THE SECRETARY OF TRANSPORTATION
WASHINGTON, DC 20590

November 2, 2021

The Honorable Maria Cantwell
Chair
Committee on Commerce, Science, and Transportation
United States Senate
Washington, DC 20510

Dear Chair Cantwell:

Enclosed is an evaluation providing information required by Section 333(f) "Packaging Improvements" of the Federal Aviation Administration (FAA) Reauthorization Act of 2018, Pub. L. No. 115-254, 116 Stat. 3009. The mandate requires the Secretary of Transportation, in consultation with interested stakeholders, to submit to the appropriate committees of Congress an evaluation of current practices for the packaging of lithium ion batteries and cells for air transportation, including recommendations, if any, to improve the packaging of such batteries and cells for air transportation in a safe, efficient, and cost-effective manner.

Safety is the foundation of our mission at the U.S. Department of Transportation (DOT), and we are engaged in several international and domestic efforts to advance the safe transportation of lithium batteries. This evaluation highlights those efforts and provides information on the current activities being pursued by the Department to address risks associated with lithium battery incidents during air transport.

A similar response has been sent to the Ranking Member of the Senate Committee on Commerce, Science, and Transportation and the Chair and Ranking Member of the House Committee on Transportation and Infrastructure.

Sincerely,

Pete Buttigieg

Enclosure

THE SECRETARY OF TRANSPORTATION
WASHINGTON, DC 20590

November 2, 2021

The Honorable Roger Wicker
Ranking Member
Committee on Commerce, Science, and Transportation
United States Senate
Washington, DC 20510

Dear Ranking Member Wicker:

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A similar response has been sent to the Chair of the Senate Committee on Commerce, Science, and Transportation and the Chair and Ranking Member of the House Committee on Transportation and Infrastructure.

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Pete Buttigieg

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THE SECRETARY OF TRANSPORTATION
WASHINGTON, DC 20590

November 2, 2021

The Honorable Peter A. DeFazio
Chair
Committee on Transportation and Infrastructure
U.S. House of Representatives
Washington, DC 20515

Dear Chair DeFazio:

Enclosed is an evaluation providing information required by Section 333(f) "Packaging Improvements" of the Federal Aviation Administration (FAA) Reauthorization Act of 2018, Pub. L. No. 115-254, 116 Stat. 3009. The mandate requires the Secretary of Transportation, in consultation with interested stakeholders, to submit to the appropriate committees of Congress an evaluation of current practices for the packaging of lithium ion batteries and cells for air transportation, including recommendations, if any, to improve the packaging of such batteries and cells for air transportation in a safe, efficient, and cost-effective manner.

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Sincerely,

Pete Buttigieg

Enclosure

THE SECRETARY OF TRANSPORTATION
WASHINGTON, DC 20590

November 2, 2021

The Honorable Sam Graves
Ranking Member
Committee on Transportation and Infrastructure
U.S. House of Representatives
Washington, DC 20515

Dear Congressman Graves:

Enclosed is an evaluation providing information required by Section 333(f) "Packaging Improvements" of the Federal Aviation Administration (FAA) Reauthorization Act of 2018, Pub. L. No. 115-254, 116 Stat. 3009. The mandate requires the Secretary of Transportation, in consultation with interested stakeholders, to submit to the appropriate committees of Congress an evaluation of current practices for the packaging of lithium ion batteries and cells for air transportation, including recommendations, if any, to improve the packaging of such batteries and cells for air transportation in a safe, efficient, and cost-effective manner.

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Sincerely,

Pete Buttigieg

Enclosure

U.S. Department
of Transportation
**Pipeline and Hazardous
Materials Safety
Administration**

1200 New Jersey Avenue, SE
Washington, DC 20590

Response to Congress

Pursuant to Section 333(f) of the Federal Aviation Administration (FAA) Reauthorization Act of 2018

Evaluation on Packaging Improvements (Lithium Batteries)

August 2021

Table of Contents:

1. Introduction

This Evaluation is responsive to Section 333(f) "Packaging Improvements" of the Federal Aviation Administration (FAA) Reauthorization Act of 2018, Pub. L. No. 115-254, 116 Stat. 3009.[1]

The mandate requires the Secretary of Transportation, in consultation with interested stakeholders, to submit to the appropriate committees of Congress an evaluation of current practices for the packaging of lithium ion batteries and cells for air transportation, including recommendations to improve the packaging of such batteries and cells for air transportation in a safe, efficient and cost-effective manner. The due date for the evaluation was 180 days after the enactment of the FAA Reauthorization Act of 2018, which was April 3, 2019. The contracting process and the time required to complete a thorough review and analysis resulted in the evaluation being completed after the due date.

The Office of the Secretary tasked the Pipeline and Hazardous Materials Safety Administration (PHMSA) with leading the Department's response to the Section 333(f) mandate. PHMSA has the lead role in developing the Hazardous Materials Regulations (HMR; 49 CFR Parts 171-180). Additionally, PHMSA currently serves as the United States representative on the Dangerous Goods Panel of the International Civil Aviation Administration (ICAO) and as the chair of the United Nations (UN) Sub-Committee of Experts on the Transportation of Dangerous Goods.

[1] FAA Reauthorization Act of 2018, Public Law 115–254 (October 5, 2018, FAA Reauthorization Act of 2018. Available at: https://www.congress.gov/bill/115th-congress/house-bill/302/text

2. Evaluation

To provide information for the evaluation, PHMSA sought a third-party assessment of current lithium battery packaging practices.[2] The third-party assessment included an identification of current packaging methods and their ability to protect the contents against exposure to transportation conditions, as well as market information derived from experience with industries that manufacture and ship lithium batteries by air, and battery trade associations. Conventional packaging practices and package configurations for cells, electric vehicles, power tools, battery packs, and medical devices are compared against data representing conditions normally found in the transportation system. The information presented indicates general compliance with the HMR by the industries considered. However, due to the small sample size of stakeholders represented in the assessment, it is difficult to draw concrete conclusions.

The packaging standards for lithium cells and batteries are tiered to the relative hazard of the cells or batteries. Specifically, UN specification packaging requiring design-type performance testing is required for the higher energy density cells or batteries, and non-specification packaging is required for other cells and batteries.

UN specification packaging was introduced into the HMR in a 1990 rulemaking (HM-181) establishing packaging standards that are based on performance criteria, rather than detailed design specifications, to accommodate technical innovation in package construction. UN specification packages are required to be designed, constructed, and tested to specific standards intended to ensure the packaging is robust enough to contain hazardous materials in transportation. Non-bulk UN specification packages are subject to the construction and testing requirements of 49 CFR Part 178, Subparts L and M. The performance testing system is intended to ensure packages can withstand conditions normally expected to occur in transport, including mechanical handling, shocks, drops, and changes in pressure and temperature. While the UN testing is not intended to replicate transport conditions, the testing does provide a baseline demonstration of the adequacy of a packaging design.

The most frequently used packaging configuration prescribed in the HMR is a combination package consisting of an outer fiberboard box with inner packagings containing lithium cells or batteries. UN-rated fiberboard boxes (UN 4G) —the most frequently used UN packaging for air transport of lithium batteries—are subject to the packaging standards of 49 CFR §178.516. The maximum net mass of a UN 4G fiberboard box is 400 kg (882 pounds). The regulations mandate the outer surface of

[2] Hazmat Safety Consulting LLC conducted the evaluation. The entirety of the report can be found here.

the fiberboard be water-resistant as determined by the Cobb method for water absorption.[3] Manufacturers must ensure the box joints are taped, lapped, and glued, or stitched with metal staples.

Non-specification packaging is constructed based on general packaging and capability requirements. These general requirements also specify that the effectiveness of the package will not be substantially reduced; for example, impact resistance, strength, packaging compatibility, etc. must be maintained for the minimum and maximum temperatures, changes in humidity and pressure, and shocks, loadings and vibrations, normally encountered during transportation.

Numerous studies have been conducted to measure the physical conditions encountered by packages in various transport environments including the express shipping environment. A 2015 study sought to characterize conditions encountered in the express air transport environment including package pick-up, handling, air transport, and delivery.[4] Three test packages were each transported on a round trip by air originating in California to five domestic destinations and four international destinations. The results were compared with package design qualification testing requirements in the HMR and differences discussed. While the 2015 study is not specific to lithium batteries, the results can be used to identify the transport conditions a package of lithium batteries might encounter. In 2019, National Research Council Canada completed a study that reviewed the environmental conditions encountered by lithium ion batteries in air transport.[5] During this study, 44 packages were sent by air to destinations in Asia, Europe, Middle East, and North America.

The data collected in the 2015 and 2019 studies were compared against the lithium battery testing criteria specified in Part III sub-section 38.3 of the United Nations Manual of Tests and Criteria and the package testing and conditioning requirements in the HMR. Both studies utilized fiberboard packages offered and transported by air instrumented to measure vibration, drops, temperature, humidity, and pressure differentials. The results of both studies showed that the temperature, atmospheric pressure and drop conditions experienced by the test packages were largely within the limits for which packages and batteries are tested.

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[3] Cobb Test described in ISO 535 (IBR, see 49 CFR §171.7)

[4] Singh J., Singh SP., Saha K. (2015). Measurement and Analysis of Physical and Climatic Distribution Environment for Air Package Shipment. *Packaging Technology and Science*. *Vol. 28*. 719–731. DOI: 10.1002/pts.2136.

[5] Decès-Petit, C., Fatih, K., Zhang, B. (2019). *Lithium battery transport: assessment of the environmental conditions for lithium batteries shipping.* National Research Council Canada. https://nrc-publications.canada.ca/eng/view/object/?id=1fbd9904-57f8-4fbe-a679-b31033315329

Shocks can occur when a package is dropped, during sorting and storage operations including loading-unloading, stacking, and lifting. Shocks are a common occurrence in the express shipping environment that can cause damage to packages. The HMR require packages containing lithium batteries to be able to withstand a 1.2 meter drop test, in any orientation, without damage to the cells or batteries contained in the package, without shifting of the contents that would allow battery-to-battery (or cell-to-cell) contact, and without release of the contents of the package. The data from the 2015 study showed that 95% of the drops occurred at or below 0.72 meters for domestic air shipments and 0.89 meters for international air shipments. Of the 44 packages measured in the Transport Canada study, only one package experienced a drop from a height greater than 1.2 meters and in 50% of the experimental shipping, the highest drop heights were less than 0.5 meters.

Inner packaging is intended to protect cells or batteries from damage and short circuit, and to ensure they are appropriately protected during normal conditions of transport. The current regulatory packaging requirements are based on the understanding that appropriately packaged lithium batteries are less likely to be subject to short circuit and damage. The packaging requirements recognize the importance of carefully preparing the inner packaging to prevent inadvertent movement and to prevent contact with other package contents, including metal objects that may cause damage or short circuiting in transport. There are multiple configurations used as inner packagings, which vary for cells and batteries.

Commonly, cell manufacturers will not enclose individual cells in individual inner packagings. Instead, they will place multiple cells inside a single inner packaging where each cell is separated and protected. Egg crate designs where cells are nested into individual compartments are a common configuration used to ship cylindrical cells, including both lithium metal and lithium ion chemistry. In this configuration, terminals are protected from contact with one another by the layer of material (typically cardboard or foam) immediately below and above the cells. This design serves to completely enclose cells and prevent movement of cells within the outer packaging. Lithium metal button cells are commonly shipped in trays — either cardboard or molded plastic — with divots that fit individual coin cells. Like the egg crate design, this serves to protect against short circuit and prevent cells from moving during transport. The trays are then stacked into outer packagings with cardboard liners and plastic sheeting separating each layer. Fiberboard dividers may also be used and are configured so that the fiberboard material completely encloses the cells or batteries.

Batteries are more commonly packed individually within inner packagings. Terminal covers are used in some circumstances, though in other cases the shipper deems them

unnecessary because terminal protection is built into the design of the pack itself. The inner packagings include anti-static plastic bags, blister packs and retail-ready fiberboard cartons. Cushioning materials include bubble wrap, heavy kraft paper, foam liners and packing peanuts. In limited cases, a fire-resistant foam or divider material intended to contain the hazards associated with a thermal runaway event is used. Such inner packaging is designed to provide passive propagation resistance, meaning the inner packaging serves to prevent propagation from cell to cell or battery to battery inside the outer packaging in the event of an incident. These more sophisticated package designs may also take into consideration the failure mode of the battery (i.e., top, bottom, or side rupture) to orient in a manner that the item and inner packaging work together as a safety system. Although the fire-resistant foam or divider material is not widely used, there are examples of this material currently available that appear to perform as designed, and which are lightweight and relatively thin. Research performed for this evaluation indicates that widespread use of the material for high volume air shippers might not be cost-effective now due to the costs of the material. However, expectations for growing automotive vehicle battery transport, containing higher energy densities than consumer batteries, would seem to provide an opportunity for expanded application and realized economies of scale. PHMSA believes further consideration of this technology is appropriate.

3. Ongoing Activities

While the current packaging standards are designed to protect lithium batteries from damage related to conditions normally incident to transport, there are additional considerations to address safety impacts resulting from high-consequence incidents. This is particularly critical for transport by air. To this end, PHMSA is actively working to improve on the current prescriptive classification system through efforts of the United Nations Sub-Committee of Experts on the Transport of Dangerous Goods to develop a testing-based hazard determination to improve hazard characterization; which could result in packaging enhancements and enable risk-based decisions on battery safety for the entire supply chain. PHMSA is also engaged with ICAO sponsored packaging standard development effort with SAE International to protect against fire and thermal events that could occur during a lithium battery thermal runaway event.

To provide for additional stakeholder consultation, PHMSA initiated a discussion of this evaluation with the Lithium Battery Air Safety Advisory Committee (also established by the FAA Reauthorization Act of 2018) during the advisory committee meeting on March 4, 2021. The Lithium Battery Air Safety Advisory Committee is comprised of industry stakeholders, and their input on the recommendations to improve the packaging of lithium batteries and cells for air transportation in a safe, efficient and cost-effective manner will be beneficial in any future policy-related decisions. The Lithium Battery Air Safety Advisory Committee agreed to consider opportunities to improve the effectiveness of packaging for lithium cells and batteries within its broad mandate to develop recommendations to enhance air transport safety. The Department will continue to actively pursue safety enhancements in its regulatory efforts as lithium battery designs and packaging types continue to evolve.

FAA Reauthorization Act of 2018, Section 333(f), Safe Air Transportation of Lithium Cells and Batteries

(f) Packaging Improvements. --Not later than 180 days after the date of enactment of this Act, the Secretary, in consultation with interested stakeholders, shall submit to the appropriate committees of Congress an evaluation of current practices for the packaging of lithium ion batteries and cells for air transportation, including recommendations, if any, to improve the packaging of such batteries and cells for air transportation in a safe, efficient, and cost-effective manner.