice is due to the importance of this test in evaluating the thermal stability of the battery under extreme operating conditions.

The short circuit represents one of the most critical scenarios for lithium batteries, as the sudden rise in current can trigger internal processes that compromise their integrity and safety. This abrupt increase in current intensifies power dissipation in the internal elements of the battery, leading to the rapid heating of its components.

If the temperature exceeds a certain threshold, the stability of the electrolytes and electrochemical materials may be compromised, leading to the phenomenon of thermal runaway. In this state, the battery enters a self-sustaining cycle of heating and decomposition of its materials, culminating in the release of flammable gases, possible fires, and, in extreme cases, explosions. To prevent such conditions, a BMS (Battery Management System) is used, which is responsible for controlling, managing, and protecting the batteries [9]. The BMS is part of the battery and must be accredited together with the cells.

Proposed Method

The short-circuit test aims to evaluate the battery's behavior under a condition of continuous external short circuit. In this case study, the test will be performed with a battery pack capable of providing two voltage levels.

Prerequisites

- Minimum of two operators.
- Assembled battery pack.
- Class D fire extinguisher – suitable for metallic lithium batteries.
- Metal barrel at least 35% filled with sand or vermiculite.
- Long metal bar with a straight end.
- Gloves with thermal protection greater than 58°C.
- PPE:
 - Protective boots with plastic toe caps.
 - Face shield or safety goggles.

Equipment

- Multimeters with a thermocouple.
- Thermal paste.
- Climatic chamber.
- Infrared thermometer.
- Thermal camera.
- Multimeters in ammeter mode with recording capability.
- Recording camera.
- Computers.
- Flexible copper cable with PVC insulation and resistance $\leq 0.1 \Omega$ – sized according to the maximum short-circuit current for each voltage level.
- Circuit breaker, curve C, with DC interruption capacity – sized according to the conductor's capacity.

Procedure

To carry out the short-circuit test, the cell or battery must be placed in the climatic chamber, where it will be heated until reaching a homogeneous stabilized temperature of $(57 \pm 4) ^\circ\text{C}$. To monitor this temperature, thermocouples fixed with thermal paste must be used on the external casing. The climatic chamber must be configured and started for heating. Temperature confirmation must be made using

an infrared thermometer and a thermal camera. Next, the short-circuit circuit assembly proceeds. The circuit breaker must be installed in series with the positive terminal of the battery, sectioning both voltage levels. Ammeters must be connected in series with each circuit to monitor current. Additionally, a recording camera must be positioned to record the entire test visually. Figure 1 shows the experimental bench for the short-circuit test, with a battery capable of providing two independent voltage levels.

After reaching the stabilized temperature, the battery must be removed from the chamber, and the ammeter recording initiated. Current data must be recorded continuously, while temperature data must be noted every 5 minutes. With the circuit assembled, the battery is subjected to a short circuit. If any apparent damage occurs, a metal bar must be used to knock the battery into the containment barrel, and then the circuit breaker must be activated to stop the test. Throughout the entire process, the temperature must be constantly monitored using thermocouples and a thermal camera.

The short-circuit condition is interrupted at least one hour after the battery returns to a temperature of $(57 \pm 4) ^\circ\text{C}$. For the battery to be approved,

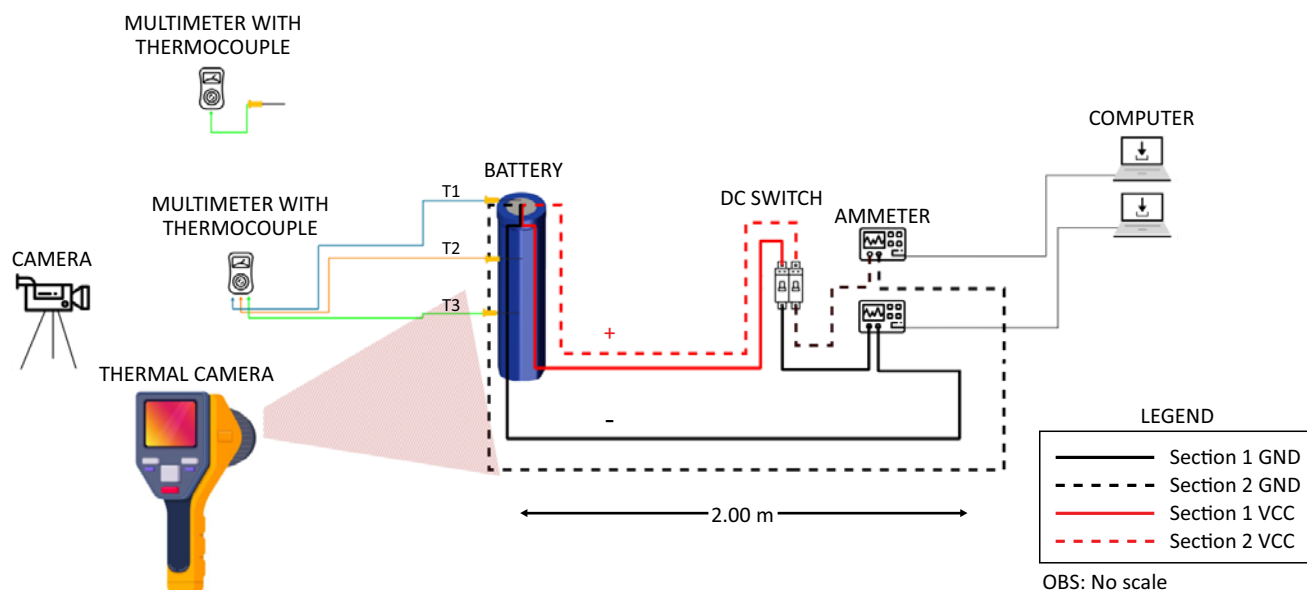
the external temperature must not exceed 170°C , and there must be no disassembly, rupture, or fire during the test and within 6 hours after the test.

Conclusion

The safety of metallic lithium batteries has been a growing concern in research and regulations. The UN38.3 standard establishes requirements for the transportation and commercialization of these batteries, especially during air transport, as a requirement of international hazardous goods regulations.

Thus, this work aimed to provide a methodology that enables researchers to apply the external short-circuit test safely, allowing for the collection of preliminary data on battery behavior before performing the test in accredited laboratories. This enables the identification of potential inadequacies and adjustments to batteries and BMS devices before the official test, thereby reducing the risk of failure and optimizing the certification time. However, this methodology does not replace formal tests conducted by certified entities; instead, it contributes to a preliminary analysis, helping to adapt products to regulatory requirements.

Figure 1. Test setup.



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References

1. Filho RP, Fontgalland IL. Tecnologia embarcada e a Indústria 4.0. *E-Acadêmica*. 2022;3(1):e103195.
2. Lopez JL, et al. On-demand ocean-bottom nodes (OD OBN) for low-cost reservoir monitoring. In: Third International Meeting for Applied Geoscience & Energy. Houston: Society of Exploration Geophysicists and American Association of Petroleum Geologists; 2023. p. 197-201.
3. Alves LM. As vantagens das baterias de lítio: um estudo de caso. Itapetininga; 2022.
4. Franchi LDC. Análise e implementação de métodos de estimação de parâmetros de célula de lítio. Porto Alegre; 2022.
5. Barreto AA, et al. Análise do efeito do tempo de descarga na vida útil de baterias de íon-lítio em aplicações de sistemas fotovoltaicos com fluxo reverso. Rio de Janeiro; 2024.
6. Micheline A. Baterias de lítio. 2020. Access: Mar 11, 2025.
7. Gomes RR, Augusto SAS. Possíveis riscos de acidentes no transporte de baterias de lítio no modal aéreo. 2023.
8. United Nations. Recommendations on the Transport of Dangerous Goods: Manual of Tests and Criteria. 7th rev. ed. New York: United Nations; 2019.
9. Alves CLGS, et al. Análise térmica e avaliação das incertezas dos parâmetros do modelo elétrico da bateria de lítio-íon. 2019.