DOT/FAA/TC-25/26

Federal Aviation Administration
William J. Hughes Technical Center
Aviation Research Division
Atlantic City International Airport
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A State of Charge Analysis of Power Banks (38.5 Wh) Shipped by Air

October 2025

Final report

U.S. Department of Transportation
Federal Aviation Administration

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1. Report No. DOT/FAA/TC-25/26	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle A State of Charge Analysis of Power Banks (38.5 Wh) Shipped by Air		5. Report Date October 2025 6. Performing Organization Code
7. Author(s) Dan Keslar		8. Performing Organization Report No.
9. Performing Organization Name and Address US Department of Transportation William J. Hughes Technical Center Aviation Research Division, Fire Safety Branch, ANG-E21 Atlantic City International Airport, NJ 08405		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Federal Aviation Administration Office of Hazardous Materials Safety (AXH-001) 800 Independence Avenue SW Washington, DC 20591		13. Type of Report and Period Covered Tech Note 14. Sponsoring Agency Code AXH-001
15. Supplementary Notes		

16. Abstract

UN 3480, lithium-ion batteries (batteries not packed with or contained in equipment) are forbidden on passenger carrying aircraft and cannot exceed a 30% state of charge (SoC) when transported on cargo aircraft. Lithium-ion power banks are included in this requirement.

In December 2024, an undeclared package containing three lithium-ion power banks experienced a thermal event. The package had been previously shipped from Florida to Kentucky via aircraft. The package was visibly smoking and had a burn hole in the side of the package. The fire eventually self-extinguished.

Members from the FAA's Office of Hazardous Materials Safety (AXH) contacted the FAA's Fire Safety Branch to aid in analysis of the power banks. Five lithium-ion power banks from packages offered by the same shipper were delivered to the FAA's Tech Center, where testing was conducted to determine the as-delivered SoC. Test findings determined that all the power banks that were shipped had a SoC exceeding 90%.

17. Key Words Lithium-ion, cells, batteries, state of charge, SoC, battery transport, UN3480, thermal runaway, smolder, incident	18. Distribution Statement This document is available to the U.S. public through the National Technical Information Service (NTIS), Springfield, Virginia 22161. This document is also available from the Federal Aviation Administration William J. Hughes Technical Center at actlibrary.tc.faa.gov.

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages	19. Security Classif. (of this report) Unclassified

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Acronyms

Acronym	Definition
A	Amperes
Ah	Ampere-Hour
AXH	Office of Hazardous Material Safety
CC-CV	Constant Current – Constant Voltage
FAA	Federal Aviation Administration
LED	Light Emitting Diode
mA	Milliampere
mAh	Milliampere-hour
SoC	State of Charge
UN	United Nations
USB	Universal Serial Bus
V	Volts
Wh	Watt-hour

Executive summary

UN 3480, lithium-ion batteries (batteries not packed with or contained in equipment) are forbidden on passenger carrying aircraft and cannot exceed a 30% state of charge (SoC) when transported on cargo aircraft. Lithium-ion power banks are included in this requirement.

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1 Introduction

UN 3480, lithium-ion batteries (batteries not packed with or contained in equipment) must be offered at a state of charge (SoC) not exceeding 30% of their rated capacity when transported on cargo aircraft (National Archives and Records Administration, 2025). Lithium batteries with a SoC above 30% pose a significant safety risk/fire hazard to aircraft systems (Webster, et al., 2016).

In December 2024, a package containing three lithium-ion power banks was shipped by aircraft from Orlando, Florida to Louisville, Kentucky. After landing, the package was moved via ground to California where it experienced a thermal event. Smoke was released from the package, and a fire burned a hole in the side of the package until it eventually self-extinguished. Other packages from the shipper were intercepted until further analysis could be conducted.

Members from the FAA's Office of Hazardous Materials Safety (AXH) contacted the FAA's Fire Safety Branch to aid in analysis. Five power banks from a package from the same shipper were delivered to the FAA's Tech Center, where testing was conducted to determine the as-delivered SoC.

2 Test setup

Upon arrival, the exterior of the five lithium-ion power banks were inspected. An exterior button on the side of the power bank powered a light and a Light Emitting Diode (LED) display which indicated the device's approximate SoC. The display indicated that all power banks were near full capacity. A picture of the power banks and its' LED display is shown in Figure 1.

Figure 1. Exterior of Power Bank with LED SoC Display

The power banks were opened so the interior could be evaluated. The inside of the power bank was powered by one large lithium-ion polymer, pouch cell.

Some relevant charging information, such as the nominal voltage, rated capacity, and energy capacity were marked on the exterior of the cell. However, much of the charging information needed was not specified. An online search was unable to find the manufacturer data or specification sheet. In order to determine the maximum charge voltage of the cell, one of the power banks was charged to full capacity using a Universal Serial Bus (USB) cable. A multimeter was used to determine the maximum voltage while the cell was plugged in, which was 4.30 Volts (V). SoC testing was conducted on the remaining four power banks.

Table 1 shows the charging parameters used within this study. The values highlighted in yellow were those not explicitly listed on the exterior of the cell.

Table 1. Charging Parameters Used

Charging Parameter	Value
Nominal Voltage	3.85 V
Rated Capacity	10,000 mAh
Rated Energy Capacity	38.50 Wh
Constant-Current Charge/Discharge Rate (0.2C)	2.00 A
Max Charge Voltage	4.30 V
Constant-Voltage Termination Current	1.00 A
Discharge Cut-off Voltage	2.75 V

SoC testing was conducted using a Chroma 17020 Battery Test System which has a full-scale range of 0-100 V and 0-100 Amps (A). The system accurately measures voltage within 0.02% of the full-scale voltage, plus 0.02% of the current voltage reading. Furthermore, it can accurately measure current within 0.05% of the full-scale current range, plus 0.1% of the current amperage reading. Based on the charging specifications used within this study, the charger would be able to accurately measure within ± 0.021 V and ± 5.2 mA of the actual values, throughout the entirety of the analysis.

To calculate SoC, cells were charged to full capacity. The electric charge measured in Ampere-hours (Ah) required to charge the power bank from its as-delivered SoC to full capacity was denoted as the Depth of Discharge. Once the Depth of Discharge was measured and the power bank was at full capacity, it was then discharged to the discharge cut-off voltage specified in Table 1 and the electric charge in Ah was recorded as the Total Capacity. Cells were charged utilizing a constant current – constant voltage (CC-CV) charging method, which is typical for lithium-ion chemistries. During this process, the total charge capacity and discharge capacity (Ah) were measured and recorded by the Chroma. From these values, the as-delivered SoC was calculated using Equation 1 below.

$$SoC = \frac{(Total\ Capacity - Depth\ of\ Discharge)}{Total\ Capacity} \quad (1)$$

Based on the methodology described within this report, the discharge capacity of the fully charged power bank is equivalent to the total capacity, as cells were discharged from 100% to 0% SoC.

3 State of charge results

Calculated from the methodology described above, SoC results for the four evaluated power banks are shown below in Table 2.

Table 2. SoC Results for Each Power Bank

Power Bank #	Depth of Discharge (Ah)	Total Capacity (Ah)	As-Delivered SoC
1	0.33	9.23	96.43%
2	0.65	8.90	92.72%
3	0.53	9.13	94.25%
4	0.89	9.04	90.17%

All four power banks were found to have exceeded the 30% SoC threshold. The average SoC of the four power banks was determined to be 93.39%.

4 References

National Archives and Records Administration. (2025, February 14th). Retrieved from Code of Federal Regulations: https://www.ecfr.gov/current/title-49/subtitle-B/chapter-I/subchapter-C/part-172/subpart-B/section-172.102

Webster, H., Maloney, T., Summer, S., Dadia, D., Rehn, S., & Karp, M. (2016). *Summary of FAA Studies Related to the Hazards Produced by Lithium Cells in Thermal Runaway in Aircraft Cargo Compartments.* Federal Aviation Administration.