



Lithium-Ion Battery Incidents and Their Impact on Aviation Safety

Executive Summary



Rechargeable devices like phones, laptops, tablets, and portable power packs are integral to the air travel experience. The lithium-ion batteries that power these devices can, however, go into thermal runaway — a state of overheating that can result in fire or even explosion — if damaged, improperly charged, poorly manufactured, or counterfeit. At 40,000 feet, the risk is more complicated.

UL Standards & Engagement's Thermal Runaway Incident Program is a voluntary reporting system designed for the aviation industry to better understand the extent of the problem and prepare for, or ideally prevent, future incidents. The 35 passenger and cargo airlines that participate in TRIP provide detailed information on incidents within their operation. This data is then anonymized and shared with industry and safety organizations to improve the safe transport and usage of lithium-ion battery-powered goods.

For the first time, UL Standards & Engagement is publicly sharing findings from TRIP, to support awareness and prevention of thermal runaway in aviation.

Key Takeaways

- 1 Incidents are at the highest point in five years of data collection.** Incidents rose 28% over the past five years, from 2019-2023. There are an average of two thermal runaway incidents reported in the TRIP database each week. While on the rise, with approximately 180,000 flights in U.S. airspace per week, it is still highly unlikely to experience a thermal runaway incident.
- 2 The average passenger brings four rechargeable devices on board.** Most common items include smartphones (82%), laptops (41%), wireless headphones (39%), and tablets (36%). E-cigarettes were responsible for the most incidents in 2023, with 35% of reported incidents attributed to vaping devices on passenger flights, followed by power banks, representing another 16% of incidents.
- 3 Most incidents happen on the aircraft with devices that are stored near the passenger's seat.** Almost nine out of ten (87%) incidents are reported on the aircraft, with the remaining 13% occurring when baggage and personal items are on the move. On the aircraft, thermal runaway incidents occur in or around the passenger's seat nearly 60% of the time.
- 4 The vast majority of incidents are addressed before reaching the fire or explosion stage of thermal runaway.** Most (85%) incidents in



2023 were addressed when batteries showed warning signs such as overheating and smoking prior to entering full thermal runaway. While only 15% of incidents resulted in fire or explosion, the speed in which thermal runaway can develop means that the events in the majority could have been more serious had the issue not been addressed quickly.

- 5 Rechargeable devices are being packed in checked luggage.** The devices that were most cited in thermal runaway incidents in 2023 were also the two most frequently put in checked luggage, according to passengers surveyed. More than a quarter (27%) of travelers reported checking portable chargers, and another 27% said they checked e-cigarettes. Devices that enter thermal runaway in checked baggage cannot be accessed by crew while in flight, and fires may not be detected as quickly in the cargo hold as they would be in the cabin.

Reversing the Trend

With more lithium-ion battery-powered devices carried on board by passengers and flights returning to pre-pandemic levels, the corresponding increase in thermal runaway incidents is unsurprising. Unsurprising does not mean acceptable.

Strategies to reduce the risk emerge via TRIP, the active participation of airlines, and additional insights and analysis from UL Standards & Engagement's interviews and focus groups:

Passenger education: ULSE surveys show an alarming lack of awareness and concerning behavior among airline passengers. Clear, repeated, and contextualized education on the issue will help passengers contribute to reducing the risk.

Flight crew training: According to ULSE interviews with flight crew, all cabin crew are trained to respond to thermal runaway incidents on board an airplane. Training that is linked to available equipment, that is regularly evaluated and revised, and that replicates common, real-world scenarios will improve training that flight crew receive.

Standards for aircraft and baggage handling: To help mitigate potentially catastrophic incidents, ULSE has developed standards that address thermal runaway. These standards include UL 5800, Battery Fire Containment Products; UL 5840, Electrical Systems of Battery Powered Aviation Ground Support Equipment; and the forthcoming UL 5810, Active Fire Protection for Air Cargo Containers.

Partnerships across industry, government, and other stakeholder groups are necessary to inform and implement all three recommendations. Diverse perspectives and experience will bolster collective efforts and help drive impactful change.

Table of Contents

Executive Summary	2
Introduction	5
Thermal Runaway Incident Rates and Trends	6
When Incidents Occur	8
Where Incidents Occur	10
Passenger Awareness Contributes to Incident Risk	12
Packing Behavior and Missed Warning Signs	14
How to Reverse the Trend	16
Cargo Considerations	19
Methodology	19

Introduction



Rechargeable devices like phones, laptops, tablets, and portable power packs are integral to the air travel experience, but with wide and increasing usage of lithium-ion batteries in these and other consumer products comes an increase in the safety hazards they present.

If damaged, improperly charged, poorly manufactured, or counterfeit, these lithium-ion batteries can enter a process called thermal runaway, which occurs when the batteries overheat, posing serious risks that include fire and the ejection of shrapnel. Lithium-ion battery fires burn with intense speed and heat, which can potentially cause significant and widespread damage within seconds. These risks are more complicated at 40,000 feet.

To better understand both the risk and the reality of thermal runaway in aviation, a group of airlines began an informal network in 2017 to share information on incidents. Two years later, this group enlisted UL Standards & Engagement to design and implement a reporting portal and expand the data set. The result was the Thermal Runaway Incident Program.

TRIP is a voluntary reporting system designed for the aviation industry to better understand the extent of the problem and prepare for — or, ideally, prevent — future incidents. It operates

as a surveillance tool, designed to capture data on the frequency, characteristics, and consequences of lithium battery thermal runaway incidents in passenger and cargo operations.

At the end of 2023, the TRIP database contained a total of 769 incident records involving 74 air carriers and the U.S. Transportation Security Administration. These incident records date back to 2006, when a counterfeit battery in a flashlight went into thermal runaway on a cargo flight.

The 35 passenger and cargo airlines that participate in TRIP provide detailed information on incidents within their operation. The information is anonymized and shared with aviation industry and safety organizations, offering insights to improve the safe transport and usage of lithium-ion battery-powered goods.

Now, for the first time, ULSE is publicly sharing findings from TRIP, with the intent to highlight a safety threat that can be largely prevented with passenger education and awareness and aligned cabin crew training and certified safety equipment.

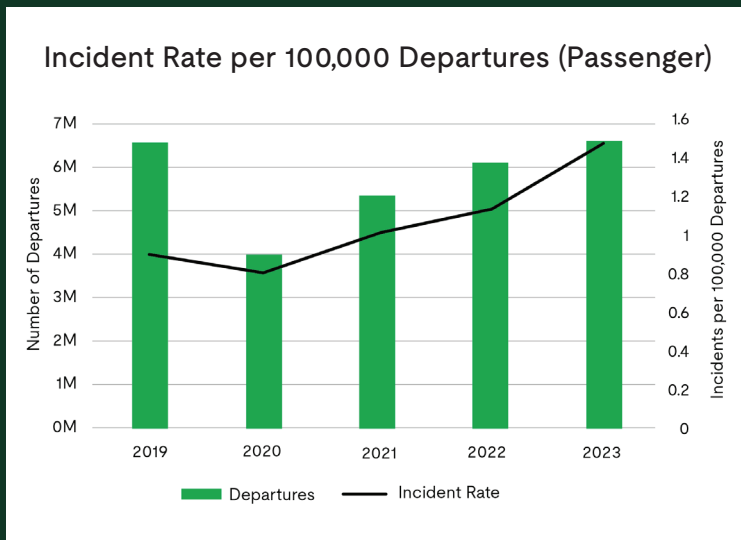
The TRIP data, in concert with ULSE's surveys of travelers, passenger focus groups, and in-depth interviews conducted with flight crew, paint a more complete picture of the threat of thermal runaway in aviation, how to mitigate the risk, and how to contain issues if — and when — they happen.

Thermal Runaway Incident Rates and Trends

Every week, there are approximately [180,000 flights](#) in U.S. airspace, and an average of just over two thermal runaway incidents reported in the TRIP database. These incidents are highly infrequent and largely preventable. They are also on the rise.

According to TRIP data, incidents per 100,000 passenger departures rose almost 65% over the past five years, from 2019-2023.

Similar data from the Federal Aviation Administration shows a [42% increase in the number of lithium-ion battery fires](#) over the same time period. Although TRIP and FAA data sets include slightly different inputs (FAA data is taken from mandatory federal reporting, while TRIP includes additional reports from every stage of the travel process by adding incidents in the terminal, bag checking, security checkpoints, and leaving baggage claim), the increase in incidents can be seen in both.



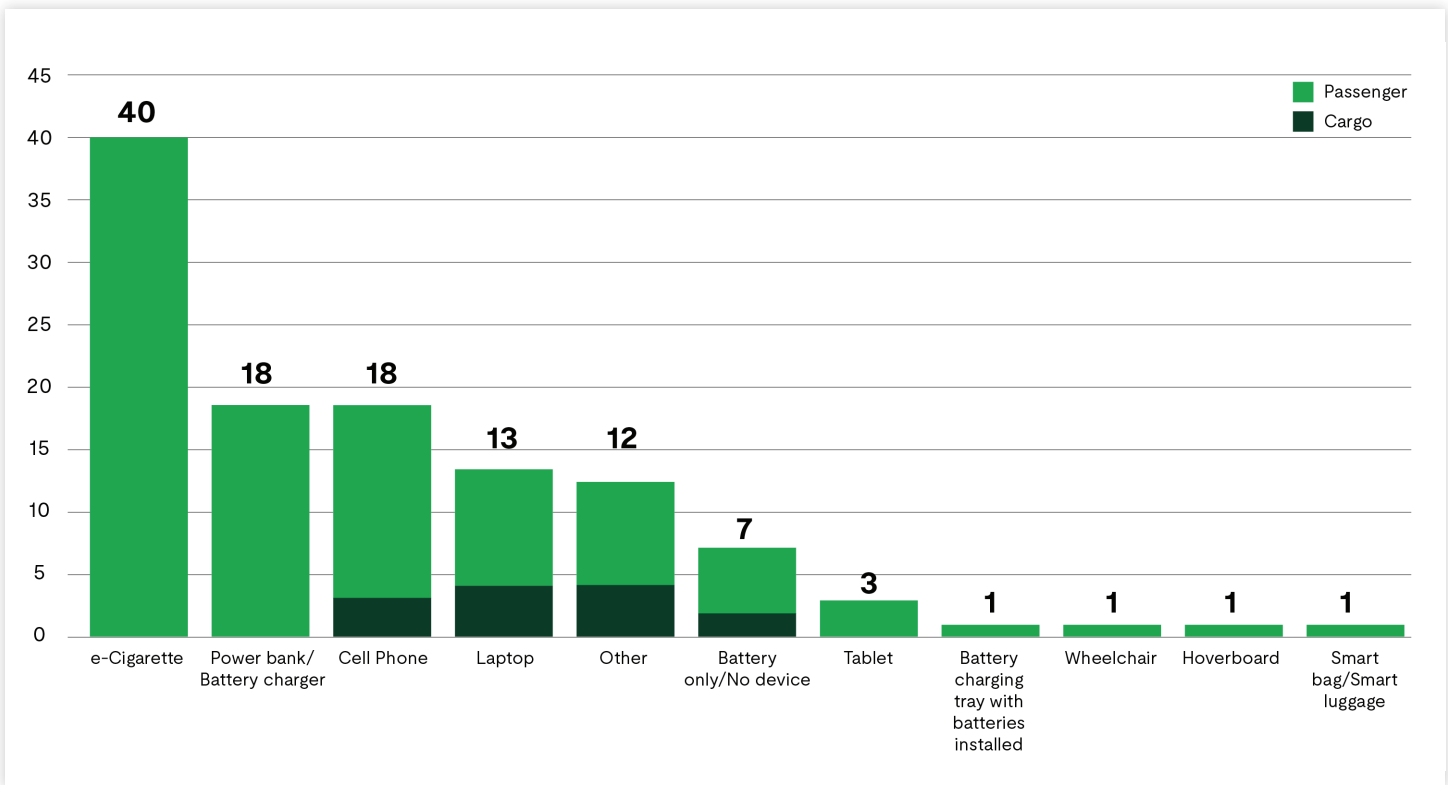
Incident Rate per 100,000 Departures on Passenger Planes, 2019-2023

Source: ULSE TRIP Database, participant and FAA reports, as of 2024-01-16. Bureau of Transportation Statistics, BTS-100 data, accessed 2024-04-03



35%

of reported incidents were attributed to vaping devices on passenger flights in 2023.



2023 Thermal Incidents by Device Type

While TRIP data shows an average of more than two incidents per week, the FAA found an average of slightly more than one incident per week.

Among the common types of devices carried on board by passengers, some are significantly more involved in thermal runaway incidents than others. E-cigarettes were responsible for the most incidents in 2023, with 35% of reported incidents attributed to vaping devices on passenger flights. Power banks are also a major culprit, representing another 16% of incidents. Together, these two types of devices make up more than half of all thermal runaway incidents. Notably, power bank incidents increased by 300% from 2022-2023.

The 2023 data also shows a variety of incidents from devices not found in previous years' data. These include rechargeable breast pumps, personal fans, thermoses, and even soldering irons — all powered by lithium-ion batteries, demonstrating the increasing prevalence of this technology in consumer products. As these new devices enter the market and passengers bring them on board airplanes, the risk of thermal runaway follows accordingly.



When Incidents Occur

As noted earlier, TRIP data covers the continuum of air travel, from when passengers walk into the airport to baggage claim pickup at the end of their journey. The vast majority (87%) of incidents from 2023 are reported on the aircraft, with the remaining 13% involving checked baggage and items carried by passengers.

Any thermal runaway incident on an aircraft is a serious safety concern, but the risk increases when they occur while the plane is in the air. Furthermore, incidents during critical phases of flight (takeoff, climb, descent, final approach, and landing) are of the highest risk, in part because the pilots are engaged in these important activities and cannot assist. More than half (55%) of incidents occurred during the cruising phase.

Location	Incidents
Security Screening	2
Bag Room	2
Baggage Handling	1
Baggage Make-up	1
Transit To/From Aircraft	2
Baggage Loading	1
Aircraft	1
Baggage Unloading	2

Incidents by Location During Baggage Processing

 87%

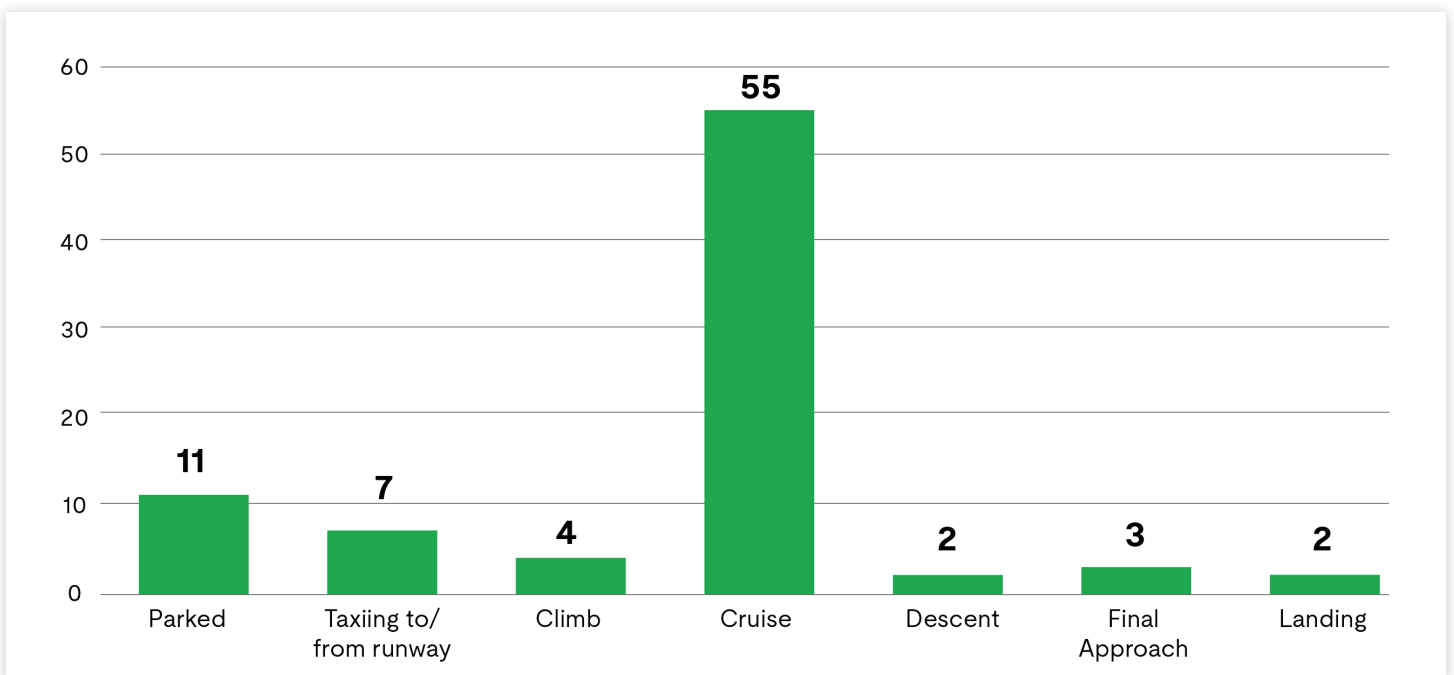
of thermal runaway incidents in 2023 were reported on the aircraft.



In 2023, 12% of thermal runaway incidents occurred during the handling of checked baggage, defined as the entire chain of events between a passenger turning over their bag to the airline and the passenger retrieving the bag at baggage claim. There was at least one incident at every step of the baggage handling process —except baggage claim.

One goal of the TRIP program is to determine the causes of thermal runaway incidents in the aviation space. Some causes are clear, such as a short-circuiting battery or device due to severe damage from handling or use. Other causes are less obvious, so data about what preceded the thermal runaway incident is captured (if known), including how the device was used.

Unfortunately, in approximately 90% of incidents, no presumed cause of the event is provided in the reports submitted by flight crews. When this information is collected, the most common preceding event is that the device or battery was crushed or compressed. Other events include electrical contact or when the battery, device, or shipment was dragged by handling equipment. In one incident, a package of batteries was struck by a forklift during cargo acceptance.

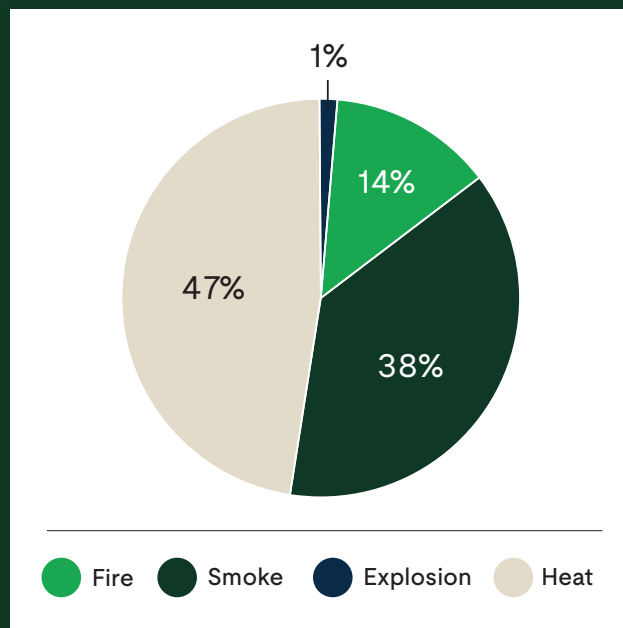


Phase of Flight (Incidents on the Aircraft)

Where Incidents Occur

With most incidents occurring on board the aircraft, TRIP data offers critical takeaways for travelers and crew, including how the device was used or stored before the thermal runaway incident.

In 40% of incidents during 2023, the battery or device was stored in baggage or a package. Twenty-five percent of the time, data for device usage wasn't available. In 17% of incidents, the device was being carried or held by the person but was not in use; 10% of the time, incidents occurred while the device was in use. Notably, only 6% of incidents involved charging the battery or device using the aircraft's USB or AC outlets. Hypotheses that charging in-flight is a contributing factor to incidents are not supported by the data; however, incidents may go underreported as TRIP only classifies a device as "charging" if the people involved in the incident verify that it was charging at the time.



Type of Thermal Runaway Event Across All Incidents



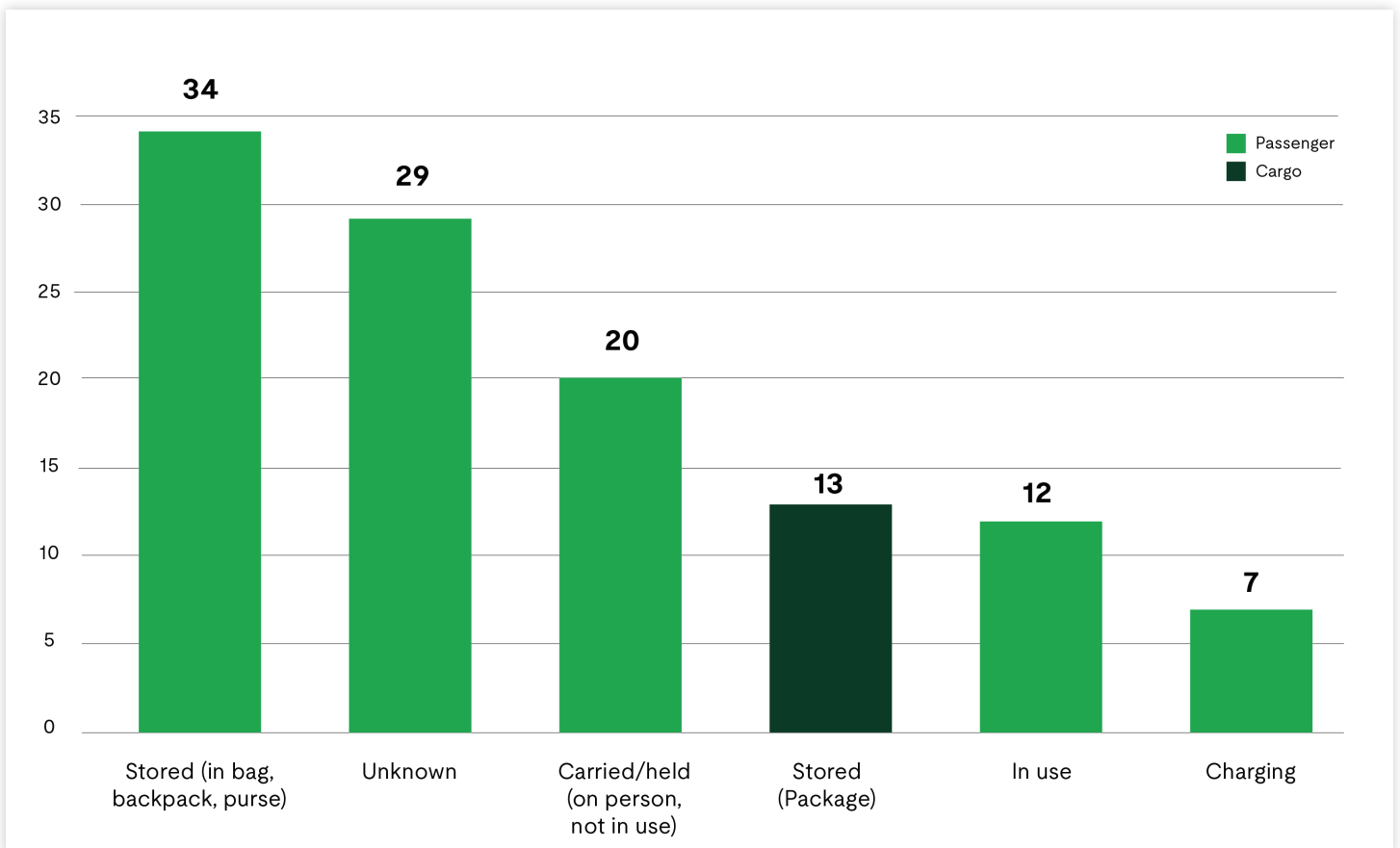
40%

of incidents in 2023 involved a lithium-ion battery or device stored in baggage or a package.

Thermal runaway incidents occur in or around the passenger's seat nearly 60% of the time. Because passengers tend to keep their devices in close reach or in use while flying, this translates to incidents being most likely to occur in a bag, backpack, or purse that has been stored.

Because incidents primarily occur near the passenger's seat, this can result in quicker corrective action during a thermal runaway event. TRIP data on the state of the battery during an incident indicates that the vast majority (85%) of incidents in 2023 were addressed when batteries showed warning signs such as overheating and smoking prior to entering full thermal runaway.

While only 15% of incidents resulted in fire or explosion, complacency to the risk is not advisable. The speed of thermal runaway means that within seconds these events could have been more serious.



2023 Thermal Runaway Incidents by Device Activity

Passenger Awareness Contributes to Incident Risk

Nearly all airline passengers (96%) typically bring at least one rechargeable product containing lithium-ion batteries on board. The average traveler brings four devices — most commonly smartphones (82%), laptops (41%), wireless headphones (39%), and tablets (36%) — according to a [2024 report published by UL Standards & Engagement](#). Thirty-one percent bring a portable charger or power bank with them, while 10% travel with an e-cigarette or vaping device.

Despite the prevalence of lithium-ion battery-powered devices, more than two in five (44%) Americans admit to knowing nothing about these batteries, and three in five consumers (60%) are unaware that lithium-ion batteries power many of the products they routinely use. These knowledge gaps have serious implications for aviation safety.

When asked about risk associated with these devices, just under one-third of travelers said they are not concerned about these risks on airplanes. Many travelers underestimate the threat their devices pose on airplanes and practice behaviors that run counter to best practices, such as ignoring battery safety signage and not following in-flight device storage recommendations — if they are even aware of them.

“

We are introducing an unknown risk by putting as many lithium batteries as we do on board.

-Veteran international flight attendant interviewed by ULSE



60% of Americans are unaware that lithium-ion batteries power many of the products they routinely use

Cabin crew interviewed by ULSE report seeing all manner of lithium-ion battery-powered devices ranging from children’s toys to travel blenders to battery-assisted strollers on recent flights. But as more types of products adopt lithium-ion battery technology, they become more difficult to identify.

The ubiquity and necessity of these devices make it difficult — if not impossible — to restrict their presence on aircraft. One flight attendant told ULSE, “Passengers are expecting the luxuries of home, of having access to your computer, iPad, a phone, and everything at the same time, and sometimes using a charging block to charge everything at one time.”

Focus groups conducted by ULSE confirmed that, for passengers, carrying lithium-ion powered devices on board is a necessity:

“I travel all the time with my small child, and there’s no way I’m flying all over the world with him when he doesn’t have a Switch or a tablet or something,” one traveler shared.

“I carry a battery backup [power bank] just because we have so many electronics, and we need to keep them charged!” another said.

Concerns about Thermal Runaway

Percentage concerned about thermal runaway risks in general



Percentage concerned about thermal runaway risks on airplanes



● General Population ● Airline Travelers

Percent of General Population and Airline Travelers Concerned About Thermal Runaway



Packing Behavior and Missed Warning Signs

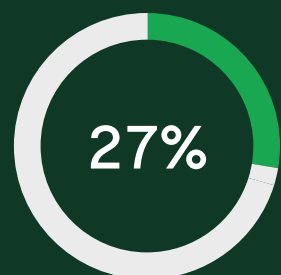
Airlines warn travelers about lithium-ion batteries; however, these warnings often go unseen and unheard.

“I don’t ever check bags. I’m hardly ever talking to an agent or anybody. I just go through security and give them my ticket and get on the plane. I don’t think [lithium-ion batteries were] ever brought up in recent times that I’ve flown,” said one traveler in a ULSE focus group.

Many travelers report similar experiences. When asked about what they recall seeing and hearing about lithium-ion batteries, five in ten airline travelers are either unsure, or did not see any signage or hear announcements about lithium-ion batteries during their travels.

In addition to missing warning signage, passengers are not always given full context during pre-departure announcements to avoid stoking fear, according to a flight attendant interviewed by ULSE:

“We make an announcement that if you drop your device in a seat, do not move your seat... but they don’t say because it could catch on fire,” she said. “We’re giving them small pieces of data without any context.”



of passengers pack e-cigarettes in their checked luggage



“

I don’t ever check bags. I’m hardly ever talking to an agent or anybody. I just go through security and give them my ticket and get on the plane. I don’t think [lithium-ion batteries were] ever brought up in recent times that I’ve flown.

-A traveler in a ULSE focus group

	Smartphone	Laptop	Tablet	Portable Chargers	E-Cigarettes
% took on recent flight	98%	91%	91%	95%	89%
Carry on	95%	77%	76%	68%	62%
On lap/In my hand	77%	23%	32%	14%	27%
Seatback pocket	7%	6%	10%	8%	5%
Under the seat	6%	21%	17%	21%	12%
Overhead compartment	5%	27%	17%	26%	18%
In checked luggage	3%	15%	15%	27%	27%

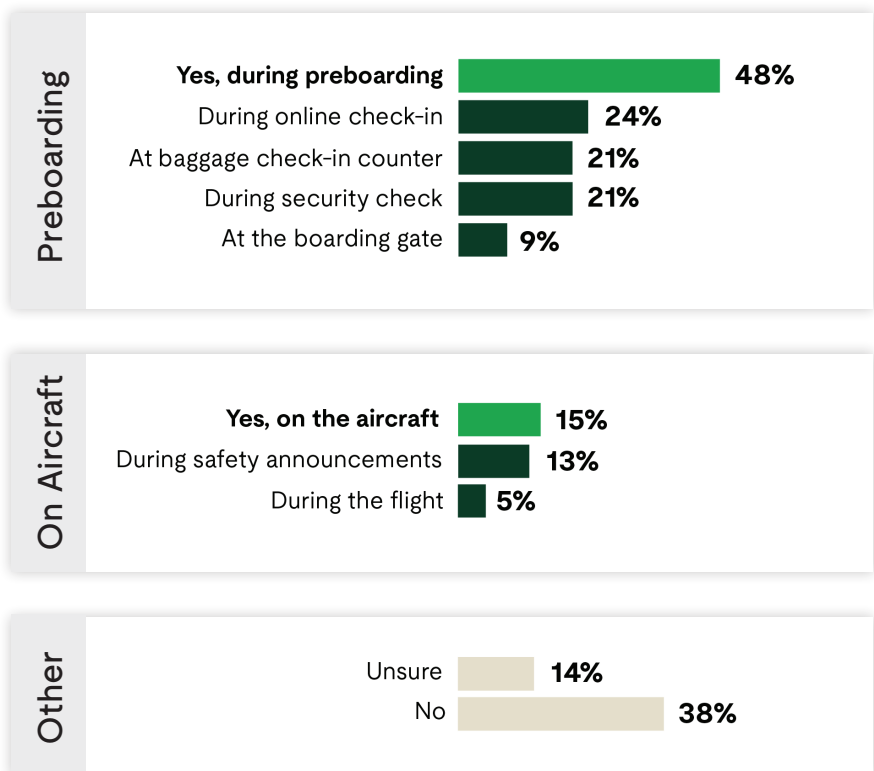
Smartphone (n=4,879) | Laptop (n=2,430) | Tablet (n=2,154) | Portable Chargers (n=1,856) | E-Cigarettes (n=598)

Where Passengers Pack and Store Devices

Despite explicit guidance prohibiting devices powered by lithium-ion batteries in checked luggage, these items are routinely checked. Airlines participating in TRIP have anecdotally shared that TSA removes a large number of laptops, cell phones, and other personal electronic devices from checked bags due to swollen batteries or other damage. However, devices without outward signs of damage are not currently being removed.

Devices that enter thermal runaway in checked baggage cannot be accessed by crew while in-flight, and fires may not be detected as quickly in the cargo hold as they would be in the cabin. When a fire is detected in the cargo hold, there are limited options to fight it — through means such as halon extinguishers and oxygen-depriving systems. However, these methods may not be as effective on lithium-ion battery fires due to the nature of thermal runaway.

If and how passengers recall seeing or hearing about lithium-ion batteries during their travels



Passengers Who Recall Seeing Signage or Hearing Announcements About Lithium-Ion Batteries at the Airport or on the Plane

How to Reverse the Trend

With more lithium-ion battery-powered devices carried on board by passengers, and the number of travelers having returned to pre-pandemic levels, the corresponding increase in thermal runaway incidents is unsurprising. Unsurprising does not mean acceptable.

Strategies to reduce the risk emerge via TRIP, active participation of the aviation community, and additional insights and analysis from ULSE's surveys, interviews, and focus groups. Three areas of opportunity have surfaced:



Passenger education



Flight crew training



Standards for aircraft and baggage handling



“

I think [cabin crew training] needs to be more focused on the importance of thermal runaway.

-A flight attendant in ULSE focus group

Passenger Education

Passengers may not know about best practices for packing and handling lithium-ion battery-powered devices. Education around this issue can make a difference.

With 52% of passengers missing warning signs and 22% of airline travelers expressing that they do not think flight crew and gate agents provide enough information about lithium-ion battery safety during the boarding and flight process, more must be done to make passengers aware of the risk and their role in mitigating it.

A component to consider for expanded passenger education initiatives would be to raise consumer awareness about using only lithium-ion battery-powered devices and accessories that are certified to meet applicable safety standards, as these are designed and constructed with safeguards intended to mitigate various hazards — including thermal runaway.

Both frequent and infrequent fliers reported that in order to change their behavior, they would like to receive information about how to pack these devices in different, and more frequent, ways than they currently do to reinforce the message. Successful passenger awareness efforts must be clear, consistent, and present at multiple points prior to, and during the passenger's journey to raise awareness and result in behavioral change.

Flight Crew Procedures and Training

All cabin crew are trained to respond to thermal runaway incidents on board an airplane. Procedures vary across airlines according to the layout of the plane, number of crew on board, and available safety equipment such as fire extinguishers, containment bags, and personal protective equipment.

Cabin crew self-identified gaps in their understanding of thermal runaway events and the appropriate order of operations when addressing these fires. The recommendations that emerged through ULSE's conversations with cabin crew include:

- 1 Training design and procedures should be closely linked to available equipment
- 2 Planes should be equipped with the appropriate equipment in the correct locations
- 3 Training should be evaluated and revised based on emerging risks
- 4 Training should replicate common, real-world scenarios, such as a device becoming overheated in an overhead bin or between the seats, or a fire occurring during the critical phases of a flight



Standards for Aircraft and Baggage Handling

To help address these potentially catastrophic incidents, containment products have been developed and marketed to airlines. These products are typically bags, large enough to hold a laptop computer, which are designed to suppress the flames, smoke, and off-gassing from lithium-ion battery fires. The FAA does not currently require airlines to have this equipment on aircraft, but some airlines have taken the initiative to stock their fleet.

Efficacy and ease of use are essential to mitigating battery fires using these products. As a result, ULSE was approached by aviation industry representatives to develop a safety standard for them. The collective effort resulted in UL 5800, Battery Fire Containment Products, first published in 2020. In-scope containment products are intended for use in the aircraft's passenger cabin or cockpit by authorized personnel for lithium-ion battery-powered portable electronic devices which are entering or have entered thermal runaway.

ULSE is also working with a technical committee and other stakeholders on the development of UL 5810, Active Fire Protection for Air Cargo Containers, to help address lithium battery-related hazards in cargo settings. Additionally, UL 5840, Electrical Systems of Battery Powered Aviation Ground Support Equipment, was published in 2022 to help address hazards related to ground support equipment operating around aircraft.

Standard	Description
UL 5800	The standard for Battery Fire Containment Products
UL 5810	The standard for Active Fire Protection for Air Cargo Containers
UL 5840	The standard for Electrical Systems of Battery Powered Aviation Ground Support Equipment



How to Make Progress

Partnerships across industry, government, and other stakeholders are necessary to inform and implement all three recommendations.

Efforts are already underway to bring stakeholders together through initiatives like TRIP and the FAA's [Lithium Battery Air Safety Advisory Committee](#).

The FAA launched its [PackSafe initiative](#) to share guidelines with passengers about safely packing lithium batteries and other hazardous materials. The campaign website provides a variety of resources for passengers including videos, infographics, brochures, and checklists along with educational posters for use in airports.

As key stakeholders and groups not currently involved are engaged to participate in these efforts, their perspective and experience can bolster collective efforts and help drive impactful change.



TRIP and Cargo Incident Analysis

Thermal runaway incidents related to airborne cargo occur with far less frequency than those on passenger flights. The majority of cargo incidents occur while the aircraft is on the tarmac.

As a result, this report focuses primarily on incidents during passenger operations. Nevertheless, there are significant and unique risks involved in cargo shipments of lithium batteries. Among these are that thousands of lithium batteries can be packaged together for shipping, creating the potential for a chain reaction in the event of a fire and/or explosion.

This reaction was the case for UPS Airlines Flight 6, which crashed in 2010 near Dubai after a pallet containing more than 81,000 lithium batteries caught fire in the cargo hold during flight. Additional factors exacerbated the situation, and the plane crashed, killing its two pilots — the only crew on board. There were no additional casualties on the ground. Should a similar scenario occur in a densely populated area, the outcome would be even more tragic and catastrophic.

As with lithium battery incidents on passenger flights, TRIP seeks to apply learnings to reduce or, ideally, eliminate them in the future. ULSE is actively engaged with cargo airlines, pilots' unions, and the International Civil Aviation Organization to pursue these goals.

Methodology

All studies were designed and formulated by UL Standards & Engagement.

Quantitative results were primarily taken from a ULSE Insights survey series of a cumulative 8,076 U.S. adults, conducted between August 2023 and December 2023. Surveys were administered online by BV Insights. As a member of the Insights Association and ESOMAR (the European Society for Opinion and Marketing Research), BV Insights adheres to industry ethics and best practices, including maintaining the anonymity of respondents.

The margin of sampling error at 95% confidence for aggregate results is +/- 2.2%. Sampling error is larger for subgroups of the data. As with any survey, sampling error is only one source of possible error. While non-sampling error cannot be accurately calculated, precautionary steps were taken in all phases of the survey design and the collection and processing of the data to minimize its influence.

Qualitative data was derived from a total of four focus groups (n=24) and seven (n=7) in-depth interviews with passengers.

YouGov administered two focus groups in July 2024 with a total of n=24 passengers, n=12 of whom had been on >7 flights in the past 12 months, and n=12 of whom had been on <7 flights in the past 12 months. Passengers were a combination of business and pleasure travelers and represented a mix of demographic groups as well as travel with and without children.

Additionally, ULSE held seven in-depth interviews (n=7) and six focus groups (n=41) focused on cabin crew experiences and preparation for a total of n=48 participating flight crew members. All qualitative data was transcribed, uploaded into the MAXQDA software platform, and analyzed with a hybrid coding frame.

Note: All numbers are percentages unless otherwise noted. Figures may not total 100% due to rounding.

** Results were primarily taken from a ULSE Insights survey series of a cumulative n=16,146 U.S. adults, conducted between August 2023 and July 2024.*

*** Results were primarily taken from a ULSE Insights survey series of a cumulative n=4,035 U.S. adults, conducted between May 2024 and July 2024.*

